Ahsanullah University of Science and Technology, Dhaka

Department of Mechanical and Production Engineering

List of sessional courses in Industrial & Production Engineering are given below from level 1/ term 1 to level 4/ term 2.

Level 1/ Term 1

Course No	Course Title	Cr. Hrs.*
IPE 1110	Machine Shop Practice-I	1.5
Phy 1106	Physics Sessional	1.5
Chem 1108	Chemistry Sessional	1.5
Hum 1108	English Language Sessional	1.5

Level 1/ Term 2

Course No	Course Title	Cr. Hrs.*
IPE 1210	Machine Shop Practice-II	1.5
EEE 1288	Electrical Engineering Sessional	1.5
CSE 1288	Computer Programming Sessional	1.5

Level 2/ Term 1

Course No	Course Title	Cr. Hrs.*
IPE 2102	Manufacturing Process Sessional	1.5
ME 2102	Basic Thermodynamics Sessional	0.75
ME 2110	Mechanical Drawing-I	1.5
EEE 2188	Electrical Machines Sessional	0.75

Level 2/ Term 2

Course No	Course Title	Cr. Hrs.*
ME 2202	Mechanics of Materials Sessional	0.75
ME 2204	Engineering Materials Sessional	0.75
ME 2210	Mechanical Drawing-II	1.5
EEE 2286	Analog & Digital Electronics Sessional	1.5

Level 3/ Term 1

Course No	Course Title	Cr. Hrs.*
ME 3132	Fluid Mechanics & Machinery Sessional	1.5
IPE 3102	Measurement, Instrumentation & Control Sessional	1.5
IPE 3104	Product Design and Development Sessional	1.5

Level 3/ Term 2

Course No	Course Title	Cr. Hrs.*
IPE 3202	Ergonomics and Productivity Engineering Sessional	1.5
IPE 3204	Material Handling & Maintenance Engineering Sessional	1.5
IPE 3210	Metal Forming and Sheet Metal Working Sessional	1.5

Level 4/ Term 1

Course No	Course Title	Cr. Hrs.*
IPE 4102	Machine Tools and Machining Sessional	1.5
IPE 4000	Project and Thesis	3.0

Level 4/ Term 2

Course No	Course Title	Cr. Hrs.*
IPE 4206	Industrial Simulation Sessional	1.5
IPE 4208	Business Communication Seminar	1.5
IPE 4000	Project and Thesis	3.0

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

1st Year, 1st Semester

Student Name :

Student ID :

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 1110: Machine Shop Practice I
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. Viva for each experiment will be taken on the next day with the report.
5. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental results and discussions (Experimental setup, Experimental conditions, Data, Graph, calculation etc.)
    - Conclusions
    - Acknowledgements
    - References
6. A quiz will be taken on the experiments at the end of the semester.
7. Marks distribution:

Total Marks		
Report	Attendance and Viva	Quiz
30	30	40

Experiment 1:

Study of Electric Arc welding process and various types of joint

Arc welding is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is usually protected by some type of shielding gas, vapor, or slag. Arc welding processes may be manual, semi-automatic, or fully automated. First developed in the late part of the 19th century, arc welding became commercially important in shipbuilding during the Second World War. Today it remains an important process for the fabrication of steel structures and vehicles.

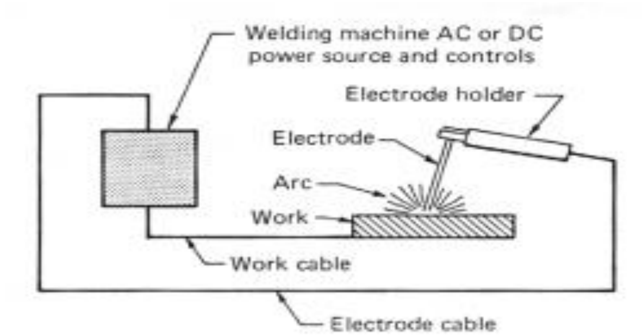


Fig. 1 The basic arc-welding circuit

In arc welding, the intense heat needed to melt metal is produced by an electric arc. The arc is formed between the actual work and an electrode (stick or wire) that is manually or mechanically guided along the joint. The electrode can either be a rod with the purpose of simply carrying the current between the tip and the work. Or, it may be a specially prepared rod or wire that not only conducts the current but also melts and supplies filler metal to the joint.

Basic Welding Circuit

The basic arc-welding circuit is illustrated in Fig. 1. An AC or DC power source, fitted with whatever controls may be needed, is connected by a work cable to the workpiece and by a "hot" cable to an electrode holder of some type, which makes an electrical contact with the welding electrode.An arc is created across the gap when the energized circuit and the electrode tip touches the workpiece and is withdrawn, yet still with in close contact.

The arc produces a temperature of about 6500ºF at the tip. This heat melts both the base metal and the electrode, producing a pool of molten metal sometimes called a "crater." The crater solidifies behind the electrode as it is moved along the joint. The result is a fusion bond.

Arc Shielding

However, joining metals requires more than moving an electrode along a joint. Metals at high temperatures tend to react chemically with elements in the air - oxygen and nitrogen. When metal in the molten pool comes into contact with air, oxides and nitrides form which destroy the strength and toughness of the weld joint. Therefore, many arc-welding processes provide some means of covering the arc and the molten pool with a protective shield of gas, vapor, or slag. This is called arc shielding. This shielding prevents or minimizes contact of the molten metal with air. Shielding also may improve the weld. An example is a granular flux, which actually adds deoxidizers to the weld.

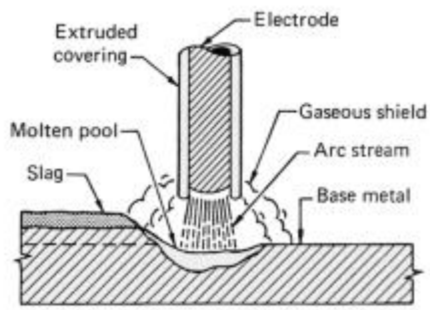


Fig. 2 This shows how the coating on a coated (stick) electrode provides a gaseous shield around the arc and a slag covering on the hot weld deposit.

Figure 2 illustrates the shielding of the welding arc and molten pool with a Stick electrode. The extruded covering on the filler metal rod, provides a shielding gas at the point of contact while the slag protects the fresh weld from the air.

Welding Joints:

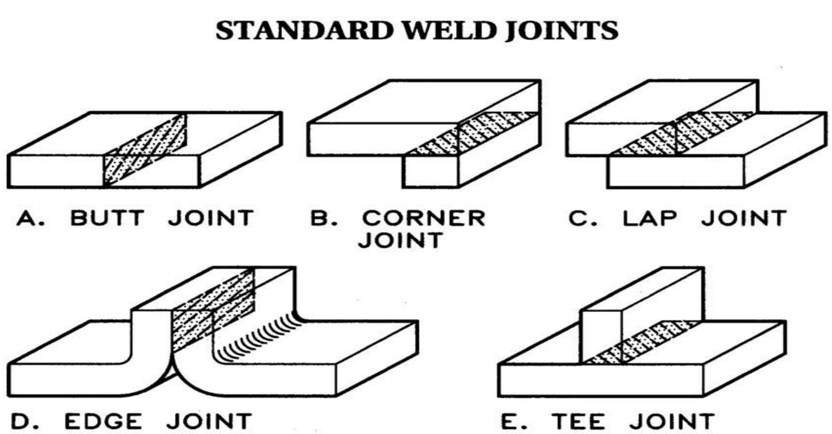


Figure 3: Standard Weld Joint

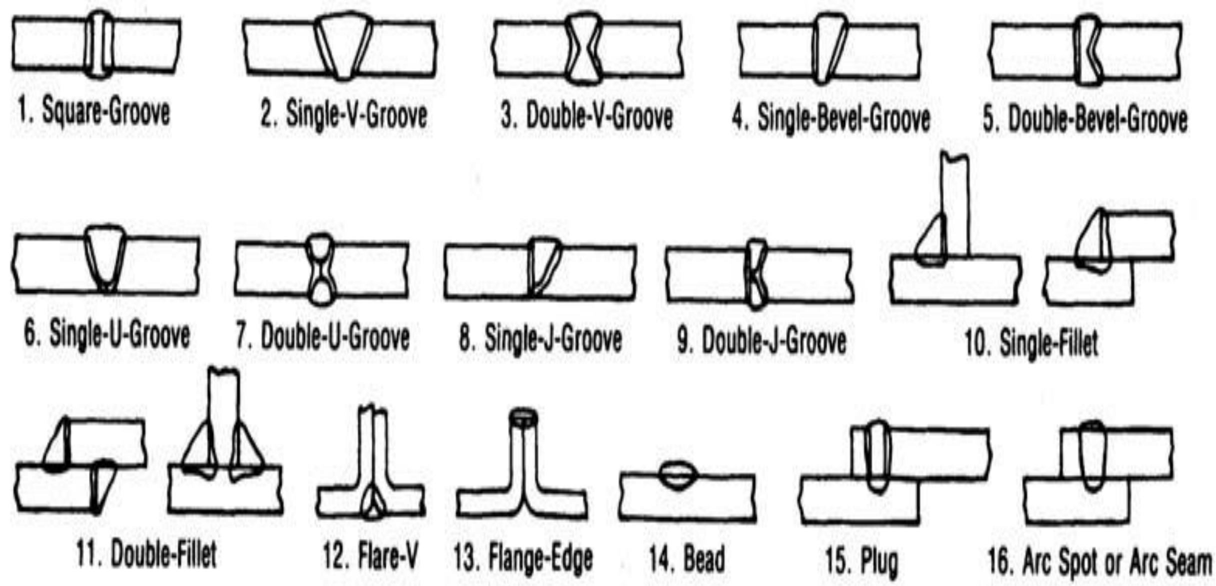


Figure 4: Other basic Weld Joints

Heat, fire, and explosion hazard

Because many common welding procedures involve an open electric arc or flame, the risk of burns from heat and sparks is significant. To prevent them, welders wear protective clothing in the form of heavy leathergloves and protective long sleeve jackets to avoid exposure to extreme heat, flames, and sparks.

Eye damage

Auto darkening welding hood with 90×110 mm cartridge and 3.78×1.85 in viewing area

Exposure to the brightness of the weld area leads to a condition called arc eye in which ultraviolet light causes inflammation of the cornea and can burn the retinas of the eyes. Welding goggles and helmets with dark face plates—much darker than those in sunglasses or oxy-fuel goggles—are worn to prevent this exposure.

Safety issues

Welding safety checklist

Welding can be a dangerous and unhealthy practice without the proper precautions; however, with the use of new technology and proper protection the risks of injury or death associated with welding can be greatly reduced.

Experiment 2:

Study on Sand Mold Preparation using single piece pattern

MANUFACTURING PROCESS:

Manufacturing processes are the steps through which raw materials are transformed into a final product. The manufacturing process begins with the creation of the materials from which the design is made. These materials are then modified through manufacturing processes to become the required part.

Casting:

Casting refers to the process of creating a metal part (using cast iron or cast steel) by pouring liquid into a mold or die to form a solid shape. Once the part cools and solidifies, it is ejected or broken out of the mold.

Sand Casting:

Sand casting is considered the most common and can accommodate a wide range of object sizes. The three dimensional replica or "pattern" of the required object is held within a mold surrounded by compressed sand and binder additives which are used to form the final shape of the desired part.The Cavity in the cavity formed by using a pattern (an approximate duplicate of the real part), which are typically made of wood, sometimes metal is called mold. The cavity is contained in an aggregate housed in a box called the flask. Core or mold that is used to locate and support the core within the mold. A riser is an extra void created in the mold cavity as the molten metal solidifies and shrinks and thereby prevents voids the main casting. The following Figure shows the green sand mold.

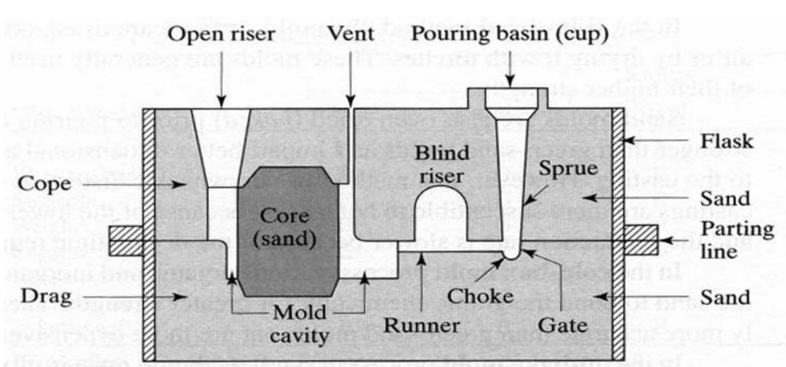


Figure 1: Gating System

<u>Major components of sand molds as shown in Fig.1 are:</u>

The mold itself, which is supported by a **flask**. A two-piece mold consists of a **cope** on top and a **drag** on the bottom. When more than two pieces are used, the additional parts are called **cheeks**.

1- **A pouring basin or pouring cup,** into which the molten metal, is poured.
2- **A sprue,** through which the molten metal flows downward.
3- **The runner system,** which has channels that carry the molten metal from the sprue to the mold cavity.
4- **Gated system –** It consists of the pouring basin, sprue, runner and gate. Its function is to fill the mold cavity in time so that the molten material does not solidify before filling the entire mold cavity. **Gates** are the inlets into the mold cavity.
5- **Riser –** A riser or feeder is a reservoir build into a metal casting mold to prevent cavities due to shrinkage. Because metals are less dense as liquids than as solids (with some exceptions), castings shrink as they cool. This can leave a void, generally at the last point to solidify. Risers prevent this by providing molten metal at the point of likely shrinkage, so that the cavity forms in the cavity forms in the riser, not the casting. **Risers,** which supply additional metal to the casting as it shrinks during solidification. Fig.2 shows two different types of risers: a blind riser and an open riser.
6- **Cores,** which are inserts made from sand. They are placed in the mold to form hollow regions or otherwise define the interior surface of the casting. **Core –** The term core, most often is referred to as a performed mass of sand introduced in the mold cavity to form a hole or recess in the casting.
7- **Caplets -** Chaplets are small metal props, placed in the mold cavity to support the core.
8- **Vents,** which are placed in the molds to carry off gases produced when the molten metal comes into contact with the sand in the molds and cores. They also exhaust air from the mold cavity as the molten metal flows into the mold

Mold Preparation:

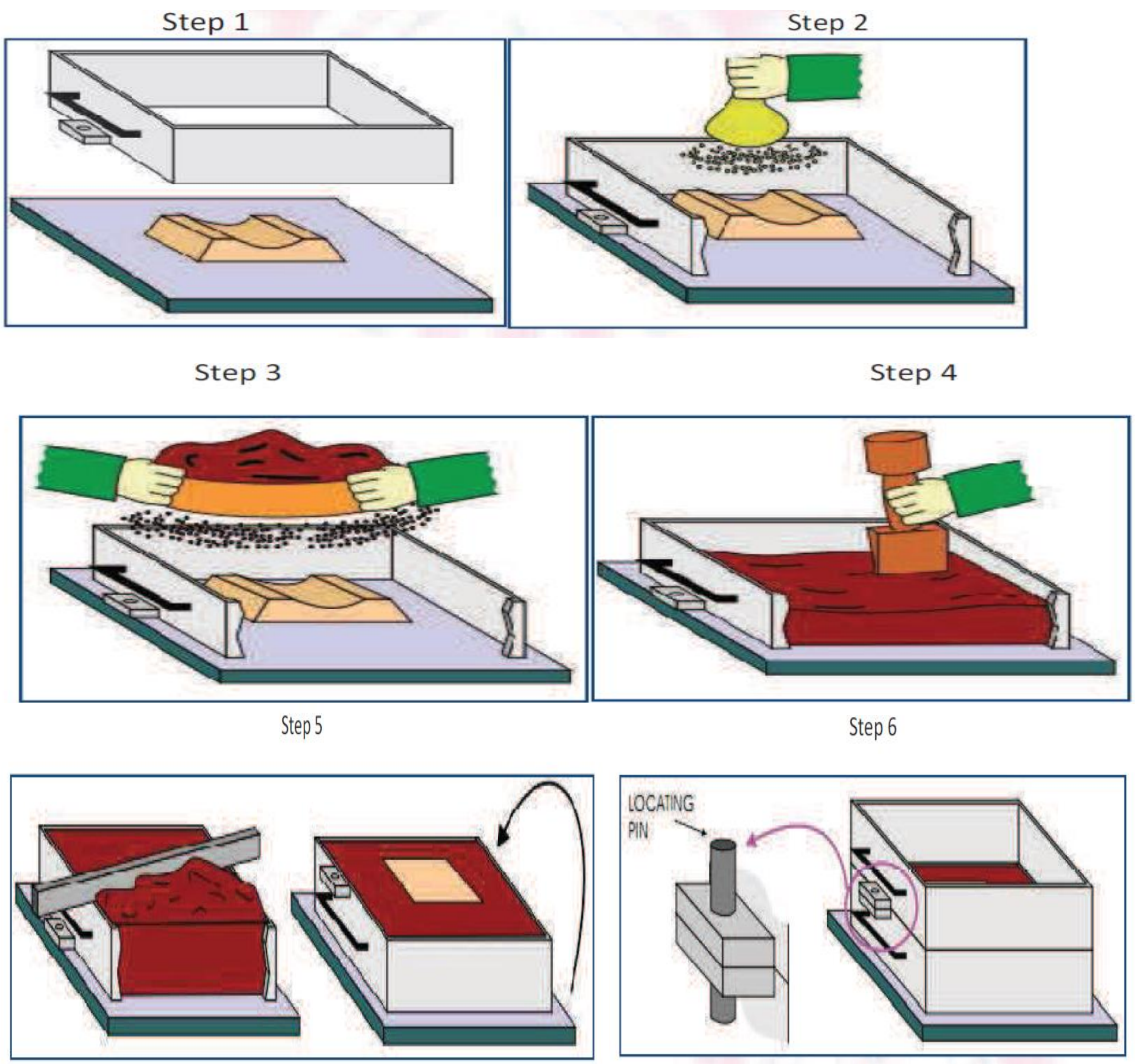
i. Prepare enough sand by riddling to fill the flask before it using facing sand.
ii. Place drag on molding board, guide pins pointing downward.
iii. Place pattern, large side down, in drag. Fill the flask with the molding sand over the pattern.
iv. Ramming with rammer. Don't ramming over the pattern.
v. Strike off excess sand to the level of drag using straight-edge or planner.
vi. Roll will be drag and replace cope part use parting sand on the drag part.
vii. Riser and runner will be replacing also then Ramming,. Strike off excess sand and use facing sand.
viii. Venting around and over pattern with vent wire.
ix. Remove riser and runner then cut pouring basin into cope. Separate cope and drag part.
x. Swap around the pattern, Rap and draw the pattern with draw spike or draw pin.
xi. Cut gate in drag ½" deep 1" wide with gate cutter and remove any loose sand form the mold.

xii. Remove extra sand and other foreign particle with Bellows. Put cope on drag in its original position.

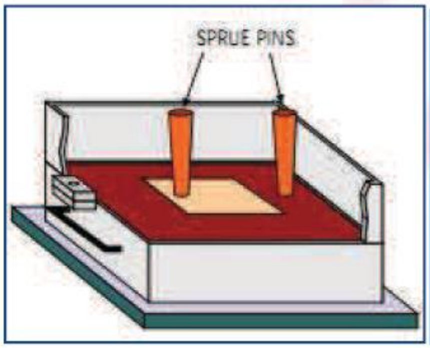
xiii. Set mold level on the floor carrying it with bottom plate held firmly in place.

xiv. Uncover pouring basin and place suitable weight on cope to hold it down against the lift of the molten metal.

Schematic illustration of the sequence of operations for Sand Casting:



Step 7



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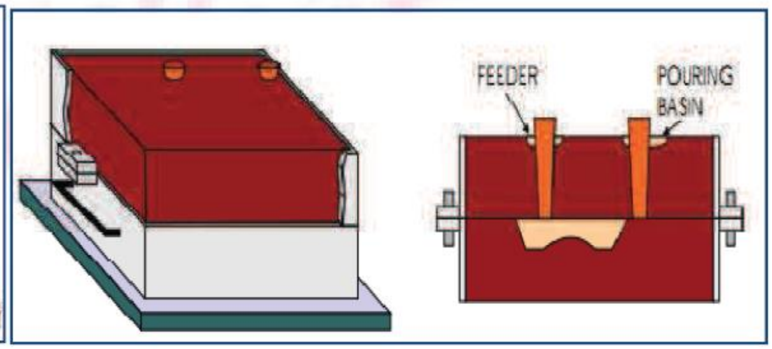

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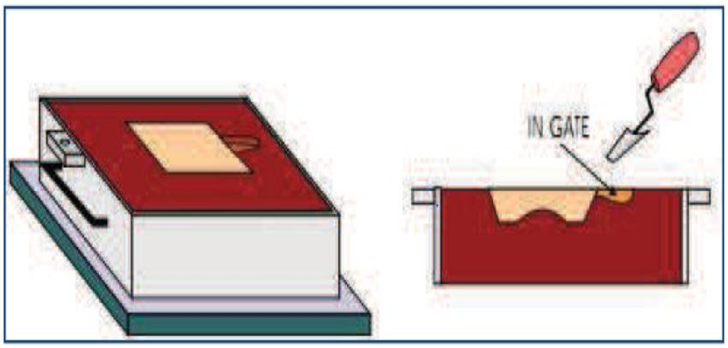

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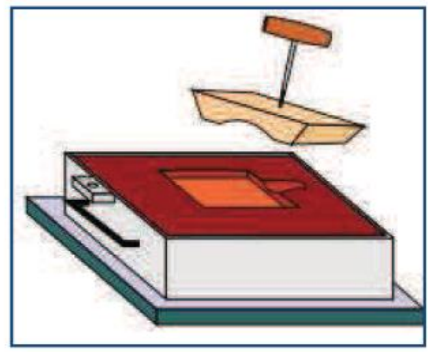

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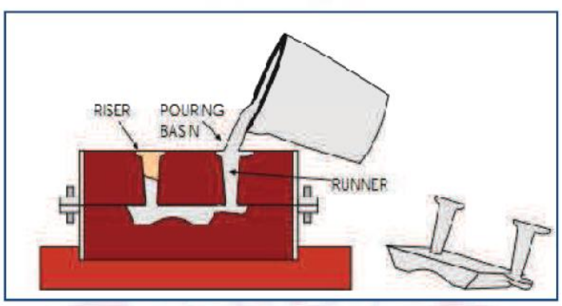

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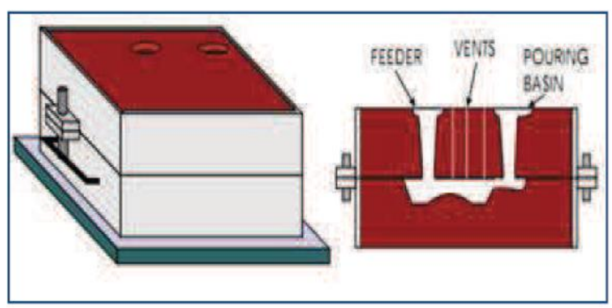
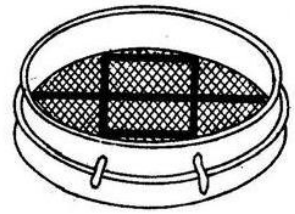
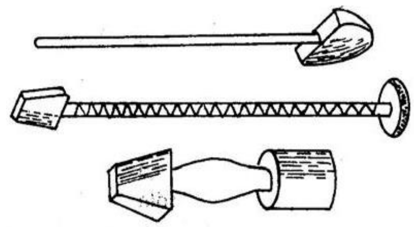


Molding Tool Kit:

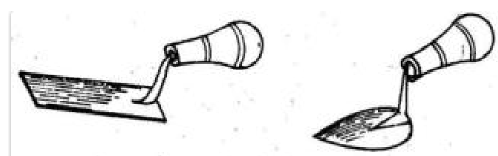
Riddle: A riddle of a standard mesh screen is used to remove lumps or foreign particles from the sand both hand and power riddles are available the letter being used where large volume of work is involved.



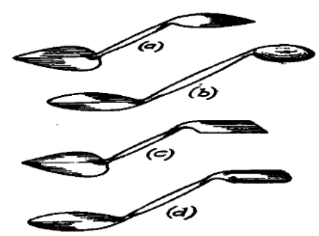
Rammer: A hand rammer generally made of wood is used to pack the sand in the mold. It has got two ends. One end is sharp and the other end is blunt. The sharp end of the rammer called the PEEN END which is used to pack the molding sand through the corner of the molding flask and the other end is called BUTT which is used to pack the sand finally.



Trowel: Small trowels of various shapes are used for finishing and repairing mold cavities as well as for smoothing over the parting sand off the mold. The usual trowels are rectangular in shape and have either round or square end.

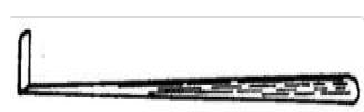


Slick-Spoon: The principal hand tools for repairing molds are called a slick-spoon. It is a small double ended tool having a flat on one end and a spoon on the other end. This tool is also made in variety of other shapes.



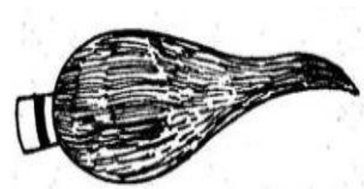
Bellows: A standard hand operated billows are used for blowing off loose sand from the mold verities and surface of the mold.

Lifter: Lifter is used for smoothing and clearing our loose sand depression in the mold. They are made of thin section of steel of various width and length with one end bent at right angles. A

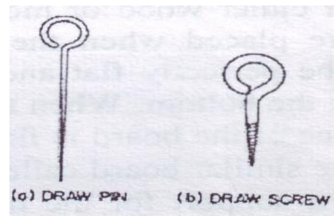


combination of slick and lifter is known as a Yankee-Lifter.

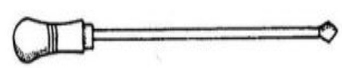
Swab: It is made of flux or hemp and used for applying water to the mould around the edge of the pattern. This prevents the sand edges from crumbling when the pattern is removed from the mould.



Draw Spike or Screw: The draw spike is a pointed steel rod with loops at one end. It is driven into a wooden pattern when it is withdrawn from the sand. The draw screw is similar in shape but threaded on the end to engage metal pattern.

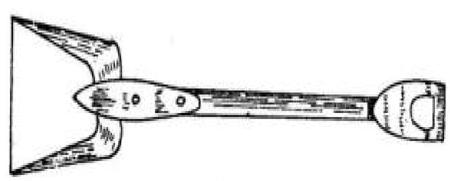


Vent wire: It is a wire rod used for making opening called 'vents' in the mould. In this manner the mold is provided with vents which carry off the steam and gases generated by the hot metal in contact with the sand.



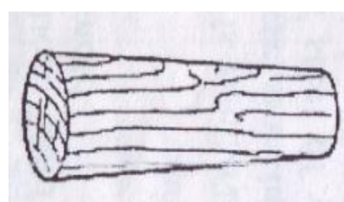
Gate cutter: It is a piece of sheet metal used to cut the opening that connects the spruce with the mould cavity. This opening is called a 'gate'.

Shovel: It is long wooden handled tool generally made of thick sheet of hardened steel like as spade can be used shifting sand from one piece to another place or to mix sand and water properly for making mold.



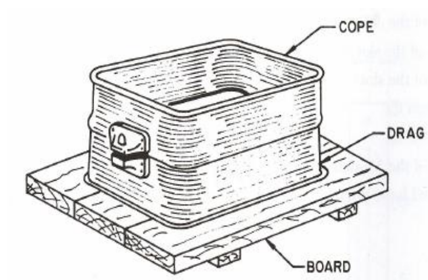
Runner: It is round or semi-round wooden bar which is used to provide a passage through which the molten metal will run into the mold cavity. The size of runner varies according to the size of the mold.

Riser or Sprue: Riser is often providing in the mold to feed molten metal into the main casting compensate for the shrinkage taking place at the time of solidification. It should be placed near

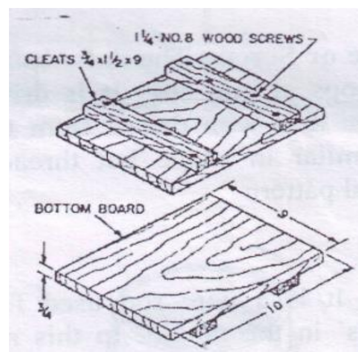


the heavy section that will be subjected to heavy shrinkage. Riser also serve as a large end for escaping a place for collecting loose sand or stage that may be the mold. Riser may be of two types, one is external or exposed and another is internal or build.

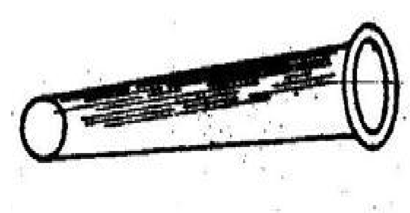
Molding Flask: Small or medium sized casting are made in a flask which is a box shaped container without top or bottom. It is made in 2 parts held in alignment by dowel pins. The top part of the flask is called the cope and the bottom parts of the flask are drag. If the flask is made in three parts then the center parts is called a cheek.



Molding Board: The molding board is a smooth surfaced board made of either wood or metal on which the flask and pattern are placed when the mold in started. The board should be perfectly flat and should be reinforced with clench on the bottom. When the mold is turned over the mold surface of the board is finished. When the mold is placed on the similar board called BOTTOM BOARD, which acts as a support for the mold until the metal is poured.



Sprue Cutter: This is a tool made of brass pipe in a various sized in diameter for cutting spruce or runner in the cope part of mold through with the molten metal will be poured into the mold cavity. It is used instead of providing runner for rapid work.



Gaggers or Lifter: These are iron rods bent at one end or both ends. These are used to reinforce sand in the two portion of the box and for supporting bidet of sand wash and then placed next to the one of the cross bar. The lower end should be placed to the pattern and the upper end should extend to the top of mold.

Types of Molding Sand:

The molding sands are classified according to their use in the following categories:

- **Green sand:** the sand in its natural condition with moisture to give it enough strength is formed as green sand.). Unlike the name suggests, "Green sand" is not a type of sand on its own, but is rather a mixture of:
  - Silica sand (SiO_2), or chromite sand ($FeCr_2O$), or zircon sand ($ZrSiO_4$), 75 to 85%, or olivine, or staurolite, or graphite.
  - bentonite (clay), 5 to 11%
  - water, 2 to 4%
  - inert sludge 3 to 5%
  - Anthracite (0 to 1%)
- **Dry sand:** the green sand mold is not very suitable for large casting. So they are dried in some suitable oven to evaporate the excess moisture and to give then extra strength.
- **Facing sand**: the sand which remains around the pattern is the facing sand. So it forms the face of the mold comes in direct contact with the molten metal.
- **Parting sand**: the cope and drag are placed over after the patterns are placed in the respective haves of the flask and the necessary operations of mold making done. There is every possibility that the sand in the cope half and drag half may stick together and with the pattern. To eliminate this possibility parting sand is sprinkled over the parting surface of the cope and drag and the pattern.
- **Baking or floor or black sand**: Around the pattern a layer of sufficient thickness of facing sand is given and the rest volume of the flask is filled with different type of sand called backing sand. The backing sand is meant to provide a good backing to the facing sand.
- **Core sand**: the sand used for making cores is called core sand. This sand has high silica content and is mixed with selected binders.
- **Loam sand**: this sand contains high percentage as high as 50 percent of clay and dried hard. It is specially prepared for loam molding for large casting.

Sand binder:binder is a one kind of extra element which is increasing binding capacity of molding sand such as clay, oil, dextrin, resin etc.

Sand additives: additives are an extra element also which is not increasing binding capacity of molding sand. It is increasing other properties of molding sand. Wood flower, straw flower, Portland cement, bentonite, coal dust, and silica flower is used as additives.

Composition of typical molding sand:

Silica sand	85-90%
Clay	10-12%
Coal dust	6-7%
Wood flower	0.5-0.8%
Water	4-5%
Others	0.5-0.8%

Patterns:

Patterns are used to mold the sand mixture into the shape of the casting. They may be **made of wood, plastic, or metal.** The **selection of a pattern material depends** on:

1- The size and shape of the casting
2- The dimensional accuracy
3- The quantity of castings required
4- The molding process to be used

Single piece pattern:

This is the simplest type of pattern, exactly like the desired casting. For making a mould, the pattern is accommodated either in cope or drag. Used for producing a few large castings, for example, stuffing box of steam engine.

Experiment 3:

Study on different types of joint by TIG welding and MIG welding

OBJECTIVE

- Become familiar with Tungsten Inert Gas (TIG) & Metal Inert Gas(MIG) welding processes

Student will be introduced to:

- The TIG, MIG welding equipment, related tools and the essential process safety considerations
- Types of work materials, filler rods, shielding gases etc.

BACKGROUND

Solid materials need to be joined together in order that they may be fabricated into useful shapes for various applications such as industrial, commercial, domestic, art ware and other uses. Depending on the material and the application, different joining processes are adopted such as, mechanical (bolts, rivets etc.), chemical (adhesive) or thermal (welding, brazing or soldering). Thermal processes are extensively used for joining of most common engineering materials, namely, metals.

WELDING PROCESSES

Tungsten Inert Gas (TIG): Tungsten Inert Gas (TIG) or Gas tungsten arc welding (GTAW) is an arc welding process that uses a non-consumable tungsten electrode and an inert gas for arc shielding. Under the correct conditions, the electrode does not melt, although the work does at the point where the arc contacts and produces a weld pool. The TIG process can be implemented with or without a filler metal. Figure 1 illustrates the latter case.When a filler metal is used, it is added to the weld pool from a separate rod or wire, being melted by the heat of the arc rather than transferred across the arc as in the consumable electrode arc welding processes. Tungsten is a good electrode material due to its high melting point of 34100C (61700F).

Since tungsten is sensitive to oxygen in the air, good shielding with oxygen-free gas is required. Typical shielding gases include argon, helium, or a mixture of these gas elements. TIG welding is easily performed on a variety of materials, from steel and its alloys to aluminum, magnesium, copper, brass, nickel, titanium, etc. Virtually any metal that is conductive lends itself to being welded using GTAW. Its clean, high-quality welds often require little or no post-weld finishing. This method produces the finest, strongest welds out of all the welding processes. However, it’s also one of the slower methods of arc welding.

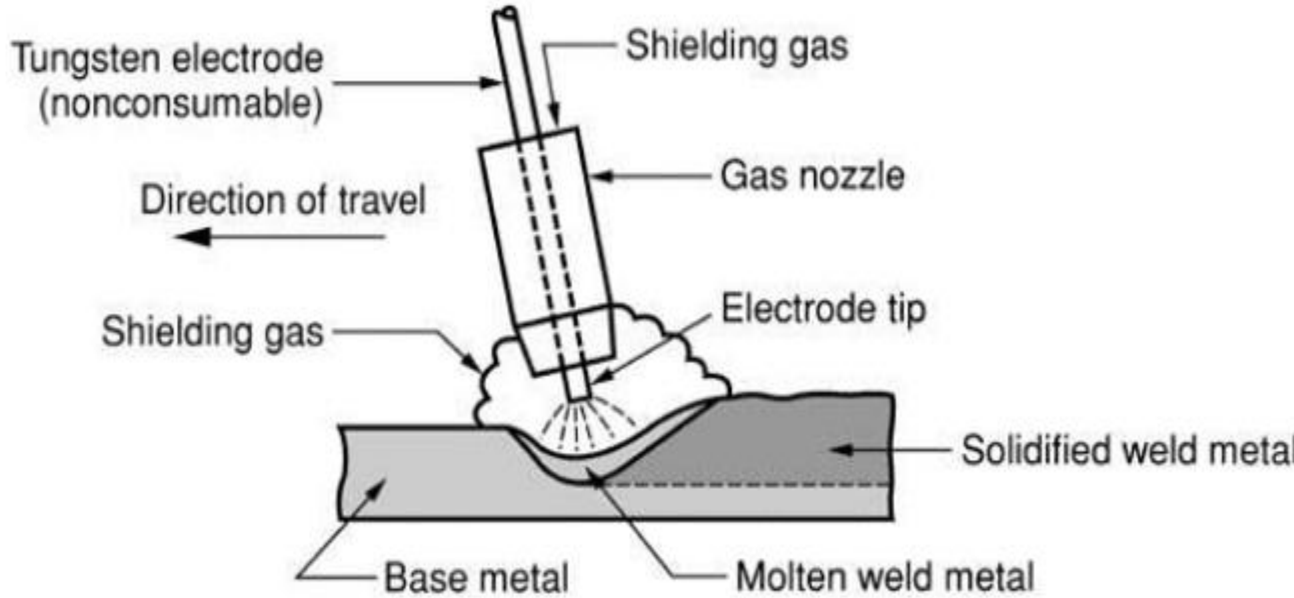


Figure 1: Tungsten Inert Gas (TIG)

Consumable electrode methods

Main articles: Shielded metal arc welding, Gas metal arc welding, Flux-cored arc welding and Submerged arc welding

Shielded metal arc welding

One of the most common types of arc welding is shielded metal arc welding (SMAW), which is also known as manual metal arc welding (MMAW) or stick welding. An electric current is used to strike an arc between the base material and a consumable electrode rod or *stick*. The electrode rod is made of a material that is compatible with the base material being welded and is covered with a flux that gives off vapors that serve as a shielding gas and provide a layer of slag, both of which protect the weld area from atmospheric contamination. The electrode core itself acts as filler material, making a separate filler unnecessary. The process is very versatile, requiring little operator training and inexpensive equipment.

Gas metal arc welding (GMAW):

commonly called *MIG* (for *metal/inert-gas*), is a semi-automatic or automatic welding process with a continuously fed consumable wire acting as both electrode and filler metal, along with an inert or semi-inert shielding gas flowed around the wire to protect the weld site from contamination. Constant voltage, direct current power source is most commonly used with GMAW, but constant current alternating current are used as well. With continuously fed filler electrodes, GMAW offers relatively high welding speeds, however the more complicated equipment reduces convenience and versatility in comparison to the SMAW process. Originally developed for welding aluminium and other non-ferrous materials in the 1940s, GMAW was soon economically applied to steels.

Flux-cored arc welding (FCAW):

It is a variation of the GMAW technique. FCAW wire is actually a fine metal tube filled with powdered flux materials. An externally supplied shielding gas is sometimes used, but often the flux itself is relied upon to generate the necessary protection from the atmosphere. The process is widely used in construction because of its high welding speed and portability.

Submerged arc welding (SAW):

It is a high-productivity welding process in which the arc is struck beneath a covering layer of granular flux. This increases arc quality, since contaminants in the atmosphere are blocked by the flux. The slag that forms on the weld generally comes off by itself and, combined with the use of a continuous wire feed, the weld deposition rate is high. As the arc is not visible, it is typically automated. SAW is only possible in the 1F (flat fillet), 2F (horizontal fillet), and 1G (flat groove) positions.

Non-consumable electrode methods

Gas tungsten arc welding (GTAW), or *tungsten/inert-gas* (TIG) welding, is a manual welding process that uses a non-consumable electrode made of tungsten, an inert or semi-inert gas mixture, and a separate filler material. Especially useful for welding thin materials, this method is characterized by a stable arc and high quality welds, but it requires significant operator skill and can only be accomplished at relatively low speeds. Because of its stable current, the method can be used on a wider range of material thicknesses than can the GTAW process and is much faster. It can be applied to all of the same materials as GTAW except magnesium; automated welding of stainless steel is one important application of the process. Other arc welding processes include atomic hydrogen welding, carbon arc welding, electroslag welding, electrogas welding, and stud arc welding.

Metal Inert Gas (MIG): Metal Inert Gas (MIG) is an arc welding process that uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide shielding.The process is illustrated in Figure 2. Under the correct conditions, the wire is fed at a constant rate to the arc, matching the rate at which the arc melts it. The filler metal is the thin wire that’s fed automatically into the pool where it melts. The filler metal used in the rod must be compatible with the metal to be welded, the composition usually being very close to that of the base metal.
The coating on the rod consists of powdered cellulose mixed with oxides, carbonates, and other ingredients, held together by a silicate binder. Metal powders are also sometimes included in the coating to increase the amount of filler metal and to add alloying elements. The heat of the welding process melts the coating to provide a protective atmosphere and slag for the welding operation. It also helps to stabilize the arc and regulate the rate at which the electrode melts.

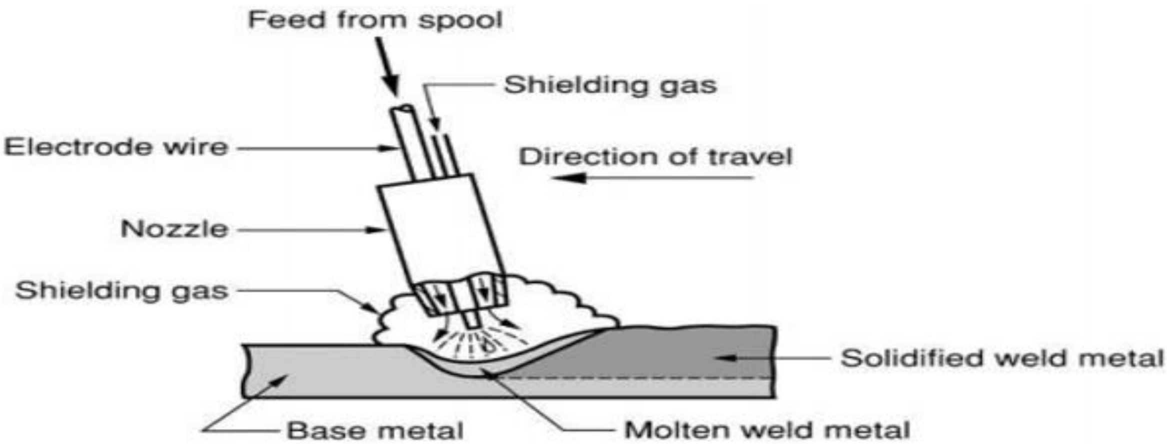


Figure 2: Metal Inert Gas (MIG)

Since fluxes are not used, the welds produced are sound, free of contaminants, and as corrosion-resistant as the parent metal.Argon, helium, and carbon dioxide can be used alone or in various combinations for MIG welding of ferrous metals.

Welding Joints:

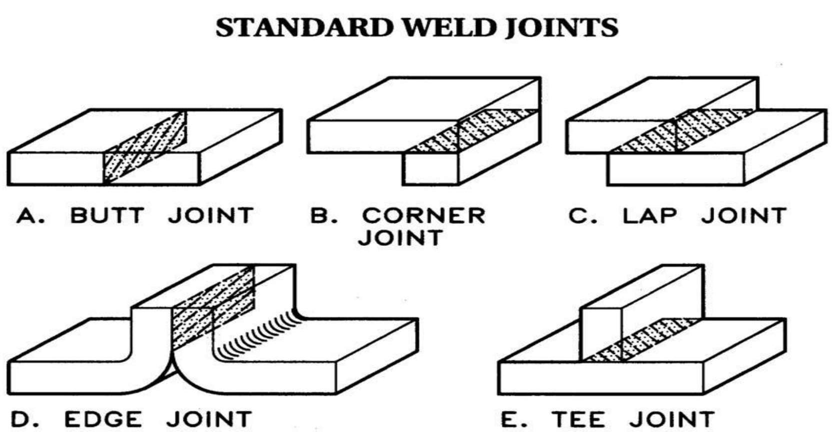


Figure 3: Standard Weld Joints

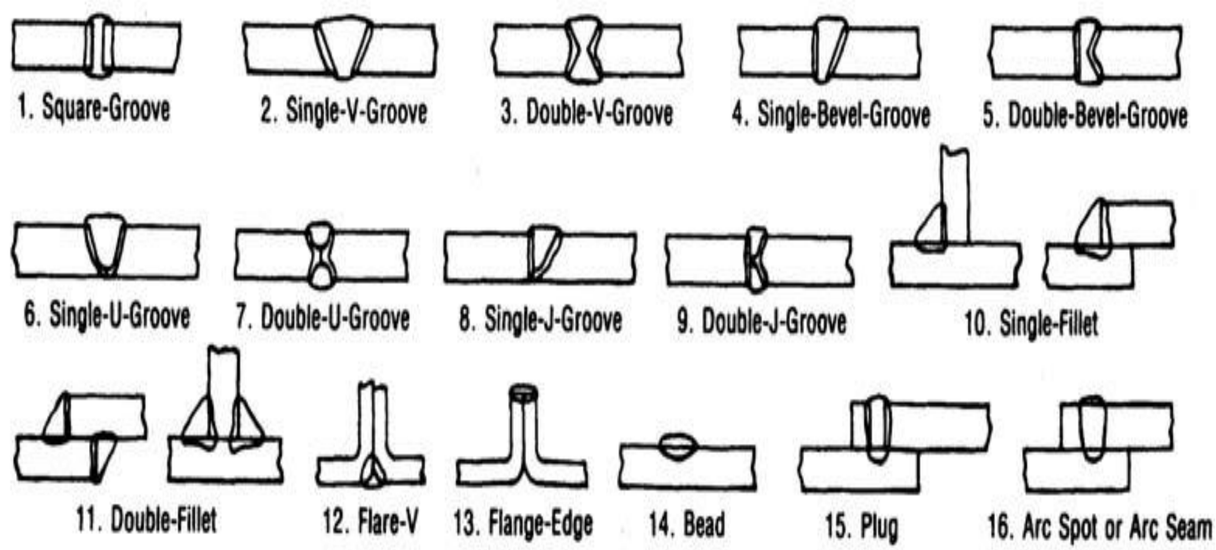


Figure 4: Other basic Weld Joints

Experiment No. : 4

Experiment Name: Study on Split Pattern and Various Types of Molding Sand Properties

Different types of patterns:

The common types of patterns are:

1) Single piece pattern
2) Split piece pattern
3) Loose piece pattern
4) Gated pattern
5) Match pattern
6) Sweep pattern
7) Cope and drag pattern

Split pattern:

These patterns are split along the parting plane (which may be flat or irregular surface) to facilitate the extraction of the pattern out of the mould before the pouring operation. For a more complex casting, the pattern may be split in more than two parts.

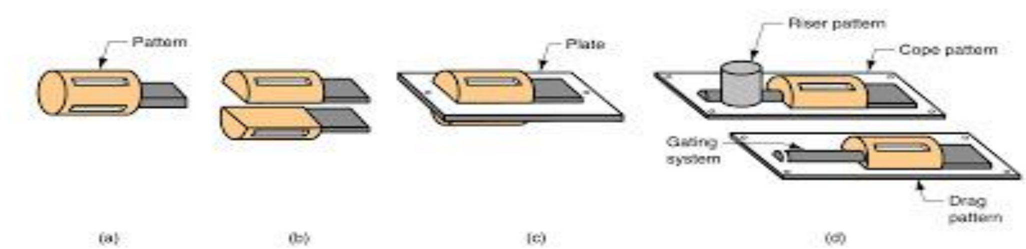


Figure 1: a) single piece pattern, b) split pattern, c) match plate pattern, d) cope and drag pattern

Loose piece pattern:

When a one piece solid pattern has projections or back drafts which lie above or below the parting plane, it is impossible to with draw it from the mould. With such patterns, the projections are made with the help of loose pieces. One drawback of loose feces is that their shifting is possible during ramming.

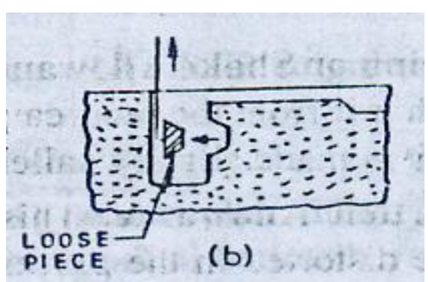


Figure: **Loose piece pattern**

Gated pattern:

A gated pattern is simply one or more loose patterns having attached gates and runners. Because of their higher cost, these patterns are used for producing small castings in mass production systems and on molding machines.

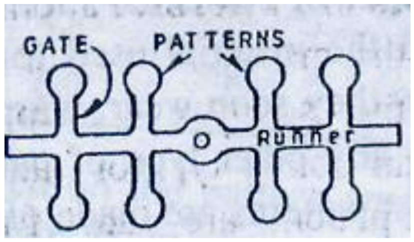


Figure: **Gated pattern**

Match plate pattern:

A match plate pattern is a split pattern having the cope and drags portions mounted on opposite sides of a plate (usually metallic), called the "match plate" that conforms to the contour of the parting surface. The gates and runners are also mounted on the match plate, so that very little hand work is required. This results in higher productivity. This type of pattern is used for a large number of castings. Piston rings of I.C. engines are produced by this process.

Sweep pattern:

A sweep is a section or board (wooden) of proper contour that is rotated about one edge to shape mould cavities having shapes of rotational symmetry. This type of pattern is used when a casting of large size is to be produced in a short time. Large kettles of C.I. are made by sweep patterns.

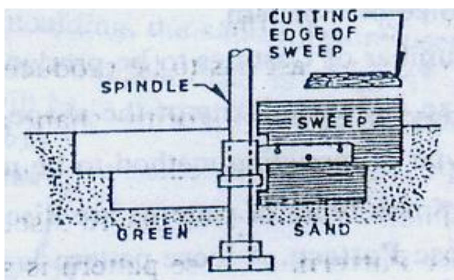


Figure: **Sweep pattern**

Cope and drag pattern:

A cope and drag pattern is a split pattern having the cope and drag portions each mounted on separate match plates. These patterns are used when in the production of large castings; the complete moulds are too heavy and unwieldy to be handled by a single worker.

Pattern Allowances:

To compensate for any dimensional and structural changes which will happen during the casting or patterning process, allowances are usually made in the pattern.

Contraction allowances / Shrinkage allowance:

The pattern needs to incorporate suitable allowances for shrinkage; these are called *contraction allowances*, and their exact values depend on the alloy being cast and the exact sand casting method being used. Some alloys will have overall linear shrinkage of up to 2.5%, whereas other alloys may actually experience no shrinkage or a slight "positive" shrinkage or increase in size in the casting process (notably type metal and certain cast irons). The shrinkage amount is also dependent on the sand casting process employed, for example clay-bonded sand, chemical bonded sands, or other bonding materials used within the sand. The actual shrinkage in the casting depends on the following factors:

- Dimension of the casting
- Design and intricacy of casting
- Resistance of mold to shrinkage
- Molding material used
- Pouring temperature of the molten metal
- Method of molding used

Draft or Taper Allowance:

The pattern needs to incorporate suitable allowances for draft, which means that its slides are tapered so that when it is pulled from the sand, it will tend not to drag sand out of place along with it. This is also known as taper which is normally between 1^0 and 3^0. The amount of the draft needed depends on the following factors:

- Shape of the pattern
- Length of the vertical side of the pattern
- Method of molding
- Intricacy of the pattern

Distortion allowance:

It is found that big castings tend to wrap or distort the cooling period due to their size, shape and type of metal. Uneven shrinkage also causes distortion. To overcome this effect, the pattern is made initially distorted in opposite direction. Such allowance depends on the judgment and experience of the pattern maker who knows the shrinkage characteristics of the metal.

Finishing or Machining Allowance:

The rough surfaces of the casting are to be finished or machined. Therefore, the rough casting must be made bigger than the actual component in size and hence the pattern should also be bigger in size than the actual components. The finishing allowance depends on the following factors:

- Machining operation
- Characteristics of metal
- Methods of casting
- Size and shape of the casting
- Degree of finish required in casting

Shake allowance:

When the pattern is rapped or shaken for easy removal from the cavity, it is found the cavity in the mold is slightly increased in size. To compensate this increase, the pattern should be initially made slightly smaller. In small and medium sized casting, this allowance can be ignored, but in large sized castings or in those that must fit together without machining or where high precision is required, shaking allowance is provided by making the pattern slightly smaller

Molding sands

Molding sands, also known as *foundry sands*, are defined by **eight characteristics**:

- ❖ **Refractoriness** — this refers to the sand's ability to withstand the temperature of the liquid metal being cast without breaking down. For example some sands only need to withstand 650 °C (1,202 °F) if casting aluminum alloys, whereas steel needs sand that will withstand 1,500 °C (2,730 °F). Sand with too low a refractoriness will melt and fuse to the casting.
- ❖ **Chemical inertness** — the sand must not react with the metal being cast. This is especially important with highly reactive metals, such as magnesium and titanium.
- ❖ **Permeability** — this refers to the sand's ability to exhaust gases. This is important because during the pouring process many gases are produced, such as hydrogen, nitrogen, carbon dioxide, and steam, which must leave the mold otherwise casting defects, such as blow holes and gas holes, occur in the casting. Note that for each cubic centimeter (cc) of water added to the mold 16,000 cc of steam is produced.
- ❖ **Surface finish** — the size and shape of the sand particles defines the best surface finish achievable, with finer particles producing a better finish. However, as the particles become finer (and surface finish improves) the permeability becomes worse.
- ❖ **Cohesiveness** (or **bond**) — this is the ability of the sand to retain a given shape after the pattern is removed.
- ❖ **Flowability** – The ability for the sand to flow into intricate details and tight corners without special processes or equipment.
- ❖ **Collapsibility** — this is the ability of the sand to be easily stripped off the casting after is has solidified. Sands with poor collapsibility will adhere strongly to the casting. When casting metals that contract a lot during cooling or with long freezing temperature ranges sand with poor collapsibility will cause cracking and hot tears in the casting. Special additives can be used to improve collapsibility.
- ❖ **Availability/cost** — the availability and cost of the sand is very important because for every ton of metal poured, three to six tons of sand is required. Although sand can be screened and reused, the particles eventually become too fine and require periodic replacement with fresh sand.

Results of Proper sand:

i. It distributes the binder uniformly around sand grains
ii. Control moisture content
iii. Eliminate foreign particles
iv. Delivers the sand at proper temperature

Experiment: 5

Study of Gas welding, Gas cutting, Soldering and Brazing

OBJECTIVE

- Become familiar with Gas welding, Gas cutting, soldering and brazing processes

Student will be introduced to:

- The gas welding equipment, related tools and the essential process safety considerations
- Types of work materials, filler rods and fluxes

THEORY

Gas Welding:

Gas Welding or Oxy-fuel gas welding is a general term used to describe any welding process that uses a fuel gas combined with oxygen to produce a flame. The most commonly used fuel is acetylene (C_2H_2) gas. The heat source is the flame obtained by combustion of oxygen and acetylene. When mixed together in correct proportions within a hand-held torch or blowpipe, a relatively hot flame is produced with a temperature of about 3300ºC (6000ºF). The chemical action of the oxyacetylene flame can be adjusted by changing the ratio of the volume of oxygen to acetylene.

The combustion of oxygen and acetylene ($C_2 H_2$) is a two-stage reaction. Chemical reactions are as follows: -

Stage 1: In the first stage, the supplied oxygen and acetylene react to produce Carbon Monoxide and Hydrogen. Approximately one-third of the total welding heat is generated in this stage.

$C_2H_2 + O_2 = 2CO + H_2 + \text{heat}$

Stage 2: The second stage of the reaction involves the combustion of the CO and H_2. The remaining two-third of the heat is generated in Stage 2. The specific reactions of the second stage are:

$2CO + O_2 = 2CO_2 + \text{heat}$

$H_2 + ½ O_2 = H_2O + \text{heat}$

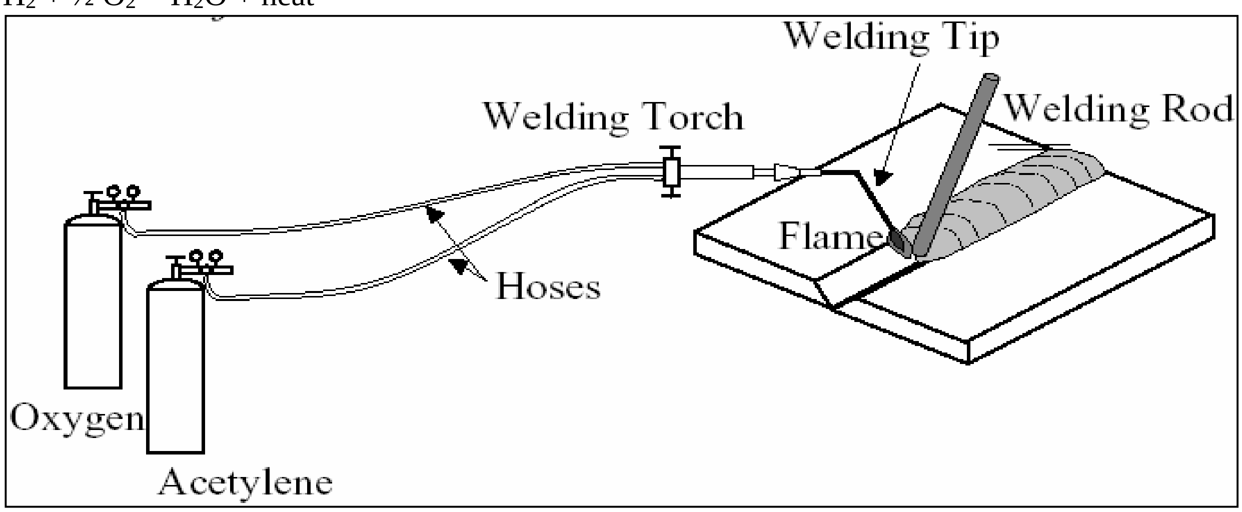


Figure 1: Gas Welding (Oxygen–fuel gas) process

<u>Types of flames:</u>

Three different types of flames can be obtained by varying the oxygen–acetylene (or oxygen–fuel gas) ratio.

Neutral Flame: When the ratio of oxygen-acetylene (or oxygen–fuel gas) is between 1:1 and 1.15:1, all reactions are carried to completion and a neutral flame is produced. As the supply of oxygen to the blowpipe is increased, the flame contracts and the white cone become clearly defined, assuming a definite rounded shape. This type of flame is the one most extensively used by the welder, who should make himself thoroughly familiar with its appearance and characteristics.

Oxidizing flame: A higher ratio of oxygen-acetylene (or oxygen–fuel gas), such as 1.5:1, produces an oxidizing flame, which is hotter than the neutral flame (about 3600°C or 6000°F). With the increase in oxygen supply, the inner cone will become shorter and sharper, the flame will turn a deeper purple color and emit a characteristic slight "hiss". An oxidizing flame is only used for special applications.

Carburizing flame: Excess fuel compared to oxygen produces a carburizing flame. The excess fuel decomposes to carbon and hydrogen, and the flame temperature is not as great (about 3050°C or 5500°F). This type of flame is mainly used for hard surfacing and should not be employed for welding steel as unconsumed carbon may be introduced into the weld and produce a hard, brittle, deposit.

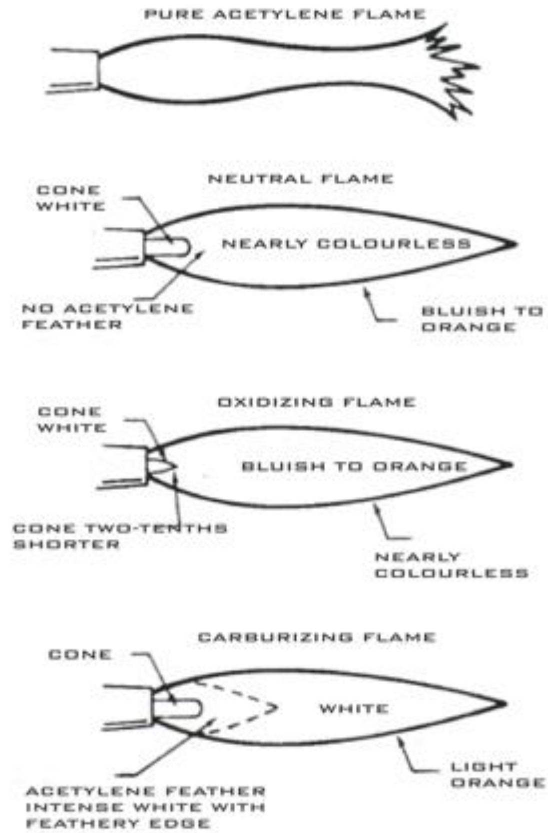


Figure 2: Gas Welding Flames

Filler Metals & Flux

Filler metals are used to supply additional material to the weld zone during welding. These consumable filler metals maybe bare or flux coated. The purpose of flux is to retard oxidation of the surfaces of the parts being welded, by generating a gaseous shield around the weld zone.

<u>Gas Cutting</u>: Gas Cutting or Oxyfuel-gas cutting, commonly called flame cutting, is the most common thermal cutting process. The oxyfuel flame is first used to raise the metal to the temperature where burning can be initiated. Then a stream of pure oxygen is added to the torch (or the oxygen content of the oxyfuel mixture

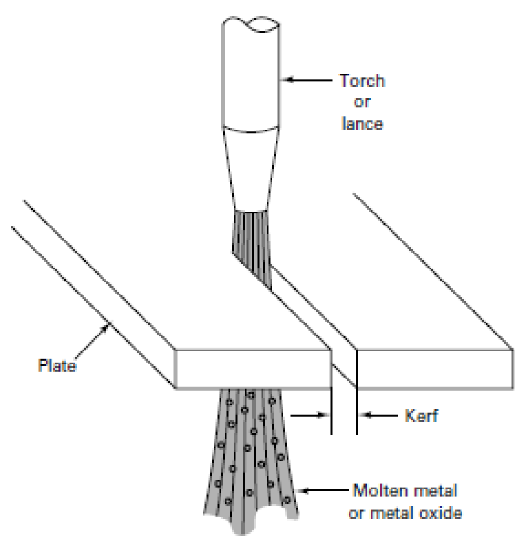


Figure 3: Gas cutting of a metal plate

is increased) to oxidize the metal. The liquid metal oxide and any unoxidized molten metal are then expelled from the joint by the kinetic energy of the oxygen-gas stream.By moving the flame and oxygen jet (torch tip) progressively forward, fresh metal and oxygen are brought together forming oxide or slag in molten form and expelling it to form a gap, or kerf, as illustrated in figure 3. A balance must be achieved among speed of movement, oxygen jet size, and intensity of flame to achieve a continuous operation.

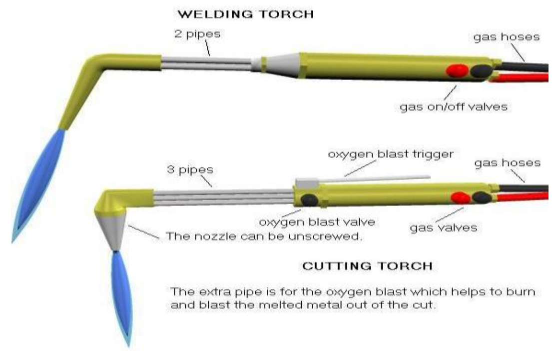


Figure 5: welding torch

Gas Welding/Cutting Equipment

The apparatus used in gas welding consists basically of an oxygen source and a fuel gas source, regulators, hoses, non-return valve, check valve and torches.

Regulator: The regulator is used to control pressure from the tanks by regulating pressure and flow rate of gas. It releases the gas at a constant rate from the cylinder despite the pressure in the cylinder becoming less as the gas in the cylinder is used.

Hoses: The hose is usually a double-hose design i.e. there are two hose joined together. The oxygen hose is green and the fuel hose is red.

Non-return valve: Between the regulator and hose and ideally between hose and torch on both oxygen and fuel lines, a non-return valve and/or flashback arrestor should be installed to prevent flame/oxygen-fuel mixture being pushed back into either cylinder and damaging the equipment.

Check valve: A check valve lets gas flow in one direction only. Not to be confused with flashback arrestor, a check valve is not designed to block a shockwave. A check valve is usually a chamber containing ball that is pressed against on end by a spring. Gas flow in a particular direction pushes the ball out of the way while no flow or flow on the other way lets the spring push the ball into the inlet thus blocking it.

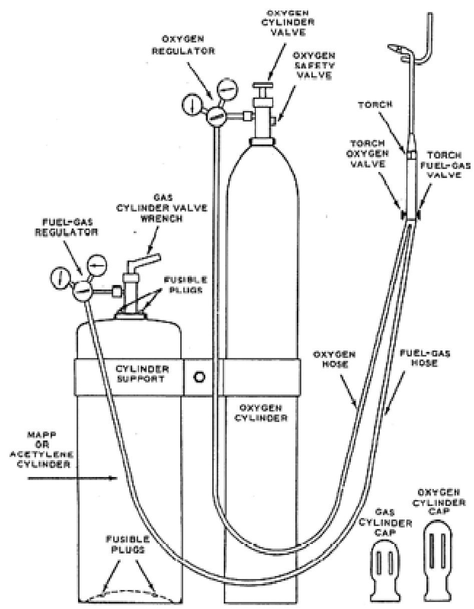


Figure 4: An Oxy-Acetylene welding outfit.

Torches: The torch is the part that the welder holds and manipulates to make the weld. It has a connection and valve for Oxygen and also a connection and valve for Fuel, a handle for grasp, a mixing chamber for mixing of the fuel and oxygen, a tip where the flame forms. A **welding torch** head is used to weld metals and can be identified by having only two pipes running to the nozzle and no oxygen blast trigger. A **cutting torch** head is used to cut metals and can be identified by having three pipes that go to an around 90^0 nozzle and also by oxygen-blast trigger that provides oxygen to blast away material while cutting.

Soldering & Brazing: In soldering & brazing, the surfaces to be joined are first cleaned, the components assembled or fixture, and a low-melting-point nonferrous metal (filler metal) is then melted, drawn into the space between the two solids by capillary action, and allowed to solidify.

Brazing is the permanent joining of similar or dissimilar metals or ceramics (or composites based on those two materials) through the use of heat and a filler metal whose melting temperature (actually, liquidus temperature) is above 450°C (840°F) but below the melting point (or solidus temperature) of the materials being joined.

Soldering is a brazing-type operation where the filler metal has a melting temperature (or liquidus temperature if the alloy has a freezing range) below 450°C (840°F). It is typically used for joining thin metals, connecting electronic components, joining metals while avoiding exposure to high elevated temperatures, and filling surface flaws and defects.

Flux is the substance added to the metal surface to stop the formation of any oxides or similar contaminants that are formed during the soldering and brazing processes. The flux increases both the flow of the filler metal and its ability to stick to the base metal.

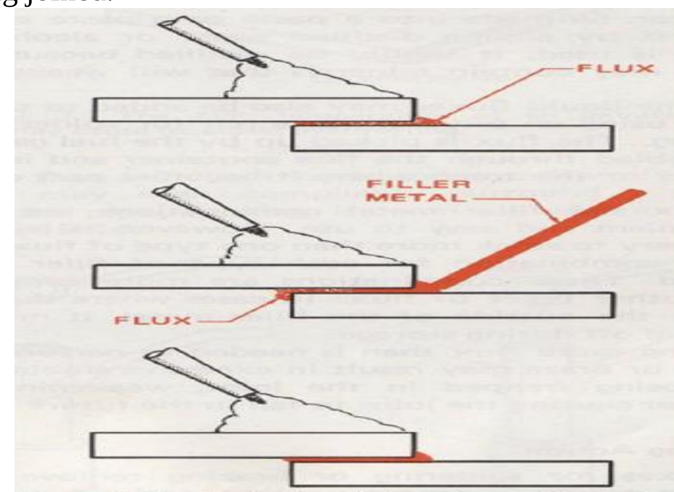


Figure 6: Flux flowing into a joint reduces oxides to clean the surfaces and gives rise to capillary action that causes the filler metal to flow.

Experiment 6:

<u>Study on single pattern double mold preparation and various types of casting defects.</u>

Casting Defects

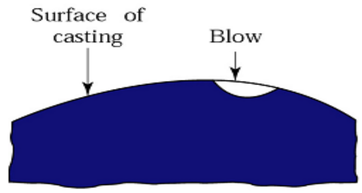
These defects may be the result of:

(a) Improper pattern design,
(b) improper mold and core construction,
(c) improper melting practice,
(d) improper pouring practice and
(e) Because of molding and core making materials.
(f) Improper gating system
(g) improper metal composition
(h) inadequate melting temp and rate of pouring it creates a deficiency or imperfection.

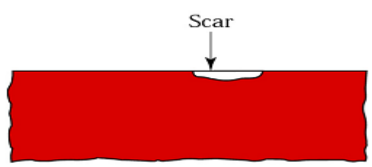
Exceeding quality limits imposed by design and service casting defects are mainly 3 categories. These are:

(1) Major or most severe defects
(2) Intermediate defects
(3) Minor defects

Surface defects:
Due to design and quality of sand molds and general cause is poor ramming.
Blow:
Blow is relatively large cavity produced by gases which displace molten metal form.

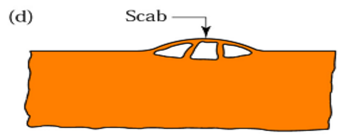


Scar:
Due to improper permeability or venting. A scare is a shallow blow. It generally occurs on flat surf; whereas a blow occurs on a convex casting surface. A blister is a shallow blow like a scar with thin layer of metal covering it.



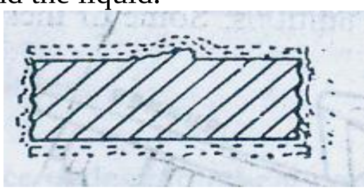
Scab:

This defect occurs when a portion of the face of a mould lifts or breaks down and the recess thus made is filled by metal. When the metal is poured into the cavity, gas may be disengaged with such violence as to break up the sand which is then washed away and the resulting cavity filled with metal. The reasons can be: - to fine sand, low permeability of sand, high moisture content of sand and uneven moulds ramming.



Drop:

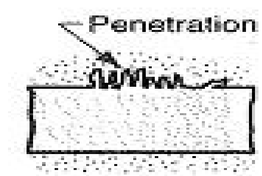
Drop or crush in a mold is an irregularly shaped projection on the cope surface of a casting. This defect is caused by the break-away of a part of mold sand as a result of weak packing of the mold, low strength of the molding sand, malfunctioning of molding equipment, strong jolts and strikes at the flask when assembling the mold. The loose sand that falls into the cavity will also cause a dirty casting surface, either on the top or bottom surface of the casting, depending upon the relative densities of the sand and the liquid.



Penetration:

It is a strong crust of fused sand on the surface of a casting which results from insufficient refractoriness of molding materials, a large content of impurities, inadequate mould packing and poor quality of mould washes.

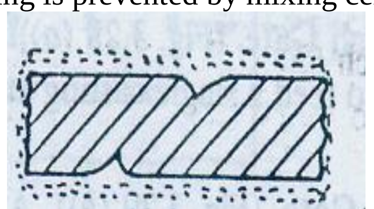
When the molten metal is poured into the mould cavity, at those places when the sand packing is inadequate, some metal will flow between the sand particles for a distance into the mould wall and get solidified.



Buckle:

A buckle is a long, fairly shallow, broad, vee depression that occurs in the surface of flat castings. It extends in a fairly straight line across the entire flat surface.

It results due to the sand expansion caused by the heat of the metal, when the sand has insufficient hot deformation. It also results from poor casting design providing too large a flat surface in the mold cavity. Buckling is prevented by mixing cereal or wood flour to sand.



Internal defects:

Blow holes:

Blow holes, gas holes or gas cavities are well rounded cavities having a clean and smooth surface. They appear either on the casting surface or in the body of a casting.These defects occur when an excessive evolved gas is not able to flow through the mold. So, it collects into a bubble at the high points of a mold cavity ad prevents the liquid metal from filling that space. This will result in open blows. Closed, cavities or gas holes are formed when the evolved gases or the dissolved gases in the molten metal are not able to leave the m ass of the molten metal as it solidifies and get trapped within the casting.

These defects are caused by:

i) Excessive moisture content (in the case of green sand moulds) or organic content of the sand, moisture on chills, chaplets or metal inserts,

ii) Inadequate gas permeability of the molding sand (due to fine grain size of sand, high clay content, hard ramming),

iii) Poor venting of mould, insufficient drying of mould and cores, cores not properly vented, high gas content of the molten metal,

iv) Low pouring temperature and incorrect feeding of the casting etc.

Pin holes:

Pin holes are small gas holes either at the surface or just below the surface. When these are present, they occur in large numbers and are fairly uniformly dispersed over the surface.

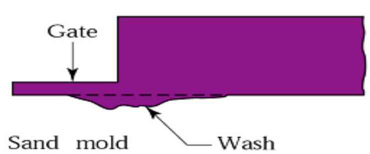
This defect occurs due to gas dissolved in the alloy and the alloy not properly degassed.

Visible defects:

Wash:

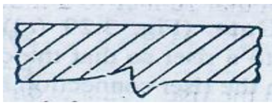
A cut or wash is a low; projection on the drag face of a casting that extends along the surface, decreasing in height as it extends from one side of the casting to the other end.

It usually occurs with bottom gating castings in which the molding sand has insufficient hot strength, and when too much metal is made to flow through one gate into the mold cavity.

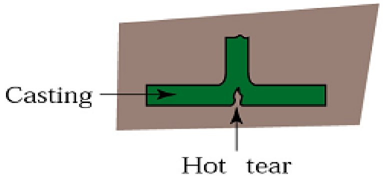


Rat tail:

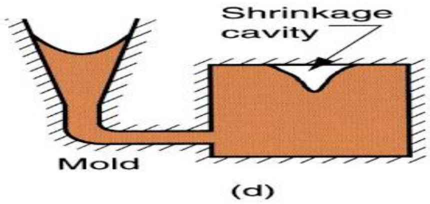
A rat tail is a long, shallow, angular depression in the surface of a flat rating and resembles a buckle, except that, it is not shaped like a broad vee. The reasons for this defect are the same for buckle.



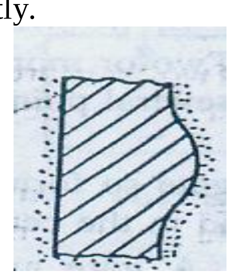
Hot tear:
Hot tears are hot cracks which appear in the form of irregular crevices with a dark oxidized fracture surface. They arise when the solidifying met does not have sufficient strength to resist tensile forces produced during solidification.
They are chiefly from an excessively high temperature of casting metal, increased metal contraction incorrect design of the gating system and casting on the whole (causing portions of the casting to be restrained from shrinking freely during cooling which in turn causes excessive high intern resistance stresses), poor deformability of the cores, and non-uniform cooling which gives rise t internal stresses. This defect can be avoided by improving the design of the casting and by having a mould of low hot strength and large hot deformation.



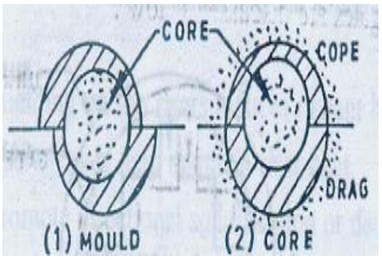
Shrinkage:
A shrinkage cavity is a depression or an internal void in a casting that results from the volume contraction that occurs during solidification.

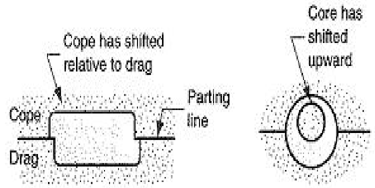


Swell:
A swell is a slight, smooth bulge usually found on vertical faces of castings, resulting from liquid metal pressure. It may be due to low strength of mold because of too high a water content or when the mold is not rammed sufficiently.



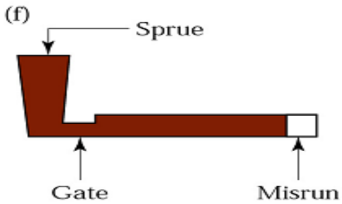
Shift:
Mold shift refers to a defect caused by a sidewise displacement of the mold cope relative to the drag, the result of which is a step in the cast product at the parting line. Core shift is similar to mold shift, but it is the core that is displaced, and (the dis-placement is usually vertical. Core shift and mold shift are caused by buoyancy of the molten metal





Misrun or cold sheet or short run:

This defect is incomplete cavity filling. The reasons can be: - inadequate metal supply, too- low mold or melt temperature, improperly designed gates, .or length to thickness ratio of the casting is too large. When molten metal is flowing from one side in a thin section, it may loose sufficient heat resulting in loss of its fluidity, such that the leading edge of the stream may freeze before it reaches the end of the cavity.



REPORT CONTENTS:

1. Title
2. Equipment used
3. Experimental setup
4. Experimental Procedure
5. Work (schematic diagram: before welding and after welding)
6. Results and the sketch (drawing) of the welded work pieces
7. Discussion
8. Question answer

Ahsanullah University of Science and Technology

Department of Arts and Sciences

LABORATORY MANUAL

FOR

CHEMISTRY SESSIONAL COURSES

Manual I

Quantitative Inorganic Analysis

Experiment No. 01

Experiment Name: **Standardization of sodium hydroxide solution with a standard solution of oxalic acid.**

Preparation of standard 0.050 M oxalic acid solution

Weigh out exactly **0.63 g** of pure crystalline oxalic acid dihydrate ($HOOC-COOH.2H_2O$) in a **100 ml** volumetric flask. Dissolve it with little amount of distilled water and fill it up to the mark.

Working Procedure

i) Take the supplied sodium hydroxide solution in the burette.
ii) Pipette out exactly **10.0 ml** of the prepared oxalic acid solution into a conical flask.
iii) Add 1-2 drops of **phenolphthalein** as indicator.
iv) Record the initial burette reading.
v) Add **sodium hydroxide** solution from the burette into the conical flask with constant shaking until the color changes from **colorless** to **pink** and record the burette (final reading) again.
vi) Repeat the procedures **(ii-v)** at least three times and take the average (for *average, data which have differences within 0.3 should be considered)*. This value is the volume of sodium hydroxide solution required to neutralize the standard 10.0 ml oxalic acid solution.
vii) Calculate the concentration in terms of **Molarity** by using both **formula** and **unitary method.**

Reaction

$$a\,\mathrm{HOOC{-}COOH\,(aq)} + b\mathrm{NaOH\,(aq)} \rightarrow p\,\mathrm{NaOOC{-}COONa\,(aq)} + q\mathrm{H_2O\,(l)}$$

Calculation:

From the above reaction, it is clear that in order to be neutralized; *a* mol **(coefficient)** of oxalic acid reacts with *b* mol **(coefficient)** of sodium hydroxide. The concentration of sodium hydroxide solution (in terms of morality) can be determined using the following formula:

$$\frac{M_1V_1}{a} = \frac{M_2V_2}{b}$$

Where M_1 = Molarity of oxalic acid solution = 0.050 M
V_1 = Volume of oxalic acid solution taken = 10.0 ml
M_2 = Molarity of sodium hydroxide solution = ? M
V_2 = Volume of sodium hydroxide solution required = Avg. burette reading (? ml)

Questions:

1. Which one of NaOH and Oxalic acid is the primary standard substance in this experiment? Explain giving definition of primary standard and secondary standard substance.
2. Why Phenolphthalein is chosen as the suitable indicator for this experiment? Use titration curve for explanation.
3. Write the balanced reaction. Mention the type of reaction with definition.
4. Calculate the strength of NaOH solution in normality (N).

Fil

Experiment No. 01

Experiment Name: Standardization of sodium hydroxide solution with a standard solution of oxalic acid.

Preparation of standard 0.050 M oxalic acid solution

Weigh out exactly **0.63 g** of pure crystalline oxalic acid dihydrate (HOOC–COOH.2H_2O) in a **100 ml** volumetric flask. Dissolve it with little amount of distilled water and fill it up to the mark.

Working Procedure

i) Take the supplied sodium hydroxide solution in the burette.

ii) Pipette out exactly **10.0 ml** of the prepared oxalic acid solution into a conical flask.

iii) Add **1-2** drops of **phenolphthalein** as indicator.

iv) Record the initial burette reading.

v) Add **sodium hydroxide** solution from the burette into the conical flask with constant shaking until the color changes from **colorless** to **pink** and record the burette (final reading) again.

vi) Repeat the procedures **(ii-v)** at least three times and take the average (for *average, data which have differences within 0.3 should be considered)*. This value is the volume of sodium hydroxide solution required to neutralize the standard 10.0 ml oxalic acid solution.

vii) Calculate the concentration in terms of **Molarity** by using both **formula** and **unitary method.**

Reaction

$$a\ \text{HOOC–COOH (aq)} + b\text{NaOH (aq)} \rightarrow p\ \text{NaOOC–COONa (aq)} + q\text{H}_2\text{O (l)}$$

Calculation:

From the above reaction, it is clear that in order to be neutralized; ***a*** mol (**coefficient**) of oxalic acid reacts with ***b*** mol (**coefficient**) of sodium hydroxide. The concentration of sodium hydroxide solution (in terms of morality) can be determined using the following formula:

$$\frac{M_1V_1}{a} = \frac{M_2V_2}{b}$$

Where M_1 = Molarity of oxalic acid solution = 0.050 M
V_1 = Volume of oxalic acid solution taken = 10.0 ml
M_2 = Molarity of sodium hydroxide solution = ? M
V_2 = Volume of sodium hydroxide solution required = Avg. burette reading (? ml)

Questions:

1. Which one of NaOH and Oxalic acid is the primary standard substance in this experiment? Explain giving definition of primary standard and secondary standard substance.
2. Why Phenolphthalein is chosen as the suitable indicator for this experiment? Use titration curve for explanation.
3. Write the balanced reaction. Mention the type of reaction with definition.
4. Calculate the strength of NaOH solution in normality (N).

Experiment No. 02

Experiment Name: Standardization of HCl solution with a secondary standard solution of sodium hydroxide (NaOH).

Standardization of sodium hydroxide solution: The supplied sodium hydroxide solution was standardized as per the procedure described in **exp # 01**

Working Procedure

i) Take the standard sodium hydroxide **(NaOH)** solution in the burette. [a]
ii) Pipette out exactly **10.0 ml** of the supplied hydrochloric acid solution into a conical flask by a volumetric pipette.
iii) Add **1-2** drops of **methyl orange** as an indicator.
iv) Record the initial burette reading.
v) Titrate the hydrochloric acid solution with the sodium hydroxide solution until the color changes from **pink to yellow.** [b]
vi) Note the final burette reading.
vii) Repeat the procedure **(ii-vi)** at least three times and take the average. This value is the volume of sodium hydroxide solution required to neutralize the hydrochloric acid solution.
viii) Calculate the concentration in terms of **Molarity** by using both **formula** and **unitary methods.**

Reaction:

$$a\mathrm{HCl(aq)} + b\mathrm{NaOH(aq)} \rightarrow p\mathrm{NaCl(aq)} + q\mathrm{H_2O(l)}$$

Calculation:

Calculate the molarity of the HCl solution from the following formula:

$$M_1V_1 / a = M_2V_2 / b$$

Where M_2 = Molarity of sodium hydroxide solution.
V_2 = Volume of sodium hydroxide solution taken.
M_1 = Molarity of hydrochloric acid solution (=?).
V_1 = Volume of hydrochloric acid solution required.

Questions:

1. Show by pH – Neutralization curve that methyl orange is suitable for this titration.
2. Do you think that phenolphthalein or methyl red can be used here? Justify your answer.
3. Calculate the concentration of HCl in terms of normality **(N)**.

Note:

(a) If this experiment is not carried out just after finishing the experiment-01 then HCl solution is better to take in the burette instead of NaOH solution.
(b) In some places color change is written as red to orange but pink to yellow is usually observed.

Experiment No. 02

Experiment Name: **Standardization of HCl solution with a secondary standard solution of sodium hydroxide (NaOH).**

Standardization of sodium hydroxide solution: The supplied sodium hydroxide solution was standardized as per the procedure described in **exp # 01**

Working Procedure

i) Take the standard sodium hydroxide **(NaOH)** solution in the burette. [a]

ii) Pipette out exactly **10.0 ml** of the supplied hydrochloric acid solution into a conical flask by a volumetric pipette.

iii) Add **1-2** drops of **methyl orange** as an indicator.

iv) Record the initial burette reading.

v) Titrate the hydrochloric acid solution with the sodium hydroxide solution until the color changes from **pink to yellow.** [b]

vi) Note the final burette reading.

vii) Repeat the procedure **(ii-vi)** at least three times and take the average. This value is the volume of sodium hydroxide solution required to neutralize the hydrochloric acid solution.

viii) Calculate the concentration in terms of **Molarity** by using both **formula** and **unitary methods.**

Reaction:

$$aHCl(aq) + bNaOH(aq) \rightarrow pNaCl(aq) + qH_2O(l)$$

Calculation:

Calculate the molarity of the HCl solution from the following formula:

$$M_1V_1 / a = M_2V_2 / b$$

Where M_2 = Molarity of sodium hydroxide solution.
V_2 = Volume of sodium hydroxide solution taken.
M_1 = Molarity of hydrochloric acid solution (=?).
V_1 = Volume of hydrochloric acid solution required.

Questions:

1. Show by pH – Neutralization curve that methyl orange is suitable for this titration.
2. Do you think that phenolphthalein or methyl red can be used here? Justify your answer.
3. Calculate the concentration of HCl in terms of normality (N).

Note:

(a) If this experiment is not carried out just after finishing the experiment-01 then HCl solution is better to take in the burette instead of NaOH solution.

(b) In some places color change is written as red to orange but pink to yellow is usually observed.

Experiment No. 03

Experiment Name: **Standardization of hydrochloric acid (HCl) solution with a standard solution of sodium carbonate (Na_2CO_3).**

Preparation of standard Na_2CO_3 solution:

Weigh out exactly **0.53 g** of pure crystalline sodium carbonate (Na_2CO_3) in a **100 ml** volumetric flask. Dissolve it with a little amount of distilled water and fill it up to the mark.

Working Procedure:

i) Take the supplied hydrochloric acid (precaution must be maintained) solution in the burette.
ii) Pipette out **exactly 10.0 ml** of the prepared **sodium carbonate** solution into a conical flask by a volumetric pipette.
iii) Add **1-2** drops of **methyl orange** as an indicator.
iv) Record the initial burette reading.
v) Titrate the sodium carbonate solution with the hydrochloric acid solution until the first drop changes its color from **yellow to pink.**
vi) Note the final burette reading.
vii) Repeat the procedure **(ii-vi)** at least three times and take the average. This value is the volume of hydrochloric acid solution required to neutralize the Na_2CO_3 solution.
viii) Calculate the concentration in terms of **Molarity** by using both **formula** and **unitary methods.**

Reaction:

$$aNa_2CO_3\,(aq) + bHCl\,(aq) \rightarrow pNaCl\,(aq) + qCO_2\,(g) + rH_2O\,(l)$$

Calculation: Calculate the molarity of the hydrochloric acid solution from the following formula:

$$M_1V_1 / a = M_2V_2 / b$$

Where, M_1 = Molarity of sodium carbonate solution.
V_1 = Volume of sodium carbonate solution taken.
M_2 = Molarity of hydrochloric acid solution.
V_2 = Volume of hydrochloric acid solution.

Questions:

1. The above reaction actually occurs in two steps. Show these steps.
2. What is salt? What type of salt sodium carbonate is: acidic or basic? Explain with reaction.
3. Sketch the titration curve and give the reason for selecting methyl orange as indicator.
4. Can you explain why indicator changes its color? **Hint:** theories of indicator action.
5. Calculate the strength of HCl in normality (N).

Experiment No. 04

Experiment Name: **Standardization of sodium thiosulphate ($Na_2S_2O_3$) solution with a standard solution of potassium dichromate ($K_2Cr_2O_7$).**

Preparation of standard potassium dichromate *($K_2Cr_2O_7$)* solution

Weigh out exactly **0.47 g** of potassium dichromate (**$K_2Cr_2O_7$**) in a **100 mL**volumetric flask. Dissolve it with a little volume of distilled water by shaking. Make the solution up to the mark by adding distilled water.

Working Procedure

i) Take the supplied **sodium thiosulphate** ($Na_2S_2O_3$) solution in the burette & note the initial reading.
ii) Take about **50 ml** of distilled water into a conical flask by using measuring cylinder.
iii) Add about **1-2 g** of potassium iodide **(KI)** into this conical flask.
iv) Add about **1 g** of **sodium bicarbonate** and shake well to dissolve it.
v) Add about **3 ml of conc. hydrochloric acid** slowly while gently rotating the flask to mix the liquids. *(CO_2 poruced here to derive out O_2 from solution and to blanket/cover the solution surface. Check the solution by a piece of litmus paper whether it is acidic or not.)*
vi) Add exactly **10.0 ml** of **potassium dichromate** solution and mix the solution well.
vii) Cover the flask immediately with a watch glass and allow standing in a **dark box** (*to prevent the solution from light*) for **5 minutes**. (*solution will be dark brown*).
viii) Take out the flask from the dark box and dilute the solution by adding **50 mL of distilled water**.
ix) Titrate the liberated **iodine** with the sodium thiosulphate solution from the burette until the color **fades and turns pale yellow**. (compare with $K_2Cr_2O_7$ solution)
x) Now add **1 ml or 10 drops of starch** (*indicator; indicates iodine*) solution into it. The solution will become **deep violet**.
xi) Continue the addition of sodium thiosulphate solution until the solution changes its color to **light green**.
xii) Note the final burette reading. This is the volume of sodium thiosulphate solution required.
xiii) Repeat the procedure **(ii-xii)** at least three times and take the average value.
xiv) Calculate the concentration in terms of **Molarity** by using both **formula** and **unitary methods**.

Reactions:

$$K_2Cr_2O_7(aq) + 14HCl(aq) + 6KI(s) = 2CrCl_3(aq) + 3I_2(g) + 8KCl(aq) + 7H_2O(l) \text{ (in dark)}$$

$$6\,Na_2S_2O_3\,(aq) + 3I_2\,(g) = 6NaI\,(aq) + 3Na_2S_4O_6\,(aq) \text{ (during titration)}$$

Therefore, $1 \text{ mol } K_2Cr_2O_7 \equiv 3 \text{ mol } I_2 \equiv 6 \text{ mol } Na_2S_2O_3$

And finally, $1 \text{ mol } K_2Cr_2O_7 \equiv 6 \text{ mol } Na_2S_2O_3$

Calculation:

Calculate the molarity of the sodium thiosulphate solution from the following formula:

$$M_1V_1 / 1 = M_2V_2 / 6$$

Where M_1 = Molarity of potassium dichromate solution
V_1 = Volume of potassium dichromate solution taken
M_2 = Molarity of sodium thiosulphate solution (=? M)
V_2 = Volume of sodium thiosulphate solution used.

Questions:

1. Define oxidation and reduction reactions in terms of electron transferred and in terms of oxidation number?
2. Give half-reactions for $K_2Cr_2O_7$, KI, $Na_2S_2O_3$ and I_2 and then level them as oxidizing and reducing agents with explanation?
3. What are Iodometric and Iodimetric titrations? Give example.
4. What is the function of $NaHCO_3$ used in this experiment? Why is the solution kept in the dark box/place and for at least 5 minutes?
5. Write the structure of starch. Mention the advantages of using starch as an indicator in this experiment. Indicator is used in this experiment at the last stage – why?

Experiment No. 05

Experiment Name: Estimation of the amount of copper present in a supplied solution by iodometric method.

Standardization of the sodium thiosulphate solution

The supplied sodium thiosulphate solution was standardized as per procedure described in **(Exp. 4).**

Working Procedure:

(i) Take the supplied sodium **thiosulphate** solution into the burette.
(ii) Take **exactly 10.0 ml** of the supplied copper solution with a volumetric pipette into a conical flask.
(iii) Add **one drop** of **concentrated acetic** acid solution into the conical flask.
(iv) Add about **1 g of** solid potassium iodide **(KI)** into it and cover it with a watch glass.
(v) Keep the flask in a **dark box** for **5 minutes**. A **reddish brown** color will be formed. Then add **20 ml** distilled water into conical flask.
(vi) Titrate the solution with standard sodium thiosulphate solution until the color becomes **light yellow**. *(this is not the end point)*
(vii) Add **10** drops of **starch** solution into the conical flask.
(viii) Add about **10 ml of 10% NH_4CNS** solution and continue adding sodium thiosulphate until the color of the solution becomes **straw/pale (white).** *(it is the end point)*
(ix) Note the final burette reading.
(x) Repeat the titration at least three times and take the average value.

Reactions:

$$2CuSO_4\,(aq) + 4KI(s) \rightarrow Cu_2I_2\,(aq) + I_2\,(g) + 2K_2SO_4\,(aq) \text{ (in dark)}$$

$$2Na_2S_2O_3\,(aq) + I_2\,(g) = 2NaI\,(aq) + Na_2S_4O_6\,(aq) \text{ (during titration)}$$

So, 2 mol $Na_2S_2O_3 \equiv 1$ mol $I_2 \equiv$ 2 mol $CuSO_4$

Calculation:

Method1: Calculate the molarity of $CuSO_4$ solution. Now use the following relationship:

$CuSO_4 \rightarrow Cu^{2+} + SO_4^{2-}$ So, 1 mol $CuSO_4$ produce 1 mol Cu^{2+}.

Therefore, the concentration of $CuSO_4$ solution = the concentration of Cu^{2+}

Now, 1M Cu^{2+} = 1mol/L Cu^{2+} = 63.54 g/L Cu^{2+}

Method 2: 1M thiosulphate solution $\equiv$ 1M $CuSO_4$ =1mol/L $CuSO_4$
= 1 mol/L Cu^{2+} = 63.54 g/L Cu^{2+}

So, 1000 ml of 1M thiosulphate solution = 63.54 g of Cu^{2+}

And finally, 1ml of 1M thisulphate solution = 0.06354 g Copper.

Questions:

1. Show the half-reactions involved here.
2. What is the function of NH_4CNS in this titration?

Experiment No. 06

ExperimentName: Standardization of potassium permanganate solution ($KMnO_4$) with a standard sodium oxalate ($Na_2C_2O_4$) solution.

Preparation of Standard sodium oxalate solution:

Weigh out accurately **0.67 g** of sodium oxalate salt in a **100 ml** volumetric flask. Dissolve by adding a little amount of distilled water and make up to the mark with distilled water.

Working Procedure

- **(i)** Take the supplied **potassium permanganate ($KMnO_4$)** solution into the burette and note the initial reading.
- **(ii)** Pipette out **exactly 10.0 ml** of **sodium oxalate ($Na_2C_2O_4$)** solution by a volumetric pipette into a conical flask.
- **(iii)** Add about **50 ml** of **1M Sulphuric** acid solution to the conical flask.
- **(iv)** Carry out the titration (add 2 – 5 drops of $KMnO_4$ solution) at the ordinary temperature until the **first point pink** color appears throughout the solution. Allow to stand until the pink color disappears and the solution becomes **colorless.**
- **(v)** Warm the solution to **50-60 °C** and continue titration to a **first permanent pink** color.
- **(vi)** Repeat the titration at least three times and take the average value.
- **(vii)** Calculate the concentration in terms of **Molarity** by using both **formula** and **unitary methods.**

Reaction:

$$aKMnO_4 + bNa_2C_2O_4 + cH_2SO_4 = dK_2SO_4 + eMnSO_4 + fCO_2 + gH_2O + hNa_2SO_4$$

Calculation

$$M_1V_1/b = M_2V_2/a$$

where
M_1 = Molarity of sodium oxalate solution
V_1 = Volume of sodium oxalate solution
M_2 = Molarity of potassium permanganate solution **(=?)**
V_2 = Volume of potassium permanganate solution

Questions:

1. Balance the above equation by half-reaction method.
2. Label $Na_2C_2O_4$ and $KMnO_4$ as oxidizing and reducing agents with reaction.
3. Sulphuric acid is used here; hydrochloric acid or nitric acid is not used. Explain why?
4. Find the normality of $Na_2C_2O_4$ and $KMnO_4$ solutions in this experiment.
5. No indicator was used in this experiment. Why?

Experiment No. 07

Experiment Name: Estimation of ferrous ions (Fe^{2+}) present in a supplied solution of ferrous sulphate ($FeSO_4$) by standard potassium permanganate ($KMnO_4$) solution.

Standardization of the supplied potassium permanganate solution

Standardize the potassium permanganate solution by the following the procedure described in **(expt.6)**.

Working Procedure

(i) Take the standard potassium permanganate solution into the burette.

(ii) Pipette out **exactly 10.0 ml** of supplied ferrous sulphate solution by a volumetric pipette into the conical flask.

(iii) Add about **10 ml of 1M sulphuric** acid solution.

(iv) Titrate the solution with a standard potassium permanganate ($KMnO_4$) solution to the first **permanent pink color**.

(v) Repeat the titration at least three times and take the average value.

Reaction:

$$2KMnO_4(aq)+10FeSO_4(aq)+8H_2SO_4(aq)=K_2SO_4(aq)+5Fe_2(SO_4)_3(aq)+2MnSO_4(aq)+8H_2O(l)$$

Therefore, $2\ mol\ KMnO_4 \equiv 10\ mol\ FeSO_4$

or, $1 mol\ KMnO_4 = 5 mol\ FeSO_4$

Calculation:

Method-1:

Calculate the molarity of $FeSO_4$ solution. To find the amount of Fe^{2+} per litre solution, see the calculation of **Method 1** in Experiment #5.

Here, $1\ mol\ Fe^{2+} = 55.85\ g\ Fe^{2+}$

Method-2: Calculate the amount of iron per liter of solution from the following equations:

$$1\ \text{mol}\ KMnO_4 \equiv 5 \times 1\ \text{mol}\ FeSO_4$$

$$1M\ FeSO_4 = 5 \times 55.85\ g/L\ of\ Fe^{2+}$$

~~So, 1 ml of 1M $KMnO_4$ = 5x 0.05585 g of~~ Fe^{2+} (see Method 2 in Exp. 5)

Questions:

1. Make the above equation by using half-reactions.
2. What is auto indicator? Give two examples.

* Auto catalyst, * Self indicator. * Temp. effect on reaction kinetics.

Experiment No. 08

Experiment Name: Determination of total Hardness of water using Eriochrome Black T (EBT) as an indicator.

Hardness

Water hardness was understood to be a measure of the capacity of water to precipitate soap. Soap is precipitated chiefly by calcium and magnesium ions present. Other polyvalent cations also may precipitate soap but they often are in complex forms, frequently with organic constituents, and their role in water hardness may be minimal and difficult to define. Total hardness is defined as the sum of the calcium and magnesium concentration, both expressed as calcium carbonate in mg/L (milligram/litre). The hardness may range from zero to hundreds of milligrams per litre, depending on the source and treatment to which has been subjected.

Basic Principle

Ethylenediaminetetraacetic acid (EDTA) from a chelated soluble complex when added to a solution of certain metal cations. If a small amount of dye such as Eriochrome Black T (EBT) is added to an aqueous solution containing calcium and magnesium ions at a P^H of 10.0 ± 0.1, the solution becomes wine red. If EDTA is added as a titrant, the calcium and magnesium will be complexed, and when all the magnesium and calcium has been complexed the solution turns from wine red to blue, making the end point of the titration.

Preparation of 0.01M EDTA disodium salt (EDTA) solution:

Weigh out accurately **0.372 g of EDTA ($C_{10}N_2O_8H_{14}Na_2.2H_2O$)** powder into a **100ml** volumetric flask and add a little water to dissolve it. Make up to mark with distilled water.

Working Procedure

- **(i)** Take the **standard EDTA** solution into the burette.
- **(ii)** Take **50 ml of sample water** (tap water) by a volumetric pipette into a conical flask.
- **(iii)** **Acidify** the sample water with **conc. hydrochloric acid** (use a litmus paper) and boil for a minute to drive off carbon dioxide (**CO_2**).
- **(iv)** **Cool** and neutralize it with sodium hydroxide (use litmus paper).
- **(v)** Add about **2 ml of** buffer solution (pH 10) and **2** drops of **EBT** indicator.
- **(vi)** Titrate the solution with a standard **0.01M EDTA** solution until the color changes from **wine red to blue**
- **(vii)** Repeat the titration at least three times and take the mean value. The mean of three readings of EDTA is the volume of EDTA required to calculate the total hardness.

Calculation

Method 1 Unitary method

Find the concentration of Ca^{2+} using 1:1 complex formation with EDTA.
Then use the relationship between Ca^{2+} and $CaCO_3$ to calculate the amount (mg) of $CaCO_3$ per litre of sample water. (*Be careful about the volume of water; it is not 10 ml*)

Method 2 (see hints below)

1 ml 0.01 M EDTA solution = 1.00 mg of $CaCO_3$ (show by calculation)

Therefore, total hardness as mg $CaCO_3$ per liter of water

= (a x b x 1000) ÷ ml of sample taken

Where, a = ml. of titrant required (mean volume of EDTA solution)

b = mg $CaCO_3$ equivalent to 1.00 ml EDTA titrant.(100 mg)

Questions:

1. Discuss on hard water and the process to soften it.
2. What are the permanent and temporary hardness of watet?
3. Define the terms Chelete and polydendate.
4. Write down the structure of EDTA. What type of reaction takes place between the Calcium and EDTA?
5. What is soap? What is meant by micelle? How soap is related with hard water or hardness of water?

Hints:

[Molar mass of $CaCO_3$ is 100 g/mol]

1 mol EDTA ≡ 1 mol Ca^{2+} = 1 mol $CaCO_3$ = 100 g $CaCO_3$

So 1M EDTA ≡ 1M $CaCO_3$ = 1mol/L $CaCO_3$ = 100 g/L $CaCO_3$

Hence 1000 ml 0.01M EDTA = 0.01 x 100 g $CaCO_3$

= 0.01x 100 x 1000 mg $CaCO_3$

= 1000 mg $CaCO_3$.

Experiment No. 09

Name of the Experiment: Determination of the available Chlorine in bleaching Powder.

Theory:

Bleaching powder consists essentially of a mixture of calcium hypochlorite, $Ca(OCl)_2$ and the basic calcium chloride $CaCl_2.Ca(OH)_2.H_2O$. Some free slaked lime is usually present. The active constituent is the hypochlorite (OCl^-), which is responsible for bleaching action. Upon treating bleaching powder with hydrochloric acid, chlorine is liberated.

$$OCl^- + Cl^- + 2H^+ = Cl_2 + H_2O$$

The available chlorine refers to the chlorine liberated by the action of dilute acid, and is expressed as the percentage by weight of the bleaching powder.

The available chlorine in bleaching powder can be determined iodometrically. For this the bleaching powder solution or suspension is treated with an excess of a solution of potassium iodide, and strongly acidified with acetic acid.

$$OCl^- + 2I^- + 2H^+ = Cl^- + I_2 + H_2O$$

The liberated iodine is titrated with a standard solution of sodium thiosulphate.

Procedure:

1. Weigh out accurately about **2.5 gm** (weight taken = X) of the bleaching powder into a clean ceramic mortar. Add a little water, and rub the mixture to a smooth paste. Add a little more water, triturate with the **pastle,** allow the mixture to settle and pour off the milky liquid into a **250 ml** volumetric flask. Grind the residue with a little more water and repeat the operation until the whole of the sample has been transferred to the flask either in solution or in a state of very fine **suspension,** and the mortar washed quite clean.
2. **Add water** to the volumetric flask up to mark and shake well.
3. Transfer **25 ml** of the turbid liquid immediately with a volumetric pipette into a **250ml** conical flask.
4. Add about **25 ml** of water into the conical flask.
5. Add about **2 gm** of solid **Iodate-free potassium iodide** to the conical flask.
6. Add **10 ml** of glacial acetic acid and shake, **Iodine** will be liberated immediately.
7. Keep the flask closed with a watch glass and place in a dark box for **5 minutes.** Then add **25 ml** distilled water to the flask.

8. Titrate the liberated iodine with standard **sodium thiosulphate** solution **(standardized as per expt.04)** until the color fades to pale yellow.
9. Add 1ml of starch indicator, a deep violet color appears.
10. Continue the titration with sodium thiosulphate until the color just disappears.

Reactions:

$$I_2 + I^- \longrightarrow I_3^-$$

$$I_3^- + 2S_2O_3^{2-} \longrightarrow 3I^- + S_4O_6^{2-}$$

Note: Sodium thiosulphate should be standardized according to procedure (04) before/ after the experiment.

Calculation:

Available Chlorine content (%) in bleaching powder =

$$\frac{0.03546g \times a \times b \times V \times 100}{P \times Q}$$

Where **a** = volume of $Na_2S_2O_3$ required in titration.
b = Molarity of $Na_2S_2O_3$ solution.
v = Total volume of suspension (250ml).
P = Amount in gm of bleaching powder taken.
Q = Volume of suspension (25ml).taken for titration.

Another Calculation:

Amount of bleaching powder in 50ml $= \frac{X \times 50}{500}$ gm

1ml $1M - Na_2S_2O_3 = 0.03546$ g of Cl

Experiment No. 10

Name of the Experiment: Drawing the pH-neutralization curves from the titration of a strong acid with a strong base and calculation the concentration of the strong acid.

Theory:

When alkali solution is gradually added to an acid solution, the pH of the solution increases due to neutralization of H^+ ions. At the end point there is a sharp increase in the value of pH. The curve showing the variation of pH with the amount of alkali added is called the neutralization curve. The end point is marked by point of inflection in the curve. Further, knowledge of this curve allows selection of appropriate **acid-base indicators** for titration. For this purpose a pH meter will be used.

Procedure:

1. Take **10.0 ml** of the supplied **HCl** solution in a **250** ml beaker, dilute to about **100 ml (90 ml water+10 ml HCl).**
2. Place the **electrode** of the pH meter in the above solution.
3. Fill the burette with the supplied **0.1 M NaOH** solution.
4. Add about **0.5 ml** aliquot from the burette to the solution in the beaker. Stir the solution and measure it's pH. **After adding 9 ml NaOH solution then gradually add NaOH solution with 0.2 ml interval upto 11 ml.** Add NaOH solution **1ml to 15 ml.**
5. Tabulate burette readings, volume of alkali added, and pH of the solution.
6. Plot *pH vs volume of NaOH* solution added.
7. Draw a smooth curve; locate the equivalent point (**end point**).This is the volume of alkali required to neutralize the acid.
8. Calculate the concentration of HCl solution in terms of Molarity and Normality.

Questions:

1. What is meant by pH? Calculate the pH values of 0.1 M H_2SO_4 and 0.1 M NaOH.
2. Draw pH – Neutralization curves for the titration of different types of acids and bases (ex. strong acid and strong base) and comment on the suitable indicators for those titrations.

Calibration of pH meter

1. Wash the probe/ electrod of pH meter with distilled water.
2. Immerge the probe and temperature probe approximately 1.5 inch into a buffer solution having **pH 7.0**
3. Stair the beaker gently.
4. Press 'CAL'.
5. Not ready indication will blink on LCD untill the ready was stabilized.
6. When the ready is stable and close to the selected buffer (indicated in the right-top side of the monitor) 'ready' indication will appear on 'CFM' will blink then press CFM to confirm the calibration.(it may take **one or two minutes** to stabilized the pH meter).
7. The calibrated value is then displayed on the right-top side of the LCD will display the second expected buffer value.
8. Repeat the same procedure for the calibration of pH meter for **pH 4.0.**
9. Press CAL for quit calibration.

Experiment No. 11

Name of the Experiment: Determination of the strength of Hydrogen peroxide (H_2O_2)

Theory:

Hydrogen peroxide (H_2O_2), generally known as an oxidizer, is commonly used as a bleaching agent. It is the simplest peroxide (a compound with an oxygen-oxygen single bond). Hydrogen peroxide is a clear liquid, more viscous than water that appears colorless in dilute solution. It is also used as a disinfectant, antiseptic etc. The oxidizing capacity of hydrogen peroxide is so strong that it is considered a highly oxidizing species. Hydrogen peroxide is naturally produced in organisms as a by-product of oxidative metabolism.

Though H_2O_2 usually act as an oxidizing agent (oxidizer), in the presence of a stronger oxidizing agent like $KMnO_4$, it behaves as a reducing agent. When potassium permanganate solution ($KMnO_4$) is added to hydrogen peroxide (H_2O_2) solution in the presence of sulphuric acid the following reaction occurs. This principle is used to determine the strength of the H_2O_2.

$$2MnO^{-}_4 + 5H_2O_2 + 6H^+ = 2Mn + 5O_2 + 8H_2O$$

Procedure:

1. Transfer 10 ml of the supplied solution of H_2O_2 into a conical flask.
2. Dilute this solution with 25 ml of water and shake thoroughly.
3. Add 10 ml of 1M H_2SO_4.
4. Perform the titration with standard 0.1M potassium permanganate to the first permanent, faint pink color.
5. Repeat the titration three times.

Note: Standardize the potassium permanganate solution **(exp: 06)**.

Calculation:

Method 1

Find out the concentration of H_2O_2. Then calculate the % as instructed by teacher.

Method 2

1. The weight of hydrogen peroxide per litre of the original solution.
2. The 'volume strength' i.e the number of ml of oxygen at N.T.P that can be obtained from 1ml of the original solution.

1ml 1M $KMnO_4$ solution = 0.01701× 5 g H_2O_2

= 0.08505 g H_2O_2

$$\text{Concentration of } H_2O_2 \text{ (\% by volume)} = \frac{0.08505 \times \text{vol. of } KMnO_4 \text{ in ml} \times \text{Molarity of } KMnO_4}{10} \times 100$$

<u>Questions:</u>

1. Give half reactions and explain how H_2O_2 act as a reducing agent.
2. What is bleaching?

Experiment No. 12

Name of the Experiment: **Preparation of Iron (11) Sulphate heptahydrate FeSO4.7H_2O**

Theory:

When metallic iron (Fe) reacts with sulphuric acid, it replaces the acidic hydrogen (H^+) in H_2SO_4 and products iron (11) sulphate.

$$Fe(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2(g)$$

$FeSO_4$ crystallizes from the aqueous solution with seven water molecules.

Procedure:

1. Pour **10 ml** of concentrated sulphuric acid slowly into **200 ml** of distilled water in a 500 ml beaker and add **10 gm** of iron turnings.
2. When the reaction **slows** down, heat the beaker until the acid is practically all neutralized as indicated by the fact that evolution of hydrogen gas ceases.
3. **Filter** the content of the beaker, using a filter paper to remove any undissolved residue.
4. The filtrate should give a **bottle green** color.
5. If the solution is oxidized, appreciable amount of sulphuric acid must be added until the color becomes green. Oxidation will be indicated by the change in color of the solution from bottle green to **yellowish shade** of green or by the formation of rusty precipitate.
6. **Slowly** evaporate the solution to crystallization and cool.
7. Then place the beaker in an ice bath to complete crystallization.
8. **Filter off** the crystals from the mother liquor.
9. **Wash** the crystals twice with small portions of mother liquor.
10. **Dry** the crystals using absorbent paper.
11. **Weigh** the product and determine the yield.
12. Store the crystal in sample bottle.

Calculation:

1. Calculate the no. of moles of iron you have taken in this experiment.
2. Calculate the no, of moles of iron (11s) sulphate that you have obtained in this experiment.

Questions:

3. What happens when iron (11) sulphate is kept in contact with air?
4. What type of reaction takes place during the conversion of iron to ferrous sulphate?
5. Write down the electronic configuration of iron (11) and iron (111).

Experiment No.s13

Name of the Experiment: Determination of Na_2CO_3 content in commercial Soda.

Theory:

Sodium carbonate (Na_2CO_3) content in commercial caustic soda solution can be determined by titrimetric method. The alkali carbonate (CO^{2-}_3) of the supplied solution can be determined by titrating with a standard acid solution. Then the carbonate ion in the solution may be precipitated by a dilute solution of $BaCl_2$.

Reaction: $Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$

Procedure:

1. Weigh out accurately **1.44** gm of washing soda in a **100 ml** volumetric flask.
2. Dissolve with a little water and make up to mark.
3. Take **10 ml** of the solution with a pipette in a **250 ml** conical flask.
4. Add about **25 ml** of water.
5. Add **1-2 drops of methyl orange** indicator to the solution.
6. Titrate the solution with standard hydrochloric acid solution **(standardized as per expr:03)**until the color changes from **yellow to orange.**
7. Repeat the procedure at three at least three times and note the mean value.

Calculation:

1 ml N HCl = 0.05300 gm Na_2CO_3

$$\% \text{ of } Na_2CO_3 \text{ in washing soda} = \frac{0.05300 \text{ gm} \times a \times b \times c}{P \times Q} \times 100$$

Where **a** = volume of HCl (ml) solution.
b = Molarity of HCl solution.
c = Total volume of solution (100ml).
P = Volume taken for titration (10ml).
Q = Weight of soda in gm.

Report writing

- Report on each experiment should be submitted on the next class.
- Report should be submitted separately for each experiment.
- A4 size offset paper should be used. Writing must be on one side.

- **Top sheet of the report must contain the following points**

Chemistry sessional report, Course no., Experiment no, Name of the experiment, Date of Performance, Date of Submission, Performer's Name, Department, ID, Group no., Group Partner's ID.

- Top sheet may be composed but the rest of the report must be hand written.

▶ **Report should contain the followings:**

- Name of the experiment
- Objective of the experiment
- Theory (related to the experiment, equation, half-reactions etc.)
- Apparatus required
- Chemicals required
- Preparation of standard solution (passive form to be used) with calculation.
- Experimental data table with title.
- Calculation (both in formula and unitary methods)
- Result
- Major cautions if any
- Answers to the questions.

Students Must Learn

Qualitative analysis and Quantitative analysis

Titration

Primary standard substance, Secondary standard substance

Indicator, Auto indicator, End point

Solution, Solute, Solvent, Dilute solution, Standard solution

Concentration

Expression of Concentartion: Molarity, Molality, Normality, %, mole fraction

Neutralization reaction

Acids and Bases (**Arrhenius**, Brönsted & Lewis concepts), Salt

pH, Buffer solution, Titration curves - suitable indicator, Theories of indicator

Redox reaction

Oxidation, Reduction half-reactions, Oxidizing agent, Reducing agent

Iodometry and Iodimetry

Hardness of water

Ligand, Complex, Chelating agent, Chelate

DOs and DON'Ts (Cautions)

- All students must wear apron (long, full sleeve, white) during the lab work.
- Students must not do anything without any given instruction.
- Students must handle apparatus and chemicals carefully.
- Put on Safety glass.
- Maitain cleanliness.
- Be disciplined.

References

1. Essentials of Physical Chemistry – by Bahl & Tuli
2. General Chemistry – by Ebbing
3. Modern Inorganic Chemistry – by S. Z. Haider
4. Vogel's Text Book of Quantitative Chemical Analysis (Pearson Education Asia)
4. Analytical Chemistry – by Gary D. Christian (John Wiley & Sons Inc.)

Manual for Physics Sessional

Course no. PHY 1106

(For the Program of B.Sc. in EEE, IPE and ME)

Department of Arts and Sciences

Ahsanullah University of Science and Technology

15/11/16

List of Experiments:

1. To determine the modulus of rigidity of the material of a wire by the method of oscillations (Dynamic method).

2. To determine the wavelength of a monochromatic light by a spectrometer using a plane diffraction grating. Hence to calculate the dispersive power of the grating.

3. To determine the radius of curvature of a plano-convex lens by Newton's rings.

4. To determine the refractive index of a liquid by pin method using plane mirror & convex lens.

5. To determine the value of acceleration due to gravity (g) by means of a Compound pendulum.

6. To determine the specific heat of a liquid by the method of cooling.

7. To determine the value of the mechanical equivalent of heat (J) by electrical method.

8. To determine the thermal conductivity of a bad conductor by Lee's and Charlton's method.

9. To determine the spring constant and effective mass of a given spiral spring.

Reference Books:

1. **Practical Physics** *by* Dr. Giasuddin Ahmed and Md. Shahabuddin
2. **Physics-I & II** *by* R. Resnick, D. Halliday
3. **Practical Physics** *by* RK Shukla, Anchal Srivastava

Experiment no 1:

Name of the Experiment: Determination of the modulus of rigidity of the material of a wire by the method of oscillations (Dynamic Method).

Theory:

A cylindrical body is supported by a vertical wire of length l and radius r as shown in Fig. 1.1. The axis of the wire passes through its center of gravity. If the body is twisted through an angle and released, it will execute torsional oscillations about a vertical axis. Therefore, the motion is simple harmonic. If at any instant the angle of twist is θ, the moment of the torsional couple exerted by the wire will be

$$\frac{\eta \pi r^4}{2l}\theta = C\theta,$$

where $C = \frac{\eta \pi r^4}{2l}$ is a constant and η is the modulus of rigidity of the material of the wire.

Therefore, the time period for torsional oscillations is,

$$T = 2\pi\sqrt{\frac{I}{C}}.$$

where I is the moment of inertia of the cylindrical body which is given by $I = \frac{1}{2}Ma^2$, here M and a are the mass and radius of the cylinder respectively.

From above two equations, we get

$$T^2 = \frac{4\pi^2 I}{C} = \frac{8\pi I l}{\eta r^4}$$

$$\text{or,}\quad \eta = \frac{8\pi I l}{T^2 r^4}\ \text{dynes/cm}^2$$

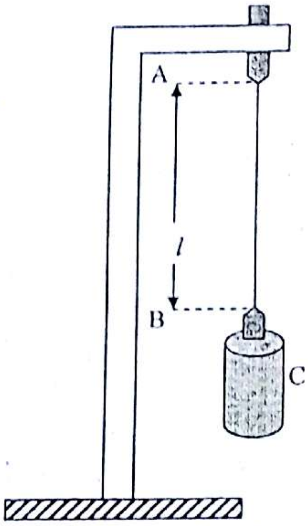


Fig. 1.1: Torsional pendulum

Apparatus:

A uniform wire, A cylindrical bar, Suitable clamp, Stopwatch, Screw gauge, Slide calipers, Meter scale, etc.

Brief Procedure:

1. Find out the value of one smallest division of the main scale and the total number of divisions of the vernier scale of the slide calipers and calculate vernier constant ($V.C$).
2. Find out the value of one smallest division of the linear scale, value of pitch (the distance along the linear scale traveled by circular scale when it completes one rotation) and the total number of divisions of the circular scale of the screw gauge and calculate least count ($L.C$).
3. Measure the radius, a of the cylinder by using the slide calipers.
4. Measure the mass, M of the cylinder. Calculate moment of inertia.
5. Measure the radius, r of the wire by using the screw gauge.
6. Measure the length, l of the wire between the point of suspension and the point at which the wire is attached to the cylinder with a meter scale.
7. Twist the cylinder from its equilibrium position through a small angle and release so that it begins to oscillate. Measure the time for 30 complete oscillations with a stop watch. Find out the time period of oscillation.

8. Calculate the value of the modulus of rigidity (η) of the material of the given wire.

Experimental Data:

Vernier Constant ($V.C.$) of the slide calipers,

$$V.C. = \frac{\text{The value of one smallest division of the main scale}}{\text{Total number of divisions in the vernier scale}}$$

Least Count (L.C.) of the Screw Gauge

$$L.C. = \frac{\text{Pitch}}{\text{Total number of divisions in the circular scale}}$$

Table-1: Table for the radius of the cylinder

No. of obs.	Main scale reading, x (cm)	Vernier scale division, d	Vernier constant, V_C (cm)	Vernier scale reading, $y = V_c \times d$ (cm)	Diameter, x + y (cm)	Mean diameter, D (cm)	Instru-mental error (cm)	Corrected diameter, D (cm)	Radius, $a = \frac{D}{2}$ (cm)
1									
2									
3									
4									
5									

Table-2: Table for the radius of the wire

No. of obs.	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Circular scale reading, $y = d \times L_c$ (cm)	Diameter, x + y (cm)	Mean diameter, D (cm)	Instru-mental error (cm)	Corrected diameter, D (cm)	Radius, $r = \frac{D}{2}$ (cm)
1									
2									
3									
4									
5									

Table-3: Table for the time period

No. of obs.	Time for 30 oscillations, t (sec)	Time period, $T = \frac{t}{30}$ (sec)	Mean T (sec)
1			
2			
3			
4			
5			

Length of the wire, l: (i) cm (ii) cm (iii) cm

Average length of the wire, l = cm

Calculations:

Moment of Inertia of the cylinder, $I = \frac{1}{2}Ma^2$ g-cm^2

Modulus of rigidity of the wire, $\eta = \frac{8\pi I l}{T^2 r^4}$ dynes/cm^2

Error Calculation:

Standard value of the modulus of rigidity of the material of the wire (steel) =

8.4×10^{11} dynes cm^{-2}.

$$\text{Percentage error} = \frac{\textit{Standard value} \sim \textit{Experimental value}}{\textit{Standard value}} \times 100\,\%$$

Result:

Discussions:

Experiment no 2:

Name of the Experiment: Determination of the wavelength of a monochromatic light by a spectrometer using a plane diffraction grating and calculation of the dispersive power of the grating.

Theory:

Diffraction grating is an array of a large number of parallel slits, all with the same width and spaced equal distances between the centers. When a monochromatic light of wavelength λ sent from collimator falls normally on a diffraction grating placed on a spectrometer table (Fig. 2.1), a series of diffracted images will be seen on both sides of the direct image.

If θ be the deviation of light for n^{th} order image and $(a+b)$ be the grating element then from the equation of diffraction,

$$(a+b)\sin\theta = n\lambda \qquad (1)$$

Thus, the wavelength of a monochromatic light is

$$\lambda = \frac{\sin\theta}{nN} \qquad (2)$$

where $N = \frac{1}{(a+b)}$ is the number of lines or rulings per cm of the grating surface also known as grating constant.

Knowing the values of n, N and θ, wavelength λ of the monochromatic light can be found.

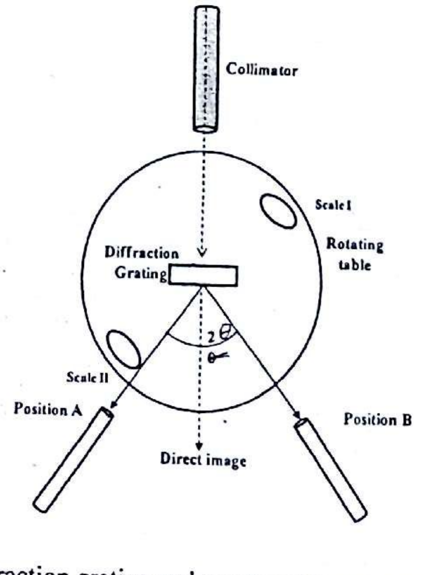


Fig. 2.1: Diffraction grating and spectrometer arrangement

Differentiating equation (2) with respect to λ we have

$$\frac{d\theta}{d\lambda} = \frac{nN}{\cos\theta}$$

This equation gives the angular dispersive power of the grating, *i.e.* it's the capacity of the grating to disperse different wavelengths.

Apparatus:

Spectrometer, Plane diffraction grating, sodium lamp set, etc.

Brief Procedure:

1. Record the grating constant.
2. Determine the vernier constant (mentioned in Exp. 1) of the scale of spectrometer.
3. Mount the grating on the spectrometer table with the grating ruling parallel to the collimator slit and plane of grating perpendicular to the collimator axis. Do not move it throughout the experiment.
4. Focus the eyepiece on the cross-wires illuminated by the light from the slit by sliding the eyepiece lens in and out until the cross-wires appear sharpest.
5. Turn the telescope to one side of central position (Say left side, A) until an image of first order diffraction appears on the cross-wires and then record the readings from both scales I & II.
6. Similarly find the image of first order diffraction on the other side (e.g. right side, B) of central position and record the readings as before.
7. Calculate the differences ($A \sim B$) between scale I and scale II readings and determine the angle of diffraction.
8. Calculate the wavelength of the monochromatic light and dispersive power of the diffraction grating using the given equations.

Experimental data:

Grating constant, $N = \frac{lines}{inch} = \frac{lines}{cm}$

Vernier constant of the spectrometer,

$$V.C. = \frac{\text{The value of one smallest division of the main scale}}{\text{Total number of divisions in the vernier scale}}$$

Table-1: Table for the angle of diffraction

Order number (n)	Scale number	Reading for the angle of diffraction, θ												Mean θ (degree)
		Left side					Right side							
		Main scale reading, x (degree)	Vernier scale division, d	Vernier constant, V_c (degree)	Vernier scale reading, $y=d\times V_c$ (degree)	Total, A = x+y (degree)	Main scale reading, x (degree)	Vernier scale division, d	Vernier constant, V_c (degree)	Vernier scale reading, $y=d\times V_c$ (degree)	Total, B = x+y (degree)	$2\theta = A\sim B$ (degree)	θ (degree)	
1	I													
	II													

Calculation:

Wavelength of the monochromatic light,

$$\lambda = \frac{\sin\theta}{nN} = \qquad \text{cm} = \qquad \text{Å}$$

Dispersive power of the grating

$$\frac{d\theta}{d\lambda} = \frac{nN}{\cos\theta} = \qquad \text{cm}^{-1}$$

Error Calculation:

Standard value of the wavelength of sodium light is 5890 Å.

$$\text{Percentage error} = \frac{\textit{Standard value} \sim \textit{Experimental value}}{\textit{Standard value}} \times 100\ \%$$

Results:

Discussions:

Experiment no 3:

Name of the Experiment: ***Determination of the radius of curvature of a plano-convex lens by Newton's rings.***

Theory:

The phenomenon of Newton's rings is an interference pattern caused by the reflection and transmission of light between a spherical surface and an adjacent flat surface which form a air thin film. When viewed with monochromatic light as shown in Fig. 3.1a, it appears as a series of concentric, alternating bright and dark rings as shown in Fig. 3.1b centered at the point of contact between the two surfaces.

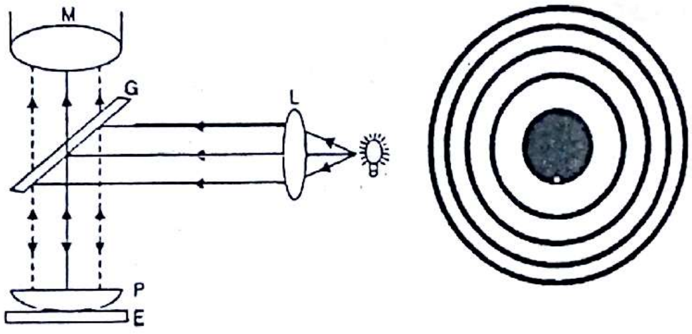


Fig.3.1: (a) Experimental setup of Newton's rings. (b) Pattern of the rings

Now the diameters of the n^{th} bright or dark rings are

$$D_n^2 = 2(2n + 1)\lambda R \quad \text{(Bright Rings)}$$

$$D_n^2 = 4n\lambda R, \quad \text{(Dark Rings)}$$

where R is the radius of curvature of the lens and λ is the wavelength of the monochromatic light.

Similarly, the diameters of the $(n+p)^{th}$ bright or dark rings are

$$D_{n+p}^2 = 2[2(n+p) + 1]\lambda R \quad \text{(Bright Rings)}$$

$$D_{n+p}^2 = 4(n+p)\lambda R \quad \text{(Dark Rings)}$$

Subtracting D_n^2 from D_{n+p}^2, we have

$$D_{n+p}^2 - D_n^2 = 4p\lambda R, \text{ for either bright or dark rings,}$$

$$\text{or, } R = \frac{D^2_{n+p} - D_n^2}{4p\lambda}$$

The above equation is employed to compute the radius of curvature R of a lens.

Apparatus:

Travelling microscope, Plano-convex lens, Sodium lamp set, etc.

Brief Procedure:

1. Determine the least count (mentioned in Exp. 1) of the micrometer screw of the travelling microscope.
2. Set the intersecting point of the cross-wires of the eye piece at the middle of the central dark spot.

3. Slide the cross-wires to 12^th^ dark ring on the left side of the central dark spot.
4. Set the vertical line of the cross-wire tangentially to 10^th^ dark ring and note the readings of the linear scale and circular divisions.
5. Set the cross-wire in the same manner to the 9^th^, 8^th^,.........., 1st rings by sliding the microscope in the same direction.
6. Cross the central dark spot by sliding the cross-wires and note the scale readings by setting the cross-wire to the right side of the 1^st^ ring.
7. Now move the cross-wires in the same direction and record the scale readings in the same manner for successive dark rings up to the 10^th^ ring on the right side.
8. Draw a best fit straight line through origin on a graph paper with square of the diameter as ordinate and number of the ring as abscissa. Calculate the slope of the line.
9. Calculate the radius of curvature of the plano-convex lens by using the given equation.

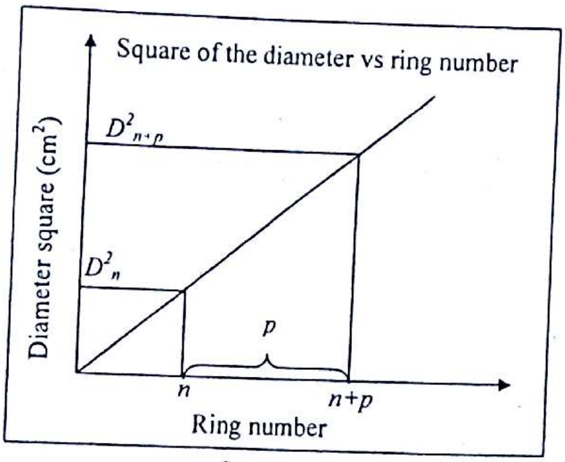
Experimental Data:

Least Count ($L.C.$) of the micrometer scale

$$L.\,C. = \frac{Pitch}{Total\ number\ of\ divisions\ in\ the\ circular\ scale}$$

Table: Table for the diameter of the rings

Ring no.	Readings of the microscope										Diameter, D = L~R (cm)	D^2 (cm^2)
	Left Side (L)					Right Side (R)						
	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Circular scale reading, $y=d\times L_c$ (cm)	Total, x+y (cm)	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Circular scale reading, $y=d\times L_c$ (cm)	Total, x+y (cm)		
1												
2												
3												
4												
6												
7												
8												
9												
10												



Graph 1

Calculation:

$$\text{From graph 1, slope} = \frac{D^2_{n+p} - D^2_n}{(n+p) - n}$$

$$R = \frac{Slope}{4\lambda}$$

Result:

Discussions:

Experiment no 4:

Name of the Experiment: Determination of the refractive index of a liquid by pin method using plane mirror and convex lens.

Theory:

A plano-concave liquid lens can be formed by the combination of a convex lens, a few drops of liquid and a plane mirror. If F be the focal length of combined lenses (convergent lens), then we have the relation

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}, \ldots \ldots (1)$$

where f_1 and f_2 are the focal lengths of the convex lens and the liquid lens, respectively. Correcting for the sign of f_2 which is negative, we get

$$\frac{1}{F}=\frac{1}{f_1}-\frac{1}{f_2}$$

$$\frac{1}{f_2}=\frac{1}{f_1}-\frac{1}{F}$$

$$\text{or, } f_2=\frac{Ff_1}{F-f_1} \ldots \ldots \ldots (2)$$

The focal length of the plano-concave liquid lens is also given by relation

$$\frac{1}{f_2}=(\mu-1)\left(\frac{1}{r}-\frac{1}{r'}\right)$$

where r', r are the radii lower and upper surfaces of liquid lens respectively and μ is the refractive index of the liquid. Being a plane $r=\infty$

$$\frac{1}{f_2}=(\mu-1)\frac{1}{r}$$

According to sign convention, both r and f_2 are negative. Thus,

$$\mu=1+\frac{r}{f_2} \ldots \ldots \ldots (3)$$

The value of μ can be found by using relations (2) and (3).

Since, the upper surface of this liquid lens has the same radius of curvature of the convex lens it can be determined by using a spherometer.

Apparatus:

Convex lens, Plane mirror, Pin/pointer, Spherometer, Slide calipers, Stand & Clamp, Experimental liquid, etc.

Brief Procedure:

1. Calculate the least count (mentioned in Exp. 1) of the spherometer.
2. Place the spherometer on the plane mirror and slowly turn the screw so that the tips of the central leg and the other three legs just touch the surface of the mirror. Note the readings of the main scale and circular divisions of the spherometer.
3. Now put a convex lens on the mirror and place the spherometer on the surface of the lens. Note the readings in the same manner of step 2. Then take the difference of A and B to calculate the height (h) of the central leg with respect to the tips of outer legs.
4. Slightly press the spherometer upon a piece of paper so that the three legs leave three dots on the paper. Measure the distances (a_1, a_2, a_3) between these dots by a scale and calculate the mean distance, a.

5. Calculate the radius of curvature of the lens by using the relation, $r = \frac{a^2}{6h} + \frac{h}{2}$
6. Calculate the vernier constant of the slide calipers.
7. Measure the thickness of the lens by using slide calipers.
8. Place a mirror on the base/table with its reflecting face upwards and put the lens on the mirror. Clamp a pin horizontally on a vertical stand.
9. Find the position of the pin by moving it up or down so that there is no parallax between the image of the tip of the pin and the tip of the pin itself.
10. Measure the distance between the pin and face of the lens at its middle by a meter scale.
11. Calculate the focal length of the convex lens.
12. Pour few drops of liquid between the convex lens and the plane mirror.
13. Repeat steps 9 and 10 and obtain the focal length of the combination of the lenses.
14. Calculate the focal length of the liquid lens.
15. Using the given formula, calculate the refractive index.

Experimental Data:

Vernier constant ($V.\ C.$) of the slide calipers

$$V.\ C. = \frac{\text{The value of one smallest division of the main scale}}{\text{Total number of divisions in the vernier scale}}$$

Least Count ($L.C.$) of the spherometer

$$L.\ C. = \frac{\text{Pitch}}{\text{Total number of divisions in the circular scale}}$$

Table-1: Table for the measurement of h

Reading on	No. of obs.	Linear scale reading, x (cm)	Circular scale Division, d	Least count, L_c (cm)	Circular scale reading, $y = L_c \times d$ (cm)	Total, $x + y$ (cm)	Mean (cm)	$h = B \sim A$ (cm)
Plane mirror, A	1							
	2							
	3							
	4							
	5							
Lens surface, B	1							
	2							
	3							
	4							
	5							

Measurement of 'a' *i.e.*, the average distance among the legs of the spherometer:

Mean value of $a = \frac{a_1 + a_2 + a_3}{3} =$ cm

Radius of curvature of the spherical surface, $r = \frac{a^2}{6h} + \frac{h}{2} =$ cm

Table-2: Table for the thickness of the lens

No. of obs.	Linear scale reading, x (cm)	Vernier scale division, β	Vernier constant, V_C (cm)	Vernier scale reading, $y = \beta \times L_c$ (cm)	Thickness, $t = x + y$ (cm)	Mean thickness, t (cm)	Instrumental error $\pm e$ (cm)	Corrected thickness, $t-(\pm e)$ (cm)
1								
2								
3								
4								
5								

Table -3: Table for the focal lengths

No. of obs.	Distance between the pin and the face of the lens (without the liquid), h_1 (cm)	Focal length of the convex lens, $f_1 = h_1 + \frac{t}{3}$ (cm)	Mean f_1 (cm)	Distance between the pin and the face of the lens (with the liquid), h_2 (cm)	Focal length of the combination, $F = h_2 + \frac{t}{3}$ (cm)	Mean F (cm)	Focal length of the liquid lens, $f_2 = \frac{Ff_1}{F - f_1}$ (cm)
1							
2							
3							
4							

Calculation:

$$\mu = 1 + \frac{r}{f_2}$$

Error Calculation:

Standard value of the refractive index of water is 1.33

$$\text{Percentage error} = \frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$$

Result:

Discussions:

Experiment no 5:

Name of the Experiment: Determination of the value of the acceleration due to gravity (g) by means of a compound pendulum.

Theory:

A compound pendulum is a rigid body of arbitrary shape which is capable of oscillating about a horizontal axis passing through it. For small angles of swinging, its motion is simple harmonic with a period given by

$$T = 2\pi\sqrt{\frac{I}{mgh}}$$

where I is the pendulum's rotational inertia about the pivot, m is the pendulum's mass, and h is the distance between the pivot and the pendulum's centre of gravity as shown in Fig. 5.1.

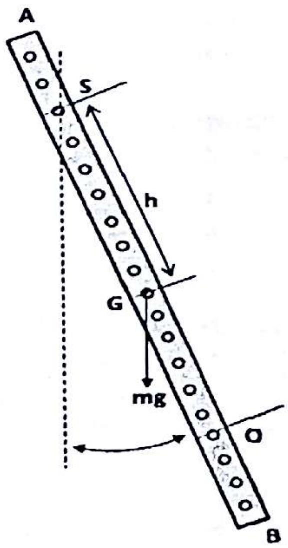


Fig. 5.1: Compound Pendulum

A compound pendulum that oscillates from a suspension point (S) with period T (as shown in Fig. 5.1) can be compared with a simple pendulum of length L with the same period T. L is called the equivalent length of the compound pendulum. The point along the compound pendulum at a distance L from the suspension point is called the oscillation point (Fig. 5.1). In a compound pendulum these two points are interchangeable.
Now using the time period expression of a simple pendulum,

$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$\text{or, } g = 4\pi^2\frac{L}{T^2}$$

The acceleration due to gravity (g) at the place of the experiment can be measured by finding L and T graphically.

Apparatus:

A bar pendulum, Stop watch, Meter Scale, etc

Brief Procedure:

1. Label the ends of the compound pendulum bar as A and B.
2. Locate the centre of gravity (G) of the bar.
3. Measure the distance of holes (1, 2, 3,... and 9) from G for both sides.
4. Insert a metal wedge in the 1st hole at end A and place the wedge on the clamp so that the bar can oscillate freely.
5. Oscillate the bar horizontally. Be careful not to make the amplitude of oscillation too large. (Should be less than 5°). Note the time for 20 complete oscillations. Calculate the time period.
6. Do this process at different holes (2, 3, ...and 9).
7. Repeat steps 3, 4 and 5 for end B.
8. Draw a graph with distance as abscissa and time period as ordinate with the origin at the centre of gravity which is put at the middle of the graph paper along the abscissa. Put the length measured towards the end A to the left and that measured toward the end B to the right of the origin (see Graph 1). Draw a line parallel to the abscissa in such a way that it intersects at four points of the two curves as shown in Graph 1. Label these points as P, Q, R and S, respectively.
9. Find out the equivalent length of the pendulum, L and time period, T from the graph.
10. Calculate the value of acceleration due to gravity using the given equation.

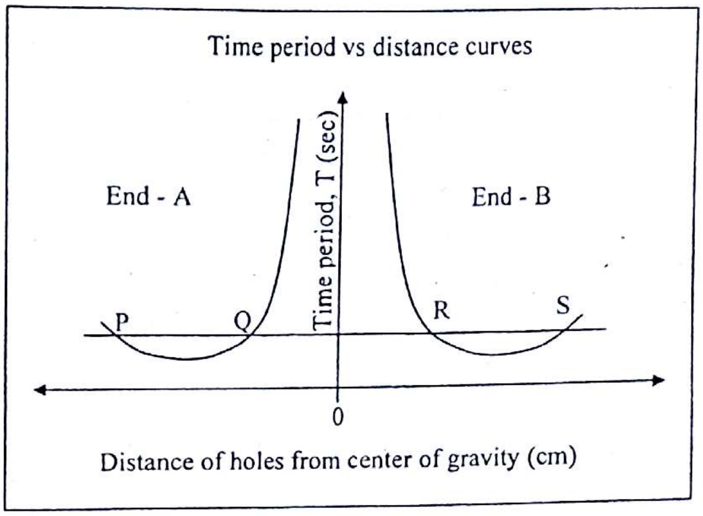
Experimental Data:

Table-1: Table for the time period for end-A

	Hole no.	Distance of the hole from center of gravity (cm.)	Time for 20 oscillations, (sec.)		Mean time, t (sec.)	Time period $T = \frac{t}{20}$ (sec.)
End-A	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					

Table-2: Table for the time period for end-B

	Hole no.	Distance of the hole from center of gravity (cm.)	Time for 20 oscillations, (sec.)		Mean time, t (sec.)	Time period $T = \frac{t}{20}$ (sec.)
End-B	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					



Graph I

Calculations:

From graph 1: Length, $PR =$ cm and length, $QS =$ cm

Equivalent length to the Simple Pendulum, $L = \frac{PR + QS}{2}$

Time period, $T =$ sec

The value of acceleration due to gravity, $g = 4\pi^2 \frac{L}{T^2} =$ cm/s^2

Error Calculation:

Standard value of the acceleration due to gravity = 981 cm/s^2

Percentage error = $\frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$

Result:

Discussions:

Experiment no 6:

Name of the Experiment: Determination of the specific heat of a liquid by the method of cooling

Theory:

Newton's law of cooling can be used to determine the specific heat of a liquid by observing the time taken by the liquid in cooling from one temperature to another.

Suppose a liquid of mass M_1 and specific heat S_1 is enclosed within a calorimeter of mass m and specific heat s. The thermal capacity of the system is (M_1S_1+ms). If the temperature of the liquid falls from θ_1 to θ_2 in t_1, then the average rate of loss of heat is

$$(M_1S_1 + ms)\frac{(\theta_1 - \theta_2)}{t_1}$$

If now the first liquid be replaced by an equal volume of second liquid of known specific heat (say water) under similar conditions and if the time taken by the second liquid to cool through the same range of temperature from θ_1 to θ_2 be t_2, then the average rate of loss of heat is

$$(M_2S_2 + ms)\frac{(\theta_1-\theta_2)}{t_2},$$

where M_2 and S_2 are the mass and specific heat of the second liquid, respectively.

Since the conditions are similar, these two rates are equal

$$(M_1S_1 + ms)\frac{(\theta_1 - \theta_2)}{t_1} = (M_2S_2 + ms)\frac{(\theta_1 - \theta_2)}{t_2}$$

or,

$$S_1 = \frac{M_2S_2t_1 + ms(t_1 - t_2)}{M_1t_2}$$

Apparatus:

Double walled enclosure, Calorimeter, Thermometer, Heater, Stop watch, etc.

Brief Procedure:

1. Clean and dry the calorimeter and measure the mass (m) of the calorimeter and stirrer using a balance.
2. Pour water up to two-third volume of the calorimeter. Measure the total mass (m'') of the calorimeter, water and stirrer. Calculate the mass (M_2) of water.
3. Put the calorimeter on the heater and hold the thermometer bulb in the middle of the water and raise the temperature around 62 °C. Keep the calorimeter into the double walled enclosure with the help of a tongs. Close the lid and fix the thermometer with holder so that its bulb is in the middle of the water.
4. Start the stop watch when the temperature just falls to 60 °C. Note this temperature in the table. Go on recording the temperature of water up to 20-25 minutes at an interval of every one minute. Gently stir the water during the whole process.
5. Pour out the water from the calorimeter and wipe it dry. Take experimental liquid in the calorimeter as the same volume of water. Repeat steps 2, 3 and 4 for liquid.
6. On a graph paper, plot curves (both for water and liquid) by taking temperature as ordinate and time as abscissa (see Graph 1). Calculate t_1 and t_2 from the graph.
7. Using the given formula, determine the specific heat of the given liquid.

Experimental data:

Table: Time–temperature record for water and liquid

No. of obs.	Time (min)	Temperature of water (°C)	Temperature of liquid (°C)
1	00		
2	01		
3	02		
4	03		
5	04		
6	05		
7	06		
8	07		
9	08		
10	09		
..	..		
..	..		
..	..		
26	25		

Mass of the calorimeter + stirrer, m = g

Mass of the calorimeter + stirrer + liquid, m' = g

Mass of the liquid, $M_1 = m' - m$ = g

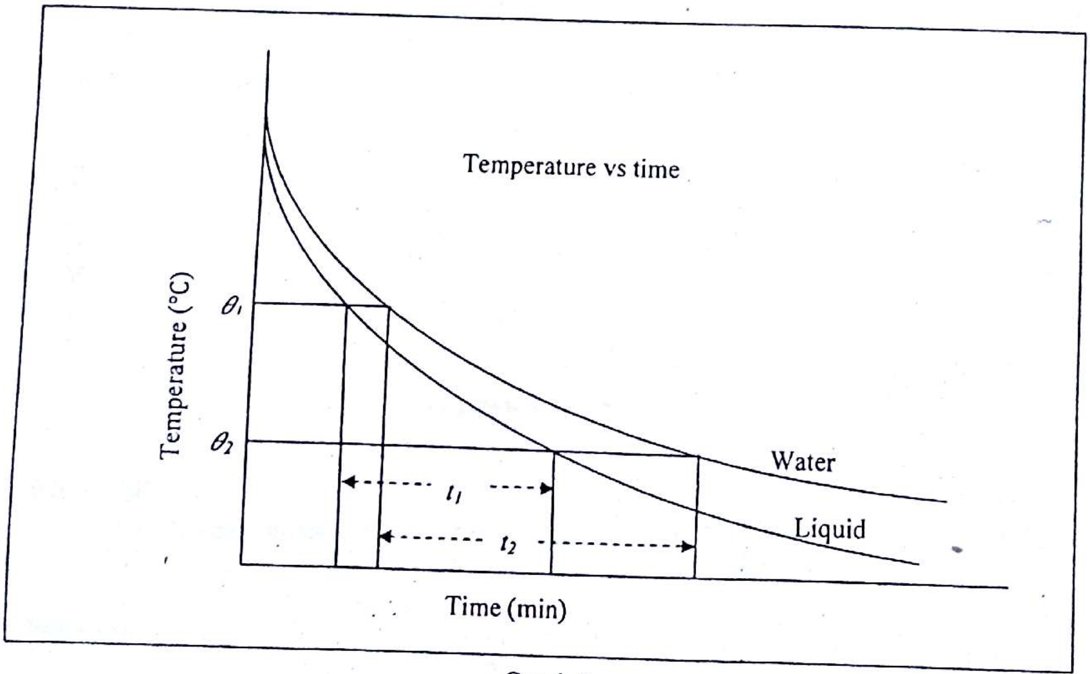
Mass of the calorimeter + stirrer + water, m'' = g

Mass of the water, $M_2 = m'' - m$ = g

Specific heat of the water, S_2 = 1.00 Cal g^{-1} °C^{-1}

Specific heat of the material of the calorimeter (Aluminum), s = 0.2096 Cal g^{-1} °C^{-1}

(Copper), s = 0.0909 Cal g^{-1} °C^{-1}



Graph 1

Calculations:

Time taken by water to cool from $\theta_1 =$ °C to $\theta_2 =$ °C as obtained from the graph 1, $t_2 =$ min

Time taken by the liquid to cool from $\theta_1 =$ °C to $\theta_2 =$ °C as obtained from the graph 1, $t_1 =$ min

Specific heat of the liquid,

$$S_1 = \frac{M_2 S_2 t_1 + ms(t_1 - t_2)}{M_1 t_2}$$

Error Calculation:

Standard value of the specific heat of turpentine is 0.42 Cal g^{-1} $°C^{-1}$.

$$\text{Percentage error} = \frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$$

Result:

Discussions:

Experiment no 7:

Name of the Experiment: **Determination of the value of the mechanical equivalent of heat (J) by electrical method.**

Theory:

The mechanical equivalent of heat J is the amount of electrical energy required to generate one calorie of heat. If E volt be the potential difference across a conducting coil (Fig. 7.1) and i ampere be the current flowing through the coil for t seconds, then the electrical energy in the coil is Eit. If this energy is converted into heat H (calories) then the mechanical equivalent of heat J is

$$J = \frac{Eit}{H} \text{ Joules/Calorie} \quad (1)$$

If H is measured by means of a calorimeter with its contents where the temperature raises from θ_1°C to θ_2°C then

$$H = (Ms + W)(\theta_2 - \theta_1), \quad (2)$$

where M is the mass of the water in the calorimeter, s is the specific heat of water and W is the water equivalent of the calorimeter and stirrer. W can be calculated from the mass and specific heat of the calorimeter and stirrer.

From equations (1) and (2), we get

$$J = \frac{Eit}{(Ms + W)(\theta_2 - \theta_1)} \text{ Joules/Calories}$$

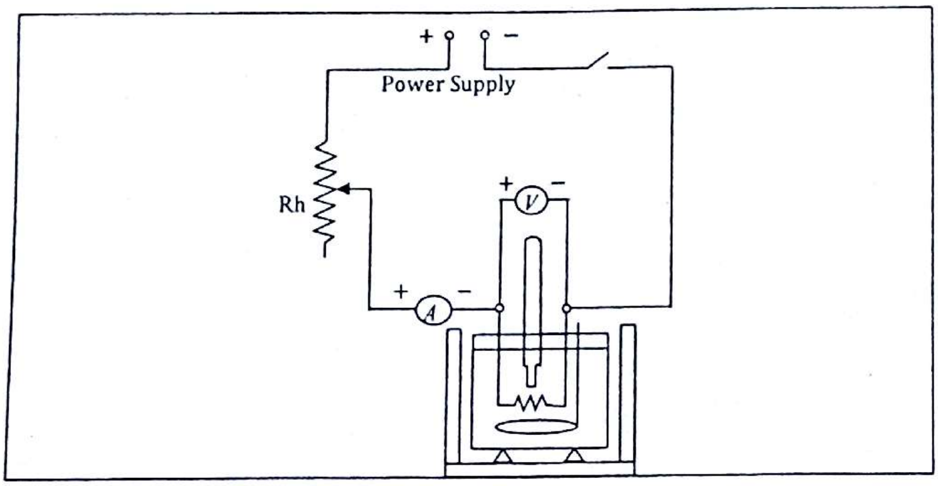


Fig. 7.1: Experimental setup for measuring the mechanical equivalent of heat

Apparatus:

Joule's calorimeter set, Ammeter, Voltmeter, Stop-watch, Thermometer, Balance, Power Supply, Rheostat, Key, etc.

Brief Procedure:

1. Measure the mass (m_1) of the calorimeter and stirrer using a balance.

2. Pour water into the calorimeter which is just sufficient to dip the heating coil and the bulb of the thermometer. Then measure the total mass (m_2) of the calorimeter, stirrer and water. Calculate the mass (M) of water.
3. Place the heating coil into the calorimeter. Keep the calorimeter with heating coil into its insulating box. Fix the thermometer with holder so that its bulb is in the middle of the water but never touching the coil and the calorimeter.
4. Complete the circuit as shown in Fig. 7.1. Switch on the circuit temporarily and adjust the control knob of the power supply until the current is about 2 amperes. Then switch off the circuit and stir the water until a steady temperature is shown by the thermometer. Record this temperature as initial temperature.
5. Switch on the circuit and start the stop watch simultaneously. Then start recording the temperature, current and voltage in the table at an interval of every 1 minute. Keeping the current supply and stop watch on, record these values for 10 minutes. Then switch off the circuit but allow the stop watch to run on and record the temperature for further 10 minutes in the same manner. Stir the water gently during the whole process.
6. Find the maximum and final temperatures. Use them to calculate the radiation correction.
7. Calculate the water equivalent of the calorimeter.
8. Using the given formula, determine the value of the mechanical equivalent of heat.

Experimental data:

Mass of the calorimeter + stirrer, m_1 = g
Mass of the calorimeter + stirrer + water, m_2 = g
Mass of the water, $M = m_2 - m_1$ = g
Specific heat of the water, s = 1 Cal g^{-1} °C^{-1}
Specific heat of the material of the calorimeter (Aluminum), s_1 = 0.2096 Cal g^{-1} °C^{-1}
(Copper), s_1 = 0.0909 Cal g^{-1} °C^{-1}

Table 1: Table for current, voltage and temperature

No of observations	Times (min)	Current, i (amp.)	Voltage, E (Volt)	Temperature, T (°C)
1	00			
2	01			
3	02			
4	03			
5	04			
6	05			
7	06			
8	07			
9	08			
10	09			
11	10			
Current Stopped				
12	11	0	0	
13	12	0	0	
14	13	0	0	
15	14	0	0	
...	...	0	0	
...	...	0	0	
21	20	0	0	

Calculations:

Water equivalent of the calorimeter, $W = m_l s_l$ = g

Initial temperature of the calorimeter + contents, θ_i = °C

Maximum temperature of the calorimeter + contents, θ_m = °C

Final temperature of the calorimeter + contents, θ_f = °C

Rise of temperature, $\theta = (\theta_m - \theta_i)$ °C

Radiation correction, $\theta_r = (\theta_m - \theta_f)/2$ = °C

Corrected rise of temperature $(\theta_2 - \theta_1) = (\theta + \theta_r)$ = °C

Time during which the current is passed, t = sec

Mean current during the interval t, i = amp.

Mean voltage during the interval t, E = volt

Mechanical equivalent of heat,

$$J = \frac{Eit}{(Ms + W)(\theta_2 - \theta_1)} \text{ Joules/Calories}$$

Error Calculation:

Standard value of the mechanical equivalent of heat, J is 4.2 Joules/Calories

$$\text{Percentage error} = \frac{\text{Standard value} \sim \text{Experimental value}}{\text{Standard value}} \times 100\ \%$$

Result:

Discussions:

Experiment no 8:

Name of the Experiment: Determination of the thermal conductivity of a bad conductor by Lee's and Charlton's method.

Theory:

Consider a thin layer of slab of a bad conductor, S (such as glass or ebonite). A and B are the thick discs of brass or copper, one on either side of S. B is a steam chamber from which heat passes to S and A (Fig. 8.1). When steam is passed through B, A is warmed up by the heat conducted through S. After some time, a steady state will be reached when the rate of flow of heat through S equals the heat lost from A by radiation and conduction.

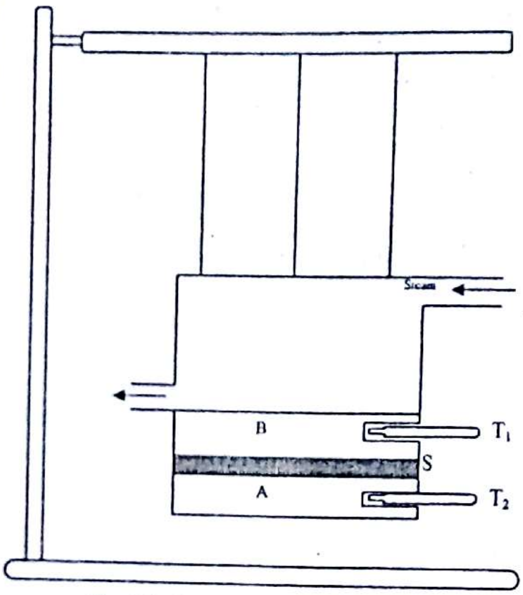


Fig. 8.1 : Lee's and Charlton's apparatus

If θ_1 and θ_2 be the temperatures of B and A in steady state, respectively, then the quantity of heat conducted per second through the slab S is

$$Q_1 = \frac{Ka(\theta_1-\theta_2)}{d},$$

where K is the thermal conductivity of the slab S and a and d are the area of cross-section and thickness of S, respectively.

If $\frac{d\theta}{dt}$ be the rate of cooling of disc A, the heat lost (radiated) per second is

$$Q_2 = ms\frac{d\theta}{dt},$$

where m and s be the mass and specific heat of A.

In the steady state, $Q_1=Q_2$.

or, $$\frac{Ka(\theta_1-\theta_2)}{d} = ms\frac{d\theta}{dt}$$

or, $$K = \frac{ms\frac{d\theta}{dt}d}{a(\theta_1-\theta_2)}$$

Apparatus:

Lee's and Charlton's apparatus, Slide calipers, Screw gauge, Thermometers, etc.

Brief Procedure:

1. Measure the diameter of the bad conductor slab by using slide calipers.
2. Measure the thickness of the bad conductor slab by using screw gauge.
3. Start heating the boiler apart from the bad conductor slab.
4. Put the slab between A and B.
5. When the steam starts to come from the outlet, start taking data from both the thermometers T_1 and T_2 after at an interval of every 5 minutes until they show steady readings (θ_1 and θ_2). Steady readings mean that they remain constant for at least 3 consecutive intervals, i. e. for 15 minutes.
6. After reaching the steady temperature θ_2 in thermometer T_2, remove B and then heat A with the slab still on the top of it up to (θ_2+10) °C.

7. Remove A with the slab still on top of it from the heater and allow it to cool. Note the temperature at an interval of every half minute until the temperature falls to $(\theta_2\text{-}10)$ ℃.
8. Plot a graph of temperature vs. time from cooling data. Draw a tangent at steady temperature (θ_2). Calculate the slope of the tangent.
9. Determine the thermal conductivity of the bad conductor using the given formula.

Experimental Data:

Vernier Constant ($V.C.$) of the slide calipers

$$V.C. = \frac{The\ value\ of\ one\ smallest\ division\ of\ the\ main\ scale}{Total\ number\ of\ divisions\ in\ the\ vernier\ scale}$$

Least Count ($L.C.$) of the Screw Gauge

$$L.C. = \frac{Pitch}{Total\ number\ of\ divisions\ in\ the\ circular\ scale}$$

Table-1: Table for the radius of the disc S

No. of obs.	Main scale reading, x (cm)	Vernier scale division, φ	Vernier constant, V_c (cm)	Vernier scale reading, $y = V_c \times \varphi$ (cm)	Diameter, D = x + y (cm)	Mean diameter, D (cm)	Instru-mental error ±e (cm)	Corrected diameter, D−(±e) (cm)	Radius, $r = D/2$ (cm)
1									
2									
3									
4									

Table-2: Table for the thickness of the disc S

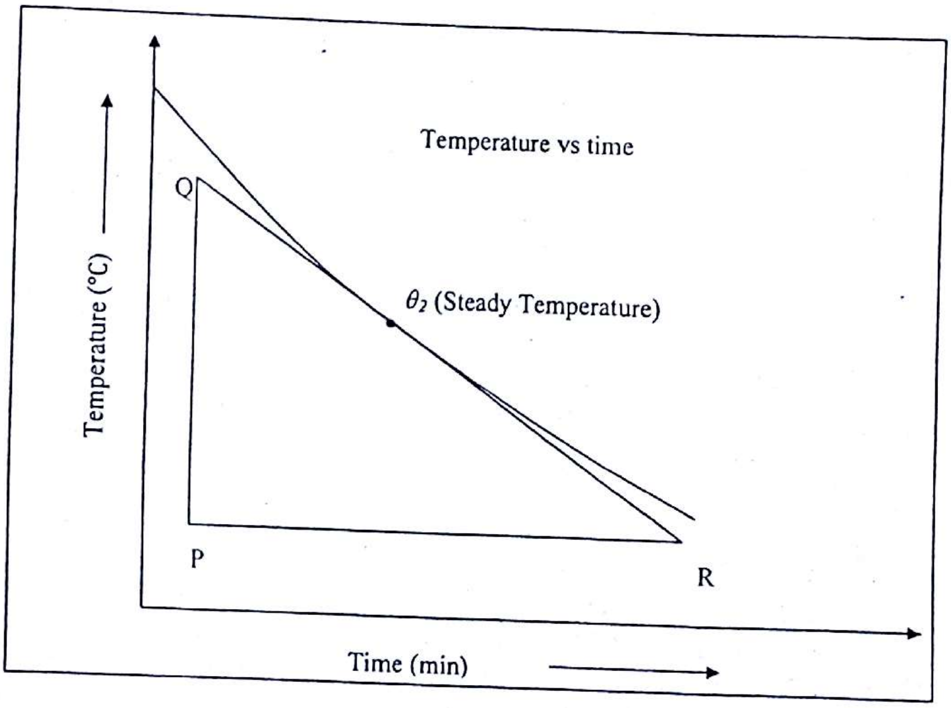
No. of obs.	Linear scale reading, x (cm)	Circular scale division, β	Least count, L_c (cm)	Circular scale reading, $y = \beta \times L_c$ (cm)	Thickness, d = x + y (cm)	Mean thickness, d (cm)	Instrumental error ±e (cm)	Corrected thickness, d−(±e) (cm)
1								
2								
3								
4								

Table-3: Time- temperature records of B and A.

No. of observation	Time (minutes)	Temperature, θ_1 (°C)	Temperature, θ_2 (°C)
1	0		
2	5		
3	10		
4	15		
..	..		
..	..		
..	..		
..	..		
..	..	$\theta_1 =$	$\theta_2 =$

Table-4: Time-temperature record of *A* during its cooling.

No. of obs.	Time, *t* (minutes)	Temperature, (°C)
1	0	θ_2+10
2	0.5	
3	1	
4	1.5	
....	....	
....	....	
....	....	
....	....	$\theta_2 - 10$



Graph 1

Calculations:

Mass of the disc A, m = g

Specific heat of the material of A, $s = 0.0909$ Cal g^{-1} °C^{-1}

Radius of the specimen disc S, r = cm

Area of cross-section, $\alpha = \pi r^2$ = cm^2

From the graph 1, the slope of the tangent at θ_2 = °C,

$$\frac{d\theta}{dt} = \frac{PQ}{PR} \text{ °C min}^{-1} = \frac{PQ}{PR\times60} \text{ °C s}^{-1}$$

Thermal conductivity,

$$K = \frac{ms\frac{d\theta}{dt}d}{\alpha(\theta_1 - \theta_2)}$$

Error Calculation:

The thermal conductivity of ebonite is 4.2×10^{-4} cal cm^{-1} s^{-1} $°C^{-1}$.

$$\text{Percentage error} = \frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$$

Result:

Discussions:

Experiment no 9:

Name of the Experiment: **Determination of the spring constant and effective mass of a given spiral spring.**

Theory:

When a spiral spring clamped vertically at upper end P (Fig. 9.1) and subjected to applied load, m_o at its lower end, then the extension l becomes proportional to the applied force i.e.

$$F = k\,l$$

$$m_o g = k\,l$$

or,

$$k = \frac{m_o g}{l} \quad \text{.............. (1)},$$

where k is a constant of proportionality called spring constant.

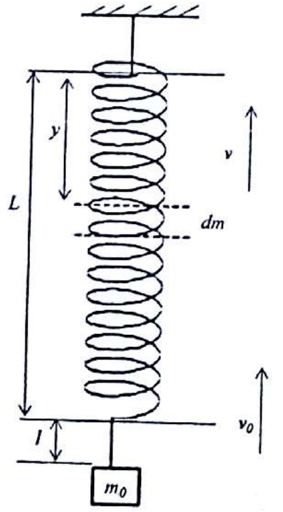


Fig.9.1: Spring-mass system

The theoretical period of a system composed of a mass M oscillating at the end of a mass less spring of force constant k is given by,

$$T = 2\pi\sqrt{\frac{M}{k}}$$

Since no spring is mass less, it would be more correct to use the equation

$$T = 2\pi\sqrt{\frac{m_0 + m_s}{k}},$$

where m_0 is the load and m_s is the mass of the spring.

For a spring of length L oscillating vertically (as shown in Fig. 9.1), the value of m_s can be derived from kinetic energy (E_k) consideration as

$$E_k = \int_0^L \frac{1}{2} v^2 dm,$$

where v is the velocity of the infinitesimal mass dm.

Now, assuming homogeneous stretching and uniform mass distribution, $dm = \frac{m_s}{L} dy$.

Let m_0 and dm are moving with velocities v_0 and v, respectively, where $v < v_0$.

Considering the velocity as the linear function of the position y measured from a fixed point P, v can be represented by

$$v = \frac{v_0}{l} y$$

From the above equations,

$$E_k = \int_0^l \frac{1}{2}\left(\frac{v_0}{l}\right)^2 y^2 \frac{m_s}{l} dy = \frac{1}{2}\frac{v_0^2}{l^3} m_s \int_0^l y^2 dy$$

$$E_k = \frac{1}{2}\frac{m_s}{3} v_0^2 = \frac{1}{2} m' v_0^2,$$

where $m' = \frac{1}{3} m_s$, is the effective mass of the spring.

Apparatus:

A spiral spring, Load, Electronic balance, Stopwatch and meter scale, etc.

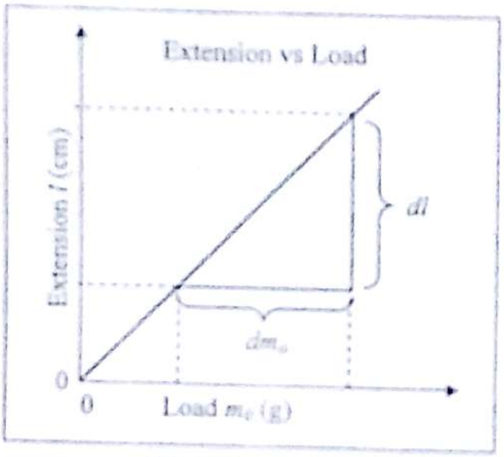
Brief Procedure:

1. Measure the mass (m_s) of the spring with a balance.
2. Clamp the spring vertically by a hook attached to a rigid frame.
3. Measure the length of the spring with a meter scale.
4. Add 100 gm load (m_0) to the free end of the spring. Measure the length of the spring with load. Calculate the extension of the spring.
5. Oscillate the spring with 100 gm load along the vertical axis and record the time for 20 complete oscillations. Then calculate the time period.
6. Repeat steps 4 and 5 for 8 to 10 sets of loads.
7. Draw a best fit straight line through origin with load as abscissa and extension as ordinate (Graph 1). Determine the slope of the line and calculate the spring constant k.
8. Plot another graph with m_0 (abscissa) against T^2 (ordinate) as shown in Graph 2. Find out the effective mass (m') by taking the point of intercept of the resulting lines on m_0 axis.

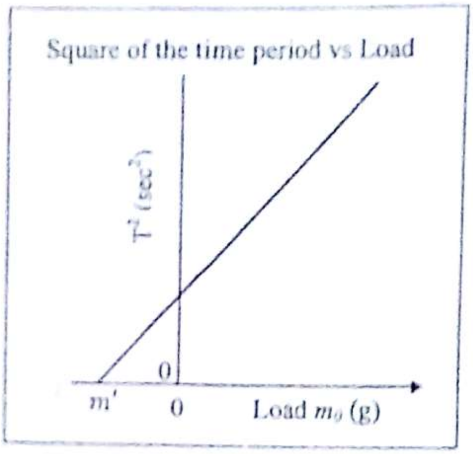
Experimental Data:

Table-1: Table for determining extensions and time periods

No. of obs	Loads, m_0 (gm)	Length of the Spring without load, L_1 (cm)	Length of the Spring with load, L_2 (cm)	Extension $l = L_2 - L_1$ (cm)	Time for 20 vibrations (sec)		Mean Time, t (sec)	Time Period, $T = t/20$ (sec)	T^2 (sec^2)
1	100								
2	200								
3	300								
4	400								
5	500								
6	600								
7	700								
8	800								
9	900								
10	1000								



Graph-1



Graph-2

Calculations:

From graph-1; Slope $= \frac{dl}{dm_o} = \frac{l}{m_o} =$ cm/g

Spring constant, $k = g\frac{m_o}{l} = 981 \times \frac{1}{Slope}$ *dynes/cm*

From graph-2, the effective mass of the spring, $m' =$ g

Error Calculation:

Standard value of the effective mass of the spring $= \frac{m_s}{3}$.

Percentage error $= \frac{Standard\ value - Experimental\ value}{Standard\ value} \times 100\ \%$

Results:

Discussions:

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

1st Year, 2nd Semester

Student Name :

Student ID :

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 1210: Machine Shop Practice II
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. Viva for each experiment will be taken on the next day with the report.
5. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental results and discussions (Experimental setup, Experimental conditions, Data, Graph, calculation etc.)
    - Conclusions
    - Acknowledgements
    - References
6. A quiz will be taken on the experiments at the end of the semester.
7. Marks distribution:

Total Marks		
Report	Attendance and Viva	Quiz
30	30	40

Experiment-1:

Study of Lathe Machine and Its Various Operations

Metal lathe or metalworking lathe are generic terms for any of a large class of lathes designed for precisely machining relatively hard materials. They were originally designed to machine metals; however, with the advent of plastics and other materials and with their inherent versatility, they are used in a wide range of applications, and a broad range of materials. Ln machining jargon, where the larger context is already understood, they are usually simply called lathes, or else referred to by more-specific subtype names (tool room lathe, turret lathe, etc.).These rigid machine tools remove material from a rotating work piece via the (typically linear) movements of various cutting tools, such as tool bits and drill bits. A typical lathe machine is shown in the following Fig.1.

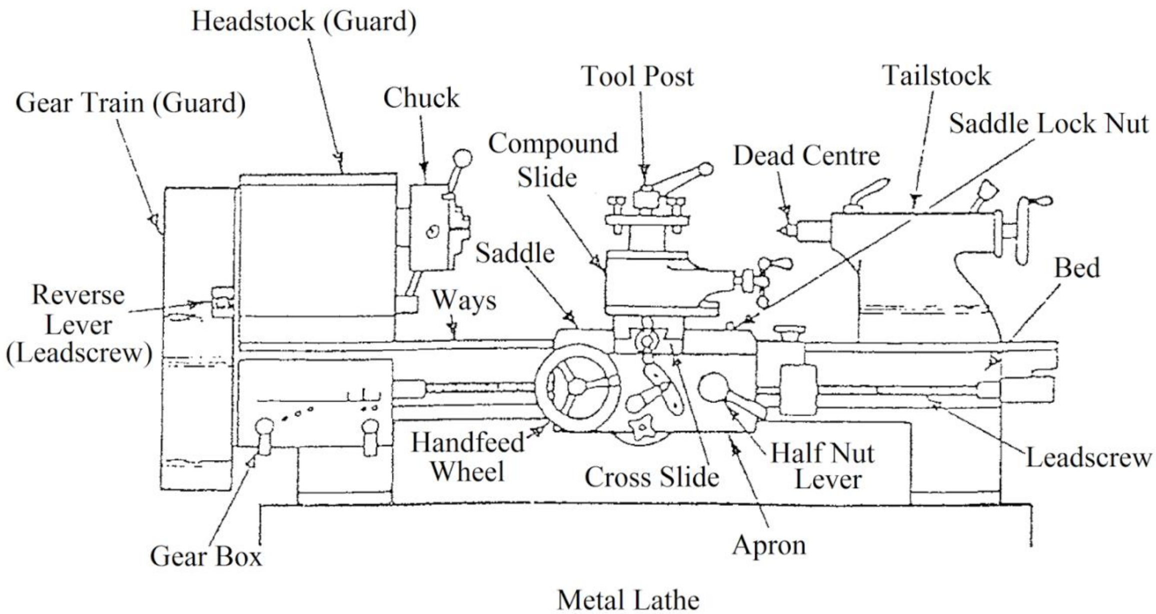


Fig.1 Schematic view of the lathe machine

Bed: The bed is the base or foundation of the parts of the lathe. The main feature of the bed is the ways, which are formed on the bed's upper surface and run the full length on the bed. The ways keep the tailstock and the carriage, which slide on them, in alignment with the headstock.

Headstock: The headstock contains the headstock spindle and the mechanism for driving it.

Tailstock: The primary purpose of the tailstock is to hold the dead center to support one end of the work being machined. However, the tailstock can also be used to hold tapered shank drills, reamers and drill chucks.

Carriage: The carriage is the movable support for the cross feed slide and the compound rest. The compound rest carries the cutting tool in the tool post. The carriage has T-slot or tapped holes to use for clamping work for boring or milling.

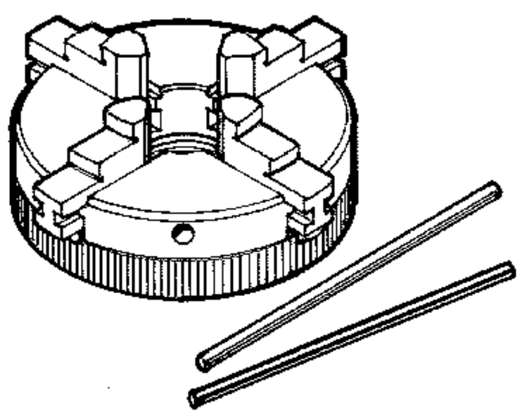
Feed Rod: The feed rod transmits power to the apron to drive the longitudinal feed and cross feed mechanisms. The feed rod is driven by-the spindle through a train of gears.

Lead Screw: The lead screw is used for thread cutting. It has accurately cut ACME threads along its length that engage the threads of half-nuts in the apron where the half-nuts are clamped over it. The lead screw is driven by the spindle through a gear train.

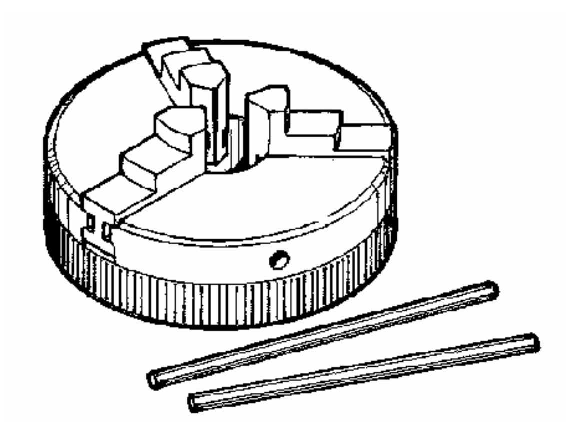
Crossfeed Slide: The crossfeed slide is mounted to the top of the carriage in a dovetail and moves on the carriage at a right angle to the axis of the lathe. A crossfeed screw allows the slide to be moved toward or away from the in accurate increments.

Lathe Chucks: The lathe chuck is a device for holding lathe work. lt is mounted on the nose of the spindle. The work is held by jaws which can be moved in radial slots toward the center of the chuck to clamp down on the sides of the work.

The 4-jaw independent lathe chuck (Fig.2A) is the most practical chuck for general work. The four jaws are adjusted one at a time, making it possible to hold work of various shapes and to adjust the center of the work to coincide the axis of the spindle .The 3-jaw **universal chuck** (Fig.2B) an be used only for holding round or hexagonal work. All three jaws move in and out together in one operation and bring the work on center automatically.



4-jaw independent lathe chuck



3-jaw universal chuck

Fig.2 lathe chuck

Cutting Speed is defined as the Speed at which a point on the Surface of the work passes the cutting edge or point of the tool and is normally given in m/min. Cutting speed can be calculated by using the following formula:

$V = \pi DN/1000$ m/min

Where:

N = Spindle Speed (RPM)

D = Diameter of Work piece (mm)

V= Cutting Speed of metal (m/min)

Feed rate: Feed rate is used to describe the distance the tool moves per revolution of the work piece and depends largely on the surface finish required. For roughing out a soft material a feed of up to 0.25 mm/rev may be used.

Cutting Tool for Lathe: There are various kinds of the cutting tools for a lathe which depends on the type of work materials and shape of the parts. Fig; 4(a) shows the well-used cutting tool called a side tool. The cutting tool shown in Fig. 4(b) is used at parting and grooving processes. The cutting tool shown in Fig.4(c) is called a boring bar. It is used to cut at an inside surface. It can make a big hole, which cannot be process by a drill and a high accurate hole.

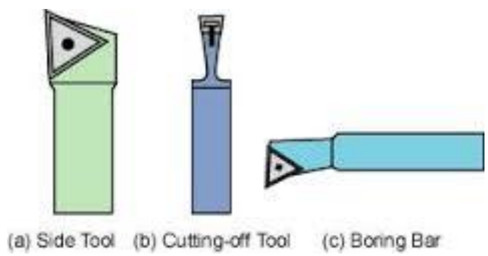
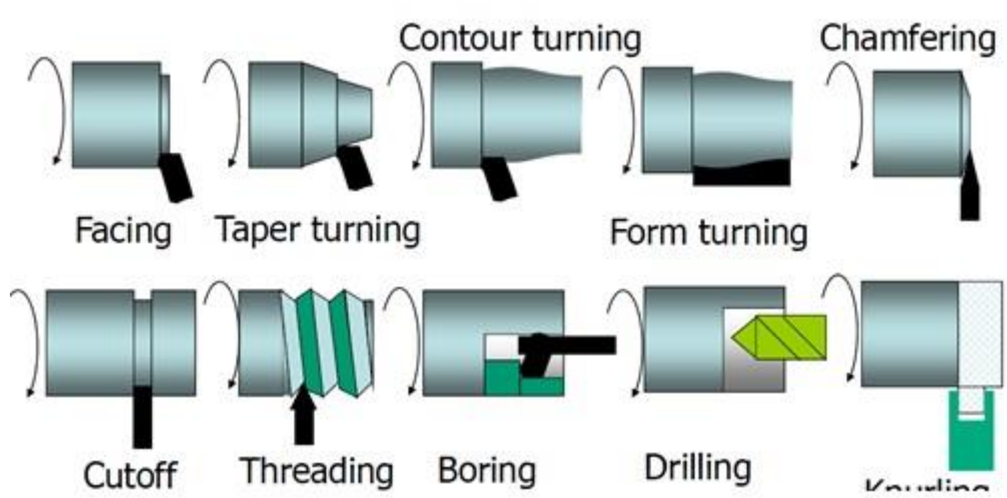


Fig.4 cutting tool used in lathe machine

Various cutting operations that can be performed on a lathe



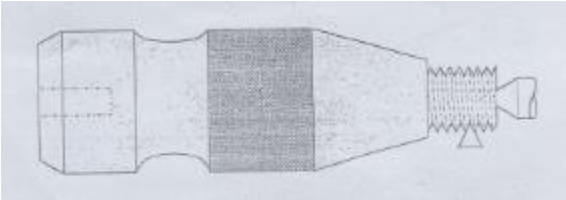
Assignment :

(a) Measure all dimensions on the specimen turned by your group. Make a neat sketch and indicate all measured dimensions.

(b) Discuss briefly how tapered portion was turned.

Exersise-1: You will need to use the Engine Lathe to perform the following operations in order to make the following shaft.

- Facing
- Chamfering
- Straight turning
- Contour turning
- Taper turning
- Knurling
- Threading and
- Drilling



Fig

The equipments/tools you will use in this part include:

- Engine lathe
- Facing tool
- Turning tool
- Center drill
- Knurling tool
- Drill bit etc.

Experiment-2:

Study of Milling Machine and Its Various Operations

Milling machine is one of the most versatile conventional machine tools with a wide range of metal cutting capability. Many complicated operations such as indexing, gang milling, and straddle milling etc. can be carried out on a milling machine. Milling machines are among the most versatile and useful machine tools due to their capabilities to perform a variety of operations. Milling machines can be classified as horizontal and vertical.

(A)Horizontal Milling Machine

Column: The column houses the spindle, the bearings, the gearbox, the clutches, the shafts, the pumps and the shifting mechanisms for transmitting power from the electric motor to the spindle at a selected speed.

Knee: The knee mounted in front of the column is for up or down motion supporting the table and to provide up and down motion along the Z axis.

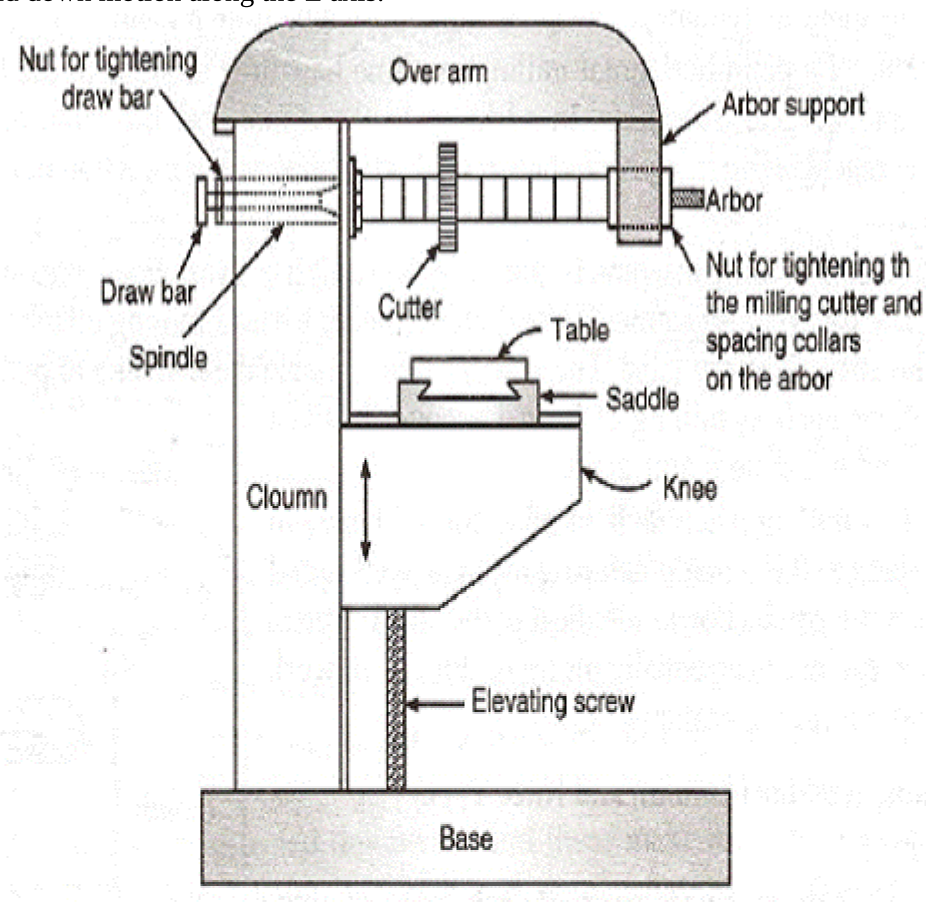


Fig : Horizontal milling machine

Saddle : The saddle consists of two slide ways , one on the top and one at the bottom located at 90◦ to each other for providing motions in the X or Y axes by means of lead screws.

Table: The table is mounted on top of the saddle and can be moved along the X axis. On top of the table are some T-slots for the mounting of workpiece or clamping fixtures.

Arbor: The arbor is an extension of the spindle for mounting cutters. Usually, the thread end of an arbor is of left hand helix.

(B) Vertical Milling Machine

Column : The column houses the spindle, the bearings, the gearbox, the clutches, the shafts, the pumps and the shifting mechanisms for transmitting power from the electric motor to the spindle at a selected speed.

Knee: the knee mounted in front of the column is for supporting the table and to provide an up or down motion along the Z axis.

Saddle: The saddle consists of two slide ways, one on the top and one at the bottom located at $90^\circ$to each other, for providing motions in the X or Y axes by means of lead screws.

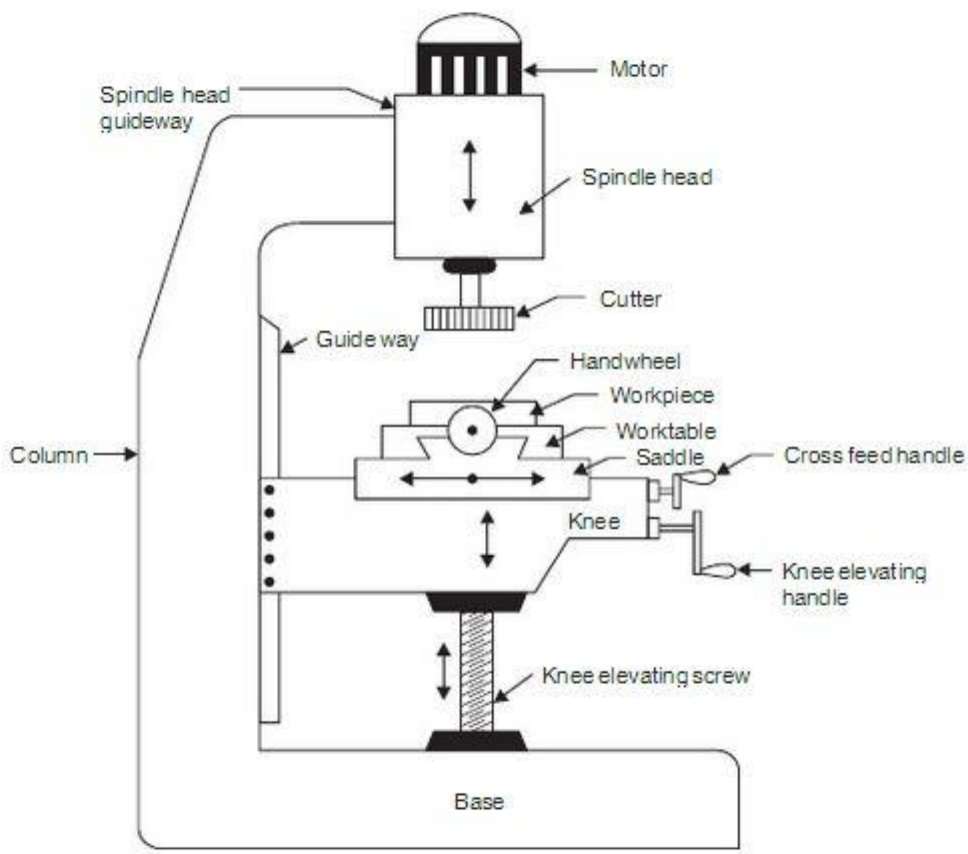


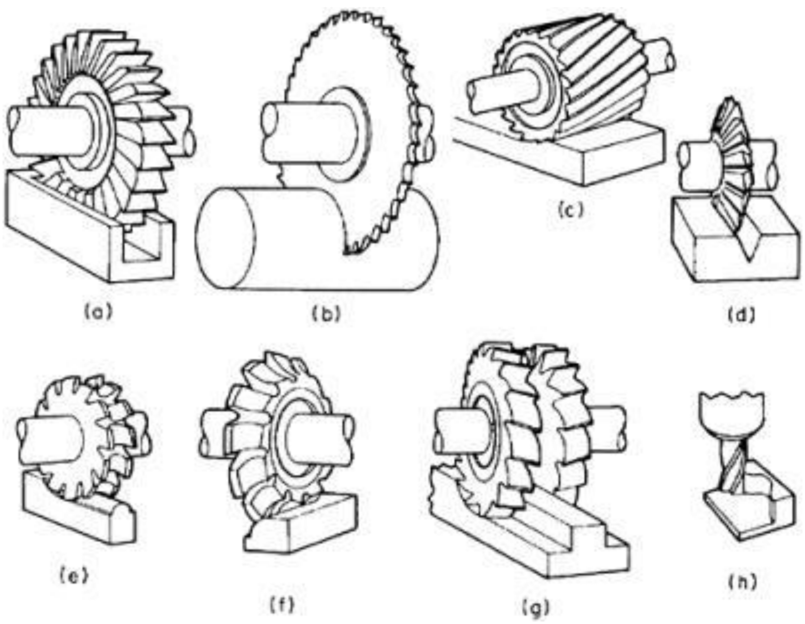
Fig. 4.10 Vertical milling machine

Table: The table is mounted on top of the saddle and can be moved along the X axis. On top of the table are some T-slots for the mounting of workpiece or clamping fixtures.

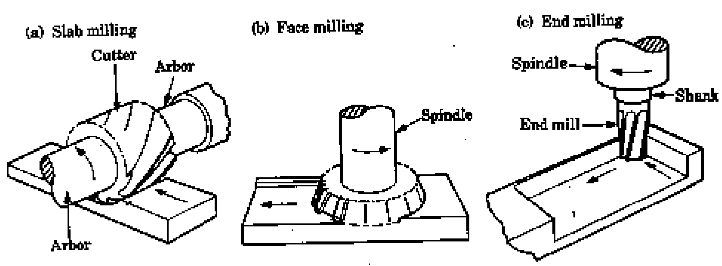
Milling head : The milling head consisting the spindle, the motor and the feed control unit is mounted on a swivel base such that it can be set at any angle to the table.

Ram: The ram on which the milling head is attached can be positioned forward and backward along the slide ways on the top of the columns.

Various cutting operations that can be performed on milling machine



Peripheral Milling
a)slotting
b)slitting
c)slab milling
d)slitting
e)form milling
f)side milling
g)straddle milling
h)end milling
Face milling



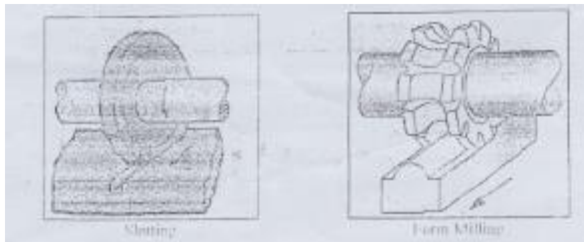
Assignment :

a)

b)

Exercise-2: You will need to use the milling machine and perform the following milling operations in in order to make the following product.

- Slotting
- Form Milling
- Pocket Milling
- End Milling



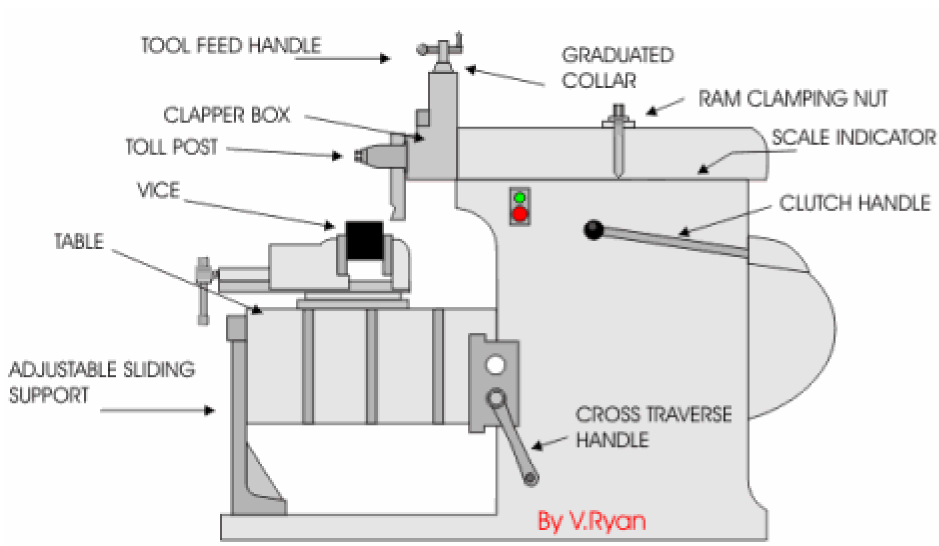
Experiment-3:

Study of Shaping Machine and Its Various Operations

The shaper is a relatively simple machine. It is used fairly often in the tool room or for machining one or two pieces for prototype work. Tooling is simple and shapers do not always require operator attention while cutting. The horizontal shaper is the most common type and its principal components are shown below and described as follows:

Ram: The ram slides back and forth in dovetail or square ways to transmit power to the cutter. The starting point and the length of the stroke can be adjusted.

Toolhead: The toolhead is fastened to the ram on a circular plate so that it can be rotated for making angular cuts. The toolhead can also be moved up or down by its hand crank for precise depth adjustments.



Shaping machine

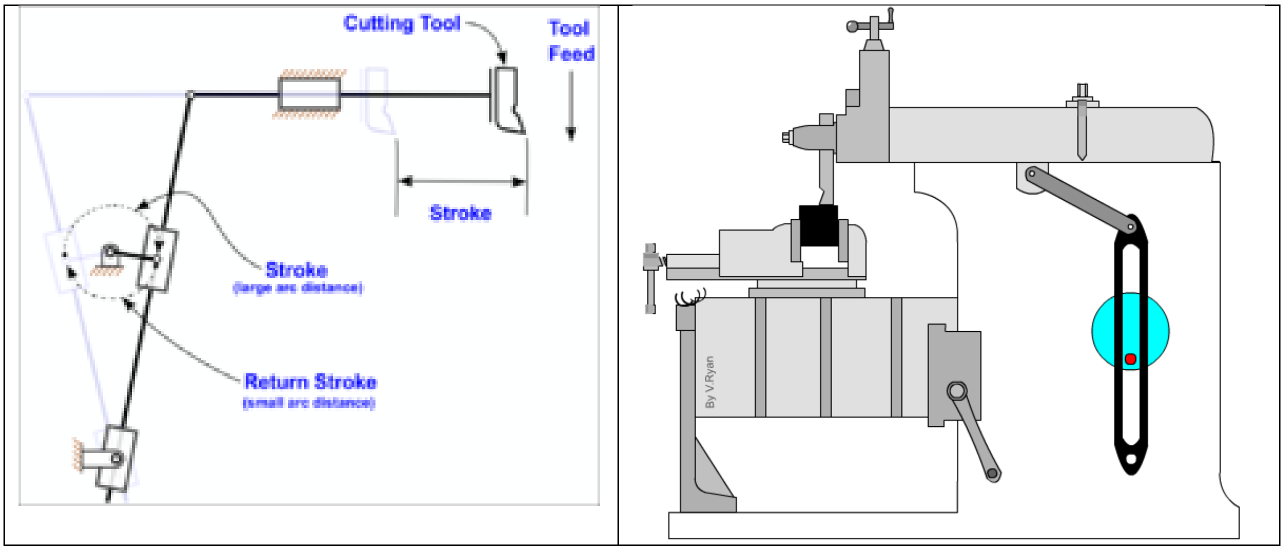
Clapper Box: The clapper box is needed because the cutter drags over the work on the return stroke. The clapper box is hinged so that the cutting tool will not dig in. Often this clapper box is automatically raised by mechanical, air or hydraulic action.

Table: the table is moved left and right, usually by hand, to position the work under the cutter when setting up. Then either by hand or more often automatically the table is moved sideways to feed the work under the cutter at the end or beginning of each stroke.

Quick Return Mechanism

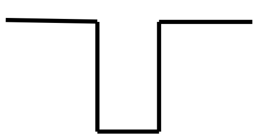
The shaping machine is used to machine is used to machine flat metal surfaces especially where a large amount of metal has to be removed. Other machines such as milling machines are much more expensive and are more suited to removing smaller amounts of metal very accurately.

The reciprocating motion of the mechanism inside the shaping machine can be seen in the diagram. As the disc rotates the top of the machine moves forwards and backwards pushing a cutting tool. The cutting tool removes the metal from work which is carefully bolted down.

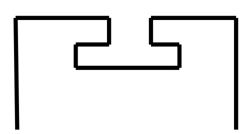


Quick return mechanism

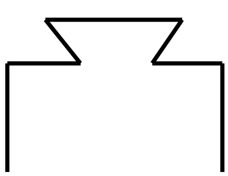
Various cutting operations that can be performed on a Shaping Machine



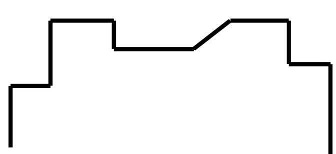
GROOVES



T -SLOT



DOVETAILS



FLATS and ANGLES

Assignment :

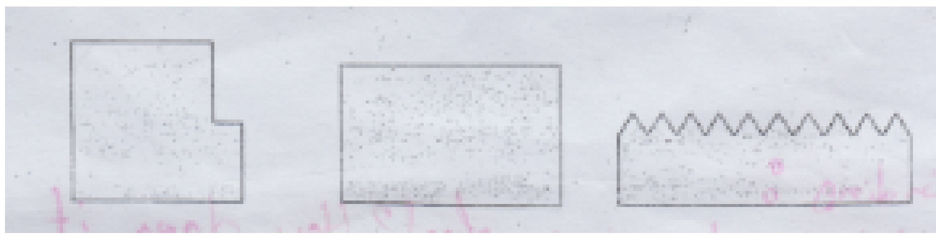
a) Explain quick return mechanism with neat sketch

b) Difference between shaper and planer machine

c) Discuss how rotary motion transforms into linear motion in housing (body)

Exercise-3: You will need to use the shaping machine and perform the following shaping operations in order to make the following product.

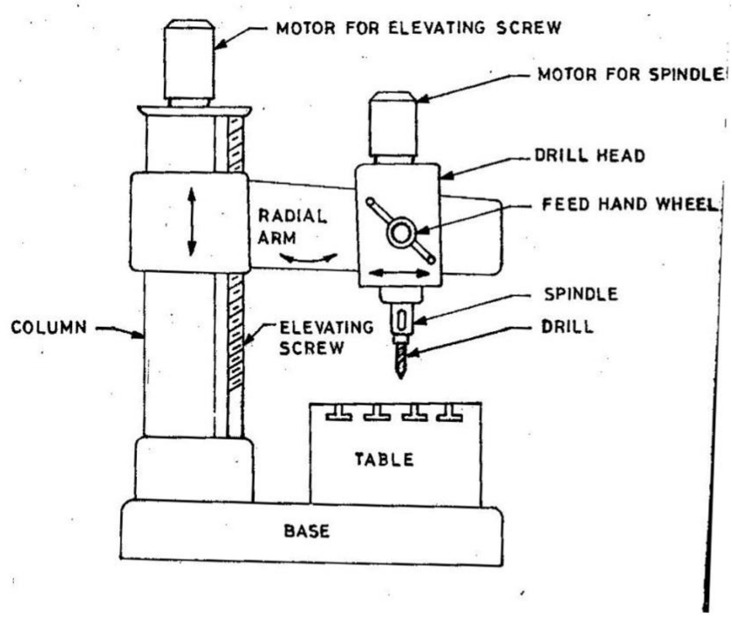
- Side cutting
- Plain shaping
- V-grooving
- Slotting



Experiment-4:

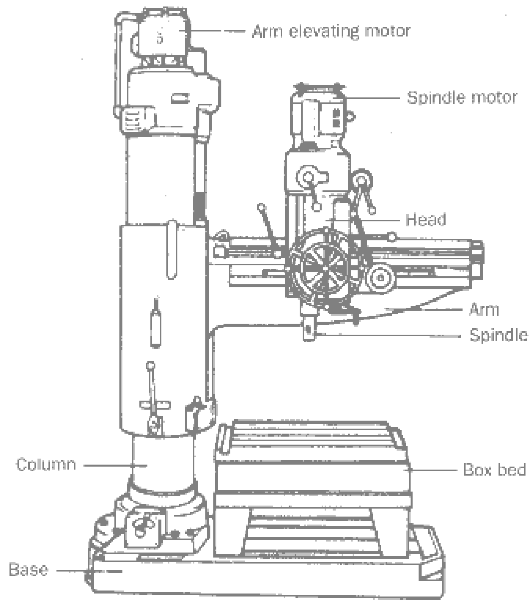
Study of Drilling Machine and Its Various Operations

A drill press is preferable to a hand drill when the location and orientation of the hole must be controlled accurately. A drill press is composed of a base that supports a column, the column in turn supports a table. Work can be supported on the table with a vise or hold down clamps or the table can be swiveled out of the way to allow tall work to be supported directly on the base. Height of the table can be adjusted with a table lift crank than locked I place with a table lock. The column also supports a head containing a motor. The motor turns the spindle at a speed controlled by a variable speed control dial. The spindle holds a drill chuck to hold the cutting tools (drill bits, center drills, deburring tools etc.)



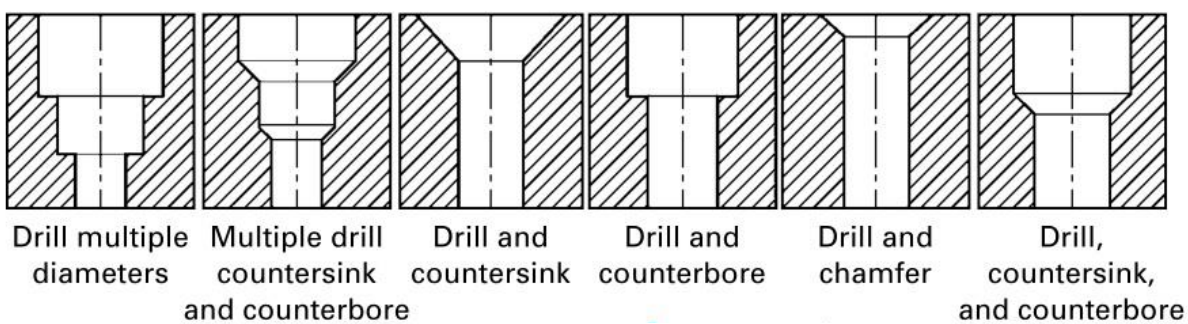
Radial drilling machines: used on large workpieces, spindle mounts on radial arm allowing drilling operations anywhere along the arm length.

Gang–drilling machines: independent columns each with different drilling operation work piece slide from one column to next



Radial drill machine Gang drill machine

Various operations that can be performed on a Drilling Machine



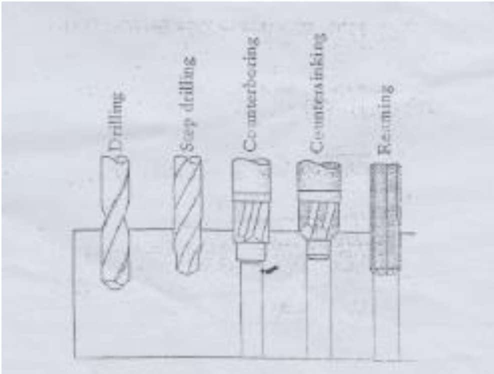
Assignment:

a) Drill bit is a single point cutting tool or multi point cutting tool?

b) Difference between counter boring and counter sinking

Exercise-4: You will need to use the drill press and perform the following drilling operations in order to make the following product.

- Drilling
- Step drilling
- Counterboring
- Countersinking
- Reaming



Fig

The equipment you will use in this part includes:

- Scribe
- Drill press
- Center drill
- 2drill bits
- Reamer
- Counter bore tool
- Countersink tool

Experiment-5:

Study of Grinding Machine and Its Various Operations

The grinding process consists of removing material from the workpiece by the use of a rotating wheel that has a surface composed of abrasive grains. Grinding is considered to be the most accurate of the existing machining processes, Grinding processes are used when high accuracies, close dimensional tolerances, and a fine surface finishes are required. Grinding processes also allow for high production rates. This allows for a lowered cost of production. Hard materials can also be machined.

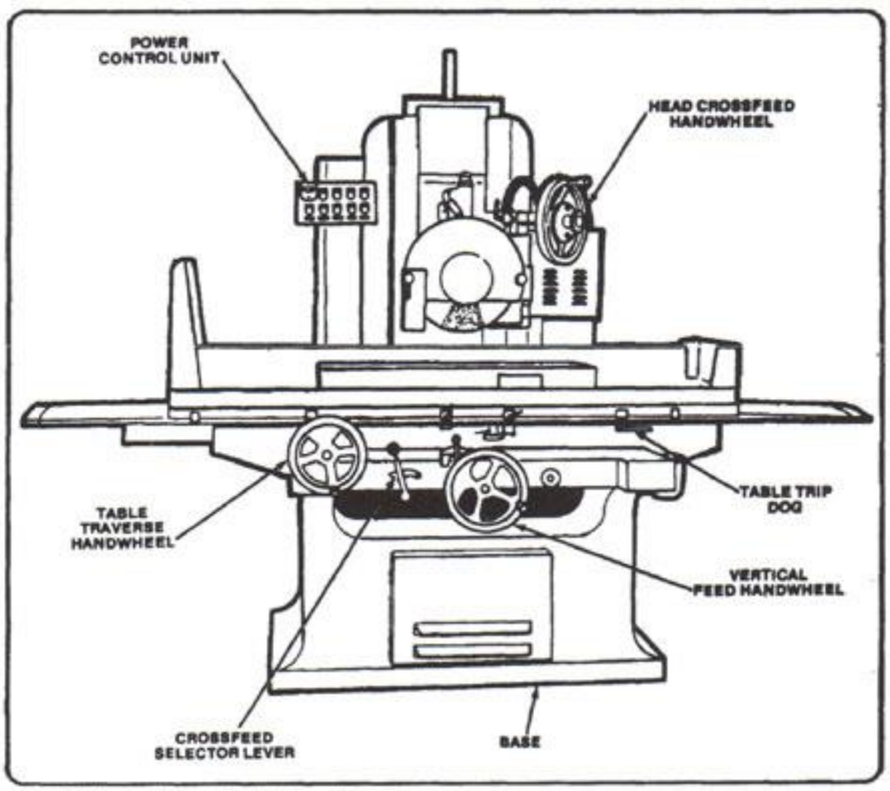


Figure 5-6. Reciprocating surface grinding machine.

Fig: Surface grinding machine

Surface grinding is most common of the grinding operations. A rotating wheel is used in the grinding of flat surfaces. Types of surface grinding are vertical spindle and rotary tables.

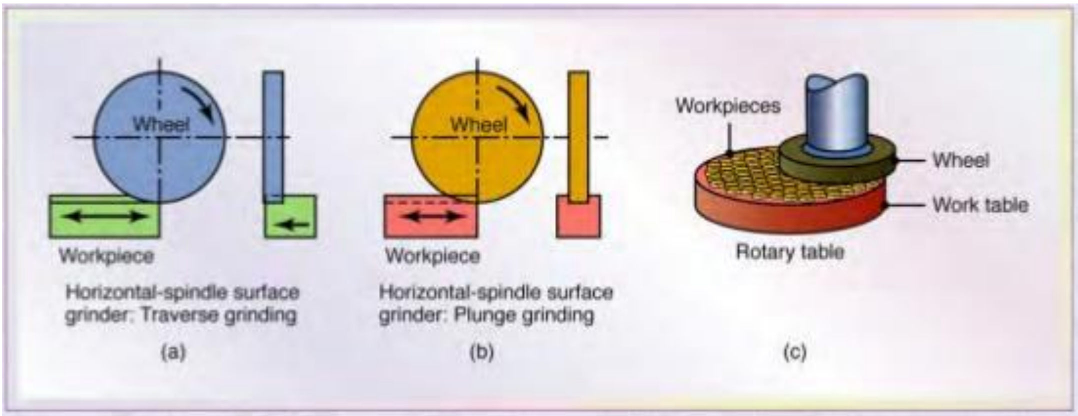


Figure 26.13 Schematic illustrations of various surface-grinding operations. (a) Traverse grinding with a horizontal-spindle surface grinder. (b) Plunge grinding with a horizontal-spindle surface grinder. (c) A vertical-spindle rotary-table grinder (also known as the *Blanchard* type.)

Internal grinding is used to grind the inside diameter of the workpiece. Tapered holes can be ground with the use of internal grinders that can swivel ion the horizontal.

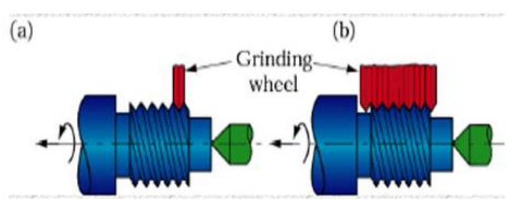


Fig: Thread grinding by (a) traverse, and (b) plunge grinding

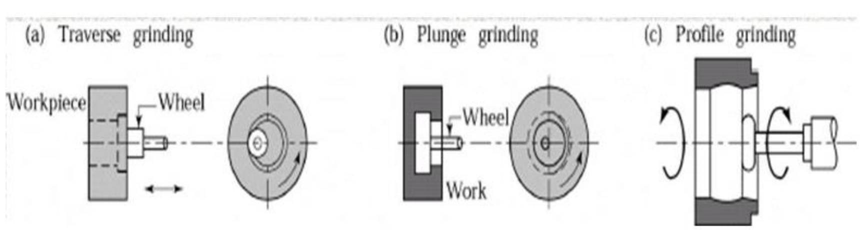


Fig: Internal grinding operations

Cylindrical grinding is also called center-type grinding and is used in the removing the cylindrical surfaces and shoulders of the workpiece. Both the tool and the workpiece are rotated by separate motors and at different speeds. The axes of rotation tool can be adjusted to produce a variety if shapes.

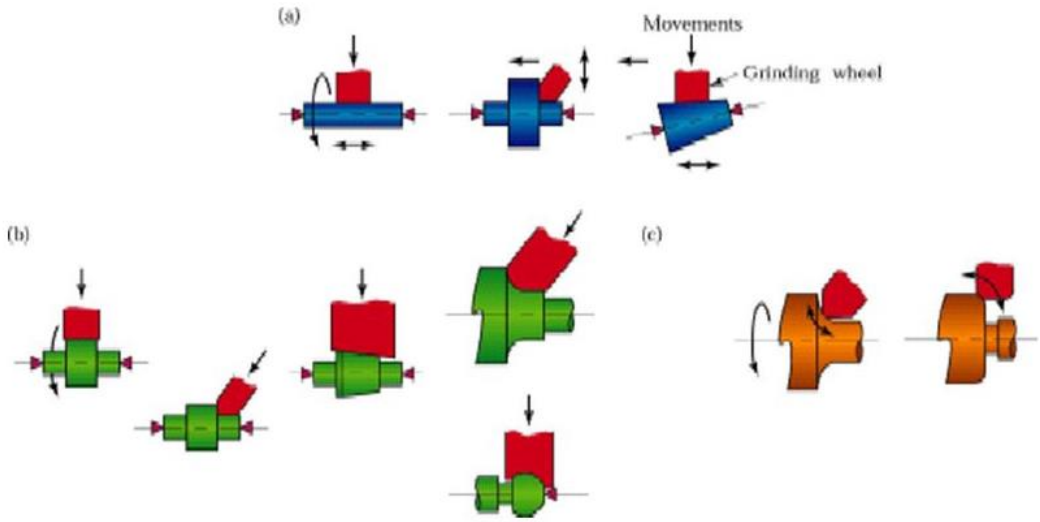
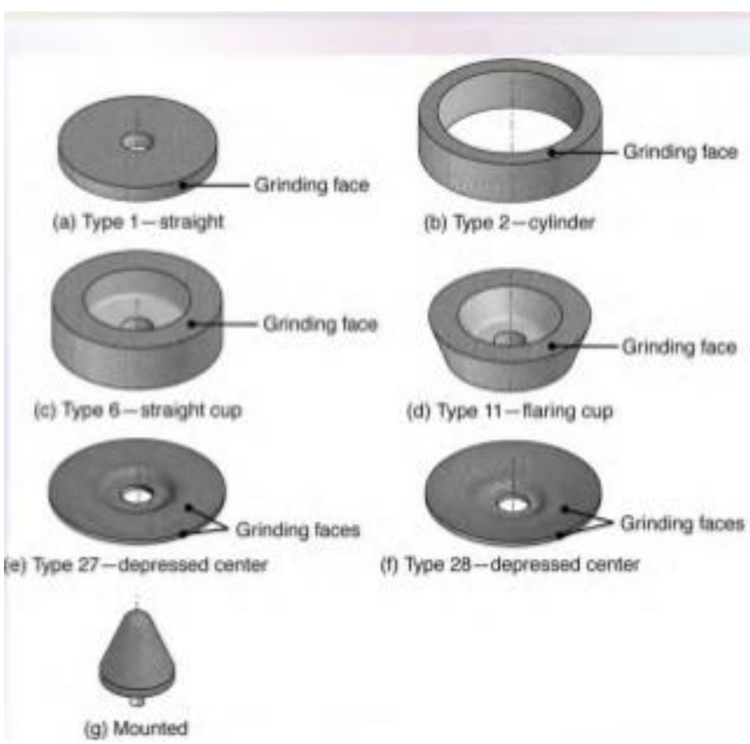
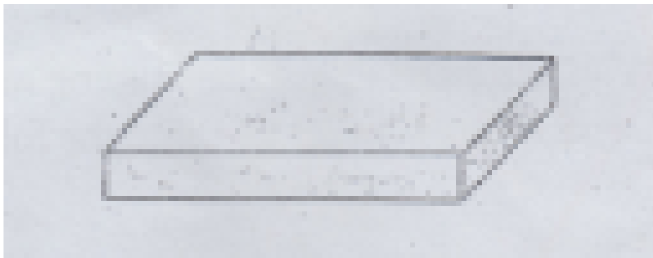


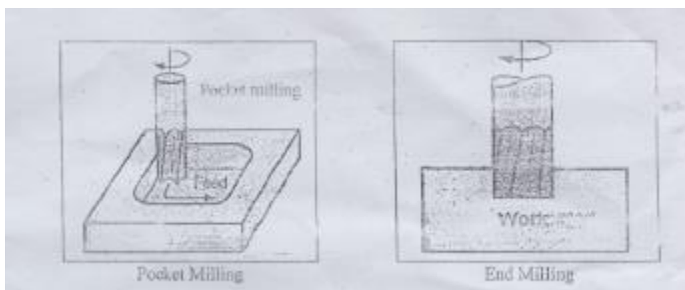
Fig: Examples of various cylindrical grinding operations. (a) Traverse grinding, (b) plunge grinding, and (c) profile grinding.

Common Grinding Wheels: A grinding wheel is made of abrasive grains held together by a bond. These grains cut like teeth when the wheel is revolved at high speed and is brought to bear against a work piece. The properties of a wheel that determine how it acts are the kind and size of abrasive how closely the grains are packed together and amount if the bonding material.



Exercise-5: You will need to use the surface grinding machine and perform the surface grinding operations in order to make the following part.





Ahsanullah University of Science and Technology

Department of Electrical and Electronic Engineering

LABORATORY MANUAL

FOR

ELECTRICAL AND ELECTRONIC SESSIONAL COURSE

Student Name :

Student ID :

EEE - 1102 ELECTRICAL CIRCUITS – I LAB

Department of EEE 1^{st} Year, 1^{st} Semester

EEE - 1132 BASIC ELECTRICAL TECHNOLOGY LAB.

Department of CE 1^{st} Year, 1^{st} Semester

EEE - 1242 BASIC ELECTRICAL ENGINEERING LAB.

Department of CSE 1^{st} Year, 2^{nd} Semester

EEE - 1288 BASIC ELECTRICAL ENGINEERING LAB.

Department of ME and MPE 1^{st} Year, 2^{nd} Semester

EEE - 2262 ELEMENTS of ELECTRICAL ENGINEERING and ELECTRONICS LAB

Department of TE 2^{nd} Year, 2^{nd} Semester

Experiment Name	:**01**
Name of the Experiment	**Familiarization of different equipment involved with Electrical Circuit Lab**

Objective:

The objective of the experiment is to learn about the commonly used equipments used in the lab and how to properly use it.

Breadboard

Breadboard is a board used for electrical circuit prototyping. Before the circuit is permanently placed in a PCB (Printed Circuit Board) prototyping boards are used to verify the electrical circuit. Some other prototyping boards are: Perfboard, Stripboard, Veroboard etc.

Top two row (A and B) of the board are internally connected sideways and the holes in *group B* are connected vertically as show in the figure 1 and this sequence continue in the rest of the board.

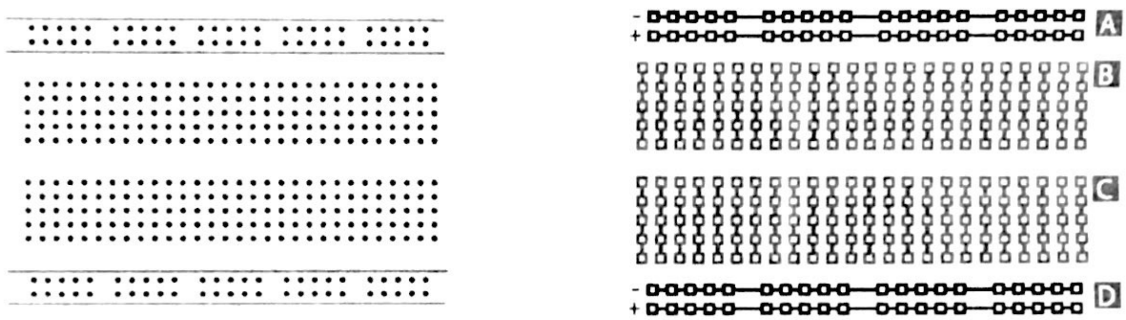


Figure 1.1: External and Internal construction of the breadboard

From circuit to Breadboard:

Closely observe the circuit diagram (electronic schematic) and the equivalent connection on breadboard.

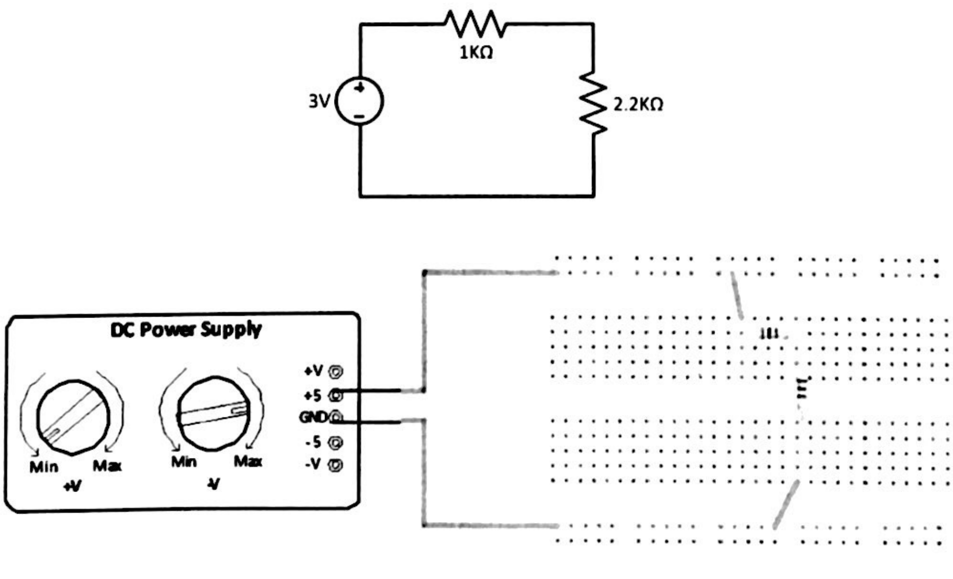
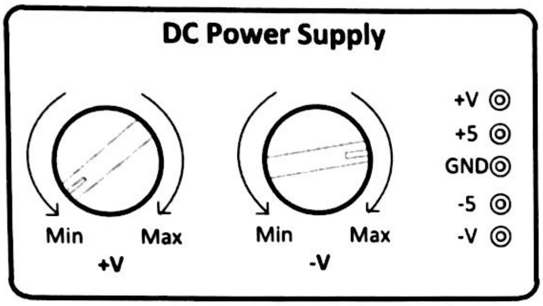


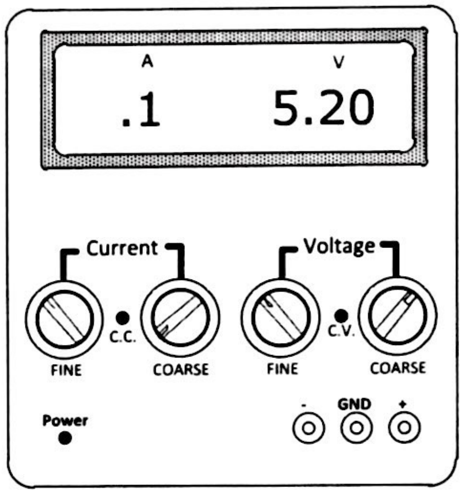
Figure 1.2: Circuit diagram and the equivalent breadboard connection

DC Power Supply:

In the Lab we have two DC source in the workbench. One can be found in the trainer board Fig 1.3(a) and another is a individual DC power supply module Fig 1.3(b).



(a) Trainer board DC source



(b) DC power supply module

Figure 1.3: DC power sources

Trainer board DC source:

Trainer board DC power supply can deliver two variable and two fixed DC voltage at the same time. The variable voltage can be adjusted using the two dial.

Voltage output at pin (reference to GND)	Value	Type
+V	1.2 V to 20 V	Variable
+5	5 V	Fixed
-5	-5 V	Fixed
-V	-1.2 V to -20V	Variable

DC power supply module:

The DC power supply module can deliver voltage ranging from 0V to 30V.

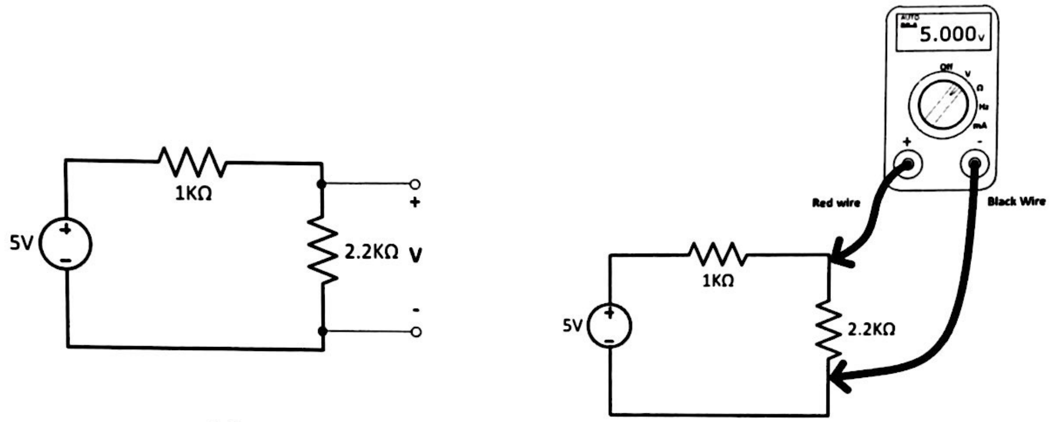
1. To set a particular voltage turn on the power supply.
2. To change the voltage in big step use the coarse dial and to precisely vary the voltage use the fine dial in the voltage group.
3. Observe the output voltage change.

The coarse and fine dial in current group is used to set the maximum current limit at the output.

Measuring Voltage:

1. To measure the voltage across the 1KΩ resistor circuit in Fig 1.4 (a), construct the circuit as shown in Fig 1.4 (b).
2. Rotate the multimeter dial in the **V** position.
3. Connect the red and black multimeter lead as shown in the Fig 1.4(a) **(parallel to the resistor)**
4. Multimeter should display the Voltage

Warning: while measuring voltage multimeter dial SHOULD NOT be in mA (current) position. It might destroy/damage the meter

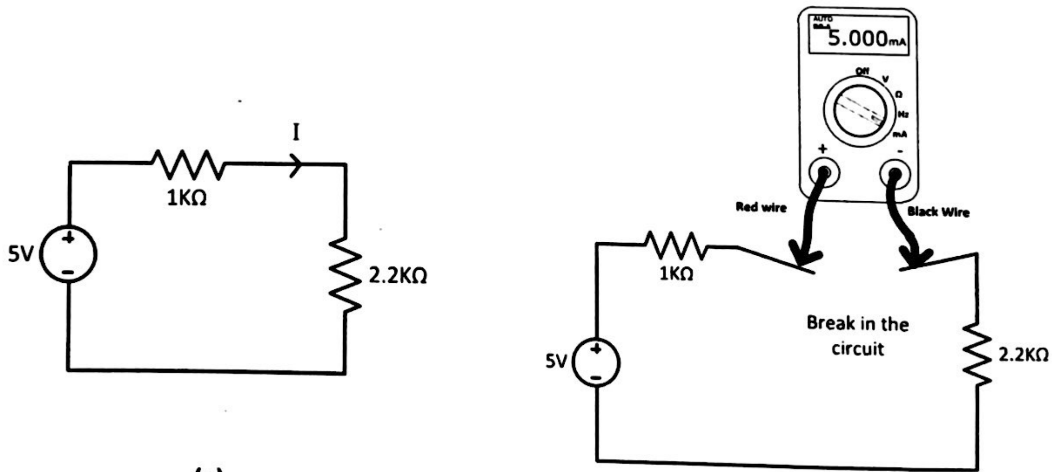


(a) **(b)**

Figure 1.4: Circuit diagram and actual connection for measuring voltage

Measuring Current:

1. To measure the current in the series circuit in Fig 1.5(a) construct the circuit and then **create a break** the circuit as shown in Fig 1.5 (b)
2. Rotate the multimeter dial in the mA position.
3. Connect the red and black multimeter lead as shown in the Fig 1.5(b) **(in series with the circuit)**
4. Multimeter should display the current



(a) **(b)**

Figure 1.5: Circuit diagram and actual connection for measuring current

Experiment No.	: **02**
Name of the Experiment	: **Verification of Ohm's Law.**

OBJECTIVE:

To verify the following two equivalent forms of Ohm's Law:

a. Express I as a function of V and R.
b. Express V as a function of I and R.

THEORY:

Ohm's law describes mathematically how voltage 'V', current 'I' and resistance 'R' in a circuit are related. According to this law:

"The current in a circuit is directly proportional to the applied voltage and inversely proportional to the circuit resistance".

Formula for voltage:
For a constant value of R, V is directly proportional to I
i.e. $V = IR$

Formula for current:
For a constant value of V, I is inversely proportional to R
i.e. $I = V/R$

EQUIPMENTS:

- Variable DC power supply -1 piece
- Digital multimeter (DMM)/ Analog multimeter-1 piece.
- Resistances: 1 KΩ, 2.2 KΩ, 3.3 KΩ, 4.7 KΩ, 5.6 KΩ, 10 KΩ -1 piece each.
- Trainer Board
- Connecting Wires.

CIRCUIT DIAGRAM:

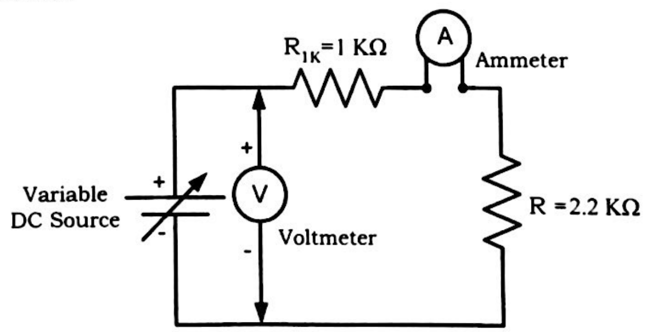


Figure 2.1: Verification of Ohm's Law

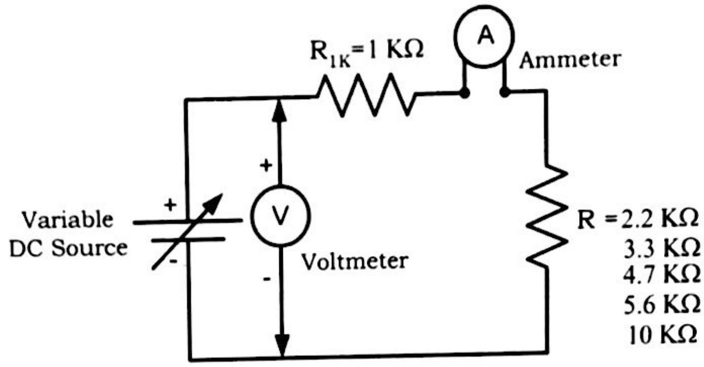


Figure 2.2: Verification of Ohm's Law

PROCEDURES:

Current versus voltage:

a. Construct the circuit of Figure 2.1. Do not switch on the power supply.

b. Turn on the power supply and adjust it to 5V by using Voltmeter. Measure the current I by ammeter and record it in the Table 2.2.

c. Increase the values of voltage as shown in the Table 2.2. Measure the current I in turn and record the values in Table 2.2.

d. Calculate the values of current I by using $I=V/R_T$. Use measured values of resistances.

Current versus resistance:

a. Construct the circuit of Figure 2.2. Do not switch on the power supply.

b. Turn on the power supply and adjust it to 20V by using Voltmeter. Measure the current I by ammeter for R=2.2 KΩ (Use measured values) and record it in the Table 2.3.

c. Turn off the power supply and remove the resistance 2.2 KΩ. Replace it by resistor 3.3 KΩ.

d. Now turn on the power supply. Measure and record the current I in turn, at each of the resistance settings shown in the Figure 2.2.

e. Calculate the values of resistance R_T by using $R_T=V/I$. Use measured values of voltage and current.

DATA SHEET:

Table 2.1: Measuring Resistances by using Ohmmeter

Nominal values of R (KΩ)	Measured values of R(KΩ) by using Ohmmeter
1	
2.2	
3.3	
4.7	
5.6	
10	

Table 2.2: Current versus voltage

Supply Voltage (V)	Measured I by using Ammeter (A)	$R_T = R_{1K} + R_{2.2K}$ [Use measured values of R]	Calculate I (amp) $I=V/R_T$
5			
10			
15			
20			
25			

Table 2.3: Current versus resistance

<table>
<tr><th>Supply Voltage (V)</th><th>Measured I by using Ammeter (A)</th><th>R_T (KΩ)
Use measured values of R</th><th>Calculate
R_T =V/I (KΩ)</th></tr>
<tr><td rowspan="2">20</td><td rowspan="2"></td><td>$R_T = R_{1K} + R_{2.2K}$</td><td rowspan="2"></td></tr>
<tr><td>$R_T =$</td></tr>
<tr><td rowspan="2">20</td><td rowspan="2"></td><td>$R_T = R_{1K} + R_{3.3K}$</td><td rowspan="2"></td></tr>
<tr><td>$R_T =$</td></tr>
<tr><td rowspan="2">20</td><td rowspan="2"></td><td>$R_T = R_{1K} + R_{4.7K}$</td><td rowspan="2"></td></tr>
<tr><td>$R_T =$</td></tr>
<tr><td rowspan="2">20</td><td rowspan="2"></td><td>$R_T = R_{1K} + R_{5.6K}$</td><td rowspan="2"></td></tr>
<tr><td>$R_T =$</td></tr>
<tr><td rowspan="2">20</td><td rowspan="2"></td><td>$R_T = R_{1K} + R_{10K}$</td><td rowspan="2"></td></tr>
<tr><td>$R_T =$</td></tr>
</table>

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Signature of the Teacher

ASSIGNMENTS:

1. What can you say about the relationship between voltage and current, provided that the resistance is fixed?

2. Plot a graph of I versus V keeping the value of resistance constant. Use measured values of I and V. Comment on the graph briefly.

3. Plot a graph of I versus R_T keeping the value of supply voltage constant. Use measured values of I and R_T. Comment on the graph briefly.

Experiment No. : 03

Name of the Experiment: **To investigate the characteristics of a series DC circuit and to verify Kirchoff's Voltage Law (KVL).**

OBJECTIVE:

The objective of this experiment is to investigate the characteristics of a series DC circuit and to verify Kirchoff's Voltage Law (KVL).

THEORY:

In a series circuit (Figure 3.1) the current is same through all of the circuit elements.

The equivalent Resistance, $R_T = R_1 + R_2 + R_3$.

By Ohm's Law, the Current is

$$I = \frac{V_{Supply}}{R_T}$$

KVL states that the voltage rises must be equal to the voltage drops around a close circuit. Applying Kirchoff's Voltage Law around closed loop of Figure 3.1, we find,

$$V_{Supply} = V_1 + V_2 + V_3$$

Where, $V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$

Current I is same throughout the circuit for figure 3.1.

The voltage divider rule states that the voltage across an element or across a series combination of elements in a series circuit is equal to the resistance of the element divided by total resistance of the series circuit and multiplied by the total impressed voltage. For the elements of Figure 3.1

$$V_1 = \frac{R_1 E}{R_T}, \quad V_2 = \frac{R_2 E}{R_T}, \quad V_3 = \frac{R_3 E}{R_T}$$

EQUIPMENTS:

- Variable DC power supply -1 piece
- Digital Multimeter (DMM)/ Analog multimeter-1 piece.
- Resistances: 100Ω, 220Ω, 470Ω -1 piece each.
- Trainer Board-1 piece
- Connecting Wires.

CIRCUIT DIAGRAM:

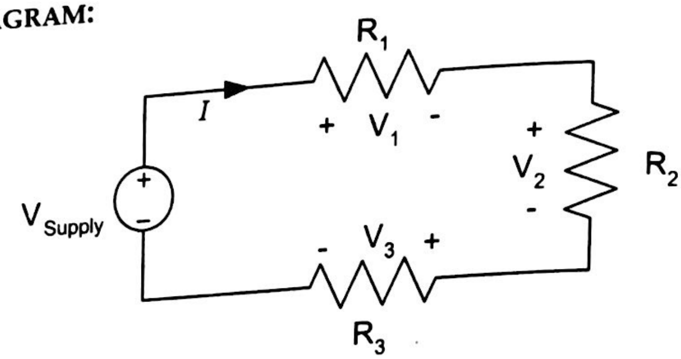


Figure 3.1

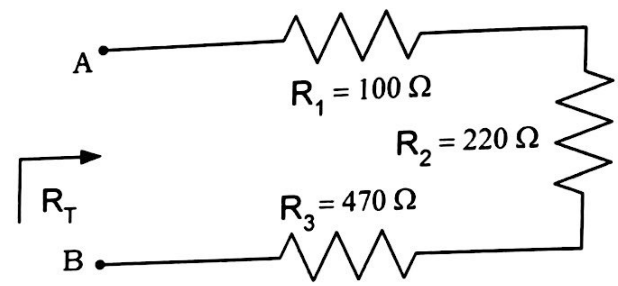


Figure 3.2

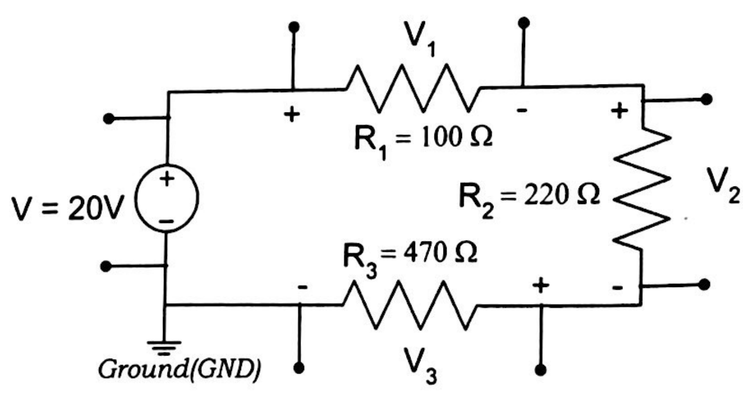


Figure 3.3

PROCEDURE:

1. Measure the resistances having values 100Ω, 220Ω & 470Ω by using Ohmmeter and record the values in Table 3.1.
2. Construct the circuit as shown in Fig 3.2.
3. Then measure input resistance R_T across points A-B using Ohmmeter and record that value in Table 3.1.
4. Now construct the circuit as shown in Fig 3.3. Turn on the DC power supply and set the DC supply to 20V by using Voltmeter.
5. Measure voltage across each resistor with Voltmeter and record in the Table 3.1
6. Calculate V_1, V_2 and V_3 using Voltage Divider Rule (VDR). ***[Use measured values of resistances for all calculations.]***

ASSIGNMENTS:

1. What can you deduce about the characteristics of a series circuit from observation Table 3.1?
2. From the data found in Table 3.1, mathematically prove that the current in the series network of figure 3.3 is equal for each resistance.
3. Verify KVL from the data obtained in Table 3.1.

DATA SHEET:

Table 3.1:

Nominal values of Resistance (Ω)	Measured values of Resistance by Ohmmeter (Ω)	Equivalent Resistance, R_T		Measured voltage across each resistor (V)	Calculated Voltage using VDR (V)
		Measured R_T by using Ohmmeter (Ω)	Calculated $R_T = R_1 + R_2 + R_3$ (Ω)		
R_1=100				V_1=	
R_2=220				V_2=	
R_3=470				V_3=	

Calculation:

Signature of the Teacher

Experiment No.	: **04**
Name of the Experiment:	**To investigate the characteristics of a Parallel DC circuit and to verify Kirchoff's Current Law (KCL).**

OBJECTIVE:

The objective of this experiment is to investigate the characteristics of a parallel DC circuit and to verify Kirchoff's Current Law (KCL).

THEORY:

In a parallel circuit (Figure 4.1) the voltage across parallel elements is the same.

The total or equivalent resistance (R_T) is given by,

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{---------} + \frac{1}{R_N}$$

If there are only two resistors in parallel, it is more convenient to use,

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

In any case, the total resistance will always be less than the resistance of the smallest resistor of the parallel network.

KCL states that the currents entering a node must be equal to the currents leaving that node. For the network of Figure 4.1 the currents are related by the following expression:

$$I_T = I_1 + I_2 + I_3 + \text{---------} + I_N$$

Applying current divider rule (CDR) for a circuit of only two resistors in parallel as shown in figure 4.2,

$$I_1 = \frac{R_2 I_T}{R_1 + R_2} \quad \text{and} \quad I_2 = \frac{R_1 I_T}{R_1 + R_2}$$

For equal parallel resistors, the current divides equally and the total resistance is the value of one divided by the 'N' number of equal parallel resistors, i.e.:

$$R_T = \frac{R}{N}$$

For a parallel combination of N resistors, the current I_1 through R_1 is:

$$I_1 = I_T \times \frac{\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{---------} + \frac{1}{R_N}}$$

EQUIPMENTS:

- Variable DC power supply -1 piece
- Digital Multimeter (DMM)/ Analog multimeter-1 piece.
- Resistances: 1KΩ, 2.2 KΩ, 4.7 KΩ -1 piece each.
- Trainer Board-1 piece
- Connecting Wires.

CIRCUIT DIAGRAM:

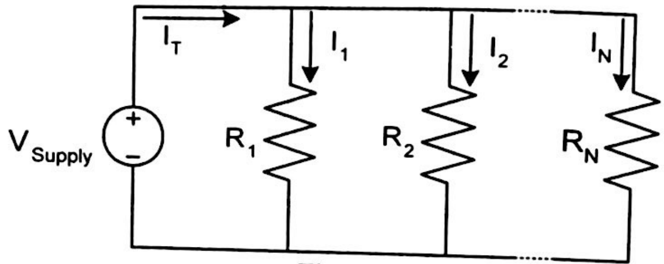


Figure 4.1

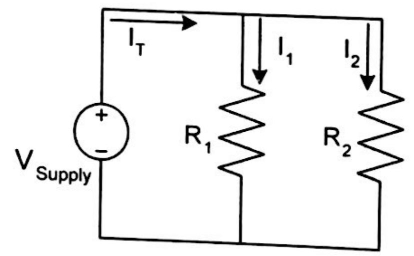


Figure 4.2

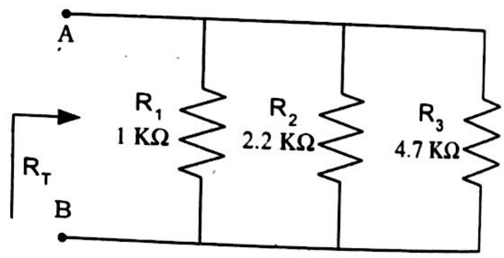


Figure 4.3

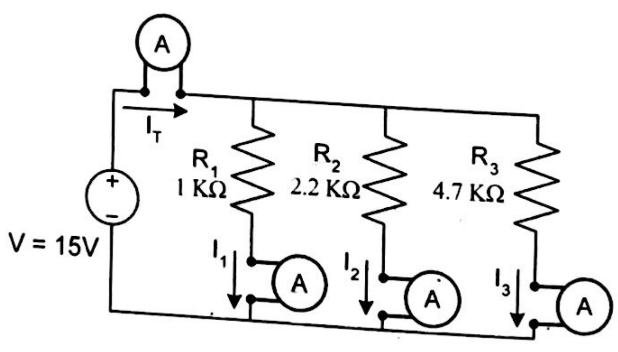


Figure 4.4

PROCEDURE:

1. Measure the resistances having values 1 KΩ, 2.2 KΩ & 4.7 KΩ by using Ohmmeter and record the values in Table 4.1.
2. Construct the circuit as shown in Fig 4.3.
3. Then measure input resistance R_T across points A-B using Ohmmeter and record that value in Table 4.1.
4. Now construct the circuit as shown in Fig 4.4. Turn on the DC power supply and set the DC supply to 15V by using Voltmeter.
5. Measure the currents I_T, I_1, I_2 and I_3 by using Ammeter and record in the Table 4.1.
6. Calculate I_1, I_2 and I_3 using Current Divider Rule (CDR). ***[Use measured values of resistances for all calculations.]***

ASSIGNMENTS:

1. What can you deduce about the characteristics of a parallel circuit from observation Table 4.1?
2. From the data found in Table 4.1, Calculate I_1, I_2 and I_3 using Ohm's Law.
3. Verify KCL from the data obtained in Table 4.1.

Data Sheet:

Table 4.1:

Nominal values of Resistance (KΩ)	Measured values of Resistance by Ohmmeter (KΩ)	Equivalent Resistance, R_T		Measured current through each resistor (A)	Calculated Current using CDR (A)
		Measured R_T by using Ohmmeter (KΩ)	Calculated $\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$ (KΩ)		
R_1=1				I_1=	
R_2=2.2				I_2=	
R_3=4.7				I_3=	

Calculation:

Signature of the Teacher

Experiment No.	: **05**
Name of the Experiment	: **Use of Galvanometer as Ammeter and Voltmeter.**

OBJECTIVE:

The objective of this experiment is to show how a galvanometer can be used as an ammeter and a voltmeter.

THEORY:

An ammeter is an instrument, while connected in series with a branch, measure the current of that branch. Ideally it should be of zero resistance, so that there is no voltage drop across it and hence it has no effect on the circuit where it is connected.

A voltmeter is an instrument, while connected in parallel with a branch, measure the voltage of that branch. Ideally it should be of infinite resistance, so that it draws no current and hence it has no effect on the circuit where it is connected.

A galvanometer is an instrument that can detect current. This meter can be used either as an ammeter or as a voltmeter. To use this meter as an ammeter, a very small resistance is connected in parallel with it so that a small voltage drop will occur across it. When the galvanometer is used as a·voltmeter, a very high resistance is connected in series with it so that it will draw a little current.

EQUIPMENTS:

- Trainer Board - 1 piece.
- Digital Multi-meter - 1 piece.
- Galvanometer - 1 piece.
- Potentiometer – (10KΩ) 1 piece.
- Resistances: 10 Ω, 100 Ω, 1 KΩ, 10KΩ -1 piece each.

PROCEDURES:

PART A:

1. Construct an ammeter using a galvanometer as shown in Figure 5.1

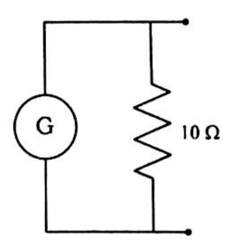


Figure 5.1: Constructed Ammeter circuit

2. Now place the constructed ammeter in the circuit shown below in Figure 5.2.

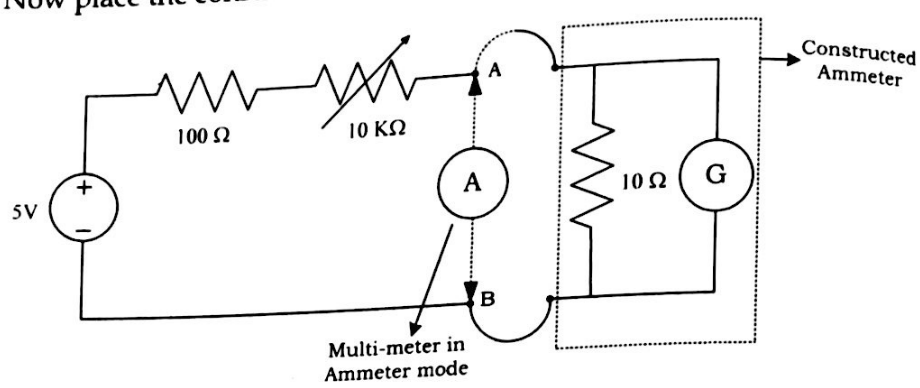


Figure 5.2: Use of galvanometer as an ammeter.

3. Connect the constructed ammeter and vary the pot until full-scale deflection is obtained. Then disconnect the constructed ammeter and the place actual ammeter. Measure the current from multi-meter in ammeter mode.

The value of each division of the galvanometer scale

$$= \frac{\text{Measured current}}{\text{No. of divisions deflected in full scale.}} =$$

4. Connect the constructed ammeter and vary the pot. Note the number of divisions deflected by the galvanometer. Then disconnect the constructed ammeter and place the actual ammeter Measure the current from multi-meter in ammeter mode. Record these readings in Table 5.1.

5. Increase the pot several times. Repeat step 4 for each increment of pot and record the readings in Table 5.1.

Table 5.1: Data for Ammeter.

No. of divisions deflected by the galvanometer	**Current = No. of divisions deflected X Value of each division. (mA)**	**Measured Current (Reading from multi-meter in ammeter mode) (mA)**

PART B:

1. Construct a voltmeter using a galvanometer as shown in Figure 5.3.

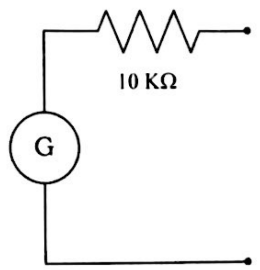


Figure 5.3: Constructed Voltmeter circuit

2. Now place the constructed voltmeter in the circuit shown below in Figure 5.4.

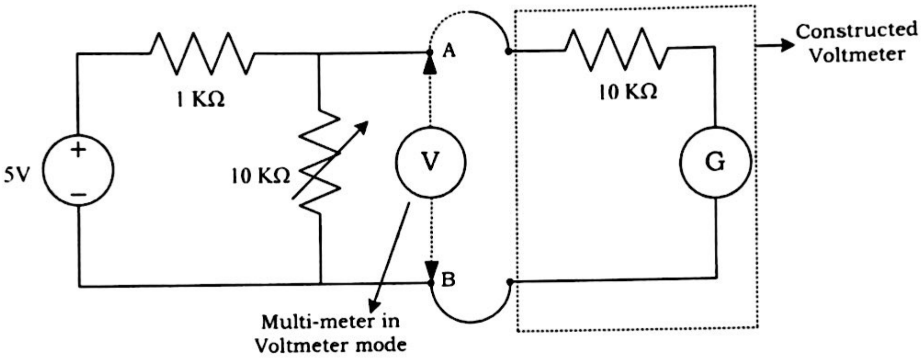


Figure 5.4: Use of galvanometer as voltmeter.

3. Connect the constructed voltmeter and vary the pot until full-scale deflection is obtained. Then place the actual voltmeter Measure the voltage from multi-meter in voltmeter mode.

   The value of each division of the galvanometer scale

   $$= \frac{\text{MeasuredVoltage}}{\text{No.of divisionsdeflectedin fullscale.}} =$$

4. Connect the constructed voltmeter and vary the pot. Note the number of divisions deflected by the galvanometer. Then place the actual voltmeter Measure the voltage from multi-meter in voltmeter mode. Record these readings in Table 5.2.

5. Increase the pot several times. Repeat step 4 for each increment of pot and record the readings in Table 5.2.

Table 5.2: Data for Voltmeter.

No. of divisions deflected by the galvanometer	Voltage = No. of divisions deflected X Value of each division. (v)	Measured Voltage (Reading from multi-meter in voltmeter mode) (v)

ASSIGNMENTS:

1. Comment on the results found in Part A and Part B.
2. Suppose we want to measure a current greater than the full-scale deflection of the constructed ammeter (Figure 5.1). In this case, should the resistance in parallel with the galvanometer be increased or decreased? Explain in brief.

Experiment No.	: **06**
Name of the Experiment	: **Verification of Superposition Theorem.**

OBJECTIVE:

Superposition theorem states that current through and element for multiple sources is equal to the summation of currents due to individual sources. In this experiment we measure the current (or voltage) due to combination of sources of the original circuit and then measure the current for each individual source. Then verify the theorem by comparing the algebraic sum to of the currents due to individual sources with the current due to original setup.

EQUIPMENTS:

- Variable DC Power Supply (20 V)-1 piece.
- Trainer Board-1 piece.
- Digital Multimeter-1 piece.
- Resistances: 100 Ω, 220 Ω, 330 Ω, 470 Ω and 560 Ω -1 piece each.
- Connecting Wires.

CIRCUIT DIAGRAM:

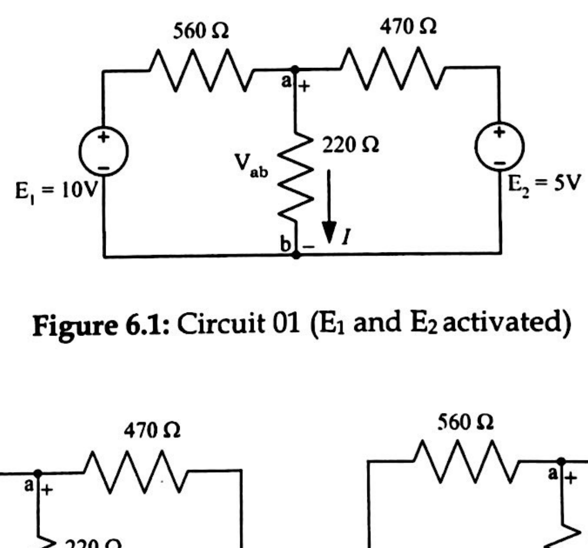


Figure 6.1: Circuit 01 (E_1 and E_2 activated)

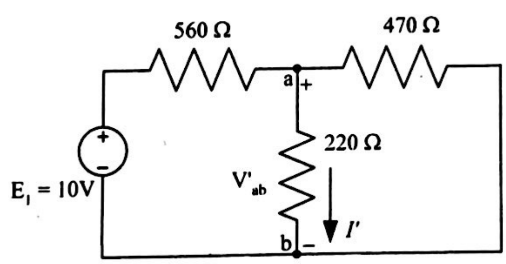


Figure 6.2: Only E_1 activated

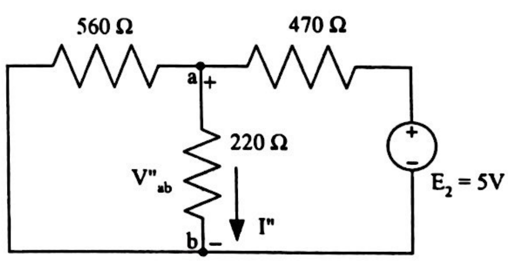


Figure 6.3: Only E_2 activated

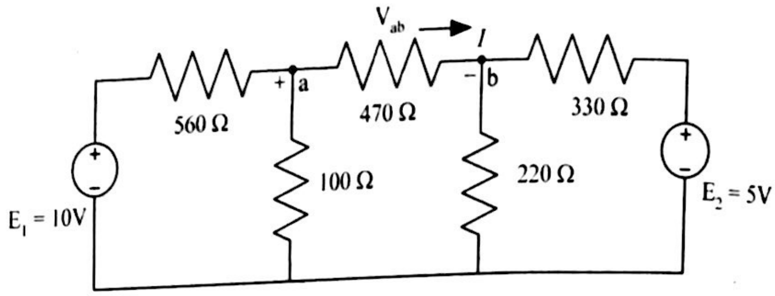


Figure 6.4: Circuit 02 (E_1 and E_2 activated)

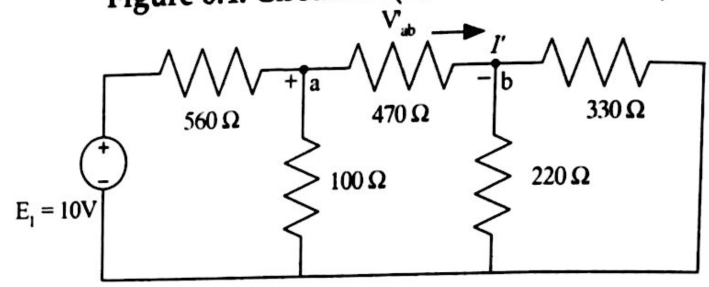


Figure 6.5: Only E_1 activated

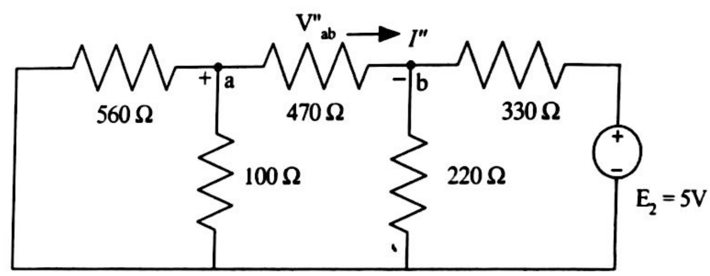


Figure 6.6: Only E_2 activated

PROCEDURES:

1. Measure the values of the resistances. Make the necessary circuit connection of circuit 01 shown in Figure 6.1.
2. Measure the voltage V_{ab}.
3. Make voltage source E_2 deactivate (Remove the source and short the terminals). Measure the voltage V'_{ab} and record the value in Table 6.2.
4. Make voltage source E_1 deactivate (Remove the source and short the terminals). Measure the voltage V''_{ab} and record the value in Table 6.2.
5. Make necessary circuit connection of circuit 02 shown in Figure 6.4.
6. Repeat procedure 2 to 4 for this circuit and record the values in Table 6.2.
7. Calculate currents and record the values in Table 6.3.

DATA SHEET:

Table 6.1: Measuring Resistances by using Ohmmeter

Nominal values of R (Ω)	Measured values of R(Ω) by using Ohmmeter
100	
220	
330	
470	
560	

Table 6.2: Data for verification of Superposition theorem

Circuit	[E_1 & E_2 active] V_{ab} (volt)	[only E_1 active] V'_{ab} (volt)	[only E_2 active] V''_{ab} (volt)
CKT - 01			
CKT - 02			

Table 6.3:

***[Use measured values of resistances for all calculations.]*

Circuit	[E_1 & E_2 active] (A)	[only E_1 active] (A)	[only E_2 active] (A)
01	$I = \frac{V_{ab}}{220\,\Omega} =$	$I' = \frac{V'_{ab}}{220\,\Omega} =$	$I'' = \frac{V''_{ab}}{220\,\Omega} =$
02	$I = \frac{V_{ab}}{470\,\Omega} =$	$I' = \frac{V'_{ab}}{470\,\Omega} =$	$I'' = \frac{V''_{ab}}{470\,\Omega} =$

Signature of the Teacher

ASSIGNMENTS:

1. Verify Superposition theorem for the circuit shown in Figure 6.1 both experimentally and theoretically. ***[Use measured value of resistance for calculations.]***
2. Verify Superposition theorem for the circuit shown in Figure 6.4 both experimentally and theoretically. ***[Use measured value of resistance for calculations.]***

Experiment No.	: 07
Name of the Experiment	: **Methods of Measuring Resistance Looking Through any Two Terminals of a Network.**

OBJECTIVE:

In this experiment we will learn the different methods used to measure the resistance looking through any two terminals of a circuit. In practical cases, it is not always possible to measure the resistance using an ohmmeter or by using circuit-reduction techniques. In many cases, especially in circuits containing electronic devices or dependent sources, indirect approaches are usually used to measure the resistance. We will be familiar with several such methods of measuring resistance. Besides, some more Spice syntax and commands will be introduced in this experiment.

EQUIPMENTS:

- Trainer board-1 piece.
- Digital multimeter (DMM)-1 piece.
- Potentiometer: 10 KΩ-1 piece.
- Resistances:
  1 KΩ-4 pieces,
  2.2 KΩ -2 pieces,
  3.3 KΩ-3 pieces,
  4.7 KΩ -2 pieces
  10 KΩ-1 piece

CIRCUIT DIAGRAM:

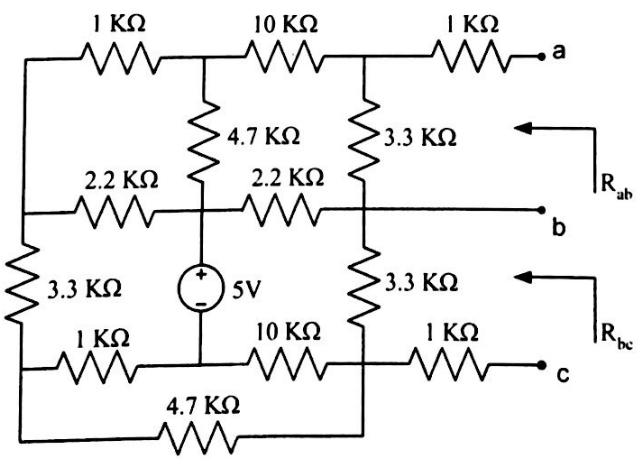


Figure 7.1: Resistance measurement

PROCEDURES:

Connect the circuit given in Figure 7.1. Then measure the equivalent resistance looking through terminals a-b (R_{ab}) and also the equivalent resistance looking through terminals b-c (R_{bc}). For this purpose, different methods will be used as described below:

Table 7.1: Measured resistances using different methods:

Resistance to be measured	Using Ohmmeter (KΩ)	Using V_S/I_S (KΩ)	Using V_{OC}/I_{SC} (KΩ)	Using Potentiometer (KΩ)
R_{ab}				
R_{bc}				

(A) USING OHMMETER:

1. As the ohmmeter itself employs a battery to measure the resistance in a circuit, we have to de-energize the circuit or deactivate all the independent sources (i.e., we have to switch all the power supplies off) before measuring any resistance. This method is not applicable if the circuit contains any dependent source.

2. Next we have to replace all the independent sources by their internal resistance. The resistance of an ideal voltage source is zero and the resistance of an ideal current source is infinite. So, the 5V voltage source in the circuit of Figure 7.1 should be removed completely and replaced by a short circuit (zero ohms). This will result in the circuit of Figure 7.2.

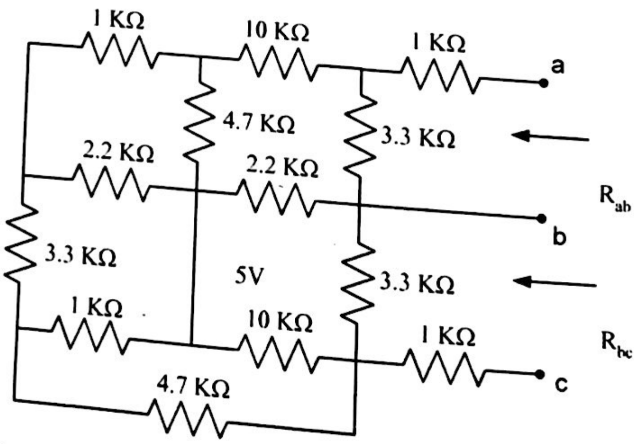


Figure 7.2: Resistance measurement using ohmmeter method

3. Now to measure the resistance R_{ab} (equivalent resistance looking through terminals a-b), hold the ohmmeter terminals at terminals a and b and record the reading in Table 7.1.

4. Similarly measure the resistance R_{bc} by holding the ohmmeter at terminals b and c and record the reading in Table 7.1.

(B) Using V_S/I_S:

1. This method is an indirect approach of the above method. For this purpose, deactivate the 5V supply of Figure 7.1 as before and replace it with a short circuit.

2. Now to measure the resistance R_{ab}, insert a voltage source V_S (take V_S = 5V) between terminals a and b as shown in Figure 7.3.

3. Measure V_S and I_S (the current supplied by V_S) and calculate R_{ab} from $R_{ab} = \frac{V_S}{I_S}$.

4. To measure R_{bc} repeat step 2 (in this case, insert V_S between terminals b and c) and step 3. Record the readings in Table 7.1.

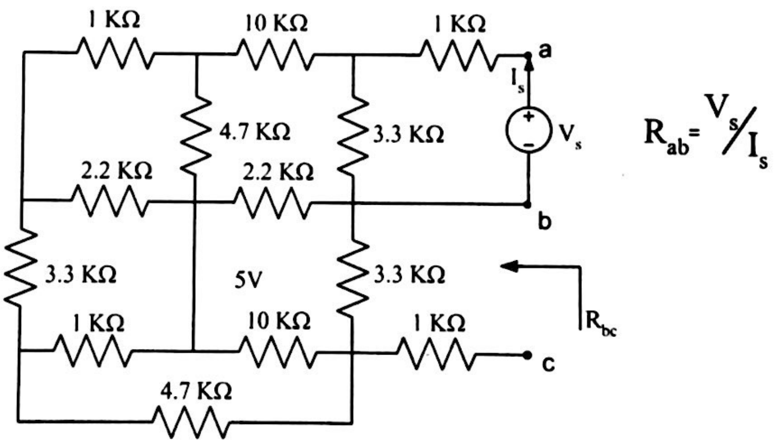


Figure 7.3: Resistance measurement using Vs/Is method

(C) Using V_{OC}/I_{OC}:

1. This method uses Thevenin's theorem. Here the source need not be removed or deactivated as in previous two methods. This method is very useful in cases where the resistance is needed to be measured without

deactivating the sources as in circuits containing dependent sources or electronic devices. Reconnect the circuit of Figure 7.1.

2. Measure the voltage V_{ab} in between terminals a and b. this voltage is called the open-circuit voltage V_{OC}.

3. Short-circuit the terminals a and b as shown in Figure 7.4 and measure the current flowing through these terminals. This is the short-circuit current I_{SC}.

4. Calculate $R_{ab} = \frac{V_{OC}}{I_{SC}}$ and record this reading in Table 7.1.

5. Repeat steps 2 to 4 to measure R_{bc} in between terminals b and c.

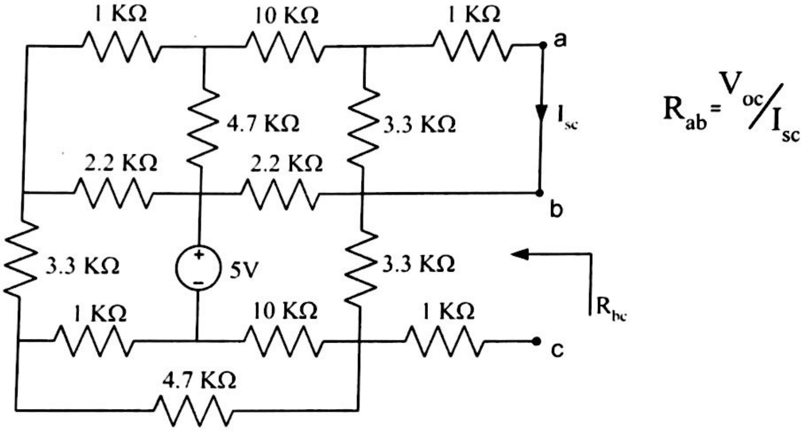


Figure 7.4: Resistance measurement using Voc/Isc method

(D) Using Potentiometer:

1. This method also uses the principle of Thevenin's theorem and can be applied without removing any source from the original circuit. For this purpose, first measure the open-circuit voltage V_{OC} across terminals a and b of Figure 7.1.

2. Now connect a potentiometer in between terminals a and b as shown in Figure 7.5. Vary the pot until the voltage $V_{ab} = \frac{V_{OC}}{2}$.

3. Carefully remove the pot from the circuit and measure its resistance. The resistance of the potentiometer gives the equivalent resistance R_{ab}.

4. To measure the resistance R_{bc}, repeat steps 1 to 3 (in this case, terminals b and c should be used). Record these readings in Table 7.1.

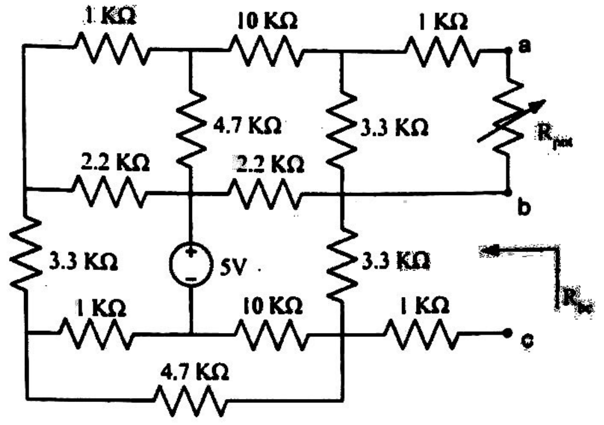


Figure 7.5: Resistance measurement using potentiometer method

Experiment No. : 08

Name of the Experiment : Verification of Thevenin's Theorem and Maximum Power Transfer Theorem.

OBJECTIVE:

To verify and interpret two most important theorems:

(1) Thevenin's Theorem

(2) Maximum Power Transfer Theorem.

THEORY:

Thevenin's Theorem states that the voltage across or current through element of a network can be calculated by constructing a Thevenin's equivalent circuit. This circuit is represented by a voltage source, called Thevenin's voltage, a resistance, called Thevenin's resistance and the element itself - all connected in series. After removing the element Thevenin's voltage and Thevenin's resistance are calculated, where the open circuit voltage (V_{oc}) measures Thevenin's voltage (V_{th}) and the resistance looking through the open circuited terminals represents Thevenin's resistance (R_{th}).

The maximum power transfer theorem states that maximum power can be transferred to the load when the load resistance is equal to equivalent resistance looking through the terminals where the load is connected.

EQUIPMENTS:

- Variable DC Power Supply (20 V)-1 piece.
- Trainer Board-1 piece.
- Digital Multimeter-1 piece.
- Resistances: 220 Ω -4 piece.
- Rheostat (1k) - 2 piece.
- Connecting Wires.

CIRCUIT DIAGRAM:

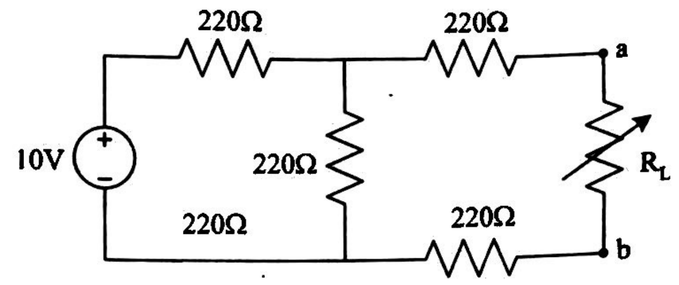


Figure 8.1: Circuit 01

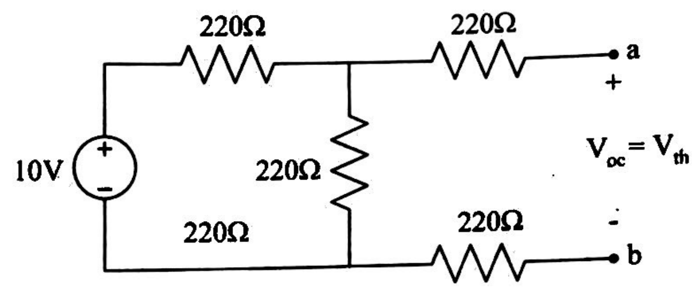


Figure 8.2: Circuit setup for finding V_{oc} or V_{th}

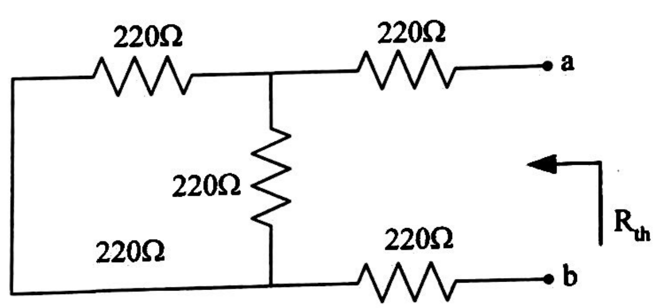


Figure 8.3: Circuit setup for finding R_{th}

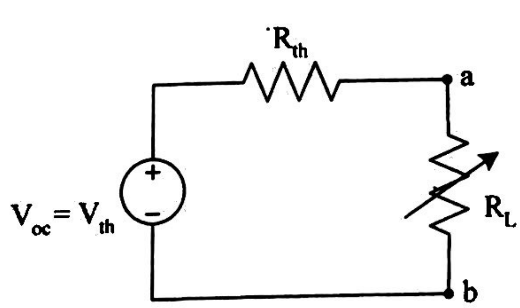


Figure 8.4: Thevenin's equivalent circuit

PROCEDURES:

1. Connect the circuit as shown in figure-8.1. Remove the load resistance (rheostat) as shown in figure-8.2. Measure the open circuited voltage, (V_{oc}). This represents Thevenin's voltage (V_{th}).

2. Now construct the circuit as shown in figure-8.3. Make voltage source deactivate (Remove the source and short the terminals). To measure the resistance R_{th} (Thevenin's equivalent resistance looking through terminals a-b), hold the ohmmeter at terminals a and b.

3. Finally construct the Thevenin's equivalent circuit as shown in figure-8.4.

4. Connect the circuit as shown in figure-8.1. Vary the load resistance (rheostat) from 100 Ω to 1K Ω with a 100 Ω stepping. For each step measure voltage across the load resistance (rheostat) and calculate the current (I_L) through the load. Fill the table-8.1 using these values.

5. Now connect the same load resistance (rheostat) at the Thevenin's equivalent circuit as shown in figure-8.4 and vary the load resistance (rheostat) from 100 Ω to 1K Ω with a 100 Ω stepping. For each step measure voltage across the load resistance (rheostat) and calculate the current I_L. Fill the table-8.2 using these values.

ASSIGNMENTS:

1. Plot V_L vs. R_L curves for both original and equivalent circuits on the same graph.

2. Plot I_L vs. R_L curves for both original and equivalent circuits on the same graph.

3. Plot P_L vs. R_L curves for both original and equivalent circuits on the same graph.

4. Comparing the graphs verify Thevenin's Theorem.

5. From P_L vs. R_L graphs verify maximum power transfer theorem.

DATA SHEET:

**[*Use measured values of resistances for all calculations.*]

Table 8.1: For original circuit

R_L (Ω)	V_L (Volt)	$I_L = \frac{V_L}{R_L}$	$P_L = \frac{(V_L)^2}{R_L}$	$P_L = (I_L)^2 \times R_L$
100				
200				
300				
400				
500				
$R_{th} = R_L =$				
600				
700				
800				
900				
1000				

SAMPLE CALCULATION:

Signature of the Teacher

DATA SHEET:

***[Use measured values of resistances for all calculations.]*

Table 8.1: For Thevenin's equivalent circuit:

R_L (Ω)	V_L (Volt)	$I_L = \frac{V_L}{R_L}$	$P_L = \frac{(V_L)^2}{R_L}$	$P_L = (I_L)^2 \times R_L$
100				
200				
300				
400				
500				
$R_{th} = R_L =$				
600				
700				
800				
900				
1000				

SAMPLE CALCULATION:

Signature of the Teacher

Experiment No.	: **09**
Name of the Experiment	: **Uses of Different Types of Switches.**

OBJECTIVE:

Different types of switches are used in electrical circuits. Each type of switch has a particular feature and its uses obviously depend on its inherent property. Although various types of switches may be involved in a particular application, we, however, concentrate our interest into the following types of switches:

a. Single pole single throw (SPST)
b. Single pole double throw (SPDT)
c. Double pole single throw (DPST)
d. Double pole double throw (DPDT)

SCHEMATIC DIAGRAM:

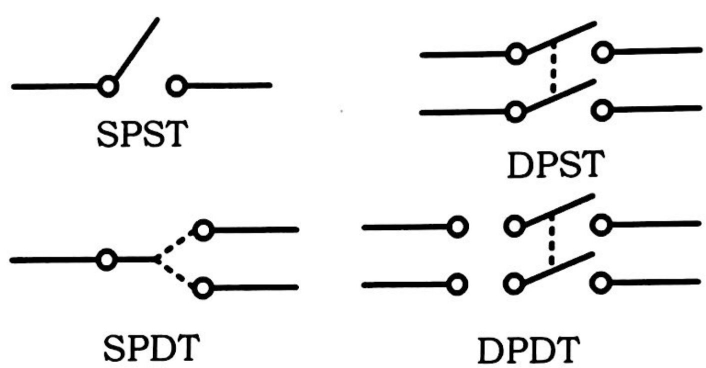


Figure 1.1: Different types of switches

EQUIPMENTS:

- Power cord-1 piece
- SPST switch-2 pieces
- SPDT switch-2 pieces
- Lamps: 60W-1piece
  100W-1piece

PROCEDURES:

1. Connect a bulb so that it can be operated from the source by an SPST switch.
2. Connect a bulb so that it may be operated by either of two SPST switches.
3. Connect two bulbs (one 60W and one 100W) so that either may be operated from a common source by its own switch.
4. Connect two bulbs (one 60W and one 100W) so that both may be operated simultaneously from a common source by one SPST switch.
5. Connect a bulb so that it may be operated independently by either of two SPDT switches from a source.

ASSIGNMENTS:

1. For each of the cases given below, mention whether the switches of procedure 2 are dependent on each other to turn the lamp ON:
    a. When the switches are connected in series.
    b. When the switches are connected in parallel.
2. Which method of procedure 4 is preferable and why?
3. Explain the variations of the brightness level of the two lamps in procedure 4.
4. What are the applications of the arrangement of procedure 5?
5. What is the drawback of the switch connection of the circuit in Figure 1.2?

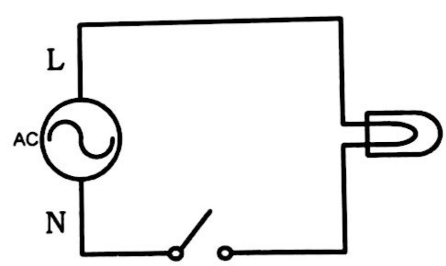


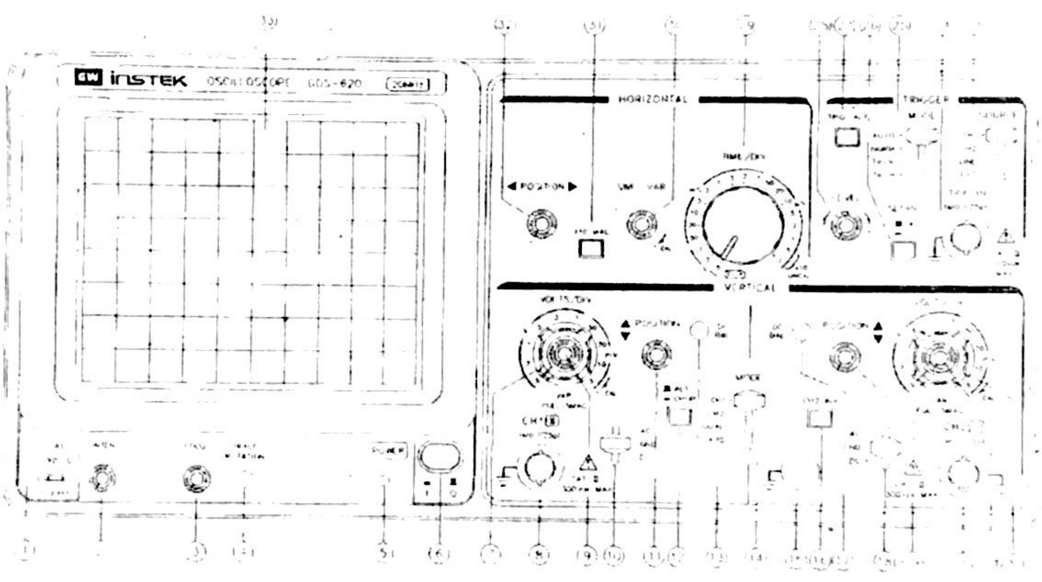
Figure 1.2: Circuit diagram for assignment 5

Experiment No.	: 10
Name of the Experiment	: **Introduction to Oscilloscope Operation.**

OBJECTIVE:

This experiment is designed for the under-graduate students to introduce themselves and to be familiar with the oscilloscope and its operation. This experiment will help the students to have basic ideas about key functions of different knobs of oscilloscope and also to know how to measure voltage/current of a circuit-using oscilloscope as a measuring instrument.

FRONT VIEW OF THE LABORATORY OSCILLOSCOPE:



Introduction to front Panel:

The front panel consists of the following parts:

- *CRT*
- *Vertical axis*
- *Triggering*
- *Time*
- *Others*

BRIEF DESCRIPTION:

1. **CRT:**
   a) Power (*6*)
   The main power switch.
   b) Inten (*2*)
   Controls the brightness of the spot.
   c) Focus (*3*)
   For focusing the spot for sharp image.
   d) Trace rotation (*4*)
   For aligning the horizontal trace in parallel with graticule lines.
   e) Filter (*33*)

2. **Vertical axis:**
   a) CH1 (X) input (*8*)
   Vertical input of CH1. When in X-Y mode this acts as an X-axis input
   b) CH2 (Y) input (*20*)
   Vertical input of CH2. When in X-Y mode this acts as a Y-axis input
   c) AC-GND-DC (*10,18*)
   Switch for selecting connection mode between input signal and vertical amplifier.
   d) Volt/Div (*7,22*)
   Selection of vertical axis sensitivity, from 5mV/Div to 5V/Div in 10 ranges.
   e) Variable (*9,21*)
   f) CH1 & CH2 DC BAL (*13,17*)
   g) Position (*11,19*)
   Control the position of the vertical trace or spot.
   h) Vert mode (*14*)
   There are four positions to switch the operation of CH1 and CH2.When position in either CH1 or CH2; then oscilloscope operates as single channel instrument with CH1 or CH2 respectively. When position in DUAL then the oscilloscope operates as dual–channel of both CH1 and CH2. When position in ADD, then oscilloscope displays the algebraic sum (CH1+CH2) or difference (CH1-CH2). During difference operation, CH2 INV must be pushed.
   i) ALT/CHOP (*12*)
   When this switch is released then CH1 and CH2 are alternately displayed. When this switch is engaged then CH1 and CH2 are chopped and displayed simultaneously.
   j) CH2 INV (*16*)
   This inverts the CH2 input signal when this knob is pushed in.

3. **Triggering:**

a) EXT TRIG IN input terminal (*24*)

b) SOURCE (23)

1) **CH1:** When Vert mode switch is at DUAL/ADD position select CH1 for internal triggering.
2) **CH2:** When Vert mode switch is at DUAL/ADD position select CH2 for internal triggering.
3) **TRIG.ALT:** It will alternately select CH1 and CH2 for internal triggering.
4) **Line**
5) **EXT**

c) SLOPE (*26*)

1) **'+':** Triggering occurs when triggering signal crosses triggering level in +ve going direction.
2) **'−':** Triggering occurs when triggering signal crosses triggering level in -ve going direction.

d) LEVEL (*28*)

To display synchronized stationary waveform and set a start point of it.

e) TRIGGER MODE (*25*)

4. **Time Base:**

a) TIME/DIV (*29*)

Ranges are available from 0.2 μsec/div to 0.5 sec/div in 20 steps.

X-Y mode: This position is used when oscilloscope functions as an X-Y oscilloscope.

b) SWP.VAR (*30*)

c) Position (*32*)

Control the position of the horizontal trace or spot.

d) x 10 MAG (*31*)

When this button is pushed, magnification of 10 occurs.

5. **Others:**

a) CAL (*1*)

This terminal gives the calibration voltage of 2 Vp-p, 1 kHz, and positive square wave.

b) GND (*15*)

The ground terminal of the oscilloscope mainframe.

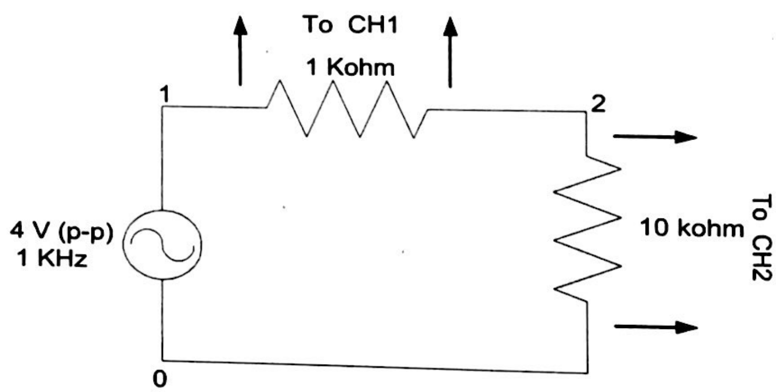
BASIC OPERATION WITH OSCILLOSCOPE:

1. Single channel operation.
2. Dual-channel operation.
3. ADD operation.
4. Frequency measurement
5. Sweep Magnification
6. X-Y Operation.
7. To display two input signals still on oscilloscope

EQUIPMENTS:

1. Oscilloscope - 1 unit
2. Oscilloscope probe (10 x)- 2 pieces
3. Signal Generator - 1 unit
4. Signal Generator probe - 1 piece
5. Resistor 1kΩ, 10kΩ
6. Bread Board - 1 piece.
7. Multi-meter

CIRCUIT DIAGRAM:



PROCEDURES:

1. Connect the circuit according to the above circuit diagram.
2. Set the AC-GND-DC of CH1 in the GND position and align the trace with horizontal central line and then set to AC position.
3. Now apply sine wave of 1 kHz from signal generator to CH1 and adjust its magnitude to 4V (p-p) by varying the attenuator knob of the signal generator.
4. If the signal is not still just slowly vary the 'level' knob to make it still.
5. Now disconnect the signal from CH1 and apply to terminals between 1 and 0.

6. Don't change the attenuator knob throughout the experiment.
7. Now connect the oscilloscope probes across 1 kΩ resistor to CH1 and across 10 kΩ resistors to CH2 according to circuit diagram.
8. Push CH2 INV button.

1. Single channel operation:

a) Set the AC-GND-DC of both channels in the GND position and align the trace with horizontal central line and then set to AC position.
b) Adjust the FOCUS control so that the trace image appears sharply.
c) Set the VOLTS/DIV switch at 1 V and TIME/DIV switch at 0.5 ms position so that signal waveform is displayed clearly.
d) Adjust vertical POSITION and horizontal POSITION controls in appropriate position so that the displayed waveform is aligned with the graticule and voltage (p-p) and period (T) can be read conveniently.
e) Set the Vert mode to CH1 and measure the p-p voltage across 1 kΩ resistor. Find the rms value of the signal from the following diagram:
   Vrms =Vmeasured (p-p)/(2*√2) volt.
f) Measure the voltage across 1 kΩ resistor by multimeter and compare with the measured value.
g) Set the Vert mode to CH2 and repeat procedure (e).
h) Change the signal frequency to 100Hz, 10 kHz and observe the waveform.

2. Dual-channel operation:

a) Set the Vert mode switch to DUAL state so that both channels are displayed simultaneously. To display each channel separately change the vertical POSITION control of both channel to convenient position.
b) When ALT/CHOP switch is released (ALT mode) signals respectively to CH1 and CH2 appear on screen alternately.
c) When ALT/CHOP switch is pushed (CHOP mode) signals respectively to CH1 and CH2 are switched at 250 kHz.

3. ADD operation:

a) When Vert mode switch is at ADD position then the displayed signal is the algebraic sum of CH1 and CH2.if the CH2 INV switch is pushed then displayed signal is the difference of CH1 and CH2.
b) Observe the waveform for both cases and draw.

4. **Frequency measurement:**

a) The frequency of any waveform can be measured by adjusting the TIME/DIV control knob of oscilloscope. Adjust the TIME/DIV control knob to position 0.5 ms to observe the waveform.

b) Now measure the frequency of the wave using the following formula:

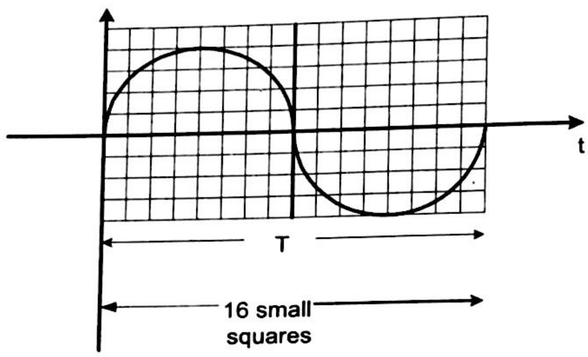
1 large square or 5 small squares = t sec, here t = 0.5 ms

# of small squares required to represent a full cycle of wave =n sec

Where, n may have fraction value.

Time period, $T = (n/5) \times t$ s

Frequency, $f = 1/T$ Hz



Now compare this value with the main signal frequency.

c) Now vary the TIME/DIV control knob to different position and repeat (b).

5. **Sweep Magnification:**

a) Set the TIME/DIV switch at 0.5 ms and VOLTS/DIV at 1 V. Set AC-GND-DC position at GND position and align the trace with horizontal central line.

b) Set the Vert mode at CH1 and AC-GND-DC at AC and then push x 10 MAG button.

c) The displayed waveform will be expanded 10 times to the right and left with the centre of the screen as the centre of expansion.

6. **X-Y operation:**

a) Set the TIME/DIV switch at X-Y position. Now CH1 acts as X-axis input and CH2 as Y-axis input.

b) X-Y positions are adjusted by horizontal position and CH2 vertical position control respectively.

c) Adjusted the amount of vertical Y-axis with CH2 VOLTS/DIV controls.

d) Adjust the amount of horizontal X-axis with CH1 VOLTS/DIV controls.
e) Observe the waveforms and draw.

7. To display two input signals still on oscilloscope:

a) Apply 2v (p-p), 1 kHz ac signal (sine wave) from signal generator-1 to CH1 of oscilloscope.
b) Set VOLT/DIV of CH1 to 1 V and TIME/DIV to convenient position to observe the wave shape clearly.
c) Repeat (1) from signal generator-2 to CH2 of oscilloscope.
d) Set VOLT/DIV of CH2 to 0.5 v.
e) Now set the Vert mode to DUAL position and observe the wave shapes.
f) Note two waves that were displayed individually still are not still now.
g) Set the SOURCE to CH1 and then CH2 position and observe what happens.
h) Push the TRIG. ALT button and observe the wave shapes.

Note:

1) Don't put any sort of electrical equipments (such as signal generator, dc supply etc.) on the top of the oscilloscope.
2) Place the oscilloscope away from any magnetic field (as far as possible)
3) If the GND horizontal line deviates significant amount then adjust it by rotating the position of oscilloscope.
4) Always check the 10x switch of probe according to your measurement.
5) Always avoid common grounding resulting from improper connection of knobs in the circuit.

COMMON MISTAKES USING OSCILLOSCOPE:

1) Changing the calibration knob during experiment.
2) Changing the SWP.VAR knob during experiment.
3) Improper 10x max for probe.
4) Improper 10x max for frequency.
5) Ground level adjustment during measurement.

Ahsanullah University of Science and Technology

Department of Electrical and Electronic Engineering

LABORATORY MANUAL

FOR

ELECTRICAL AND ELECTRONIC SESSIONAL COURSE

Student Name :

Student ID :

EEE - 1102 ELECTRICAL CIRCUITS – I LAB

Department of EEE 1^{st} Year, 1^{st} Semester

EEE - 1132 BASIC ELECTRICAL TECHNOLOGY LAB.

Department of CE 1^{st} Year, 1^{st} Semester

EEE - 1242 BASIC ELECTRICAL ENGINEERING LAB.

Department of CSE 1^{st} Year, 2^{nd} Semester

EEE - 1288 BASIC ELECTRICAL ENGINEERING LAB.

Department of ME and MPE 1^{st} Year, 2^{nd} Semester

EEE - 2262 ELEMENTS of ELECTRICAL ENGINEERING and ELECTRONICS LAB

Department of TE 2^{nd} Year, 2^{nd} Semester

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

2nd Year, 1st Semester

Student Name :

Student ID :

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 2102: Manufacturing process sessional
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. Viva for each experiment will be taken on the next day with the report.
5. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental results and discussions (Experimental setup, Experimental conditions, Data, Graph, calculation etc.)
    - Conclusions
    - Acknowledgements
    - References
6. A quiz will be taken on the experiments at the end of the semester.
7. Marks distribution:

Total Marks		
Report	Attendance and Viva	Quiz
30	30	40

Experiment-1

Study of Sand Casting and Casting Defects

Objectives:

- To understand the fundamental principles and basic operations of industrially used casting processes
- To be conversant with commonly used terminology in casting process
- To learn about common casting defects
- To recognize the importance of safety in a foundry and execute proper safety measures in carrying out casting processes.

Introduction:

This foundry workshop sessional aims to provide students good appreciation of commonly used industrial casting technologies. The applications, limitations, advantages and common industrial practices in obtaining integrity metal casting will be addressed throughout this sessional class.

This experiment will provide students with both theatrical and practical knowledge of foundry and casting by short lectures and hand-on practices. Students can benefit the most by active interactions with our staff members and self-exploration while ding the casting exercises.

Apparatus:

- Flask
- Master pattern
- Round nose trowel
- Rammer
- Slicker spoon
- Lifter/Cleaner
- Spatula

Process Description:

Sand casting is one of the traditional casting methods fabricating metal parts. The sand cast part is produced by forming a mold from a sand mixture and pouring molten liquid metal into the cavity in the mold. A pattern with a shape very similar to the desired casting, is first placed in sand to make an imprint. A gating system is incorporated and the resultant cavity is filled with molten metal. After the melts cool and solidify, casting can then be obtained by breaking the sand mold. Since the molding material of sand casting is sand, rough surface and lack of dimensional accuracy are the intended result and therefore post machining is usually needed. Typical application of sand casting are machine tool bases, engine blocks and cylinder heads.

There are six steps in the process:

- Place a pattern in sand to create a mold.
- Incorporate gating system

- Remove the pattern
- Fill the mold cavity with molten metal
- Allow the metal to cool
- Break away the sand mold and remove the casting.

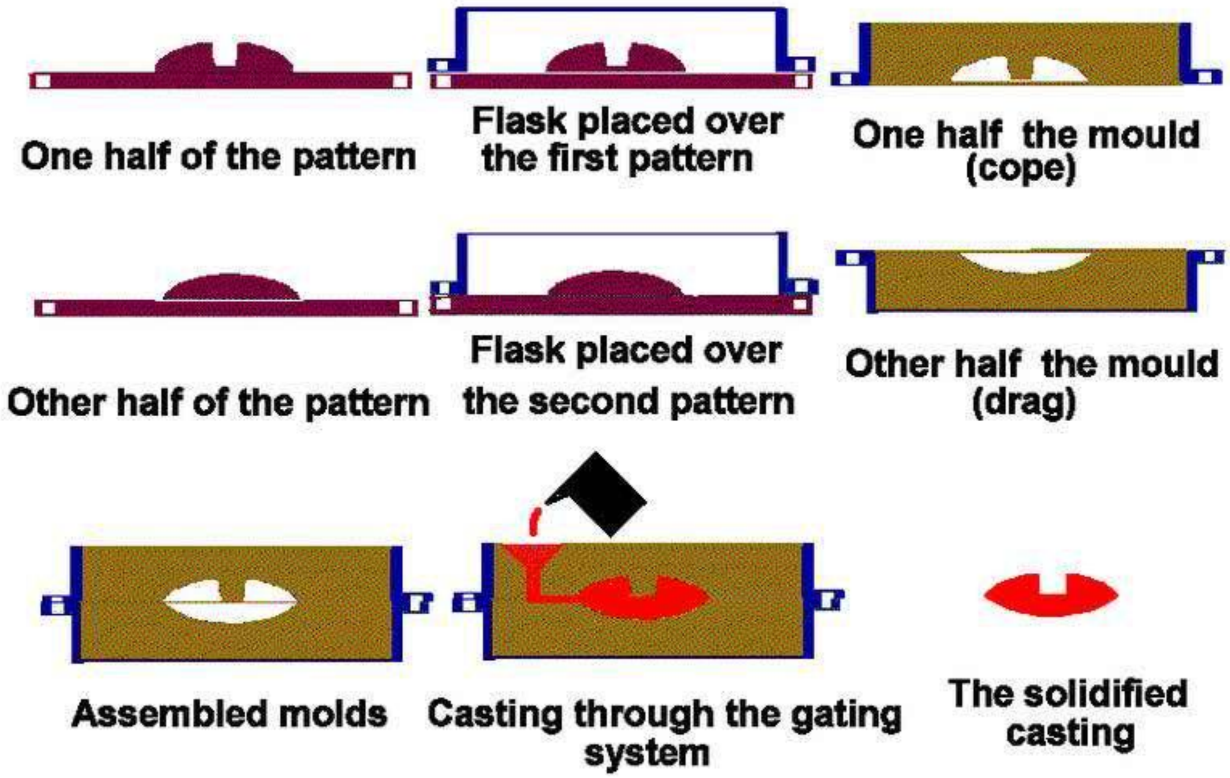


Figure 1.1: A METAL CASTING POURED IN SAND MOLD

Casting defects:

Common casting defects are:

- Blow holes
- Gas porosity
- Shrinkage porosity
- Hot tear
- Misrun
- Cold shut
- Etc

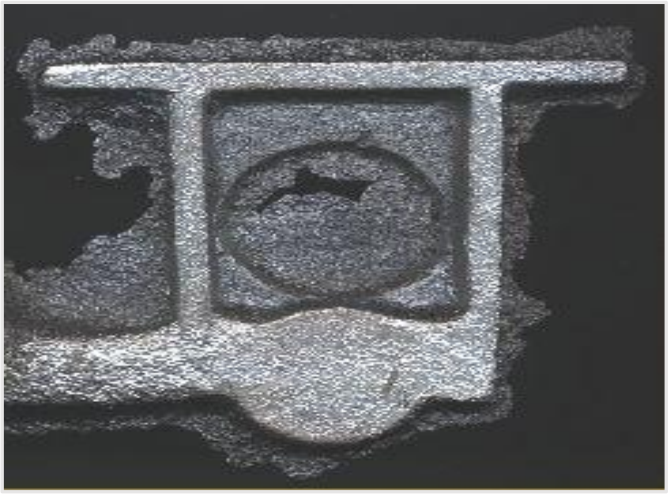


Figure 1.2

Figure 1.3

Figure 1.4

Figure 1.5

Figure 1.6

Figure 1.7

1. **Blow holes:** Small holes visible on the surface of the casting are called open blows whereas occurring below the surface of the casting.
   Causes: High moisture in sand resulting in low permeability, very hard ramming of sand and improper venting of mold.

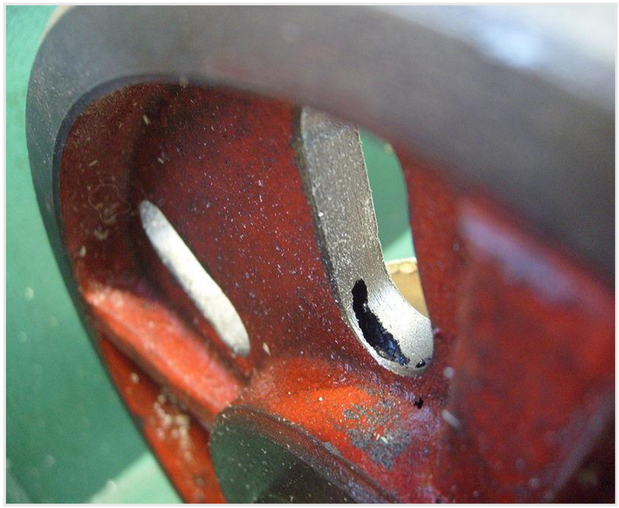


Figure 1.8: Blow Hole

2. **Misrun:**It is a casting that is incomplete in its outermost sections, because either it is too large or because the metal was poured with insufficient superheat.

   Causes: Too cold molten metal, too thin casting section, too small gates

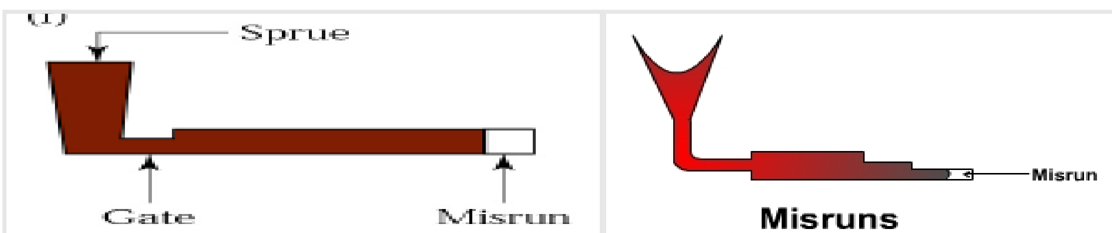
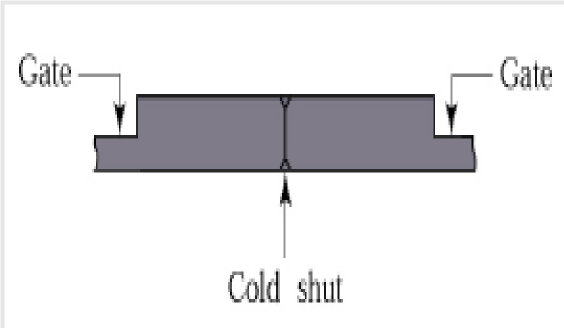


Figure 1.9: Misrun

3. **Cold shut:** It is an interface within a casting that lacks complete fusion and is formed when two streams of liquid from two different directions come together after the leading surfaces are solidified
   Causes: Metal lacking in fluidity, too small gates, too cold molten metal.



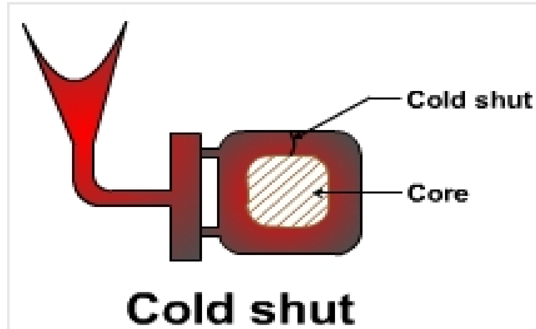


Figure 1.10: Cold Shut

4. **Shrinkage porosity:**This is a porosity due to shrinkage. May be caused to any kind of castings.
   Causes: Non-uniformity of metal cooling and insufficient metal pouring may result in shrinkage porosity. So enough material should be poured through the riser.

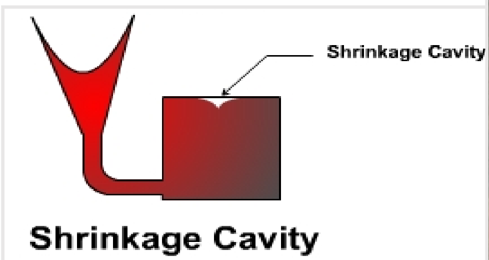


Figure 1.11

5. **Hot tear:** Inter-granular (along grain boundaries) failure at a high temperature the larger sections for intensive strain induced by solid contraction of adjacent thinner section**.**
   Causes: Excessive mold hardness, high drag and hot strength of sand mold, too much shrinkage of metal while solidifying, too low pouring temperature

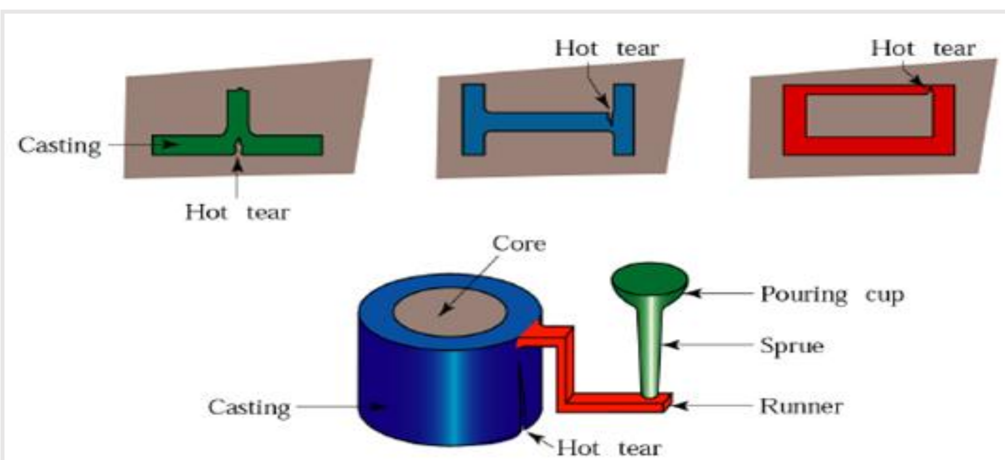


Figure 1.12

6. **Gas porosity:** Formation of bubbles within the casting after it has cooled.Solubility in liquid is high but in solid it is low. So, gas is rejected during cooling.
Causes: Using faulty or poor quality metal, use excessive moist sand

Figure 1.13

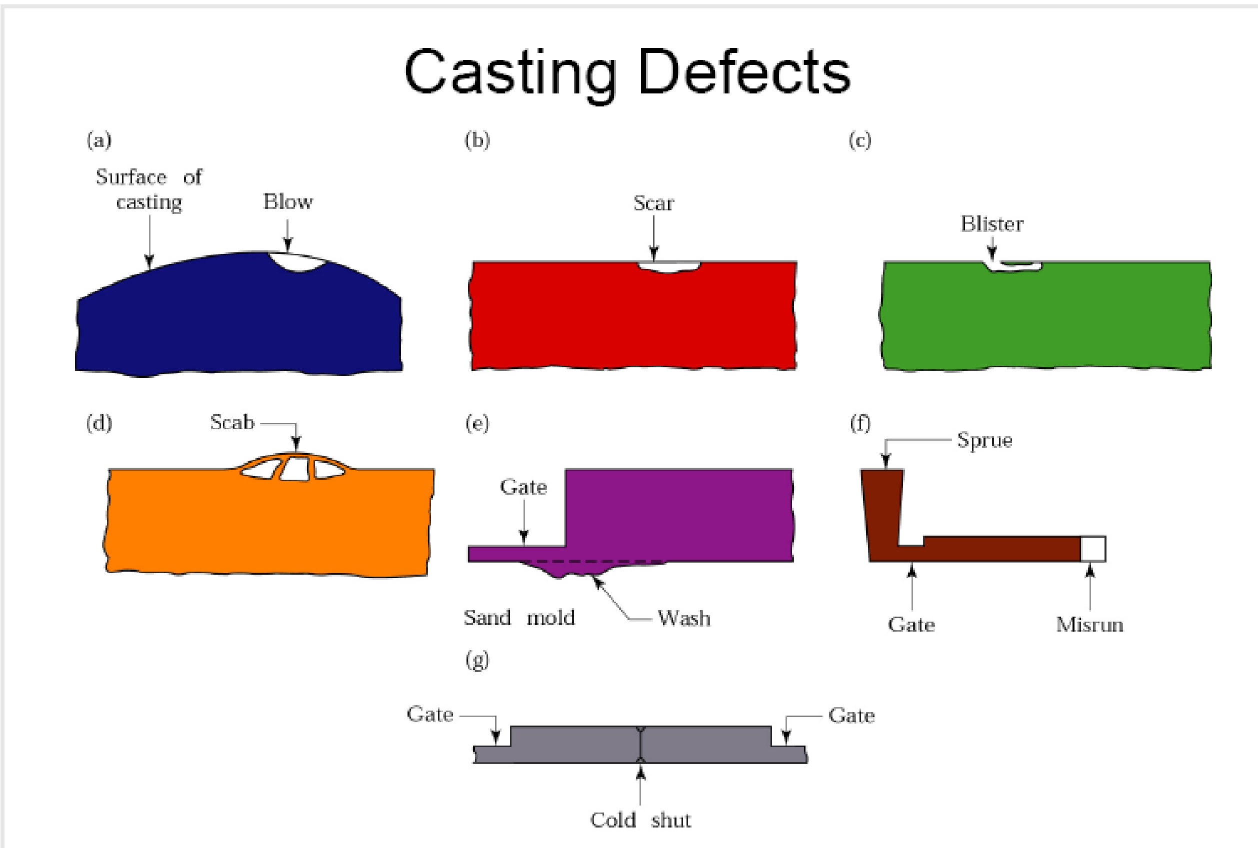


Figure 1.14

Assignments:

- Define Pattern. List different types of patterns in foundry.
- Describe the different types of pattern allowances. Can any of the allowances be negative? If yes, then explain why?
- What are the usual defects in green sand casting? What may be their remedies?

Experiment-2

Study of Different types of Joints and Defects by Arc-Welding TIG MIG Welding

Arc Welding:

Objective:

- Get familiar with arc and TIG MIG welding.
- To weld 3 pieces of dimensions 40mm*80mm making butt and lap joints.
- Get acquainted with different types of welding defects.

Apparatus:

- Welding holders
- Electrodes
- Arc-welding machine
- Arc-welding station
- Gloves
- Welding screen
- Tong and
- Chipping Hammer

Process (Arc Welding) Detail:

Arc welding is a process where two or more metals are joined by the immense heat generated by the arc produced between the filler metal and the work piece (s).Filter metal is the material that is added to the weld pool to assist in filling the gap (or groove). Filler metal forms an integral part of the weld.Filler rods have the same or nearly the same chemical composition as the base metal.

During welding, if the metal is heated/melted in air, oxygen from the air combines with the metal to form oxides which result in poor quality, low strength welds or, in some cases, may even make welding impossible. A flux is a material used to prevent, dissolve or facilitate removal of oxides and other undesirable substances. A flux prevents the oxidation of molten metal. The flux (material) is fusible and non-metallic.During welding, flux chemically reacts with the oxides and a slag is formed that floats to and covers the top of the molten puddle of metal and thus helps keep out atmospheric oxygen and other gases.

Figure 2.1: Filler rod

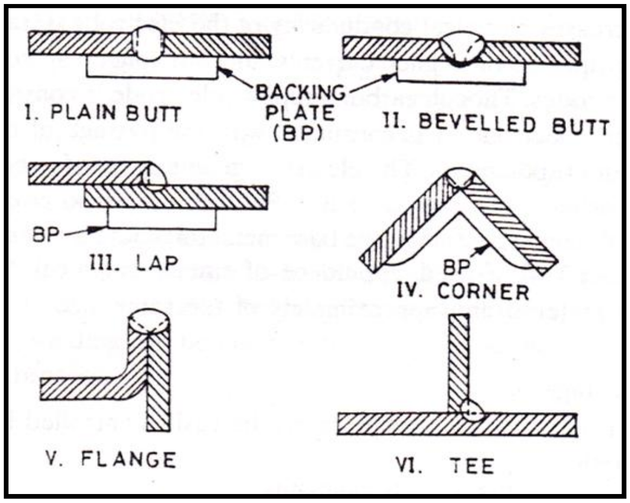


Figure 2.2: Joints produced by arc welding

Procedures:

- Keep two pieces side by side and make a small weld on the edges of the two sides. See that the pieces are uniformly joint.
- Make a clean welding by moving the electrode (held in the holder slowly along the joint on both sides).
- Now hold the pieces with a long and chip off the flux with a chipping hammer.
- Now place the third piece on the other work pieces such that half of the piece lies on it.
- Now proceed as earlier.

Precautions:

- Wear an apron.
- Wear a full sleeves cotton shirt so that sparks don't harm.
- Wear shoes with a rubber sole.
- Use a shield to protect eyes from spark.
- Handle the equipment carefully.

WELDING PROCESSES

Tungsten Inert Gas (TIG): Tungsten Inert Gas (TIG) or Gas tungsten arc welding (GTAW) is an arc welding process that uses a non-consumable tungstenelectrode and an inert gas for arc shielding. Under the correct conditions, the electrode does not melt, although the work does at the point where the arc contacts and produces a weld pool. The TIG process can be implemented with or without a filler metal. Figure 1 illustrates the latter case.When a filler metal is used, it is added to the weld pool from a separate rod or wire, being melted by the heat of the arc rather than transferred across the arc as in the consumable electrode arc welding processes. Tungsten is a good electrode material due to its high melting point of 34100C (61700F).

Since tungsten is sensitive to oxygen in the air, good shielding with oxygen-free gas is required.Typical shielding gases include argon, helium, or a mixture of these gas elements. TIG welding is easily performed on a variety of materials, from steel and its alloys to aluminum, magnesium, copper, brass, nickel, titanium, etc. Virtually any metal that is conductive lends itself to being welded using GTAW. Its clean, high-quality welds often require little or no post-weld finishing. This method produces the finest, strongest welds out of all the welding processes. However, it's also one of the slower methods of arc welding.

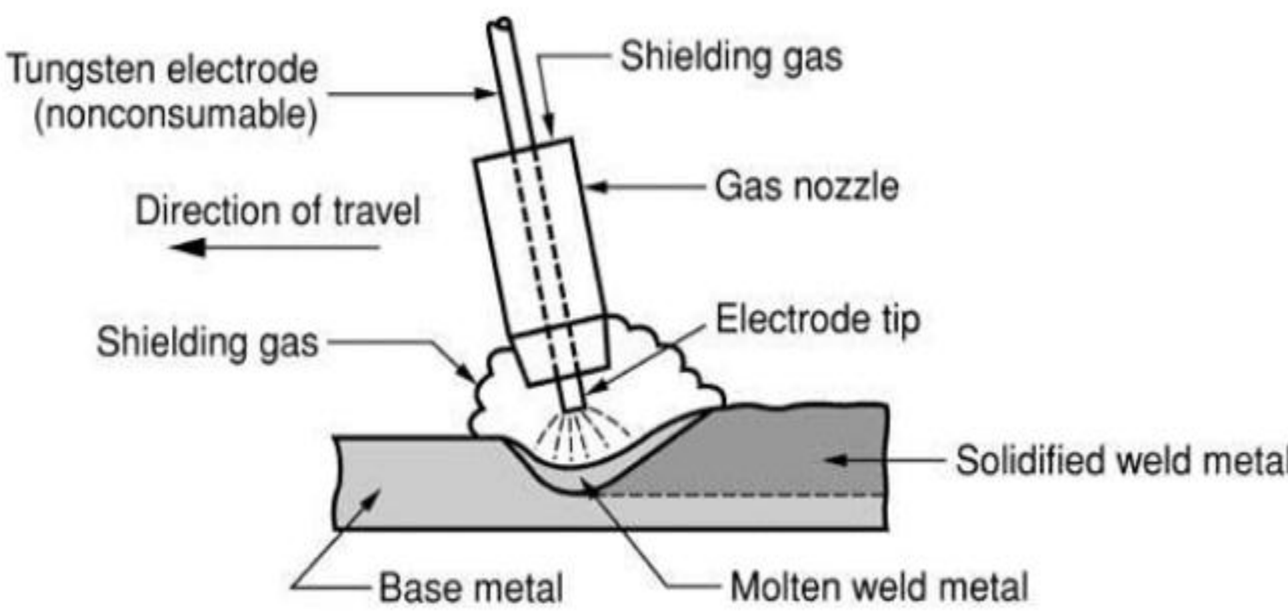


Figure 1: Tungsten Inert Gas (TIG)

Figure 2.3

Metal Inert Gas (MIG): Metal Inert Gas (MIG) is an arc welding process that uses a consumable electrode consistingof a filler metal rod coated with chemicals that provide shielding.The process is illustratedin Figure2. Under the correct conditions, the wire is fed at a constant rate to the arc, matching the rate at which the arc melts it. The filler metal is the thin wire that's fed automatically into the pool where it melts. The filler metal used in the rod must be compatible with the metal to be welded, the composition usually being very close to that of the base metal.

The coating on the rod consists of powdered cellulose mixed with oxides, carbonates, and other ingredients, held together by a silicate binder. Metal powders are also sometimes included in the coating to increase the amount of filler metal and to add alloying elements. The heat of the welding process melts the coating to provide a protective atmosphere and slag for the welding operation. It also helps to stabilize the arc and regulate the rate at which the electrode melts.

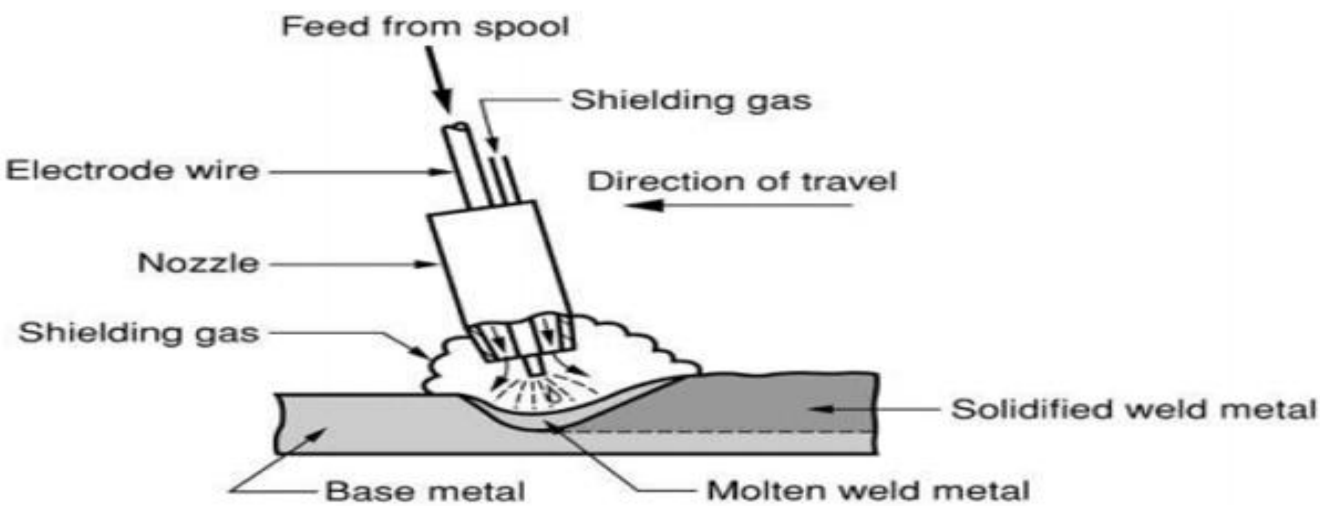


Figure 2: Metal Inert Gas (MIG)

Figure 2.4

The molten metal is sensitive to oxygen in the air, good shielding with oxygen-free gases is required. This shielding gas (Argon, Helium, etc.) provides a stable, inert environment to protect the weld pool as it solidifies. Consequently it is known as MIG (metal inert gas) welding. Since fluxes are not used, the welds produced are sound, free of contaminants, and as corrosion-resistant as the parent metal.Argon, helium, and carbon dioxide can be used alone or in various combinations for MIG welding of ferrous metals

Welding Joints:

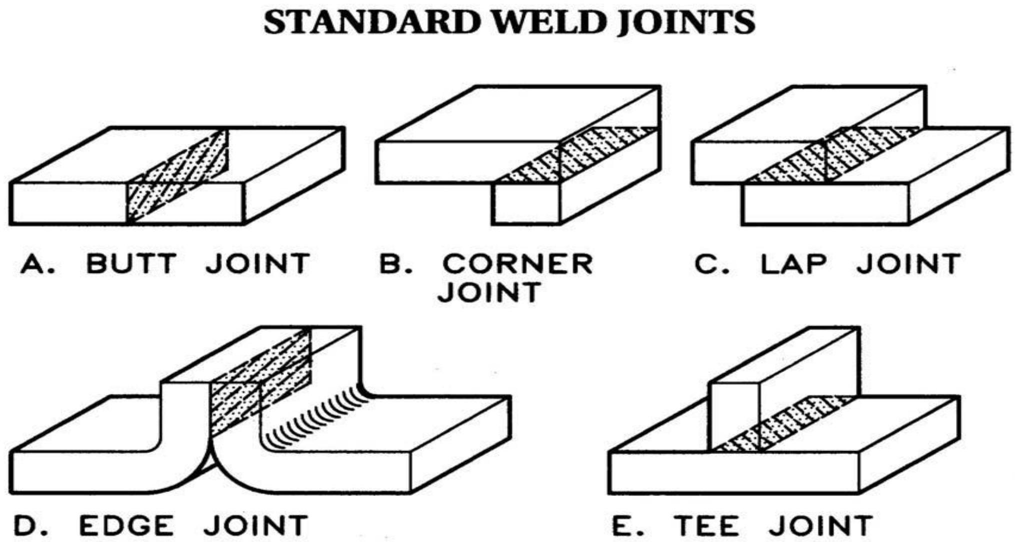


Figure 2.5:Standard Weld Joints

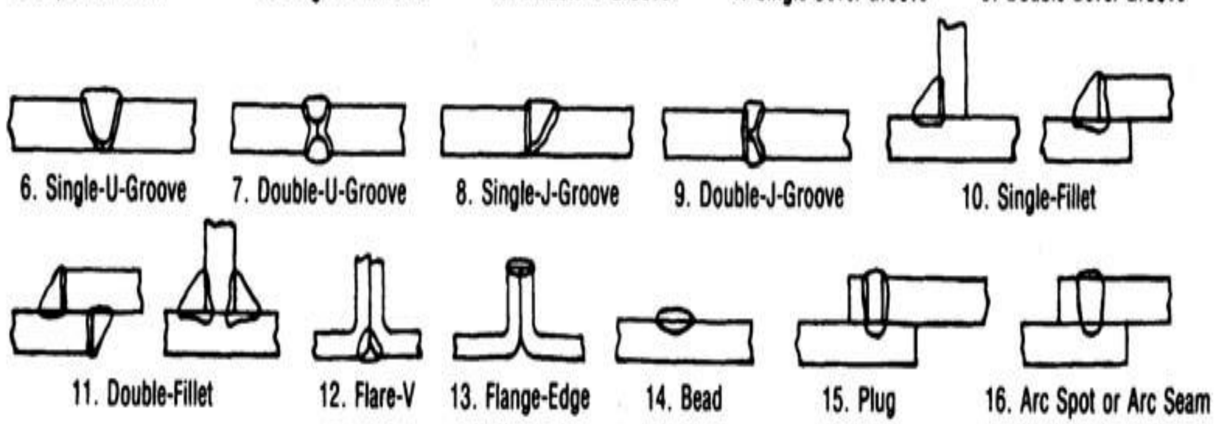


Figure 2.6: Other basic Weld Joints

Common Welding Defects:

Arc strike cracking

Arc strike cracking occurs when the arc is struck but the spot is not welded. This occurs because the spot is heated above the material's upper critical temperature and then essentially quenched. This forms martensite, which is brittle and may lead to higher chances of micro-cracks. Usually the arc is struck in the weld groove so this type of crack does not occur, but if the arc is struck outside of the weld groove then it must be welded over to prevent the cracking. If this is not an option then the arc spot can be post heated, that is, the area is heated with an oxy-acetylene torch, and then allowed to cool slowly.

Cold cracking

Residual stresses can reduce the strength of the base material, and can lead to catastrophic failure through cold cracking. Cold cracking is limited to steels and is associated with the formation of martensite as the weld cools. The cracking occurs in the heat-affected zone of the base material. To reduce the amount of distortion and residual stresses, the amount of heat input should be limited, and the welding sequence used should not be from one end directly to the other, but rather in segments.[7]

Cold cracking only occurs when all the following preconditions are met:

- susceptible microstructure (e.g. martensite)
- hydrogen present in the microstructure (hydrogen embrittlement)
- service temperature environment (normal atmospheric pressure): -100 to +100 °F
- high restraint

Eliminating any one of these will eliminate this condition.

Crater crack

Crater cracks occur when a crater is not filled before the arc is broken. This causes the outer edges of the crater to cool more quickly than the crater, which creates sufficient stresses to form a crack. Longitudinal, transverse and/or multiple radial cracks may form.

Hat crack

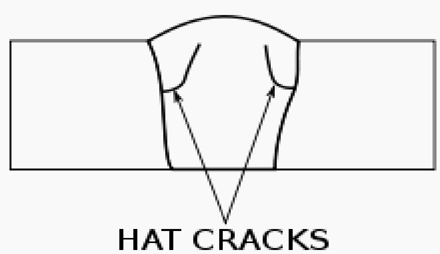


Figure 2.7

Hat cracks get their name from the shape of the cross-section of the weld, because the weld flares out at the face of the weld. The crack starts at the fusion line and extends up through the weld. They are usually caused by too much voltage or not enough speed.

Hot cracking

Hot cracking, also known as solidification cracking, can occur with all metals, and happens in the fusion zone of a weld. To diminish the probability of this type of cracking, excess material restraint should be avoided, and a proper filler material should be utilized.Other causes include too high welding current, poor joint design that does not diffuse heat, impurities (such as sulfur and phosphorus), preheating, speed is too fast, and long arcs.

Underbead crack

An undercut crack, also known as a heat-affected zone (HAZ) crack, is a crack that forms a short distance away from the fusion line; it occurs in low alloy and high alloy steel. The exact causes of this type of crack are not completely understood, but it is known that dissolved hydrogen must be present. The other factor that affects this type of crack is internal stresses resulting from: unequal contraction between the base metal and the weld metal, restraint of the base metal, stresses from the formation of martensite, and stresses from the precipitation of hydrogen out of the metal.

Longitudinal crack

Longitudinal cracks run along the length of a weld bead. There are three types: check cracks, root cracks, and full centerline cracks. Check cracks are visible from the surface and extend partially into the weld. They are usually caused by high shrinkage stresses, especially on final passes, or by a hot cracking mechanism. Root cracks start at the root and extent part way into the weld. They are the most common type of longitudinal crack because of the small size of the first weld bead. If this type of crack is not addressed then it will usually propagate into subsequent weld passes, which is how full cracks (a crack from the root to the surface) usually form.[8]

Reheat cracking

Reheat cracking is a type of cracking that occurs in HSLA steels, particularly chromium, molybdenum and vanadium steels, during postheating. The phenomenon has also been observed in austenitic stainless steels. It is caused by the poor creep ductility of the heat affected zone. Any existing defects or notches aggravate crack formation. Things that help prevent reheat cracking include heat treating first with a low temperature soak and then with a rapid heating to high temperatures, grinding or peening the weld toes, and using a two layer welding technique to refine the HAZ grain structure.

Root and toe cracks

A root crack is the crack formed by the short bead at the root(of edge preparation) beginning of the welding, low current at the beginning and due to improper filler material used for welding. Major reason for happening of these types of cracks is hydrogen embrittlement. These types of defects can be eliminated using high current at the starting and proper filler material. Toe crack occurs due to moisture content present in the welded area, it as a part of the surface crack so can be easily detected. Preheating and proper joint formation is must for eliminating these types of defects.

Transverse crack

Transverse cracks are perpendicular to the direction of the weld. These are generally the result of longitudinal shrinkage stresses acting on weld metal of low ductility. Crater cracks occur in the crater when the welding arc is terminated prematurely. Crater cracks are normally shallow, hot cracks usually forming single or star cracks. These cracks usually start at a crater pipe and extend longitudinal in the crater. However, they may propagate into longitudinal weld cracks in the rest of the weld.

Distortion

Welding methods that involve the melting of metal at the site of the joint necessarily are prone to shrinkage as the heated metal cools. Shrinkage then introduces residual stresses and distortion. Distortion can pose a major problem, since the final product is not the desired shape. To alleviate certain types of distortion the workpieces can be offset so that after welding the product is the correct shape. The following pictures describe various types of welding distortion:[15]

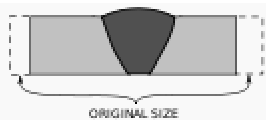
- 

Figure 2.8: Transverse shrinkage

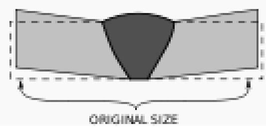
- 

Figure 2.9: Angular distortion

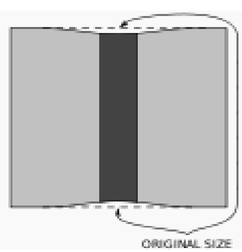
- 

Figure 2.10: Longitudinal shrinkage

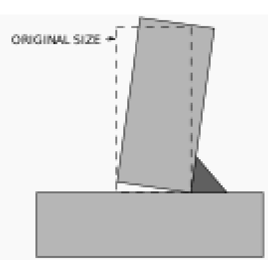


Figure 2.11: Fillet distortion

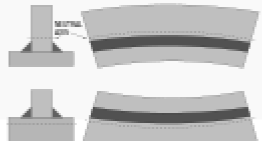


Figure 2.12: Neutral axis distortion

Gas inclusion

Gas inclusions is a wide variety of defects that includes porosity, blow holes, and pipes (or wormholes). The underlying cause for gas inclusions is the entrapment of gas within the solidified weld. Gas formation can be from any of the following causes: high sulphar content in the workpiece or electrode, excessive moisture from the electrode or workpiece, too short of an arc, or wrong welding current or polarity.

Inclusions

There are two types of inclusions: linear inclusions and rounded inclusions. Inclusions can be either isolated or cumulative. Linear inclusions occur when there is slag or flux in the weld. Slag forms from the use of a flux, which is why this type of defect usually occurs in welding processes that use flux, such as shielded metal arc welding, flux-cored arc welding, and submerged arc welding, but it can also occur in gas metal arc welding. This defect usually occurs in welds that require multiple passes and there is poor overlap between the welds. The poor overlap does not allow the slag from the previous weld to melt out and rise to the top of the new weld bead. It can also occur if the previous weld left an undercut or an uneven surface profile. To prevent slag inclusions the slag should be cleaned from the weld bead between passes via grinding, wire brushing, or chipping.

Isolated inclusions occur when rust or mill scale is present on the base metal.

Lack of fusion and incomplete penetration

Lack of fusion is the poor adhesion of the weld bead to the base metal; incomplete penetration is a weld bead that does not start at the root of the weld groove. Incomplete penetration forms channels and crevices in the root of the weld which can cause serious issues in pipes because corrosive substances can settle in these areas. These types of defects occur when the welding procedures are not adhered to; possible causes include the current setting, arc length, electrode angle, and electrode manipulation. Defects can be varied and classified as critical or non critical. Porosity (bubbles) in the weld are usually acceptable to a certain degree. Slag inclusions, undercut, and cracks are usually unacceptable. Some porosity, cracks, and slag inclusions are visible and may not need further inspection to require their removal. Small defects such as these can be verified by Liquid Penetrant Testing (Dye check). Slag inclusions and cracks just below the surface can be discovered by Magnetic Particle Inspection. Deeper defects can be detected using the Radiographic (X-rays) and/or Ultrasound (sound waves) testing techniques.

Undercut

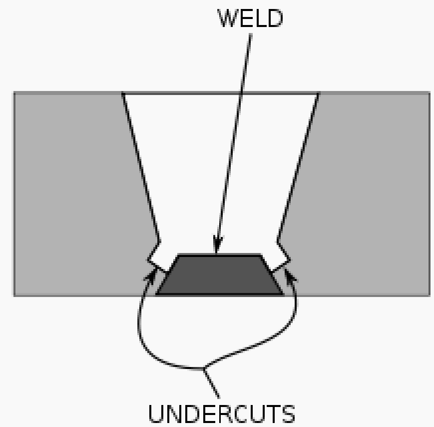


Figure 2.13

Undercutting occurs when the weld reduces the cross-sectional thickness of the base metal and which reduces the strength of the weld and workpieces. One reason for this type of defect is excessive current, causing the edges of the joint to melt and drain into the weld; this leaves a drain-like impression along the length of the weld. Another reason is if a poor technique is used that does not deposit enough filler metal along the edges of the weld. A third reason is using an incorrect filler metal, because it will create greater temperature gradients between the center of the weld and the edges. Other causes include too small of an electrode angle, a dampened electrode, excessive arc length, and slow speed.

Assignments:

- What are the criteria for good welding?
- How penetration of welding joint can be varied?
- Discuss the problems faced in arc welding.
- Why shielded electrodes are used?
- What do you understand by straight and reverse polarity?
- Differentiate between traverse crack and hat crack.
- What can be remedies of gas inclusion and distortion?

Experiment-3

Different Types if Turning Operations in Lathe Machine

Objectives:

- Become familiar with basic lathe operations.
- Experiencing various types of turning operations in lathe machine.
- Learn to calculate cutting speed, material removal rate, and spindle horsepower.

Introduction:

Turning is the process whereby a center lathe is used to produce "solids of revolution". It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a computer controlled and automated lathe which does not. This type of machine tool is referred to as having computer numerical control, better known as CNC and is commonly used with many other types of machine tool besides the lathe.

When turning, a piece of material (wood, metal, plastic even stone) is rotated and a cutting tool is traversed along 2 axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside (also known as boring) to produce tubular components to various geometries. Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solids; although until the advent of CNC it had become unusual to use one for this purpose for the last three quarters of the twentieth century. It is said that the lathe is the only machine tool that can reproduce itself.

Different types of turning operations:

1. Straight turning
2. Taper turning
3. Facing
4. Grooving
5. Boring
6. Threading
7. Knurling
8. Drilling
9. Countersinking
10. Counterboring
11. Etc.

Straight Turning:

In straight turning the feed of the tool is parallel to the axis of rotation of the job resulting in a straight cylindrical shape.

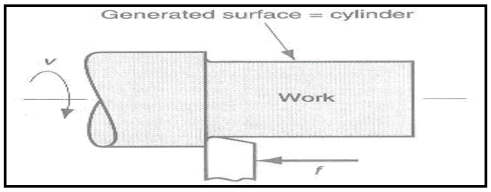


Figure 3.1: Straight Turning

Taper Turning:

Instead of feed the tool parallel to the axis of rotation of the work, the tool is fed at an angle, thus creating a taper cylinder or conical shape.

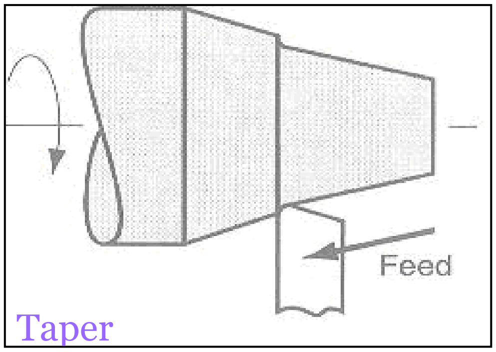


Figure 3.2: Taper Turning

Facing:

The tool is fed radially into the rotating work on one end to create a flat surface on the end.

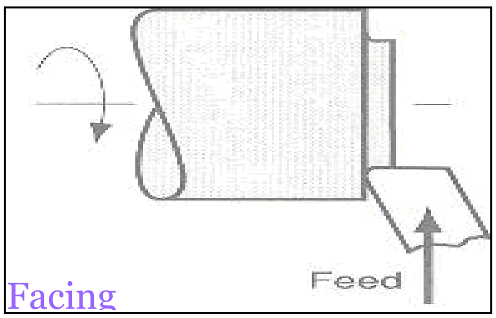


Figure 3.3: Facing

Grooving:

In this the shape of the cutting tool is imparted on the job. So it is also called form turning or forming.

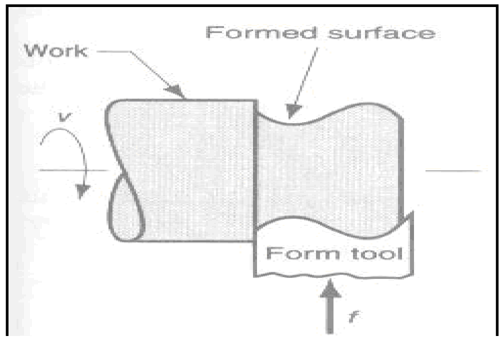


Figure 3.4: Grooving

Boring:

A single point is fed linearly parallel to the axis of rotation, on the inside diameter of an existing hole in the part.

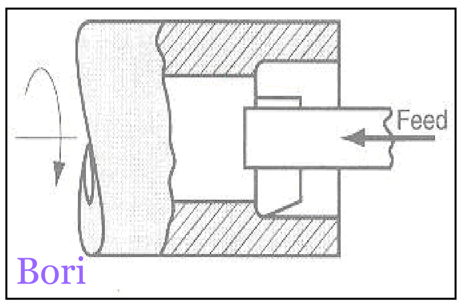


Figure 3.5: Taper Turning

Threading: A pointed tool is fed linearly across the outside surface of the rotating work part in a direction parallel to the axis of rotation at a large effective feed rate, thus creating threads in the cylinder.

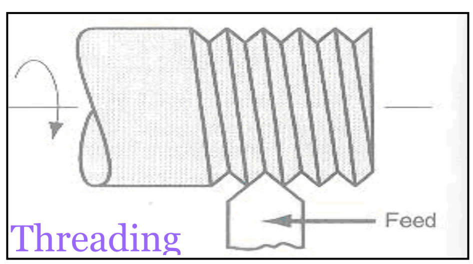


Figure 3.6: Threading

Drilling: Drilling can be performed on a lathe by feeding the drill into the rotating work along its axis. Reaming can be performed in a similar way.

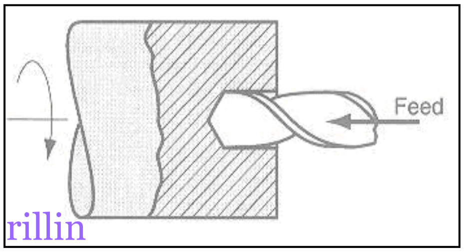


Figure 3.7: Drilling

Counterboring:

Counterboring is the process of producing a cylindrical flat-bottomed hole that enlarges another coaxial hole. A counterbore hole is typically used when a fastener, such as a socket head cap screw, is required to sit flush with or below the level of a work piece’s surface.

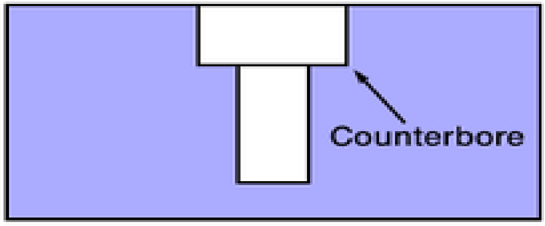


Figure 3.8: Counterboring

Counterbores are made with standard dimensions for a certain size of screw or are produced in sizes that are not related to any particular screw size. In either case, the tip of the counterbore has a reduced diameter section referred to as the pilot, a feature essential to assuring concentricity between the counterbore and the hole being counterbored. Counterboring can be done by lathe, milling or drilling machines.

Figure 3.9: Counterboring tools

Countersinking:

A countersink is a conical hole cut into a manufactured object, or the cutter used to cut such a hole. A common use is to allow the head of a countersunk bolt or screw, when placed in the hole, to sit flush with or below the surface of the surrounding material (by comparison, a counterbore makes a flat-bottomed hole that might be used with a socket-head cap screw). A countersink may also be used to remove the burr left from a drilling or tapping operation thereby improving the finish of the product and removing any hazardous sharp edges.

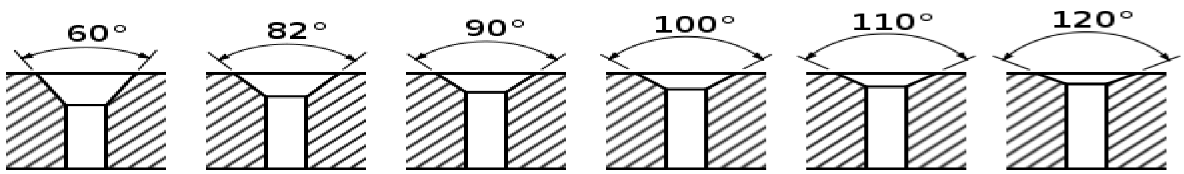


Figure 3.10: Cross-section of countersunk holes of chamfer angles

Countersinking tools can ne fluted or non-fluted. The fluted countersink cutter is used to provide a heavy chamfer in the entrance to a drilled hole. This may be required to allow the correct seating for a countersunk-head screw or to provide the lead in for a second machining operation such as tapping. Countersink cutters are manufactured with six common angles, which are 60°, 82°, 90°, 100°, 110°, or 120°.

Figure 3.11: Countersinking cutters (4-fluted and non-fluted)

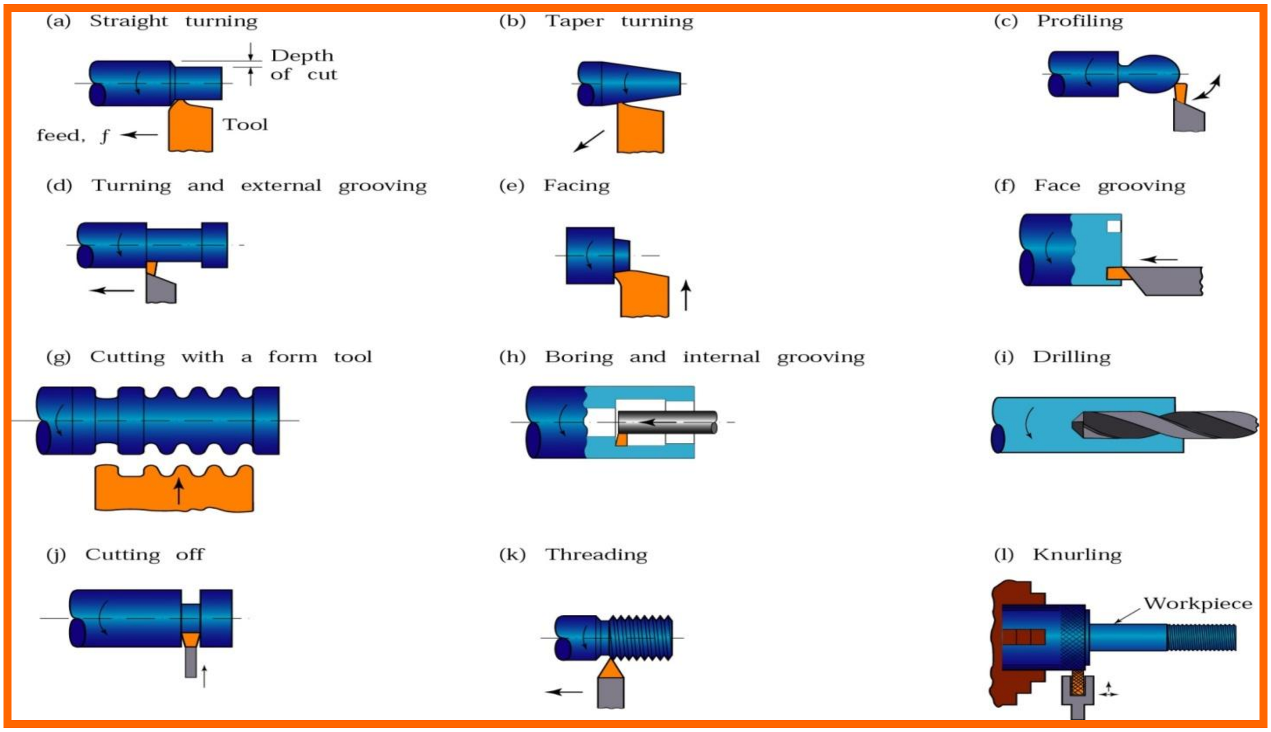


Figure 3.12: Different types of turning operations

Precautions:

- Never turn on the lathe machine when the tool and work piece is in contact.
- Wear shoes and apron to protect skin from heated chips.

Assignments:

- Differentiate between countersinking and counter-boring operation.
- Explain the function of cutting fluid in lathe work.
- Explain why high RPM does not mean high cutting speed?
- What are the four ways of taper turning in a lathe machine?

Experiment-4

Study of Different Types of Milling Operations in Order to Make a Part

Objectives:

- Become familiar with basic milling operations
- Get firsthand experience at trying to maintain tolerances in machining.
- Learn to calculate cutting speed, material removal rate, spindle horsepower etc.
- Become familiar with different types of milling cutters.

Apparatus:

- Milling machine
- Vice
- Job
- Different types of milling cutters

Types of milling machine:

There are two major types of milling machine, the vertical milling machine and the horizontal milling machine. As their names imply, a vertical milling machine spindle is vertical and the horizontal milling machine spindle is horizontal (Figure: 4.1). In addition the vertical milling machine has a machine table that moves perpendicular to the spindle axis of rotation and the horizontal milling machine has a work table that moves parallel to the spindle axis of rotation(Figure: 4.2).

The vertical milling machine is the most common type found in the machine shop today. However during the first half of 20th century the horizontal milling machine was the primary machine tool used for milling purposes. There are far fewer horizontal milling machines in production today than vertical machines. Another type of mill is the combination milling machine (Figure: 4.3). This is a hybrid of the vertical and horizontal. Still another type of specialty milling machine is the universal milling machine (Figure: 4.4). It is usually a horizontal milling machine with a swiveling plate. This type of milling machine will be shown in the machine tool sessional lab.

Figure: 4.1

Figure: 4.2

Figure: 4.3

Figure: 4.4

Parts of Horizontal Milling Machine:

- **Column:** The column houses the spindle, the bearings, the gearbox, the clutches, the shafts, the pumps, and the shifting mechanisms for transmitting power from the electric motor to the spindle at a selected speed.
- **Knee:** The knee mounted in front of the column is for supporting the table and to provide an up or down motion along the Z axis.

- **Saddle:** The saddle consists of two slide ways, one on the top and one at the bottom located at 90º to each other, for providing motions in the X or Y axes by means of lead screws

- **Table:** The table is mounted on top of the saddle and can be moved along the X axis. On top of the table are some T-slots for the mounting of work piece or clamping fixtures.

- **Arbor:** The arbor is an extension of the spindle for mounting cutters. Usually, the thread end of an arbor is of left hand helix.

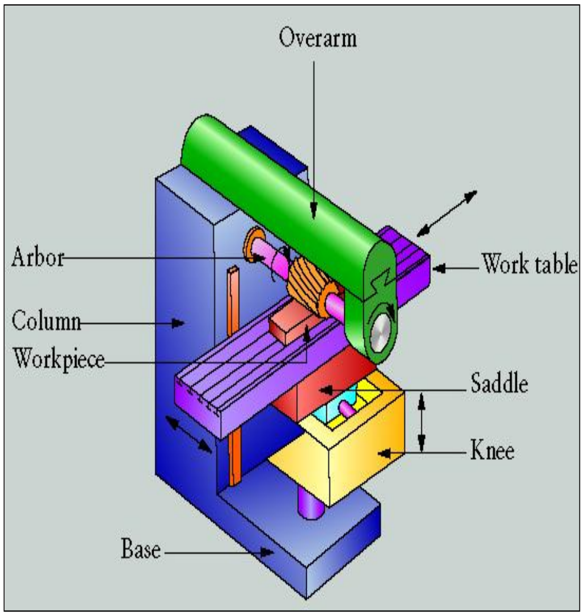


Figure 4.5: Horizontal Milling Machine

Parts of Vertical Milling Machine:

- **Column:** The column houses the spindle, the bearings, the gearbox, the clutches, the shafts, the pumps, and the shifting mechanisms for transmitting power from the electric motor to the spindle at a selected speed.

- **Knee:** The knee mounted in front of the column is for supporting the table and to provide an up or down motion along the Z axis**.**

- **Saddle:** The saddle consists of two slide ways, one on the top and one at the bottom located at 90º to each other, for providing motions in the X or Y axes by means of lead screws.

- **Table:** The table is mounted on top of the saddle and can be moved along the X axis. On top of the table are some T-slots for the mounting of work piece or clamping fixtures.

- **Milling head:** The milling head consisting the spindle, the motor, and the feed control unit is mounted on a swivel base such that it can be set at any angle to the table.

- **Ram**: The ram on which the milling head is attached can be positioned forward and

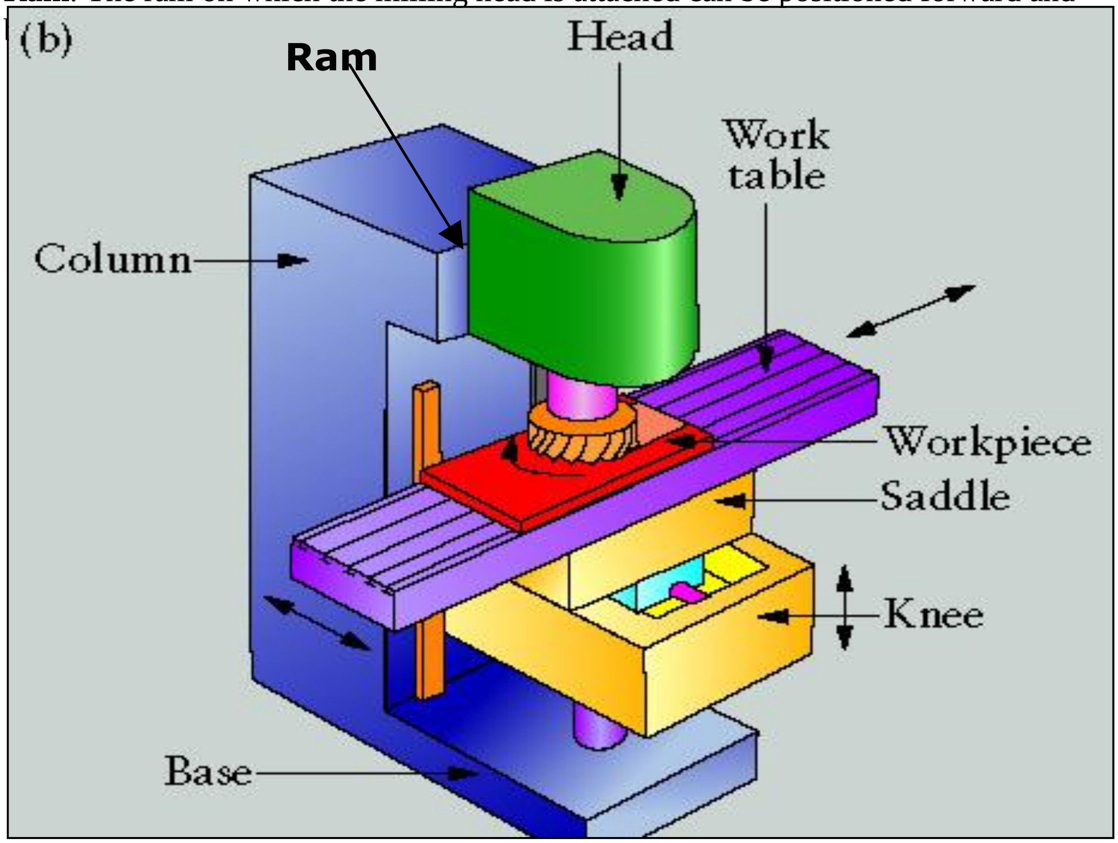


Figure 4.6: Vertical Milling Machine

Milling Methods:

1.Up Milling:

In up cut milling, the cutter rotates in a direction opposite to the table feed as illustrated in the following Figure. It is conventionally used in most milling operations because the backlash between the lead screw and the nut of the machine table can be eliminated.

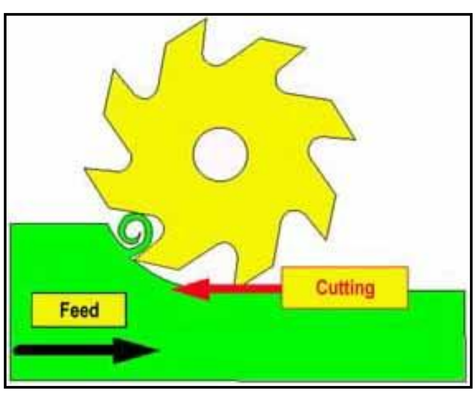


Figure 4.7: Up milling

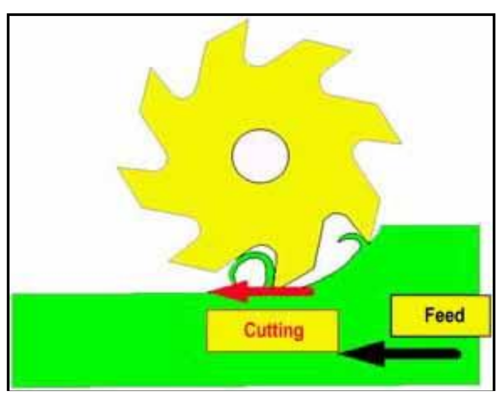


Figure 4.8: Down milling

2. Down Milling:

In down cut milling, the cutter rotates in the same direction as the table feed as illustrated in the following Figure. This method is also known as Climb Milling and can only be used on machines equipped with a backlash eliminator or on a CNC milling machine. This method, when properly treated, will require less power in feeding the table and give a better surface finish on the work piece.

Classification of Milling Operations:

- **Peripheral Milling:** In peripheral milling, the milled surface is generated by teeth located on the periphery of the cutter body. The axis of cutter rotation is generally in a plane parallel to the work piece surface to be machined. Slab milling, slotting, slitting etc. are examples of peripheral milling.
- **Face Milling:** In face milling, the cutter is mounted on a spindle having an axis of rotation perpendicular to the work piece surface. The milled surface results from the action of cutting edges located on the periphery and face of the cutter. Conventional milling, partial face milling, end milling, surface contouring etc. are examples of face milling.

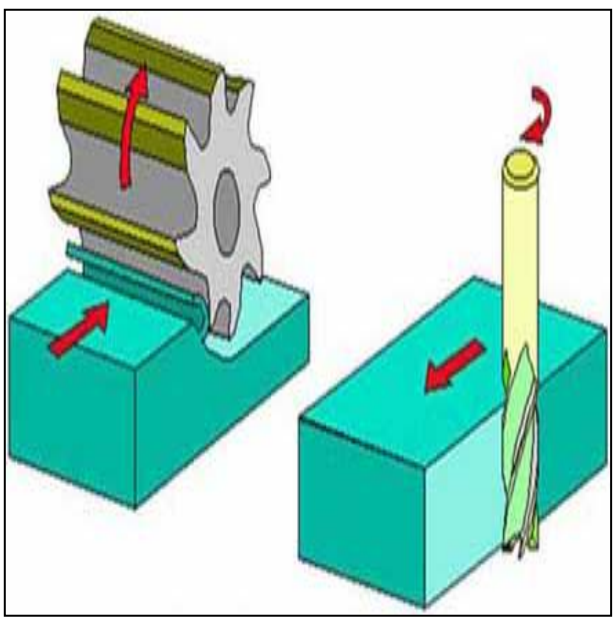


Fig 4.9:Peripheral Milling

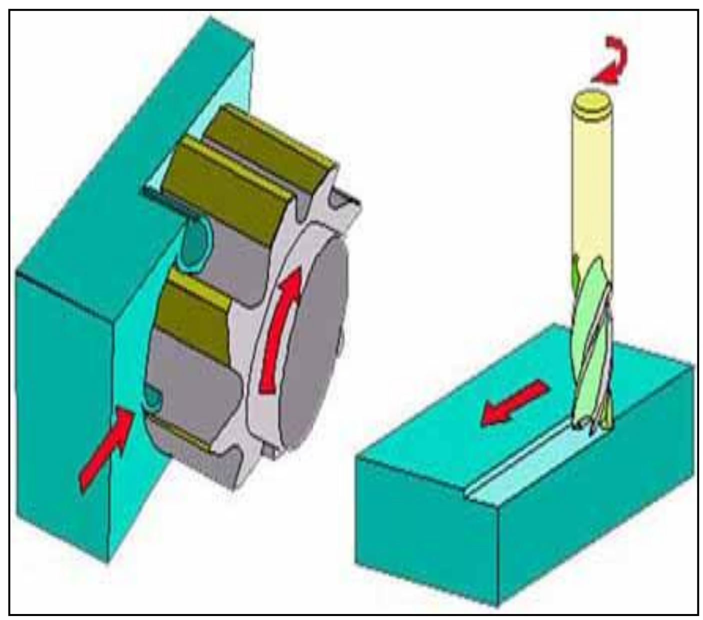
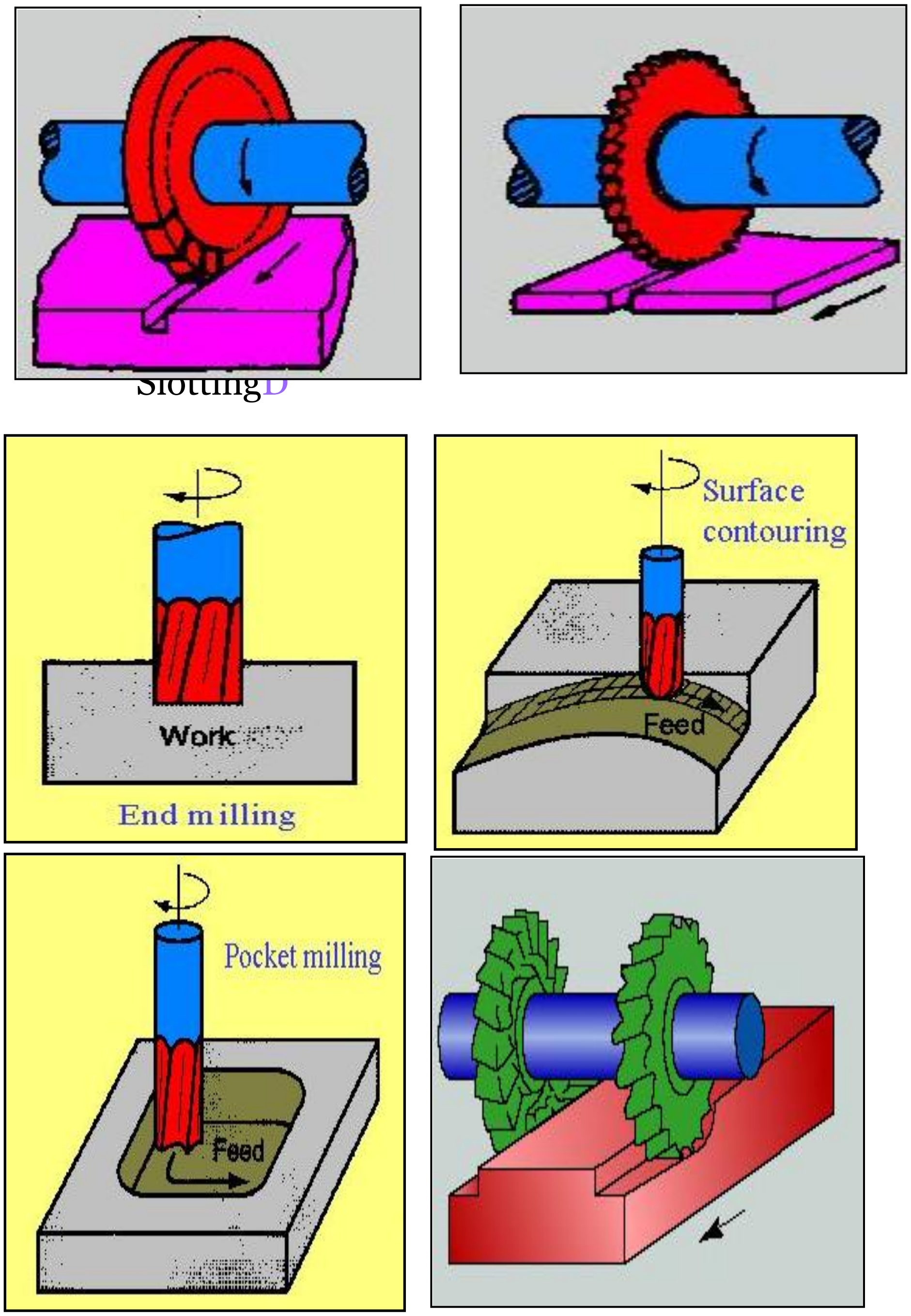


Fig 4.10: Face Milling



StraddleSlitting

Figure 4.11: Different types of milling operations

Formulae Necessary for Calculations:

$$\text{Spindle Speed}, N = \frac{1000\,V}{\Pi\,D}$$

Where

N = R.P.M. of the cutter
V = Linear cutting speed of the material in m/min. (as shown in Table-1)
D = Diameter of cutter in mm

Table feed rate, f= ft. N. n

Materialremoval rate, MRR= w. d. f

Where,

f = Table fee

d in mm/min

f_t = Movement per tooth of cutter in mm or chip load in mm/tooth

n = No. of teeth of cutter end

N = R.P.M. of the cutter

w = Width of cut

d = Depth of cut

Table-1: Cutting speed and Feed rate for some common material			
Tool Material	**High Speed Steel**		**Carbide**
Material	**Cutting speed (v)**	**Feed (f)**	**Cutting speed (v)**
Mild Steel	**25**	**0.08**	**100**
Aluminium	**100**	**0.15**	**500**
Hardened Steel	**---**	**---**	**50**

Assignments:

- Explain the differences between peripheral and face milling.
- List four types of knee and column type milling machines.
- Differentiate between up milling and down milling. Which method do you think is more efficient?
- What are the functions of arbor and ram of a horizontal milling machine?

Experiment-5

Study of Different Types of Operation in Grinding Machine

Objectives:

- Becoming familiar with the grinding machine and its various operations.
- Study of different types of grinding wheels.
- To learn about proper safety measures and their applications while using the machine.

Apparatus:

- Grinding machine
- Grinding wheels
- Work piece
- Vice

Introduction to Grinding Process and Grinding Machine:

Grinding is basically an abrasive machining process. Abrasive machining is the basic process in which chips are formed by very small cutting edges that is the integral part of the abrasive particles. The results that can be obtained from abrasive machining like grinding range from the finest and smoothest surfaces produced by any machining processes, in which very little material is removed, to rough, coarse surfaces and accompany high material removal rate(MRR). The abrasive particles may be (1) Free, (2) Mounted in resin on a belt, or (3) Close packed into wheels or stones, with abrasives held together by bonding material called bonded product. The metal removal process is basically the same in all three cases but with important differences due to spacing of active grains and degree of fixation of grains. Different types of abrasive machining includes:

- **Grinding**: It uses wheels as machining tool and provides accurate sizing, finishing and low MRR.
- **Abrasive Machining**:Its MRR is high and used to obtain desired shapes and approximate sizes.
- **Snagging**: High MRR, rough rapid technique to clean up castings, forgings.
- **Honing**: “Stones” containing fine abrasives are uses as tool, primarily a hole finishing process.
- **Lapping**: Fine particles embedded in soft metal or cloth; primarily a surface-finishing process.

An abrasive is a hard and tough substance. It has many sharp edges. An abrasive cuts or wears away materials that are softer than it. So in abrasive machining abrasives are used as cutting tools or materials. The following figure shows an illustration of a typical grinding machine. The main parts of the machine are

1. Base/Bed
2. Column

3. Saddle
4. Table

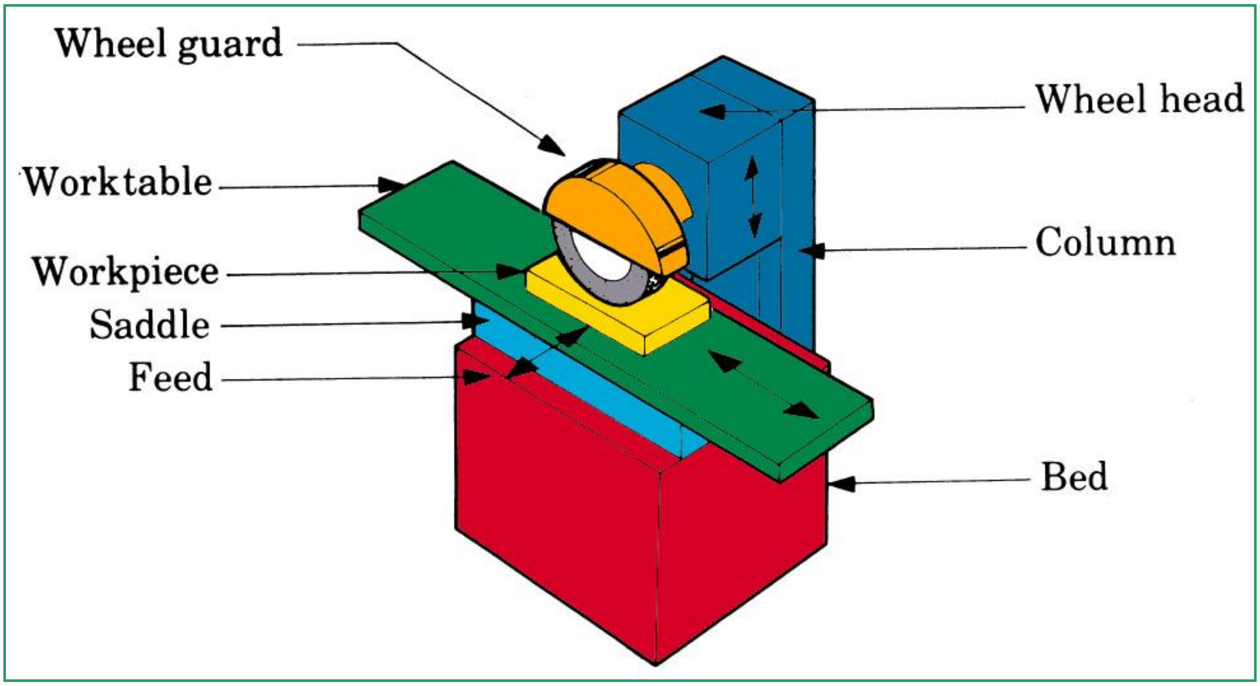


Figure 5.1: Schematic illustration of grinding machine

5. Wheel guard
6. Wheel head

Properties of Abrasives:

- **Penetration Hardness:** This property refers to tire ability of the scratch or cut a softer material.
- **Fracture Resistance:** This property refers to the abilityof an abrasive material to resist breaking or cracking under load.
- **Wear Resistance:** It refers to the ability of the abrasive grain to maintain sharpness. Wear resistance is largely related to penetration hardness and tensile strength of the abrasive.

Types of Abrasives:

- **Natural Abrasives:** Natural abrasives are obtained from nature. They are being replaced by artificial ones, Except for diamond, the natural abrasives are relatively soft in comparison to artificial abrasives. Some of the natural abrasives are:

1. Crocus: Reddish-brown oxide of iron and may be natural or synthetic.
2. Emery: Composed of corundrum (A1203) and 40% iron oxide and other impurities.
3. Diamond: The hardest material known, is used in the form of grains bonded together to form an abrasive stick or grinding wheel.

- **Artificial Abrasives:** They are harder and have greater impact toughness than any natural abrasives except diamond. The commonly used artificial abrasives are Silicon Carbide, Aluminum Oxide, Boron Carbide, Synthetic diamond etc.

Grinding Wheels and Their Selection:

A grinding wheel is made of abrasive grains held together by a bond. These grains cut like teeth when the wheel is revolved at high speed and is brought to bear against a work piece. The properties of a wheel that determine how it acts are the kind and size of abrasive, how closely the grains are packed together and amount of the bonding material.

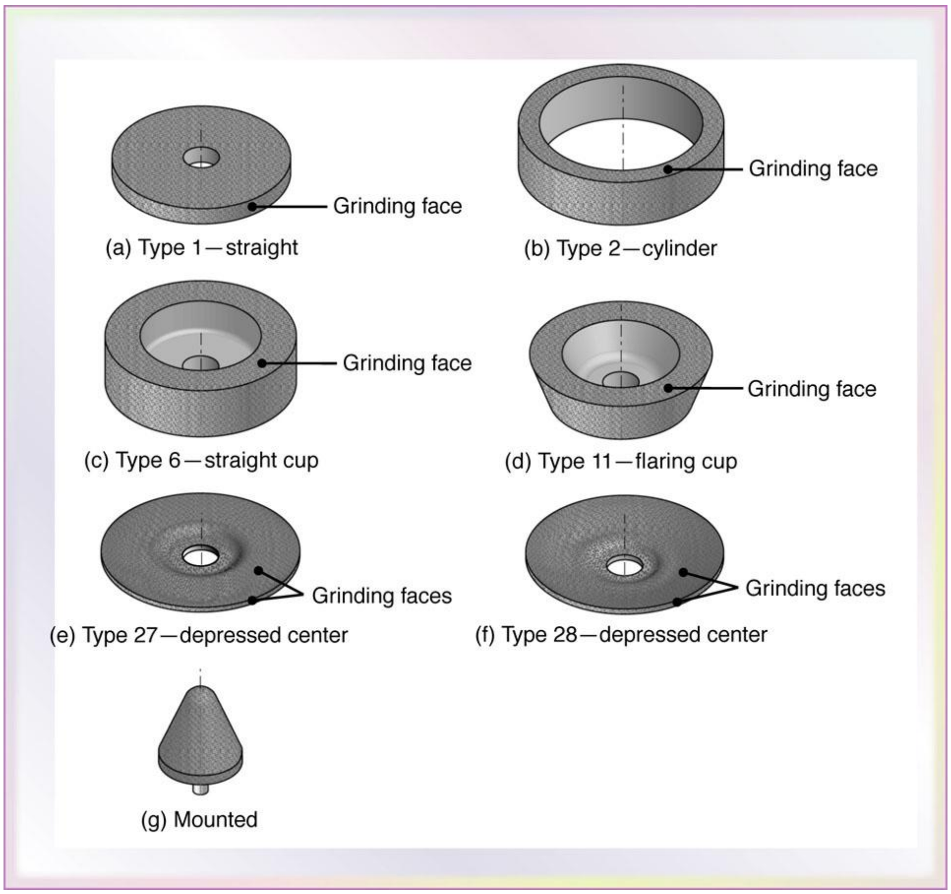


Figure 5.2: Common types of grinding wheels

Cutting Action of Grinding Wheel:

Each abrasive grain in a grinding wheel is a cutting tool. Each has sharp cutting edge which cutoff tiny particles from the metal being ground. The following figure shows a schematic view of cutting action by grinding wheel.

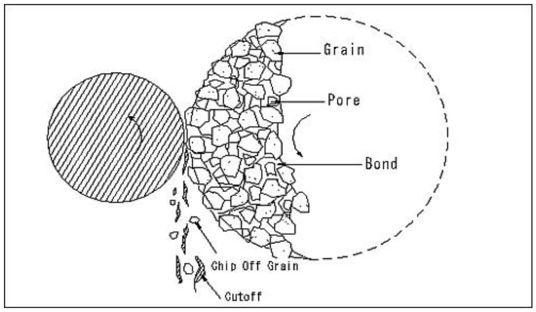


Figure 5.3: Cutting action of wheel

Classification of Grinding Operations:

- **Rough Machining Operations:** On abrasive-machining operations, metal is removed more rapidly than on finish-grinding operations. It involves depth of cut 1.5mm or more.
- **Finish Grinding:** On finish-grinding operations, grinding wheels remove metal relatively slowly in comparison with other cutting tools. Finish grinding usually follows other rough-machining slowly in comparison with other cutting tools. It usually follows rough-machining operations, and generally involves machining to very close tolerance.Three types of precision grinding exists
  - **External cylindrical grinding**
  - **Internal cylindrical grinding**
  - **Surface grinding**

Surface grinding: It is most common of the grinding operations. A rotating wheel is used in the grinding of flat surfaces. Types of surface grinding are vertical spindle and rotary tables.

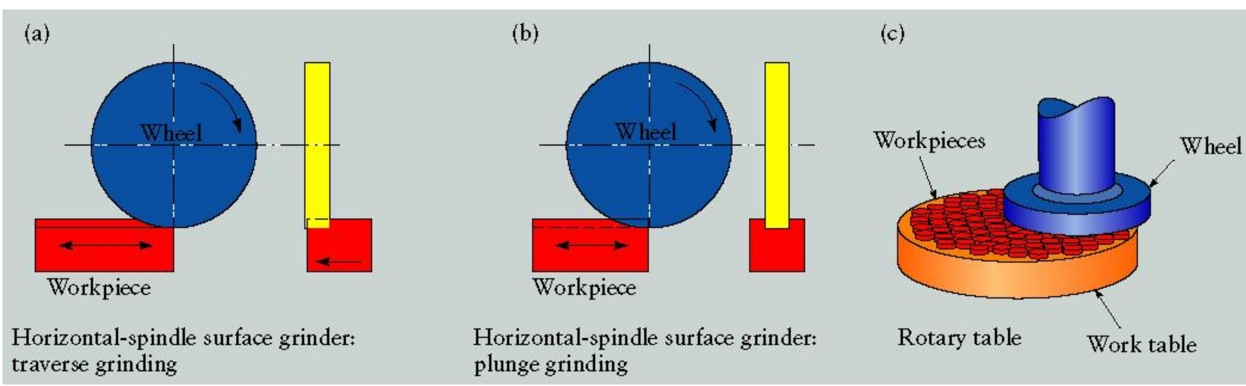


Figure 5.4: Different types of grinding operations

Cylindrical grinding is also called center-type grinding and is used in the removing the cylindrical surfaces and shoulders of the workpiece. Both the tool and the workpiece are

rotated by separate motors and at different speeds. The axes of rotation tool can be adjusted to produce a variety of shapes.

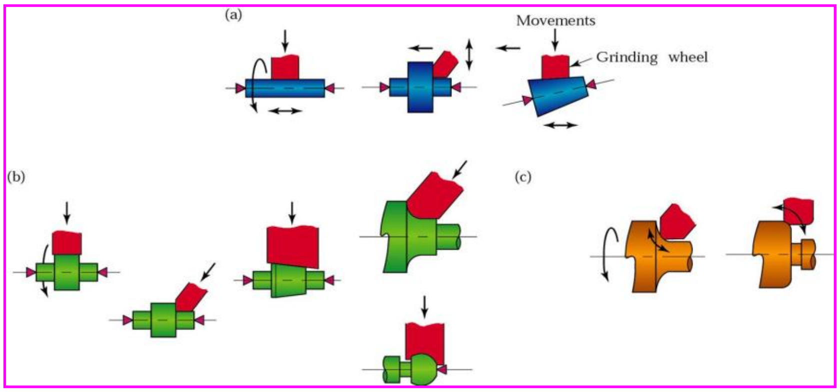


Figure5.5: Examples of various cylindrical grinding operations. (a) Traverse grinding, (b) plunge grinding, and (c) profile grinding.

Internal grinding is used to grind the inside diameter of the workpiece. Tapered holes can be ground with the use of internal grinders that can swivel on the horizontal.

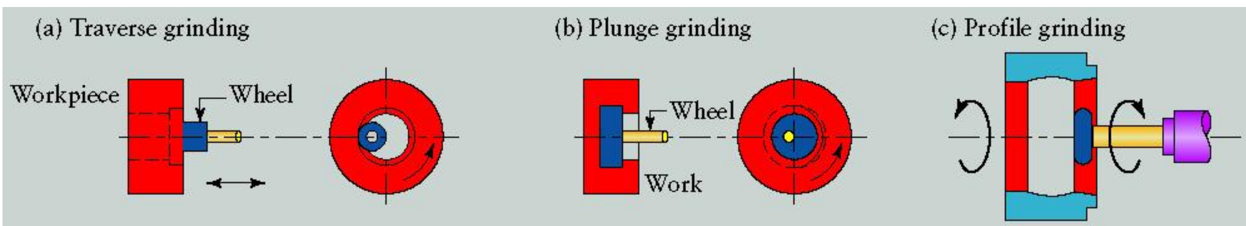


Figure 5.6: Schematic of Internal Grinding

Turing of Grinding Wheels:

A grinding wheel should be trued each time it is put on the spindle. It should be dressed whenever it becomes dull, loaded or grazed with use. Turing refers to correcting an out of round condition of the wheel. A dressing tool is used to remove particles of the abrasive from the high part of wheel. Turing also refers to remove particles of the abrasive from the high part of the wheel. Turing also refers to forming the wheel to a particular shape, such as concave or convex. To be in good condition, the wheel must be sharp and run true on both the periphery and the sides.

Dressing produces a sharp grinding surface. A diamond tool is used to remove the dull or loaded surface of the wheel. Dressing is necessary whenever the wheel cuts poorly, usually resulting in burning the work.

Calculation of Grinding Ratio:

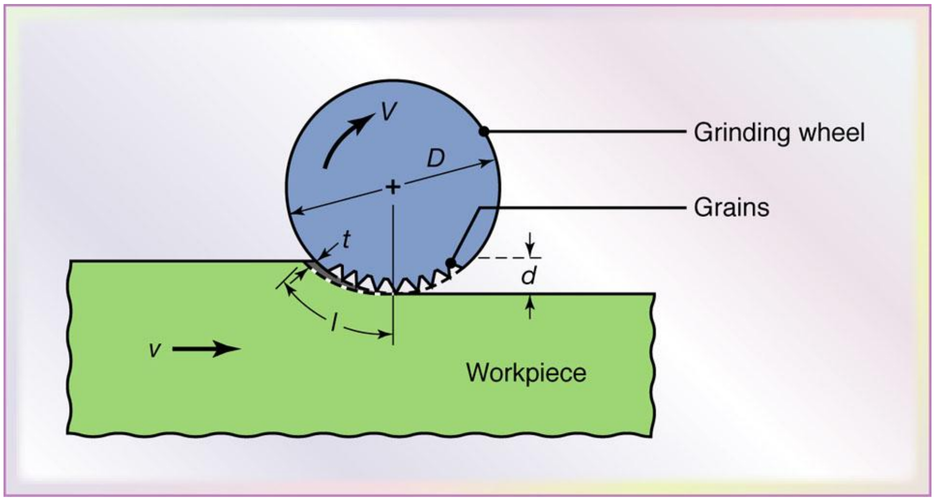


Figure 5.7

Where,

D=Grinding wheel diameter

d= Wheel depth of cut

V= Tangential velocity

v= Workpiece velocity

t= Undeformed thickness (grain depth of cut)

Grinding ratio, G=Volume of material removed/Volume of wheel wear

Assignments:

- Why is grinding an abrasive machining process?
- Differentiate between rough and finish grinding process.
- Why is dressing of wheel necessary for grinding? Explain.
- What do you understand by fracture resistance and wear resistance?
- Calculate the MRR of your machining operation.

Experiment-6:

Study of Shaping Machine, Its Various Operations and MRR calculation

Objective: The objective of this experiment is to get familiar with shaper machine, its operation and calculation of material removal rate.

Apparatus:

- Shaper machine
- Vice
- Job
- Single point cutting tool

Shaper Machine and its components:

Ram: The ram slides back and forth in dovetail or square ways to transmit power to the cutter. The starting point and the length of the stroke can be adjusted.

Toolhead: The toolhead is fastened to the ram on a circular plate so that it can be rotated for making angular cuts. The toolhead can also be moved up or down by its hand crank for precise depth adjustments.

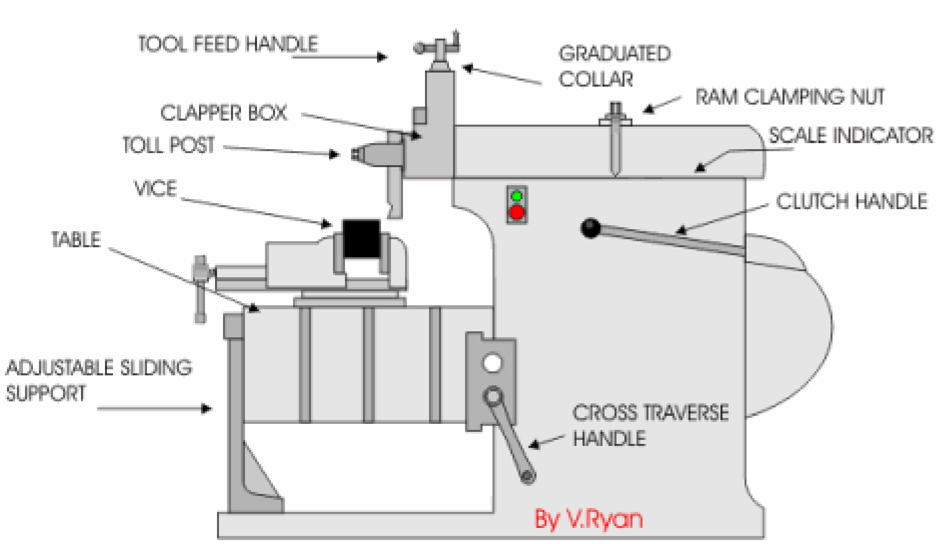


Figure 6.1: Shaping machine

Clapper Box: The clapper box is needed because the cutter drags over the work on the return stroke. The clapper box is hinged so that the cutting tool will not dig in. Often this clapper box is automatically raised by mechanical, air or hydraulic action.

Table: the table is moved left and right, usually by hand, to position the work under the cutter when setting up. Then either by hand or more often automatically the table is moved sideways to feed the work under the cutter at the end or beginning of each stroke.

Quick Return Mechanism

The shaping machine is used to machine is used to machine flat metal surfaces especially where a large amount of metal has to be removed. Other machines such as milling machines are much more expensive and are more suited to removing smaller amounts of metal very accurately.

The reciprocating motion of the mechanism inside the shaping machine can be seen in the diagram. As the disc rotates the top of the machine moves forwards and backwards pushing a cutting tool. The cutting tool removes the metal from work which is carefully bolted down.

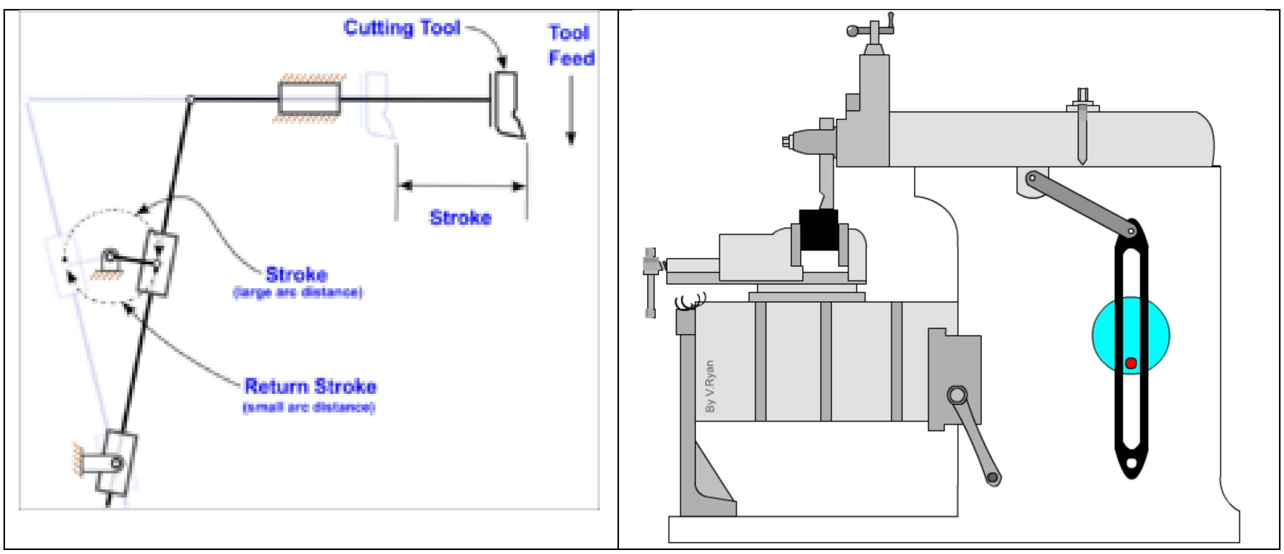


Figure 6.2: Quick return mechanism

Various cutting operations that can be performed on a Shaping Machine

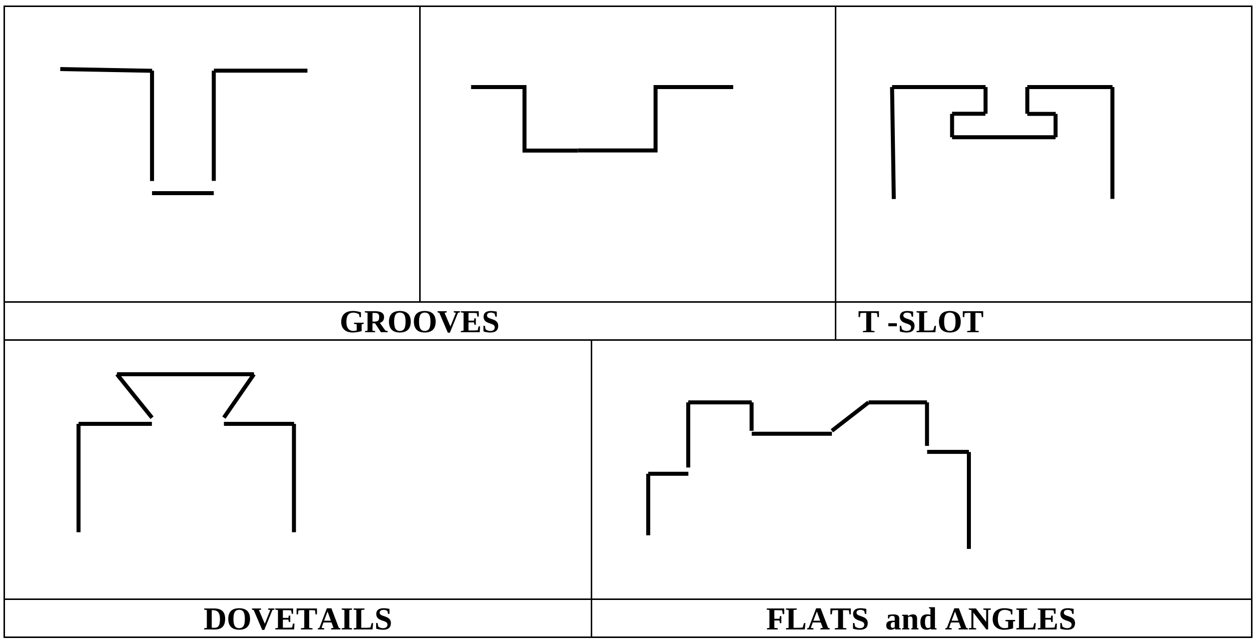


Figure 6.3

Calculation of MRR (Material Removal Rate):

MRR = d . w. t / total machining time

where, d = length of job

w = width of job

t = depth of cut

Assignments:

- Explain quick return mechanism with neat sketch.
- Difference between shaper and planer machine.
- How many degrees of freedom are there in a shaper machine?
- What are functions of the clapper box?
- What are the advantages and disadvantages of high MRR?

Experiment-7

Study of Injection Molding Machine and its operations

Objectives:

- Becoming familiar with injection molding machine.
- To learn about plastic processing operation.
- Learning about common injection molding defects.

Process Description:

The plastic melt flows from the injection nozzles and enters the mold at the sprue. From the sprue the plastic flows into the runners and ultimately through the gates into the part. Gate and runner design is an important part of the mold design. To help ensure that the mold fills completely, one should balance the mold so that all cavities fill at the same time. When the cavities are the same, a symmetric layout is used. If the cavities are all markedly different, often the gates and runners must be sized/shaped differently in order to allow all cavities to fill in the same amount of time.

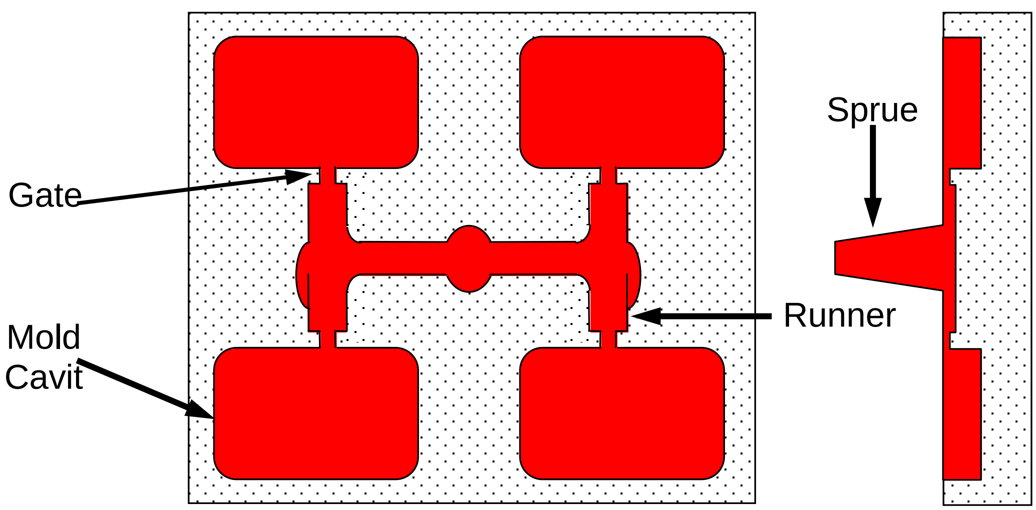


Figure 7.1

There are two basic types of injection molding press.

1. Plunger type
2. Screw type

Screw Type Injection Presses: The original plunger type has had one important modification. A reciprocating screw now forces material into the mold. This screw action ensures that the same amount of material is always metered in, and it is equally dense along the length of the screw. Additionally the material will be much better mixed by the screw action which helps to maintain better consistency from shot to shot. Since the screw action generally helps to pack the material in better, a given plunger travel will push more material into the cavity. Finally the action of the screw, as it rotates and mixes, adds energy to the melt. However, band heaters are still needed to fully heat the melt. All of this results in a much better and more consistent part. This is why the screw press is essentially the only press found in industry. Small plunger presses are still made for prototype/lab purposes.

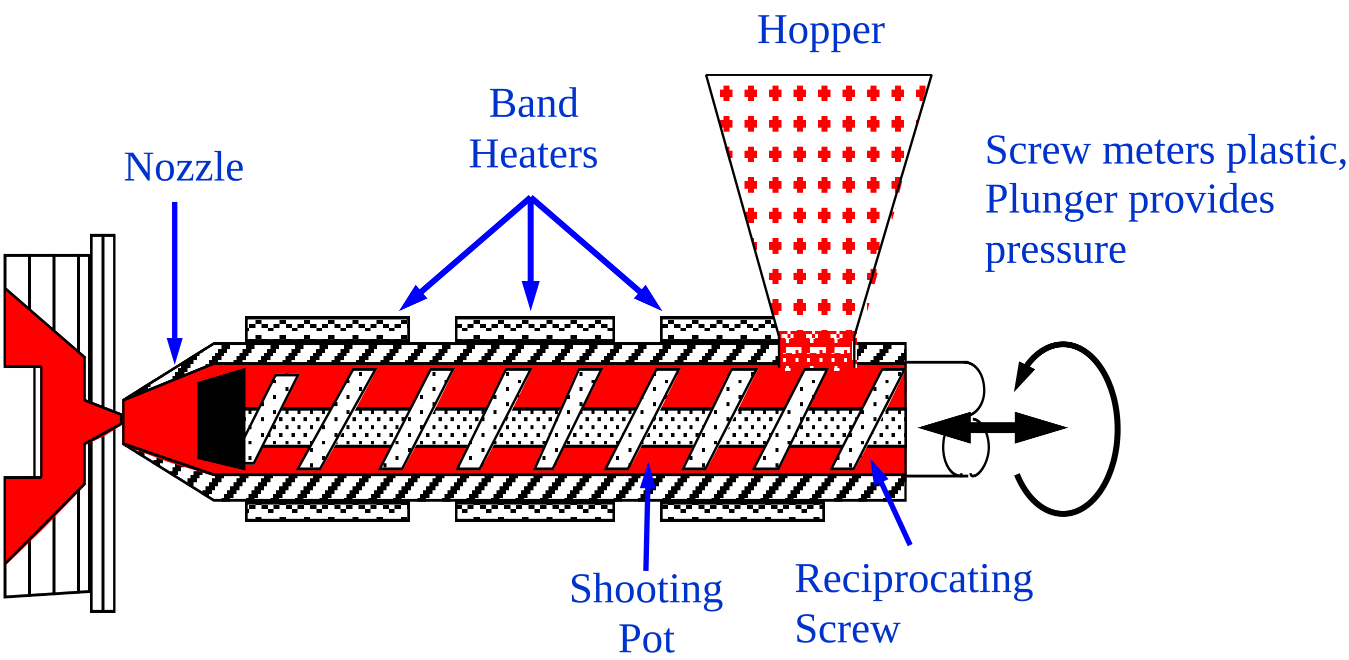


Figure 7.2: Schematic of Injection molding press

The injection molding screw plunges forward to provide holding and packing pressure. The screw rotates as it retracts to meter and plasticize the melt. The screw is broken up into 3 regions. The Feed Section draws material from the hopper and starts movement into the shooting pot. In this section, channels between the flights are deep and the depth is constant. The next section, called the Transition Section, compresses and melts the plastic pellets. Most plasticization occurs in this section. The root diameter tapers, causing the channel depth to decrease. In the last section, the Metering Section, the correct fill is precisely measured out. This section has a constant channel depth.

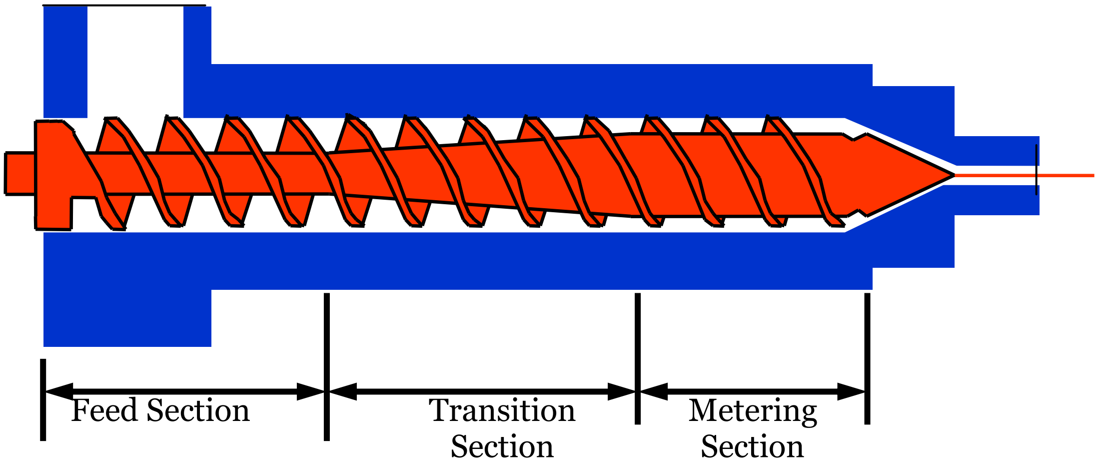


Figure 7.3: Different section of the Injection molding machine

Plunger Type Injection Molding Press: In this molding press, the plastic is fed into the mold when a cylinder plunger extends and forces the plastic into the mold. After the plunger retracts more material can be fed from the hopper to the shooting pot. (Thus the stroke of the plunger determines the additional material fed in each time.) Of course the shooting pot is long enough to hold several shots, so the plastics stays in the pot for a while, giving the band heaters time to heat and melt the plastic. Notice the torpedo, which is basically an obstruction to the plastic flow in the shooting pot. As the plastic moves around the torpedo, it is better mixed.

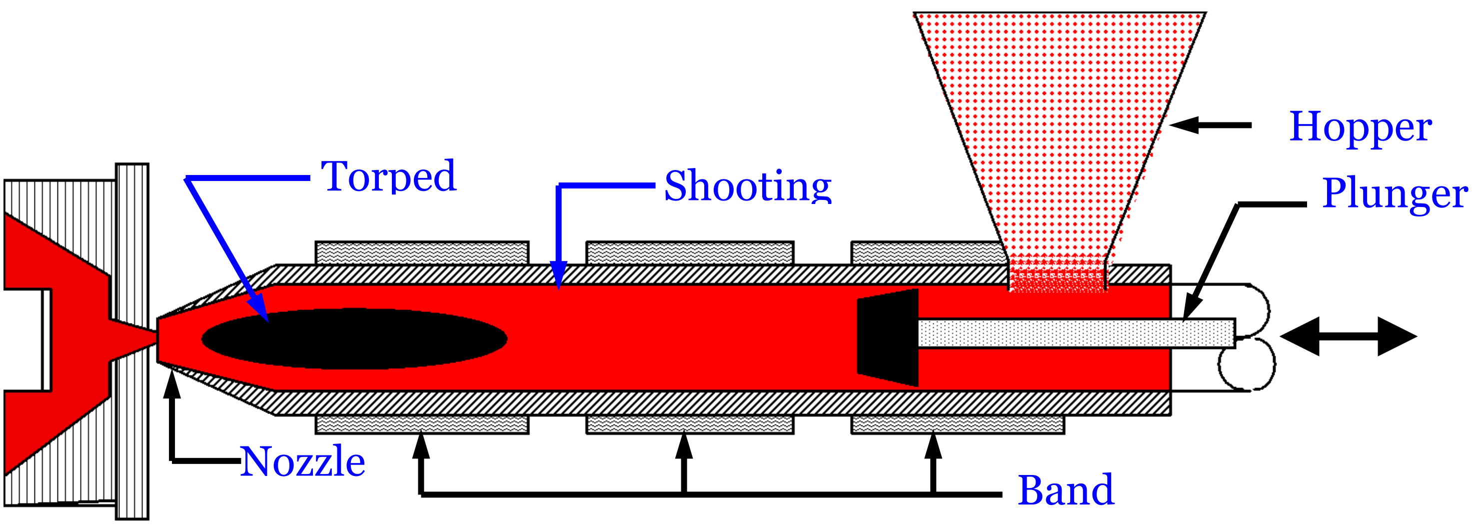


Figure 7.4: Schematic view of Plunger type Injection Molding Machine

Generally, there are three common parameters used to describe the injection molding press capacity: **clamping force**, **shot size**, and **injection pressure**.

- **Clamping force** is usually the most common method to refer to the injection molding press capacity. Thus, presses are talked about as being 20 ton, 50 ton, etc. The clamping force is the force available to hold the platens together.

- **Shot size** is the amount of material that can be transferred into the mold in one shot. Shot sizes are usually specified in cubic centimeters or ounces.
- **Injection pressure** is the pressure at the sprue that forces or injects the plastic melt into the mold. Specification by this parameter refers to the maximum injection pressure.

Injection Molding Defects:

- **Short Shot**
- **Flashing**
- **Weld Lines**
- **Jetting**
- **Ejector Pin Marks**
- **Sink Marks**
- **Warpage**

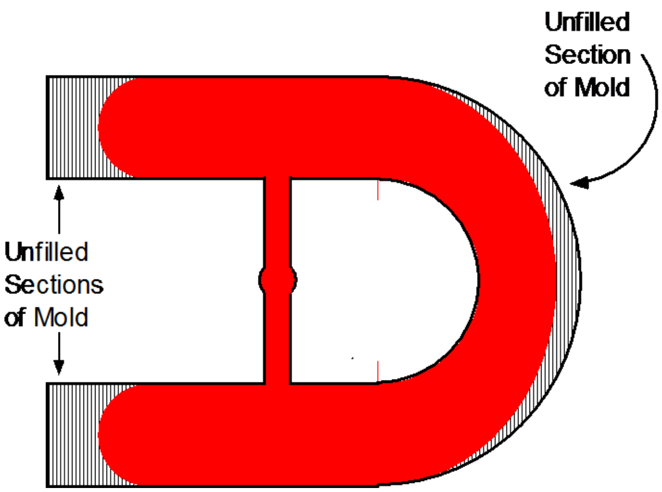


Figure 7.5: Short shot

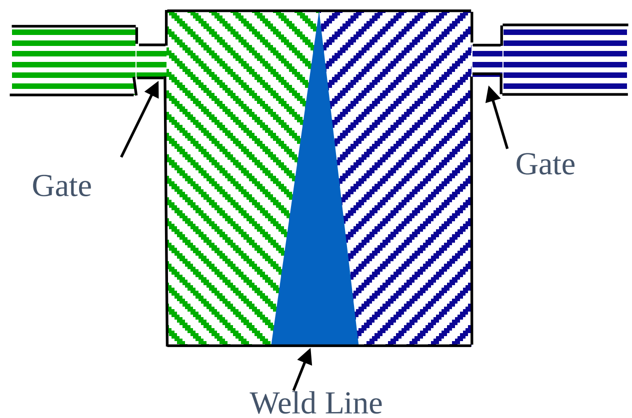


Figure7.6: Weld line

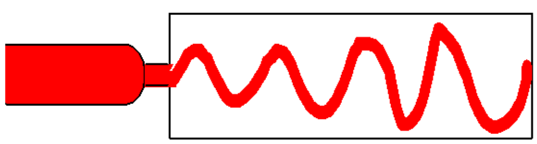


Figure7.7: Jetting

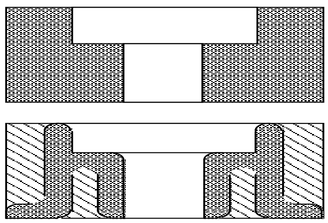


Figure 7.8: Sink marks

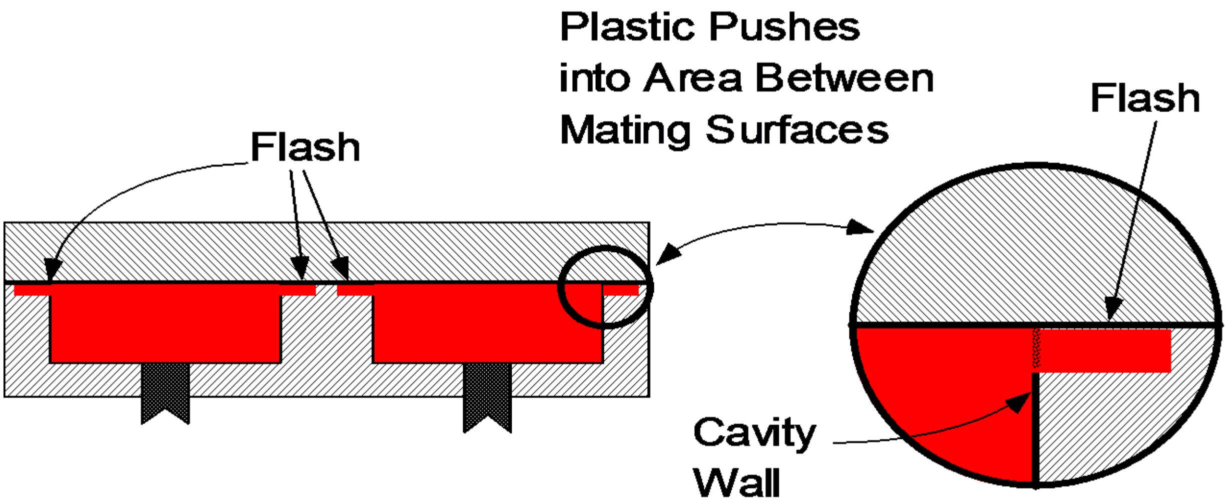


Figure 7.9: Flash

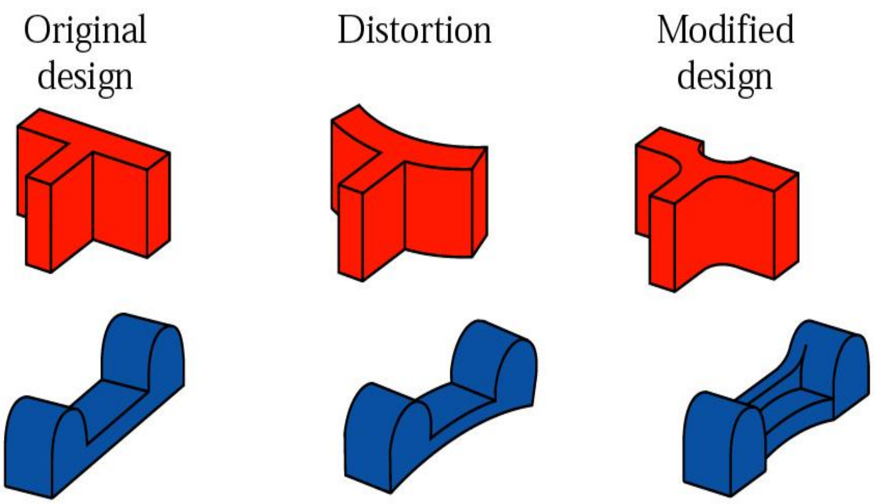


Figure 7.10: Warpage

Short Shot: Short shot occurs when there is insufficient material to fill the mold cavity and/or the material solidifies too soon. It has several causes, including insufficient injection pressure, or insufficient time allowed during the injection process. Sometimes the material will freeze in a given section before it can reach the edges of the mold.

Flashing: Flashing occurs when there is too much material and it pushes its way out of the die; basically, the material overflows the cavity. This can be caused by too much injection pressure, too much injection time, or insufficient clamping force. It also can be caused by a poorly machined die that does not properly seal off the cavity.

Weld Lines: Weld lines occur when flow fronts meet in the mold. In addition to being aesthetically unappealing, weld lines decrease the strength of the part. This normally occurs around holes or obstructions and causes very weak areas in the molded part. Additionally, weld lines are much more pronounced if flow fronts are moving in completely opposite directions, as opposed to when the flow fronts share some components of velocity. Weld lines are more pronounced if melt is cooler when fronts meet.

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Jetting: Jetting is generally caused when one gates a part in such a way that the material flow enters an open section with much space between the gate and the opposite wall. When the flow area is squeezed through the gate, the velocity increases, and the plastic melt shoots into the empty cavity mold.

To reduce the risk of jetting, one should always gate the part so that incoming material flow is directed into a nearby wall. After the stream has impinged on the wall, the plastic melt will spread in the appropriate fashion. Melt moves rapidly, cools unevenly and traps flow lines.

Sink Marks: Sink marks are also common injection molding flaws. Sink marks occur at excessively thick wall sections, or where there are abrupt changes in thickness- thick sections solidify too late and shrink away from the wall. Proper design reduces/eliminates sink marks (ribs, core out sections)

Warpage/Residual Stresses: Warpage is the "out of plane" distortion of an injection molded part, generated by constraining the part while cooling. Warpage is typically caused by anisotropic shrinkage. Several causes for anisotropic shrinkage are: Variations in thickness, Differing shrink rates due to melt orientation. Uneven cooling, Differences in the mold cavity pressure.

If the part is massive enough to resist warpage, residual stresses will result. Since gates are usually highly oriented and have extremely fast cooling rates, residual stresses are always present near the gates.

Assignments:

- What are the three sections of the injection molding screw? What are their features?
- Explain the three parameters that describe the molding press capacity.
- Differentiate between Plunger type and Screw type Injection Molding Machine.
- Explain the causes and remedies of common injection molding defects.

Experiment 8:

Study of Drilling Machine and Its Various Operations

A drill press is preferable to a hand drill when the location and orientation of the hole must be controlled accurately. A drill press is composed of a base that supports a column, the column in turn supports a table. Work can be supported on the table with a vise or hold down clamps or the table can be swiveled out of the way to allow tall work to be supported directly on the base. Height of the table can be adjusted with a table lift crank than locked I place with a table lock. The column also supports a head containing a motor. The motor turns the spindle at a speed controlled by a variable speed control dial. The spindle holds a drill chuck to hold the cutting tools(drill bits, center drills, deburring tools etc.)

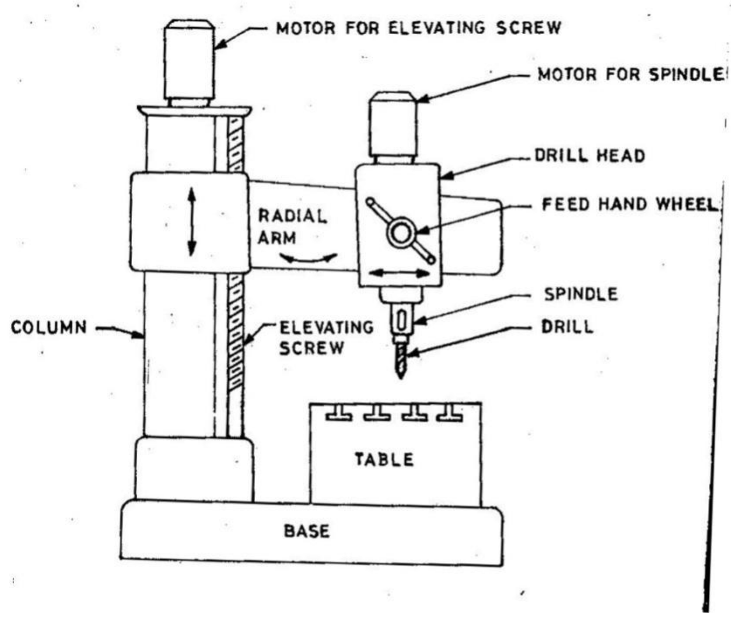
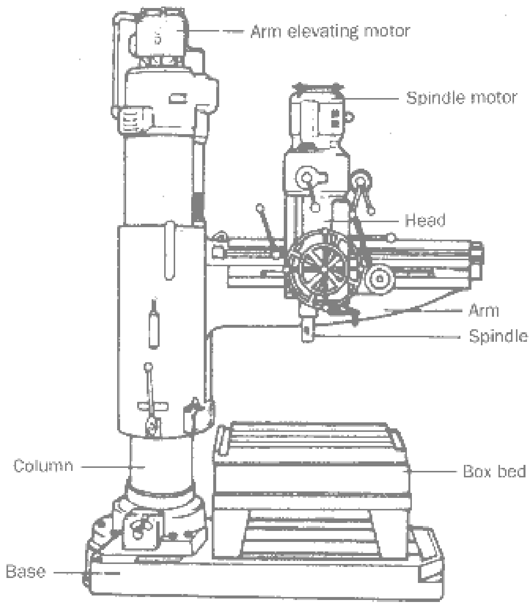


Figure 8.1

Radial drilling machines: used on large workpieces, spindle mounts on radial arm allowing drilling operations anywhere along the arm length.

Gang–drilling machines: independent columns each with different drilling operation work piece slide from one column to next



Radial drill machine Gang drill machine

Figure 8.2

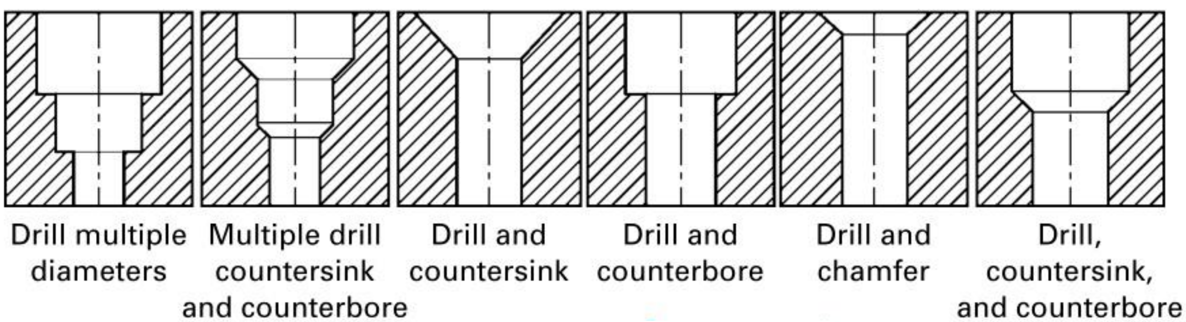


Figure 8.3: Various operations that can be performed on a Drilling Machine

Assignment:

a)Drilling can be done by a lathe machine but can turning be done by a drill machine?

b) What are degrees of freedom of a drill machine?

AHSANULLAH UNIVERSITY OF SCIENCE & TECHNOLOGY

Department of Mechanical and Production Engineering

ME 2102: Basic Thermodynamics Sessional
(Applied Thermodynamics Laboratory: 8B01)

List of the Experiments

1. Determination of Heating Value of Coal by Bomb Calorimeter
2. a) Analysis of Air using Orsat Gas Analyzer

   b) Flash Point and Fire point of Fuel (kerosene oil)
3. a) Study of Psychrometer and determination of humidity of air using Sling Psychrometer

   b) Calibration of a Pressure Gauge
4. Determination of Carbon Residue of an Oil (Conradson Method)

General Instructions

1. Attend to the lab 5 minutes prior to the scheduled time.
2. Sessional grade will be calculated in the following way:

a) Attendance	10%
b) Lab reports	20%
c) Viva	20%
d) Quiz (End of semester)	50%
Total	100%

3. Students must bring the necessary instruments, data sheet (for particular experiment), calculator, normal graph paper.
4. Report should be submitted in the following week during the sessional time.
5. Write report on one side of an 80 gms A4 paper and follow the following format
   a) Top sheet
   b) Objectives
   c) Apparatus (including technical specifications)
   d) Figure/Experimental Setup
   e) Data Sheets/Result
   f) Sample calculation
   g) Graphs
   h) Discussion
      i) Discuss the graphs and results
      ii) Discuss about the experimental setup if it could be improved
      iii) Discuss the different parameters that could affect the result
      iv) Discuss any assumption made
      v) Discuss any discrepancies in the experimental procedure and result
      vi) Discuss what you have learnt and the practical application of this knowledge

Experiment No.: 1
Determination of Heating Value of Coal by Bomb Calorimeter

Objectives:

To find the heating value of coal experimentally using a bomb calorimeter

Apparatus:

Bomb Calorimeter, Thermometer, Stop Watch, Analytic Balance, Fuse Wire, Water Container etc.

Description:

The so called bomb calorimeter is used to determine the heating value of fuel when burned at constant volume. The fuel whose heating values is desired is placed in the fuel pan (crucible). A coil of fine wire dips in the pan. The bomb is charged with oxygen under pressure. When an electric current is passed through the wire, it ignites the fuel. Surrounding the bomb is a bucket containing water to absorb the heat released as the fuel burn. The bomb has an outer jacket, and a dead-air space surrounds the bucket to minimize heat losses to the surroundings. Although the water in the bucket absorbs the major portion of the heat, this heat is not the heating value of the fuel, for the following reasons:

1. The bomb itself absorbs some heat
2. There is heat exchange with the outer jacket
3. The ignition wire liberates some energy
4. The product of combustion are not cooled to the original temperature
5. Because combustion takes place in oxygen, high temperature is attained resulting in the formation of nitric and sulfuring acid, which would not be formed in the normal combustion process.

It is true that the products of combustion are not cooled to the original temperature. However, the final and original temperatures are so close that the error is only a small fraction of 1%. Furthermore the error is almost entirely offset when the bomb is standardized. The "water equivalent" of the bomb is furnished by the manufacturer. This is the amount of water having the same thermal capacity as the bomb is furnished by the manufacturer. This is the amount of water having the same thermal capacity as the bomb and its bucket (empty). When there is a doubt about the validity of this value, the bomb should be standardized.

The exchange of heat with outer jacket is minimized by maintaining a minimum temperature difference between the two. Corrections are made for small amount of heat transfer which occurs due to radiation. Corrections are also made for the heat liberated by the ignition wire by determining the amount actually burned. In the absence of exact heating value to the fuse wire, a value of 2.3 cal/cm of wire may be used.

Operations:

1. Weigh the calorimeter bucket empty. Put into calorimeter 1900 gm of water, having a temperature of about 3°C below the temperature in the jacket (It is assumed that the jacket is at room temperature)
2. Make certain that interior of the bomb is clear. Clean up the holdes in the removable lining with those in the bomb. Place the lower half of the bomb in the iron plate holder.
3. Insert the tapered pin and its crucible holder.
4. Obtain a true sample of coal and place approximately 1 gm of coal in the crucible, weigh and place it in the bomb.
5. Select the proper type of fuse wire, measure the length and install it in the form of a coil. The coil should touch the coal but not the crucible.
6. Add a few drops (about 0.5 ml) of water at the bottom of the bomb to saturate the space. This will cause complete condensation of the water vapor of combustion and the heating value obtained will be the higher heating value.
7. Place the gasket in place making certain that there is no dirt present. Assemble the bomb and tighten the cap. Be careful not to spill the fuel out of the crucible by tipping or jarking the bomb.
8. Charge the bomb with oxygen to a pressure of approximately 300 psi. Open the charging valve very slowly to avoid blowing of coal from the crucible.
9. Immerse the bomb in water; preferably in a glass jar, to see whether there are any leaks. The bomb should be dried with a cloth and placed it in the bomb jacket. The thermometer and stirrer should be installed. The thermometer should be immersed in at least 3 inch. Of water and should not be no closer than ½ inch to the bomb.
10. Start the stirrer. After 3 to 4 min for temperature equalization of water in the bucket, take temperature readings every minute for 5 min. These temperature readings are required for calculating the heat exchange with the jacket.
11. Switch on the firing switch for an instant.
12. Record the temperature according to data sheet until the maximum temperature is reached. The observer of the thermometer must be alert, because a rapid temperature rise occurs shortly after firing occurs.
13. After reaching the maximum temperature, temperature should be read every minute for 5 min. These temperatures are required in accounting for the heat exchange with the jacket water.
14. Remove the bomb from calorimeter, release the gases, and disassemble bomb. Collect and measure the length of the fuse wire which remains.
15. When accurate results are required, the bomb should be washed with distilled water and the washing should be titrated to obtain the amount of acid formed.

Heat loss by radiation from the calorimeter is minimized by starting the determination with the water in the calorimeter enough below room temperature so that the final temperature after combustion will be slightly above room temperature. Thus the radiation from the room before ignition will tend to compensate that to the room after the temperature rise. Since an appreciable amount of time elapses before the rise in temperature is completed, there will be some heat transfer in spite of this precaution.

The Dickinson method of correction for radiation is prescribed by the ASTM. The rate of temperature change in degree per minute is determined over a 5 min. period just before ignition and again after ignition when the maximum temperature has been reached. The time of ignition (time a), the temperature at ignition, the thermometer reading taken when the temperature change has become uniform after attaining a maximum and the time at this maximum temperature (time c) are recorded. Time b is defined as the time at which six-tenths of the temperature rise from a to c has taken place. The ignition temperature is then corrected by adding (b-a).r_1, where r_1 is the rate in degrees per minute at which the temperature was rising before ignition. The final temperature is corrected by adding (c-b).r_2, where r_2 is the rate of temperature decrease after the maximum was reached. The temperature rise used for calculating the energy liberated is the difference between the corrected ignition and final temperatures. The corrected temperatures are to be indicated in figure.

Because a portion o the fuse wire will be found to have burnt to the oxide, a correction for the energy liberated by this reaction must be subtracted from the observed heating value of the sample. This is best accomplished by knowing the heat of combustion of the fuse wire per unit length and the length of the original and unburned portions of the wire.
When extreme accuracy is required, the ASTM test procedure should be consulted for the method to be used in correcting the observed heating value for the formation of HNO_3 and H_2SO_4.

Since the water vapor resulting from the combustion of hydrogen in the fuel sample is condensed because of the low bomb temperature, the heating value obtained is known as the higher heating is known as the higher heating value. The lower heating value is determined by subtracting from the higher heating value a quantity equal to the product of the weight of water vapor formed by combustion and the latent heat of vaporization of the water.

Calculations:

Temperature Rise

$$t = t_c - t_a - r_1(b - a) - r_2(c - b)$$

where,

- t = corrected temperature rise
- t_a = temperature at time of firing
- t_c = temperature at time, c
- r_1 = rate (temperature units per min.) at which temperature was rising during 5 min period before firing.
- r_2 = rate (temperature units per min.) at which temperature was falling during the 5 min period after time, c.

Temperature at time b, $t_b = t_a + 0.6\,(t_c - t_a)$

Heating value = Heat absorbed by calorimeter – Heat from fuse wire

$$= \frac{(1900+526)gm \times 1\frac{cal}{g℃} \times t - 2.3\frac{cal}{cm} \times 10\ cm}{m\ gm\ of\ fuel}$$

AHSANULLAH UNIVERSITY OF SCIENCE & TECHNOLOGY

ME 2102: Basic Thermodynamics Sessional

Experiment No.: 1
Name of the Experiment:
Determination of Heating Value of Coal by Bomb Calorimeter

Name of the student:
Student ID:
Date:

Data & Result Sheet

Calorimeter: Parr Oxygen Bomb Calorimeter
Manufactured by Parr Instrument Company
Moline, Illinois, USA

Weight of empty pan : __________ gm
Weight of pan + coal : __________ gm
Weight of coal : __________ gm
Weight of water : ____*1900*____ gm
Water equivalent of Calorimeter : ____*526*____ gm

Total length of fuse wire used: ____*10*____ cm
Length of remaining fuse wire: __________ cm
Fuse wire actually burnt : __________ cm
Calorimeter value of fuse Wire : ____*2.3*____ cal/cm
Room Temperature : __________ ºC

Time (min.)	Thermometer Reading °C	Time (min.)	Thermometer Reading °C
0		8:30	
1		9	
2		9:30	
3		10	
4		10:30	
5 (Ignition)		11	
5:15		12	
5:30		13	
5:45		14	
6		15	
6:15		16	
6:30		17	
6:45		18	
7		19	
7:15		20	
7:30		21	
7:45		22	
8		23	

Calorific value of coal : ______________________________ cal/gm
______________________________ Btu/lb

Experiment No.: 2(a)
Analysis of Air using Orsat Gas Analyzer

Objectives:

To analyze the air from surrounding using the Orsat apparatus.

Apparatus:

As shown in figure, the Orsat apparatus consists of a water-jacketed 100m1 burette B connected at its top to a glass manifold M and at its bottom to a leveling bottle L. The glass manifold M is connected to three reagent bulbs called pipettes P_1, P_2 and P_3 via three cocks C_1, C_2 and C_3. Each tube is filed with its own absorbing chemical solution:

P_1: potassium hydroxide (30 % w/v) to absorb CO_2
P_2: alkaline pyrogallol to absorb 0_2
P_3: cuprous chloride in hydrochloric acid to absorb CO.

Pipettes P_1 and P_2 are partly filled with glass tubes to increase the contact surface area between liquid and glass. P_3 contains copper wire to protect acid against possible oxidation. The 3-way cock C_4 is used to connect manifold M to the atmosphere (via suction pump SP), to connect it to the sampler tube or to isolate the trapped gas.

Procedure:

a) <u>Trapping the Gas Sample</u>
-By turning the cock C_4 connect the glass manifold M to the sampler line.
-Lower bottle L slowly until the water level in burette B is slightly below the zero mark on the scale. Then close C4 and disconnect the sampler line.
-Slightly lift cock C_4 off its seat to equalize the pressure inside burette B with the ambient pressure. Then raise bottle L gently until water level in the burette coincides with the zero mark. This ensures that the burette now contains 100 ml of exhaust gas at atmospheric pressure.

b) <u>Absorption of Gas Constituents</u>
The following steps should be done for each pipette, one at a time, in the order P_1 then P_2 then P_3.
-Open cock C_1, and slowly raise bottle L to allow the gas to flow into pipette P_1 until water in the pipette reaches the (100)-mark.
-Slowly lower bottle L to let gas leave pipette P_1 and re-enter burette B until the chemical solution in pipette P_1 reaches the top mark on its stem. Close C_1.
-Bring the levels of water in burette B and bottle L to coincide. Read the scale on burette B to get the volume of CO_2 absorbed, measured at atmospheric pressure.
-Repeat this procedure a few times until the reading becomes constant which means that all CO_2 has been absorbed. Then close cock C_1.
-For the next pipettes, the volume absorbed is obtained as the difference between the current scale reading and the one just preceding it.

AHSANULLAH UNIVERSITY OF SCIENCE & TECHNOLOGY

ME 2102: Basic Thermodynamics Sessional

Experiment No.: **2**(a)
Name of the Experiment: **Analysis of Air using Orsat Gas Analyzer**

Name of the student:
Student ID:
Date:

Data & Result Sheet

Ambient Conditions: P_A=______ KPa, T_A= ______ ^OC

Zero Reading R_o = _______ ml → V_{sample}= 100 – R_o =

CO_2 Reading R_{CO2} = _______ ml → V_{CO2}= R_{CO2} – R_o =

O_2 Reading R_{O2} = _______ ml → V_{O2}= R_{O2} – R_{CO2} =

CO Reading R_{CO} = _______ ml → V_{CO}= R_{CO} – R_{O2} =

Volume of Nitrogen → V_{N2}= 100 – R_{N2} =

____
Teacher's Signature

Experiment No.: 3(a)
Study of Psychrometer and determination of humidity of air using Sling Psychrometer

Objectives:
To find relative humidity, absolute humidity, dew point and enthalpy of air using psychrometer and psychrometric chart.

Procedure:
The sling psychrometer is used to determine the humidity of air. This instrument has two similar thermometer mounted on a frame, one to read dry bulb temperature and the other wet-bulb temperature. The bulb of the wet bulb thermometer is covered with a wick wetted with distilled water. The thermometer and wetted wick is whirled in the air, the water evaporate into the surrounding unsaturated air, causing the general conditions around the wet thermometer bulb to be similar to. and closely approximate to, those of adiabatic saturation. After sufficient whirling the thermometer reach equilibrium conditions. The both temperature should be read quickly in order to get dependable readings.

The sling psychrometer should be rotated at a speed of 10 to 15 fps or 100 to 200 rpm. It is important that clean wawter should be used, since the slightest trace of oil on the wick cause errors. The wick should be kept fully wet when reading are being made.

Definition of Different Terms:
Absolute Humidity

This is the ratio of the mass of water vapor to the mass of dry air in a given volume of the mixture.

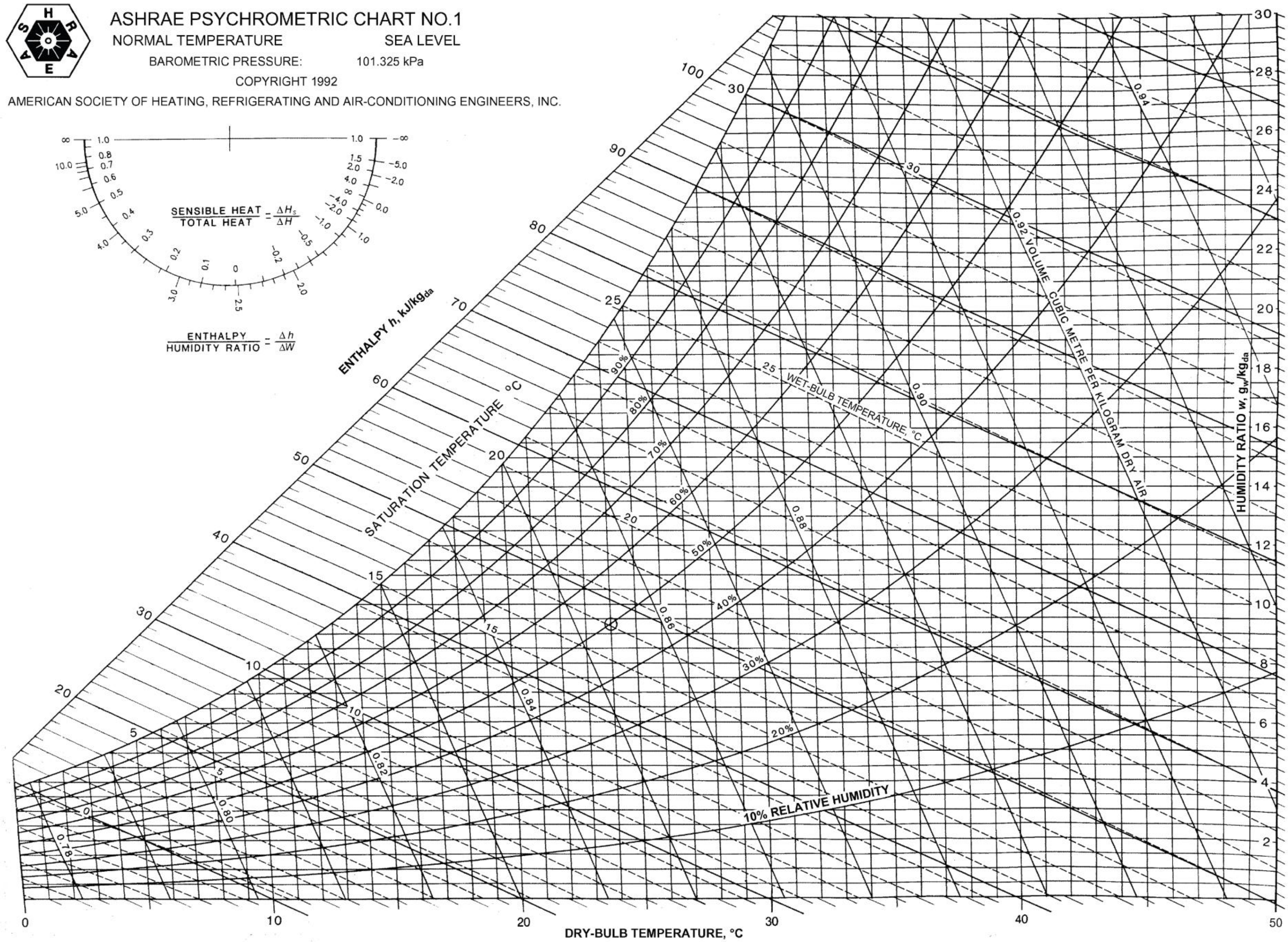
Relative Humidity

This is the ratio of the actual water vapor pressure in the air to the vapor pressure which would exist in a saturated mixture at the temperature of the air.

Dew Point Temperature

The temperature at which the water vapor in the air is saturated.

Operations:
1. Wet the wick of the wet bulb thermometer and whirl the psychrometer for about a minute.
2. Note the reading of the wet bulb thermometer quickly with the help of a magnifying glass. Then read the dry bulb temperature. This will correspond to thermometer temperature.
3. Located the point on the psychrometeric chart which corresponds to the measured dbt and wbt.
4. Find (i) Relative Humidity (ii) Absolute Humidity (iii) Dew Point and (iv) Enthalpy using the psychrometric chart.


ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
COPYRIGHT 1992
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔH
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY h, kJ/kgda
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
10% RELATIVE HUMIDITY
HUMIDITY RATIO w, gw/kgda
DRY-BULB TEMPERATURE, °C

AHSANULLAH UNIVERSITY OF SCIENCE & TECHNOLOGY

ME 2102: Basic Thermodynamics Sessional

Experiment No.: 3
Name of the Experiment:
Study of Psychrometer and determination of humidity of air using Sling Psychrometer

Name of the student:
Student ID:
Date:

Data Sheet

Wet Bulb Temperature	: ______________	ºC
Dry Bulb Temperature	: ______________	ºC
Relative Humidity	: ______________	%
Absolute Humidity	: ______________	kg_w/kg_{da}
Dew Point Temperature	: ______________	ºC
Enthalpy	: ______________	kJ/Kg

____

Teacher's Signature

Experiment 2(b)

Flash Point and Fire point of Fuel (kerosene oil)

Introduction:

Flash Point:

The **flash point** of a volatile material is the lowest temperature at which it can vaporize to form an ignitable mixture in air.

Measuring a flash point requires an ignition source. At the flash point, the vapor may cease to burn when the source of ignition is removed.

The flash point is not to be confused with the auto ignition temperature, which does not require an ignition source, or the fire point, the temperature at which the vapor continues to burn after being ignited. Neither the flash point nor the fire point is dependent on the temperature of the ignition source, which is much higher.

The flash point is often used as a descriptive characteristic of liquid fuel, and it is also used to help characterize the fire hazards of liquids. “Flash point” refers to both flammable liquids and combustible liquids. There are various standards for defining each term. Liquids with a flash point less than 60.5 or 37.8 °C (140.9 or 100.0 °F) — depending upon the standard being applied — are considered flammable, while liquids with a flash point above those temperatures are considered combustible.

Fire Point:

The **fire point** of a fuel is the temperature at which it will continue to burn for at least 5 seconds after ignition by an open flame.

At the flash point, a lower temperature, a substance will ignite briefly, but vapor might not be produced at a rate to sustain the fire. Most tables of material properties will only list material flash points, but in general the fire points can be assumed to be about 10 °C higher than the flash points. However, this is no substitute for testing if the fire point is safety critical. It is done by open cup apparatus

Experimental setup:

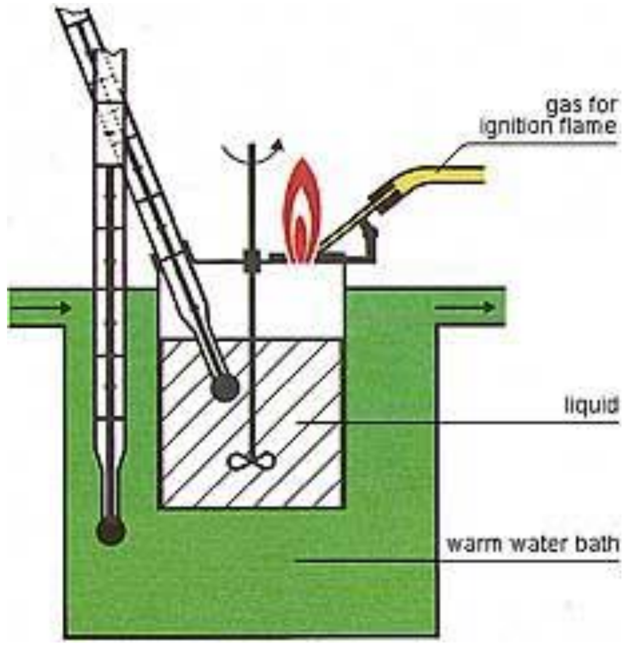


Fig: Experimental set up of fire and flash point apparatus

Experiment procedure:

1. First measure 60ml of kerosene
2. Set the two thermometer to measure the temperature of oil bath and the temperature of kerosene
3. Light the pilot light on the cover and adjust the same flame to size the of a small white bead by means of regulating the valve on the gas hose connection.
4. Switch on the electric heater.
5. Take the temperature readings of the oil bath and kerosene after every 5 minutes.
6. Every time after the temperature reading, open the cover over the kerosene oil and place the pilot light at the top.
7. If you find a flash of fire inside the bath of kerosene oil. It is the flash point of kerosene. Note down the flash point.
8. For some more temperature, it is expected to get the flash point. It is just the band of flash point.
9. After more continuous heating at one temperature, we will get the fire point where the fire inside the kerosene bath exists for some time. It is the fire point. Note down the fire point temperature.
10. For some more temperature, it is expected to get the fire point. It is just the band of fire point.

Result

Flash Point:

Band of Flash point:

Fire Point:

Experiment No.: 4
Determination of Carbon Residue of Oil (Conradson Method)

Objective:
To determination of carbon residue of High Speed Diesel Oil

Summary of the Conradson Method:
A weighed quantity of oil sample is placed in a crucible and subjected to destructive distillation. The residue undergoes cracking and cooking reactions during a fixed period of severe heating. At the end of the specified heating period the test crucible containing the carbonaceous residue is cooled in a desiccator and weighed. The residue remaining is calculated as a percentage of the original sample and reported as **Conradson carbon residue.**

Apparatus:
- Porcelain Crucible
- Skidmore Iron Crucible
- Spun Sheet Iron Crucible
- Wire Support (Triangle of bare Nichrome wire)
- Circular Sheet Iron Hood
- Insulator (Ceramic block/ refractory ring)
- Burner

Working Procedure:
1. Weigh to the nearest 10 mg sample of the oil to be tested, free of moisture and other suspended matters into a tarred porcelain crucible containing two glass beads about 0.1 inch in diameter. Place the crucible in the center of the skidmore crucible. Level the sand in the large sheet iron crucible and set the skidmore crucible on it in the exact center of the iron crucible.

2. Apply cover to both the skidmore and the iron crucible, the one on the latter fitting loosely to allow free exit to the vapors as formed.

3. On a suitable stand or, ring, place the bare Nichrome wire triangle and on it the insulator. Next, center the sheet iron crucible in the insulator with its bottom resting on top of the triangle, and cover the whole with the sheet iron hood in order to distribute the heat uniformly during the process.

4. Apply heat with a high strong flame from the gas burner. So the precognition period will be 10 ± 1.0 min (a shorter time may start the distillation so rapidly as to cause foaming or too high a flame). When smoke appears above the chimney, immediately move or, tilt the burner so that the gas flame plays on the sides of the crucible for the purpose of igniting the vapors. Then

remove the heat temporarily and before replacing adjust by screwing down the pinch cock on the gas tubing so that the ignited vapors burn uniformly with the flame above the chimney but not above the wire bridge. The period of burning the vapors shall be 10.0 to 12.0 min. If it is found impossible to meet the requirements for both flame and burning time, the requirements for burning time is the more important.

5. When the vapor ceases to burn and no further blue smoke can be observed, readjust the burner and held the heat as at the sheet iron crucible a cherry red and maintain for exactly 7.0 min. The total period of heating shall be 30$\pm$2.0 min. which constitutes as additional limitation on the tolerances for the pre-ignition and burning periods. There should be no difficulty in carrying out the test exactly as directed with the gas burner of the type named using city gas (about 550 Btu) with top of the burner about 2 in below the bottom of the crucible. The time periods shall be observed with whatever burner and gas is used.

6. Remove the burner and allow the apparatus to cool until no smoke appears and then remove the cover of the skidmore crucible (about 15.0 min). Then remove the porcelain or, silica crucible with heated tongs, place in the desiccator, cool and weigh. Calculate the percentage of carbon residue on the original sample.

AHSANULLAH UNIVERSITY OF SCIENCE & TECHNOLOGY

ME 2102: Basic Thermodynamics Sessional

Experiment No.: 4
Name of the Experiment:
Determination of Carbon Residue of Oil (Conradson Method)

Datasheet

Name of the student:
Student ID:
Date:

Weight of the empty crucible = ________________________ gms

Weight of crucible + Weight of oil, W_1 = ________________________ gms

Weight of the oil, M = ________________________ gms

Weight of crucible + carbon residue, W_2 = ________________________ gms

Loss of oil, $X = (W_1 - W_2)$ gms = ________________________ gms

Carbon residue, $A = (M - X)$ gms = ________________________ gms

Percentage of carbon residue = $(A/M) \times 100$ = _______________ %

____
Teacher's Signature

Experiment 5

CALIBRATION OF A PRESSURE GAUGE

Introduction

Many types of gauge are available for measurement of pressure. The most simple form is a manometer tube, in which the rise of level of a liquid indicates the static head, this being converted to pressure by multiplying by the liquid density. An example of a much more sophisticated instrument is a pressure transducer, in which the pressure is used to deflect a diaphragm. The deflection causes an electrical signal to be generated by some means such as an electric resistance strain gauge, and this signal is displayed, typically in digital form, as the corresponding pressure. The response is rapid, being typically 1 ms, and the display can be remote from the point of measurement. The Bourdon gauge (named after its inventor Eugene Bourdon) uses the deflection of a tube of oval cross-section to cause a pointer to move over a scale. Its response time is therefore long, being of the order of 1 second. Moreover, the distance between the measuring point and the gauge is limited by the practicable length of the capillary line connecting the gauge to the sensing point. Nevertheless, because of its simplicity and low cost, and the large selection of pressure ranges which are available, the Bourdon gauge is widely used in engineering practice. All pressure gauges, of whatever type, need to be calibrated. If the required accuracy is low, then a standard calibration obtained from a sample of the particular model will suffice. For higher accuracy, a manufacturer will take special care and will supply a calibration certificate for an individual gauge. As the calibration may change over a period, repeat calibrations will be needed from time to time. For the highest accuracy. transducers and gauges are sometimes calibrated before each use. The normal calibration procedure is to load the gauge with known pressures using a dead weight tester using oil. The present experiment, however, works satisfactorily with water instead of oil.

Description of apparatus

The Bourdon pressure gauge shown in Fig 3.1 has a transparent dial through which the construction may be viewed. It consists essentially of a thin-walled tube of oval cross-section. which is bent to a circular arc encompassing approximately 270°. It is rigidly held at one end. where the pressure is admitted. The other end is free to move

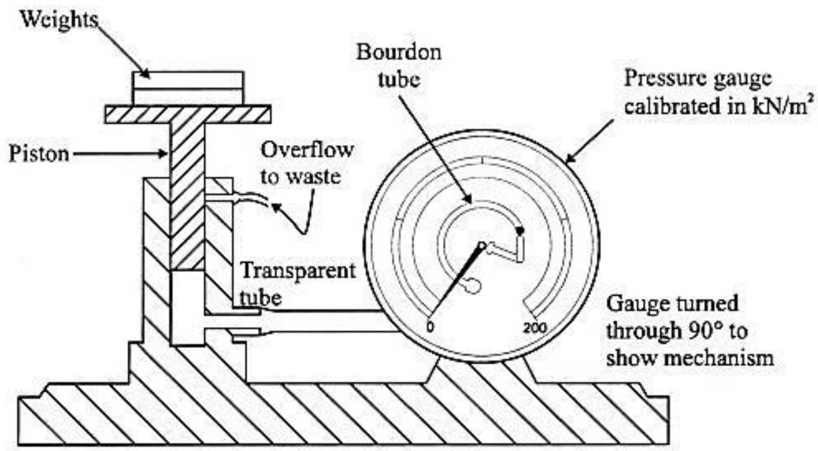


Fig 3.1 Apparatus for calibration of pressure gauge

and is sealed. When pressure is applied, the tube tends to straighten, so that the free end moves slightly. This movement operates a mechanism which drives a pointer round the graduated dial, the movement of the pointer being proportional to the applied pressure. The construction of the dead weight tester is also shown in Fig 3.1. A cylindrical piston. free to move vertically in a closely-fitting cylinder, is loaded with known weights. The space below the piston is filled with water, and the pressure is transmitted by the water to the gauge under test through a transparent hose. The pressure generated by the piston is easily found in terms of the total weight supported and the cross-sectional area of the piston.

Pressure gauge calibrated in kN/m2.

Procedure

The weight of the piston. and its cross-sectional area, should be noted. To fill the cylinder, the piston is removed, and water is poured into the cylinder until it is full to the overflow level. Any air trapped in the tube may be cleared by tilting and gently tapping the apparatus. In point of fact, a small amount of air left in the system will not affect the experiment, unless there is so much as to cause the piston to bottom on the base of the cylinder. The piston is then replaced in the cylinder and allowed to settle. A spirit level placed on the platform at the top of the piston may be used to ensure that the cylinder stands quite vertically.

Weights are now added in convenient increments, and at each increment the pressure gauge reading is observed. A similar set of results is then taken with decreasing weights. To guard against the piston sticking in the cylinder, it is advisable to rotate the piston gently while the pressure gauge is being read.

Calculation and Results:

Weight of piston =1 kg =9.81 N

Cross-sectional area =333 mm^2 = O.333e-3 m

Table 3.1 True pressures and gauge readings

Total Load including Piston Weight		True Pressure (KN/m^2)	Gauge Reading	
Kgf	N		Increasing Pressure (KN/m^2)	Decreasing Pressure (KN/m^2)

Discussions:

1. What suggestions have you for improving the apparatus?
2. No correction has been made for the difference in elevation of the piston of the dead weight tester and of the pressure gauge. If the center of the gauge were 200 mm higher than the base of the piston. Should a correction be made, and if so. how big would it be?
3. What alterations would you make to the dimensions of the piston if it were? Desired to calibrate a gauge with a full scale reading of 3500 kN/m^2 using the same weights?

Ahsanullah University of Science and Technology

Department of Electrical and Electronic Engineering

LABORATORY MANUAL

FOR

ELECTRICAL AND ELECTRONIC SESSIONAL COURSES

Student Name :

Student ID :

Course no : EEE-2188

Course Title : Electrical Machines

For the students of

Department of Mechanical and Production Engineering

2nd Year, 1st Semester

Experiment no: **1**
Experiment name: **Study of a Single-Phase Transformer.**

Introduction:

A transformer is a static device by means of which electric power in one circuit is transferred into electric power in another circuit of the same frequency. It can raise or lower voltage in the circuit with a corresponding decrease or increase in current. So the volt-ampere rating of two circuits remains same. The simple structure of a 1-ϕ transformer is shown below:

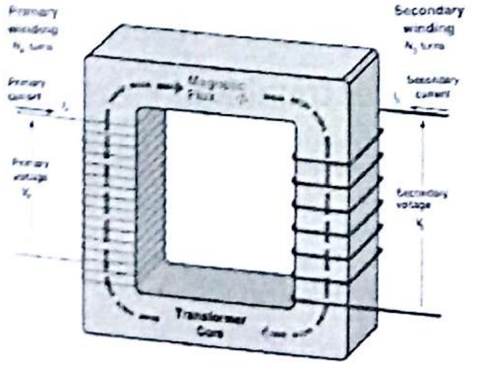


Fig: Simple structure of a 1-ϕ transformer

As the volt-ampere rating of two sides are same so

$$V_1 * I_1 = V_2 * I_2$$

$$\text{i.e. } V_1/V_2 = I_2/I_1 \text{ ....(1)}$$

Again the induced voltage in the transformer is directly proportional to the no of turns surrounding the transformer windings. So

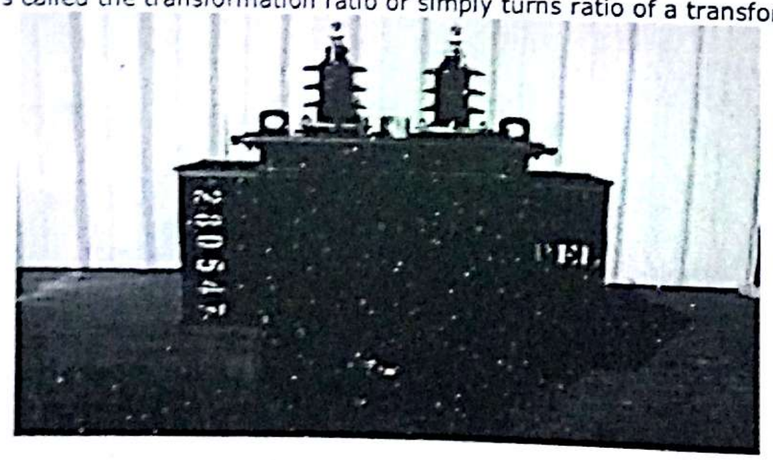
$$V_1 \propto N_1 \quad \text{and} \quad V_2 \propto N_2$$

$$\text{i.e. } V_1/V_2 = N_1/N_2 \text{ ---------- (2)}$$

Combining these two equations, (1) and (2) we get

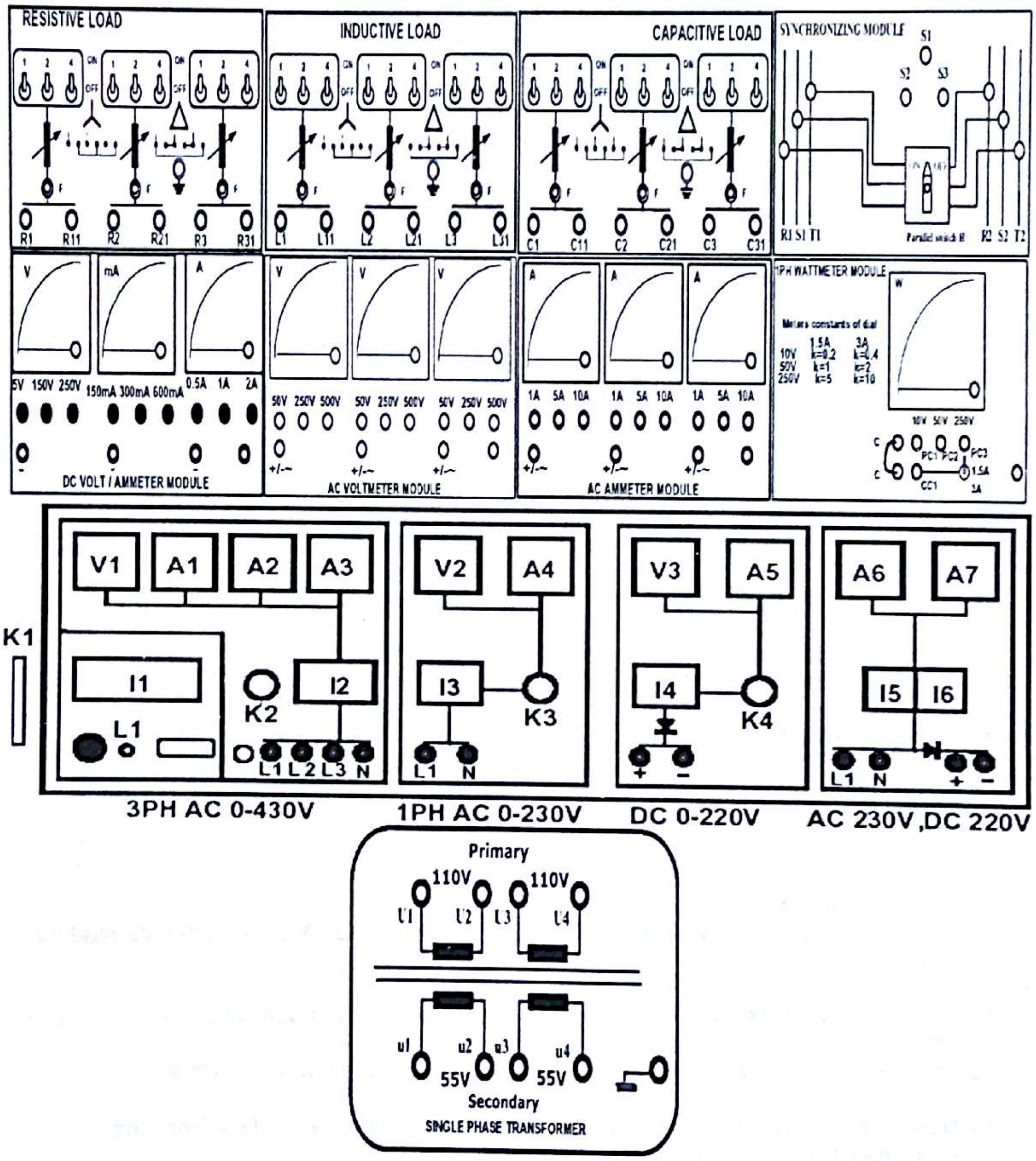
$$V_1/V_2 = I_2/I_1 = N_1/N_2$$

Where N_1/N_2 is called the transformation ratio or simply turns ratio of a transformer



Equipments:

1. Universal Power Supply Module
2. 1PH Transformer
3. AC Ammeter Module 0-1A
4. AC Voltmeter Module 0-250 V
5. Resistive Load
6. 1PH Wattmeter Module

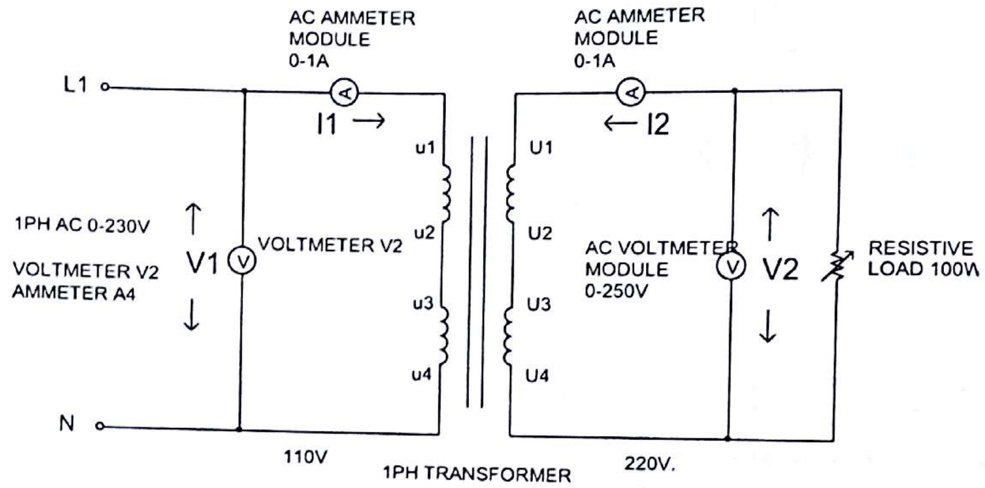


Ratio Test:

For a transformer, we know, the transformation ratio is given by

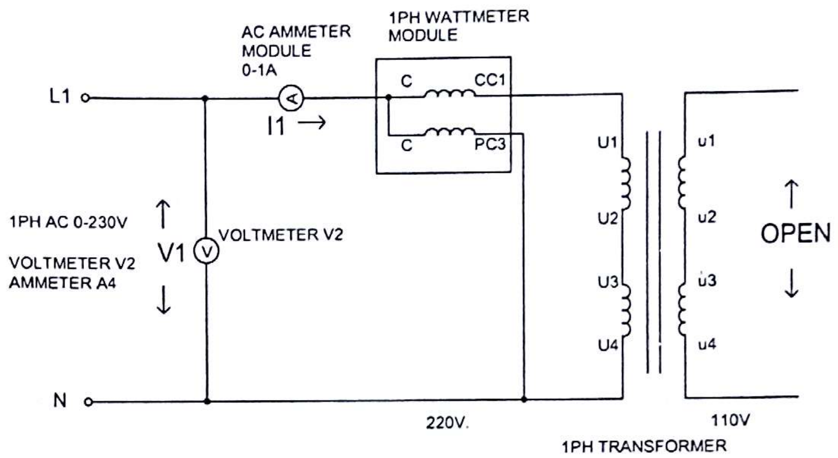
$$\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

We shall determine the transformation ratio by measuring the voltages and currents both in the primary and secondary side.



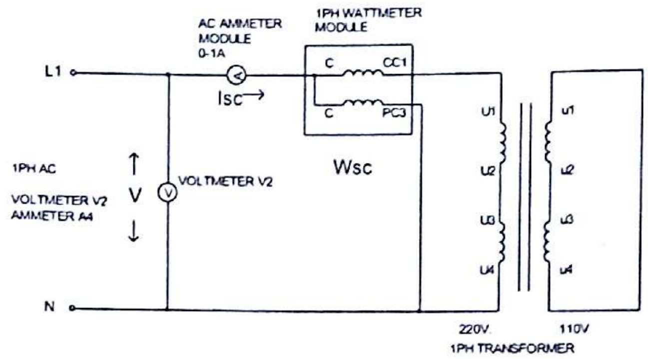
1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. Make sure all the switches (1,2,4) of the Resistive Load Module are OFF (downwards)
4. Make connections according to the above diagram.
5. Verify the connection by your Lab Teacher
6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
8. Make sure the 3PH supply Voltmeter V1 reading 400V.
9. Turn Knob K3 at min (CCW)
10. Turn ON switch I3 (upwards).
11. Slowly Increase 1PH AC Voltage to 110V, Turn Knob K3 CW, Voltmeter V2 reading 110V
12. Increase the Resistive Load by turning ON the switches (1,2,4) of the Resistive Load Module.
13. Increase Load until the current becomes 0.5A, so that power >= 100W
14. Note the voltages and currents both in the primary and secondary from the AC Voltmeter & Ammeter Module

Transformer on No-load/Open Circuit Test:



1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher
5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
7. Make sure the 3PH supply Voltmeter V1 reading 400V.
8. Turn Knob K3 at min (CCW)
9. Turn ON switch I3 (upwards).
10. Slowly Increase 1PH AC Voltage to 220V, Turn Knob K3 CW, Voltmeter V2 reading 220V
11. Note the voltages and currents in the primary from the AC Voltmeter & Ammeter Module

Short Circuit Test: This test determines copper loss in the transformer. Finding this loss the regulation of the transformer can be determined. The circuit arrangement of this test is shown below:



From the wattmeter, voltmeter, ammeter readings, we get

$$W_{CU} = W_{SC} = R_{01} * I_{SC}^2 \quad \text{i.e.} R_{01} = W_{SC}/I_{SC}^2$$

$$X_{01} = \sqrt{((V/I_{SC})^2 - R_{01}^2)}$$

Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.
3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher
5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
7. Turn Knob K3 at min (CCW)
8. Turn ON switch I3 (upwards).
9. **Carefully increase the voltage till the rated current (300VA ÷ 220V = 1.4A) flows through the HT, Turn Knob K3 CW**
10. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module

***** For each case write down the data on data sheet.**

Report:

1. What effects are produced in a transformer by change in voltage?
2. Does the transformer draw any current when its secondary is open? If yes, then why?

Group No: **Roll no:**

Data Sheet

Ratio test:

V_1 = V_2 = I_1 = I_2 =

Calculate Transformation ratio:

Transformer on No-load:

I_{OC} = V_{OC} = W_{OC} =

Short Circuit Test

I_{SC} = V_{SC} = W_{SC} =

Calculation

Core loss = W_{OC} =

$\Phi_0 =$

$I_W = I_{OC} \cos\Phi_0 =$

$I\mu = I_{OC} \sin\Phi_0 =$

Core resistance (ref. to H.T. side) = $\dfrac{V_{OC}}{I_W}$ =

Core reactance (ref. to H.T. side) = $\dfrac{V_{OC}}{I_\mu}$ =

Copper loss = $W_{Cu} = W_{SC}$ =

Equivalent Resistance (ref. to H.T. side) = $R_{01} = \dfrac{W_{SC}}{I_{SC}^2}$ =

Equivalent Reactance (ref. to H.T. side) = $X_{01} = \sqrt{(V_{SC}/I_{SC})^2 - R_{01}^2}$

Signature of the Lab teacher:

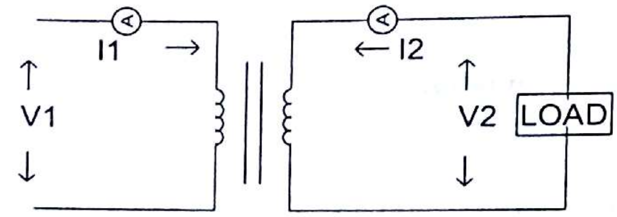
Experiment no: **2**

Experiment name: **To determine the regulation of a transformer under different power factor for both Single and Three phase Transformer.**

Introduction:

Regulation is an indication of voltage changes due to change in load. Any equipment is said to have good regulation if this change of voltage is less. It is defined as

$$\%R = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

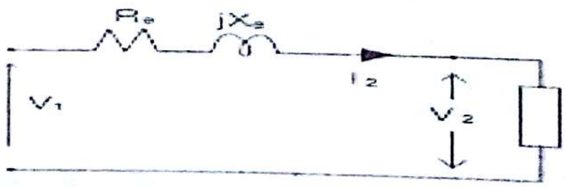


1PH TRANSFORMER

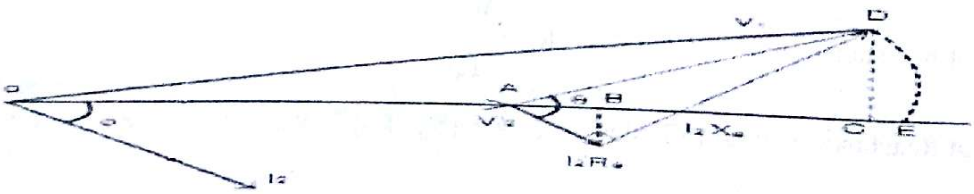
For a transformer, for constant primary voltage as load increases, the voltage at the load decreases, as there is voltage drop due to internal resistance and reactance of the transformer. If we know the resistance and reactance of the transformer, its regulation can be determined under various load conditions.

Equipments:

1. Universal Power Supply Module
2. 1PH Transformer
3. AC Ammeter Module 0-1A
4. AC Voltmeter Module 0-250 V
5. 1PH Wattmeter Module
6. Resistive Load Module
7. Inductive Load Module
8. Capacitive Load Module
9. Connecting Cables

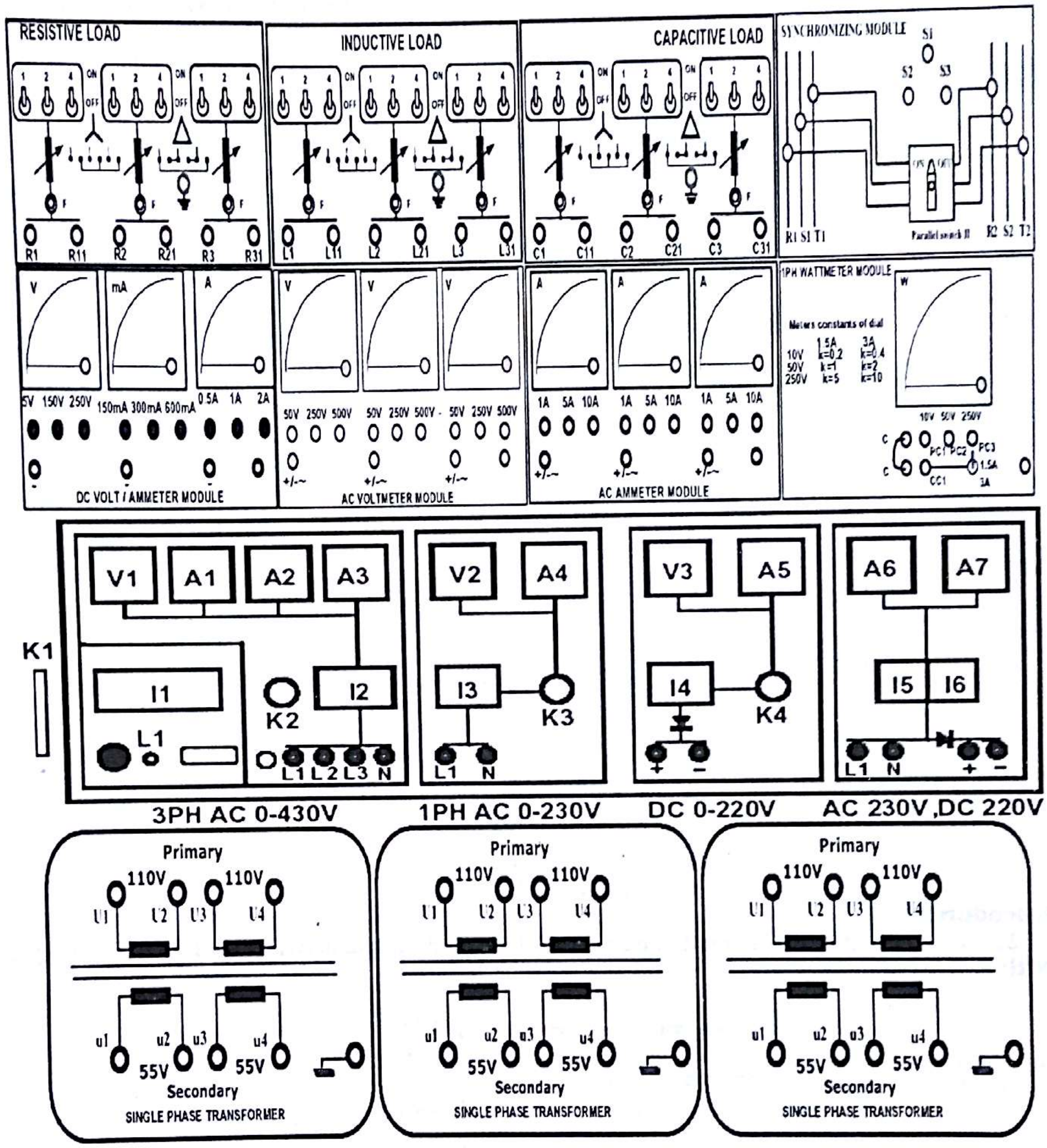


(a) Equivalent Circuit



(b) Phasor Diagram

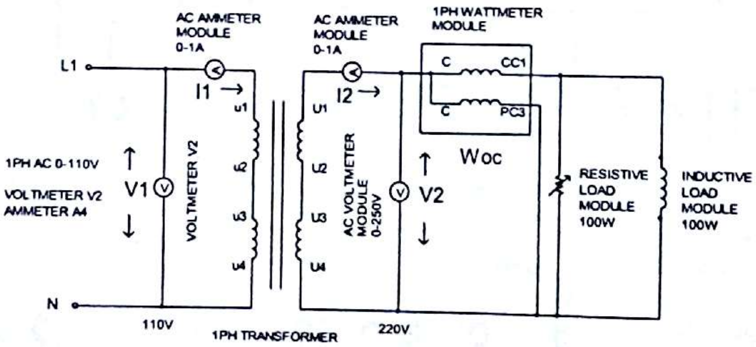
Connection Diagram:



Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.
3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher
5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
7. Turn Knob K3 at min (CCW)
8. Turn ON switch I3 (upwards).
9. Keep all the Loads at OFF position
10. Apply voltage **110V** on the LT side.
11. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module
12. Now turn ON all the Loads
13. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module

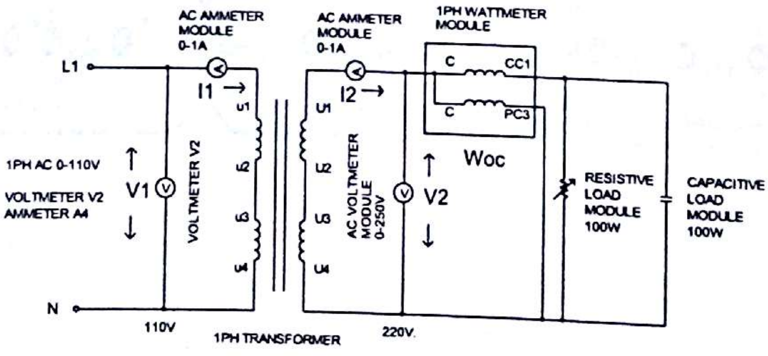
With R-L Load:



Procedure:

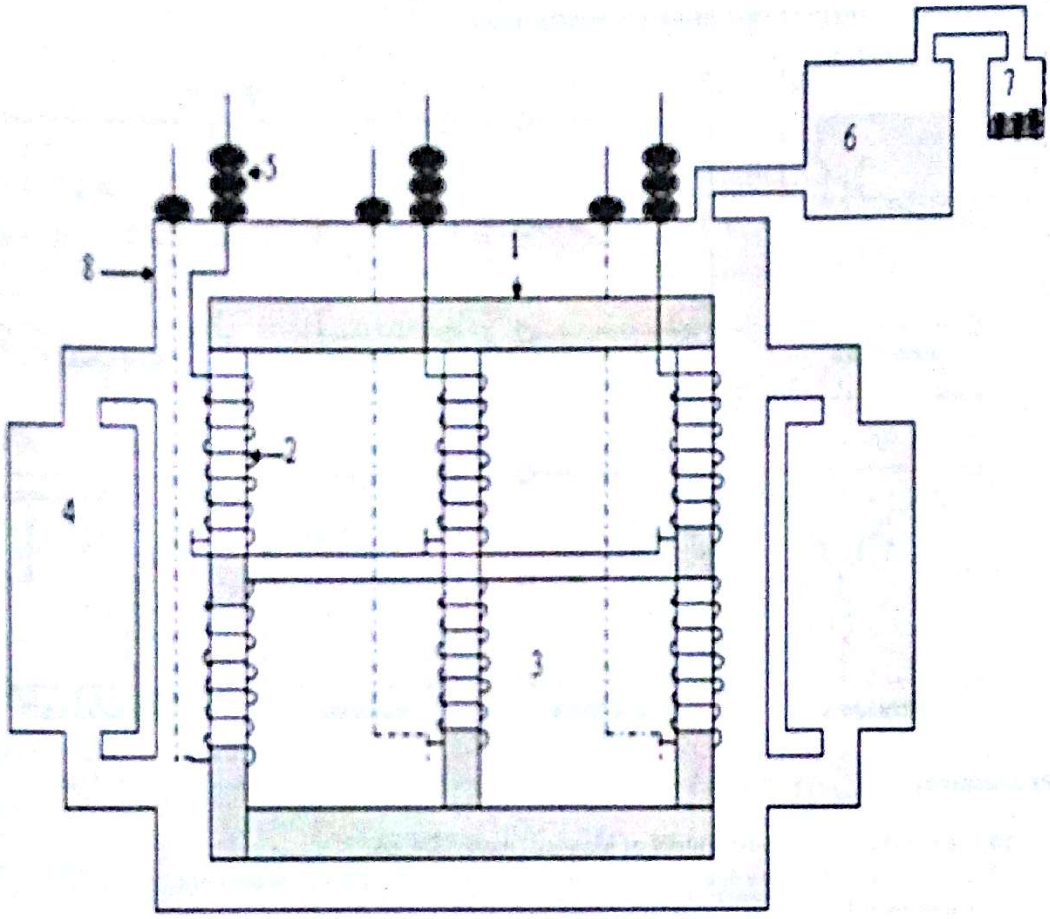
1. Follow the procedure mentioned on Resistive Load for the above Diagram

With R-C Load:



Procedure:

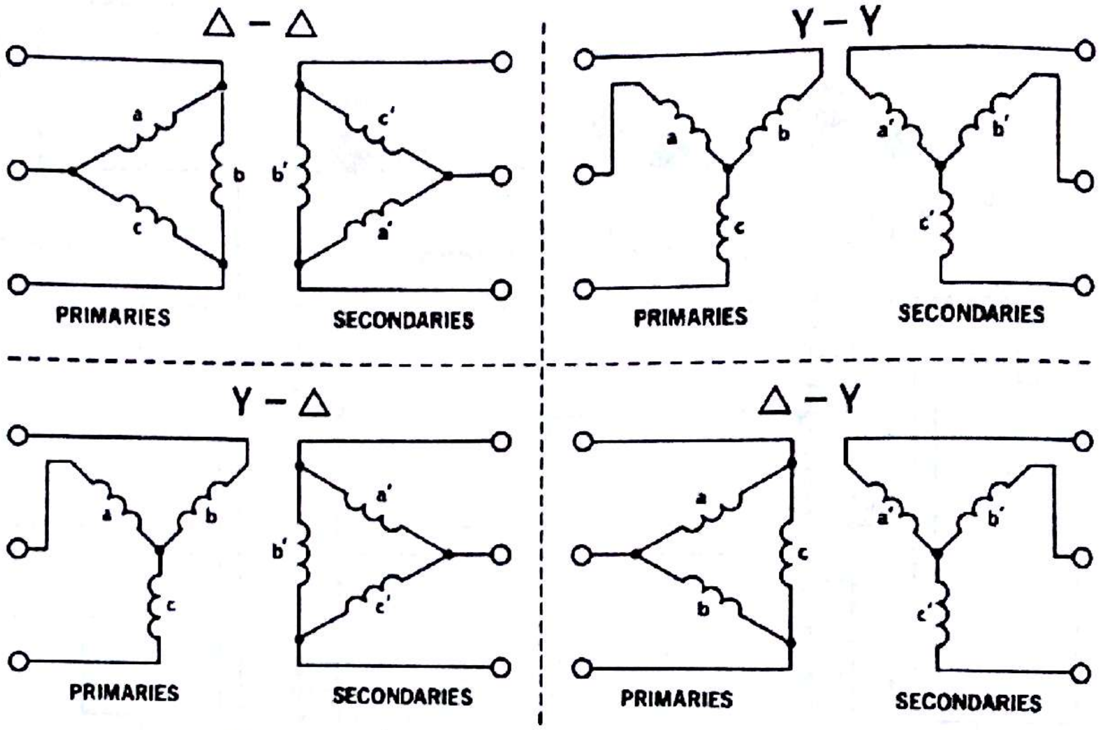
1. Follow the procedure mentioned on Resistive Load for the above Diagram



Important parts of a three-phase transformer

1. **Core**- Core is made by laminated silicon steel
2. **Coil**- Coil(winding) is simply made by insulated copper wire
3. **Transformer oil (mineral oil)** - Transformer oil has two functions one is to provide necessary insulation for the core and coli and other one is to absorb the heat produce by the power loss of transformer.
4. **Fin**- Cooling system for heated transformer oil.
5. **Bushing**- Bushing is used to connect the coils (primary and secondary) to the outer circuit for rigid fitting and avoiding the contact with transformer tank.
6. **Conservator**- Conservator holds the excess oil when the oil gets expanded.
7. **Breather with Silica gel**- Breather is used to pass the air inward and outward of a transformer through conservator and silica gel absorb the moisture of air.
8. **Transformer tank**- Transformer tank houses core, coil and oil.

Connection to form three-phase transformer:



Procedure:

14. Select three 1-ϕ transformers of identical manufacturer.
15. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
16. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.
17. Make connections according to the above diagram.
18. Verify the connection by your Lab Teacher
19. Now verify the advantages for each type of combination.
20. Keep all the Loads at OFF position
21. Apply voltage **110V** on the LT side.
22. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module.
23. Now turn ON all the Loads.
24. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module.

With constant resistive load determine the efficiency for each combination.

Report:

Draw the vector diagrams under unity, lagging and leading pf and calculate analytically the regulation in each case. Compare the value of regulation found analytically with that of experimental value.

Comment on the regulation under leading pf is it something different? Comment on this value.

Group No:
Roll no:

Data Sheet

With Resistive Load
Terminal Voltage = Load current = Load power =
With R-L Load
Terminal Voltage = Load current = Load power =
With R-C Load
Terminal Voltage = Load current = Load power =

With Δ-Δ connection

With Resistive Load
Terminal Voltage = Load current = Load power =
With R-L Load
Terminal Voltage = Load current = Load power =
With R-C Load
Terminal Voltage = Load current = Load power =

With Y Y connection

With Resistive Load
Terminal Voltage = Load current = Load power =
With R-L Load
Terminal Voltage = Load current = Load power =
With R-C Load
Terminal Voltage = Load current = Load power =

With Y-Δ connection

With Resistive Load
Terminal Voltage = Load current = Load power =
With R-L Load
Terminal Voltage = Load current = Load power =
With R-C Load
Terminal Voltage = Load current = Load power =

With Δ-Y connection

With Resistive Load
Terminal Voltage = Load current = Load power =
With R-L Load
Terminal Voltage = Load current = Load power =
With R-C Load
Terminal Voltage = Load current = Load power =

Signature of the lab Teacher

Experiment no: **3**
Experiment name: **Open Circuit Characteristics (OCC) Of Separately- Excited Shunt Generator**

Introduction:
In this type of generator, the field coil is energized from an independent external DC source. The circuit diagram of a separately excited shunt generator is shown below:

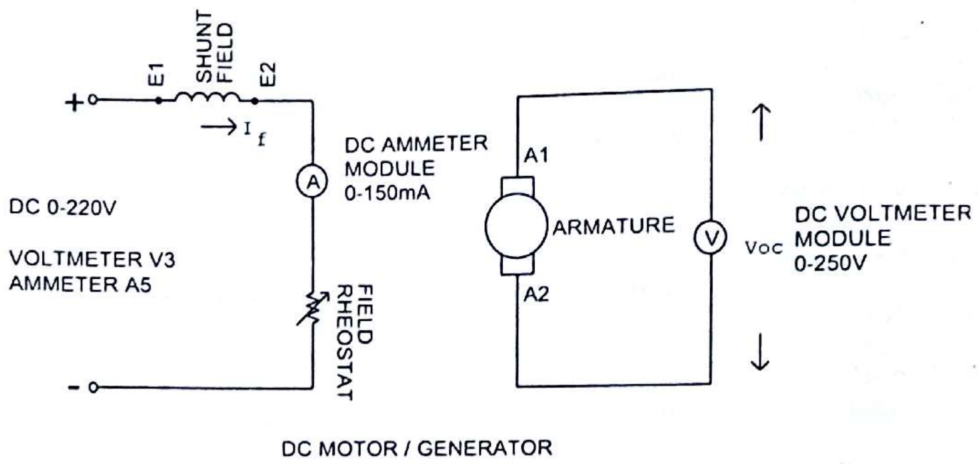


Fig: Separately Excited Shunt Generator

Voltage developed in the DC generator in general form,
$E_G = \phi ZN/60 * (P/A)$ **volt**
Where, E_G = Generated Emf.
ϕ = Flux/pole in Weber.
Z = Total no of armature conductors.
N = Armature rotation in rpm.
P = No of generator poles.
A = No of parallel paths in armature.

For a given D.C machine Z, P, A are constant. So the voltage equation becomes
$E_G = K_g \phi N$ **volt**, Where $K_g = ZP/(60*A)$

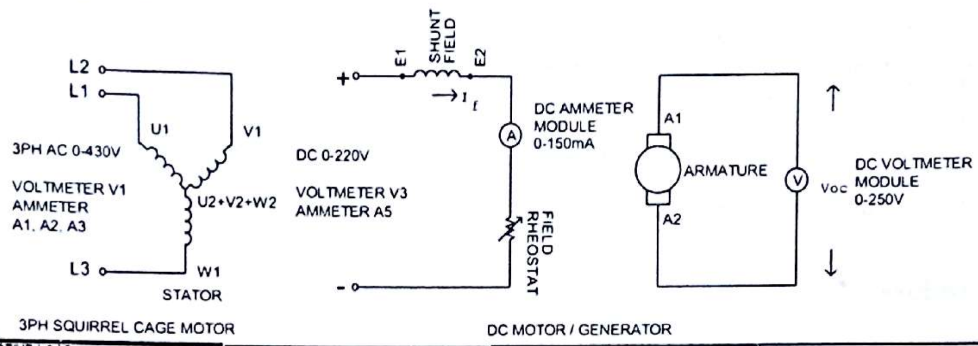
If armature rotation is constant, then $E_G = K\phi$ **volt.**

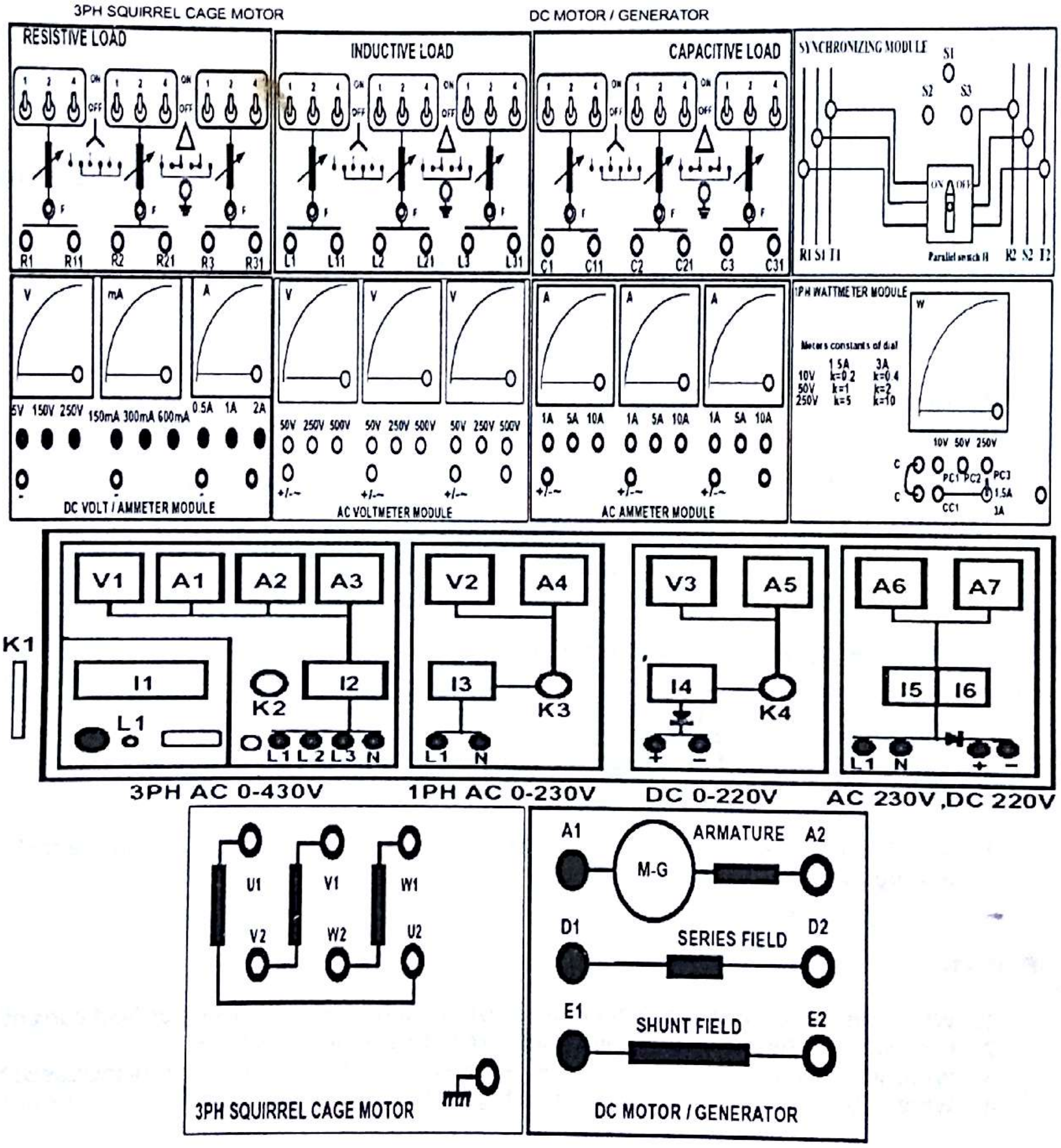
So the generated voltage is directly proportional to field flux, i.e. field current I_f.
One of the generator characteristics is defined by the **O.C.C** i.e. open circuit characteristics.

The shape of the **O.C.C** is same for all kinds of generator whether separately excited or self excited. It shows the relation between the no-load generated voltage in armature, E_G and the field or exciting current I_f at a given speed.

It is just the magnetization curve for the material of the electromagnet.

Circuit Diagram:





Equipments:

1. Universal Power Supply
2. 3PH Squirrel Cage Induction Motor (Prime Mover)
3. DC Motor / Generator
4. Field Rheostat
5. DC Voltmeter / Ammeter Module
6. Coupling Sleeve
7. Connecting Cables

Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. With a sensitive Multi-meter, measure the shunt field and armature resistance; write the values on the data sheet.
4. Make connections according to the above diagram.
5. Verify the connection by your Lab Teacher
6. Make sure the 3PH Squirrel Cage Induction Motor is mechanically coupled with DC Motor / Generator through the coupling sleeve.
7. Turn ON Switch I1 (upwards).
8. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
9. Make the 3PH supply at 400V by turning Knob K1, the Voltmeter V1 reading 400V.
10. Turn ON Switch I2 (upwards).
11. 3PH Squirrel Cage Induction Motor should start running at this point.
12. Also DC Motor / Generator starts running since it is mechanically coupled with 3PH Squirrel Cage Induction Motor.
13. Take reading Voc on DC Voltmeter Module (0-250V), If=0.
14. Turn Knob K4 at min (CCW)
15. Turn ON switch I4 (upwards).
16. Increase Shunt Field DC Voltage to 220V, Turn Knob K4 CW, Voltmeter V3 reading 220V
17. Vary Field Rheostat from Min to Max and take readings of Voc & If. Fill up the table-1. Plot Voc vs. If.

Report:

1. Why does the curve tend to become horizontal after a certain value of field current?
2. Can you use the same machine as self-excited generator? Explain.
3. What will happen to the O.C.C curve, if the speed of the prime mover is increased?
4. What is the reason of having some voltage without any excitation?

Group No:
Roll no:

Data Sheet

Armature resistance, $\mathbf{R_a}$ =
Field resistance, $\mathbf{R_{sh}}$ =

Table-1

Field current I_f (mA)	Open circuit voltage V_{oc} (volt)

Calculation and Graph

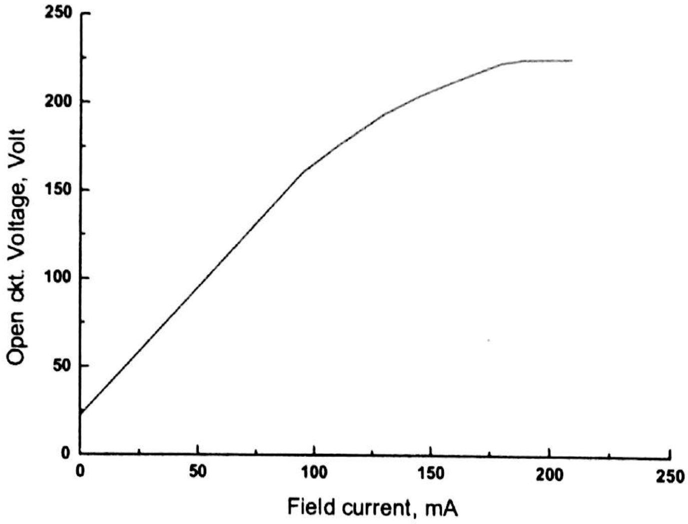
Plot $\mathbf{V_{oc}}$ vs. $\mathbf{I_f}$ on a graph paper and determine the value of critical resistance from this plot.

Signature of the Lab teacher:

Sample Data & Graph

Field current I_f (mA)	Open circuit voltage V_{oc} (volt)
0	22
95	161
110	176
120	185
130	194
145	204
160	212
180	222
190	224
200	224
210	224

<u>Plot of O.C.C:</u>



Experiment no: **4**
Experiment name: **Determination of losses of a DC machine.**

Introduction:
When a DC machine runs either as a motor or generator, losses take place.

These losses are:
Copper losses: Armature copper loss + field copper loss.
Magnetic losses: Eddy current loss + Hysteresis loss
Mechanical losses: Friction loss + bearing loss

Magnetic losses and mechanical losses are collectively known as stray losses. They are also known as rotational losses.

Equipments:

1. Universal Power Supply
2. DC Motor / Generator
3. Field Rheostat
4. DC Voltmeter / Ammeter Module
5. Tachometer
6. Multimeter
7. Coupling Sleeve
8. Connecting Cables

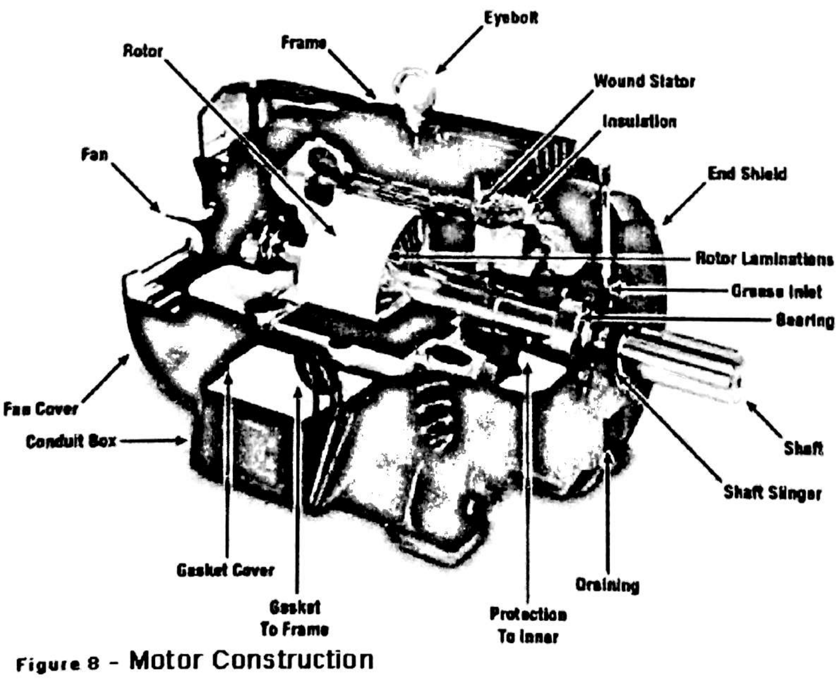
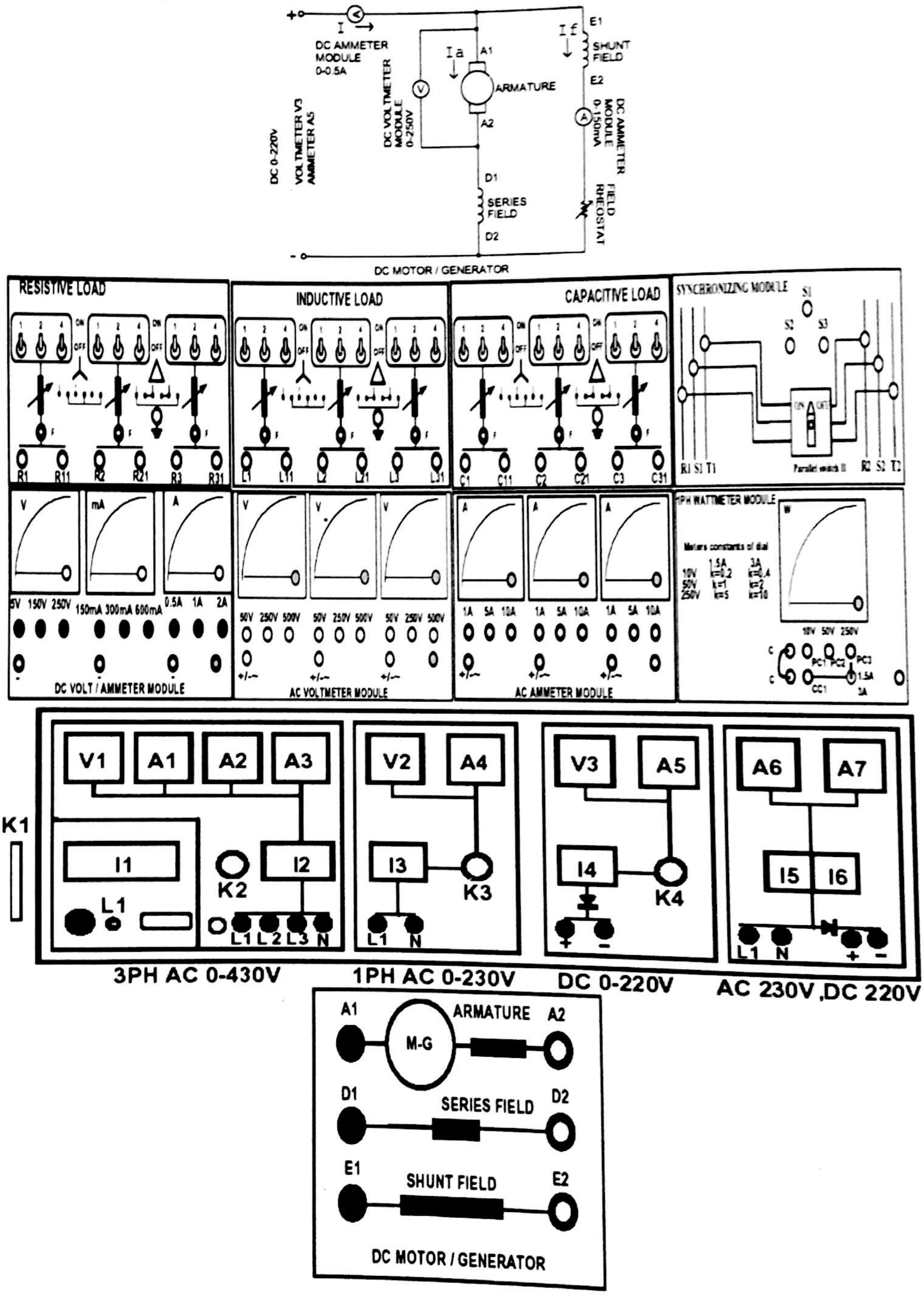


Figure 8 - Motor Construction

Connection Diagram:



Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.
3. With a sensitive Multi-meter, measure the shunt field and armature resistance; write the values on the data sheet.
4. Make connections according to the above diagram.
5. Verify the connection by your Lab Teacher
6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
8. Make sure the 3PH supply Voltmeter V1 reading 400V.
9. Turn Knob K4 at min (CCW)
10. Turn ON switch I4 (upwards).
11. **SLOWLY** Increase Armature DC Voltage to 120V, Turn Knob K4 CW, Voltmeter V3 Adjust field rheostat to obtain the rated speed 3000RPM
12. Now increase the armature voltage by 20 V in each step and adjust the speed to rated speed 3000 RPM by varying field rheostat.
13. Take readings up to rated armature voltage 220V. Fill-up the table-1.
14. Now repeat step 11-13, adjust field rheostat to obtain 75% of rated speed 3000 RPM fill-up table-2.

Calculation + Graph:

1. Calculate copper losses, total power input and armature power output, Po
2. Po vs. armature voltage, Va using the data of table-1 and draw a tangent and extend the tangent to Y-axis. This interception at the Y-axis is the mechanical loss of a machine at rated speed.
3. Repeat step-2 using the data of table-2.
4. At first from plot-1 find Po for a voltage say 180 V. Then subtract mechanical loss (from step-2) from that Po. This will represent the Eddy current and Hysteresis loss. Term this loss as W_1.
5. Repeat step-4 using plot-2 and term this loss as W_2.
6. Now use this equation to isolate Eddy current and Hysteresis loss.
7. $W_1 = AN_1 + BN_1^2$, where N_1 is rated speed
8. $W_2 = AN_2 + BN_2^2$, where N_2 is 75% of rated speed.
9. A and B are Eddy current and Hysteresis loss respectively. Solve two equations to find A and B.

Report:

1. Discuss about the nature of Po vs. armature voltage curve at two different speeds.
2. Comment on the results.

Data Sheet

Armature resistance, R_a =
Field resistance, R_{sh} =
Rated Speed, N =
Rated Voltage =

Group No:
Roll no:

At rated Speed, N =

(A)	(B)	(C)	(D)	(E)	(F)	(G)
V_a (Volt)	I_a (D)-(C) (Amp)	I_f (Amp)	Total Current, I (Amp)	Copper loss (Watt) $V_a I_f + I_a^2 R_a$	Power Input (watt) Va x I (A)×(D)	Armature Power Output (watt) Po=(F)-(E)

Table-1

At 75% of rated Speed, N =

(A)	(B)	(C)	(D)	(E)	(F)	(G)
V_a (Volt)	I_a (Amp)	I_f (Amp)	Total Current, I (B)+(C)	Copper loss (Watt) $V_a I_f + I_a^2 R_a$	Power Input (watt) (A)×(D)	Armature Power Output (watt) Po=(F)-(E)

Table-2

Signature of the Lab Teacher

Experiment no: **5**
Experiment name: **Speed Control of a DC Shunt Motor**

Introduction:
Voltage developed in the D.C generator in general form ---

$$E_g = \phi ZN/60 * (P/A) \text{ volt}$$

The same equation can be written for motor replacing E_g by E_b ---

$$E_b = \phi ZN/60 * (P/A) \text{ volt} \quad \text{------------------- (1)}$$

Where, E_b is called the Back EMF.

The simple diagram of a DC motor is shown below:

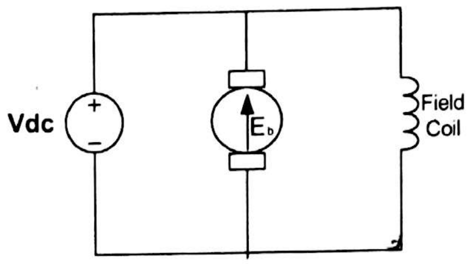


Figure 1: DC Motor

From the diagram, $E_b = V - I_a * R_a$ Where, V = Supply voltage in volt.
I_a = Armature Current in Ampere.
R_a = Armature Resistance in Ohm.

From the equation (1) we get ---- $E_b = \phi * N (Z*P/60*A)$
$= \phi * N * K$, where K is constant

i.e. $N = (1/K) * E_b/\phi$
$= K_m * (V - I_a * R_a)/\phi$ r.p.m

So the speed of the DC motor is directly proportional to the supplied voltage applied across the armature and Proportionally decreasing with armature current. The speed is also inversely proportional to the field flux i.e. field current.

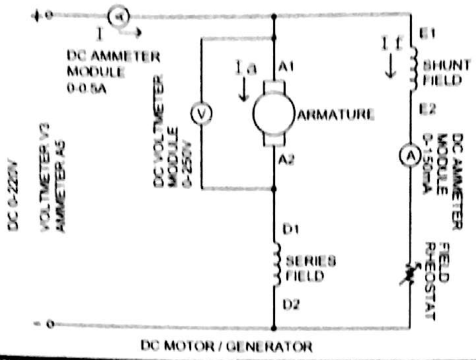
So the speed of the DC motor can be controlled by three methods. They are-

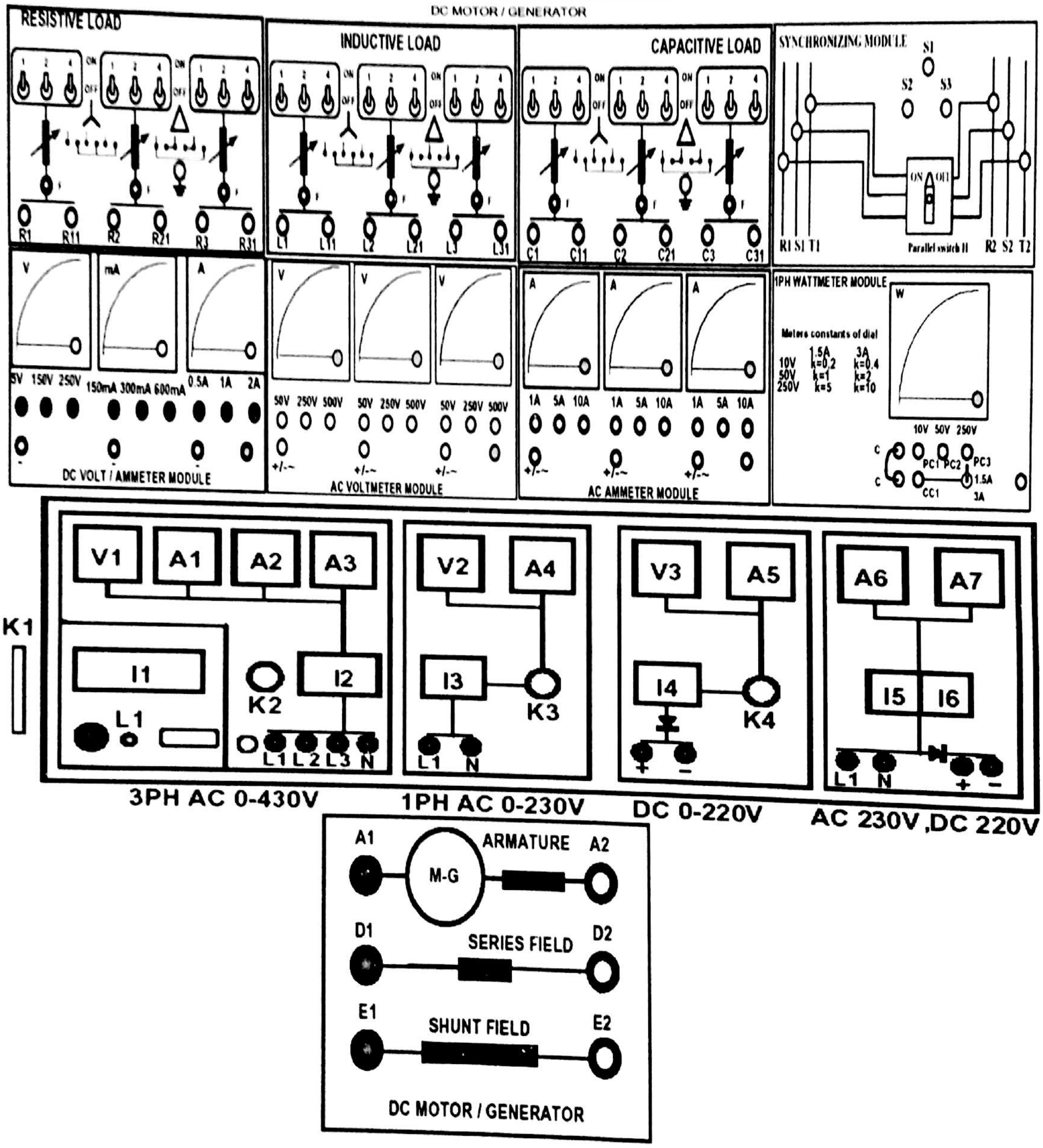
1. Flux Control
2. Armature Resistance Control
3. Voltage Control

Equipments:

1. Universal Power Supply
2. DC Motor / Generator
3. Field Rheostat
4. DC Voltmeter / Ammeter Module
5. Coupling Sleeve
6. Connecting Cables
7. Multimeter

Flux Control Method:





Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.

3. With a sensitive Multi-meter, measure the Series, Shunt field and Armature resistance; write the values on the data sheet.

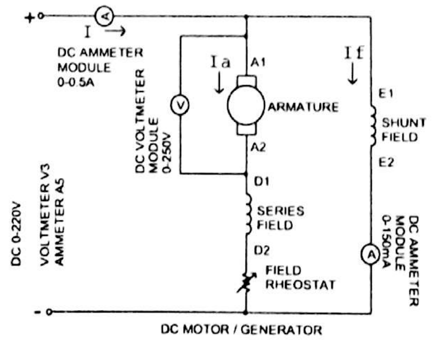
4. Make connections according to the above diagram.
5. Verify the connection by your Lab Teacher

6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.

8. Turn Knob K4 at min (CCW)
9. Turn ON switch I4 (upwards).
10. Keep the Field Rheostat to the Min
11. Make the Motor running by increasing the voltage to 200VDC

12. Make the supply voltage at **200VDC** and keep Field Rheostat at minimum position.
13. Now vary the Field Rheostat and measure the field current $\mathbf{I_f}$ and the motor speed **N** and fill up the Table-1.

b**) Armature Resistance Control**:



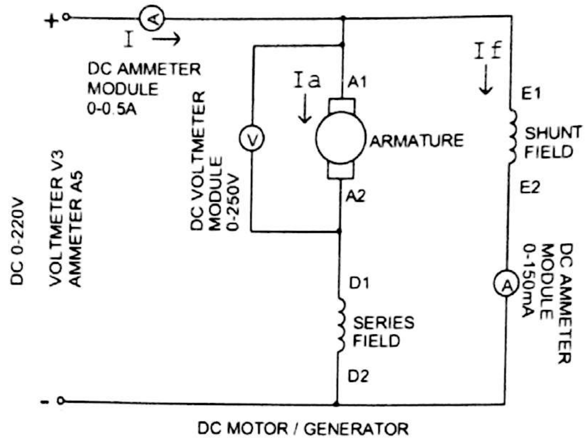
Procedure:

1. Follow the steps from 1-11 of Flux Control Method

2. Make the Motor running by increasing the voltage to **200VDC**

3. Make the supply voltage at **200VDC** and keep Field Rheostat at minimum position.
4. Now vary the Field Rheostat and measure the Armature current Ia and the motor speed N and fill up the Table-2.

c) Voltage Control:



Procedure:

1. Follow the steps from 1-11 of Flux Control Method
2. Make the Motor running by increasing the voltage to **200VDC**
3. Make the supply voltage at **120VDC**
4. Increase the supply voltage and fill up the Table-3.

Report:

1. Explain the curves plotted on the graph paper.
2. Variation of which parameter affects the speed most? Why?
3. Explain the relative merits and demerits of each method.
4. What the significance of Back EMF? Briefly explain.

Group No:
Roll no:

Data Sheet

Table-1		Table-2		Table-3	
I_f (mA)	N (rpm)	I_a (mA)	N (rpm)	V_a (volt)	N (rpm)

Graph

Plot I_f **vs. N**, I_a **vs. N** and V_a **vs. N** on the same graph paper.

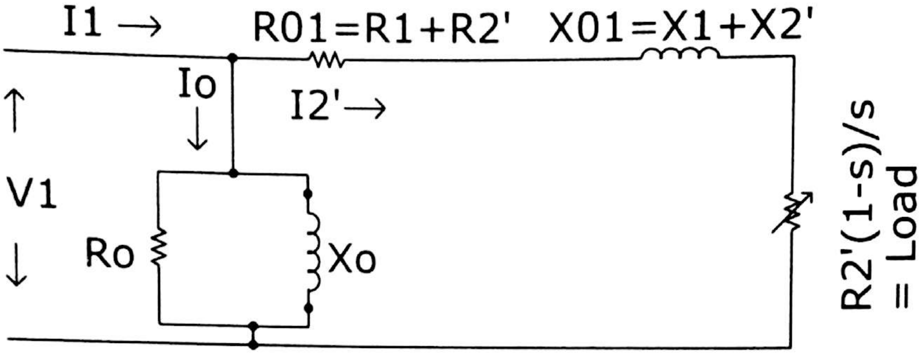
Signature of the Lab Teacher

Experiment no: **6**

Experiment name: **Determination of Circuit Parameters of a 3 Phase Induction Motor.**

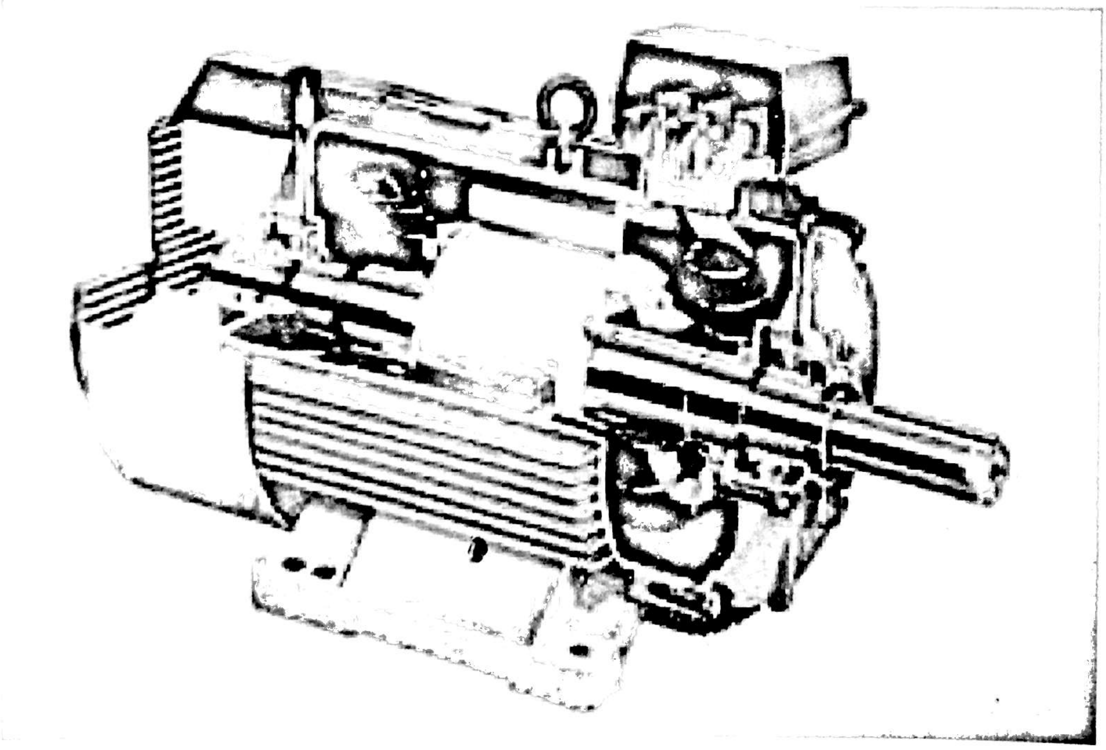
Introduction:

For an induction motor the equivalent circuit referred to secondary (rotor) is basically an R-X circuit with variable s (slip). As load varies, s varies so the magnitude of R varies.



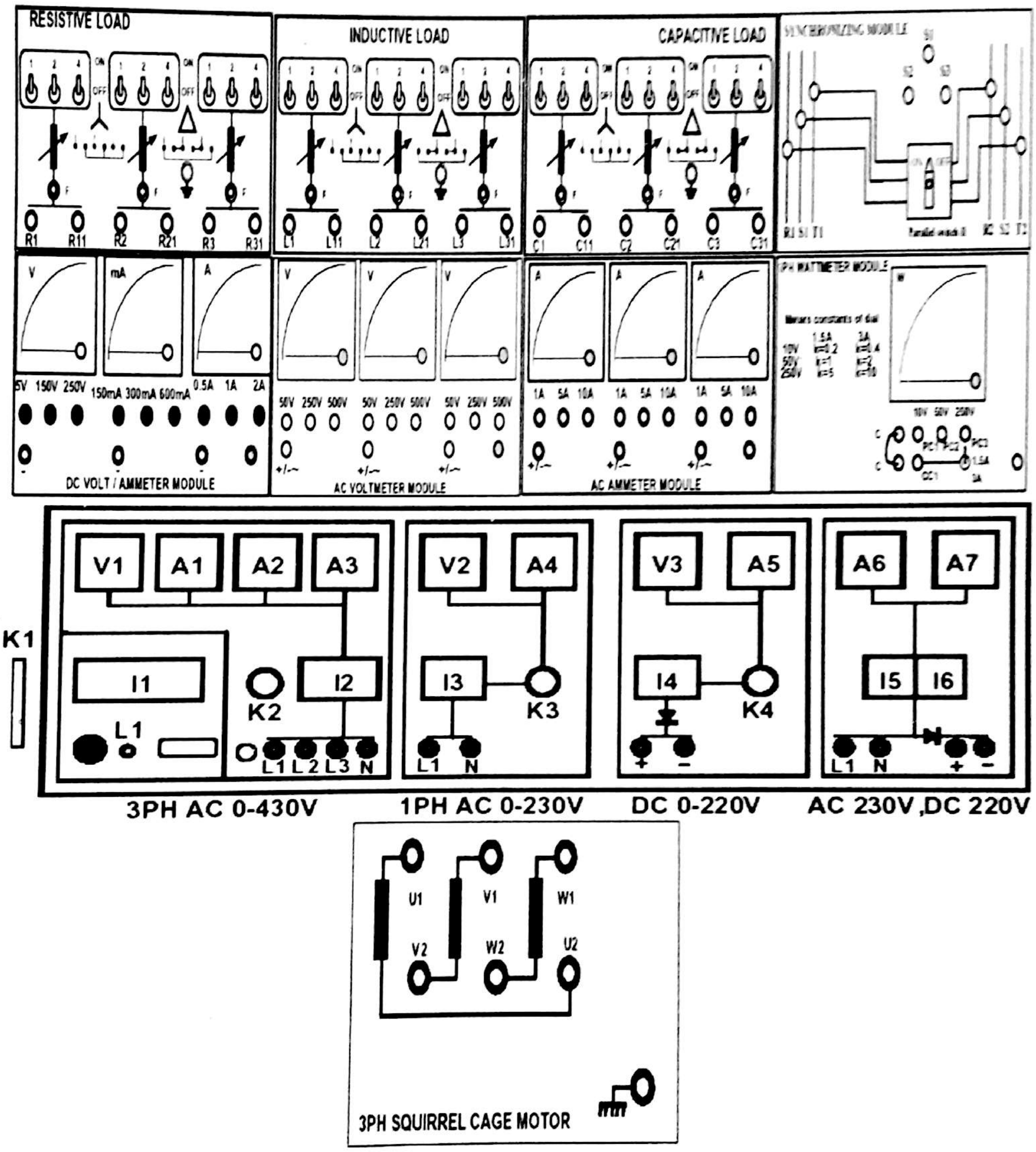
The following tests are required to determine the circuit constants.

1. No- load test
2. Blocked rotor test

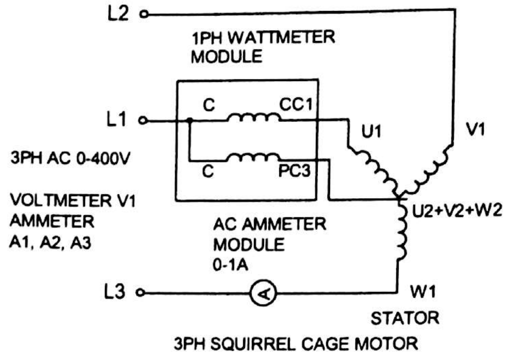


Equipments:

1. Universal Power Supply Module
2. 3 Phase Squirrel Cage Induction Motor
3. AC Ammeter Module 0-1A
4. AC Voltmeter Module 0-250 V
5. 1PH Wattmeter Module
6. Connecting Cables



A. No-Load Test:



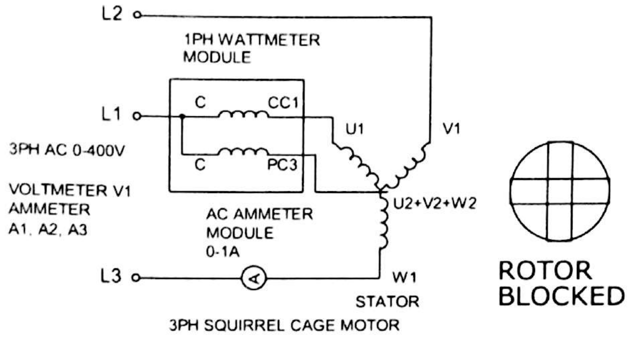
Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher
5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
7. Turn knob K1, Apply **400VAC** on the Stator of the Motor.
8. Turn ON Switch I2 (upwards).
9. 3 Phase Squirrel Cage Motor Starts Running
10. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module

B. Blocked Rotor Test

This is also known as locked rotor or short circuit test. This test is used to find:

(i) Short circuit current with normal voltage applied to the stator.
(ii) Power factor on short circuit
(iii) To plot the circle diagram.
(iv) To find resistance of motor R01 and leakage reactance X01 (ref. to primary).



Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher
5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
7. ****IMPORTANT:** Make the Stator Voltage **0VAC**
8. ****IMPORTANT:** Note the Rated Stator Current of the 3 Phase Squirrel Cage Motor
9. ****IMPORTANT:** Turn ON Switch I2 (upwards).
10. ****IMPORTANT: Block the rotor** and slowly increase the voltage till rated current flows in the stator.
11. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module

Report:

1. What is slip of an induction motor?
2. Draw the approximate equivalent circuit of an induction motor.
3. Explain, "The principle of an induction motor is similar to that of a transformer."

Group No: **Roll no:**

Data Sheet

No load test:

W_0 = I_0 = V_0 =

$$R_0 = \frac{V_0^2}{W_0} \qquad Z_0 = \frac{V_0}{I_0} \qquad \therefore X_0 = \sqrt{Z_0^2 - R_0^2}$$

$$W_0 = V_0 I_0 \cos\Phi_0 \qquad \Rightarrow \cos\Phi_0 = \frac{W_0}{V_0 I_0}$$

Blocked rotor test:

W_{SC} = I_{SC} = V_{SC} =

$W_{SC} = V_{SC} I_{SC} \cos\Phi_S$, i.e.Φ_S =

$$W_{SC} = I_{SC}^2 R_{01} \qquad Z_{01} = \frac{V_{SC}}{I_{SC}} \qquad \therefore X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$$

Signature of the lab Teacher

Experiment no: **7**

Experiment name: **Measuring Synchronous Generator Model Parameters.**

Introduction:

Three quantities are required to describe the behavior of a synchronous generator. These are:

1. The relationship between field current and flux, i.e. EA Vs If.

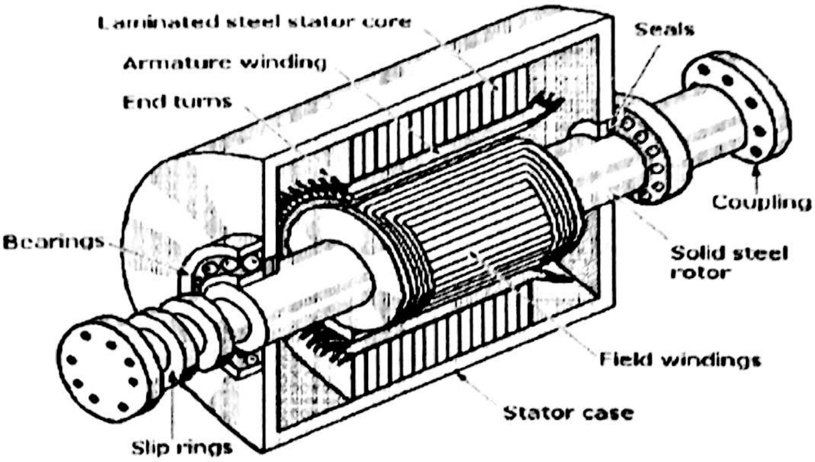
2. Synchronous reactance.

3. Armature resistance.

The first step is to perform the open circuit test. To perform this test, the generator is turned at the rated speed. The terminals are disconnected from load and the field current is set to zero. Then the field current is a gradually increased in step and the corresponding terminals voltage is measured. Plotting of VT Vs If gives the open circuit characteristic of the generator (O.C.C).

Equipments:

1. 3-φ synchronous generator
2. 3-φ induction motor
3. DC ammeter (0-500 mA)
4. AC ammeter (0-2.5 A)
5. AC voltmeter (0-300 V)
6. Rheostat (0- 1000 Ω)
7. Tachometer
8. Wire for connection.



Cutaway view of a synchronous AC generator with a solid cylindrical rotor capable of high-speed rotation.

Connection Diagram:

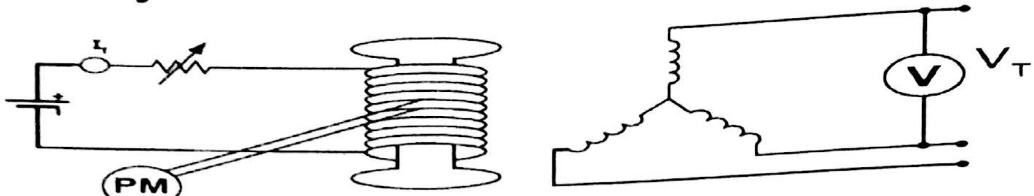


Fig 01: Open Circuit Test

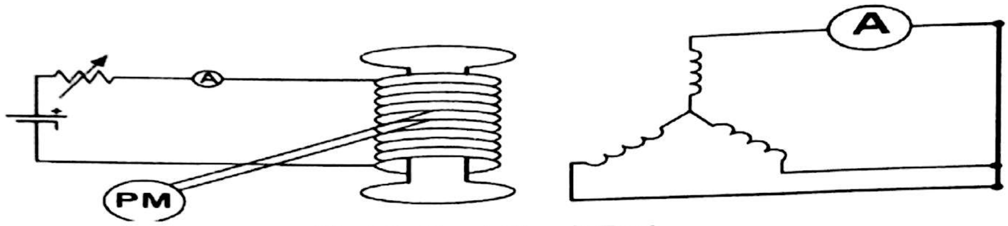
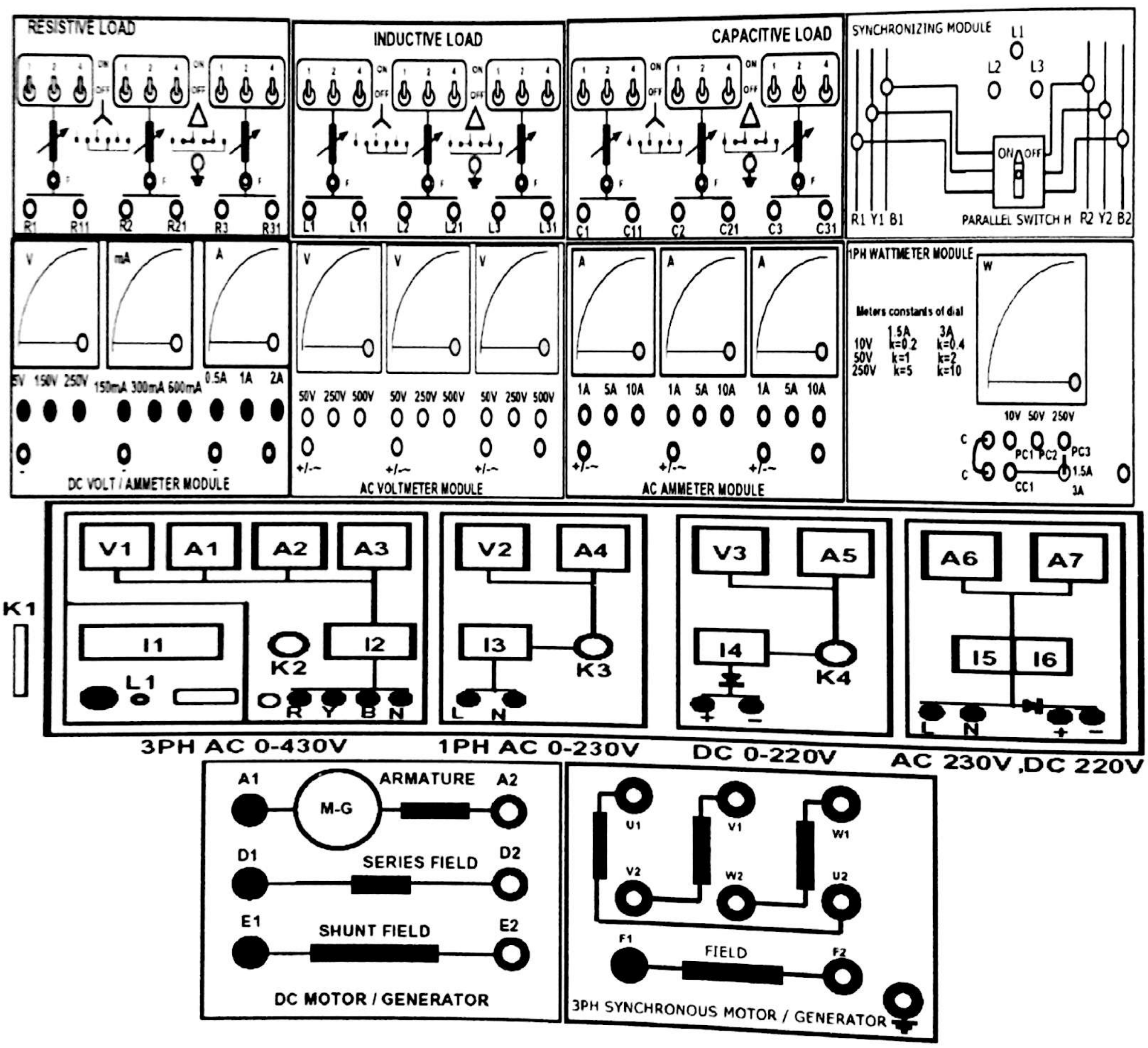


Fig 02: Short Circuit Test



Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.

3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher
5. Make sure the 3PH synchronous Motor / Generator is mechanically coupled with DC Motor / Generator through the coupling sleeve.

6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
8. Make the 3PH supply at **400VAC** by turning Knob K1, Voltmeter V1
9. ****Starting the Prime Mover**
10. Keep the Field Rheostat of the DC Motor at **Maximum**
11. Turn ON Switch I6 (upwards).
    Obtain speed 3000 RPM by varying the Field Rheostat, measure the speed with Tachometer

For Open circuit test:

12. Put highest resistance in the rotor of the alternator.
13. Open the stator terminals. Apply voltage on the rotor while the prime mover is rotating at the rated speed.
14. Slowly increase the field current and fill up the table for O.C test.

For Short circuit test:

15. Put highest resistance in the rotor of the alternator.
16. Short the stator terminals. Apply voltage on the rotor while the prime mover is rotating at the rated speed.
17. Slowly increase the field current and fill up the table for S.C. test.
18. For each step, at constant If, divide V_T by I_{SC} to determine X_S.

Report:
1. On the same graph paper draw V_T Vs I_f, I_{SC} Vs I_f and X_S Vs I_f.
2. Why the value of X_S does not remain constant?
3. Why do you get a linear relationship between I_A Vs I_f during short circuit test?

Group No:
Roll no:

Data Sheet

O.C.C. Test

I_f	V_T

Short Circuit Test

I_f	I_{SC}

By Calculation

I_f	X_S

Signature of the Lab teacher:

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

2^{nd} Year, 2^{nd} Semester

Student Name :

Student ID :

Ahsanullah University of Science and Technology

Department of Electrical and Electronic Engineering

LABORATORY MANUAL

FOR

ELECTRICAL AND ELECTRONIC SESSIONAL COURSES

Student Name :

Student ID :

Course no : EEE 3104

Course Title: Digital Electronics-I Laboratory

For the students of

Department of Electrical and Electronic Engineering

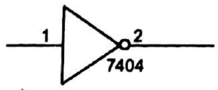
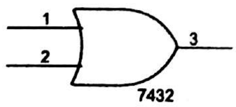
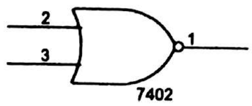
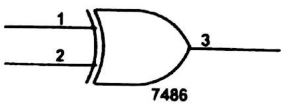
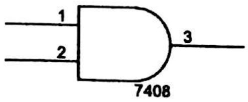
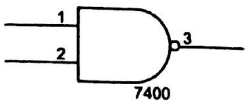
3^{rd} Year, 1^{st} Semester

Experiment: 1
Experiment name: *Introduction to different digital ICs.*

Introduction:

In this experiment you will be introduced to different digital ICs that will be used in this digital lab to perform different functions and also the function of each IC. You are asked to memorize the followings associated with each IC.

1. IC number
2. IC name
3. Total number of pins
4. V_{cc} pin number
5. Ground pin number

IC number	IC name	Schematic view
7404	NOT	
7432	OR	
7402	NOR	
7486	XOR	
7408	AND	
7400	NAND	

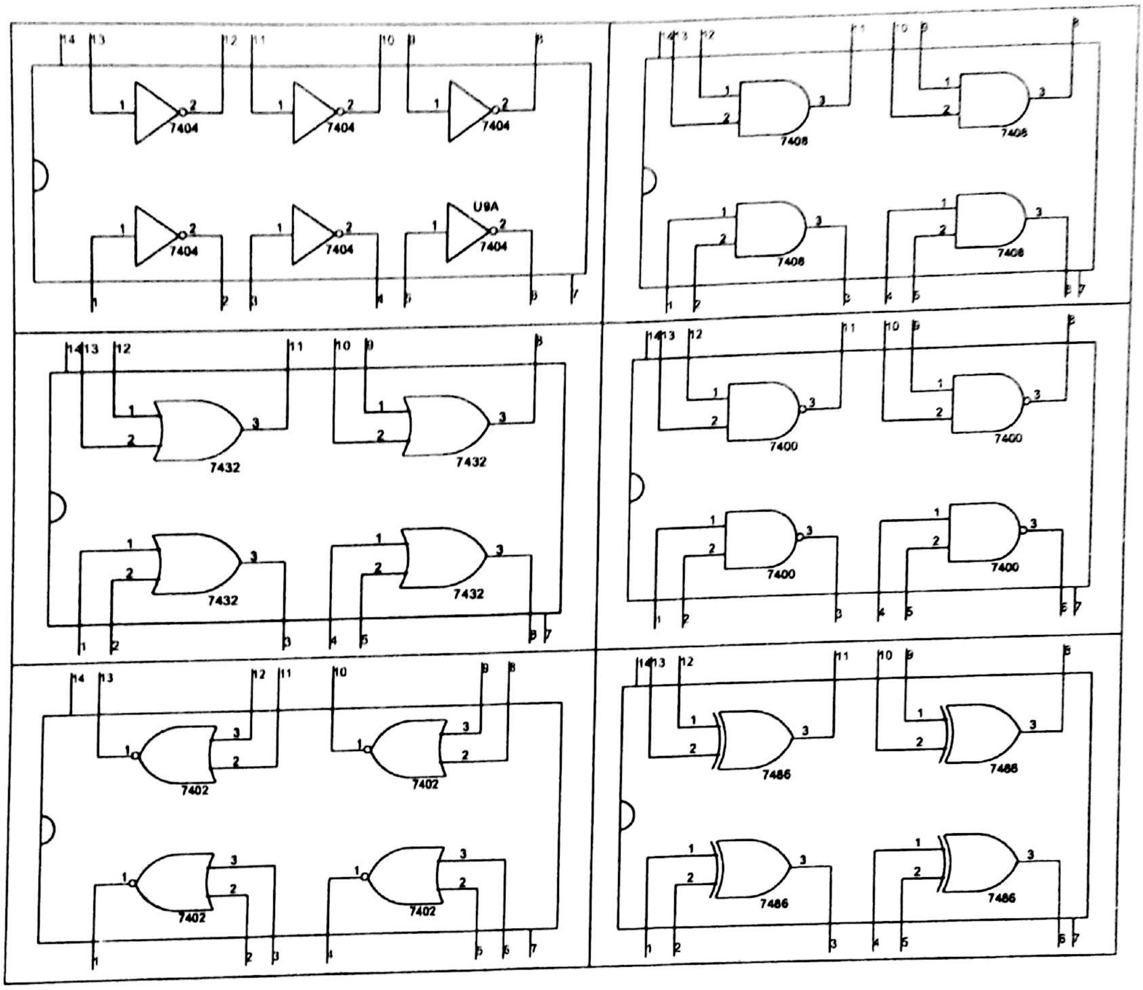
Equipment:

1. Trainer Board
1. IC 7400,7402,7404,7408,7432,7486
2. Microprocessor Data handbook

Procedure:

1. Take any of the ICs. From microprocessor data handbook find the name of the IC, total number of pins that it has, V_{cc} pin and ground pin.

IC Number	IC name	Total number of pin	V_{cc} pin no.	Ground pin no.
7400	NAND	14	14	7
7402	NOR	14	14	7
7404	NOT	14	14	7
7408	AND	14	14	7
7432	OR	14	14	7
7486	XOR	14	14	7



1. Note the number of gates each IC has from the handbook.
2. Now fill up the following table.

Input A	Input B	7400 NOT $Y = \overline{A}$	7432 OR $Y = A + B$	7402 NOR $Y = \overline{A+B}$	7486 XOR $Y = A \oplus B$	7408 AND $Y = AB$	7400 NAND $Y = \overline{AB}$
0	0						
0	1						
1	0						
1	1						

3. Now verify the observed output with the desired output for different combination of inputs.
4. Repeat step 1 to 4 for different ICs.

Assignment:

1. How can you make a three input AND/OR/XOR gate with a two input AND/OR/XOR gate?
2. Is it possible to make a three input NAND/NOR gate with a two input NAND/OR gate? Justify your answer.

Experiment: 2
Experiment name: *Introduction to Combinational logic.*

Introduction:

Logic design basically means the construction of appropriate function, presented in Boolean algebraic form, then edification of the logic diagram, and finally choosing of available ICs and implementing the IC connection so that the logic intended is achieved. The efficiency in simplifying the algebra leads to less complicated logic diagram, which in the end leads to easier IC selection and easier circuit implementation.

Caution:

1. Remember to properly identify the pin numbers so that no accidents occur.
2. Properly bias the ICs appropriate voltages to appropriate pins.

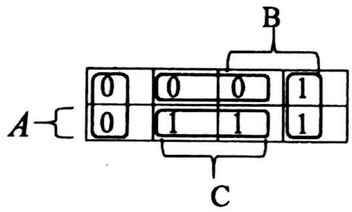
Equipment:

1. Trainer Board
2. IC 7400,7402,7404,7408,7432,7486
3. Microprocessor Data handbook

Job 1:

Implement of function $f = AB + BC' + CA$

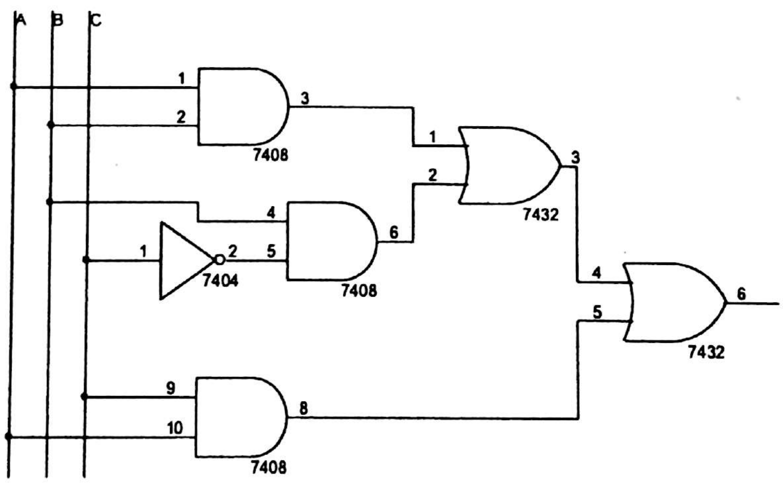
$$= ABC + ABC' + ABC' + A'BC' + ABC + AB'C$$
$$= ABC + ABC' + A'BC' + AB'C$$
$$= m_7 + m_6 + m_2 + m_5$$



$F = AC + BC'$ $\quad$ $F' = B'C' + A'C$

$= SOP$

$$\Rightarrow F = (B'C' + A'C)'$$
$$\Rightarrow F = (B + C)(A + C')$$



Procedure:

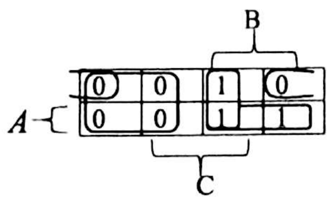
1. Draw logic diagram to implement the function.
2. Select ICs from the equipment list.

3. Note the output logic for all combination of inputs.
4. Now fill up the truth table for that function.
5. Simplify the function in POS and in SOP form using K-map.
6. Repeat step-1, 2 and 3.

Job 2:

Implement of function $f = (AB + B)(C + A)(AC + B)$

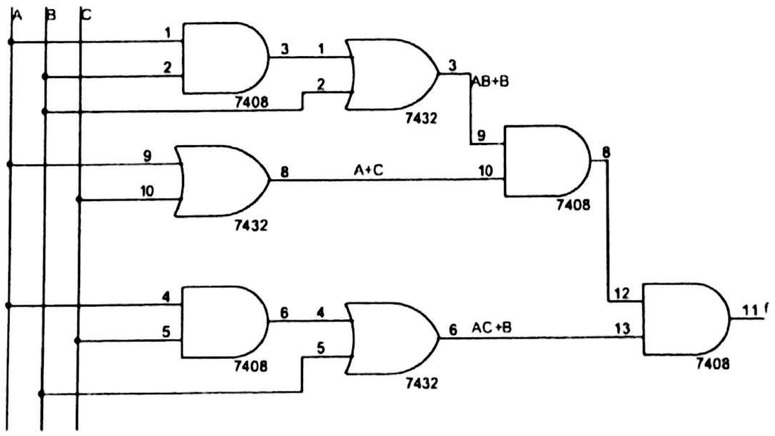
$$= B(A + B)(A + C)(A + B)(B + C)$$
$$= B(A + B)(A + C)(B + C)$$
$$= B(AA')(A + B)(A + C)(B + C)$$
$$= (A + B)(A' + B)(A + C)(B + C)$$
$$=(A+B+C)(A+B+C')(A'+B+C)(A'+B+C')(A+B+C)(A+B'+C)(A+B+C)(A'+B+C)$$
$$= (A + B + C)(A + B + C')(A' + B + C)(A' + B + C')(A + B' + C)$$
$$= M_0 M_1 M_4 M_2 M_5$$



$F = AB + BC$

$F' = B' + A'C'$

$\Rightarrow F = B(A + C)$



Procedure:

1. Simplify the function in POS form and in SOP form by using Boolean algebra.
2. Draw logic diagram to implement the function.
3. Select ICs from the equipment list.
4. Note the output logic for all combination of inputs.

Experiment: 3
Experiment name: *Construction of adders and sub tractors using basic logic gates.*

Introduction:
Adders and sub tractors are the basic operational units of simple digital arithmetic operations. In this experiment, the students will construct the basic adder and sub tractor circuit with common logic gates and test their operability. Then in the last job, they will cascade adder ICs to get higher bit adders.

Caution:
1. Remember to properly identify the pin numbers so that no accidents occur.
2. Properly bias the ICs with appropriate pins.

Equipment:
1. Trainer Board
2. IC 7400, 7402, 7404, 7408, 7432, 7486
3. Microprocessor Data handbook

Job 1:
Implementation of a half adder and a half sub tractor.

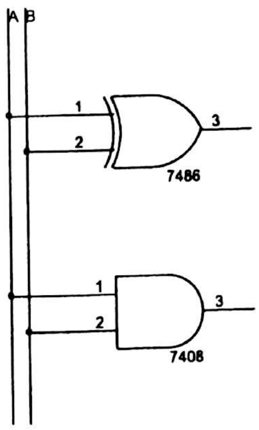


Fig: Half Adder

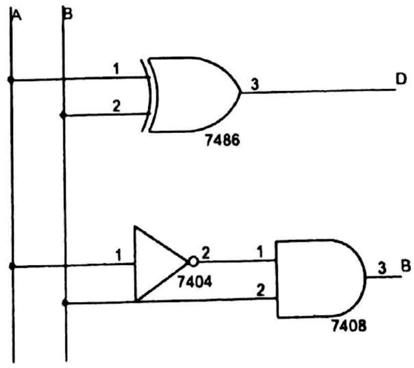


Fig: Half sub tractor

Procedure:
1. Fill up the truth table for a half adder.

A	B	C	S

$S = A \oplus B$
$C = AB$

2. Determine the Boolean function for a half adder.
3. Construct the logic diagram from the Boolean functions.
4. Select the ICs from the equipment list.
5. Implement the output logic and compare with step-1.
6. Repeat the whole procedure for half a sub tractor.

A	B	B	D

$D = A \oplus B$
$B = A'B$

Job 2:

Implement of a full adder and a full sub tractor.

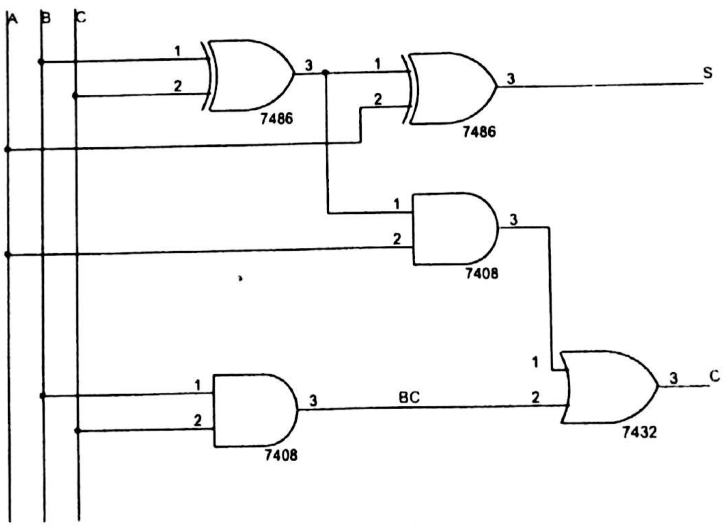


Fig: full adder

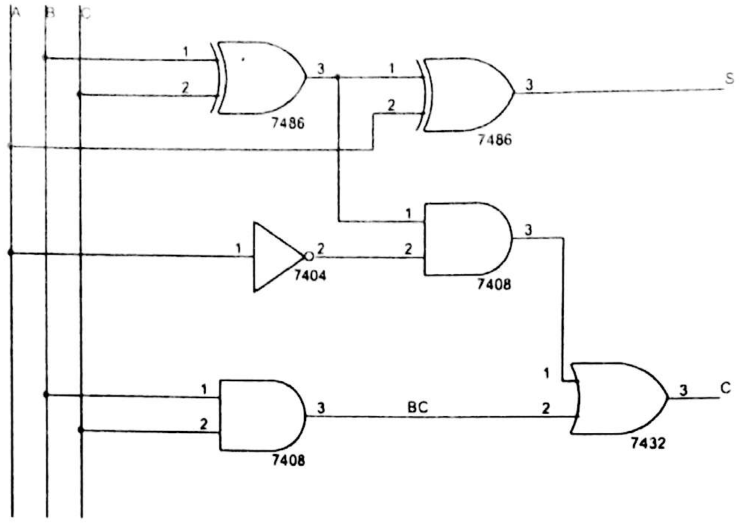


Fig: full subtractor

Procedure:

1. Fill up the truth table for a full adder.

A	B	C	C	S
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

$S = A'B'C + A'BC' + AB'C' + ABC$

$\Rightarrow S = A \oplus B \oplus C$

$C = A'BC + AB'C + ABC' + ABC$

$\Rightarrow C = BC + A(B \oplus C)$

2. Determine the Boolean function for a full adder.
3. Construct the logic diagram from the Boolean functions.
4. Select the ICs from the equipment list.
5. Implement the output logic and compare with step-1.
6. Repeat the whole procedure for a full sub tractor.
7. Now draw a full adder using two half adder block and basic gates.
8. Repeat step-7 for a full sub tractor.

A	B	C	B	D
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

$S = A'B'C + A'BC' + AB'C' + ABC$

$\Rightarrow S = A \oplus B \oplus C = D$

$C = A'BC + AB'C + ABC' + ABC$

$\Rightarrow C = BC + A'(B \oplus C)$

Experiment: 4

Experiment name: *Design a Combinational circuit that will act as an Adder if control bit is '0' and as a sub tractor if control bit is '1'.*

Introduction:

Addition of two 4-bit binary numbers can be easily done using a 4-bit binary adder IC (7483/74283). Taking the 2's complement of the subtrahend and then adding that with the minuend can do subtraction of two 4-bit binary numbers.

Caution:

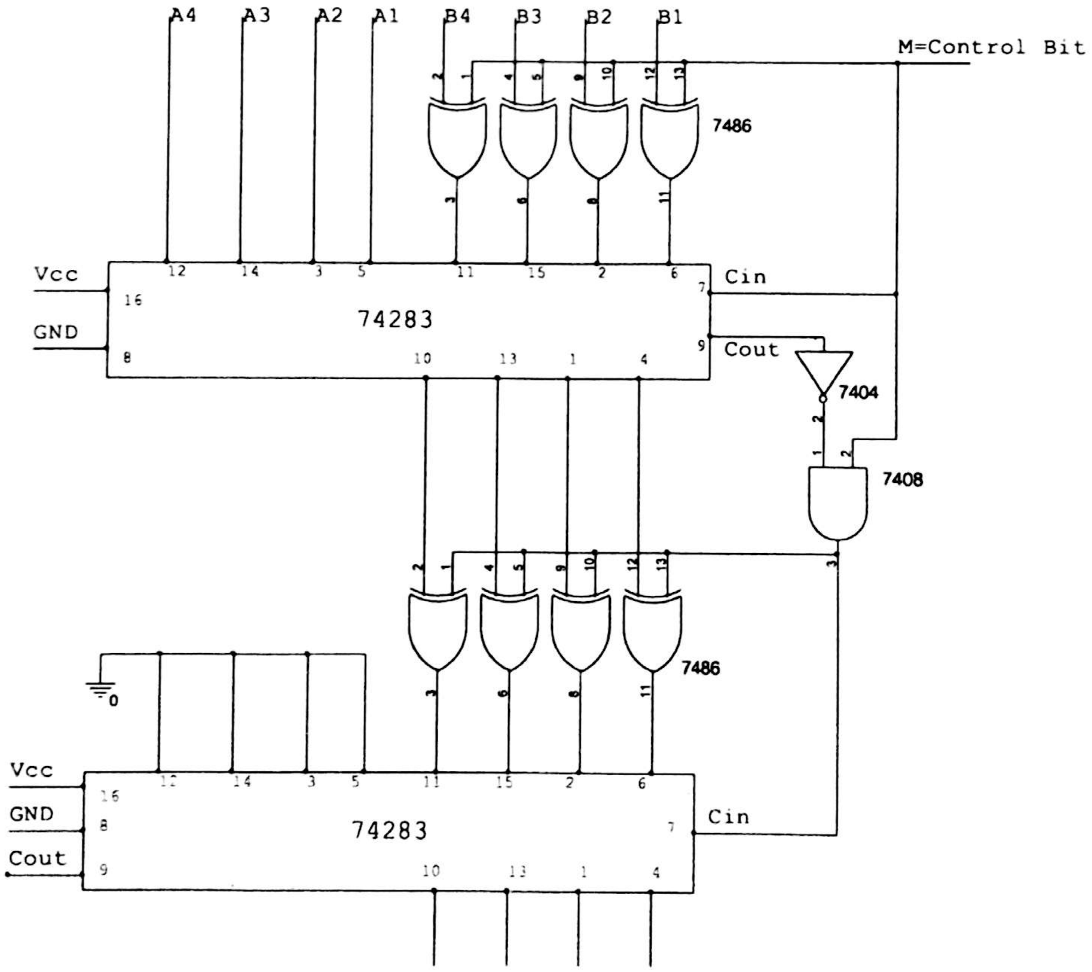
1. Remember to properly identify the pin numbers so that no accidents occur.
2. Properly bias the ICs with appropriate voltages to appropriate pins.

Equipment:

1. Trainer Board
2. IC 74283,7408,7432,7486.
3. Microprocessor Data handbook

Procedure:

1. Draw the logic diagram to implement the task.



2. Select the required ICs.
3. Note the output logic for different inputs.

A	*B*	*S*	Output
0001	0010	0	
0001	0010	1	
1001	0011	0	
1011	0111	1	
1011	0111	0	
1100	1001	1	
1111	1111	0	
1111	1111	1	

Experiment: 5

Experiment name: *Design a BCD adder that will add two BCD numbers and the sum will be also in BCD.*

Introduction:

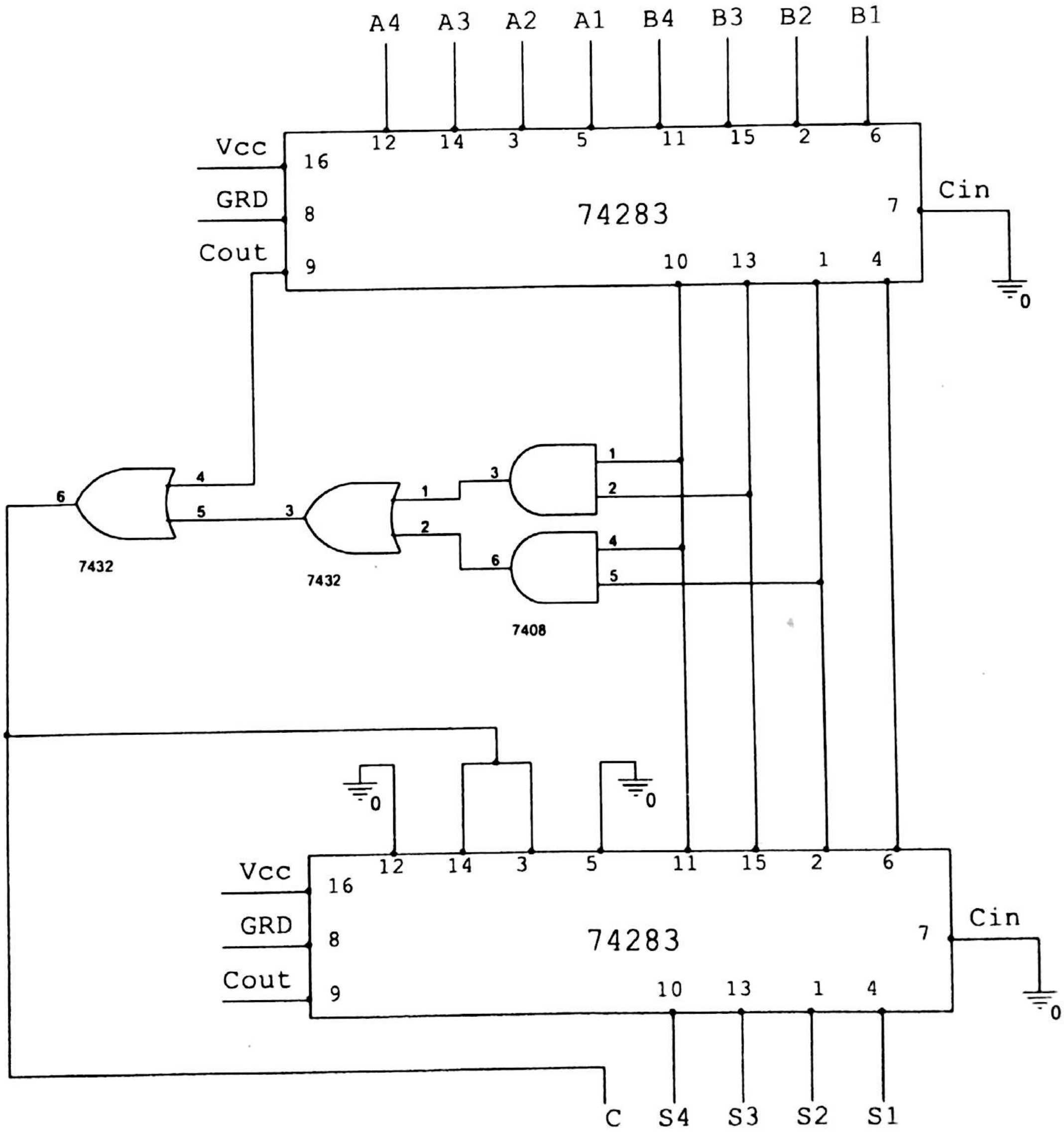
A BCD adder can be designed by considering the arithmetic addition of two decimal digits in BCD, together with a possible carry from a previous stage. Since each input digit does not exceed 9, the output sum cannot be greater than 9+9+1=19. This can be designed with a 4-bit binary adder together with a correction logic circuit.

Caution:

1. Remember to properly identify the pin numbers so that no accidents occur.
2. Properly bias the ICs with appropriate voltages to appropriate pins.

Procedure:

1. Draw the logic diagram to implement the task.



2. Select the required ICs.
3. Fill up the following truth table for 19 inputs.

	Binary Sum					BCD Sum				
Decimal	K	Z_8	Z_4	Z_2	Z_1	C	S_8	S_4	S_2	S_1
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										

Experiment: 6
Experiment name: *Introduction to Multiplexers.*

Introduction:
Multiplexers are the most important attributions of digital circuitry in communication hardware. These digital switches enable us to achieve the communication network we have today. In this experiment the students will have to construct MUX (as they call multiplexers) with simple logic gates and they will implement general logic using 8:1 MUX as the basic constructional unit.

Caution:

1. Remember to properly identify the pin numbers so that no accidents occur.
2. Properly bias the ICs with appropriate voltages to appropriate pins.

Equipment:

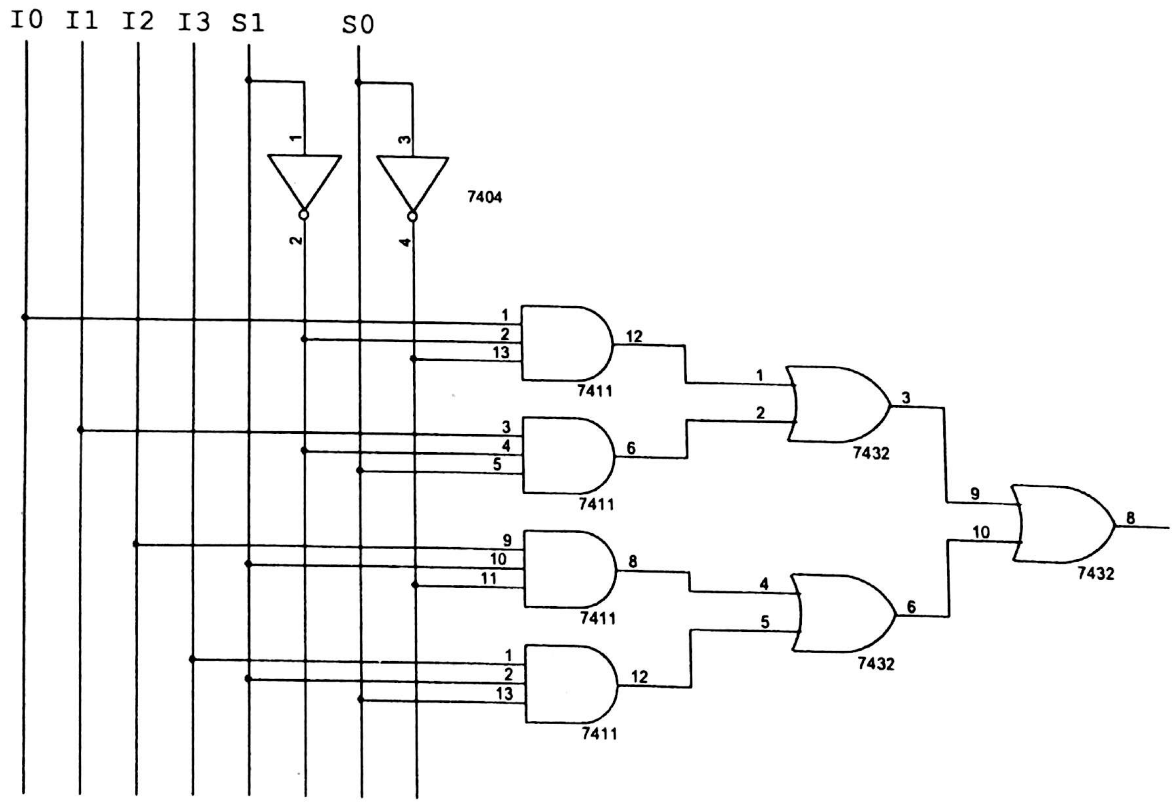
1. Trainer Board
2. IC 74151, 7432, 7408, 7404
3. Microprocessor Data handbook.

Job 1:

Implementation of a four to one way Multiplexer, (4:1 MUX) with basic gates.

Procedure:

1. Write the truth table for four to one way MUX.
2. Write the Boolean function for the output logic.
3. Draw the logic diagram to implement the Boolean function.



4. Select ICs from the equipment list.
5. Observe and note the output logic for all combination of inputs.

Job 2:

Implement the following function using an 8:1 MUX.

$$F(A,B,C,D)=\sum(0,1,3,5,8,9,14,15)$$

Procedure:

1. Write the truth table for the above function.

	I_0	I_1	I_2	I_3	I_4	I_5	I_6	I_7
A'								
A								

2. Draw the logic diagram to implement the Boolean function.

A	B	C	D	Y

3. Select ICs from the equipment list.
4. Observe and note the output logic for all combination of inputs.

Assignment:

1. Implement a Full Adder using an 8:1 MUX.
2. Repeat 1 using two 4:1 MUX and basic gates.
3. How can you implement a 4:1 MUX using only three 2:1 MUX?

Experiment: 7
Experiment name: *Implementation of Demultiplexers and Priority Encoders.*

Introduction:

A Demultiplexer does the opposite function of multiplexers. It has one input line and 2^n output lines, where n is the number of selection bits. The output channel can be selected depending on the combination of selection bits. An encoder has 2^n input lines and n output line. A priority encoder is designed to give output for lowest/highest input lines. For example, If D3, D2 and D1 lines have '1' as in their inputs, the output would be '11' as priority is given to highest input line.

Caution:

1. Remember to properly identify the pin numbers so that no accidents occur.
2. Properly bias the ICs with appropriate voltages to appropriate pins.

Equipment:

1. Trainer Board
2. IC 7432, 7408, 7404
3. Microprocessor Data handbook.

Job 1:

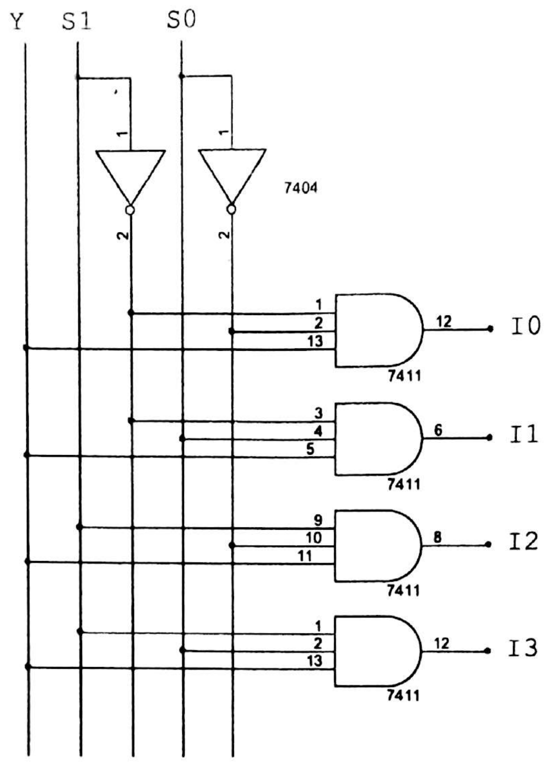
Implementation of a one to four way Demultiplexer, (1:4 DEMUX) with basic gates.

Procedure:

1. Write the truth table for one to four way DEMUX.

S_1	S_0	I_0	I_1	I_2	I_3

2. Write the Boolean function for the output logic.
3. Draw the logic diagram to implement the Boolean function.



4. Select ICs from the equipment list.
5. Observe and note the output logic for all combination of inputs.

Job 2:

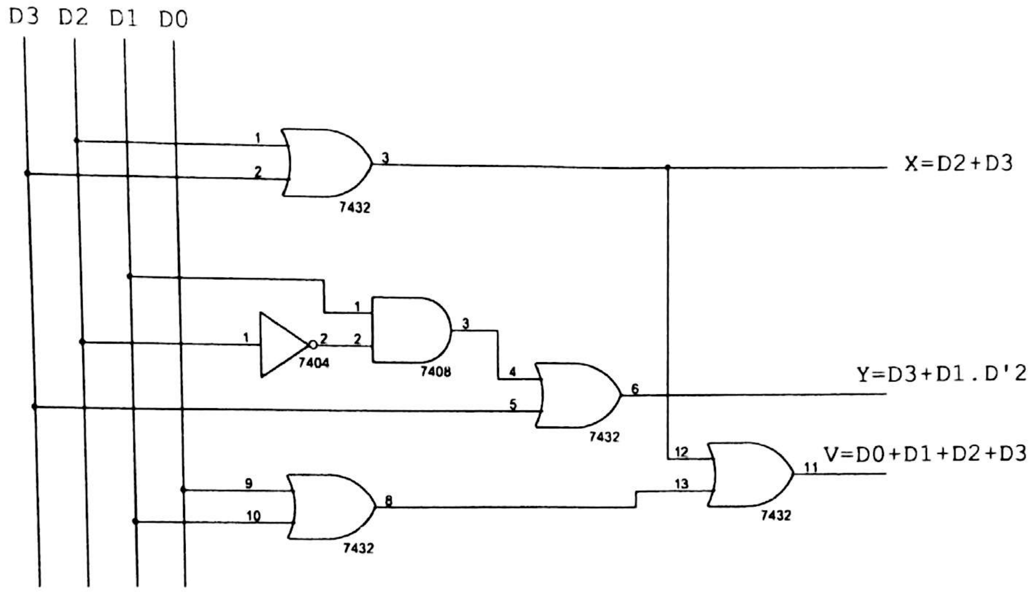
Implement a 4×2 *priority encoder with basic gates.*

Procedure:

1. Write the truth table for 4×2 priority encoder.

D_3	D_2	D_1	D_0	X	Y	V

2. Write the Boolean function for the output logic.
3. Simplify the Boolean function using K-map.
4. Draw the logic diagram to implement the simplified Boolean function.



5. Select ICs from the equipment list.
6. Observe and note the output logic for all combination of inputs.

Experiment: 8
Experiment name: *Design of Flip-flop using basic gates.*

Caution:

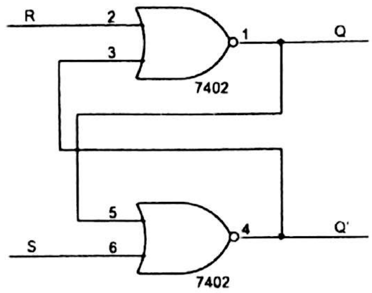
1. Remember to properly identify the pin numbers so that no accidents occur.
2. Properly bias the ICs with appropriate voltages to appropriate pins.

Equipment:

1. Trainer Board
2. IC 7400, 7402, 7432, 7408, 7404
3. Microprocessor Data handbook

Job 1:

Design of an SR Flip-flop using NOR gates only.



Procedure:

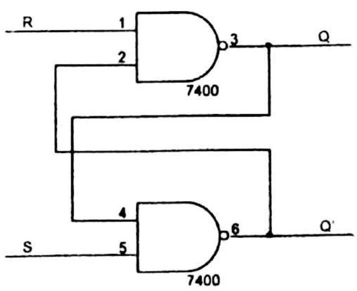
1. Draw the logic diagram to implement SR Flip-flop.
2. Fill up the table with different combination of inputs.

S	*R*	*Q*	*Q'*
1	0		
0	0		
0	1		
0	0		
1	1		

3. Observe the combination for which no change and invalid or race conditions arise.

Job 2:

Design of an SR Flip-flop using NAND gates only.



Procedure:

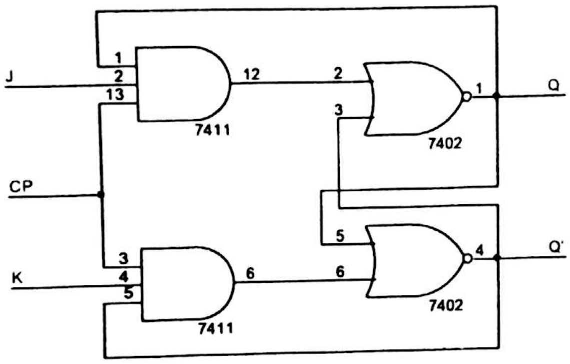
1. Draw the logic diagram to implement SR Flip-flop.
2. Fill up the table with different combination of inputs.

S	R	Q	Q'
1	0		
0	0		
0	1		
0	0		
1	1		

3. Observe the combination for which no change and invalid or race conditions arise.

Job 3:

Design of a J-K Flip-flop using AND & NOR gate only.



Procedure:

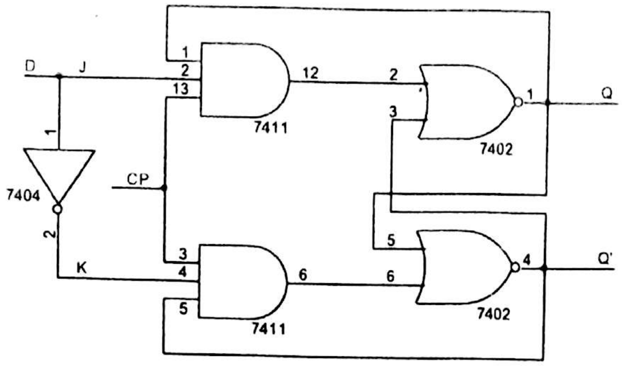
1. Draw the logic diagram to implement J-K Flip-flop.
2. Fill up the table with different combination of inputs.

Q	J	K	$Q(t+1)$
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

3. Observe the combination for which no change and invalid or race conditions arise.

Job 4:

Design of a D Flip-flop from a J-K Flip-flop.



Procedure:

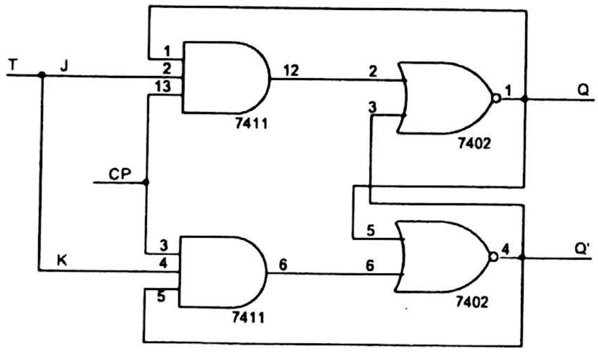
1. Draw the logic diagram to implement D Flip-flop.
2. Fill up the table with different combination of inputs.

Q	D	$Q(t+1)$
0	0	
0	1	
1	0	
1	1	

3. Observe the combination for which no change and invalid or race conditions arise.

Job 5:

Design of a T Flip-flop from a J-K Flip-flop.



Procedure:

1. Draw the logic diagram to implement T Flip-flop.
2. Fill up the table with different combination of inputs.

Q	T	$Q(t+1)$
0	0	
0	1	
1	0	
1	1	

3. Observe the output logic.

Ahsanullah University of Science and Technology

Department of Electrical and Electronic Engineering

LABORATORY MANUAL

FOR

ELECTRICAL AND ELECTRONIC SESSIONAL COURSES

Student Name :

Student ID :

Course no : EEE - 2104

Course Title : Electronic Circuits - I Lab

For the students of

Department of Electrical and Electronic Engineering

2^{nd} Year, 1^{st} Semester

Price : Tk. 14.00

Experiment No: 1

Name of the Experiment : I-V Characteristics of diode.

Objective :

Study the I-V characteristic of diode.

Theory :

A diode is a bi-polar device that behaves as the short circuit when it is in forward bias and as an open circuit when it is in reverse bias condition.

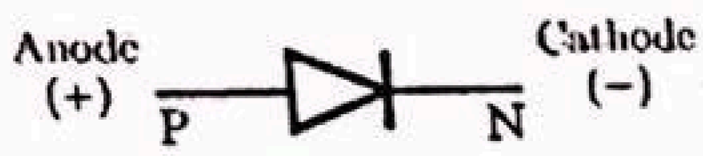


Figure 1.1 : Schematic Diagram of Diode.

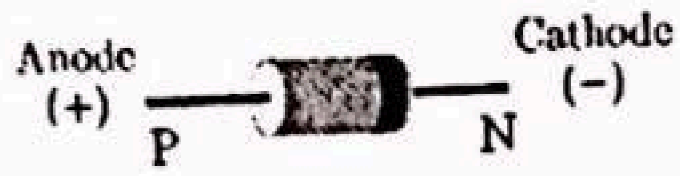


Figure 1.2 : P - N Junction Diode .

There are two types of biasing condition for a diode :

1. When the diode is connected across a voltage source with positive polarity of source connected to p side of diode and negative polarity to n side, then the diode is in forward bias condition.

2. When the diode is connected across a voltage source with positive polarity of source connected to n side of diode and negative polarity to p side, then the diode is in reverse bias condition.

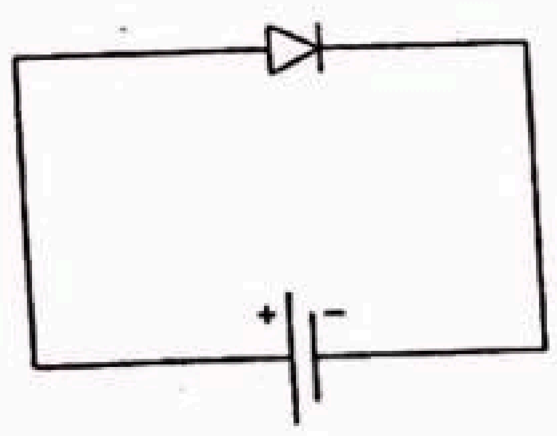


Figure 1.3 : Forward Bias connection.

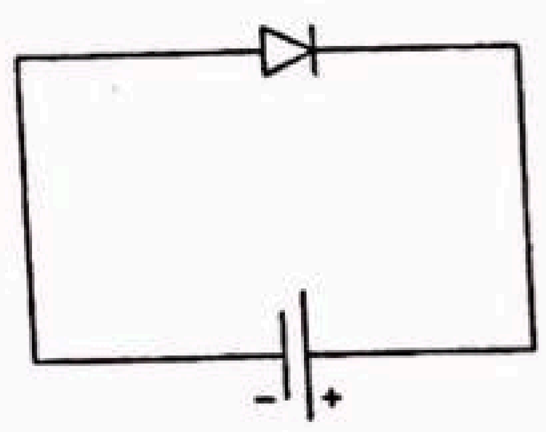


Figure 1.4 : Reverse Bias connection.

If the input voltage is varied and the current through the diode corresponds to each voltage are taken then the plot of diode current (I_d) vs diode voltage (V_D) will be follows :

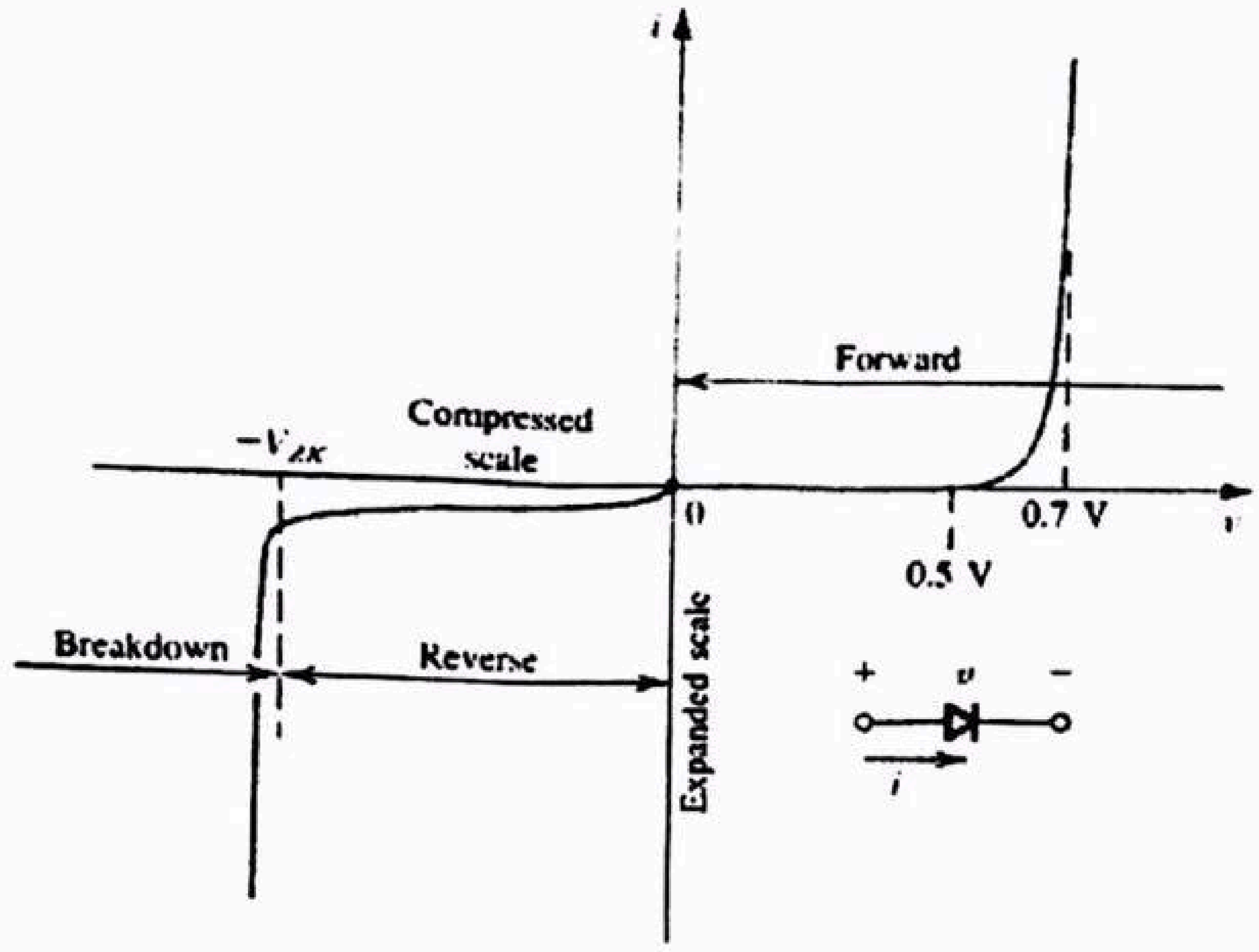


Figure 1.5 : I - V Characteristics of Diode.

At the reverse bias condition the amount of current flows through the diode is very small (at microampere range). But if the voltage continuously increases in reverse direction, at a certain value the diode will break down and huge amount of current will flow in reverse direction. This is called breakdown of diode. In laboratory the breakdown will not tested because it will damages the diode permanently.

From the characteristics curve it can be seen that, a particular forward bias voltage (V_T) is required to reach the region of upward swing. This voltage, V_T is called the cut-in voltage or threshold voltage of diode. For Si diode the typical value of threshold voltage is 0.7 volt and for Ge diode is 0.3 volt.

Equipments And Components :

Serial no.	Component Details	Specification	Quantity
1.	p-n junction diode	1N4007	1 piece
2.	Resistor	1 KΩ	1 piece
3.	DC power supply		1 unit
4.	Signal generator		1 unit
5.	Trainer Board		1 unit
6.	Oscilloscope		1 unit
7.	Digital Multimeter		1 unit
8.	Chords and wire		as required

Experimental Setup :

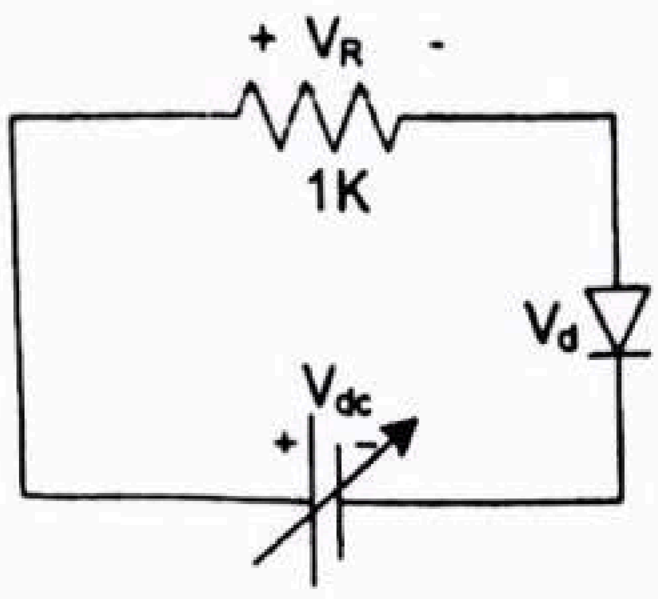


Figure 1.6 : Circuit Diagram for Obtaining Diode Diode Forward Characteristics.

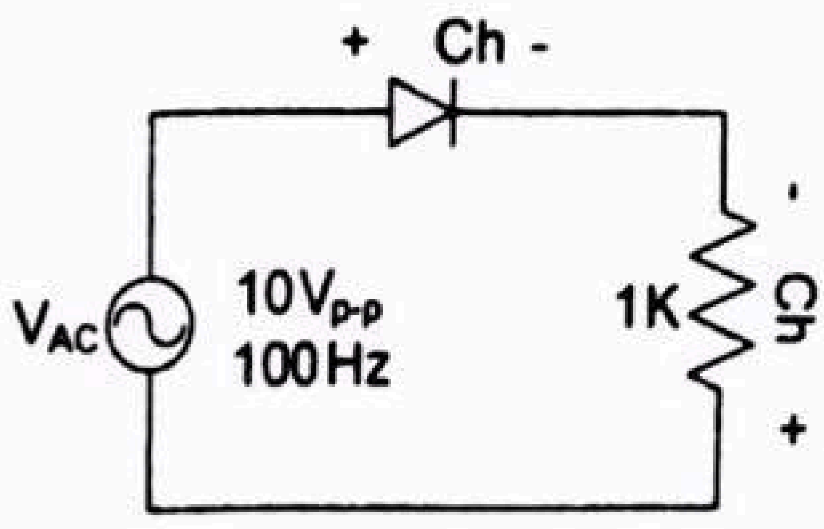


Figure 1.7 : Circuit Diagram for Obtaining Characteristics From Oscilloscope.

Procedure :

1. Measure the resistance accurately using multimeter.
2. Construct the circuit as shown in figure - 1.6.
3. Vary input voltage V_{dc}. Measure V_{dc}, V_d, V_R for the given values of V_d and record data on data table. Obtain maximum value of V_d without increasing V_{dc} beyond 25 volt.
4. Calculate the values of I_d using the formula, $I_d = V_R / R$.
5. Construct the circuit as shown in figure - 1.7.
6. Ste the oscilloscope in X-Y mode. Identify zero record on oscilloscope display. Make proper connection and observe the output.
7. Repeat the step 5 and 6 by increasing the input supply frequency 5 KHz.

Data Table :

V_{dc} (volt)	V_d (volt)	V_R (volt)	$I_d = V_R / R$ (mA)

Report :

1. Draw the I - V characteristics curve of diode from the reading obtain in this experiment.
2. Calculate static resistance for I_d = 5 mA and I_d = 10 mA.
3. Determine the Q- point for the circuit in figure - 6, when V_{dc} = 8 volt.

Experiment No: 02

Name of the Experiment: Diode rectifier circuits.

Objective:

Study of different diode rectifier circuits.

Theory:

A rectifier converts an AC signal into a DC signal. From the characteristic curve of a diode we observe that if allows the current to flow when it is in the forward bias only. In the reverse bias it remains open. So, when an alternating voltage (signal) is applied across a diode it allows only the half cycle (positive half cycle depending on the orientation of diode in the circuit) during its forward bias condition, other half cycle will be clipped off. In the output the load will get DC signal.

Diode rectifier can be categorized in two major types. They are -

1. Half-wave rectifier.
2. Full-wave rectifier.

Half - Wave Rectifier: Half-wave rectifier can be built by using a single diode. The circuit diagram and the wave shapes of the input and output voltage of half wave rectifier are shown bellow (figure 2.1) -

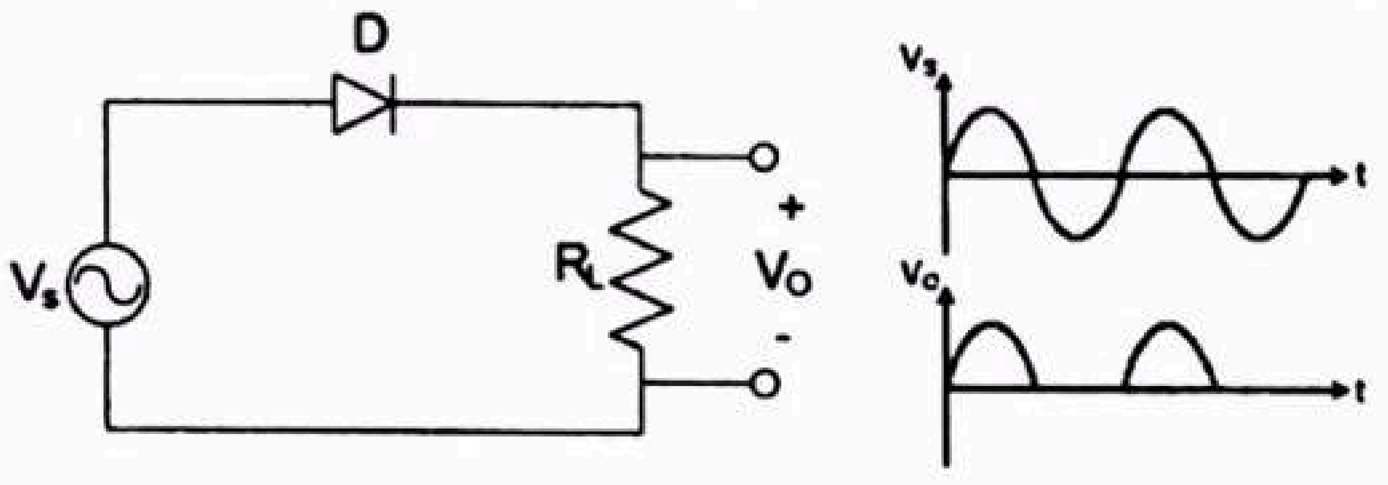


Figure 2.1: Half Wave Rectifier.

The major disadvantages of half wave rectifier are -

- In this circuit the load receives approximately half of input power.
- Average DC voltage is low.
- Due to the presence of ripple output voltage is not smooth one.

Full Wave Rectifier: in the full-wave rectifier both the half cycle is present in the output. Two circuits are used as full-wave rectifier are shown bellow -

a) Full-wave rectifier using center-tapped transformer.
b) Full-wave bridge rectifier.

Full-wave rectifier using center-tapped transformer: two diodes will be connected to the ends of the transformer and the load will be between the diode and center tap. The circuit diagram and the wave shapes are shown in bellow (figure 2.2) -

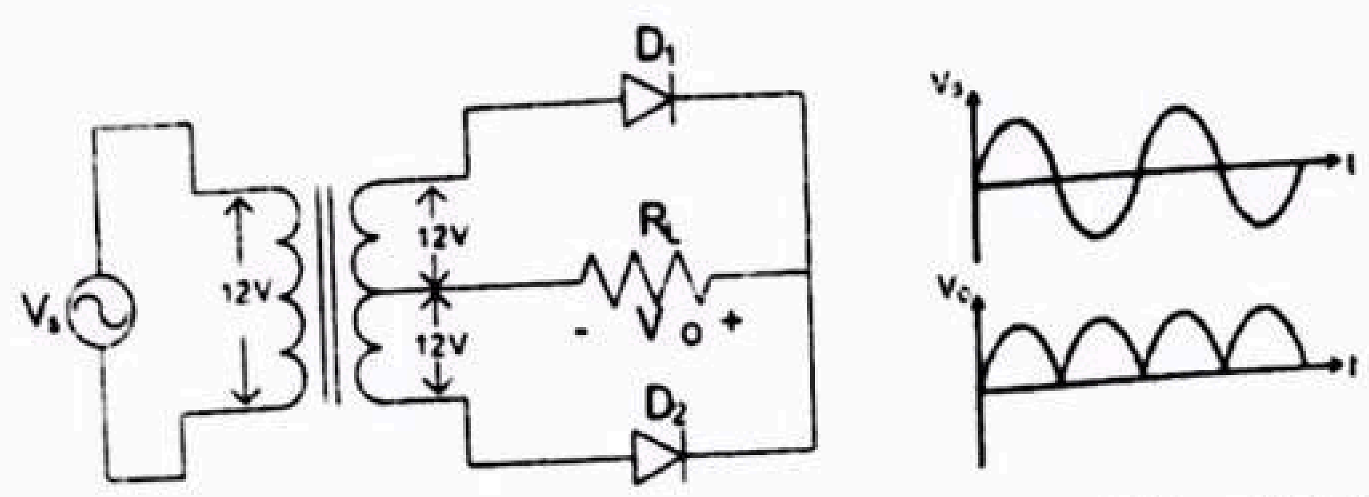


Figure 2.2: Full Wave Rectifier Using Center Tapped Transformer.

Full-wave rectifier using center-tapped transformer circuit has some advantages over full-wave rectifier. Those are -

- Wastage of power is less.
- Average DC output increase significantly.
- Wave shape becomes smoother.

The disadvantages of full-wave rectifier using center-tapped transformer are -

- Require more space and becomes bulky because of the transformer.
- Not cost effective (for using transformer).

Full-wave bridge rectifier: a bridge rectifier overcomes all the disadvantages of described above. Here four diodes will be connected as bridge connection. The circuit diagram and the wave shapes are shown in bellow (figure 2.3) -

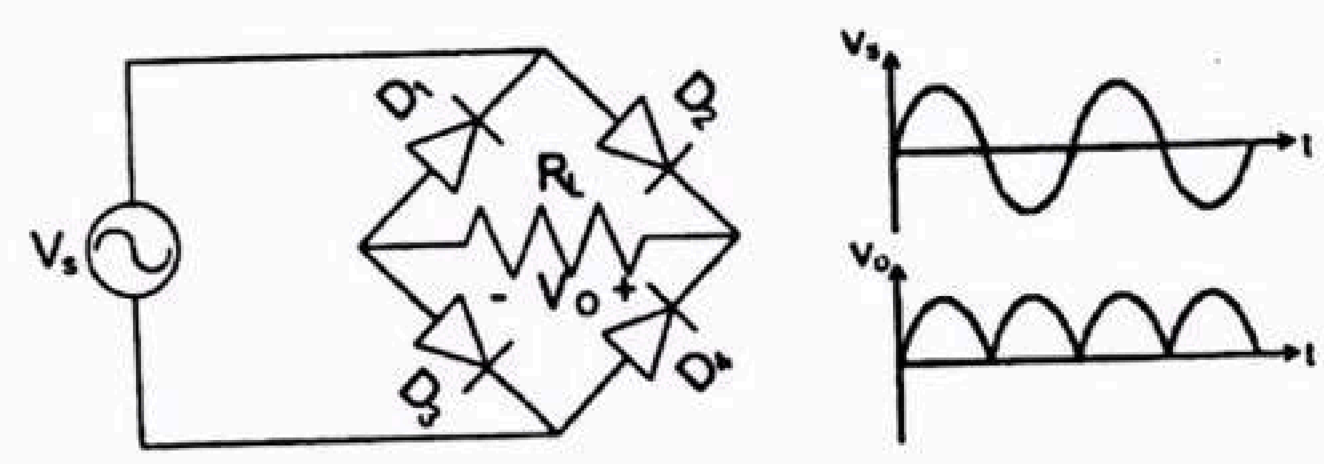


Figure 2.3: Full Wave Bridge Rectifier.

This rectifier however cannot produce a smooth DC voltage. It produces some ripple in the output. This ripple can be reducing by using filter capacitor across the load.

Equipments And Components:

Serial no.	Component Details	Specification	Quantity
1.	p-n junction diode	1N4007	4 piece
2.	Resistor	10KΩ	1 piece
3.	Capacitor	0.22µF, 10µF	1 piece each
4.	Signal generator		1 unit
5.	Trainer Board		1 unit
6.	Oscilloscope		1 unit
7.	Digital Multimeter		1 unit
8.	Chords and wire		as required

Experimental Setup:

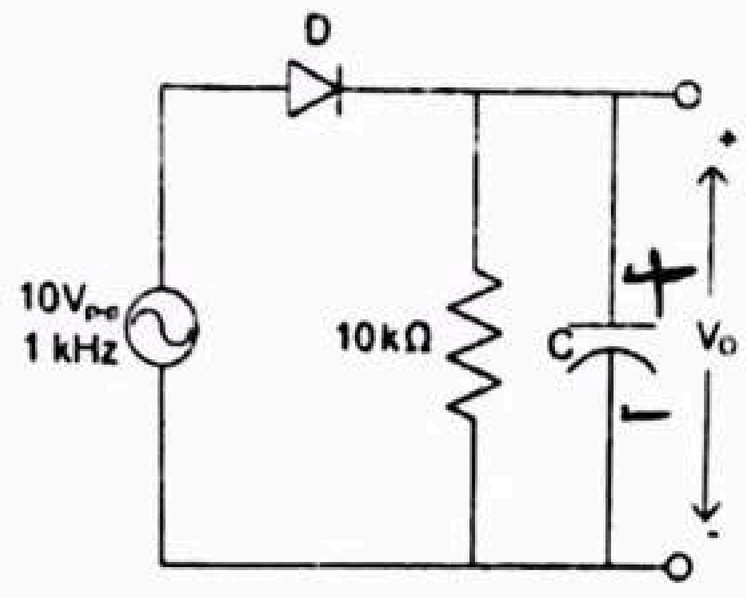


Figure 2.4 : Experimental Circuit 1.

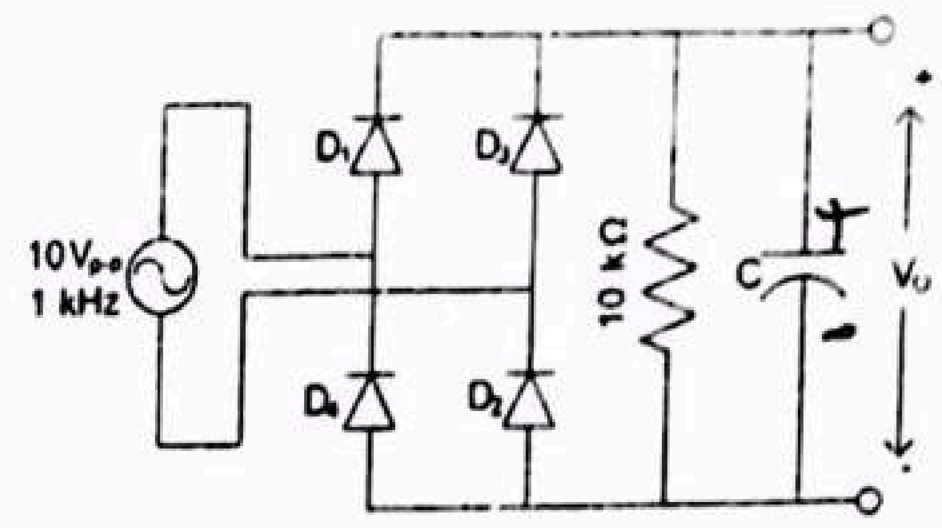


Figure 2.5 : Experimental Circuit 2.

Procedure:

1. Connect the circuit in breadboard as shown in figure 2.4 without capacitor.
2. Observe the output and input voltages in the oscilloscope and draw them.
3. Connect the 0.22μF capacitor and repeat step 2.
4. Connect the 10μF capacitor and repeat step 2. How does the output wave-shape differ from that in step 3?
5. Vary the frequency from 10 KHz to 100 Hz. What effects do you observe when frequency is changed?
6. Connect the circuit breadboard as shown in figure 2.5 without capacitor.
7. Observe the output and input voltages in the oscilloscope and draw them.
8. Connect the 0.22μF capacitor and repeat step 7.
9. Connect the 10μF capacitor and repeat step 7. How does the output wave-shape differ from that in step 8?
10. Vary the frequency from 10 KHz to 100 Hz. What effects do you observe when frequency is changed?

Report:

1. Write the answers that were asked during the working procedure.
2. Draw the input wave, output wave (without and with capacitor) for both the circuits.
3. What is the effect in output for changing input signal frequency for both the circuits (without and with capacitor)?
4. What is the function of capacitor in the both circuits? Why a capacitor of higher value is preferable?

Experiment No : 04

Name of the Experiment : Zener Diode applications.

Objective:

Study of the Zener Diode applications.

Theory :

The diodes we have studied before do not operate in the breakdown region because this may damage them. A Zener diode is different; it is a silicon diode that the manufacturer has optimized for operation in the breakdown region. It is used to build voltage regulator circuits that circuits that hold the load voltage almost constant despite large change in line voltage and load resistance. The symbol of Zener diode shows in figure 4.1.

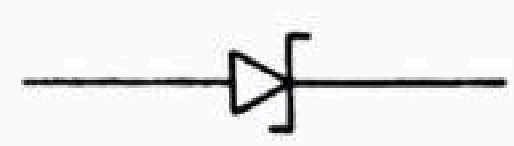


Figure 4.1 : Symbol of Zener Diode.

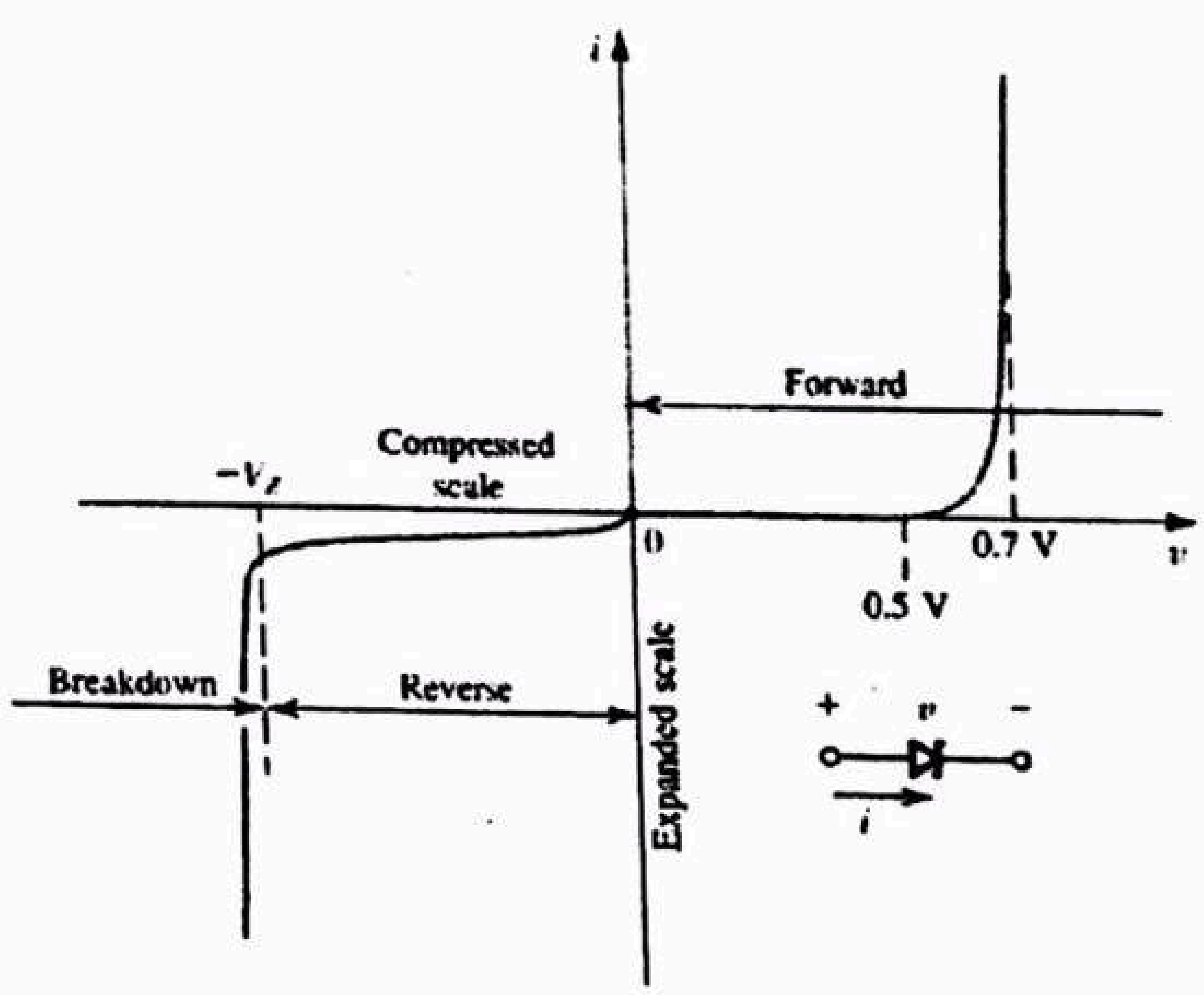


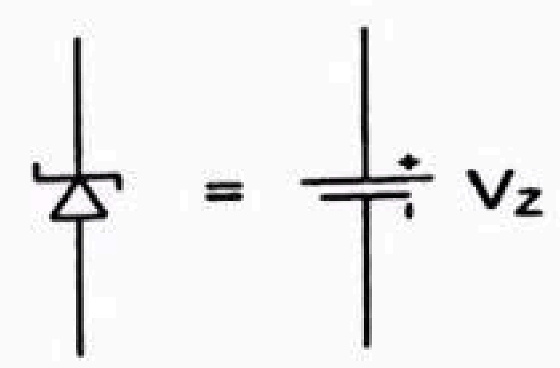
Figure 4.2 : I - V Characteristics of Zener Diode.

The Zener diode may have a breakdown voltage from about 2 to 200 volts. These diodes can operate in any of three regions – forward, leakage and breakdown. Figure 4.2 shows the I-V characteristics curve of Zener diode.

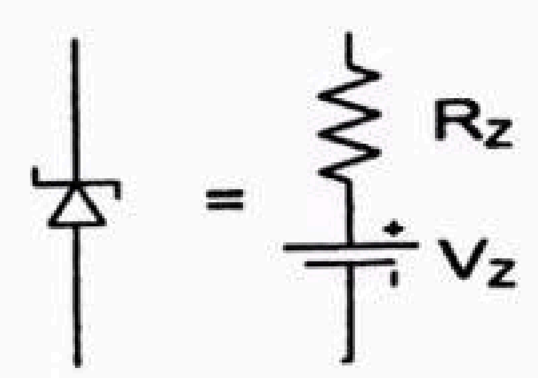
- In the forward region it works as an ordinary diode.
- In the leakage region (between zero and breakdown) it has only a small reverse saturation current.
- In the breakdown it has a sharp knee, followed by an almost vertical increase in current without changing the voltage.
- The voltage is almost constant, approximately equal to V_z over most of the breakdown region.

Equivalent circuits of Zener Diode : Two approximation are used for Zener Diode equivalent circuit.

First Approximation : As the voltage remains constant across the Zener diode though the current changes through it, it is considered as a constant voltage source according to the first approximation.



Second Approximation : A Zener resistance is in series with the ideal voltage source is approximated.



Equipments and Components:

Serial no.	Component Details	Specification	Quantity
1.	Zener diode	5 volts	1 piece
2.	Resistor	220Ω, 470Ω, 1KΩ	1 piece each
3.	POT	10KΩ	1 unit
4.	Trainer Board		1 unit
5.	DC Power Supply		1 unit
6.	Digital Multimeter		1 unit
7.	Chords and wire		as required

Experimental Setup:

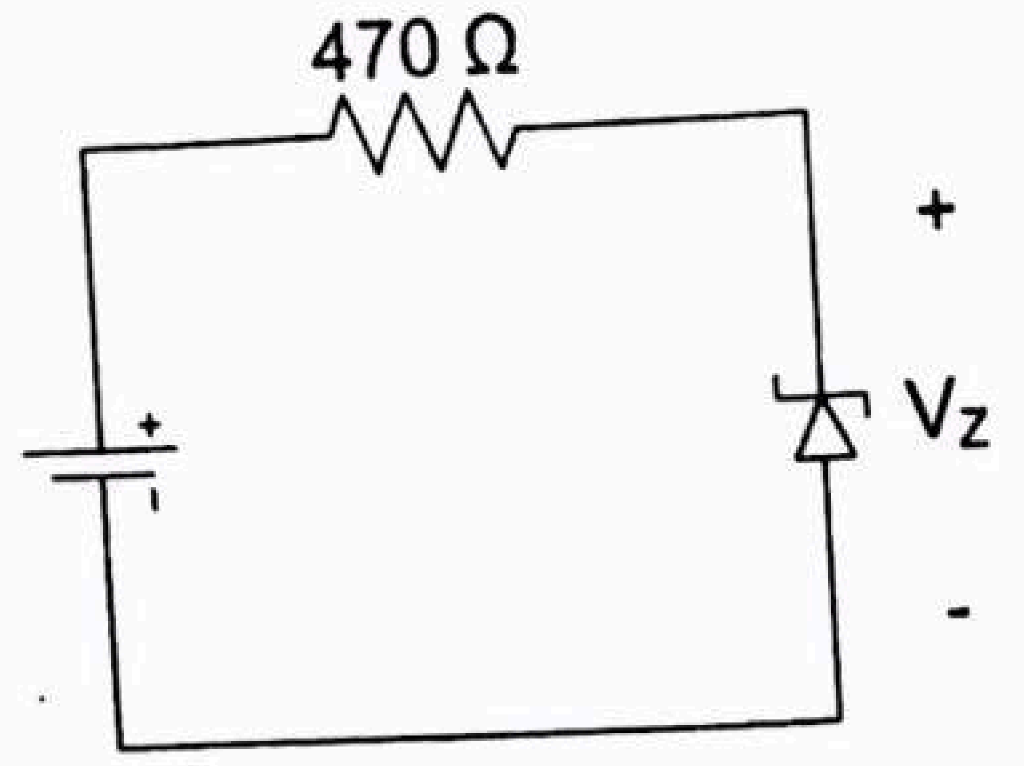


Figure 4.3 : Experimental Circuit 1.

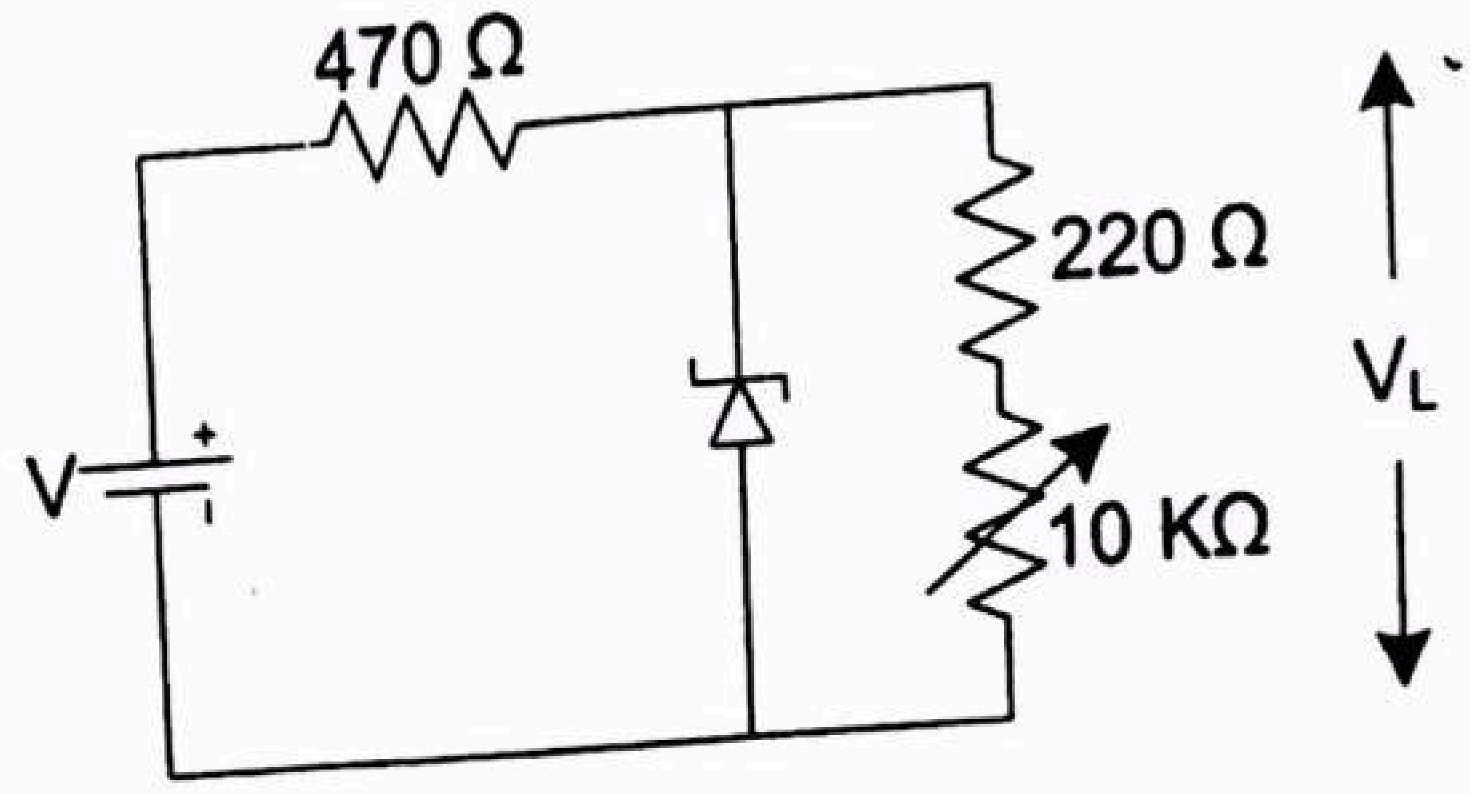


Figure 4.4 : Experimental Circuit 2.

Procedure :

1. Connect the circuit as shown in the figure 4.3
2. Vary the supply voltage from zero volt, complete the Table 4.1.
3. Connect the circuit as shown in the figure 4.4
4. Keep the POT at maximum position and power up the circuit. Apply 10 as V.
5. Gradually decrease the POT resistance and complete the Table 4.2.
6. Replace load with 1KΩ resistance, vary the supply voltage and take reading for Table 4.3.

Table 4.1 : Data for I - V characteristics.

V (volts)	V_R (volts)	V_z (volts)	$I_z = V_R / R$ (mA)
1.0			
2.0			
3.0			
4.0			
5.0			
6.0			
7.0			
8.0			
9.0			
10.0			
11.0			
12.0			

Table 4.2 : Data for regulation due to load variation.

V_{220} (mV)	V_L (volts)	I_L (Amp)

Table 4.3 : Data for regulation due supply voltage variation.

V (volts)	V_L (volts)
5.0	
6.0	
7.0	
8.0	
9.0	
10.0	
11.0	
12.0	

Report :

1. **Plot the I - V characteristics of Zener diode. Determine the Zener breakdown voltage from the plot.**
2. **Plot I_L vs V_L for the data table 4.2. Find the voltage regulation.**
3. **Plot V_L vs V for the data table 4.3. Find the voltage regulation.**

Experiment No: 05

Name of the Experiment : The output characteristics of CE (common emitter) configuration of BJT.

Objective:

Study of the output characteristics of CE (common emitter) configuration of BJT.

Theory :

Unlike the diode, which has two doped region, a transistor has three doped region. They are as follows –

a) Emitter,
b) Base and
c) Collector.

These three doped regions form two junctions: One between the emitter and base and other between the collector and the base. Because of these it can be thought as combination of two diodes, the emitter and the base form one diode and the collector and base form another diode. The emitter is heavily doped. Its job is to emit or inject free majority carrier (electron for NPN and hole for PNP) into the base. The base is lightly doped and very thin. It passes the most of the emitter-injected electron (for NPN) into the collector. The doping level of the collector is between emitter and base. Figure 5.1 shows the biased NPN transistor.

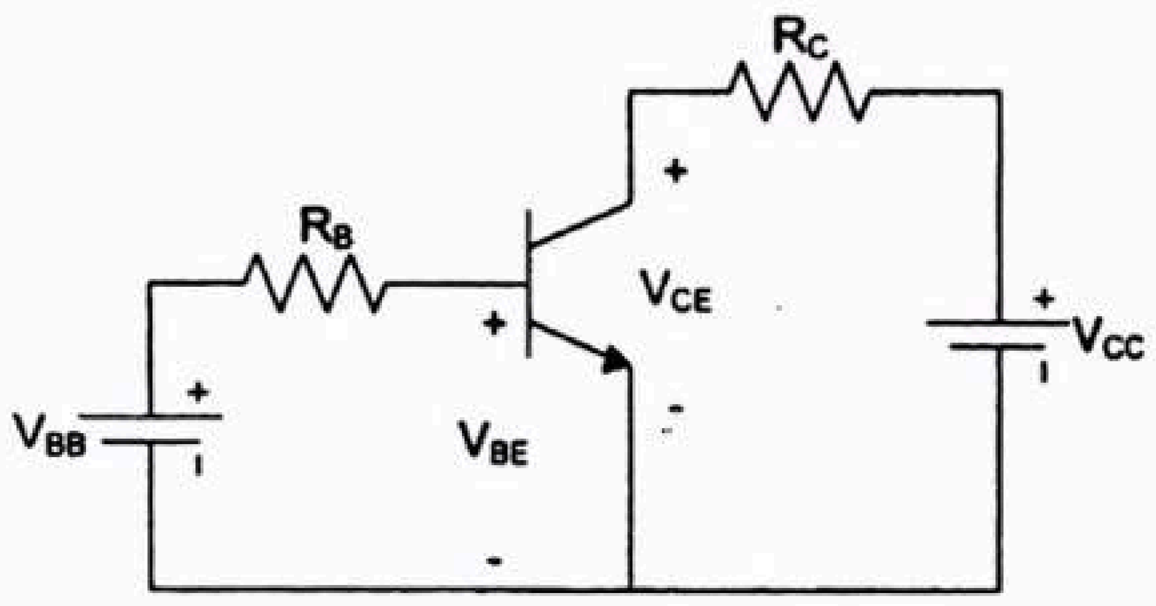


Figure 5.1 : Biasing of an NPN transistor.

If the V_{BB} is greater than the barrier potential, emitter electron will enter base region. The free electron can flow either into the base or into the collector. As base lightly doped and thin, most of the free electron will enter into the collector.
There are three different current in a transistor. They are emitter current (I_E), collector current (I_C) and the base current (I_B) are shows in figure 5.2.

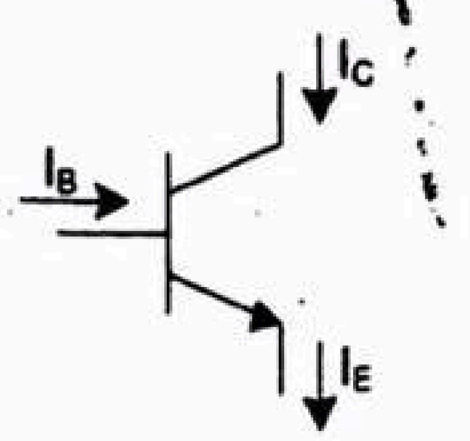


Figure 5.2 : Different current in transistor.

Here, $I_E = I_C + I_B$, and the current gain $\beta = \frac{I_C}{I_B}$

Characteristics Curve : The characteristics of a transistor is measured by two characteristics curve. They are as follows –

a) Input characteristics curve.
b) Output characteristics curve.

Input Characteristics Curve : Input characteristics is defined as the set of curves between input current (I_B) vs. input voltage (V_{BE}) for the constant output voltage (V_{CE}). It is the same curve that is found for a forward biased diode.

Output Characteristics Curve : Output characteristics is defined by the set of curves between output current (I_C) vs. output voltage (V_{CE}) for the constant input current (I_B). The curve has the following features –

- It has three regions namely Saturation, Active and Cutoff region.
- The rising part of the curve, where V_{CE} is between 0 and approximately 1 volt is called saturation region. In this region the collector diode is not reversed biased.
- When the collector diode of the transistor becomes reverse biased, the graph becomes horizontal. In this region the collector remains almost constant. This region is known as the active region. In applications where the transistor amplifies weak radio and TV signal, it will always be operation in the active region.
- When the base current is zero, but there is some collector current. This region of the transistor curve is known as the cutoff region. The small collector current is called collector cutoff current.
- For different value of base current (I_B) an individual curve can be obtained.

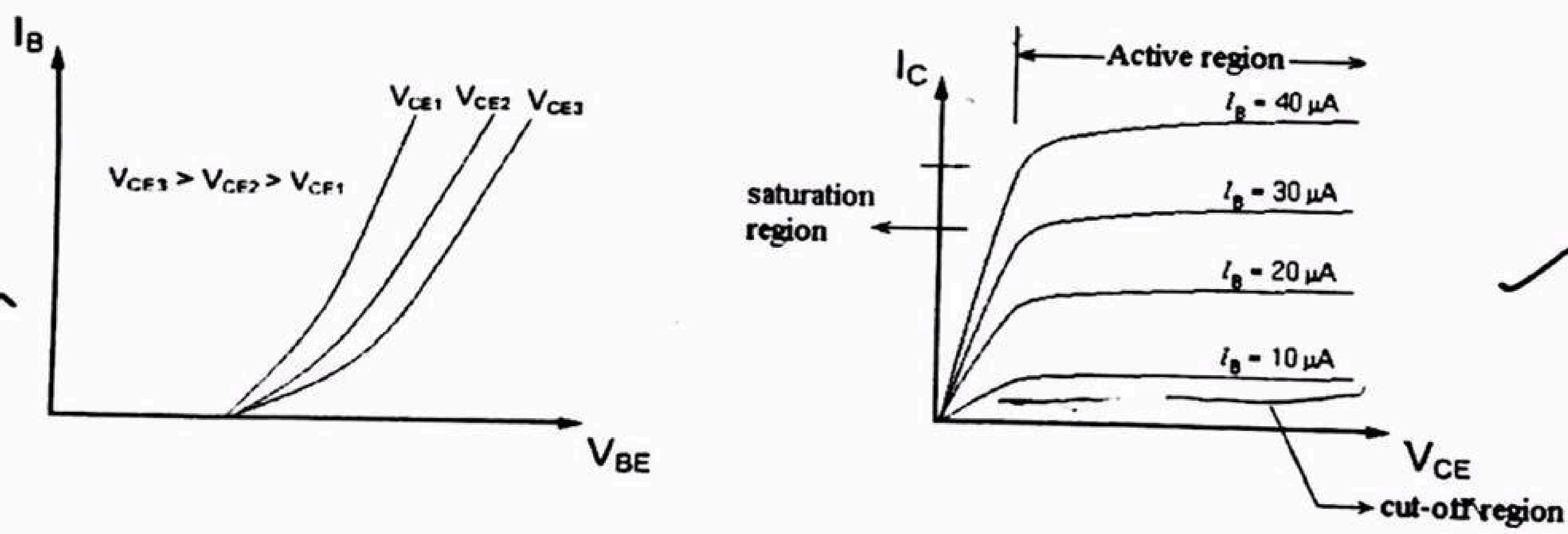


Figure 5.3 : (a) Input Characteristic, (b) Output Characteristic of NPN transistor.

Equipments And Components:

Serial no.	Component Details	Specification	Quantity
1.	Transistor	C828	1 piece
2.	Resistor	470Ω, 2.2KΩ, 3.3KΩ, 4.7KΩ, 10KΩ, 470KΩ	1 piece each
3.	POT	100KΩ	1 unit
4.	Trainer Board		1 unit
5.	DC Power Supply		1 unit
6.	Digital Multimeter		1 unit
7.	Chords and wire		as required

Experimental Setup:

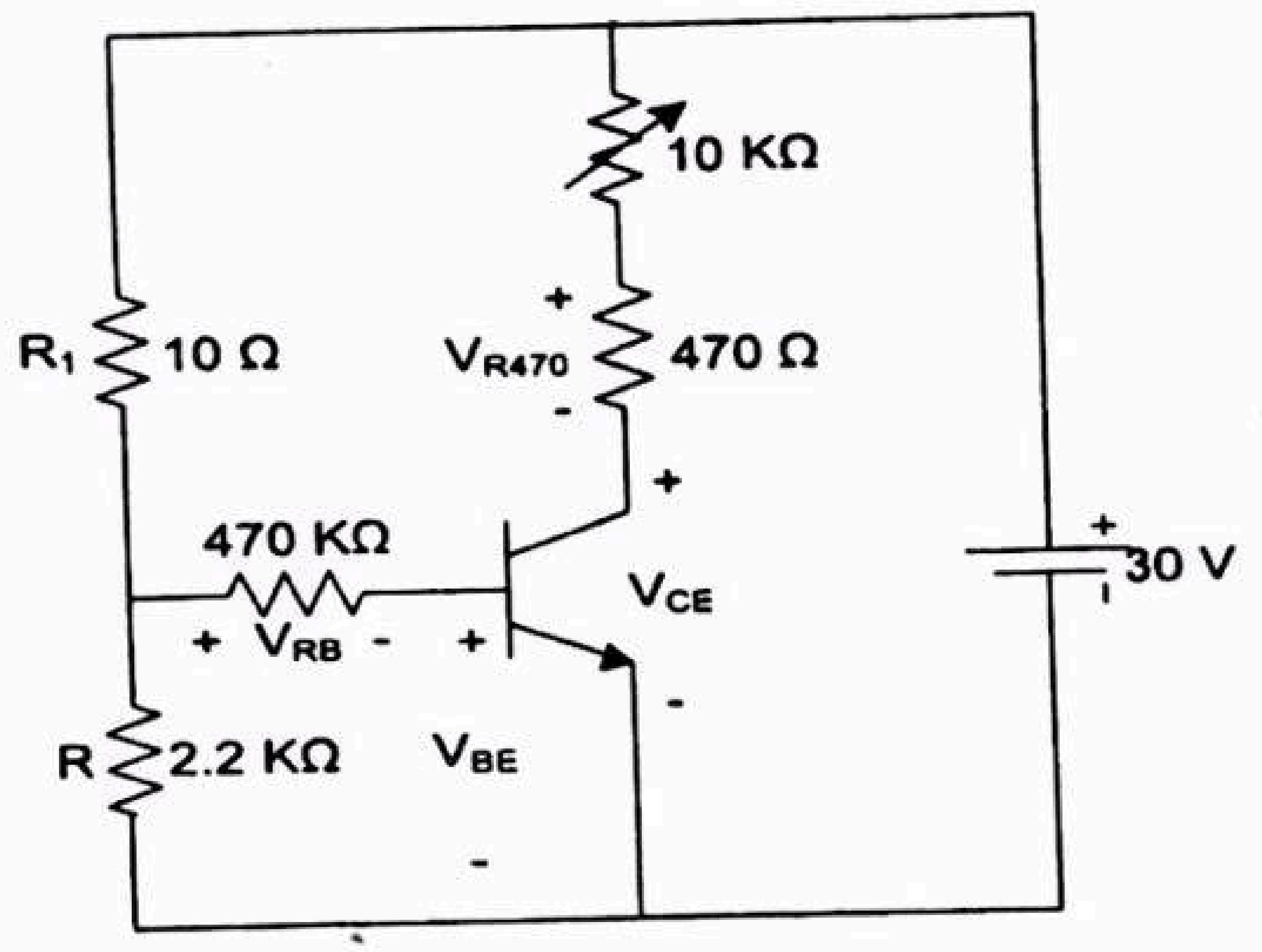


Figure 5.4: Experimental Circuit.

Procedure:

1. Connect the circuit as shown in the figure 5.4. Use 2.2 KΩ as R.
2. Measure V_{RB} and calculate I_S using $I_E = V_{RB} / R_B$. (We will assume that I_B to be constant for a particular setup at input.)
3. Measure the voltages of V_{CE} and V_{R470}. And calculate I_C using $I_C = V_{R470} / R_{470}$.

4. Take at least 10 reading by varying the POT.
5. Repeat step 1 to 4 with resistance R as 3.3 KΩ and 4.7 KΩ.

Table 5.1 : Data for I - V characteristics of transistor.

R (KΩ)	$I_B = V_{RB} / R_B$ (μA)	V_{CE} (volts)	V_{R470} (volts)	$I_C = V_{R470} / R_{470}$ (mA)
2.2				
3.3				
4.7				

Report:

1. Plot the graph of I_C vs. V_{CE} with necessary details. Show the different regions of operation.
2. Plot a hypothetical output characteristic using PNP transistor.
3. Find β for the three different condition.

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

ME 2202: Mechanics of materials
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. Viva for each experiment will be taken on the next day with the report.
5. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental results and discussions (Experimental setup, Experimental conditions, Data, Graph, calculation etc.)
    - Conclusions
    - Acknowledgements
    - References
6. A quiz will be taken on the experiments at the end of the semester.
7. Marks distribution:

Total Marks		
Report	Attendance and Viva	Quiz
30	30	40

Experiment No. 01
Tension test of mild steel specimen

OBJECTIVES

a. To test a mild steel specimen till failure under tensile load
b. To draw stress-strain diagram
c. To determine:
   I. Proportional limit
   II. Modulus of elasticity
   III. Yield limit
   IV. Ultimate strength
   V. Breaking strength
   VI. Percentage elongation
   VII. Percentage reduction in cross-sectional area
   VIII. Modulus of resilience

THEORY

When a specimen is subjected to the action of a force it is deformed, no matter how small the force is. If the specimen is elongated due to the application of the force, the specimen is said to be in tension and the force may be termed as tensile force. In 1678, Hooke showed that, up to a certain limit, a piece of material will extend in proportion to the load that produces the extension.

Tension test: Tension test, also known as tensile test, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. This test is performed to determine various fundamental mechanical properties of the specimen material. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. The most common testing machine used in tensile testing is the *Universal Testing Machine (UTM)*.

Stress: When an external force is applied on the specimen an internal force is developed in order to resist the external force. The internal force per unit area at any section is called stress. Stress is denoted by $\boldsymbol{\sigma}$.

Therefore, $\sigma = \frac{F}{A}$ N/mm² (MPa)

Where, F is applied load; A is the original cross-section of the specimen.

Strain: When the force is applied on the specimen, it is deformed. For the tensile force the specimen is elongated. The elongation per unit length is called strain. Strain is denoted by $\boldsymbol{\varepsilon}$.

$$\text{Therefore, } \varepsilon = \frac{\delta}{L} \text{ N/mm}^2 \text{ (MPa)}$$

Where, δ is the deformation over the length L.

Stress-strain diagram:

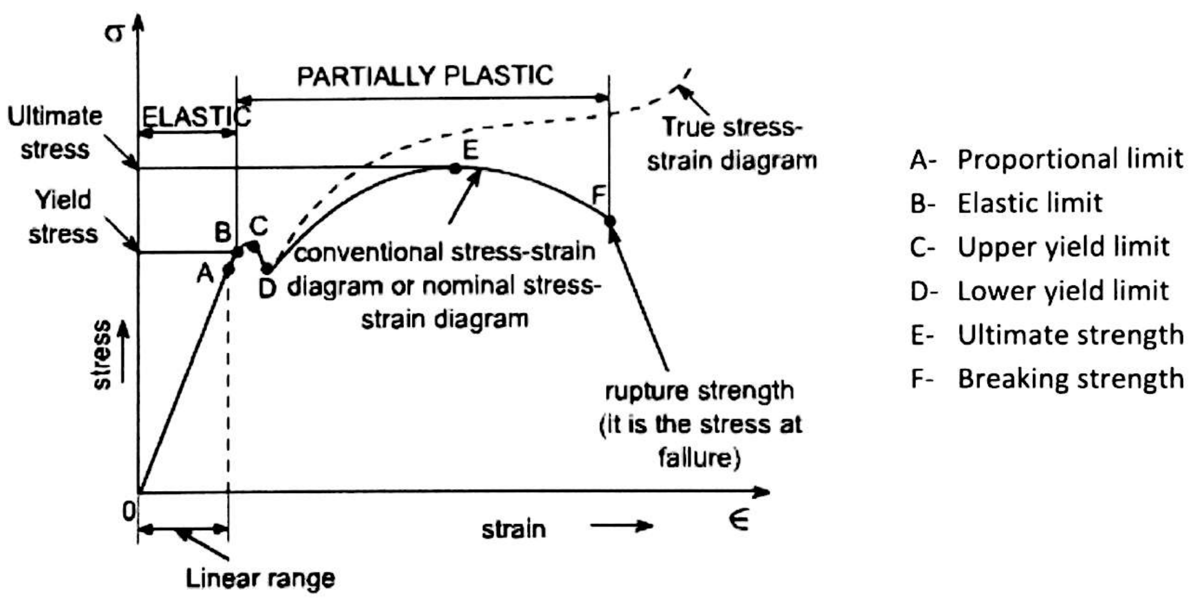


Figure: typical stress-strain diagram for mild steel specimen.

Proportional limit: The point in the stress-strain diagram up to which the stress is proportional to strain is called the proportional limit.

Elastic limit: The point in the stress-strain diagram up to which the specimen remains elastic is known as elastic limit.

Yield limit: The point in the stress-strain diagram at which there is an increase in strain with no further increase in stress is called the yield point. In the case of mild steel there are two yield points, upper and lower.

Ultimate strength: The maximum stress in the stress-strain diagram is called the ultimate strength or tensile strength.

Breaking strength: the stress at which the specimen breaks away is called the breaking strength.

Percentage elongation: The difference between the length after rupture and the initial length divided by the length after rupture and multiplied by 100 is termed as the percentage elongation.

$$\text{Percentage elongation} = \frac{L_f - L_i}{L_i} \times 100\ \%$$

Where,

L_i is the initial gauge length
L_f is the final gauge length

Percentage reduction in area: The difference between the original cross-sectional area and the cross-sectional area at the neck (when the rupture takes place) divided by the original area and multiplied by 100 is termed as the percentage reduction in area.

$$\text{Percentage reduction in area} = \frac{A - a}{A} \times 100\ \%$$

Where,

A is the original cross-sectional area
a is the cross-sectional area at the neck

Modulus of elasticity: Below the proportional limit, stress is proportional to strain and the constant of proportionality is called the modulus of elasticity. This is denoted by ***E***.

Therefore, $E = \frac{\sigma}{\varepsilon}$ N/mm^2 (MPa)

Modulus of elasticity is a measure of material stiffness.

Modulus of resilience: The modulus of resilience is defined as the ability of a material to absorb energy within its proportional limit. This may be calculated as the area under the stress-strain curve from the origin up to the proportional limit. Modulus of resilience is denoted by U_p.

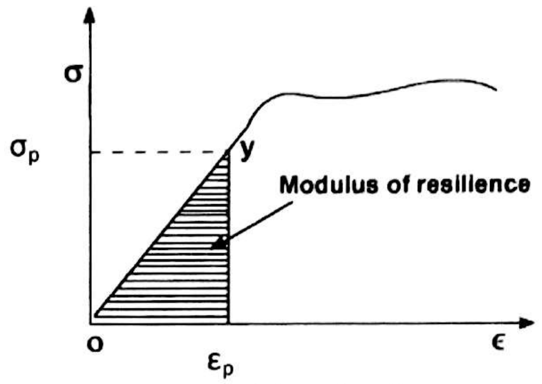


Figure: Modulus of resilience

Therefore, $U_p = \frac{1}{2}\sigma_p \varepsilon_p$ mJ/mm^3

Where, σ_p is the proportional limit.

Modulus of toughness: Toughness is the ability of a material to absorb energy and plastically deform before it fractures. Toughness is calculated by evaluating the area under the stress-strain curve. It is denoted by $\boldsymbol{U_T}$.

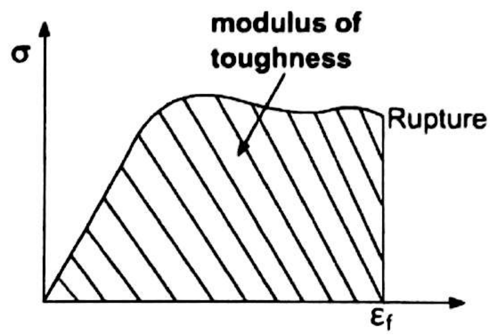


Figure: Modulus of toughness

$$U_T = \int_0^{\varepsilon_f} \sigma d\varepsilon$$

Where, ε_f is the strain at fracture. Modulus of toughness can also be calculated by using either of the following two simplified formulae.

1. $U_T = \sigma_u \varepsilon_f$
2. $U_T = \frac{\sigma_u + \sigma_y}{2} \varepsilon_f$

Where, σ_u is the ultimate strength and σ_y is the yield strength.

APPARATUS

1. UTM
2. Extensometer

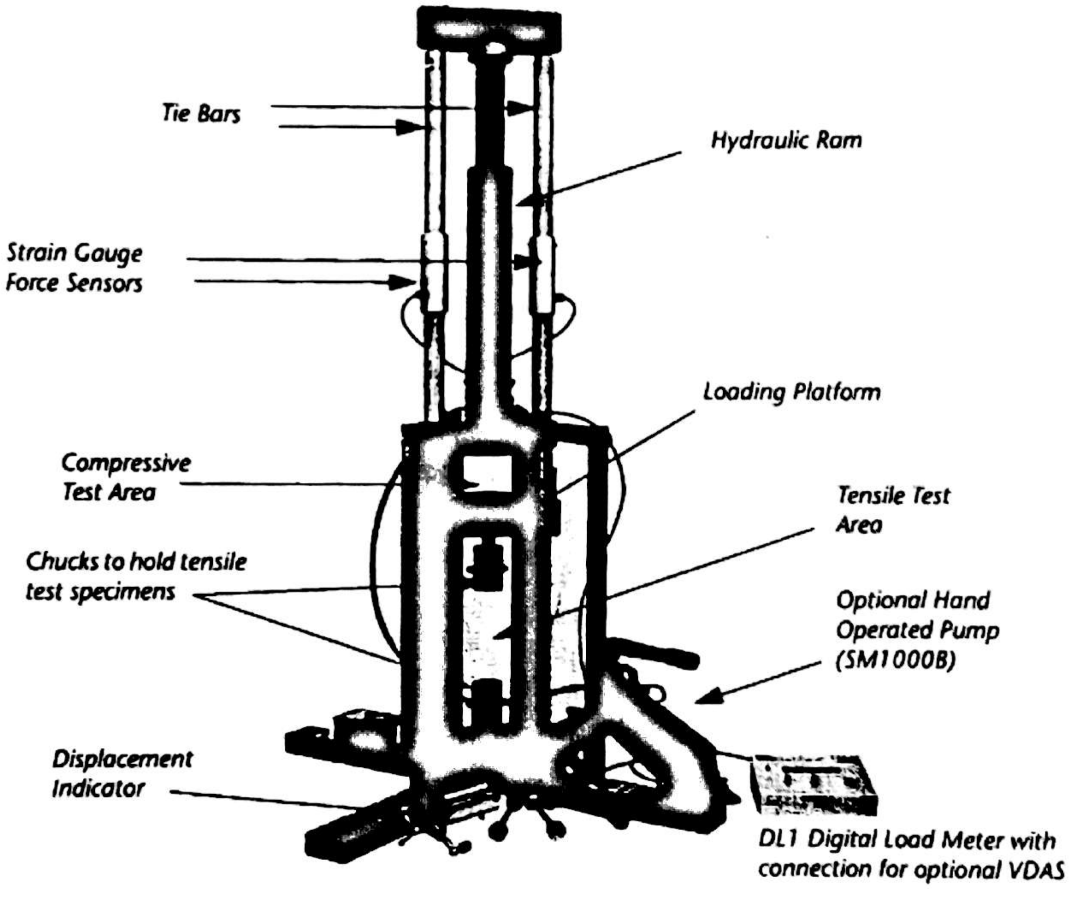


Figure 2 The 100kN Universal Testing Machine

SPECIMENS

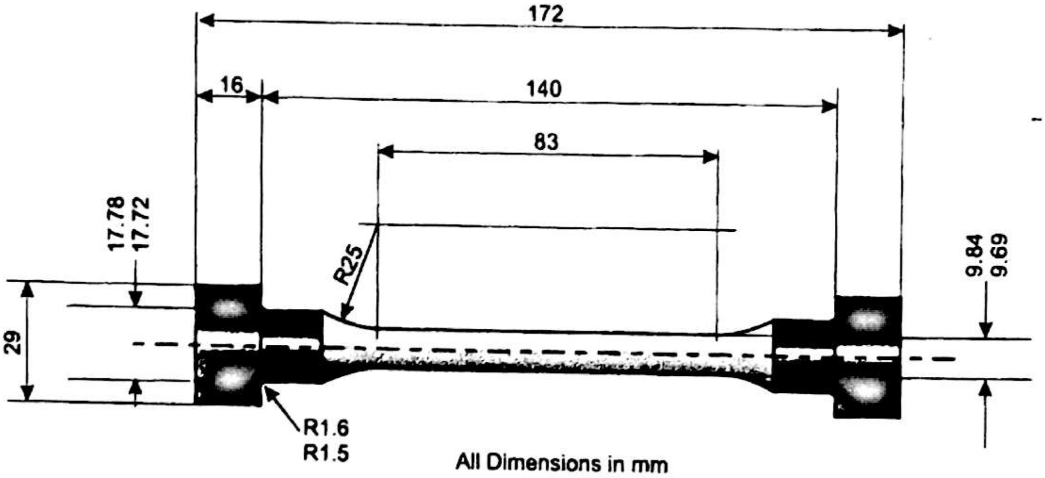


Figure: Dimensions of the Tensile Specimens (Included with the Universal Testing Machine)

DATA TABLE

Specimen type:

Initial gauge length, $L_i =$

Initial diameter of the specimen, $d_i =$

Initial cross-sectional area of the specimen, $A_i =$

Final diameter of the specimen, $d_f =$

Final cross-sectional area of the specimen $A_f =$

Final gauge length $L_f =$

Table: Data for the tension test of mild steel specimen

Obs. No.	*Force (KN)*	*Digital Displacement indicator reading (mm)*	*Extensometer reading (mm)*	*Strain, ε (mm/mm)*	*Stress, σ (MPa)*

Obs. No.	Force (KN)	Digital Displacement indicator reading (mm)	Extensometer reading (mm)	Strain, ε (mm/mm)	Stress, σ (MPa)

Obs. No.	*Force (KN)*	*Digital Displacement indicator reading (mm)*	*Extensometer reading (mm)*	*Strain, ε (mm/mm)*	*Stress, σ (MPa)*

Obs. No.	*Force (KN)*	*Digital Displacement indicator reading (mm)*	*Extensometer reading (mm)*	*Strain, ε (mm/mm)*	*Stress, σ (MPa)*

Obs. No.	*Force (KN)*	*Digital Displacement indicator reading (mm)*	*Extensometer reading (mm)*	*Strain, ε (mm/mm)*	*Stress, σ (MPa)*

Report Writing

Expt. No.: 01

Expt. Name: Tension test of mild steel specimen

1. **Objectives**
2. **Apparatus** (with specification)
3. **Experimental Setup:** Draw a schematic diagram of UTM
4. **Data table:** Photocopy the data table with the collected data. Then do the necessary calculation and fill up the whole data table individually.
5. **Sample calculation:** Show how displacement, stress and strain are calculated from the collected data using a sample data. The sample number should correspond to the last three digits of the student ID number of the student.
6. **Graph:** Draw load vs. deformation and stress vs. strain diagram using *MS Excel* and label it.
7. **Calculation from graph:** Calculate the following properties of the mild steel specimen from load vs. deformation and stress vs. strain curve:
   1. Proportional limit
   2. Modulus of elasticity
   3. Yield limit
   4. Ultimate strength
   5. Breaking strength
   6. Percentage elongation
   7. Percentage reduction in cross-sectional area
   8. Modulus of resilience
8. **Discussion:** Discuss the following points regarding the experiment:
   1. *Discuss the results and graph*
   2. *Discuss about the failure mode and fracture surface*
9. **Reference**

Hardness Test

1. Objective

The primary objective of this experiment is to measure the Rockwell and Brinell hardness number using the correct indenter, loading, and scale. The tensile strength of the specimen material will also be calculated using the determined hardness number.

2. Theory

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Hardness tests can be used for many engineering applications to achieve the basic requirement of mechanical property. For example:

- Surface treatments where surface hardness has been much improved.
- Powder metallurgy
- Fabricated parts: forgings, rolled plates, extrusions, machined parts.

The hardness test produces permanent deformation (or change of shape) of the material. The test is therefore destructive. Because deformation of the material is controlled by dislocation motion, it is not surprising the hardness can be correlated with both yield strength and tensile strength. Typically, hard material have high strength, soft material have low strength.

However, there are three general types of hardness measurements depending on the manner in which the test is conducted:

a) Scratch Hardness measurement: Scratch tests are the simplest form of hardness test. In this test, various materials are rated on their ability to scratch one another. Moh's hardness test is of this type. This test is used mainly in mineralogy.
b) Rebound Hardness measurement: In rebound hardness measurement, a standard body is usually dropped on to the material surface and the hardness is measured in terms of the height of its rebound. Shore Hardness is measured by this method.
c) Indentation Hardness measurement: Static Indentation tests are based on the relation of indentation of the specimen by a penetrator under a given

load. The relationship of total test force to the area or depth of indentation provides a measure of hardness. The Rockwell, Brinell, Knoop, Vickers and ultrasonic hardness tests are of this type. For engineering purposes, mostly static indentation tests are used.

2.1 Rockwell Hardness testing

This hardness test uses a direct reading instrument based on the principle of differential depth measurement.

Rockwell Hardness tests are conducted in four steps:

1. The minor load (usually 10 kg for Regular and 3 kg for Superficial) is applied. Use of minor load greatly increases the accuracy of this type of test, because it eliminates the effects of backlash in the system and causes the indenter to break through slight surface roughness.
2. The major load (usually 60, 100 or 150 kg for Regular and 15, 30 and 45 for Superficial) is applied. This causes the indenter to dent the material surface.
3. The major load is removed, leaving the minor load on. Doing this relaxes the elastic deformation, leaving the indenter resting in the plastically deformed dent.
4. The difference in indenter height between steps 1 and 3 is measured.

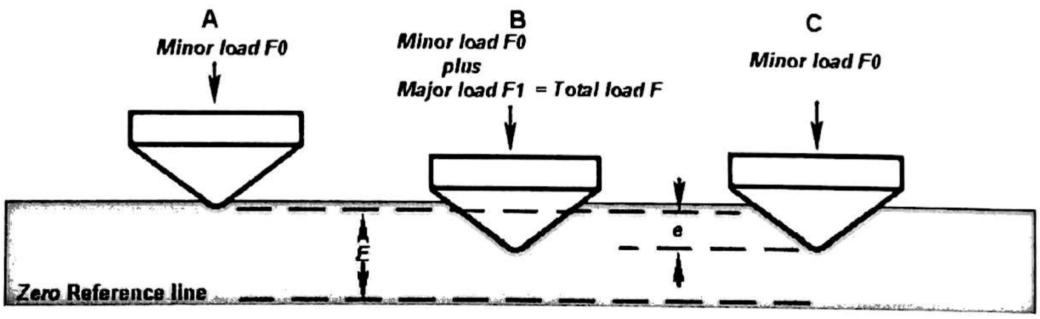


Fig. 1: Rockwell hardness test.

$$HR = E - e$$

Here,

F0 = preliminary minor load in kgf

F1 = additional major load in kgf
F = total load in kgf
e = permanent increase in depth of penetration due to major load F1
E = a constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter
HR = Rockwell hardness number
D = diameter of steel ball

There are a large number of Rockwell Hardness scales. Each scale represents a specific combination of indenter and major load. The different scales make it possible to measure the Rockwell Hardness of a huge variety of materials. There are also "Regular" and "Superficial Rockwell Scales". The following discussion refers to the Regular Rockwell scales. Superficial scales are used for measuring thin and soft materials.

Rockwell Hardness values are expressed as HR (scale) (value). For example, very hard steel might read HRC 62. HRA 55 might be annealed mild steel.

2.2 Fields of application with different Rockwell scales

There is a considerable number of Rockwell scales and choosing the right one depends on the hardness of the material, and the thickness of the specimen or hardened surface (in case where there have been surface treatments such as carburization, nitriding, etc.). The hardness of the material determines the choice of the penetrator, diamond cone or ball.

There are usually two types of indenters. The conical diamond (Brale) indenter is used mainly for testing hard materials such as hardened steel and cemented carbides. It is recommendable for steel with solidity below 785 N/mm² (20 HRC, 230 HB/30).

Hardened steel ball indenters with diameters 1/16", 1/8", 1/4", 1/2" are used for testing softer materials such as fully annealed steels, softer grades of cast iron, and a wide variety of non-ferrous metals. The softer material, the larger should be the diameter of the ball and / or the smaller should be the total test load. For instance, the materials that can be tested with the HRB scale (ball 1/16" – total test load 980.7 N) are harder than the materials tested with the HRL scale (ball 1/4" – total test load 588.4 N).

The most frequent Rockwell Scales are given below:

1. HRC (diamond cone – 150 kgf)

It is used for steel, hardened steel, case hardened steel, pearlitic cast iron, titanium.

2. HRA (diamond cone - 60 kgf)
   For thinner or more brittle specimens of the RC families: cemented carbides, thin case hardened parts, thin gauge steels.
3. HRB (steel ball of 1/6" diameter - 100 kgf)
   In Europe, this scale is usually used for copper alloys (brass, bronze etc.). In the US, it is also used for steel up to approx. 686 N/mm².

2.3 Brinell hardness Scale:

The test is achieved by applying a known load to the surface of the tested material through a hardened steel ball of known diameter. The typical test uses a 10 millimeters diameter steel ball as an indenter with a 3000 kgf force. For softer materials, a smaller force is used; for harder materials, a tungsten carbide ball is substituted for the steel ball.

Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings. Brinell testing often use a very high test load (3000 kgf) and a 10mm wide indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies.

The Brinell method applies a predetermined test load (F) to a carbide/steel ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured across at least two diameters - usually at right angles to each other and these result averaged (d). The resulting measurement is converted to a Brinell value using the Brinell formula or a conversion chart based on the formula.

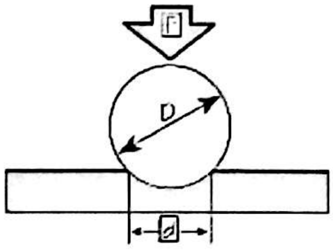


Fig. 2: Brinell hardness test.

$$HB = \frac{2F}{\pi D(D-\sqrt{D^2-d^2})}$$

D = ball diameter
d = impression diameter
F = load
HB = Brinell hardness

3. Experimental Procedure

- First examine the Rockwell hardness tester insuring that the operating lever is in the position closest to the operator and that the correct major load is in a position to be applied.
- Insert the proper indenter into the testing machine and place the test specimen on the anvil.
- Next, turn the elevating screw, raising the specimen into contact with the indenter. Continue to elevate the specimen until the initial load (10 kg) is fully applied, determined by the pointer.
- The machine will automatically apply the major load
- Finally, record the result of the test in the proper scale.

3.1 Precautions

1. Thickness of the specimen should not be less than 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen.
2. Indentation should not be made nearer to the edge of a specimen to avoid unnecessary concentration of stresses. In such cases, distance from the edge to the center of indentation should be greater than 2.5 times diameter of indentation.
3. Rapid rate of applying load should b avoided. Load applied on the ball may rise a little because of its sudden action. Also rapidly applied load will restrict plastic flow of a material, which produces effect on size of indentation.

4. Calculation

- Rockwell hardness number will be directly given by the hardness testing machine.
- Brinell hardness will be calculated by the formula given in the theory section.
- Tensile strength will be determined by the following formula.

$TS = 3.55\ HB\ (HB \leq 175)$

$3.38\ HB\ (HB > 175)$

5. Result

Students will fill up this section with their individual outcome/results about the test.

6. Discussion

Students should fill up this section with their individual findings and shortcomings/improvements regarding the test.

Experiment No.: 05
IMPACT TEST

Objectives:

1. To study the impact testing machine
2. To determine the energy absorbed in fracturing the given specimens
3. To observe the appearance of the fracture of the specimens

Theory:

The impact test is done to measure the impact strength of materials. The impact strength indicates the amount of energy required to fracture the materials under dynamic or impact loading.

Toughness:

Toughness is the property of a material that it does not break under a sudden shock. It is simply expressed as the ability of a material to withstand shock loading. Toughness property is required in many parts such as: car chassis, hammer head, connecting rod, and anvils to do the job they intended to do properly.

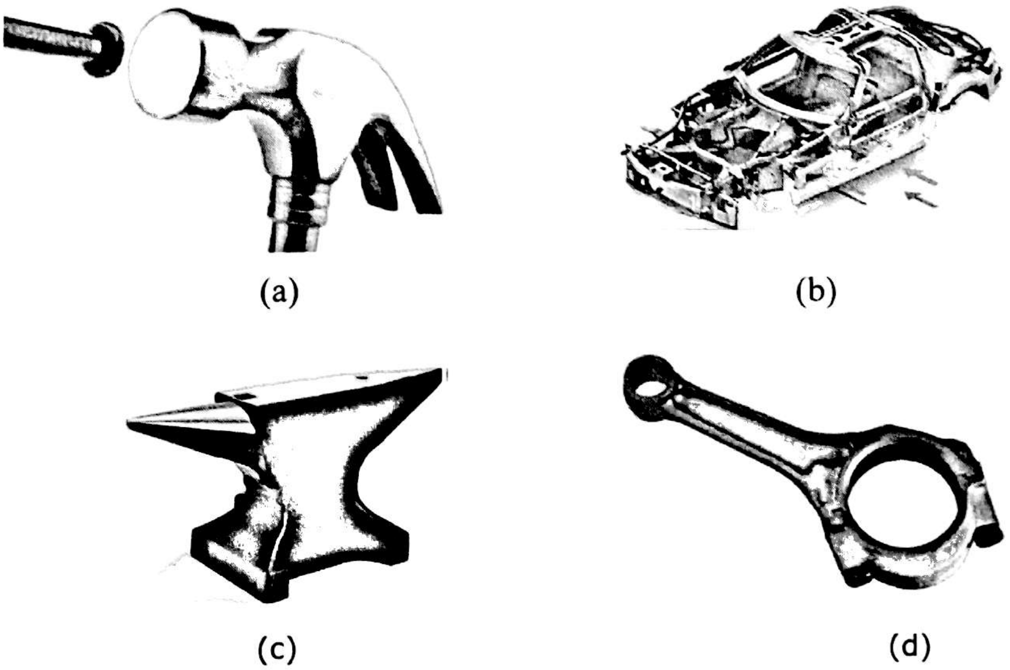
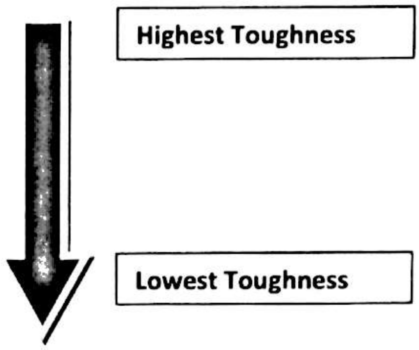


Fig.5.1: (a) Hammer (b) Car chassis (c) Anvil (d) Connecting rod.

Examples of toughness of materials arranged in a descending order:

1. Copper
2. Nickel
3. Iron
4. Aluminum
5. Lead
6. Tin
7. Cobalt



How to compare toughness of different metals?

One way to compare toughness of different materials is by comparing the areas under the stress strain curves from the tensile tests of these materials as shown in Fig. 5.2. This value is simply called "material toughness" and it has units of energy per volume.

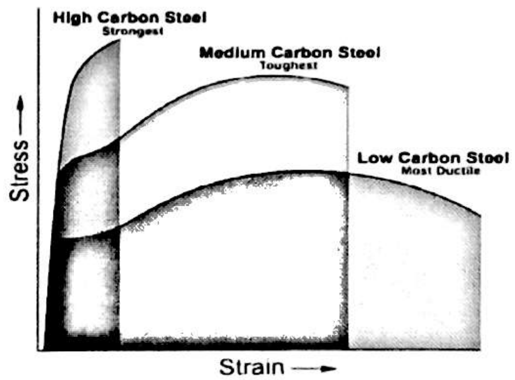


Fig. 5.2: The stress strain curve for different materials.

Toughness and Impact Tests:

There are basically three types of impact tests for evaluating the toughness of materials:

• The Pendulum test.

• The Drop Weight test.

• The Instrumented test

In this experiment, we shall only study the most commonly used impact which is the "**Pendulum Test**".

The pendulum impact test

The pendulum impact test measures the kinetic energy absorbed by a material specimen of specific dimensions as it fractures by the impact of a known energy value of a special hammer mounted in a pendulum. See Fig.7.3.

The kinetic energy of the hammer at the time of impact equals to the potential energy of the hammer before its release.

The potential energy of the hammer (PE) can be calculated using the following formula:

$$PE = m*g*h$$

Where:

PE = the potential energy.

m = the mass of the hammer in Kilograms (Kg).

g = the gravity acceleration in m/s^2.

h = the vertical height in meters (m).

The mass of the hammer and the height of fall (h_F) determine the energy In the elevated position, the pendulum possesses a definite potential energy which is converted to kinetic energy during its downward swing. The pendulum achieves maximum kinetic energy at the lowest swing position just before it strikes the specimen.

The impact energy absorbed by the specimen during rupture is measured as the difference between the height of the drop before fracture (h_F) and the height of rise after fracture of the test specimen (h_R) and is directly read on the dial scale which is calibrated to give the reading directly in joules.

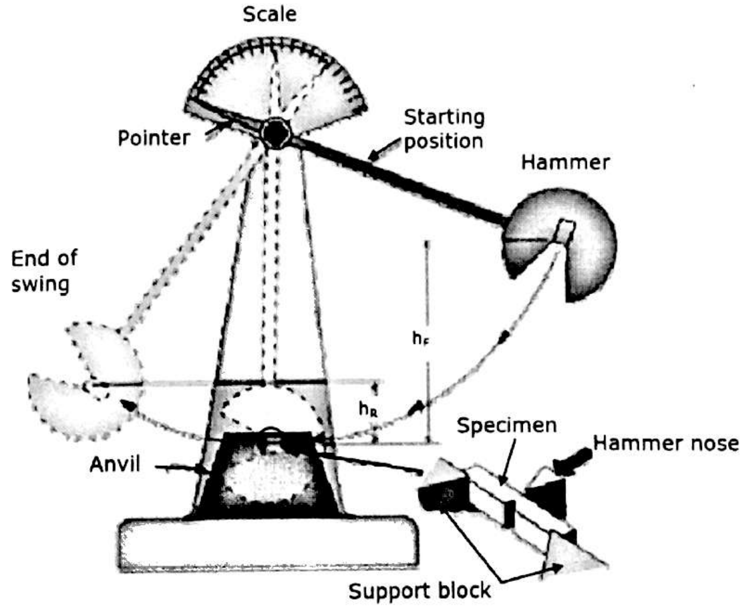


Fig.5.3: Pendulum Impact test

$$\textbf{Impact strength} = mg(h_F - h_R)$$
$$= mgR(Cos\theta_R - Cos\theta_F) \quad \text{Joule}$$

The testing machine which is used here is of the pendulum type. Mostly used types of the test are 1) Charpy and 2) Izod.

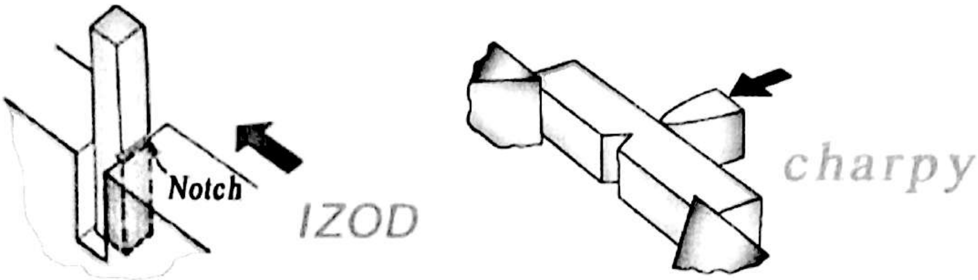


Figure 5.4: Difference between Charpy and Izod impact test.

Apparatus Used:

Specimen Used:

Experimental Setup:

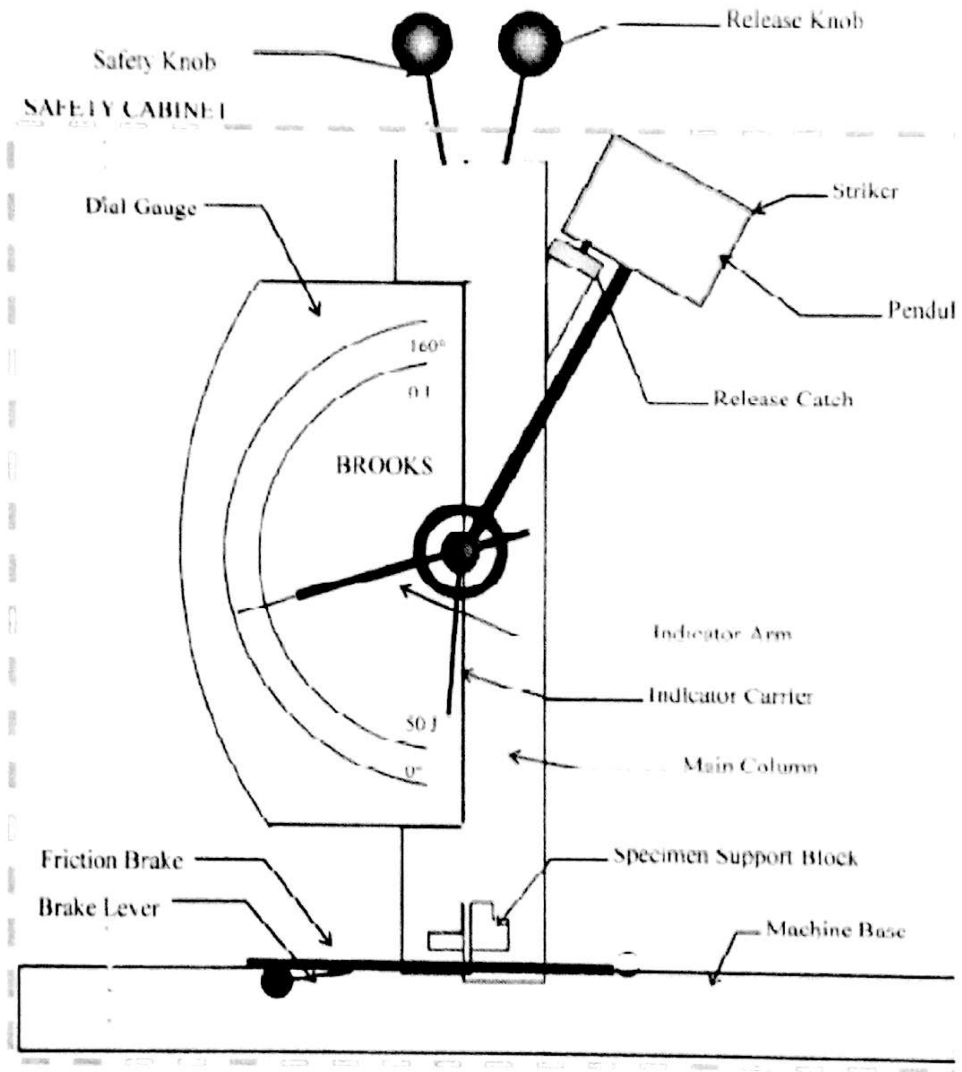
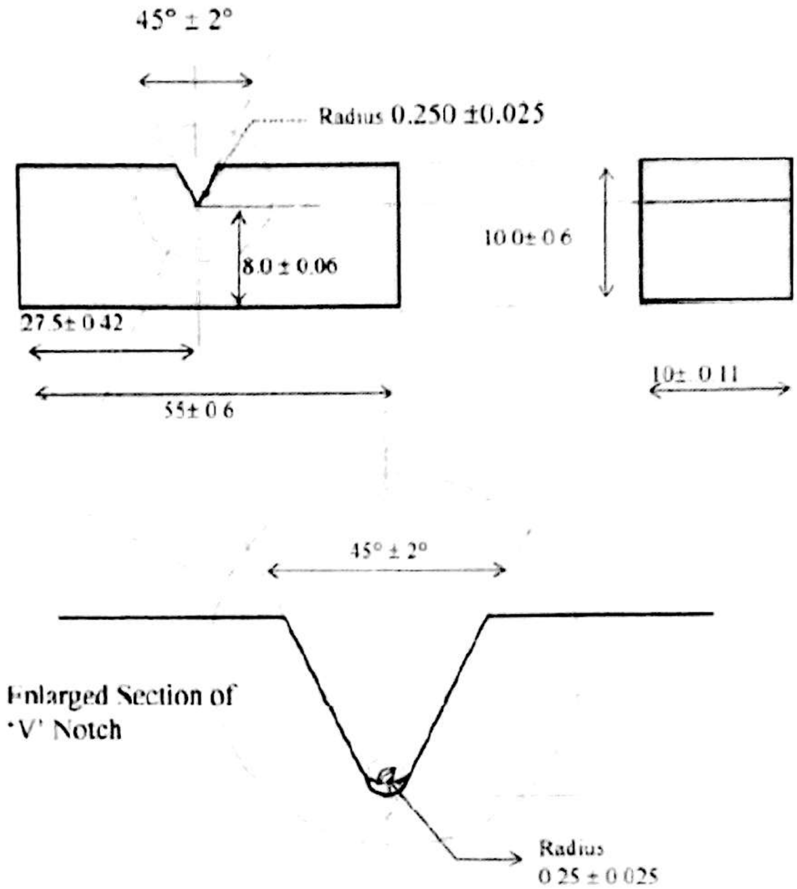


Fig. 5.5: Experimental setup

Standard Test Specimen Dimensions:

The specimens used in this apparatus can be made of a low carbon steels as well as plastic materials and must be of the dimensions shown in Fig.5.6.



All Dimensions are in mm

Fig. 5.6: Impact test specimen dimension

Procedure:

1. Open the safety cabinet and raise the pendulum till it engages with the release catch as shown in Fig.5.7.

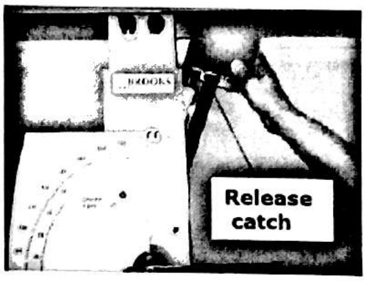
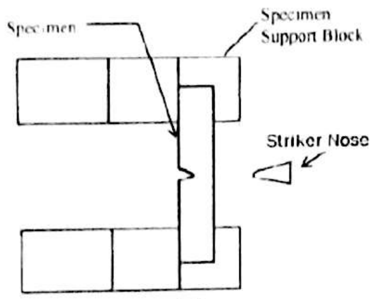


Fig. 5.7: engaging the pendulum with the release catch.

2. Place the prepared specimen on the support block and ensure that its notch is facing the opposite side of the hammer as shown in Fig.5.8a.

N.B: When inserting the test piece into the support, the pendulum must be supported by the safety support pin shown in Fig.5.8b.



(a)

(b)

Fig. 5.8: (a) specimen orientation on the support block. (b) Safety Release catch Safety pin

3. Adjust the indicator with its carrier to the "zero" position (set to zero or 50 joules) as shown in Fig.5.9.

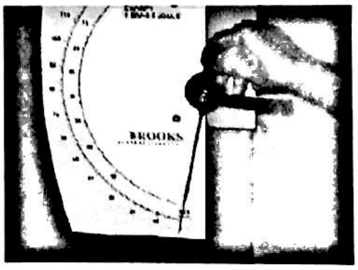


Fig.5.9: setting the indicator to zero.

4. Check for safety fall and close the safety cabinet.

N.B: When operating the equipment, the access door should be firmly closed and remains secured until the pendulum stop. See in Fig.5.9.

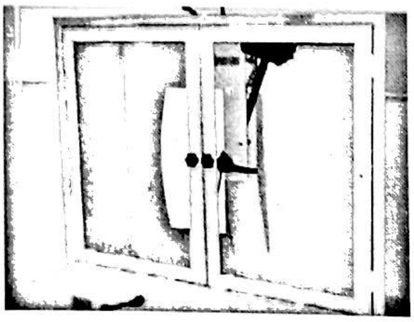


Fig.5.9: The access door is firmly closed.

5. Release the pendulum latching device by operating the two knobs in sequence (safety knob first and then the release knob) as shown in Fig.5.11.

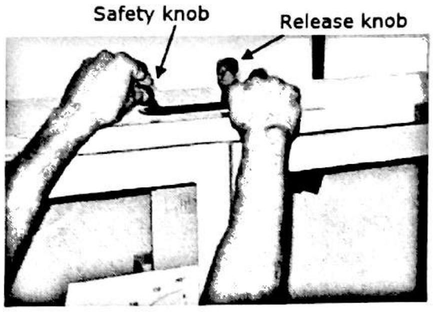


Fig.5.11: Starting the test.

6. After the specimen breaks and the pendulum complete its initial swing, apply the friction brake to stop the pendulum and open the cabinet as shown in Fig.5.12.

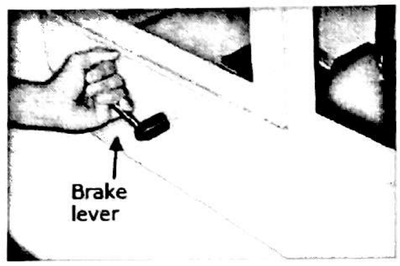


Fig.5.12: Using the brake lever to stop the pendulum.

7. Read the energy absorbed by the broken specimen from the pointer on the dial See Fig.5.13.

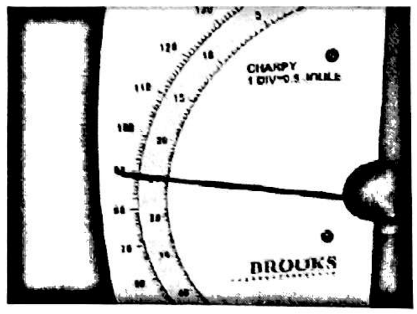


Fig.5.13: read the dial

EXPERIMENT NO. 05

IMPACT TEST

DATA SHEET

Course no.:
Group no.:

Student ID no.:
Date:

Particulars of Specimen:

Weight of the hammer, W = 6.6 kg

No. of observation	Type of Specimen	Area under the notch (mm^2)	Notch Impact Strength (Nm/mm^2)

Signature of the teacher

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

ME 2204: Engineering Materials
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. Viva for each experiment will be taken on the next day with the report.
5. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental results and discussions (Experimental setup, Experimental conditions, Data, Graph, calculation etc.)
    - Conclusions
    - Acknowledgements
    - References
6. A quiz will be taken on the experiments at the end of the semester.
7. Marks distribution:

Total Marks		
Report	Attendance and Viva	Quiz
30	30	40

AHSANULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Course Number: ME 2204

Course Title: Engineering Materials Sessional

Title: Study of different types of cast iron &their properties.

Questions:

1. Draw an Iron- Carbide phase diagram up to 6.67% of carbon.
2. What is the classification of cast iron?
3. A machine part is made that have to take higher tensile strength and must have ductility, which cast iron you should be used. Draw the microstructure of the cast iron in-
    1. Fast cooling
    2. Slow cooling
4. Write the properties of gray cast iron so that it is produced in higher quantities.
5. What is the heat treatment to produce malleable cast iron from white cast iron? Draw the diagram of two types of malleable cast iron.

AHSANULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Course Number: ME 2204

Course Title: Engineering Materials Sessional

Q 1: A copper–nickel alloy of composition 70 wt% Ni–30 wt% Cu is slowly heated from a temperature of 1300°C (2370°F).

(a) At what temperature does the first liquid phase form?

(b) What is the composition of this liquid phase?

(c) At what temperature does complete melting of the alloy occur?

(d) What is the composition of the last solid remaining prior to complete melting?

Q 2: Is it possible to have a copper–nickel alloy that, at equilibrium, consists of an α phase of composition 37 wt% Ni–63 wt% Cu, and also a liquid phase of composition 20 wt% Ni–80 wt% Cu? If so, what will be the approximate temperature of the alloy? If this is not possible, explain why.

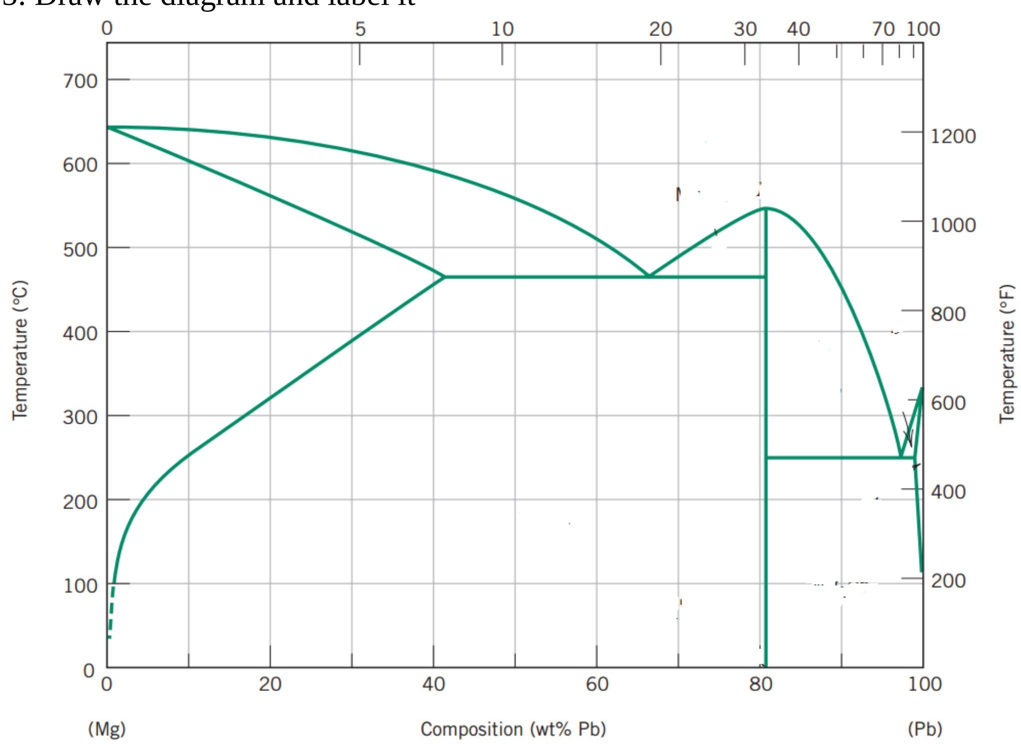
Q 3: For a 35 wt% Ni- 65 wt% Cu alloy at 1250^{0}c ------

1. What phase(s) is(are) present?
2. What is(are) the composition(s) of the phase?
3. What is (are) phase amount?
4. Draw the microstructure at this phase?

Q 4: For a 40 wt% Sn- 60 wt% Pb alloy at 150^{0}c ------

1. What phase(s) is(are) present?
2. What is(are) the composition(s) of the phase?
3. What is (are) phase amount?
4. Draw the microstructure at this phase?

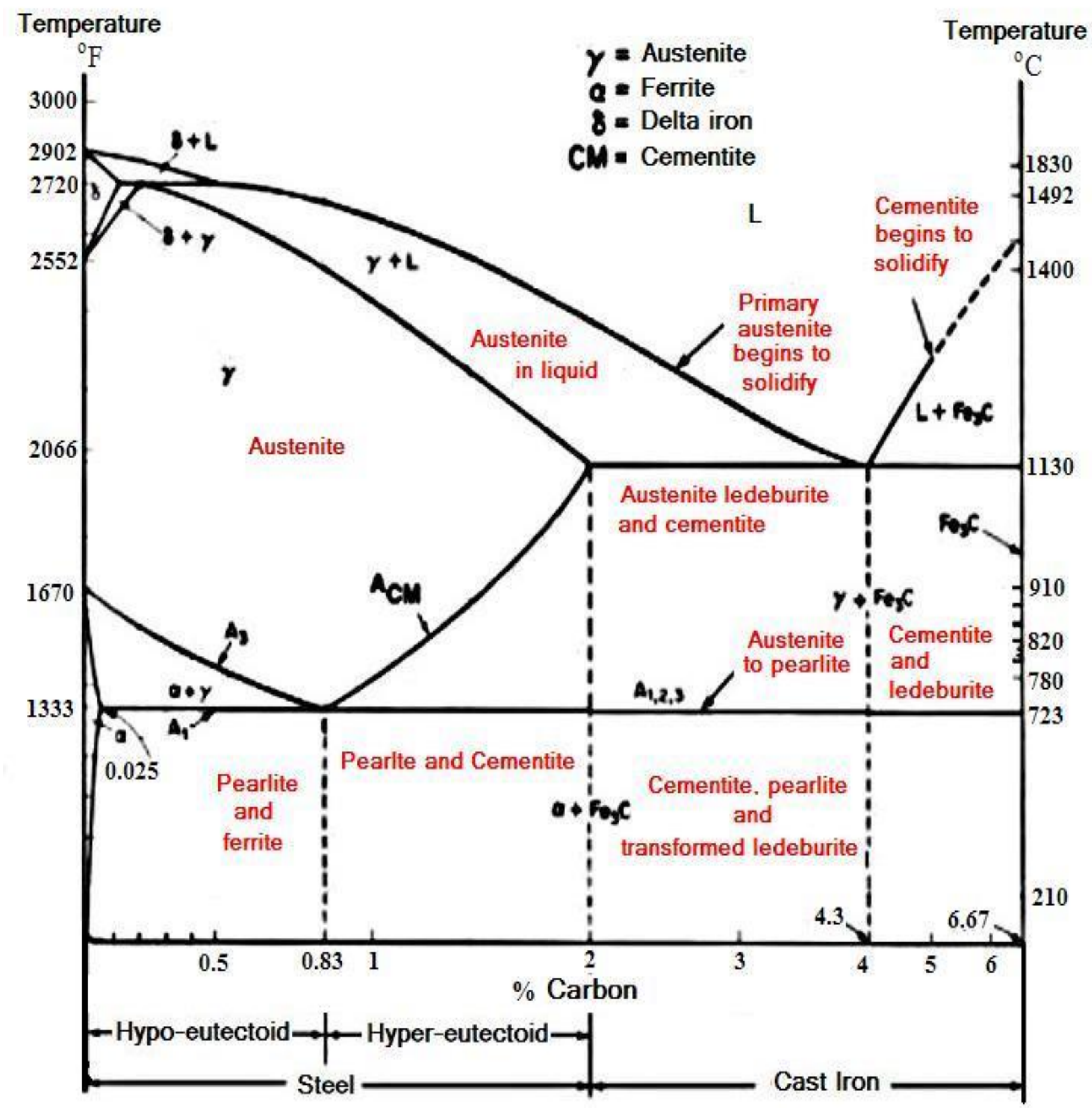
Q 5: Draw the diagram and label it-



AHSANULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Course Number: ME 2204

Course Title: Engineering Materials Sessional



<u>**The Iron–Iron Carbide (Fe–Fe3C) Phase Diagram**</u>

Questions:

1. What is the distinction between hypoeutectoidand hypereutectoid steels?

2. What is the carbon concentration of an iron–carbon alloy for which the fraction of total ferrite is 0.94?

3. Consider 1.0 kg of austenite containing 1.15 wt% C, cooled to below 723C (1333F).

   (a) What is the proeutectoid phase?

   (b) How many kilograms each of total ferrite and cementite form?

   (c) How many kilograms each of pearlite and the proeutectoid phase form?

   (d) Schematically sketch and label the resulting microstructure.

4. The microstructure of an iron–carbon alloy consists of proeutectoid ferrite and pearlite; the mass fractions of these microconstituents are 0.20 and 0.80, respectively. Determine the concentration of carbon in this alloy.

5. Consider 2.0 kg of a 99.6 wt% Fe–0.4 wt% C alloy that is cooled to a temperature just below the eutectoid.

   (a) How many kilograms of proeutectoid ferrite form?

   (b) How many kilograms of eutectoid ferrite form?

   (c) How many kilograms of cementite form?

6. Is it possible to have an iron–carbon alloy for which the mass fractions of total cementite and pearlite are 0.039 and 0.417, respectively? Why or why not?

7. For a 79.65 wt% Fe-0.35 wt% C alloy at a temperature just below the eutectoid, determine the following:

   (a) The fraction of total ferrite and cementite phases.

   (b) The fractions of the proeutectoid ferrite and pearlite.

   (c) The fraction of eutectoid ferrite.

AHSANULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

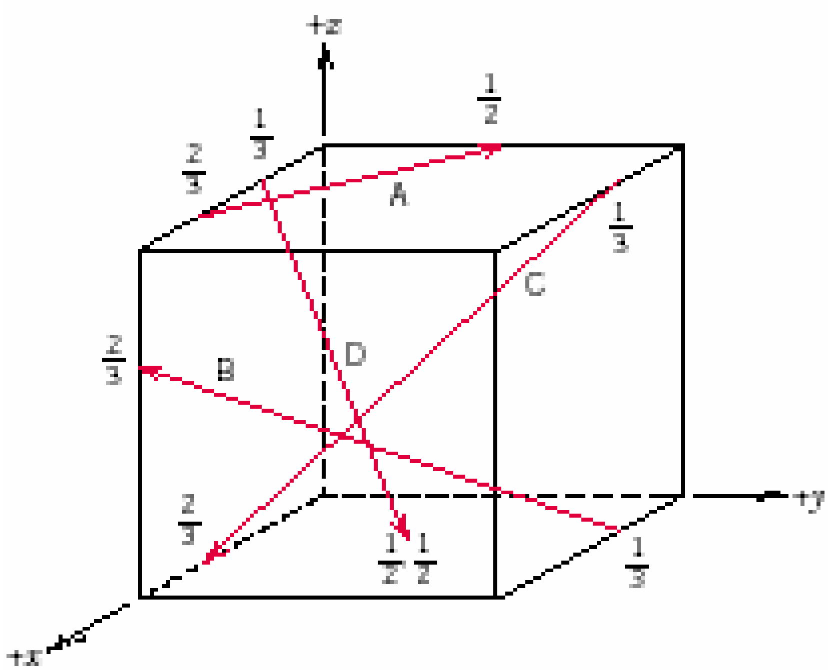
Course Number: ME 2204

Course Title: Engineering Materials Sessional

Experiment No: 04

Name of the Experiment: Calculation of Crystallographic direction and planes for different crystal system.

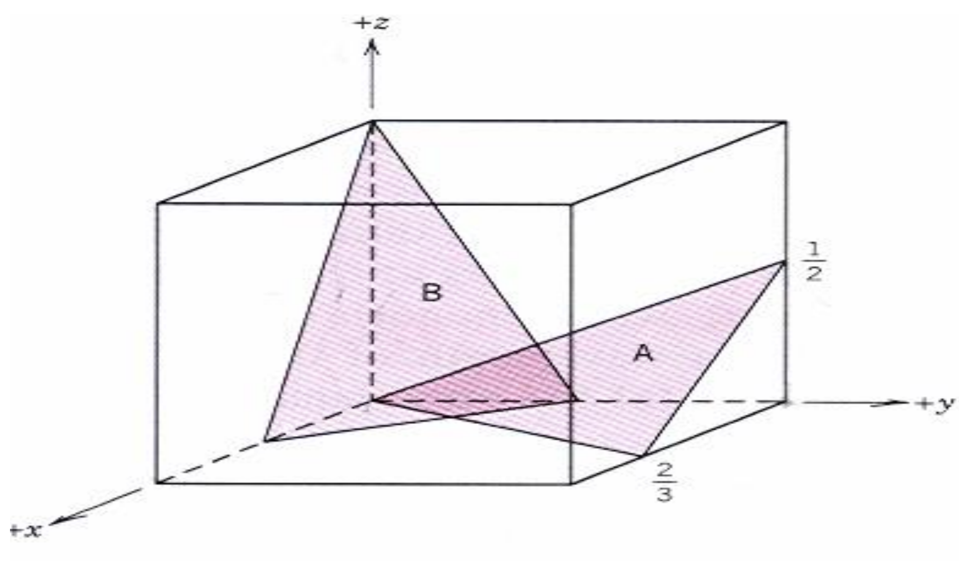
1. Determining the indices of line directions.



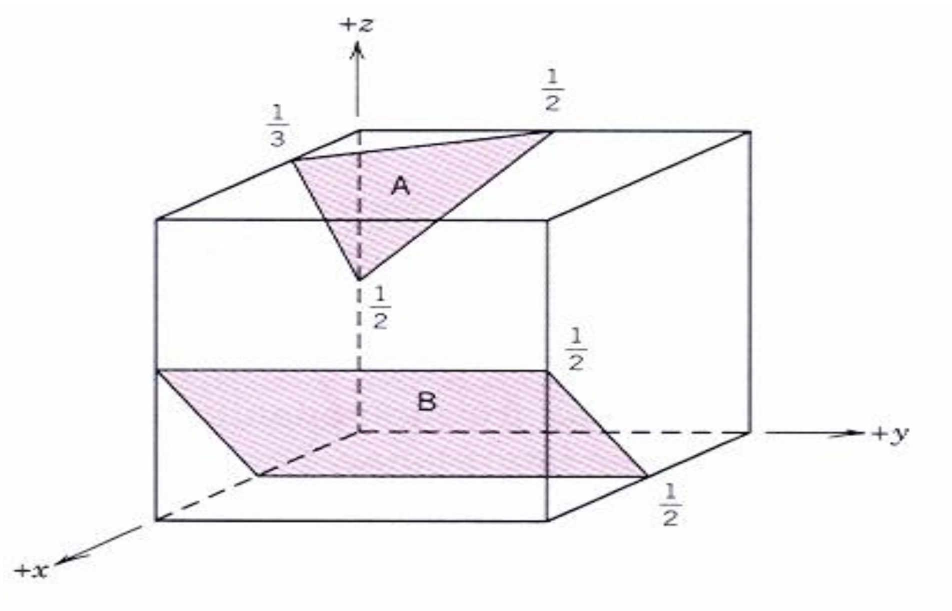
2. Sketch the following direction:**[110], [120], [-1 0 2]**

3. Determine Miller indices of planes A and B:

(a)



(b)



4. Construct planes by Miller indices of planes **(110), (200), (634)**

5. Find the angle between two planes **(111) and (1-1 1)**

6. Calculate Planar density for Simple cubic system of **(100)** plane where lattice parameter **(a=3.03A^{o})**

7. Calculate linear density of FCC structure in **[110]** direction where lattice parameter **(a=4.20A^{o})**

Ahsanullah University of Science & Technology(AUST)

ME-2204:Engineering Materials Sessional

Credit Hour: 1:50

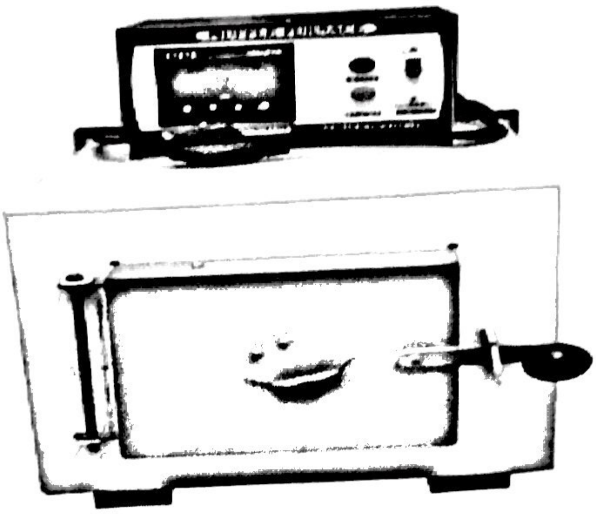
Experiment No: 5

a. Microstudy of Carburized and furnace cooled low carbon steel.
b. Microstudy of Carburized, quenched and Low carbon steel.
c. Microstudy of Carburized, quenched, Sub-zero treatment and tempered low carbon steel.
d. Microstudy of Induction hardened steel.

Questions and Answers:

1. Draw heat treatment cycle for Annealing, Normalizing and Hardening process.
2. Draw heat treatment cycle for Carburized, quenched, Sub-zero treated and Tempered low carbon steel.
3. Draw the Hardness profile for Carburizing sample.
4. Draw the microstructure for a, b,c and d.

MUFFLE FURNACE



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Department of Mechanical & Production Engineering

Ahsanullah University of Science & Technology(AUST)

ME-2204:Engineering Materials Sessional

Credit Hour: 1:50

Experiment No: 1

Metallography Specimen Preparation and Examination in order to reveal Microstructure.

Objectives

1. To learn and to gain experience in the preparation of metallographic specimens.
2. To familiarize with different types of Work materials for Specimen Preparation.

Abstract

Proper preparation of metallographic specimens to determine microstructure and content requires that a rigid step-by-step process be followed. In sequence, the steps include sectioning, mounting, course grinding, fine grinding, polishing, etching and microscopic examination. Specimens must be kept clean and preparation procedure carefully followed in order to reveal accurate microstructures. Each group of students will prepare and examine the given sample for metallographic examination.

The basic techniques can be learned through patient persistence in a matter of hours. This module takes the student through the metallographic sample preparation process step-by-step with demonstrations and explanations of sectioning, mounting, course & fine grinding, polishing, etching and microscopic examination.

Apparatus

1. Emery Paper
2. Acetone
3. Cotton wool
4. Etching Reagent
5. Wet polishing Machine
6. Alumina Powder

Nital, a Nitric Acid - Alcohol mixture, is the etchant commonly utilized with common irons and steels. Nital is dripped onto the specimen using an eye-dropper or cotton swab. Ten seconds to one minute is usually sufficient for proper etching depending on sample and nital concehtration.

Etchants

Materials	Composition	Application Procedure
Iron & Steel	1-5 Parts Nitric Acid 100 Parts Alcohol	Immerse/Swab
Copper & Brass	1 Part Ammonium Hydroxide 1 Part 3% Hydrogen Peroxide 1 Part Water	Swab
	5 g Ferric Chloride, 10 ml Hydrocloric Acid 100 ml Water	Immerse
Aluminum	5-10 g Ammonium Persulphate 1 ml Hydrofluoric Acid 99 ml Water	Immerse
	10 g Sodium Hydroxide, 100 ml Water	Immerse
Stainless Steels	10 g Oxalic Acid 100 ml Water	Use Electrolytically
	5 ml Sulfuric Acid 100 ml Water	Use Electrolytically

Lab Requirements

Each group of students will prepare the given specimen for microscopic observation. Prepare a metallographic specimen going through the coarse grinding, fine grinding, polishing and etching stages of specimen preparation. Clearly label your specimen and submit it with the lab write up; the quality of your specimen will be graded.

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

3^{rd} Year, 1^{st} Semester

Student Name :

Student ID :

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 3102: Measurement, Instrumentation and Control Sessional
Credit Hour: 1.5

Objective:

To get familiar with different types of measuring procedures and control equipment. Designing concepts of sampling plan, hypothesis testing.

General Instructions:

1. Attend to the lab 5 minutes prior to the scheduled time and be prepared for the experiment.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. Report should be submitted in the following week during the sessional time.
5. Write report on one side of an 80 gram A4 paper and follow the following format
    a) Top sheet
    b) Objective
    c) Apparatus
    d) Figure
    e) Data Sheets
    f) Sample calculation
    g) Result
    h) Graph
    i) Discussion
        i) Discuss the graphs and results
        ii) Discuss about the experimental setup if it could be improved
        iii) Discuss the different parameters that could affect the result
        iv) Discuss any assumption made
        v) Discuss any discrepancies in the experimental procedure and result
        vi) Discuss what you have learnt and the practical application of this knowledge
    j) Finally, add the data sheet with the report.

Marks Distribution:

Total Marks		
Report	Attendance and Viva	Quiz
40	10	50

Experiment no: 01

Experiment name: Goodness of Fit Test (Chi-Square Test)

<u>THEORY:</u>

A **statistical model** is a formalization of relationships between variables in the form of mathematical equations. A statistical model describes how one or more random variables are related to one or more random variables. The model is statistical as the variables are not deterministically but stochastically related.

Goodness of fitof a statistical model refers to how close the observed data are to those data which are predicted from a hypothesis. Measurements of goodness of fit typically summarize the discrepancy between observed values and the values expected under the model in question. Such measures can be used in statistical hypothesis testing, e.g. to test for normality of residuals, to test whether two samples are drawn from identical distributions, or whether outcome frequencies follow a specified distribution.

The chi-square test is a statistical method used to determine goodness of fit. It is used to test if a sample of data came from a population with a specific distribution.**The chi square test does not prove that a hypothesis is correct rather it evaluates to what extent the data and the hypothesis have a good fit.**

The general formula-

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_{i} - E_i)^2}{E_i}$$

Here,

O_i= Observed Data/ Frequency in each category

E_i= Expected Data/ Frequency in each category (based on hypothesis)

If the observed frequencies are close to the corresponding expected frequencies, the χ^2 value will be small, indicating a good fit. If the observed frequencies differ considerably from the expected frequencies, the χ^2 value will be large and the fit is poor.

In other words,

- Low chi square values indicate a high probability that the observed deviations could be due to random chance alone
- High chi square values indicate a low probability that the observed deviations are due to random chance alone

APPLYING THE CHI-SQUARE TEST:

1: Propose a null hypothesis (Ho) that allows us to calculate the expected values

2: Calculate the expected values

3: Apply the chi square formula

4: Interpret the chi square value (χ^2)

5: For a level of significance (α) and degrees of freedom (ν), find the critical value (χ_α^2) from chi-square table.*

6: Then $\chi^2 > \chi_\alpha^2$ constitutes the critical region. In practice, if the chi square value results in a probability/ level of significance that is less than 0.05 (i.e.: less than 5%) it is considered statistically significant.

[The decision criterion described here should not be used unless each of the expected frequencies is at least equal to 5]

*** Degrees of Freedom:**

The concept of degrees of freedom is central to the principle of estimating statistics of populations from samples of them. "Degrees of freedom" is commonly abbreviated to df.The number of degrees of freedom associated with the chi-squared distribution used here is equal to (k-1). The number of degrees of freedom is the number of values in the final calculation of a statistic that are free to vary or, it is a measure of the number of groupings/ classes that are independent of each other. If you know the 2 of the 3 classes you can deduce the 3rd(Total number of issue – categories 1-2).

Therefore, **df = n – 1**, where, n = total number of categories

Check of normality by χ^2– test:

No. of Roller	Diameter(mm)	No. of Roller	Diameter(mm)	No. of Roller	Diameter(mm)
1	19.11	40	19.18	79	19.25
2	19.14	41	19.25	80	19.06
3	19.08	42	19.15	81	19.14
4	19.13	43	19.14	82	19.23
5	19.04	44	19.06	83	19.09
6	19.17	45	19.07	84	19.13
7	19.22	46	19.12	85	19.03
8	19.14	47	19.19	86	19.15
9	19.23	48	19.08	87	19.25
10	19.08	49	19.07	88	18.92
11	19.08	50	19.08	89	19.17
12	19.17	51	19.11	90	19.19
13	19.3	52	19.11	91	19.14
14	19.14	53	19.12	92	19.19
15	18.94	54	19.13	93	19.12
16	19.19	55	19.11	94	19.19
17	19.15	56	19.01	95	19.15
18	18.93	57	19.24	96	19.07
19	19.15	58	19.12	97	19.04
20	19.31	59	19.21	98	19.19
21	19.15	60	19.2	99	18.98
22	19.11	61	19.18	100	19.14

23	19.21	62	19.18	101	19.15
24	19.11	63	19.13	102	19.09
25	19.17	64	19.11	103	19.19
26	19.15	65	19.09	104	19.1
27	19.1	66	19.14	105	19.16
28	19.11	67	19.24	106	19.25
29	18.89	68	19.14	107	19.12
30	19.21	69	19.14	108	19.13
31	19.14	70	19.15	109	19.16
32	19.12	71	19.08	110	19.16
33	19.14	72	19.11	111	19.01
34	19.18	73	19.07	112	18.93
35	19.22	74	19.18	113	19.11
36	19.07	75	19.14	114	19.09
37	19.14	76	19.15	115	19.04
38	19.06	77	19.12	116	18.94
39	19.08	78	19.16	117	19.06

No. of Roller	Diameter(mm)	No. of Roller	Diameter(mm)	No. of Roller	Diameter(mm)
118	19.06	129	19.2	140	19.01
119	19.12	130	19.15	141	19.05

120	19.01	131	18.98	142	18.85
121	19.11	132	19.15	143	18.99
122	19.08	133	19.12	144	19.2
123	19.03	134	19.12	145	19.35
124	19.12	135	19.06	146	19.02
125	19.09	136	19.16	147	19.04
126	19.02	137	19.29	148	19.11
127	19	138	19.11	149	19.1
128	19.19	139	19.09	150	19.15

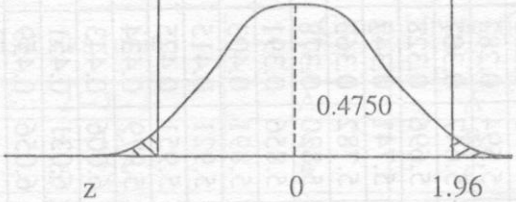
STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
1.0	.84134	.84375	.84614	.84849	.85083	.85314	.85543	.85769	.85993	.86214
1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361
2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99896	.99900
3.1	.99903	.99906	.99910	.99913	.99916	.99918	.99921	.99924	.99926	.99929
3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
3.4	.99966	.99968	.99969	.99970	.99971	.99972	.99973	.99974	.99975	.99976
3.5	.99977	.99978	.99978	.99979	.99980	.99981	.99981	.99982	.99983	.99983
3.6	.99984	.99985	.99985	.99986	.99986	.99987	.99987	.99988	.99988	.99989
3.7	.99989	.99990	.99990	.99990	.99991	.99991	.99992	.99992	.99992	.99992
3.8	.99993	.99993	.99993	.99994	.99994	.99994	.99994	.99995	.99995	.99995
3.9	.99995	.99995	.99996	.99996	.99996	.99996	.99996	.99996	.99997	.99997

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
-3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
-3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
-3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
-3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
-3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
-3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
-3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
-3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
-3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00104	.00100
-2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139
-2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
-2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
-2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
-2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
-2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
-2.3	.01072	.01044	.01017	.00990	.00964	.00939	.00914	.00889	.00866	.00842
-2.2	.01390	.01355	.01321	.01287	.01255	.01222	.01191	.01160	.01130	.01101
-2.1	.01786	.01743	.01700	.01659	.01618	.01578	.01539	.01500	.01463	.01426
-2.0	.02275	.02222	.02169	.02118	.02068	.02018	.01970	.01923	.01876	.01831
-1.9	.02872	.02807	.02743	.02680	.02619	.02559	.02500	.02442	.02385	.02330
-1.8	.03593	.03515	.03438	.03362	.03288	.03216	.03144	.03074	.03005	.02938
-1.7	.04457	.04363	.04272	.04182	.04093	.04006	.03920	.03836	.03754	.03673
-1.6	.05480	.05370	.05262	.05155	.05050	.04947	.04846	.04746	.04648	.04551
-1.5	.06681	.06552	.06426	.06301	.06178	.06057	.05938	.05821	.05705	.05592
-1.4	.08076	.07927	.07780	.07636	.07493	.07353	.07215	.07078	.06944	.06811
-1.3	.09680	.09510	.09342	.09176	.09012	.08851	.08691	.08534	.08379	.08226
-1.2	.11507	.11314	.11123	.10935	.10749	.10565	.10383	.10204	.10027	.09853
-1.1	.13567	.13350	.13136	.12924	.12714	.12507	.12302	.12100	.11900	.11702
-1.0	.15866	.15625	.15386	.15151	.14917	.14686	.14457	.14231	.14007	.13786
-0.9	.18406	.18141	.17879	.17619	.17361	.17106	.16853	.16602	.16354	.16109
-0.8	.21186	.20897	.20611	.20327	.20045	.19766	.19489	.19215	.18943	.18673
-0.7	.24196	.23885	.23576	.23270	.22965	.22663	.22363	.22065	.21770	.21476
-0.6	.27425	.27093	.26763	.26435	.26109	.25785	.25463	.25143	.24825	.24510
-0.5	.30854	.30503	.30153	.29806	.29460	.29116	.28774	.28434	.28096	.27760
-0.4	.34458	.34090	.33724	.33360	.32997	.32636	.32276	.31918	.31561	.31207
-0.3	.38209	.37828	.37448	.37070	.36693	.36317	.35942	.35569	.35197	.34827
-0.2	.42074	.41683	.41294	.40905	.40517	.40129	.39743	.39358	.38974	.38591
-0.1	.46017	.45620	.45224	.44828	.44433	.44038	.43644	.43251	.42858	.42465
-0.0	.50000	.49601	.49202	.48803	.48405	.48006	.47608	.47210	.46812	.46414

Table A. Standard Normal Distribution Values (Areas under the normal curve).



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990

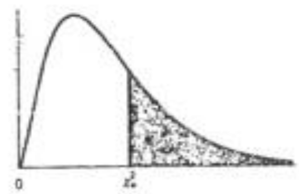


Table A.5 Critical Values of the Chi-Squared Distribution

	α									
v	0.995	0.99	0.98	0.975	0.95	0.90	0.80	0.75	0.70	0.50
1	0.0^4393	0.0^3157	0.0^3628	0.0^3982	0.00393	0.0158	0.0642	0.102	0.148	0.455
2	0.0100	0.0201	0.0404	0.0506	0.103	0.211	0.446	0.575	0.713	1.386
3	0.0717	0.115	0.185	0.216	0.352	0.584	1.005	1.213	1.424	2.366
4	0.207	0.297	0.429	0.484	0.711	1.064	1.649	1.923	2.195	3.357
5	0.412	0.554	0.752	0.831	1.145	1.610	2.343	2.675	3.000	4.351
6	0.676	0.872	1.134	1.237	1.635	2.204	3.070	3.455	3.828	5.348
7	0.989	1.239	1.564	1.690	2.167	2.833	3.822	4.255	4.671	6.346
8	1.344	1.647	2.032	2.180	2.733	3.490	4.594	5.071	5.527	7.344
9	1.735	2.088	2.532	2.700	3.325	4.168	5.380	5.899	6.393	8.343
10	2.156	2.558	3.059	3.247	3.940	4.865	6.179	6.737	7.267	9.342
11	2.603	3.053	3.609	3.816	4.575	5.578	6.989	7.584	8.148	10.341
12	3.074	3.571	4.178	4.404	5.226	6.304	7.807	8.438	9.034	11.340
13	3.565	4.107	4.765	5.009	5.892	7.041	8.634	9.299	9.926	12.340
14	4.075	4.660	5.368	5.629	6.571	7.790	9.467	10.165	10.821	13.339
15	4.601	5.229	5.985	6.262	7.261	8.547	10.307	11.037	11.721	14.339
16	5.142	5.812	6.614	6.908	7.962	9.312	11.152	11.912	12.624	15.338
17	5.697	6.408	7.255	7.564	8.672	10.085	12.002	12.792	13.531	16.338
18	6.265	7.015	7.906	8.231	9.390	10.865	12.857	13.675	14.440	17.338
19	6.844	7.633	8.567	8.907	10.117	11.651	13.716	14.562	15.352	18.338
20	7.434	8.260	9.237	9.591	10.851	12.443	14.578	15.452	16.266	19.337
21	8.034	8.897	9.915	10.283	11.591	13.240	15.445	16.344	17.182	20.337
22	8.643	9.542	10.600	10.982	12.338	14.041	16.314	17.240	18.101	21.337
23	9.260	10.196	11.293	11.689	13.091	14.848	17.187	18.137	19.021	22.337
24	9.886	10.856	11.992	12.401	13.848	15.659	18.062	19.037	19.943	23.337
25	10.520	11.524	12.697	13.120	14.611	16.473	18.940	19.939	20.867	24.337
26	11.160	12.198	13.409	13.844	15.379	17.292	19.820	20.843	21.792	25.336
27	11.808	12.878	14.125	14.573	16.151	18.114	20.703	21.749	22.719	26.336
28	12.461	13.565	14.847	15.308	16.928	18.939	21.588	22.657	23.647	27.336
29	13.121	14.256	15.574	16.047	17.708	19.768	22.475	23.567	24.577	28.336
30	13.787	14.953	16.306	16.791	18.493	20.599	23.364	24.478	25.508	29.336
40	20.707	22.164	23.838	24.433	26.509	29.051	32.345	33.66	34.872	39.335
50	27.991	29.707	31.664	32.357	34.764	37.689	41.449	42.942	44.313	49.335
60	35.534	37.485	39.699	40.482	43.188	46.459	50.641	52.294	53.809	59.335

Table A.5 (continued) Critical Values of the Chi-Squared Distribution

	α									
v	0.30	0.25	0.20	0.10	0.05	0.025	0.02	0.01	0.005	0.001
1	1.074	1.323	1.642	2.706	3.841	5.024	5.412	6.635	7.879	10.827
2	2.408	2.773	3.219	4.605	5.991	7.378	7.824	9.210	10.597	13.815
3	3.665	4.108	4.642	6.251	7.815	9.348	9.837	11.345	12.838	16.266
4	4.878	5.385	5.989	7.779	9.488	11.143	11.668	13.277	14.860	18.466
5	6.064	6.626	7.289	9.236	11.070	12.832	13.388	15.086	16.750	20.515
6	7.231	7.841	8.558	10.645	12.592	14.449	15.033	16.812	18.548	22.457
7	8.383	9.037	9.803	12.017	14.067	16.013	16.622	18.475	20.278	24.321
8	9.524	10.219	11.030	13.362	15.507	17.535	18.168	20.090	21.955	26.124
9	10.656	11.389	12.242	14.684	16.919	19.023	19.679	21.666	23.589	27.877
10	11.781	12.549	13.442	15.987	18.307	20.483	21.161	23.209	25.188	29.588
11	12.899	13.701	14.631	17.275	19.675	21.920	22.618	24.725	26.757	31.264
12	14.011	14.845	15.812	18.549	21.026	23.337	24.054	26.217	28.300	32.909
13	15.119	15.984	16.985	19.812	22.362	24.736	25.471	27.688	29.819	34.527
14	16.222	17.117	18.151	21.064	23.685	26.119	26.873	29.141	31.319	36.124
15	17.322	18.245	19.311	22.307	24.996	27.488	28.259	30.578	32.801	37.698
16	18.418	19.369	20.465	23.542	26.296	28.845	29.633	32.000	34.267	39.252
17	19.511	20.489	21.615	24.769	27.587	30.191	30.995	33.409	35.718	40.791
18	20.601	21.605	22.760	25.989	28.869	31.526	32.346	34.805	37.156	42.312
19	21.689	22.718	23.900	27.204	30.144	32.852	33.687	36.191	38.582	43.819
20	22.775	23.828	25.038	28.412	31.410	34.170	35.020	37.566	39.997	45.314
21	23.858	24.935	26.171	29.615	32.671	35.479	36.343	38.932	41.401	46.796
22	24.939	26.039	27.301	30.813	33.924	36.781	37.659	40.289	42.796	48.268
23	26.018	27.141	28.429	32.007	35.172	38.076	38.968	41.638	44.181	49.728
24	27.096	28.241	29.553	33.196	36.415	39.364	40.270	42.980	45.558	51.179
25	28.172	29.339	30.675	34.382	37.652	40.646	41.566	44.314	46.928	52.619
26	29.246	30.435	31.795	35.563	38.885	41.923	42.856	45.642	48.290	54.051
27	30.319	31.528	32.912	36.741	40.113	43.195	44.140	46.963	49.645	55.475
28	31.391	32.620	34.027	37.916	41.337	44.461	45.419	48.278	50.994	56.892
29	32.461	33.711	35.139	39.087	42.557	45.722	46.693	49.588	52.335	58.301
30	33.530	34.800	36.250	40.256	43.773	46.979	47.962	50.892	53.672	59.702
40	44.165	45.616	47.269	51.805	55.758	59.342	60.436	63.691	66.766	73.403
50	54.723	56.334	58.164	63.167	67.505	71.420	72.613	76.154	79.490	86.660
60	65.226	66.981	68.972	74.397	79.082	83.298	84.58	88.379	91.952	99.608

Experiment no: 02

Experiment name: Applying Two Ball& Four Ball Method to Determine Diameter of a Recessed Hole

<u>THEORY:</u>

Diameter of a hollow cylinder can be measured using a Vernier Caliper. But, this method might not work well with a recessed hole. “Two ball” method can be applied to obtain the diameter of a recessed hole. Though, higher accuracy cannot be attained with this method, this is an optimal solution to know about the diameter of a recessed hole approximately.

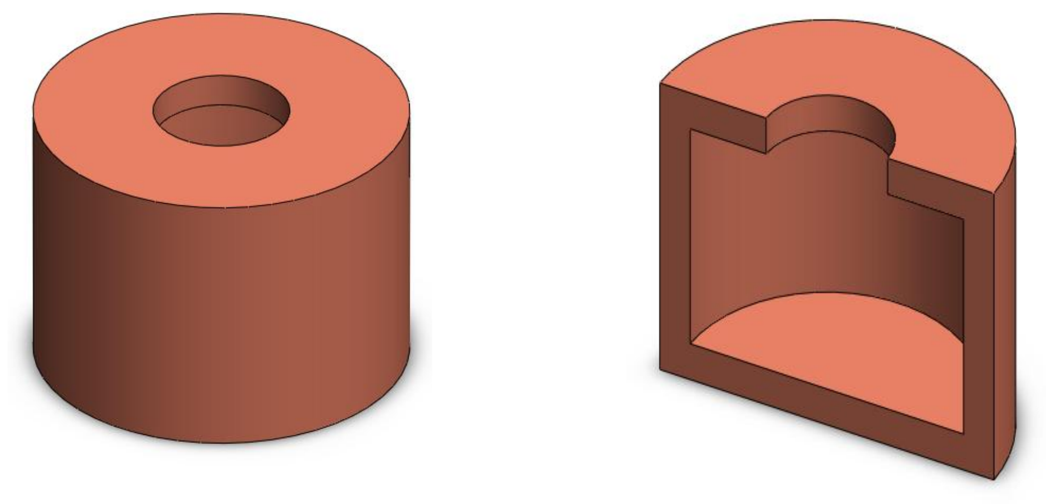


Fig. 2.1: Recessed hole (a) Isometric View (b) Section or, Cutaway view of the hole

CALCULATION:

$$C^2 = \left(\frac{d_1 + d_2}{2}\right)^2 - \left(H_2 - H_1 + \frac{d_2 - d_1}{2}\right)^2$$

$$D = C + \frac{d_1 + d_2}{2}$$

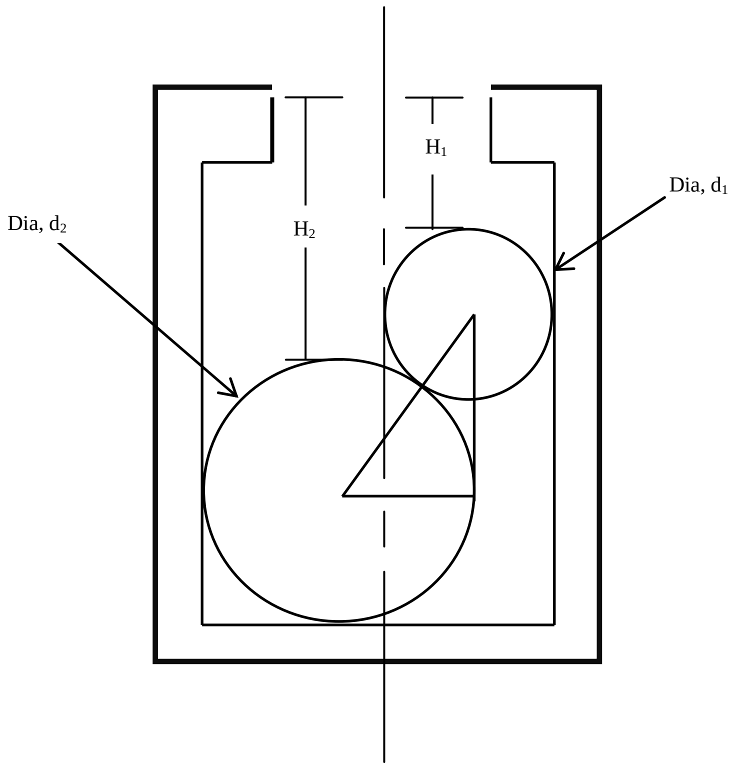


Fig. 2.2: Measurement of Diameter of Hole by Two Balls

Ahsanullah University of Science and Technology

Department of Mechanical and Production Engineering

IPE 3102

Datasheet

Experiment 02

Name of the Student:

Student ID:

Diameter of ball 1, d_1 = mm

Diameter of ball 2, d_2 = mm

Height recorded from the top to ball 2, H_2 = mm

Height recorded from the top to ball 1, H_1 = mm

Result:

Diameter of the recessed hole, D = mm

Signature of Course Teacher

Experiment no: 03

Experiment name: Design and Implementation of a Lot-By-Lot Acceptance Sampling Plan

THEORY:

Sampling is a quality assurance tool. It is based on the idea that a random selection of sample from a homogenous lot or, batch of goods represents the quality of the lot. It is obvious that sampling involves risks but apart from the necessity of acceptance sampling as in the case of destructive testing, advantages of sampling are significant. It is also to be remembered that the purpose of sampling is to guide the course of action, not to estimate the lot quality and also the quality of the goods being inspected is not improved. Further, acceptance sampling is not an attempt to **'control'**the quality but to **'assure'** the quality.

As mentioned above, acceptance Sampling is a form of inspection which is used to determine whether or not products or, goods are coherent with a preset standard of quality. Acceptance Sampling is applied to lots or batches of products or, goods before or after a process to judge conformance to predetermined standards. The lot is either accepted or, rejected depending on the quality standard of the samples taken. It can be applied at the input stage of a production process to prevent raw materials that don't meet the standards from entering into the process. Applying sampling plan at the initial stage of production saves reworking time and money. Acceptance sampling is also applied at the output stage of a production process which reduces the risk of bad quality being passed on from the process to a consumer.

Sampling Plans specify the lot size, sample size, number of samples and acceptance/rejection criteria. Most generally used sampling scheme is single sampling plan. Among others there are double sampling plans, multiple sampling plan and sequential sampling plans.

Single Sampling Plan:

A single sampling plan is a lot sentencing procedure in which one sample of 'n' units is selected randomly from a lot of 'N' units. Each item in the sample is examined and classified as good/defective. If the number of defective exceeds a specified rejection number (k) the whole lot is rejected; otherwise the whole lot is accepted.

Here,

N = Lot size

n = Sample size

k = Acceptance number

If 'k' or less non-conforming units are found in the sample, the lot is **accepted**, else it is **rejected**.

The real problem in most acceptance sampling is to design a satisfactory acceptance sampling system or more commonly, to select such a system from a number of possible systems already developed. To judge the suitability of any proposed acceptance sampling system in a particular case, it is desirable to have an understanding of the strategy and tactics built into the various available types of systems.

Based on manufacturer's product quality, data-type e.g. variables and attributes, can also classify sampling plan. Variables, of course are quality characteristics that are measured on a numerical scale. Attributes are quality characteristics that are expressed on a "go, no-go" basis. Present day industrial practice of acceptance sampling is by attributes. But, the growth of knowledge of statistical quality control techniques has led to a considerable increase in the industrial use of acceptance sampling by variables. Acceptance sampling by variables is often preferable, though costly, to acceptance sampling by attributes, particularly for those quality characteristics that are sources of troubles. The great advantage of the use of acceptance sampling by variables is that more information is obtained about the quality characteristics in question. In this experiment, an acceptance sampling plan for variables will be designed and implemented.

Nomenclature:

α = Producer's risk

β = Consumer's risk

P_1 = Lot fraction defective for which probability (Acceptance) $\geq 1 - \alpha$

P_2 = Lot fraction defective for which probability (Acceptance) $\leq \beta$

LSL = Lower specification limit

USL = Upper specification limit

n = Sample size

k = Critical value

$\bar{X}$ = Sample mean

$\hat{P}_{LSL}$ = Fraction defective estimates corresponding to LSL

$\hat{P}_{USL}$ = Fraction defective estimates corresponding to USL

M = Allowable fraction defective

$$S = \sqrt{\frac{\sum(X - \bar{X})^2}{n-1}}$$

$$Z(LSL) = \frac{\bar{X} - LSL}{s}$$

$$Z(USL) = \frac{USL - \bar{X}}{s}$$

Procedure:

The nomograph shown in fig. 3.1 is used to find the required sample size n and the critical value k to meet a set of given conditions P_1,P_2, 1 – α, β for both the σ known and σ unknown cases. The greater the uncertainty in the case where the standard deviation is unknown requires a larger sample size than does σ known case but the same value of k is used.

After determining n and k from the nomograph, the diameters of the balls supplied is measured and $\bar{X}$ and S is calculated. From given LSL and USL values Z (LSL) and Z (USL) is calculated. From fig. 3.2 the value of M is determined. $\hat{P}_{LSL}$ and $\hat{P}_{USL}$ can be determined from fig 3.3.

If $\hat{P}_{LSL} + \hat{P}_{USL} \leq M$,the lot will be accepted, otherwise it will be rejected.

Assignment:

The density of a plastic used in a packet calculator to be at least 0.70 gm/cm^3. The parts are supplied in large lots and a variable sampling plan is to be used to sentence the lots. It is desired to have α = 0.1, β = 0.05, P_1 = 0.02 and P_2 = 0.1. The variability of the manufacturing process is unknown but will be estimated by the sample standard deviation.

a) Find an appropriate variable sampling plan.
b) Suppose that a sample of appropriate size was taken, and $\bar{X} = 0.73$and S = 1.05×10^{-2} Should the lot be accepted or rejected.

Question:

a) Explain: Acceptance sampling is not an attempt to **'control'** the quality but to **'assure'** the quality.
b) Why $P_1 \geq 1 - \alpha$and$P_2 \leq \beta$ explain?
c) What are the advantages of lot by lot acceptance sampling?
d) Write the difference between attributes and variables type acceptance sampling plan?

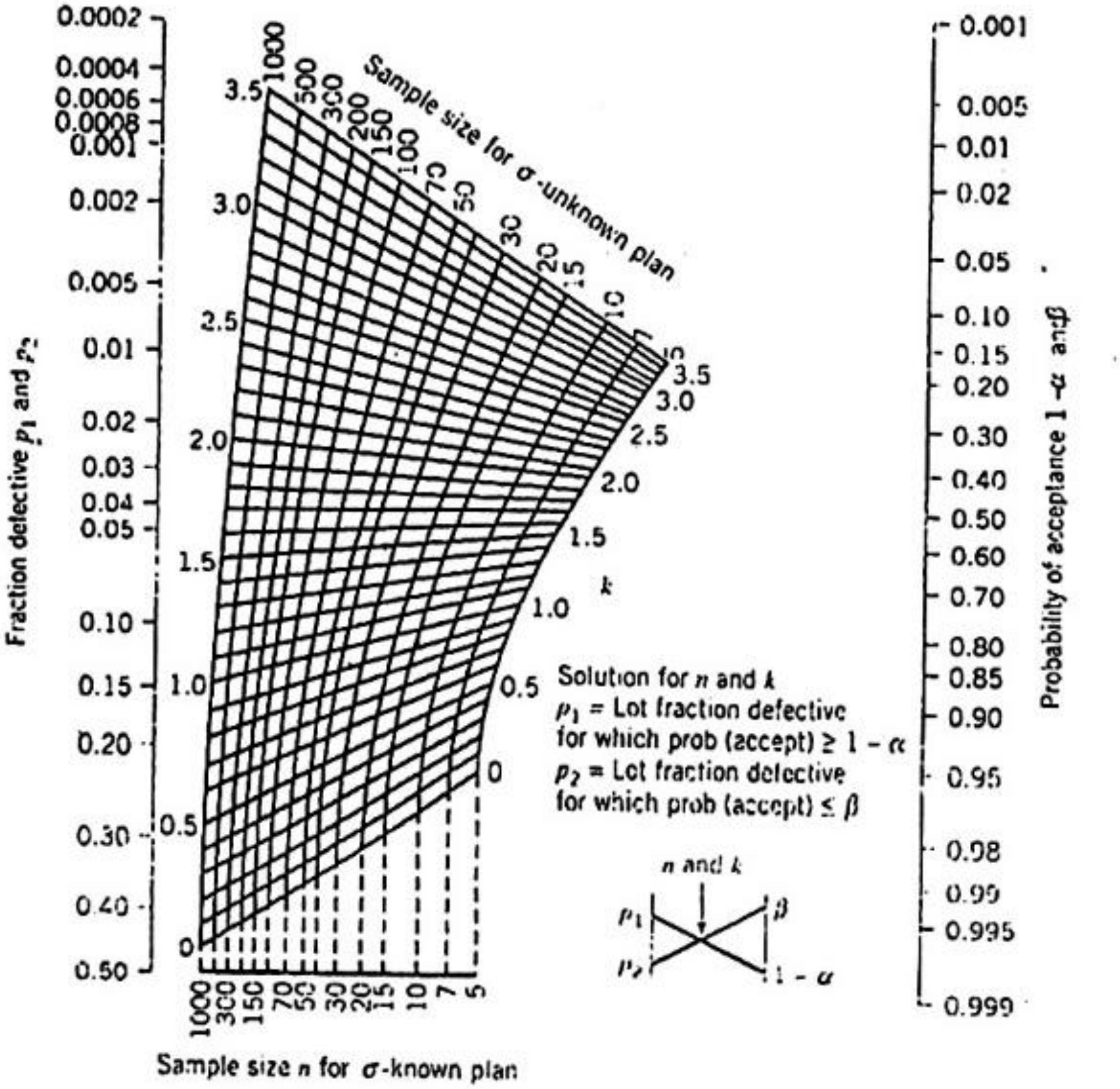


Figure 3.1 : Nomograph for Designing Variables Sampling Plan

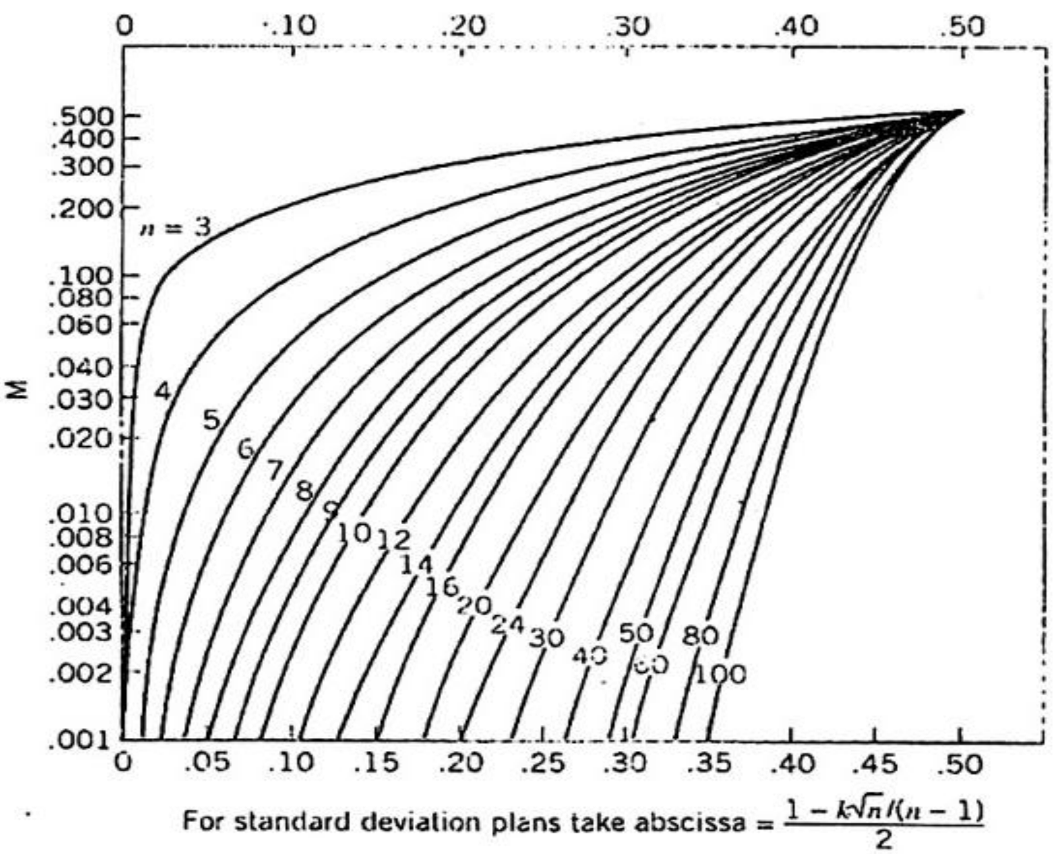


Figure 3.2 Chart for determining maximum allowable fraction defective M

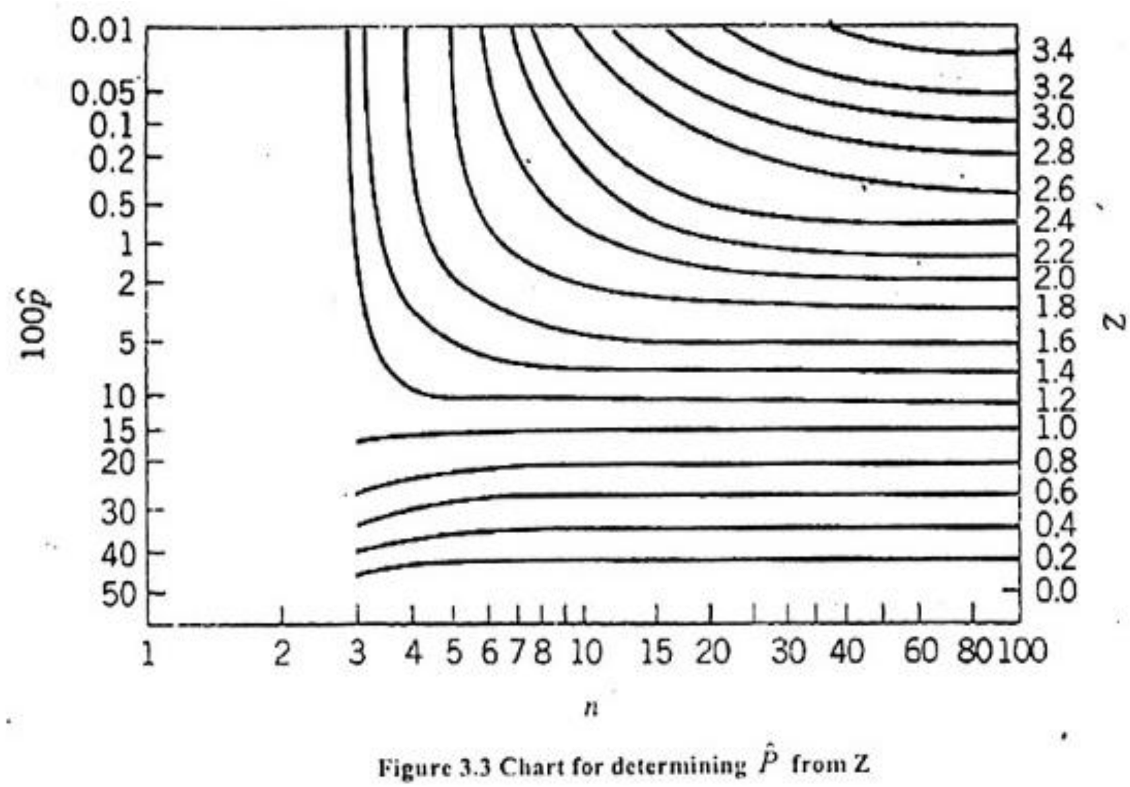


Figure 3.3 Chart for determining $\hat{P}$ from Z

Experiment No: 04

Experiment Name: Vernier Bevel Protractor

Objectives:

- Learn and understand different parts of Vernier Bevel Protractor
- Know the use and working principle of Vernier Bevel Protractor
- Understand the use of Vernier Bevel Protractor

Vernier Bevel Protractor:

It is also called universal bevel protractor. It is one of the simplest instruments for angular measurement. It is a direct type of angular measuring instrument. The range of this instrument is 0 to 360 degrees i.e. it can measure angles up to 360 degrees which any other angular measuring instrument cannot measure. It also has two arms (fixed blade and adjustable blade), which can be set along the faces and a circular scale to indicate the angle between them. Workpiece is set in between these two arms (two blades, fixed blade and adjustable blade), and the difference of two scale (main scale and Vernier scale) gives accurate measurement. Main parts of bevel protractor are-

- Fixed base blade and a circular body is attached to it
- Adjustable blade
- Blade clamp
- Scale magnifier lens
- Acute angle attachment

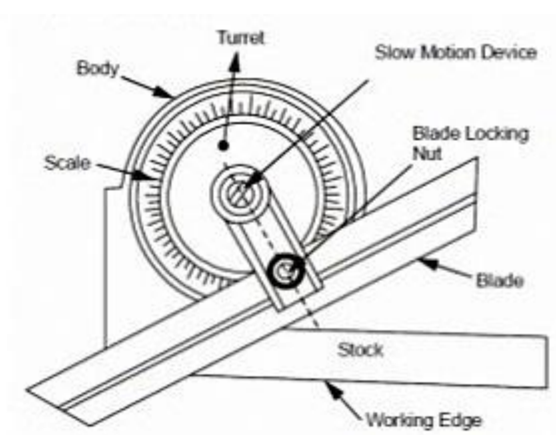


Fig 4.1: Vernier Bevel Protractor

Note that, magnifying lens has been provided for easy reading of the instrument. Main scale is circular and is graduated in degrees on the circular body. Main scale graduations are all around the circular body which is attached to fixed base blade. Fixed base blade also called as stock is attached to circular body of bevel protractor as shown in figure. Once the reading is fixed, blade clamp fixes the reading. Blades are about 150 mm long or 300 mm long, 13 mm thick. Its ends are beveled at 45 degrees and 60 degrees. Vernier scale is also marked on turret which can rotate all over the fixed body. Adjustable can pass through the slot provided in turret. So as the turret rotates, adjustable blade also rotates full 360 degrees. There are 12 graduations of Vernier scale starting from 0 to 60 degrees on both sides of zero of Vernier scale.

How to read Vernier scale:

- If the indicator on the Vernier is corresponding to that on the main scale, then directly read on the main scale.
- If the zero indicator on the Vernier indicates rightward of the zero indicator on the main scale, read on the right side of the Vernier. Example of fig 3.2 shows that 15 degree on the right side of the Vernier is directly in correspondence with the main scale so the reading is 12^{o} 15′.
- If the zero indicator of the Vernier indicates on the left side of the zero indicators on the main scale, read on the left side of the Vernier.

Fig 4.2: How to read Vernier scale

Least count of Vernier Bevel Protractor:

Least count of Vernier Bevel Protractor $= \frac{\text{smallest division on the main scale}}{\text{Total no of division on the Vernier scale}}$

$= 1^{o}$ (equal to 60′) i.e. $\frac{60}{12}$

= 5 minutes (written as 5′)

Application of Vernier Bevel Protractor:

The bevel protractor can be used in the following applications-

- For checking V-block
- For measuring acute angle

Fig 4.3: Checking V-block

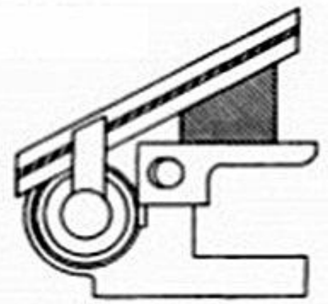


Fig 4.4: Measuring acute angle

Assignment:

Find the difference of the angle in between the dial of hour and the dial of minute when your clock indicates-

a) 3:30
b) 11:59
c) 12:00

Experiment 1

Basics of Programmable Logic Controller (PLC)

Objective: To learn basics of Programmable logic controller, logic diagrams, Boolean algebra and ladder logic diagrams.

<u>What is PLC:</u>

- Programmable Logic Controller or PLC's are the solid state member of computer family.
- It is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic in order to control machines and processes.
- It uses integrated circuit instead of electromechanical devices to implement control.
- A PLC monitors inputs, makes decisions based on its program, and controls outputs to automate a process or machine.
- PLCs are similar to computers, but whereas computers are optimized for calculation and display tasks, PLCs are optimized for control tasks and the industrial environment.

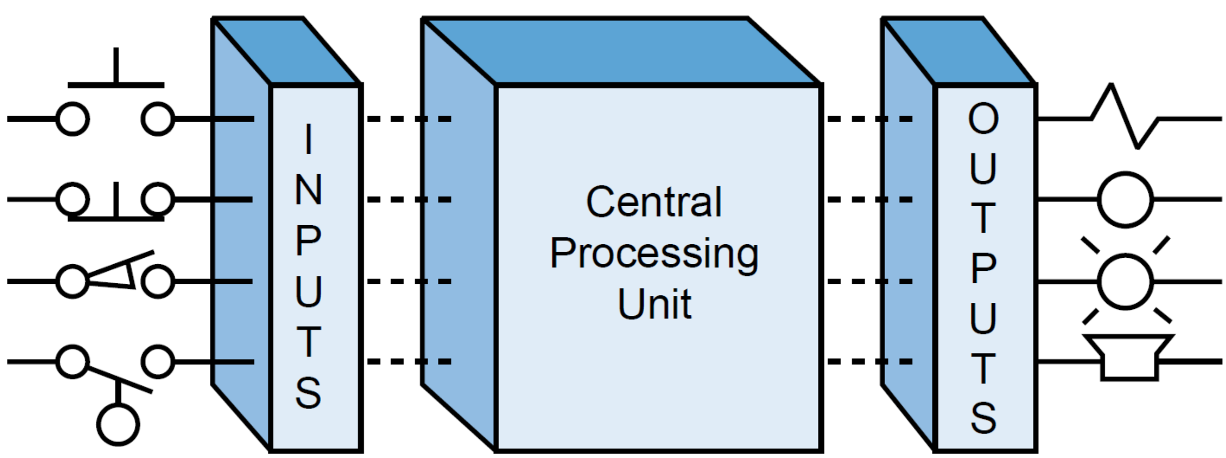


Figure: PLC schematic

Features of PLC:

- Rugged design; suitable for harsh industrial environments against high temperature variations, dust and vibrations.

- Industry standard I/O interfaces; capable of communicating with other PLCs, computers and intelligent devices.
- Industry standard programming languages; easily learned and understood. Programming is primarily concerned with logic, timing, counting and switching operations.
- Field programmable.
- Reduces hard wiring and wiring cost.
- Monitoring, error checking and diagnostics capability.
- Competitive in both cost and space requirements.

Applications of PLC:

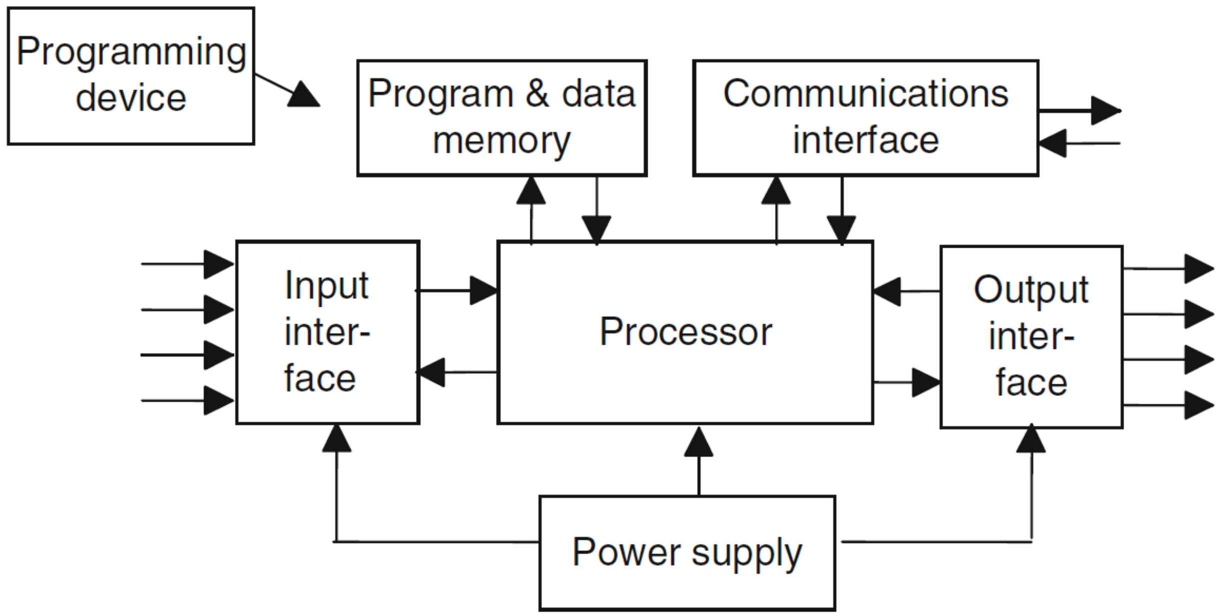
- Manufacturing/Machining
    - Assembly machines
    - Boring
    - Cranes
    - Energy demand
    - Grinding
    - Injection/blow molding
    - Material conveyors
    - Metal casting
    - Milling
    - Painting
    - Plating
    - Tracer lathe
    - Welding
- Metals
    - Blast furnace control
    - Continuous casting
    - Rolling mills
    - Soaking pit
- Mining
    - Bulk material conveyors
    - Loading/unloading
    - Ore processing
    - Water/waste management
- Lumber/Pulp/Paper
    - Batch digesters
    - Chip handling

Major Components: PLC consists of five major sections:

1. Power Supply
2. Memory
3. Central Processing Unit (CPU)
4. I/O Interface
5. Programming Section

Principles of Operation:

- An **input** accepts a variety of digital or analog signals from various field devices or ***sensors*** and converts them into a logic signal that can be used by the CPU.
- These field devices may be discrete or analog input devices, such as,
    - Limit switches
    - Pressure transducers
    - Push buttons
    - Motor starters
    - Solenoids, etc.
- The **CPU** makes decisions and executes control instructions based on program instructions in memory.
- During its operation, the CPU completes three processes:
    - It *reads*, or accepts, the input data from the field devices via the input interfaces
    - It *executes*, or performs, the control program stored in the memory system, and
    - It *writes*, or updates, the output devices via the output interfaces.
- This process of sequentially reading the inputs, executing the program in memory and updating the outputs is known as ***scanning***.



- **Output** modules convert control instructions from the CPU into a digital or analog signal that can be used to control various field devices or ***actuators***.
- A **programming devices (programmer)**, usually a personal computer or a manufacturer's miniprogrammer unit, is required to enter the control program or instructions into memory.
- These instructions determine what the PLC will do for a specific input.
- An operator interface device allows process information to be displayed and new control parameters to be entered.

The system power supply provides all the voltages required for the proper operation of the various central processing.

PLC Programming Languages:

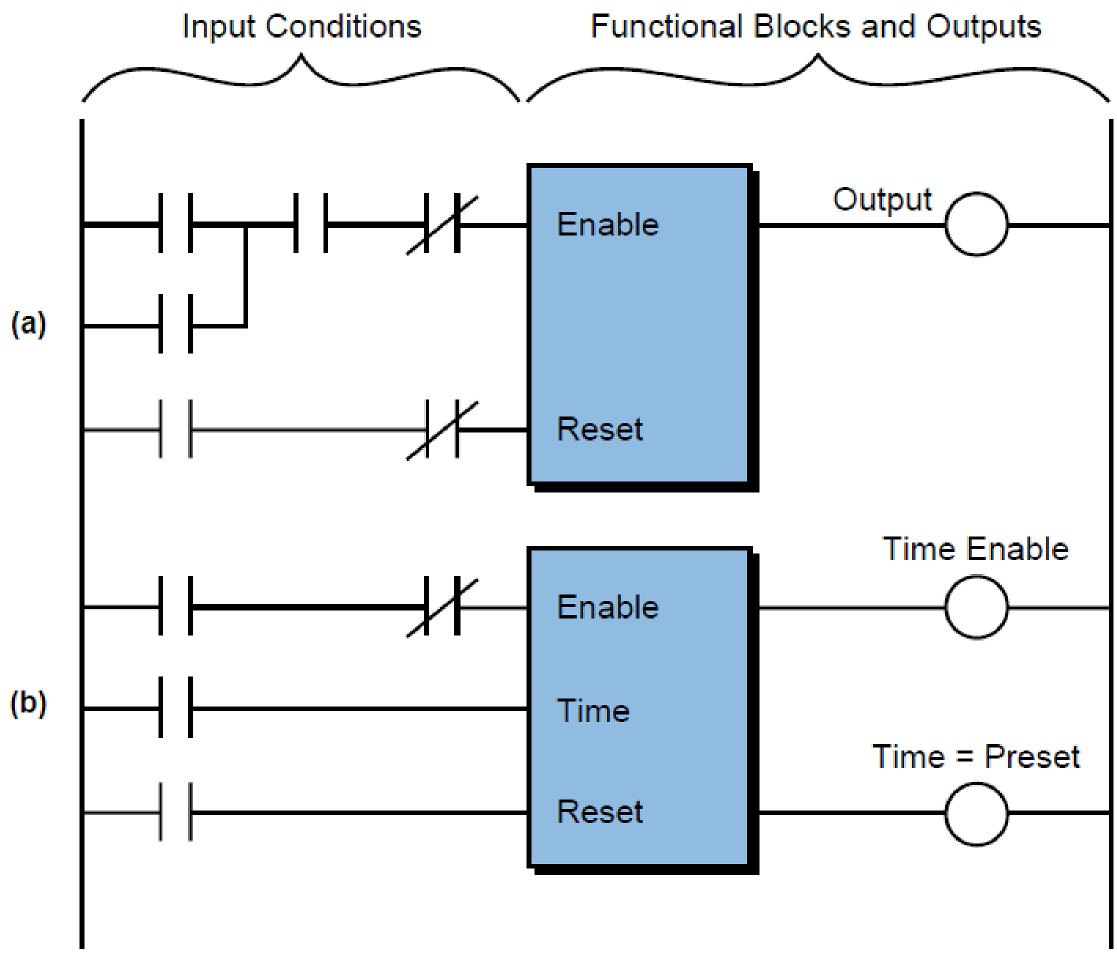
- There are five PLC programming languages;
  1. **Ladder Diagram(LAD):** Graphic language derived from circuit diagram of directly wired relay controls
  2. **Function Block Diagram (FBD)** :Functions & functions block are represented graphically and interconnected into networks.
  3. **Instruction List (IL):** Textual assembler-type language consisting of an operator and an operand.
  4. **Structured Text (ST)**: High level language based on Pascal.
  5. **Sequential Function Chart (SFC):** A language resource for the structuring of sequence-oriented control programs.

Ladder Diagram:

- Ladder diagram is type of graphic language for automatic control systems it had been used for a long period since World War II.
- The use of ladder programming involves writing a program in a manner to drawing a switching circuit.
- Originally there are only few basic elements available such as Normally Open or contact, Normally Closed or contact, output coil, timers and counters.

Ladder Programming Convetions:

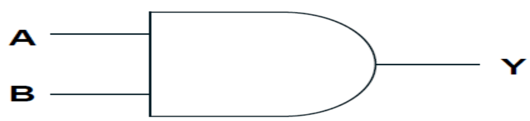
- When a ladder diagram contains a functional block, contact instructions are used to represent the input conditions that drive the block's logic.
- A functional block can have one or more enable inputs that control its operation. In addition, it can have one or more output coils, which signify the status of the function being performed.



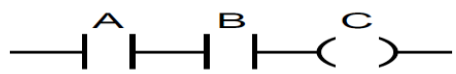
Ladder Programming Convetions

Logical Functions:

AND Gate

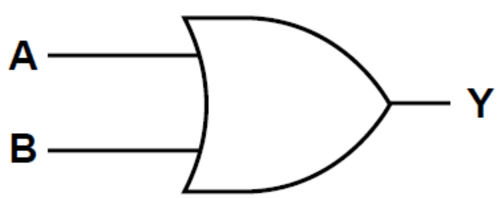


AND Truth Table		
Inputs		Output
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1



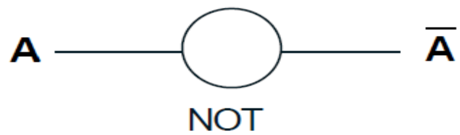
AND
Equivalent Circuit

OR Gate:



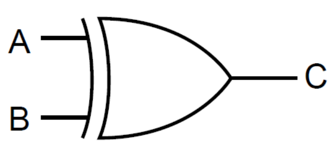
OR Truth Table		
Inputs		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

NOT Gate:



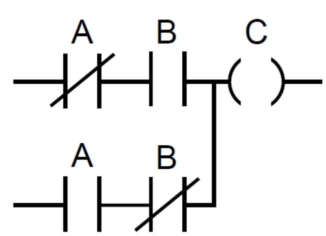
NOT Truth Table	
Input	Output
A	$\overline{A}$
0	1
1	0

XOR gate:



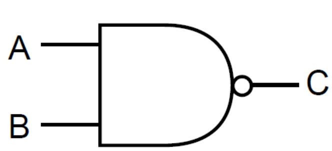
Exclusive-OR
Gate

A	B	C
0	0	0
0	1	1
1	0	1
1	1	0



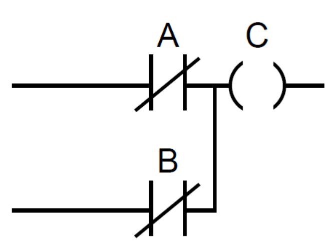
Exclusive-OR
Equivalent Circuit

NAND gate:



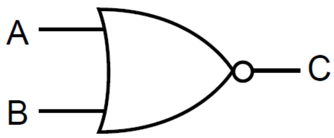
NAND
Gate

A	B	C
0	0	1
0	1	1
1	0	1
1	1	0



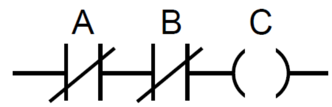
NAND
Equivalent Circuit

NOR GATE:



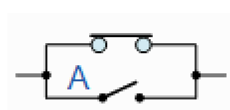
NOR
Gate

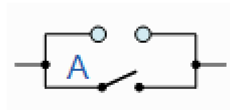
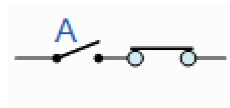
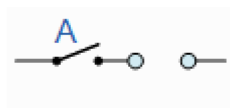
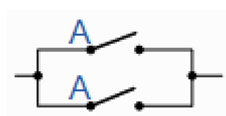
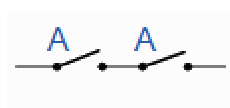
A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

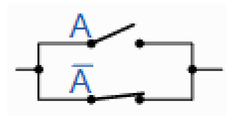
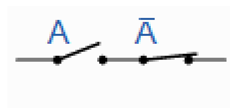
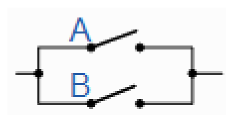
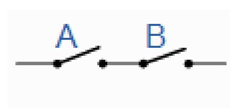


NOR
Equivalent Circuit

Laws of BOOLEAN Algebra:

Boolean Expression	Description	Equivalent Switching Circuit	Boolean Algebra Law or Rule
A + 1 = 1	A in parallel with closed = "CLOSED"		Annulment

A + 0 = A	A in parallel with open = "A"		Identity
A . 1 = A	A in series with closed = "A"		Identity
A . 0 = 0	A in series with open = "OPEN"		Annulment
A + A = A	A in parallel with A = "A"		Idempotent
A . A = A	A in series with A = "A"		Idempotent
NOT A = A'	NOT NOT A (double negative) = "A"		Double Negation

$A + A' = 1$	A in parallel with NOT A = "CLOSED"		Complement
$A \, . \, A' = 0$	A in series with NOT A = "OPEN"		Complement
A+B = B+A	A in parallel with B = B in parallel with A		Commutative
A.B = B.A	A in series with B = B in series with A		Commutative
$(A+B)' = A'.B'$	invert and replace OR with AND		de Morgan's Theorem
$(A.B)' = A'+B'$	invert and replace AND with OR		de Morgan's Theorem

Assignment:

1. Draw the following logic diagrams

a. A.(B+C ')= Output

b. A ' (B+C) = Output

2. Prove that, A+BC = A.B + A.C according to BOOLEAN algebra.

3. Show the ladder logic diagrams for the three fundamental logic expressions (AND,OR, NOT)

Experiment 2

Pneumatic Control System (Pneumatic Trainer)

Objective: The objective of the experiment is to get acquainted with different types of control systems, components of pneumatic control system and its application.

Pneumatic Control System: Pneumatics is a branch of engineering that makes use of gas or pressurized air. Pneumatic systems used extensively in industry are commonly powered by compressed air or compressed inert gases. A centrally located and electrically powered compressor powers cylinders, air motors, and other pneumatic devices. A pneumatic system controlled through manual or automatic solenoid valves is selected when it provides a lower cost, more flexible, or safer alternative to electric motors and actuators.

Factory-plumbed pneumatic-power users need not worry about poisonous leakage, as the gas is usually just air. Smaller or stand-alone systems can use other compressed gases that present an asphyxiation hazard, such as nitrogen—often referred to as OFN (oxygen-free nitrogen) when supplied in cylinders.

Any compressed gas other than air is an asphyxiation hazard—including nitrogen, which makes up 78% of air. Compressed oxygen (approx. 21% of air) would not asphyxiate, but is not used in pneumatically-powered devices because it is a fire hazard, more expensive, and offers no performance advantage over air.

Portable pneumatic tools and small vehicles, such as Robot Wars machines and other hobbyist applications are often powered by compressed carbon dioxide, because containers designed to hold it such as soda stream canisters and fire extinguishers are readily available, and the phase change between liquid and gas makes it possible to obtain a larger volume of compressed gas from a lighter container than compressed air requires. Carbon dioxide is an asphyxiate and can be a freezing hazard if vented improperly. Some other common uses of pneumatic system are lifts, bus doors etc.

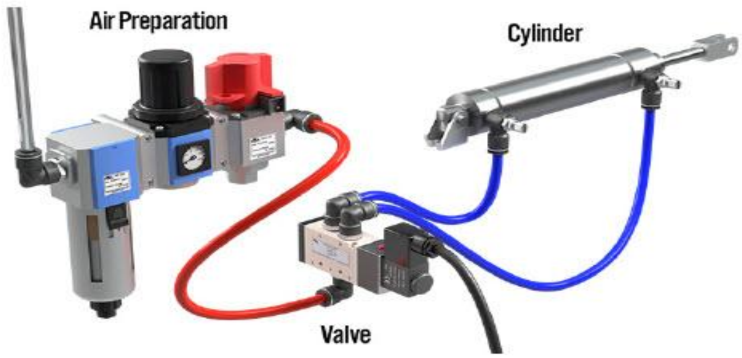


Figure 1C : Basic pneumatic system

Comparison to hydraulics:

Advantages of pneumatics:

- Simplicity of design and control—Machines are easily designed using standard cylinders and other components, and operate via simple on-off control.
- Reliability—Pneumatic systems generally have long operating lives and require little maintenance. Because gas is compressible, equipment is less subject to shock damage. Gas absorbs excessive force, whereas fluid in hydraulics directly transfers force. Compressed gas can be stored, so machines still run for a while if electrical power is lost.
- Safety—There is a very low chance of fire compared to hydraulic oil. Newer machines are usually overload safe.

Advantages of hydraulics:

- Liquid does not absorb any of the supplied energy.
- Capable of moving much higher loads and providing much higher forces due to the incompressibility.
- The hydraulic working fluid is basically incompressible, leading to a minimum of spring action. When hydraulic fluid flow is stopped, the slightest motion of the load releases the pressure on the load; there is no need to "bleed off" pressurized air to release the pressure on the load.
- Highly responsive compared to pneumatics.
- Supply more power than pneumatics.
- Can also do many purposes at one time: lubrication, cooling and power transmission.

Components of a Pneumatic Control System:

1. Sensor: A sensor is like a brain of a control system. It does not execute an action but it signals the actuator when to execute the required actions and accordingly it runs the total systems. There are several types of sensors like light sensor, proximity sensor, motion sensor etc.

2. Actuator: The actuator is like the hand or leg of a control system. It executes the required action in response to the signal of the sensor. There are two types of actuators used in a pneumatic system

a. Single Acting Cylinder (SAC): It has only one port for inlet and outlet of gas or air. It has a restoring force (spring) to come back to its initial position without any impact of air. It can be operated with a single 3 port valve.

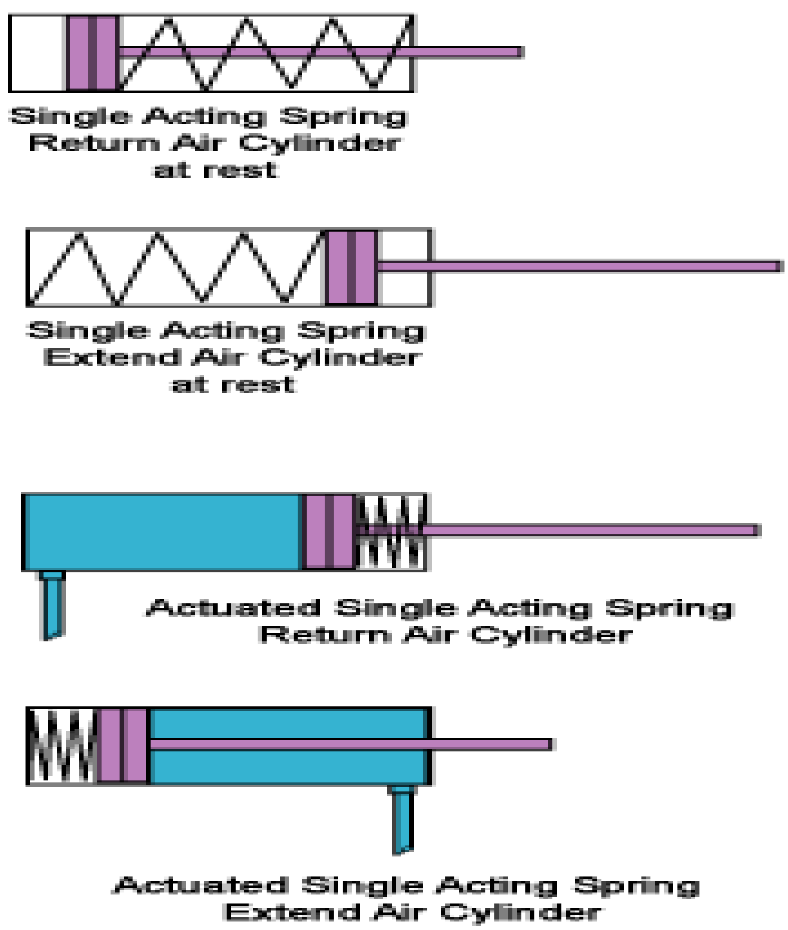
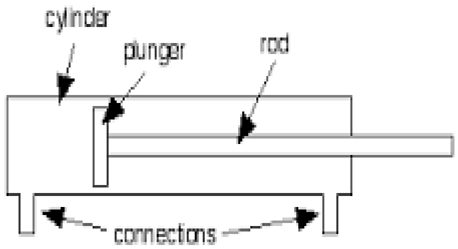
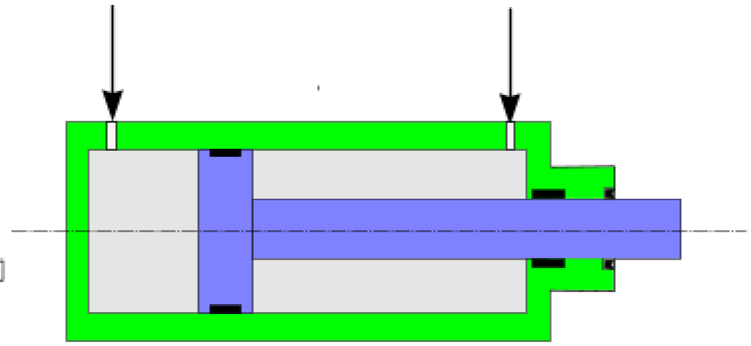


Figure: Single Acting Cylinder

b. Double Acting Cylinder(DAC): It has two ports, one inlet and one outlet port for air in and out. It has no restoring force attached to it. To operate a double acting cylinder, two 3-port valves or a single 5-port valve is required.





Double Acting Cylinder

3. Valves: Two types of valves are used to operate the actuators of a pneumatic system.

a. 3-port valve : It has only three ports along with a maximum of one connections between them and one port always open. A 3-port valve can be lever operated or push/pull switch operated. In any position of the lever/switch if port 1 is connected to port 2 then in the other position port 2 will be connected to port 3 leaving port 3 open in one position and port 1 open in the next. The follwing figures show a lever operated and a push-pull operated 3 port valves.

Figure: 3-port Valve

5-port valve: : It has 5 ports along with a maximum of two connections between them and two ports always open. A port can be lever operated or push/pull switch operated. The advantage of a 5-port valve is that it can handle a DAC on its own whereas in case of 3-port valves two are simultaneously required to be operated to handle a DAC. Moreover a 5-port valve can be used as a 3-port valve as well.

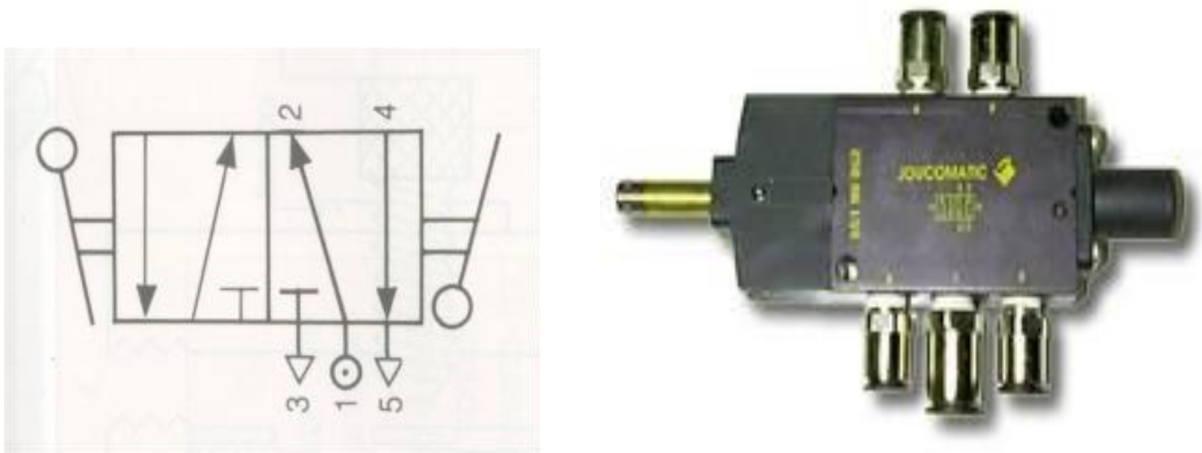


Figure: 5-port valve

In your control you will be demonstrated the actions of a pneumatic system through a pneumatic trainer which uses air as power input.

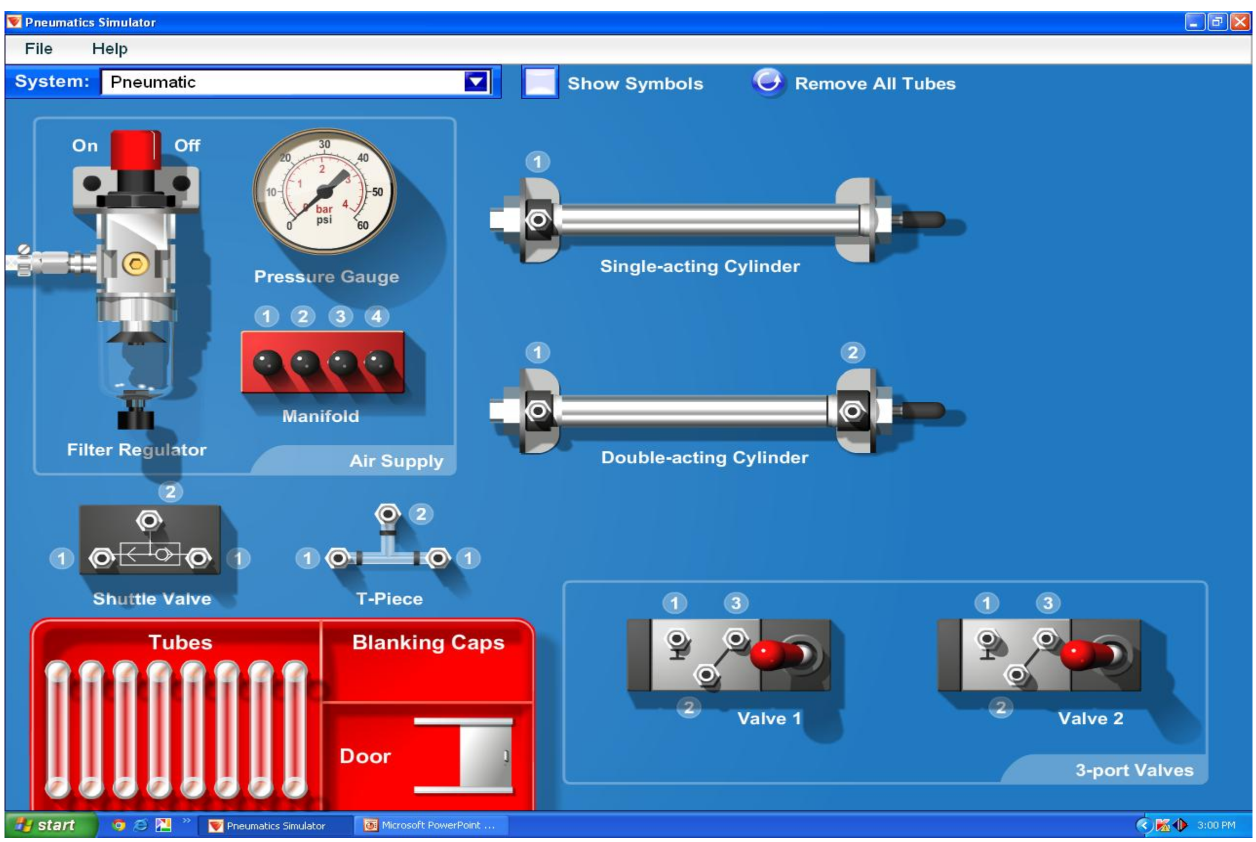


Figure: Pneumatic trainer simulation

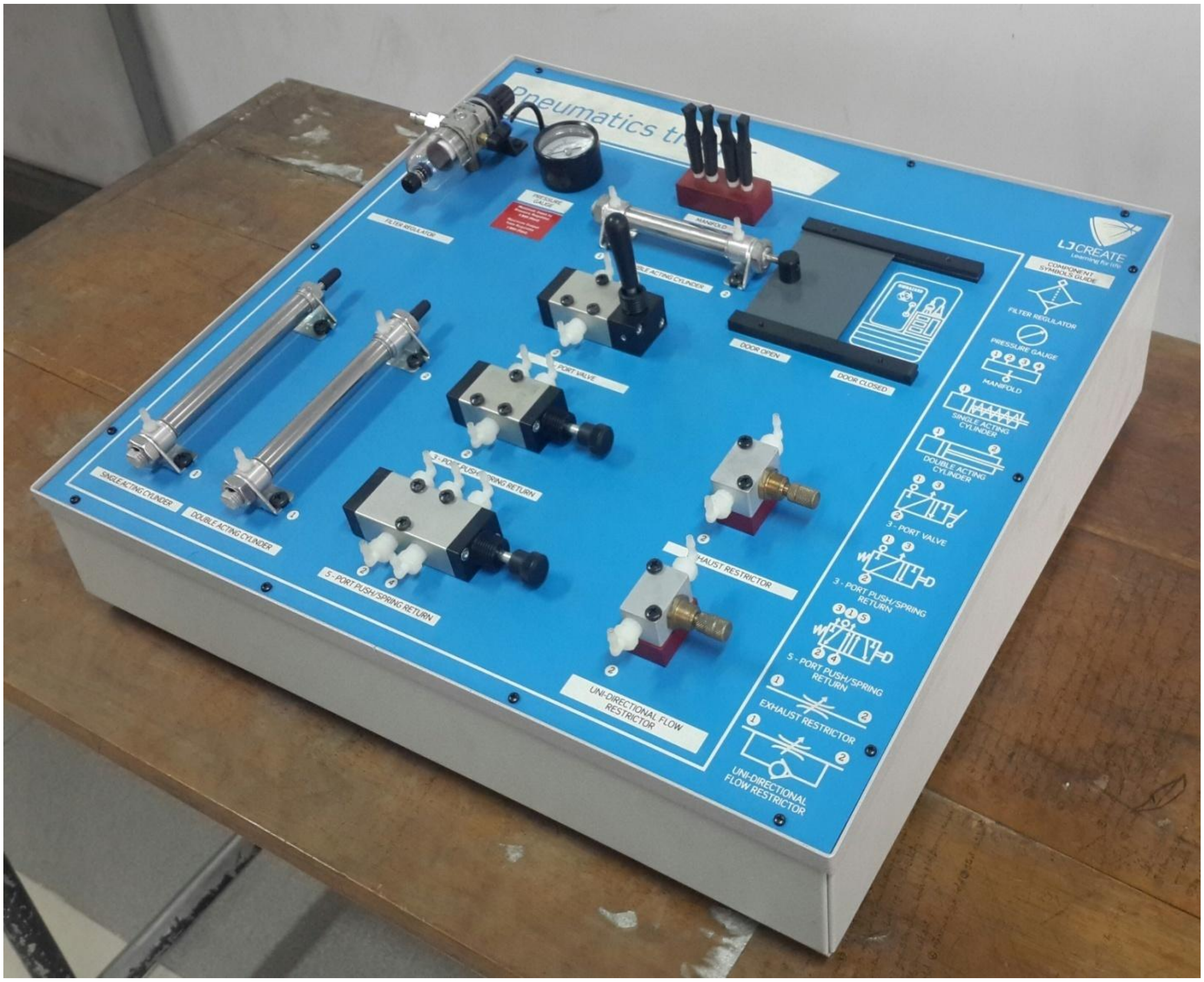


Figure: Pneumatic Trainer

Assignment:

1. What are the advantages of a pneumatic system over a hydraulic one?

2. If you are driving a car on highway would you recommend a pneumatic break system in it? Why?

3. Is there any way a DAC can be operated with a single 3-port valve? If yes/no, why?

Experiment 3

Electro-Pneumatic Control System

Objective: The purpose of this experiment is to get exposure to a practical implementation of combination of pneumatic control system and PLC logics.

Electro pneumatic control: A electro pneumatic control system uses compressible fluid as its input power and facilitates automation through the use of PLC logics. So it is actually a combination of a pneumatic and an electronic system.

In this experiment you will be illustrated an action of the electro-pneumatic trainer which will be powered by the pneumatic trainer shown in previous experiment. And several logic gates will be used to design a circuit which will facilitate the disposal of two different items in two different bins. The pneumatic trainer has 3 cylinders to push the object to be disposed, One solenoid valve to take pneumatic input and power the cylinders and three sensors (Dispenser sensor, Check point sensor and transparency sensor). There is a PLC board attached to it to design the circuit to perform required actions. The sequence of operations can be controlled both manually and automatically. The following diagrams shows the Electro-Pneumatic trainer of this experiment

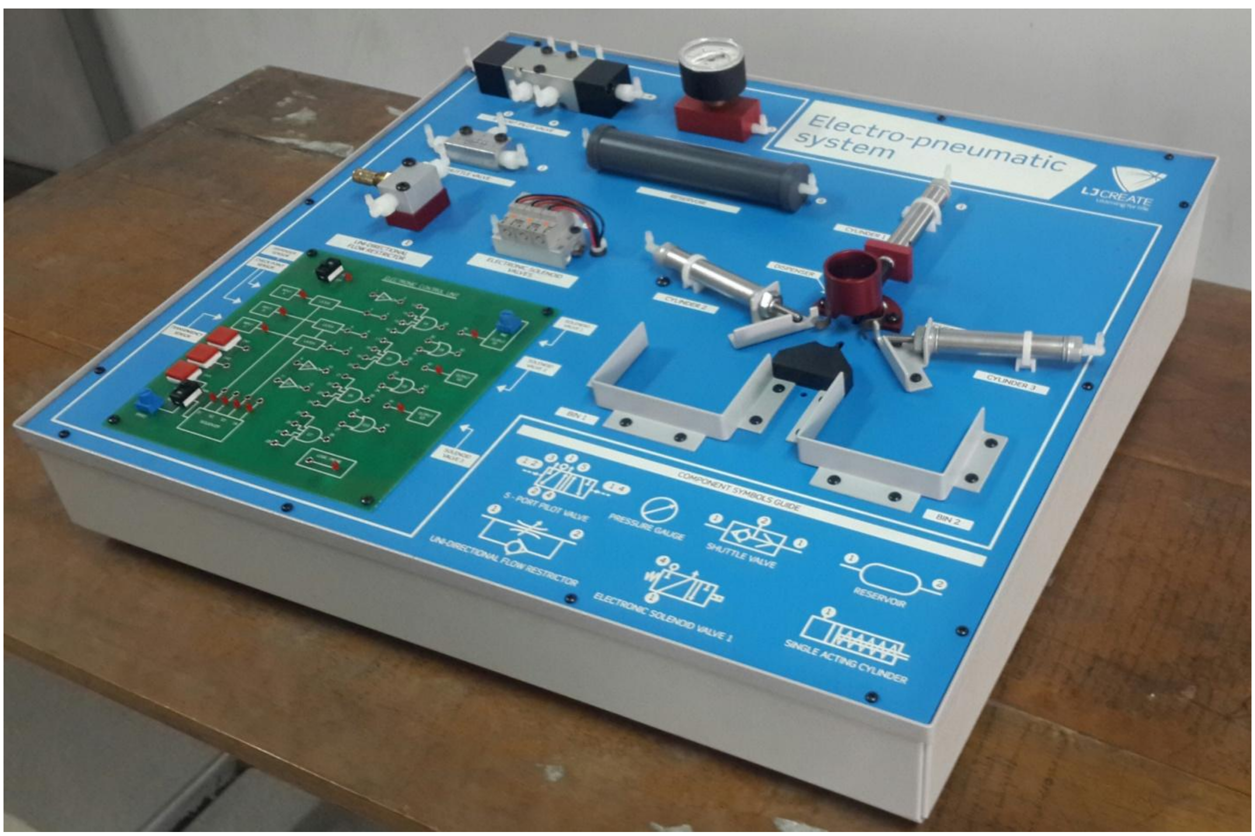


Figure: Electro-pneumatic trainer

Experimental details will be taught in the lab experiment. And the simulation of the device will also be illustrated during the experiment.

Assignments

1. Draw the logic diagram of the that was designed in this experiment.

2. Draw the block diagram of the solenoid valve used in this experiment.

Experiment 4

Proportional Integral Derivative Pressure Control System

Objective: The objective of this experiment is to learn the mechanism of PID control system and its industrial applications.

Theory: A proportional–integral–derivative controller (PID controller) is a control loop feedback mechanism (controller) commonly used in industrial control systems. A PID controller continuously calculates an error value as the difference between a desired set point and a measured process variable and applies a correction based on proportional, integral, and derivative terms, respectively (sometimes denoted P, I, and D) which give their name to the controller type. The controller attempts to minimize the error over time by adjustment of a control variable u(t), such as the position of a control valve, a damper, or the power supplied to a heating element, to a new value determined by a weighted sum:

$$u(t) = K_P e(t) + K_d \frac{de(t)}{dt} + K_I \int_0^t e(t)dt$$

where K_P, K_I and K_d, all non-negative, denote the coefficients for the proportional, integral, and derivative terms, respectively (sometimes denoted P, I, and D). In this model:

- P accounts for present values of the error. For example, if the error is large and positive, the control output will also be large and positive.
- I accounts for past values of the error. For example, if the current output is not sufficiently strong, the integral of the error will accumulate over time, and the controller will respond by applying a stronger action.
- D accounts for possible future trends of the error, based on its current rate of change

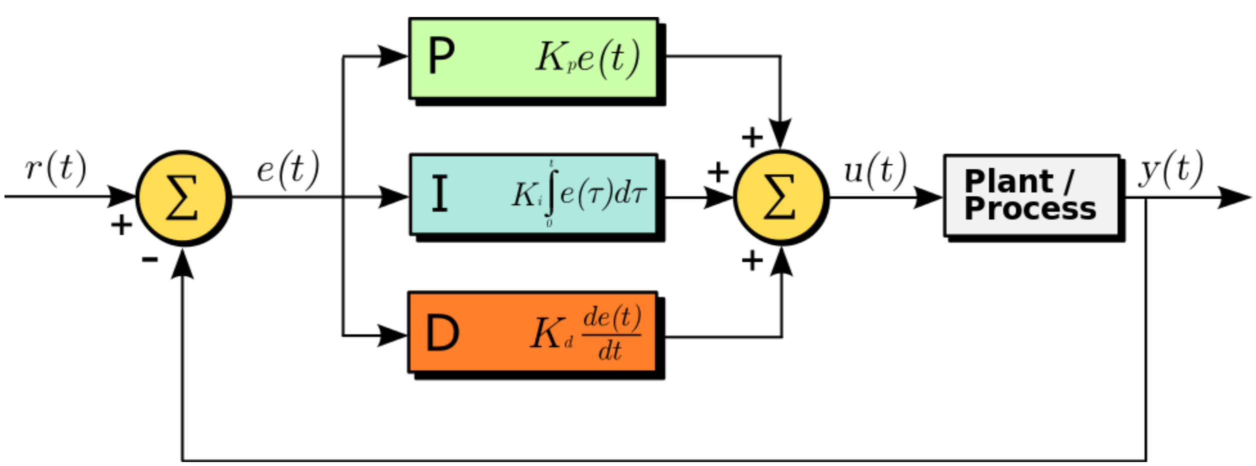


Figure: A schematic of PID control system

As a PID controller relies only on the measured process variable, not on knowledge of the underlying process, it is broadly applicable. By tuning the three parameters of the model, a PID controller can deal with specific process requirements. The response of the controller can be described in terms of its responsiveness to an error, the degree to which the system overshoots a set point, and the degree of any system oscillation. The use of the PID algorithm does not guarantee optimal control of the system or even its stability.

Some applications may require using only one or two terms to provide the appropriate system control. This is achieved by setting the other parameters to zero. A PID controller is called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are fairly common, since derivative action is sensitive to measurement noise, whereas the absence of an integral term may prevent the system from reaching its target value.

For discrete-time systems, the term PSD (proportional-summation-difference) is often used.

Proportional Term: The proportional term produces an output value that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain constant.

The proportional term is given by,

$P_{out} = K_P e(t)$

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable (see the section on loop tuning). In contrast, a small gain results in a small output response to a large input error, and a less responsive or less sensitive controller. If the proportional gain is too low, the control action may be too small when responding to system disturbances. Tuning theory and industrial practice indicate that the proportional term should contribute the bulk of the output change.

Integral Term: The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. The integral in a PID controller is the sum of the instantaneous error over time and gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain (K_i) and added to the controller output.

The integral term is given by

$I_{out} = K_I \int_0^t e(t)dt$

The integral term accelerates the movement of the process towards set point and eliminates the residual steady-state error that occurs with a pure proportional controller. However, since the integral term responds to accumulated errors from the past, it can cause the present value to overshoot the set point value (see the section on loop tuning).

Derivative term: The derivative of the process error is calculated by determining the slope of the error over time and multiplying this rate of change by the derivative gain K_d. The magnitude of the contribution of the derivative term to the overall control action is termed the derivative gain, K_d.

The derivative term is given by,

$D_{out} = K_d \frac{de(t)}{dt}$

Derivative action predicts system behavior and thus improves settling time and stability of the system. An ideal derivative is not causal, so that implementations of PID controllers include an additional low-pass filtering for the derivative term to limit the high-frequency gain and noise. Derivative action is seldom used in practice though – by one estimate in only 25% of deployed controllers because of its variable impact on system stability in real-world applications.

Loop tuning: Tuning a control loop is the adjustment of its control parameters (proportional band/gain, integral gain/reset, derivative gain/rate) to the optimum values for the desired control response. Stability (no unbounded oscillation) is a basic requirement, but beyond that, different systems have different behavior, different applications have different requirements, and requirements may conflict with one another.

PID tuning is a difficult problem, even though there are only three parameters and in principle is simple to describe, because it must satisfy complex criteria within the limitations of PID control. There are accordingly various methods for loop tuning, and more sophisticated techniques are the subject of patents; this section describes some traditional manual methods for loop tuning.

Designing and tuning a PID controller appears to be conceptually intuitive, but can be hard in practice, if multiple (and often conflicting) objectives such as short transient and high stability are to be achieved. PID controllers often provide acceptable control using default tunings, but performance can generally be improved by careful tuning, and performance may be unacceptable with poor tuning. Usually, initial designs need to be adjusted repeatedly through computer simulations until the closed-loop system performs or compromises as desired.

Some processes have a degree of nonlinearity and so parameters that work well at full-load conditions don't work when the process is starting up from no-load; this can be corrected by gain scheduling (using different parameters in different operating regions).

There are two types of tuning system,

Manual tuning where the parameters are manually controlled to optimize the output and the other is **software controlled** where the parameters are controlled by the software to get the desired set point for both input and output control loop.

Experimental device: The pressure control device we use in our experiment is PCT 53 pressure control device. It is software operated and the parameters can be manually or automatically controlled. Both will be9 demonstrated in your experiment.

Figure: PID pressure control device

The software simulates the graphical representation of pressure change with time along with the numerical values of the set parameters and set point. There are four valves in the device along with a solenoid valve, one input valve, one output valve and an emergency valve to protect air entrapping.

Limitations of PID: While PID controllers are applicable to many control problems, and often perform satisfactorily without any improvements or only coarse tuning, they can perform poorly in some applications, and do not in general provide optimal control. The fundamental difficulty with PID control is that it is a feedback control system, with constant parameters, and no direct knowledge of the process, and thus overall performance is reactive and a compromise. While PID control is the best controller in an observer without a model of the process, better performance can be obtained by overtly modeling the actor of the process without resorting to an observer.

PID controllers, when used alone, can give poor performance when the PID loop gains must be reduced so that the control system does not overshoot, oscillate or hunt about the control setpoint value. They also have difficulties in the presence of non-linearities, may trade-off regulation versus response time, do not react to changing process behavior (say, the process changes after it has warmed up), and have lag in responding to large disturbances.

The most significant improvement is to incorporate feed-forward control with knowledge about the system, and using the PID only to control error. Alternatively, PIDs can be modified in more minor ways, such as by changing the parameters (either gain scheduling in different use cases or adaptively modifying them based on performance), improving measurement (higher sampling rate, precision, and accuracy, and low-pass filtering if necessary), or cascading multiple PID controllers.

Another problem faced with PID controllers is that they are linear, and in particular symmetric. Thus, performance of PID controllers in non-linear systems (such as HVAC systems) is variable. For example, in temperature control, a common use case is active heating (via a heating element) but passive cooling (heating off, but no cooling), so overshoot can only be corrected slowly – it cannot be forced downward. In this case the PID should be tuned to be overdamped, to prevent or reduce overshoot, though this reduces performance (it increases settling time).

Assignment:

1. Why is PID suboptimal in case of non-linearities?

2. What problems may arise if the differential part is missing in a PID?

3. What are the limitations of a PID?

4. Mention a few industrial applications of PID.

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

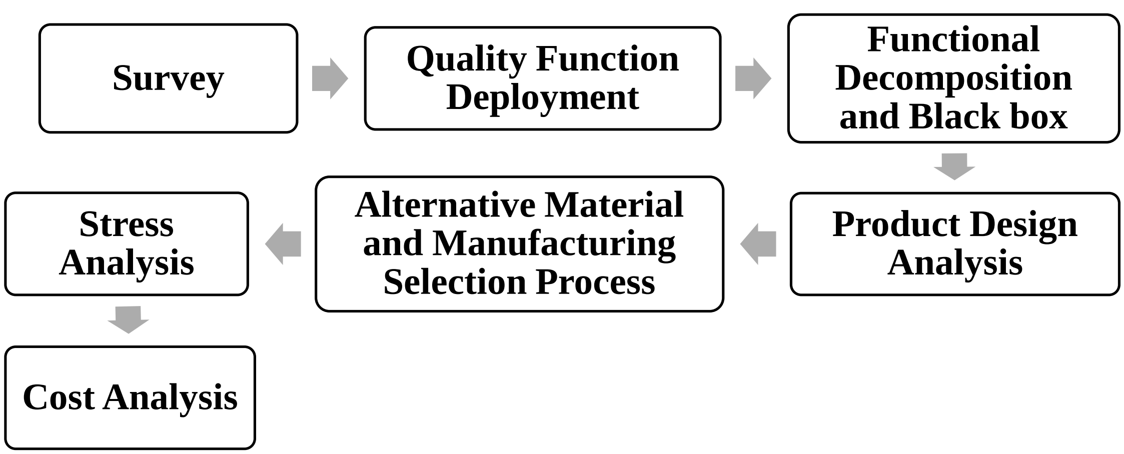
IPE 3104: Product Design and Development sessional
Credit Hour: 1.5

General Guidelines:

1. Students must form group and submit at least five ideas for product development by each group with in the first week of the beginning of class
2. Students must be present on time as per the scheduled time of each briefing
3. Report/ Assignment of a briefing must be submitted in the next briefing
4. Viva for each brief may be taken on the next day with the report/ assignment
5. The structure of the Report/ Assignment of each briefing will be provided by the respective teacher
6. Final presentation will be taken at the end of the semester before the preparatory leave.
7. Students must bring their complete product at the day of presentation for product demonstration
8. A tentative marks distribution is given below:

Report/ Assignment	Attendance and Viva	Final Presentation	Product demonstration
30	20	25	25

Steps regarding briefing of Product Design and Development sessional will be followed as mentioned below-



Brief-1

Survey

Market surveys are an important part of market research that measure the feelings and preferences of customers in a given market. Varying greatly in size, design, and purpose, market surveys are one of the main pieces of data that companies and organizations use in determining what products and services to offer and how to market them. These steps will teach you the basics of how to make a market survey and offer tips for optimizing your results.

Clarify the goal of your market survey. Before starting any planning, be certain what the goal of your market survey is. What do you want to find out? Do you want to try to assess how well your market will accept a new product? Maybe you want to figure out how well your marketing is working or reaching its designated audience. Whatever it is, be sure that you have a clear goal in mind.

Determine and define the nature, extent, and size of your market. Before conducting a survey in a given market, you need to know what market you're targeting. Choose geographic and demographic parameters, identify customers by types of product, and get an idea of how many people there are in the market.

Determine what aspects of the market you want to investigate. This will depend entirely on your marketing goals and there are a large variety of options here. If you have a new product, you may want to figure out how well it is recognized or desired in a given market. Alternately, you may want to know about the specific buying habits of your market, like when and where and how much they buy. Just be sure to have a clear idea of what you want to find out.

Find out where and when you can reach customers in your market. You might conduct a survey at the mall or on the street, via telephone, online, or through the mail. Your results may change based on the time of day and year. Choose a method and time that best suits your research.

Determine what type of survey to use. Surveys can be split into two different general categories: questionnaires and interviews. The only difference is who does the recording of the respondents' information; in the questionnaire, the respondent records their own answers to the questions, whereas in the interview, the interviewer writes down what the respondent says. Beyond that, there are other options as to how the survey is administered, whether that's online or in person. Surveys can also be done individually or in groups.

Consider online survey platforms. Online survey platforms offer a cost and time-effective way to organize your survey and survey results. Simply search for these platforms online and compare several that you find to assess which one offers the right tools for your survey. Just make sure that your choices are reputable survey platforms. You should also consider whether or not your target market is computer-savvy enough for online surveys to be effective

In order to get the best results students have to consider some important assumption before doing survey such as:

- **Choose a sample size**
- **Prepare a list of questions with answers that will provide the data you need for your market research**
- **Devise a way to quantify the answers you receive.**
- **Identify variables that might affect your results.**
- **Have someone else look over your survey.**
- **Set a time period and location for your survey**
- **Conduct your survey, maximizing sample size and accuracy of responses.**
- **Analyze your results.**

Brief-2

QUALITY FUNCTON DEPLOYMENT

Definition of QFD -QFD stands for quality function deployment. It is a very systematic and organized approach of taking customer needs and demands in the consideration when designing a new products and services or when improving existing products or services.

- Quality -meeting customer requirements
- Function - What must be done-Focusing the attention
- Deployment - who will do it, When

Benefits of QFD

- create customer driven environment
- reduces the cycle time for new products
- reduces design to manufacturing costs
- increases communication through cross functional teams
- establish priority requirements and improves quality

Characteristics of QFD

❖ **Four main phases of QFD**

- Product planning including the 'House of Quality' (requirements engineering life cycle)
- Product design (design life cycle)
- Process planning (implementation life cycle)
- Process control (testing life cycle)

Product planning - define and prioritize customer needs - analyze competitive opportunities - plan a product to respond to a need - establish target values	**Part planning** - identify critical parts and sub-assemblies - identify interaction effect between parts - identify important parts characteristics that can fulfill product needs
Process requirement - determine critical process and material flow - determine process parameters - identify equipment requirements	**Production planning** - establish operational requirement - determine operation sequence - establish process control methodology

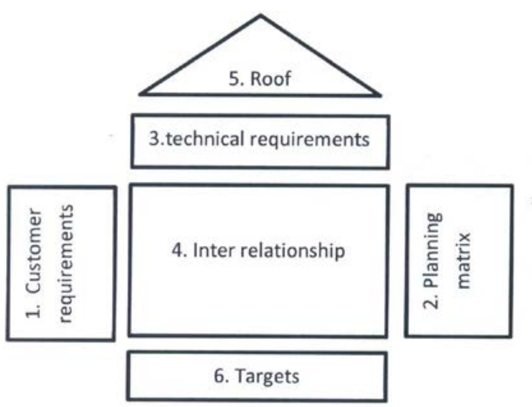
House of Quality

The primary planning tool used in QFD is the house of quality. The house of quality translates the voice of the customer into design requirements that meet specific target values and matches that against how an organization will meet those requirements. Many managers and engineers consider the house of quality · to be the primary chart in quality planning.

To build House of Quality

- Identify customer **wants**
- Identify **how** the good/services will satisfy customer wants
- Relate customer **wants** to product **how**
- Identify relationships between the firm's **how** and the customer's **how**
- Develop importance rating
- Evaluate competing products

The structure of QFD can be thought of as a framework of a house, as shown in the figure below



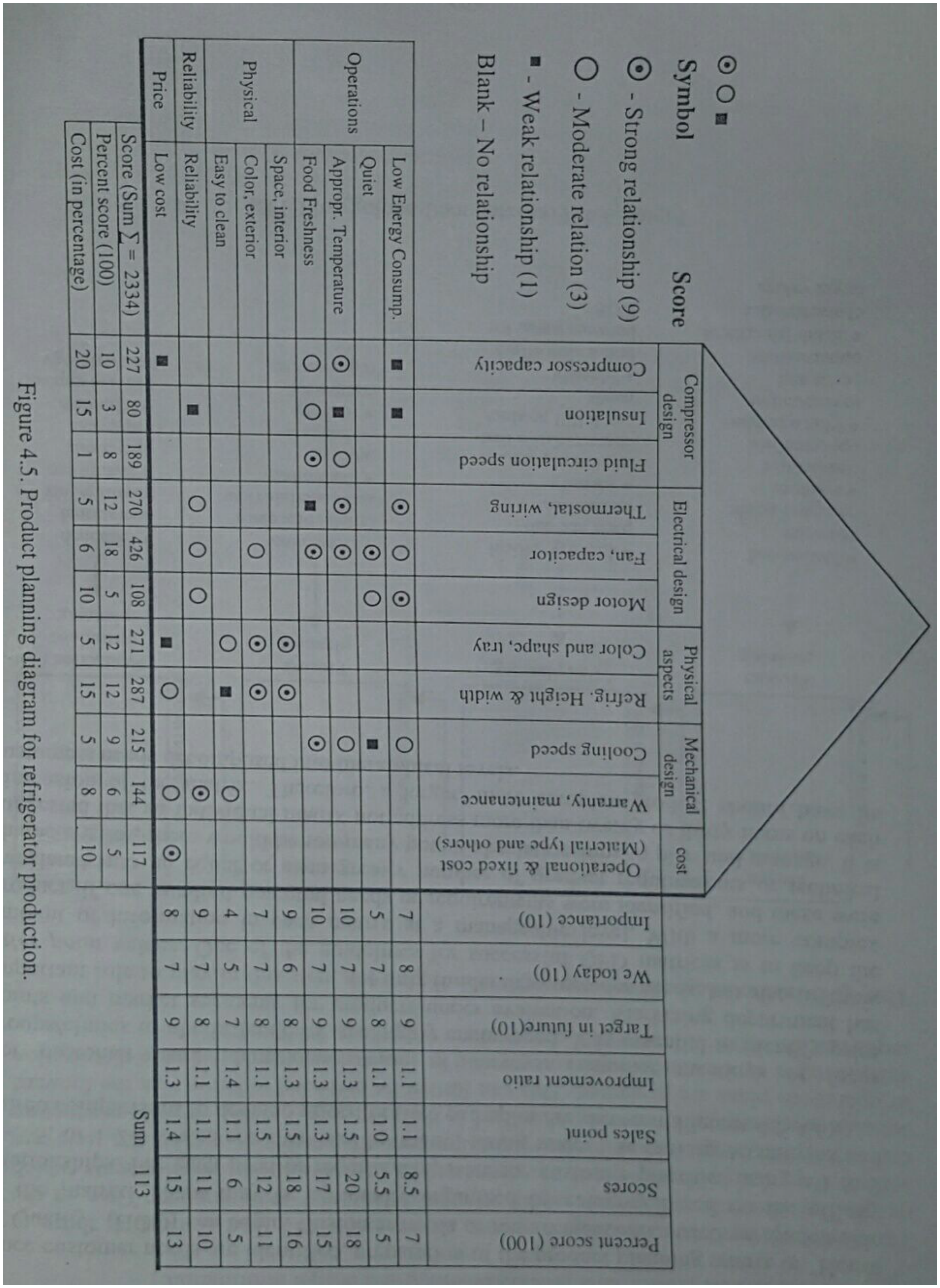
1. **Customer requirements** -the voice of customer in their own words
2. **Planning matrix**

- Customer satisfaction-existing products fulfilling specified requirements.
- Improvement ratio = (existing rating-planned rating)/highest rating+l
- Sales point-weight for marketability
- Overall weighting=improvement factor* sales point*customer importance

3. **Technical requirement** - engineering characteristics, voice of the company

4. **Interrelationships** -between customer requirements and technical requirements

5. **S. Roof –** consider impact of technical requirements on each other



		Compressor design			Electrical design			Physical aspects		Mechanical design		cost							
		Compressor capacity	Insulation	Fluid circulation speed	Thermostat, wiring	Fan, capacitor	Motor design	Color and shape, tray	Refrig. Height & width	Cooling speed	Warranty, maintenance	Operational & fixed cost (Material type and others)	Importance (10)	We today (10)	Target in future(10)	Improvement ratio	Sales point	Scores	Percent score (100)
Operations	Low Energy Consump.	■	■		⊙	○	⊙			○			7	8	9	1.1	1.1	8.5	7
	Quiet					⊙	○			■			5	7	8	1.1	1.0	5.5	5
	Appropr. Temperature	⊙	■	○	⊙	⊙				○			10	7	9	1.3	1.5	20	18
	Food Freshness	○	○	⊙	■	⊙				⊙			10	7	9	1.3	1.3	17	15
Physical	Space, interior							⊙	⊙				9	6	8	1.3	1.5	18	16
	Color, exterior					○		⊙	⊙				7	7	8	1.1	1.5	12	11
	Easy to clean							○	■		○		4	5	7	1.4	1.1	6	5
Reliability	Reliability		■		○	○	○				⊙		9	7	8	1.1	1.1	11	10
Price	Low cost	■						■	○		○	⊙	8	7	9	1.3	1.4	15	13
	Score (Sum $\sum$ = 2334)	227	80	189	270	426	108	271	287	215	144	117					Sum	113	
	Percent score (100)	10	3	8	12	18	5	12	12	9	6	5							
	Cost (in percentage)	20	15	1	5	6	10	5	15	5	8	10							

Figure 4.5. Product planning diagram for refrigerator production.

Brief-3

<u>Functional Decomposition and Black Box</u>

Functional Decomposition

Function:

A function of a product is a statement of a clear, reproducible relationship between the available input and the desired output of a product, independent of any particular form. The product function is the overall intended function of the product.

Sub function:

A sub function is a component of a product function. An overall function has to be divided into identifiable sub functions and the overall function is often governed by a constraint or input-output relationship.

An elementary approach to developing a function description of a product is to decompose the prime function hierarchically into sub functions that, when all are fulfilled, completes the overall product function. Function trees can be developed to understand the product function. The following is an example of the functional decomposition of Ice crusher machine.

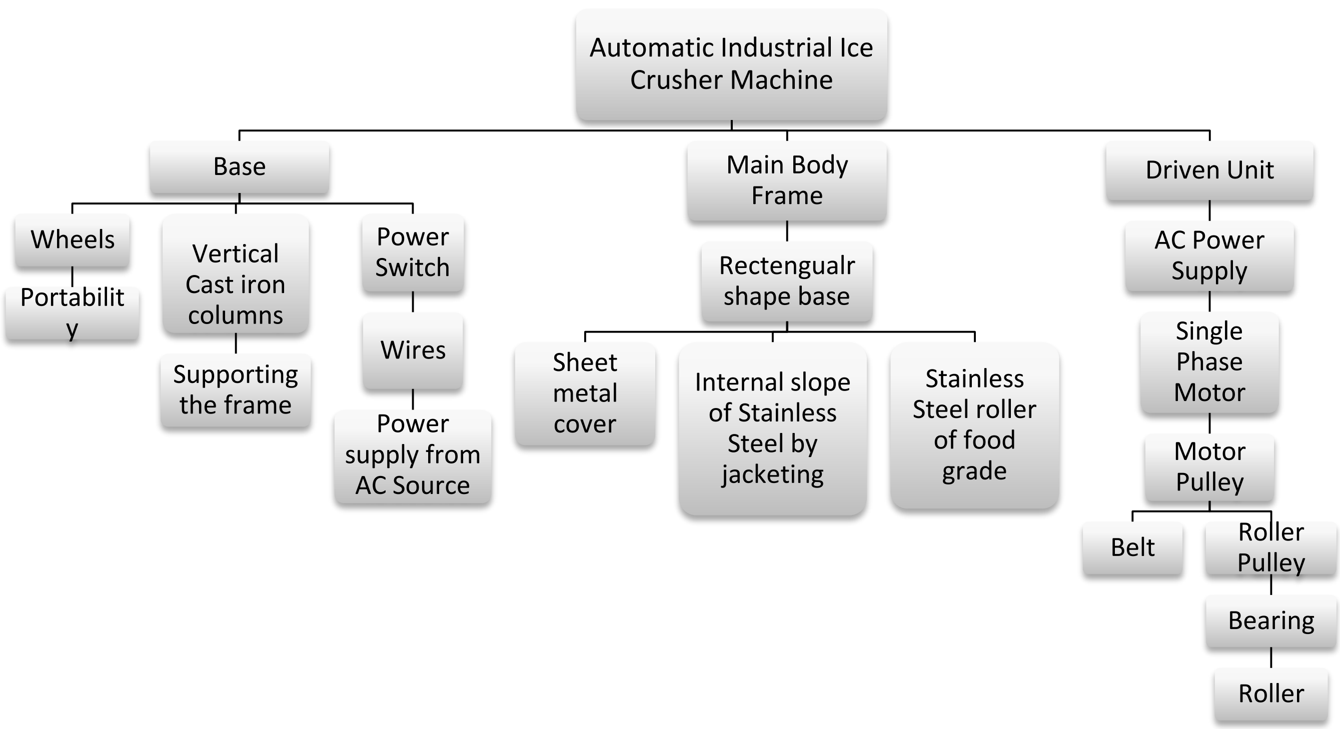
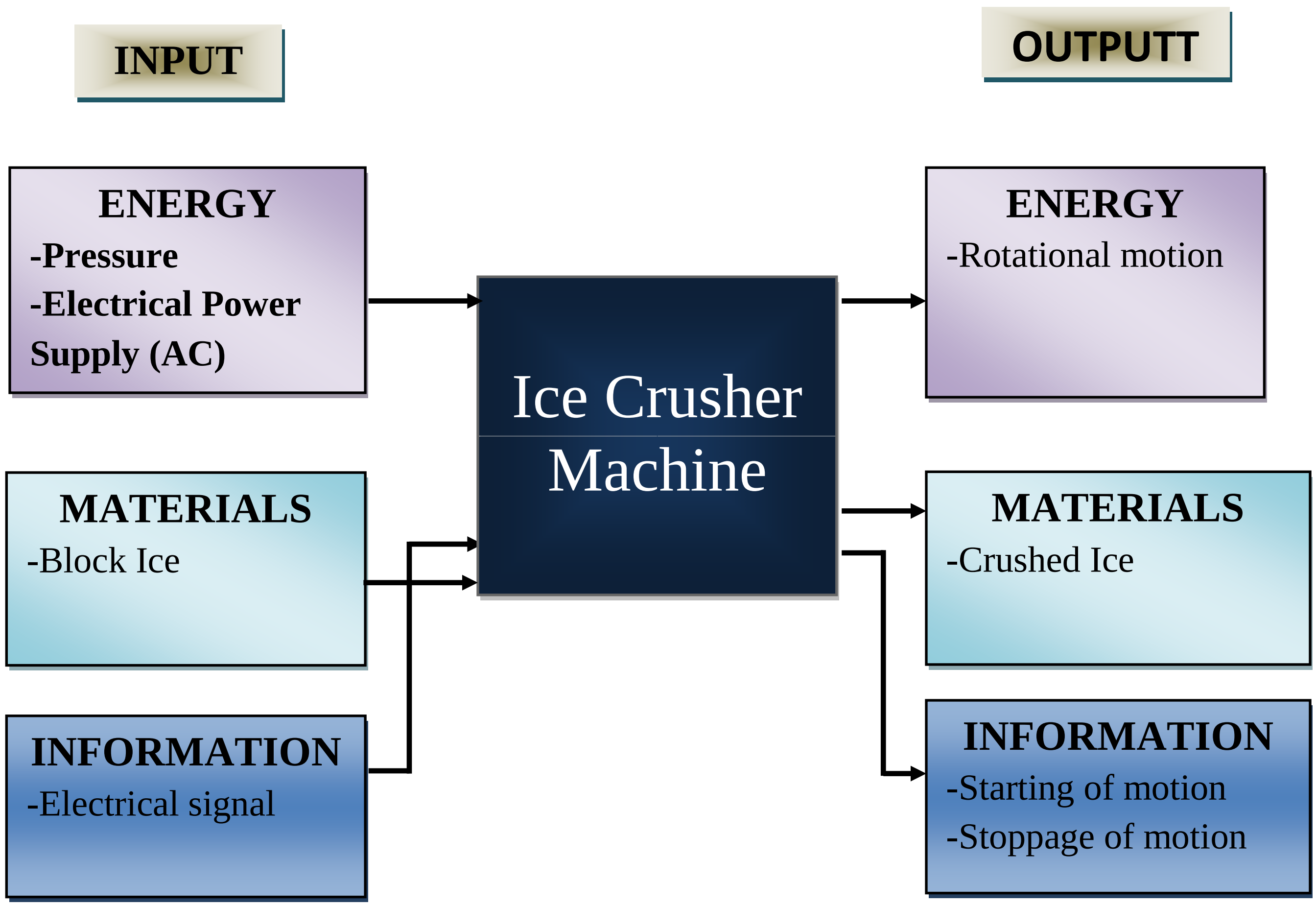


Figure 3: Functional decomposition of Automatic Industrial Ice Crusher Machine.

Black Box:

Black Box Model is a robust and complete method for modeling product's functionality. It is called "black-box" because its internal form is deemed unknown. It allows us to focus on the greatest and overall need for a product. The Black Box initiates a technical understanding of a product based on its inputs and outputs, known as material, energy and information. an example is illustrated below.



BLACK BOX MODEL OF AUTOMATIC ICE CRUSHER MACHINE

Brief -4

Product Design Analysis

Product design analysis means studying how well a product does its job. The justification of a product lies in its use, however abstract that use may be (e.g. the use of a car to boost a driver's image); the product has no right of existence in itself. In this context it is important to note that the physical appearance of a product is only one of the many possible design implementations of the set of functions it is supposed to perform.

Designers and manufacturers use product design analysis to help them develop ideas for new or improved products and to analyze the work of other designers. Quality assurance is a system of checks and inspections to ensure high standards throughout design and manufacture. The purpose of the design analysis is to define a product that performs these functions as well as possible within the constraints of cost, (development) time and performance (quality), and the design problem to be solved is how to accomplish this.

The necessary condition to be fulfilled prior to the start of the design analysis properly is to know, what the user's intended use of the product will be:

- What he wants to do with the product (so its desired functions),
- How well he wants these functions performed and why,
- Which functions are the crucial ones?

Especially the last item is of importance, as it is the source for the set of criteria to be used in taking design decisions. During the design process the design team must continuously check whether the chosen design implementation meets the requirements from the user's point of view. To be able to do this, product characteristics must be linked back to the functions the product has to perform. Also, when choosing between design alternatives the key functions, in addition to the major constraints the product has to comply with, again deliver the criteria to screen and rank the alternatives.

A list of Universal Design principles are mentioned below-

1. **Equitable Use:** The design is useful and marketable to people with diverse abilities.
2. **Flexibility in Use:** The design accommodates a wide range of individual preferences and abilities.
3. **Simple & Intuitive to use:** Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
4. **Perceptible Information:** The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

5. **Tolerance for Error**: The design minimizes hazards and the adverse consequences of accidental or unintended actions.
6. **Low Physical Effort**: The design can be used efficiently and comfortably and with a minimum of fatigue.
7. **Size and space for approach & use:**The design provides for appropriate size and space for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

The attributes of a properly designed product are mentioned below-

1. **Functionality:** The product must function properly for intended purpose.
2. **Reliability:** The product must perform properly for the designated period of time.
3. **Productivity:** The product must be produced with a required quantity and quality at a defined and feasible cost.
4. **Quality:** The product must satisfy customer's stated and unstated needs.
5. **Standardization:** The product should be designed in such a fashion so that most of the components are standardized and easily available in the market.
6. **Maintainability:** The product must perform for a designated period with a minimum and defined maintenance. Adequate provision for maintenance should be kept in the product.
7. **Cost effectiveness:** The product must be cost effective. The must be manufactured in the most cost effective environment.

Product Architecture

Product contains components (CD players have a chassis, motors, disk drive, and speaker and so on), that can be combined into chunks (the base, the disk handling system, the recording system, and the sound producing system). A product is also composed of functional elements (for a CD player, these might include reading disks, recording sound, producing sound, and adjusting sound quality). The product architecture is how the functional elements are assigned to the chunks and how the chunks are interrelated.

Design for Manufacturing

<u>Value Analysis or engineering:</u> Simplification of products and processes. Value analysis seeks to improve the secondary function, e.g. how to open a can or make a tool box.

Terms in Value Analysis:

- Objective: Primary purpose of the product
- Basic Function: Makes the objective possible
- Secondary Function: How to perform the basic function

Modular Design: Multiple products using common parts, processes and modules.

- Allows greater variety through ‘mixing and matching’ of modules
- Develops a series of basic product components (modules) for later assembly into multiple products
- Reduces complexity and costs associated with large number of product variations
- Easy to subcontract production of modules

Design Variables & Attributes

Design Variables: Set of input variables (parameters) to the design simulation software (e.g. Motor type, Gear type, Gear ratio, DC voltage, ambient temperature)

Performance Attributes: Set of attributes that is the output of the simulation software, and identifies a product design (e.g. manufacturing cost, Weight, Time per operation per battery charge)

Design Alternative Generation

Two methods for generating design alternatives-

Multi objective Optimization

- Formulate a multiobjective optimization problem, solve for the alternatives that satisfy the objectives (performance attributes) the most.
- There is no closed form representation of the objective functions
- The design input parameters consist of both continuous and discrete variables
- Multiobjective Genetic Algorithm is a good choice to handle this type of problems
- The solution points constitute a non-dominated set w.r.t. all objective functions.

Permutation over Attributes

- Generating design alternatives by permuting the attributes over all (or certain) levels
- Mapping between the attributes and the design variables is simple(i.e. we can easily obtain the corresponding design variables, once we get the attribute levels)
- Very easy to implement but less likely to be able to handle real applications.

Brief-5

Alternative Material and Manufacturing Selection Process

It is estimated that there are more than 40,000 currently useful metallic alloys and probably close to that number of nonmetallic engineering materials such as plastics, ceramics and glasses, composite materials, and semiconductors. This large number of materials and the many manufacturing processes available to the engineer, coupled with the complex relationships between the different selection parameters, often make the selection of a materials for a given component a difficult task. If the selection process is carried out haphazardly, there will be the risk of overlooking a possible attractive alternative material. This risk can be reduced by adopting a systematic material selection procedure.

A variety of quantitative selection procedures have been developed to analyze the large amount of data involved in the selection process so that a systematic evaluation can be made. Several of the quantitative procedures can be adapted to use computers in selection from a data bank of materials. The materials and process selection is often thought of in terms of new product development

Quantitative Methods

Having specified the performance requirements of the different parts, the required material properties can be established for each of them. These properties may be quantitative or qualitative, essential or desirable. The essential material properties are tensile and fatigue strengths, while the desirable properties that should be maximized are process ability, weight, reliability, and resistance to service conditions. All these properties should be achieved at a reasonable cost. The selection process involves the search for the material or materials that would best meet those requirements. The starting point for materials selection is the entire range of engineering materials.

After narrowing down the field of possible materials using one or more of the quantitative initial screening methods quantitative methods can be used to further narrow the field of possible materials and matching manufacturing processes to a few optimum candidates that have good combinations of soft requirements.

Weighted-Properties Method

In the weighted-properties method each material requirement, or property, is assigned a certain weight, depending on its importance to the performance of the part in service. A weighted-property value is obtained by multiplying the numerical value of the property by the weighting factor (α). The individual weighted-property values of each material are then summed to give a comparative materials performance index (β). Materials with the higher performance index (β) are considered more suitable for the application.

Digital Logic Method

The digital logic approach can be used as a systematic tool to determine α. In this procedure evaluations are arranged such that only two properties are considered at a time. Every possible combination of properties or goals is compared and no shades of choice are required, only a yes or no decision for each evaluation. To determine the relative importance of each property or goal a table is constructed, the properties or goals are listed in the left-hand column, and comparisons are made in the columns to the right, as shown in Table 1. In comparing two properties or goals, the more important goal is given numerical one (1) and the less important is given zero (0). The total number of possible decisions $N = n (n - 1)/2$, where n is the number of properties or goals under consideration. A relative emphasis coefficient or weighting factor, α, for each goal is obtained by dividing the number of positive decisions for each goal (m) into the total number of possible decisions (N). In this case $\sum \alpha = 1$.

Table 1 Determination of Relative Importance of Goals Using Digital Logic Method

Goals	Number of Positive Decisions $N = n(n - 1)/2$										Positive Decisions	Relative Emphasis Coefficient α
	1	2	3	4	5	6	7	8	9	10		
1	1	1	0	1							3	0.3
2	0				1	0	1				2	0.2
3		0			0			1	0		1	0.1
4			1			1		0		0	2	0.2
5				0			0		1	1	2	0.2
Total number of positive decisions											10	$\Sigma\alpha = 1.0$

Performance Index

The property with higher numerical value will have more influence than is warranted by its weighting factor. This drawback is overcome by introducing scaling factors. Each property is so scaled that its highest numerical value does not exceed 100. When evaluating a list of candidate materials, one property is considered at a time. The best value in the list is rated as 100 and the others are scaled proportionally. Introducing a scaling factor facilitates the conversion of normal material property values to scaled dimensionless values. For a given property, the scaled value, B, for a given candidate material is equal to:

$$B = \text{Scaled property} = \frac{\text{Numerical value of prperty} \times 100}{\text{Maximum value in the list}}$$

For properties such as cost, corrosion or wear loss, weight gain in oxidation, etc., a lower value is more desirable. In such cases, the lowest value is rated as 100 and *B* is calculated as:

$$B = \text{Scaled property} = \frac{\text{Minimum value in the list} \times 100}{\text{Numerical value of property}}$$

For material properties that can be represented by numerical values, application of the above procedure is simple. However, with properties such as corrosion and wear resistance, machinability and weldability, etc. numerical values are rarely given and materials are usually rated as very good, good, fair, poor, etc.In such cases, the rating can be converted to numerical values using an arbitrary scale. For example, corrosion resistance rating—excellent, very good, good, fair, and poor—can be given numerical values of 5, 4, 3, 2, and 1, respectively. After scaling the different properties, the material performance index (γ) can be calculated as:

$$\text{Material performance index} = \gamma = \sum_{i=1}^{n} B_i\alpha_i$$

where *i*is summed over all the *n* relevant properties.

CASE STUDY IN MATERIAL SELECTION

The objective is to select the least expensive component that satisfies the requirements for a simple structural component for cryogenic storage tank.

Materials requirements

- used in cryogenic applications for liquefied nitrogen gas) must not suffer ductile-brittle transition at -196° C
- Using stronger material gives thinner walls, which means a lighter tank, lower cool down losses, and easier to weld
- Lower specific gravity gives lighter tank
- Lower specific heat reduces cool down losses
- Lower thermal expansion coefficient reduces thermal stress
- Lower thermal conductivity reduces heat losses
- The cost of material and processing

Table 2: **Digital logic method to cryogenic tank problem**

Property	Decision number																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Toughness	1	1	1	1	1	1															
Yield strength	0						1	0	0	1	1										
Young's modulus		0					0					0	0	0	1						
Density			0					1				1				1	1	1			
Expansion				0					1				1			0			1	1	
Conductivity					0					0				1			0		0		0
Specific heat						0					0				0			0		0	1

Table 3 **Weighting factors for cryogenic tank**

Property	Positive decisions	Weighting factor
Toughness	6	0.28
Yield strength	3	0.14
Young's modulus	1	0.05
Density	5	0.24
Expansion	4	0.19
Conductivity	1	0.05
Specific heat	1	0.05
Total	21	1.00

Table 4 Properties of candidate materials for cryogenic tank

Material	1 Toughness index [a]	2 Yield strength (MPa)	3 Young's modulus (GPa)	4 Specific gravity	5 Thermal expansion [b]	6 Thermal conductivity [c]	7 Specific heat [d]
Al 2014-T6	75.5	420	74.2	2.8	21.4	0.37	0.16
Al 5052-O	95	91	70	2.68	22.1	0.33	0.16
SS 301-FH	770	1365	189	7.9	16.9	0.04	0.08
SS 310-3/4H	187	1120	210	7.9	14.4	0.03	0.08
Ti-6Al-4V	179	875	112	4.43	9.4	0.016	0.09
Inconel 718	239	1190	217	8.51	11.5	0.31	0.07
70Cu-30Zn	273	200	112	8.53	19.9	0.29	0.06

Table 5 Scaled values of properties and performance index

Material	Scaled properties							Performance index (γ)
	1	2	3	4	5	6	7	
Al 2014-T6	10	30	34	96	44	4.3	38	42.2
Al 5052-O	12	6	32	100	43	4.8	38	40.1
SS 301-FH	100	100	87	34	56	40	75	70.9
SS 310-3/4H	24	82	97	34	65	53	75	50.0
Ti-6Al-4V	23	64	52	60	100	100	67	59.8
Inconel 718	31	87	100	30	82	5.2	86	53.3
70Cu-30Zn	35	15	52	30	47	5.5	100	35.9

From the above calculations the value of performance index has shown we can choose SS 301-FH for cryogenic tank.

Brief-6
<u>Stress Analysis</u>

As the manufacturing and engineering industry tend to become more complex and challenging, the importance of stress analysis in product and systems development is experienced better than ever.

Across manufacturing, biomedical, automotive, chemicals, aerospace, electronics, energy, and Geo-technical industries, analysis and prediction of potential stress and fatigue in the product are often performed as the last step of more complex multi-disciplinary analysis of electromechanical devices. It helps in determining the response of a structure, product or system on application of load. It is critical in evaluating structural analysis based on assessing fatigue and failure analysis process.

What is Stress Analysis?

Stress analysis is the process of comprehensive industrial testing based on the calculations of mechanical strain, stress, and related deformations on application of load. It is an advanced computational method of applying load on a structure to determine its response.

The analysis method is used for counter evaluating the effectiveness of FEA structural analysis based on the report for fatigue and stress assessment and failure analysis. The calculations can be used in determining the stress and fatigue level of different industrial structures, aircraft and aerospace, sub-sea components, rail, marine components, and nuclear structures and components.

Key Features of Stress Analysis

Stress analyzing modules come with different features that are of key benefit to engineering and manufacturing companies. However, some of the most important features include:

- Plane stress and strain
- Anisotropic stretch properties
- Electric and magnetic forces
- Thermal stresses
- Rigorous and dispersed loading

Stress Analysis example:

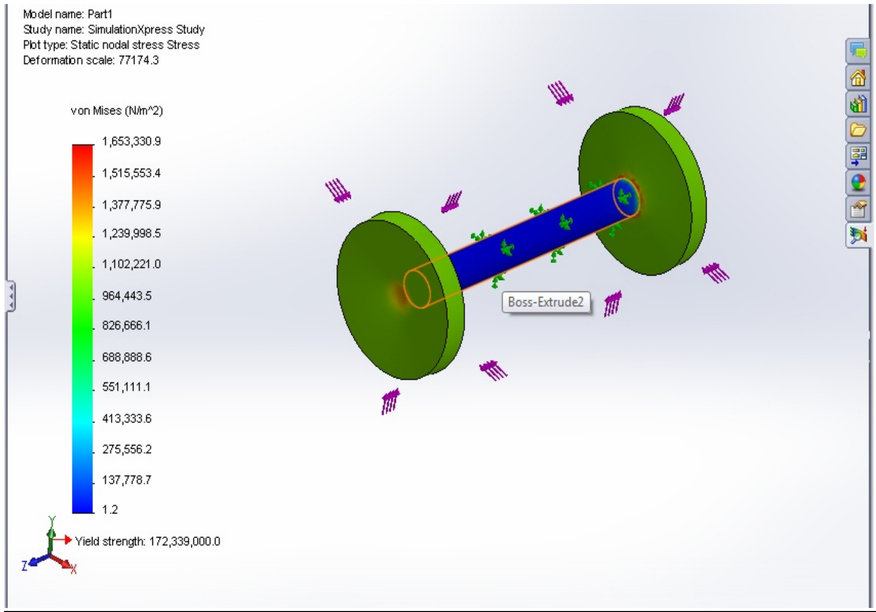


Figure 1: Static Stress Analysis for a Roller

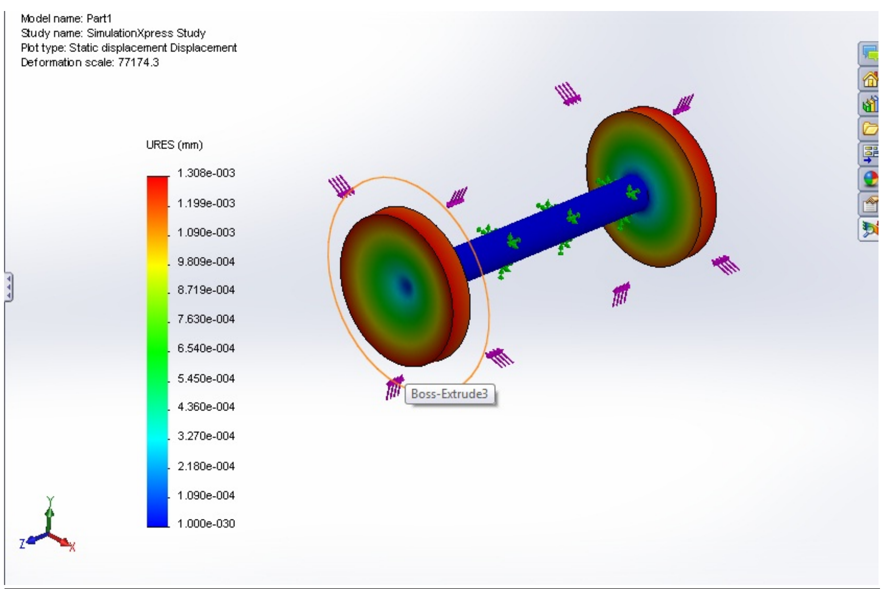


Figure -2: Static Displacement Analysis for a Roller

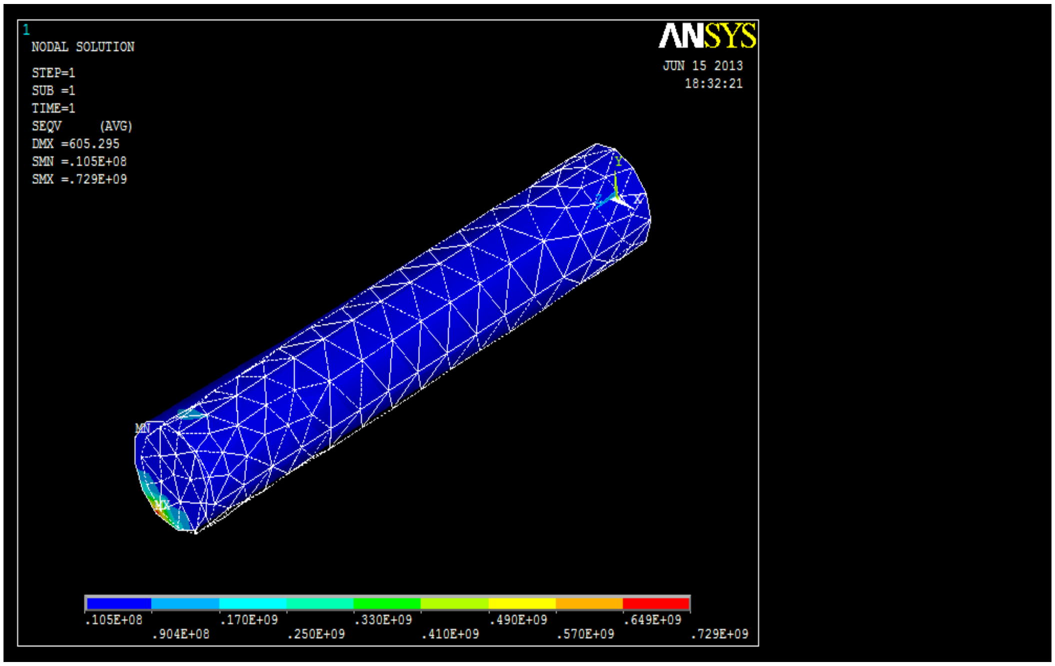


Figure -3: Nodal Solution for stress analysis of a motor Shaft

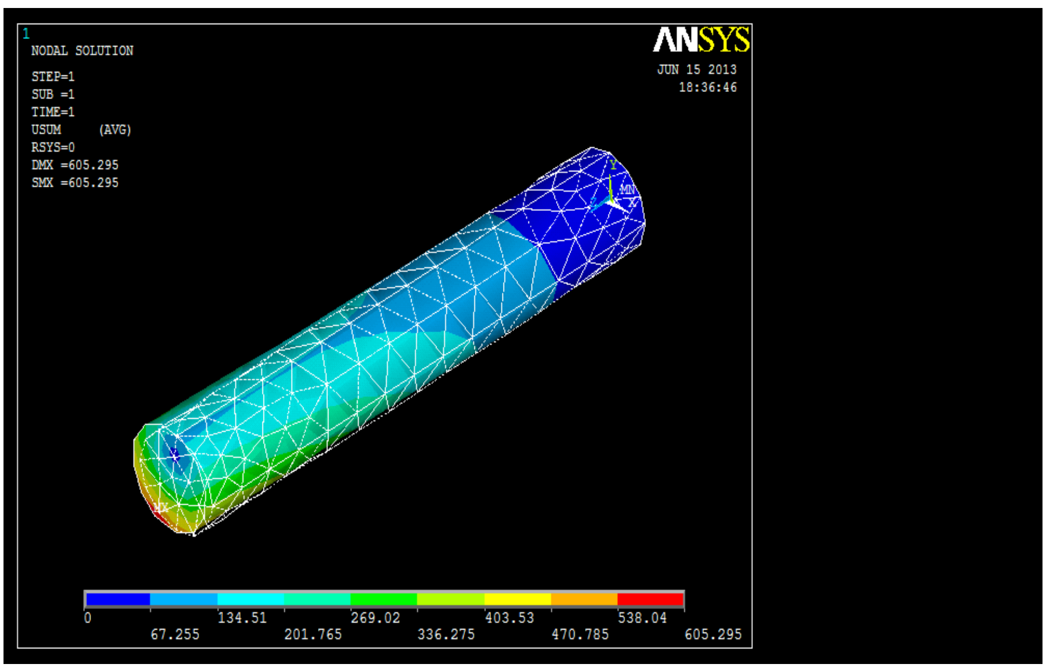


Figure -4: Nodal Solution for Displacement Analysis of a motor Shaft

PRNSOL Command

File

PRINT S NODAL SOLUTION PER NODE

***** POST1 NODAL STRESS LISTING *****
PowerGraphics Is Currently Enabled

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0
NODAL RESULTS ARE FOR MATERIAL 1

NODE	S1	S2	S3	SINT	SEQV
1	0.55116E+08	0.58021E+07	-0.35734E+08	0.90850E+08	0.78775E+08
2	0.46245E+08	-0.27993E+06	-0.46526E+08	0.92771E+08	0.80342E+08
4	0.53465E+08	0.48825E+07	-0.37608E+08	0.91073E+08	0.78930E+08
6	0.50495E+08	0.21217E+07	-0.41317E+08	0.91812E+08	0.79553E+08
8	0.35748E+08	-0.49749E+07	-0.54891E+08	0.90639E+08	0.78632E+08
10	0.41346E+08	-0.20357E+07	-0.50262E+08	0.91608E+08	0.79375E+08
12	0.37550E+08	-0.50746E+07	-0.54344E+08	0.91893E+08	0.79652E+08
14	0.43559E+08	21750.	-0.43570E+08	0.87128E+08	0.75455E+08
16	0.35908E+08	-0.49033E+07	-0.52277E+08	0.88185E+08	0.76441E+08
18	0.39176E+08	-0.22733E+07	-0.47880E+08	0.87056E+08	0.75421E+08
21	0.48090E+08	0.22571E+07	-0.39243E+08	0.87333E+08	0.75664E+08
23	0.52376E+08	0.47746E+07	-0.35769E+08	0.88145E+08	0.76417E+08
55	0.32815E+08	0.28848E+07	-0.23219E+08	0.56033E+08	0.48564E+08
56	0.18265E+08	0.19442E+06	-0.17699E+08	0.35964E+08	0.31146E+08
57	0.20134E+08	-0.21893E+07	-0.27484E+08	0.47618E+08	0.41265E+08
58	0.21439E+08	-0.24581E+07	-0.29634E+08	0.51072E+08	0.44260E+08
59	0.23955E+08	-0.21785E+06	-0.24664E+08	0.48619E+08	0.42105E+08
60	0.19662E+08	0.13955E+07	-0.15021E+08	0.34683E+08	0.30051E+08
61	0.55682E+07	-0.59918E+06	-0.75654E+07	0.13134E+08	0.11381E+08
62	0.10357E+08	0.12102E+07	-0.40949E+07	0.14452E+08	0.12684E+08
63	0.24565E+08	-0.14255E+08	-0.38748E+08	0.63313E+08	0.55328E+08
65	0.19007E+07	-27573.	-0.10617E+08	0.12517E+08	0.11708E+08
67	-0.72543E+06	-0.16698E+07	-0.30371E+08	0.29646E+08	0.29186E+08
69	0.86704E+07	0.27707E+07	-0.48567E+07	0.13527E+08	0.11763E+08
71	0.31485E+08	-0.12469E+08	-0.40883E+08	0.72368E+08	0.63152E+08
73	0.21763E+08	0.18828E+07	-0.12891E+07	0.23052E+08	0.21641E+08
75	0.38989E+09	0.78807E+07	-0.38416E+09	0.77405E+09	0.67053E+09
77	0.46123E+07	0.19645E+06	-0.36187E+08	0.40799E+08	0.38781E+08
79	0.26370E+08	-0.23539E+07	-0.23101E+09	0.25738E+09	0.24432E+09
82	0.22990E+09	-0.15627E+07	-0.11291E+08	0.24119E+09	0.23654E+09
84	0.40269E+08	-0.16017E+07	-0.26727E+07	0.42942E+08	0.42418E+08

Figure -5: List of result For Stress Analysis of a motor shaft

The Process of Stress Analysis

Analysis of stress within a structure encompasses determining the capability across all the points of the structure on application of load. The stress and fatigue rate is determined on a scale of 9-stress components to give a comprehensive view of the structure's performance and response in the face of the load. It helps in determining the purpose of interior allocation of stress within a structure.

The process of stress analysis includes the following stages:

- Building a part or structure to serve the function but at the same time, with reduced material usage and minimal cost
- Determining and setting the nature of the loads that can act on a structure, which includes density, tension, torsion, winding, trim, or amalgamation of these loads.
- When force is continuously applied to the structure, it tends to fail or get ruptured over time; more so due to lack of stable load condition. Stress analysis determines the level of stress under such cyclic load conditions

- To make sure that a particular part can efficiently work without breaking under force, it is tested based on the level of stress that it can take

Benefits of Stress Analysis Services

The key benefits of stress analysis services to engineering and manufacturing industries are underlined below:

- Facilitates accurate and reliable calculation of strain, distribution of load, and deflection
- Vast domain expertise in structure and thermal stress
- Leverage the power of efficient FEA solutions for product designing and development
- Minimum errors and loopholes, which ensures no product failure
- Cost-effective solutions

Brief-7

<u>Cost Analysis</u>

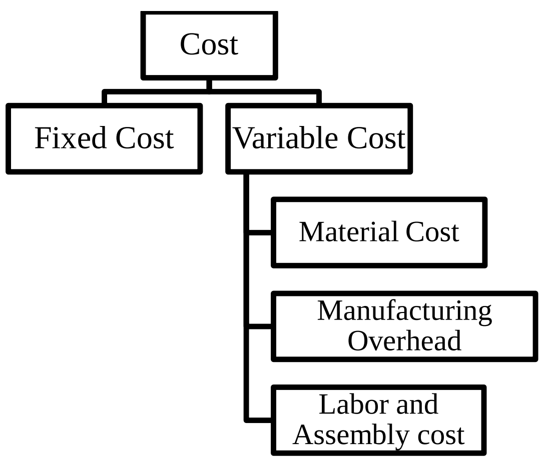
Cost analysis is a detailed outline of the potential risks and gains of a projected venture. The accumulation, examination, and manipulation of cost data for comparisons and projection are called cost analysis.

Cost estimate is the approximation of the cost of a program, project, or operation. The cost estimate is the product of the cost estimating process. The cost estimate has a single total value and may have identifiable component values.

Project underestimation of resources and costs is one of the most common contributors to project failure. Project teams should estimate costs for all resources that will be charged to the project. This includes but is not limited to

- Labor
- Materials
- Equipment
- Services
- Facilities
- Software etc.

Cost Analysis hierarchy for mass production



Fixed Cost

Fixed costs are costs that are independent of output. These remain constant throughout the relevant range and are usually considered sunk for the relevant range (not relevant to output decisions). Fixed costs often include rent, buildings, machinery, etc.

Variable Cost

Variable costs are costs that vary with output. Generally variable costs increase at a constant rate relative to labor and capital. Variable costs may include wages, utilities, materials used in production, etc.

Break Even Analysis

The main objective of break-even analysis is to find the cut-off production volume from where a firm will make profit. Let

s = selling price per unit
v = variable cost per unit
FC = fixed cost per period
Q= volume of production
The total sales revenue (*S*) of the firm is given by the following formula:
$S = s \times Q$
Total Cost= Total variable cost + Fixed cost = $v \times Q + FC$

The linear plots of the above two equations are shown in Fig. 1.

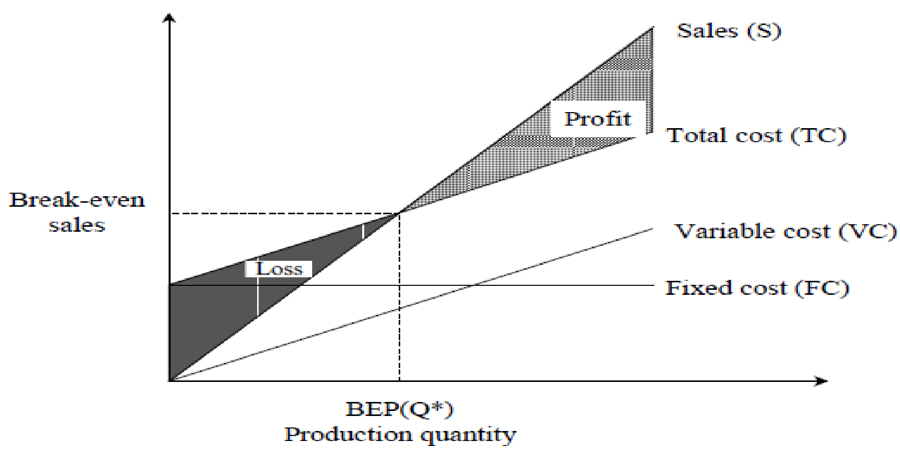


Fig. 1: Break-even chart.

The intersection point of the total sales revenue line and the total cost line is called the break-even point. The corresponding volume of production on the *X*-axis is known as the break-even sales quantity. At the intersection point, the total cost is equal to the total revenue. This point is also called the no-loss or no-gain situation. For any production quantity which is less than the break-even quantity, the total cost is more than the total revenue. Hence, the firm will be making loss.

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

3rd Year, 1st Semester

Student Name :

Student ID :

Experiment No. 1

STUDY OF BERNOULLI'S THEOREM

General

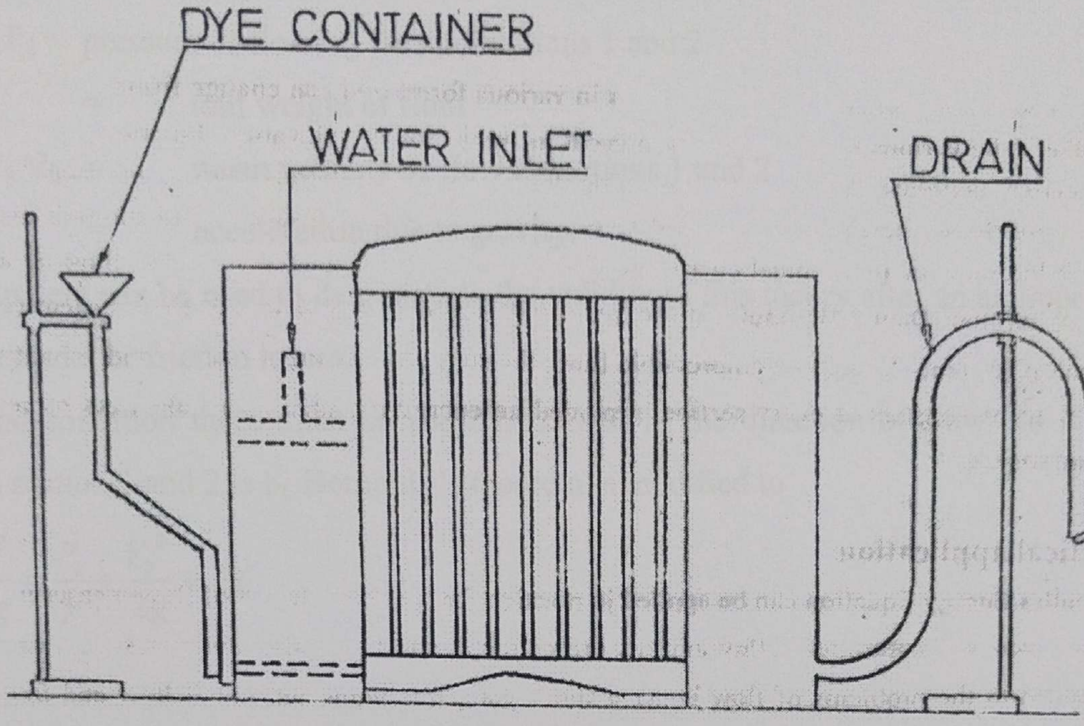
Energy is the ability to do work. It manifests in various forms and can change from one form to another. This various forms of energy present in fluid flow are elevation, kinetic, pressure and internal energies. Internal energies are due to molecular agitation and manifested by temperature. Heat energy may be added to or subtracted from a flowing fluid through the walls of the tube or mechanical energy may be added to or subtracted from the fluid by a pump or turbine. Daniel Bernoulli in the year 1738 stated that in a steady flow system of frictionless (or non-viscous) incompressible fluid, the sum of pressure, elevation and velocity heads remains constant at every section, provided no energy is added to or taken out by an external source.

Practical application

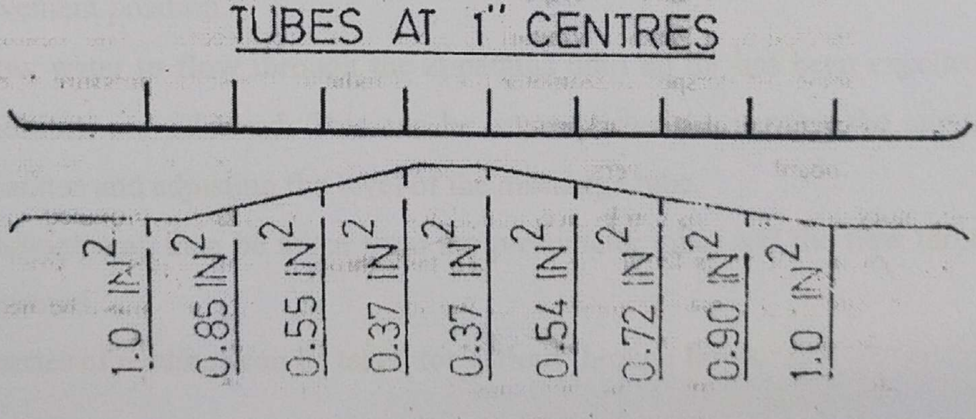
Bernoulli's Energy Equation can be applied in practice for the construction of flow measuring devices such as venturimeter, flow nozzle, orifice meter and Pitot tube. Furthermore, it can be applied to the problems of flow under a sluice gate, free liquid jet, radial flow and free vortex motion. It can also be applied to real incompressible fluids with good results in situations where frictional check is very small.

Description of apparatus

The unit is constructed as a single Perspex fabrication. It consists of two cylindrical reservoirs inter-connected by a Perspex Venturi of rectangular cross-section. The Venturi is provided with a number of Perspex piezometer tubes to indicate the static pressure at each cross-section. An engraved plastic backboard is fitted which is calibrated in British and Metric units. This board can be reversed and mounted on either side of the unit so that various laboratory configurations can be accommodated. The inlet vessel is provided with a dye injection system. Water is fed to the upstream tank through a radial diffuser from the laboratory main supply. For satisfactory results, the main water pressure must be nearly constant. After flowing through the venture, water is discharged through a flow-regulating device. The rate of flow through the unit may be detrimental either volumetrically or gravimetrically. The equipment for this purpose is excluded from the manufacturer's supply. The apparatus has been made so that the direction of flow through the venture can be reversed for demonstration purpose. To do this the positions of the dye injector and discharge fitting have to be interchanged.



SKETCH OF APPARATUS



VENTURI DETAILS

Governing Equation

Assuming frictionless flow, Bernoulli's Theorem states that, for a horizontal conduit

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}=\frac{P_3}{\gamma}+\frac{V_3^2}{2g}=\text{............}$$

where, $P_1 P_2$ = pressure of flowing fluid at sections 1 and 2

γ = unit weight of fluid

V_1, V_2 = mean velocity of flow at sections 1 and 2

g = acceleration due to gravity.

The equipment can be used to demonstrate the validity of this theory after an appropriate allowance has been made for friction losses.

For actual condition there must be some head loss in the direction of flow. So if the head loss between section 1 and 2 is h_L Bernoulli's theorem is modified to

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}+h_L$$

Procedure

1. The apparatus should be recurrently leveled by means of screws provided at the base.
2. Connect the water supply to the radial diffuser in the upstream tank.
3. Adjust the level of the discharge pipe by means of the stand and clamp provided to a convenient position.
4. Allow water to flow through the apparatus until all air has been expelled and steady flow conditions are achieved. This can be accomplished by varying the rate of inflow into the apparatus and adjusting the level of the discharge tube.
5. Readings may then be taken from the piezometer tubes and the flow through the apparatus measured.
6. A series of readings can be taken for various through flows.

Objective

1. To calculate the total head loss $h_L = h_I - h_{11}$
2. To plot the static head, velocity head and total head against the length of the passage in one plain graph paper.
3. Verification of total head loss by plotting head loss in each passage or segment.
4. To plot the total head loss h_L, against the inlet kinematics head, $V^2/2g$, for different in- flow conditions in plain graph paper.

Practice Question

1. What are the assumptions underlying the Bernoulli's energy equation?
2. Do you need any modification (s) of Eqn (1) when (a) the frictional head loss is to be considered, and (b) the conduit is not horizontal?

Experiment No. 1

STUDY OF BERNOULLI'S THEOREM

Experimental Data Sheet

Course no.: **Student ID no.:**

Group no.: **Date:**

Cross-sectional area of the measuring tank = ____________________

Initial point gage reading = ____________________

Final point gage reading = ____________________

Collection time = ____________________

Volume of water = ____________________

Discharge Q = ____________________

Piezometer tube no.	1	2	3	4	5	6	7	8	9	10	11
A											
V=Q/A											
$V^2/(2g)$											
p/γ											
$h=p/\gamma + v^2/(2g)$											

Head loss in each segment	0	$h_{1-2} = h_2 - h_1$	h_{2-3}	h_{3-4}	h_{4-5}	h_{5-6}	h_{6-7}	h_{7-8}	h_{8-9}	h_{9-10}	h_{10-11}
h_L	0										

Gr. NO	1	2	3	3	5
$V_1^2/2g$					
h_L					

Signature of the teacher

Experiment No. 2

FLOW THROUGH VENTURIMETER

General

The converging tube is an efficient device for converting pressure head to velocity head, while the diverging tube converts velocity head to pressure head. The two many be combined to form venture tube. As there is a definite relation between the pressure differential and the rate of flow. The tube may be made to serve as metering device.

Venturi meter consists of a tube with a constricted throat that produces an increased velocity accompanied by a reduction in pressure followed by a gradual diverging portion in which velocity is transformed back info pressure with slight frictions loss.

Practical application

The venturimeter is used for measuring the rate of flow of both compressible and incompressible fluids.

The venturimeter provides an accurate means for measuring flow in pipelines. Aside from the installation cost, the only disadvantage of the venturi meter is that in introduces a permanent frictional resistance in the pipelines.

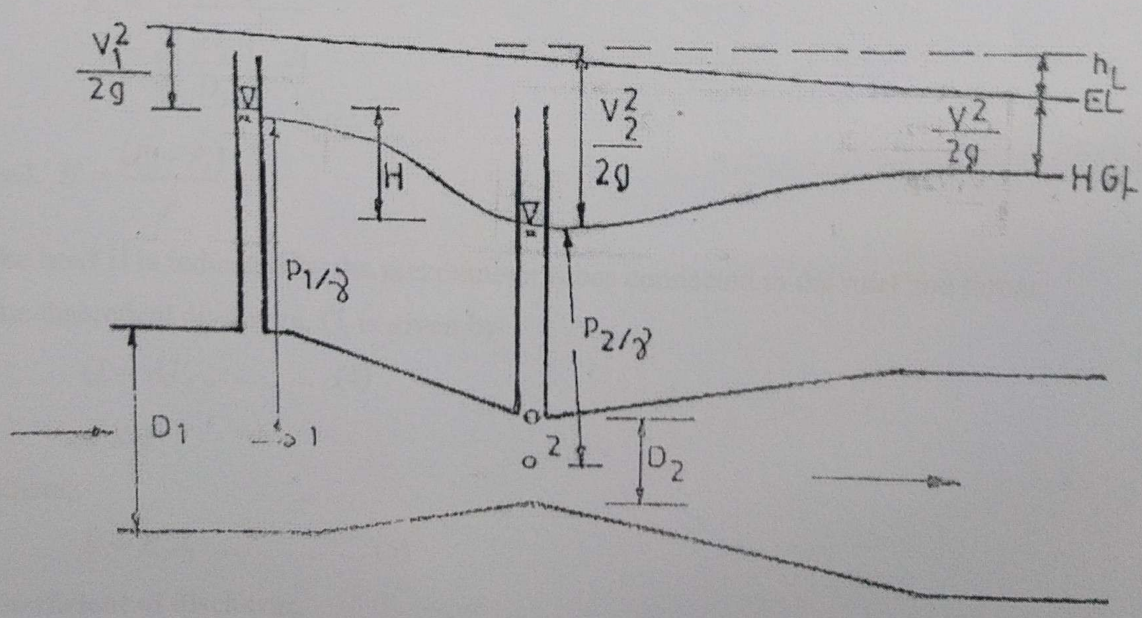


Fig. 1 Flow through a Venturimeter

Theory

Consider the Venturimeter shown in the above figure. Applying the Bernoulli's equation between Point 1 at the inlet and point 2 at the throat, we obtain.

$$\frac{P_1}{\gamma}+\frac{V_1^2}{2g}=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}\text{........(1)}$$

Where P_1 and V_1 are the pressure and velocity at point 1, P_2 and V_2 are the corresponding quantities at point 2, γ is the specific weight of the fluid and g is the acceleration due to gravity from continuity equation, we have.

$$A_1V_1 = A_2V_2\text{...........(2)}$$

Where, A_1 and A_1 re the cross sectional areas of the inlet and throat respectively since

$$A_1=\frac{\pi}{4}D_1^2, A_2=\frac{\pi}{4}D_2^2$$

From Equations (1) and (2), we have

$$V_1=\sqrt{\frac{2g}{\left(\frac{D_1}{D_2}\right)^4-1}\frac{(P_1-P_2)}{\gamma}}$$

$$= K_1H^{1/2}\text{.............(3)}$$

Where,

$$K_1=\sqrt{\frac{2g}{\left(\frac{D_1}{D_2}\right)^4-1}}$$

And, $H=\frac{(P_1-P_2)}{\gamma}$

The head H is indicated by the piezonmeter tubes connected to the inlet and throat.

The theoretical discharge, Q_t is given by

$$Q_t = A_1V_1\text{........... (4)}$$

$$= KH^{1/2}$$

Where,

$$K = K_1A_1\text{................ (5)}$$

Coefficient of discharge

Theoretical discharge is calculated from theoretical formula neglecting loses, friction losses. For this season we introduce a coefficient named coefficient of discharge which is the ration of actual discharge to theoretical discharge.

Now, if C_d is the coefficient of discharge (also known as the meter coefficient) and Q_a is the actual discharge then,

$$C_d = \frac{Q_a}{Q_t}$$

$$Q_a = C_d Q_t$$

$$= C_d K H^{1/2}$$

$$= CH^n \text{ .... (6)}$$

The value of Cd may be assumed to be about 0.99 for large meter and about 0.97 or 0.98 for small ones provided the flow is such as to give reasonably high Reynolds number.

Calibration

One of the objectives of the experiment is to find the values of C and n for a particular meter so that in future we can measure actual discharge only by measuring H. Here C and n are called calibration parameters.
For five sets of actual discharge and H data we plot Q_a vs. H in log-log paper and draw a best –fit straight line.

The Equation of line

$\log Q_a = \log CH^n$

$\log Q_a = \log C + n \log H$

Now from the plotting we take two points on the straight line say (H_1, Q_{a1}) and (H_2, Q_{a2})
So from the equation (3) we get

$\log Q_{a1} = \log C + n \log H_1$

$\log Q_{a2} = \log C + n \log H_2$

$$Solving, n = \frac{\log \frac{Q_{a1}}{Q_{a2}}}{\log \frac{H_1}{H_2}}$$

C= antilog [anti log Q_{a1}-n $\log H_1$]
So the calibration equation is $Q_a = CH^n$

Now $C = C_d K$

$C_d = C/K$

Now from the calibration equation we can calculate actual discharge for different H and plot on a plain graph paper. In practice we can use the plot to find actual discharge for any H. Thus the venturi meter is calibrated.

Objective

1. To find C_d for the Venturimenter
2. To plot Qa against H in log-log paper and to find (a) exponent of H and(b) C_d-
3. To calibrate the Venturimeter.

Practice Questions

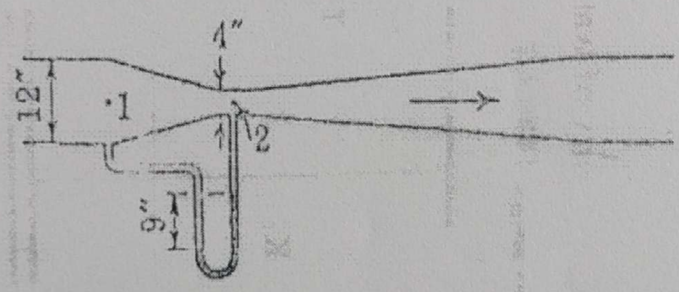
1. Why is the diverging angle smaller than the converging angle for a venturimeter?

2. How can the accuracy of venturimeter be increased in use?

3. On what factors does the meter co-efficient depend?

4. What is cavitations? Discuss its effect on flow through a venturimeter. How can you avoid cavitation in a venturimcter?

5. A Venturi meter having a throat 4 in. in diameter is installed in a horizontal 12 in pipe line carrying light oil (sp gr 0.82). A mercury U tube as shown in fig 1. shows a difference in height of mercury columns of 9 in, the remainder of the tube being filled with oil. Find the rate of discharge, Q in cubic meter per second, if C_d=0.975.



Experiment No.2

FLOW THROUGH A VENTURIMETER

Experimental Data and Calculation Sheet

Course no.: **Student ID no.:** **Group no.:** **Date:**

Cross sectional area of the measuring tank, A= ____________

Pipe diameter, D_1= ____________ Area of the pipe, A_1= ____________

Throat diameter D_2= ____________ Area of the throat, A_2= ____________

Temperature of water, t= ____________ Kinematic viscosity of water v= ____________

Initial point gage reading= ____________ Final point gage reading = ____________

No of obs	Volume of water v	Collection time T	Actual Dis-charge Q_a	Piezometer reading			k_1	k	Theoretical discharge Q_t	$C_d = \frac{Q_a}{Q_t}$	$V_2 = \frac{Q_a}{A_2}$	Reynolds number R_e
				Left h_1	Right h_2	Diff. H						

roup No					
Actual discharge Qa					
Head difference H					
Coefficient of discharge					
Reynolds number					

Signature of the Teacher

Experiment No. 6
FLOW THROUGH AN ORIFICE

General

An orifice is an opening in the wall of a tank or in a plate normal to the axis of a pipe, the plate being either at the end of pipe or in some intermediate location. An orifice is characterized by the fact that the thickness of the wall or plate is very small relative to the size of the opening. For a standard orifice there is only a line contact with fluid.

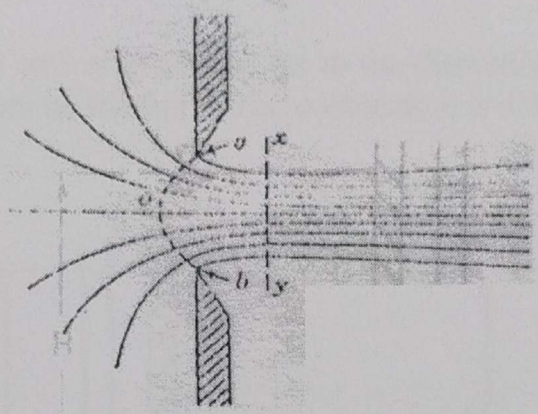


Fig 1 Jet contraction

Where the streamlines converge in approaching an orifice, they continue to converge beyond the upstream section of the orifice until they reach the section xy where they become parallel. Commonly this section is about $0.5D_0$ from the upstream edge of the opening, where D_o is diameter of the orifice. The section xy is then a section of minimum area and is called the vena contracta. Beyond the vena contracta the streamlines commonly diverge because of frictional effects.

Practical application

The usual purpose of an orifice is the measurement or control of flow from a reservoir. The orifice is frequently encountered in engineering practice operating under a static head where it is usually not used for metering but rather as a special feature in a hydraulic design. Another problem of orifice flow, which frequently arises in engineering practice, is that of discharge from an orifice under falling head, a problem of unsteady flow.

Theory

Coefficient of contraction:

The ratio of the area of a jet at the vena contracta to the area of the orifice is called the coefficient of contraction.

Coefficient of velocity:

The velocity that would be attained in the jet if the friction did not exist may be termed the theoretical velocity. The ratio of actual to the theoretical velocity is called coefficient of velocity.

Coefficient of discharge:

The ratio of the actual rate of discharge Qa to the theoretical rate of discharge Q (the flow that would occur if there were no friction and no contraction) is defined as the coefficient of discharge.

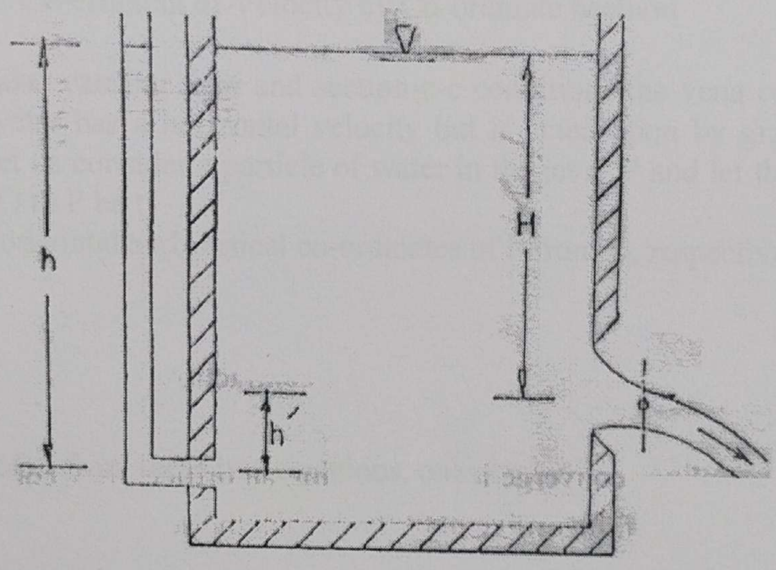


Fig. 2 Flow Through an orifice

Consider a small orifice having a cross–sectional area A and discharging water under a constant head H as shown in the above figure. Applying Bernoulli's theorem between the water surface

$$H = 0 + v^2/2g$$

so, $V_t = \sqrt{2gH}$

where g is the acceleration due to gravity. Let Q_a be the actual discharge.

So theoretical discharge Qt is given by

$Q_1 = A\sqrt{2gH}$

Then the coefficient of discharge, C_d is given by

$$C_d = \frac{Q_a}{Q_t}$$

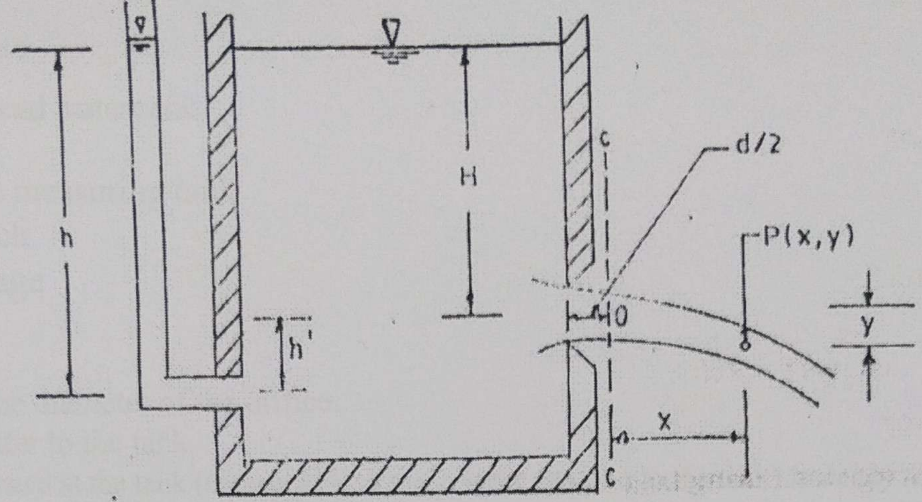


Fig 3: Co-efficient of Velocity by Co-ordinate Method

Let H be the total head causing flow and section-c-c conditions the vena contract as shown in the figure. The jet of water has a horizontal velocity but is acted upon by gravity with a downward acceleration of g. Let us consider a particle of water in the jet at P and let the time taken for this to move particle from O to P be t.

Let x and y be the horizontal and vertical co-ordinates of P from O, respectively. Them,

$$x = V_a t$$

and

$$y = \frac{1}{2} g t^2$$

Equating the value of t^2 from these two equations, one obtains

$$\frac{x^2}{V_a^2} = \frac{2y}{g}$$

$$V_d = \sqrt{\frac{gx^2}{2y}}$$

But, the theoretical velocity, $V_t = \sqrt{2gH}$

Hence, the coefficient of velocity, C_v is given by

$$C_v = \frac{v_a}{v_t} = \sqrt{\frac{x^2}{4yH}}$$

And the head loss is given by

$$H_l = (1 - C_v^2)H$$

$$C_v = \frac{v_a}{v_t} = \frac{v_a}{\sqrt{2gH}}$$

Coefficient of contraction, C_c is defined as the area of jet at vena contracta to the area of orifice, thus,

$$C_c = \frac{A_a}{A}$$

It follows that

$$C_d = C_c x C_v$$

Apparatus
1. Constant head water tank
2. Orifice
3. Discharge measuring tank
4. Stop watch
5. Point gauge

Procedure
1. Measure the diameter of the orifice.
2. Supply water to the tank.
3. When the head at the tank (measured by a manometer attached to the tank) is steady record the reading of the manometer.
4. Measure the x and y co-ordinate of the jet from the vena contracta.
5. Measure the flow rate.
6. Repeat the procedure for different combinations of discharge.

Objective
1. To find the value of C_d for the orifice.
2. 3.To plot Q_a vs. H in log-log paper and to find the value of (a) the exponent of H an (b) C_d.
3. To find C_v for the orifice.
4. To find the head loss, H_L.
5. To plot V_a vs. H in log-log paper and to find (a) C_v and (b) the exponent of H.

Practice Questions

1. What are the coefficient of velocity, coefficient of contraction and coefficient of discharge for an orifice? On what factors do these coefficients depend? What are average values of these coefficients for a sharp-crested orifice?
2. What is a submerged orifice? What are the average values of the coefficient of velocity, coefficient of contraction and coefficient of' discharge for a submerged orifice?
3. Why is the actual discharge through an orifice less than the theoretical discharge?
4. Define vena contracta. Why does it form?
5. Will the value of C_v be different for sharp-edged and rounded orifices? Why?

Experiment No. 6

FLOW THROUGH AN ORIFICE

Observation and Calculation Sheet

Course no.: **Student ID no.:**

Group no.: **Date:**

Cross-sectional area of the measuring tank= ____________________

Diameter of the orifice, D = ____________________

Area of the orifice= ____________________

Head correction, h= ____________________

No of obs	Observed Head			Point gage reading			Collection time T	Vol. of Water V	Actual Head H=h-h'	Actual discharge Q_a	Theoretical Discharge Q_t	Coeff. of discharge C_d
	Initial	Find	Mean	Initial	Final	Diff						

No Of Obs.	Horizontal Coordinate x	vertical Coordinate y	Actual velocity V_a	Coeff. of velocity C_v	Head loss H_L

No of observation					
Actual discharge, Q_a					
Theoretical Discharge Q_t					
Actual Velocity V_a					
Theoretical velocity V_t					
Actual head H					

Practice Questions

1. Explain why the discharge through an orifice is increased by fitting a standard short tube to it?
2. What will happen to the coefficient of discharge if the tube is shorter than the standard length or the head causing the flow is relatively high?
3. What is the effect of rounding the entrance of the mouthpiece?
4. What is a submerged tube? Does the coefficient of the tube change due to submergence?

Experiment No. 4
FLOW OVER A V-NOTCH

General

The most common types of sharp-crested weir are the rectangular weir and the triangular weirs. The triangular or V-notch weir is preferable to the rectangular weir for the measurement of widely variable flows. In the case of a rectangular weir, the total weighted perimeter does not vary directly with the head, as the length of the base is the same for all heads. Therefore, the coefficient of contraction, which depends on the wetted perimeter, is not constant for all heads. But in case of a V-notch there is no base to cause contraction which will be due to the sides only. The coefficient of contraction will therefore, be a constant for all heads. For this reason, the V-Notch is the most satisfactory type for flow measurement in canals.

Practical application

The V-notch weir is preferred when small discharges are involved, because the triangular cross-section of the flow 'nappe' leads to a relatively greater variation in head. V-notch Weir has the advantage that it can function for a very small flows and also measure reasonably larger flows as well.

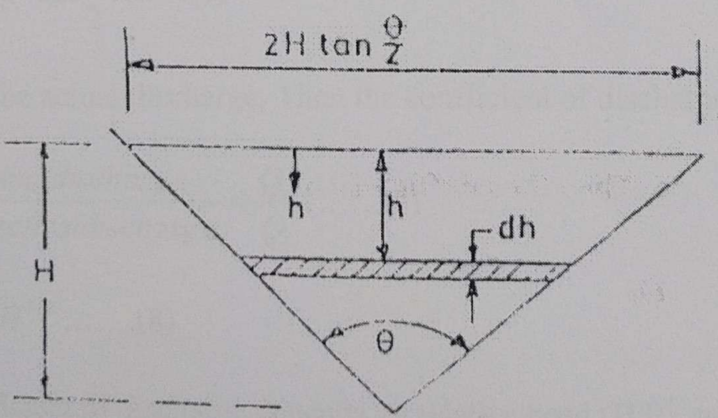


Fig. 1 Flow over a V-Notch

Theory

Consider the V-notch shown in the figure. Let H be the height of water surface and θ be the angle of notch. Then width of the notch at the water surface.

$$L = 2H \tan\frac{\theta}{2} \quad ....(1)$$

Consider a horizontal strip of the notch of thickness dh under a head h. Then, width of the strip,

$$W = 2(H-h)\tan\frac{\theta}{2} \quad ....(2)$$

Hence, the theoretical discharge through the strip

dQ_t = area of the strip x velocity =2(H-h) tan $\frac{\theta}{2} dh\sqrt{2gh}$ ....(3)

Integrating between the limits 0 and H and simplifying, the total theoretical discharge over the notch is given by

$$Q_t = \frac{8}{15}\sqrt{2g}\ \tan\frac{\theta}{2} H^{5/2} \quad ....(4)$$

$$= KH^{5/2} \quad ....(5)$$

Where,

$$K = \frac{8}{15}\sqrt{2g}\ \tan\frac{\theta}{2} \quad ....(6)$$

Let Q_a be the actual discharge, Then the conffficient of discharge, Cd is given by

$$C_d = \frac{actual discharge}{theoretical discharge} = \frac{Q_a}{Q_t} \quad ....(7)$$

$$Q_a = KC_d H^{5/2} \quad ....(8)$$

The co-efficient of discharge depends on relative head (H/P), relative height (P/B) and angle of the notch (θ)

From hydraulic point of view a weir may be fully contracted at low heads while at increasing head it becomes partially contracted. The flow regime in a weir is said to be partially contracted when the contractions along the sides of the V-notch are not fully developed due to proximity of the walls and bed of approach channel. Whereas a weir which has an approach channel and whose bed and sides of the notch arc sufficiently remote from the edges of the V-notch to allow for a sufficiently great approach velocity component parallel to the weir face so that the contraction is fully developed is a fully contracted weir. In case of a fully contracted weir C_d is fairly constant for a particular angle of notch.

At lower heads, frictional effects reduce coefficients. For the most common angle of notch 90 degree, the discharge coefficient, C_d is about 0.6.

Apparatus

1. A constant steady water supply with a means of varying the flow rate.
2. An approach channel
3. A V-notch weir plate
4. A flow rate measuring facility
5. A point gauge for measuring H.

Procedure

1. Position the weir plate at the end of approach channel, in a vertical plane, with the sharp edge on the upstream side.
2. Admit water to channel until the water discharges over the weir plate.
3. Close the flow control valve and allow water to stop flowing over weir.
4. Set the point gauge to a datum reading.
5. Position the gauge about half way between the notch plate and stilling baffle.
6. Admit water to the channel and adjust flow control valve to obtain heads, H, increasing in steps of 1 cm.
7. For each flow rate, stabilize conditions, measure and record H.
8. Take readings of volume and time using the volumetric tank to determine the flow rate.

Objective

1. To find C_d for the V-notch.
2. To plot Q_t vs. Q_a in a plain graph paper.
3. To plot Q_a vs. H in a log-log paper and to find (a) the exponent of H and (b) C_d

Practice Questions

1. Why does the V-notch give more accurate flow measurement than any other weirs and orifices when the flow is slightly fluctuating?
2. What is the average value of C_d for a 90° V-notch? Does it depend on flow condition (partially or fully contracted)?
3. Determine the discharge of water over a 60° triangular weir if the measured head is 0.623 ft.

Experiment No. 4
FLOW OVER A V-NOTCH
Observation and Calculation Sheet

Course no.:

Group no.:

Student ID no.:

Date:

Angle of the notch, θ = ____________________

K= ____________________

Cross-sectional area of the measuring tank= ____________________

Initial point gauge reading = ____________________

Final point gauge reading= ____________________

Difference in reading = ____________________

Datum water level reading = ____________________

Water level above vertex= ____________________

Final water level reading= ____________________

No of obs	Vol. of water	Collection time T	Actual discharge Q_a	Effective head H	Theoretical discharge Q_t	Co-eff. of discharge

No of observation					
Actual discharge Q_a					
Effective head H					
Theoretical discharge					

Signature of the Teacher

Head losses in pipes and fittings

Objective

- To find the head losses in pipe, elbow, expansion and contraction in pipe, globe valve and overall system.
- To plot the Head losses vs. Velocity graph and to analyze the losses characteristics in flow.
- To calculate the friction factor of pipe.
- To calculate the minor loss coefficients of elbow, expansion and contraction in pipe, and globe valve.

Theory

Friction loss is the loss of energy or "head" that occurs in pipe flow due to viscous effects generated by the surface of the pipe. Friction Loss is considered as a "major loss" and it is not to be confused with "minor loss", which includes energy lost due to obstructions.

This energy drop is dependent on the wall shear stress between the fluid and pipe surface. The shear stress of a flow is also dependent on whether the flow is turbulent or laminar. For turbulent flow, the pressure drop is dependent on the roughness of the surface. In laminar flow, the roughness effects of the wall are negligible because, in turbulent flow, a thin viscous layer is formed near the pipe surface that causes a loss in energy, while in laminar flow, this viscous layer is non-existent.

One of the accepted methods to calculate friction losses resulting from fluid motion in pipes is by using the Darcy–Weisbach equation. For a circular pipe:

$$h_f = \frac{f\,Lv^2}{2gd}$$

Where:

h_f = Head loss due to friction, given in units of length

f = Darcy friction factor

L = Pipe length

d = Pipe diameter

v = Flow velocity

g = Gravitational acceleration

The minor losses of energy are those which are caused on account of the change in velocity of flowing fluid. In case of long pipes these losses are usually quite small as compared with the loss of energy due to friction and hence these are termed 'minor losses' which may even be neglected without serious error. However, in short pipes, these losses may sometimes outweigh the friction loss. Some of the losses of energy which may be caused due to the change of velocity are indicated below:

(a) Loss of energy in bends and various pipe fittings

(b) Loss of energy due to sudden expansion and contraction

(c) Loss of energy due to gradual expansion and contraction

(d) Loss of energy at the entrance and exit of pipe

With pipe bends, valves etc., it is usually to account for head losses through these devices, in addition to the losses sustained by the pipes. This must almost always be done by resorting to experimental results. Such minor loss is given in the form

$$h_l = K\frac{v^2}{2g}$$

Where,

h_l = Minor loss

K = Minor loss coefficient

v = Flow velocity

g = Gravitational acceleration

As there are two different velocities in expansion and contraction, the largest velocity of the smaller diameter pipe is considered to calculate minor losses.

Setup components

Piping arrangement with the wall-

i. GI pipes
ii. Pressure gauges
iii. Water meter
iv. Ball valve
v. Globe valve
vi. Pipe fittings
vii. Couplers
viii. Flexible pipes

Manometer-

i. Coupler
ii. Acrylic tube
iii. Mercury
iv. Flexible rubber tube
v. Ring clips
vi. Measuring scale
vii. Hardboard

Working procedures

1. Water meter is connected in the path of flow to evaluate the volumetric flow-rate.
2. Calculating the time period of certain flow by stopwatch the volumetric flow-rate can be measured.
3. Thus from the known diameter of the pipes, the velocity of the flow can be computed.
4. Female ports of the couplers are connected with the male ports at certain points covering 1.94m of the pipe, elbow, globe valve, and expansion and contraction sockets; in order to find the pressure difference of those points in mercury column in manometer.
5. Pressure losses are converted to SI unit by essential calculations and are further assigned to calculate the friction factor of pipe and minor loss coefficients of the fittings, valves, and expansion and contraction in pipe.

Experimental Data

Specifications:

Pipe length, L = 1.94m

Thin pipe dia. = ¾ inch = 0.01905m; Thick pipe dia. = 1½ inch

Cross-sectional area of smaller pipe, $A = \frac{1}{4}\pi d^2 = \frac{1}{4} \times 3.1416 \times (0.01905)^2 = 2.85 \times 10^{-4}\ m^2$

Density of Mercury, ρ_{hg} = 13550 kg/m^3; Specific weight of Water, γ_w = 9810

Table: Flow Rate, Velocity and Losses in Pipes and Fittings

No. of Observations	Flow rate, Q (m^3/s)	Velocity, v = Q/A (m/s)	Head loss, h_{hg} (mm mercury column)					
			Loss in pipe	Loss in elbow	Loss for expansion	Loss for contraction	Loss in globe valve	Overall loss
1								
2								
3								
4								
5								

Calculation Data

Table: Friction Factor of Pipe and Minor Loss Coefficients of Fittings

No. of obs.	Pipe friction factor *F*	Elbow loss coefficient, K	Expansion loss coefficient, K	Contraction loss coefficient, K	Globe valve loss coefficient, K	Overall loss from manometer (m of water)
1						
2						
3						
4						
5						
Avg.						

Sample calculation

- Pressure drop due to pipe friction, $p = \gamma_{hg} h_{hg}$

$$= \rho_{hg} g h_{hg}$$

$$=$$

Head loss of water due to friction, $h_f = \dfrac{p}{\gamma_w}$

$$=$$

$\therefore$ Friction factor, $f = \dfrac{2gdh_f}{Lv^2}$

$$=$$

- Pressure drop in elbow, $p = \gamma_{hg} h_{hg}$

$$=$$

Head loss of water, $h_l = \dfrac{p}{\gamma_w}$

$$=$$

$\therefore$ Elbow loss coefficient, $K = \dfrac{2gh_l}{v^2}$

$$=$$

- Pressure drop for expansion, $p = \gamma_{hg} h_{hg}$

$$=$$

Head loss of water, $h_l = \dfrac{p}{\gamma_w}$

$$=$$

$\therefore$ Expansion loss coefficient, $K = \dfrac{2gh_l}{v^2}$

=

- Pressure drop for contraction, $p = \gamma_{hg} h_{hg}$

=

Head loss of water, $h_l = \frac{p}{\gamma_w}$

=

∴ Contraction loss coefficient, $K = \frac{2gh_l}{v^2}$

=

- Pressure drop in globe valve, $p = \gamma_{hg} h_{hg}$

=

Head loss of water, $h_l = \frac{p}{\gamma_w}$

=

∴ Globe valve loss coefficient, $K = \frac{2gh_l}{v^2}$

=

- Overall Pressure drop, $p = \gamma_{hg} h_{hg}$

=

∴ Overall head loss of water, $h_l = \frac{p}{\gamma_w}$

=

Experiment Name:Study of A Centrifugal Pump and Pump Characteristics.

Theory:

A centrifugal pump is a machine which converts mechanical energy into kinetic and pressure energy through centrifugal force.

A centrifugal pump consists of two main parts:

- A rotating element, including an impeller and a shaft.
- A stationary element made up of a casing, stuffing box and bearings.

The shaft of the pump is driven by power from an external source by which means the impeller along with the vanes inside is rotated. The fluid receives energy from the vanes during flow through the rotating impeller resulting in an increase in both velocity and pressure. Fluid flows from the suction pipe due to the formation of partial vacuum in the center of impeller. A large part of the total energy of the fluid leaving the impeller is kinetic energy. It is necessary to reduce the absolute velocity and transform the large portion of the velocity head into pressure head. In overcoming the delivery head of the pump the high pressure head of the leaving fluid is utilized.

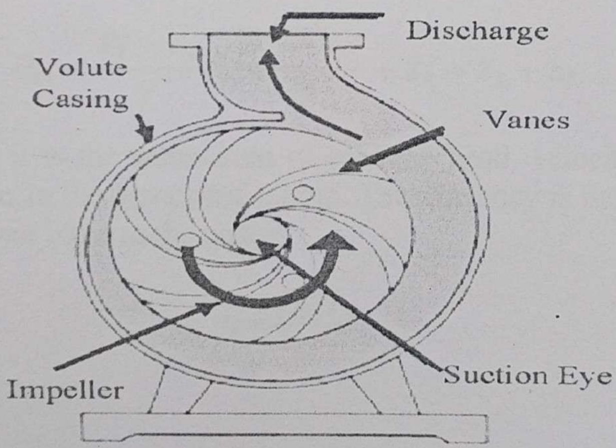


Figure 1: Liquid flow paths of a centrifugal pump

The actual head rise (H) produced by acentrifugal pump is a function of the flow rate (Q). It is possible to determine the head-flow relationship by appropriate selection of the geometry of the impeller blades. Normally, pumps are designed so that the head decreases with increasing flow since such a design results in a stable flow rate when the pump is connected to a piping system. A typical head flow curve for a pump is shown in Figure 2.

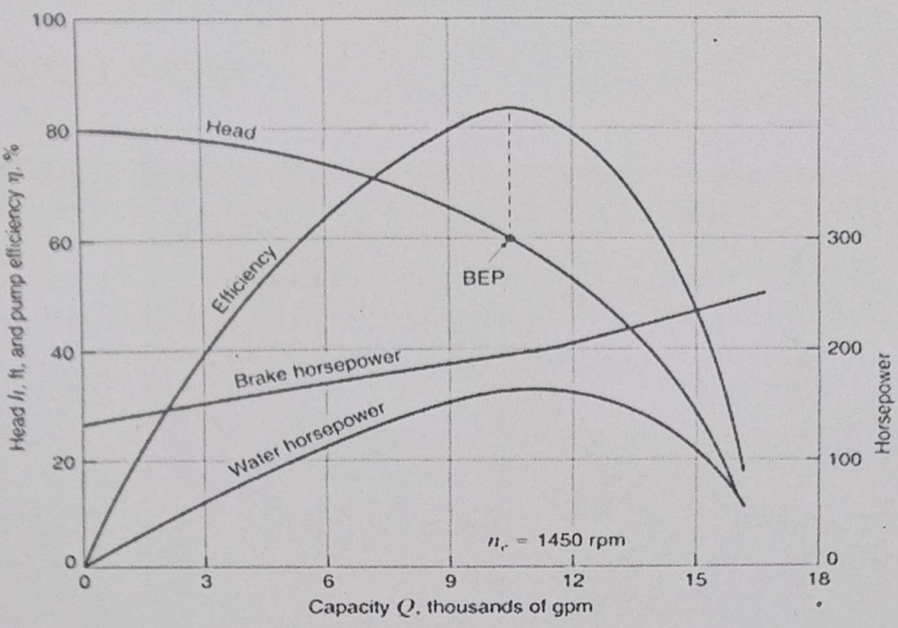


Figure 2: Characteristics curve of Centrifugal Pump.

If the mechanical energy equation is applied, section 1 is located as the pump inlet and section 2 asthe pump outletbetween two points in a piping system onopposite sides of the pump, then

$$\frac{P_1}{\gamma}+\frac{V_1^{\,2}}{2g}+Z_1+H_m=\frac{P_2}{\gamma}+\frac{V_2^{\,2}}{2g}+Z_2+h_f$$

$$H_m=\frac{P_2-P_1}{\gamma}+\frac{V_2^{\,2}-V_1^{\,2}}{2g}+Z_2-Z_1+h_f$$

$H_m$is the pump head and it is the summation of pressure head, velocity head, elevation head andh_f is the total head loss in the associated piping. Theefficiency is defined as the ratio of the fluid work to the shaft power input to the pump:

$$\eta=\frac{\gamma Q H_m}{P}$$

Experimental Setup

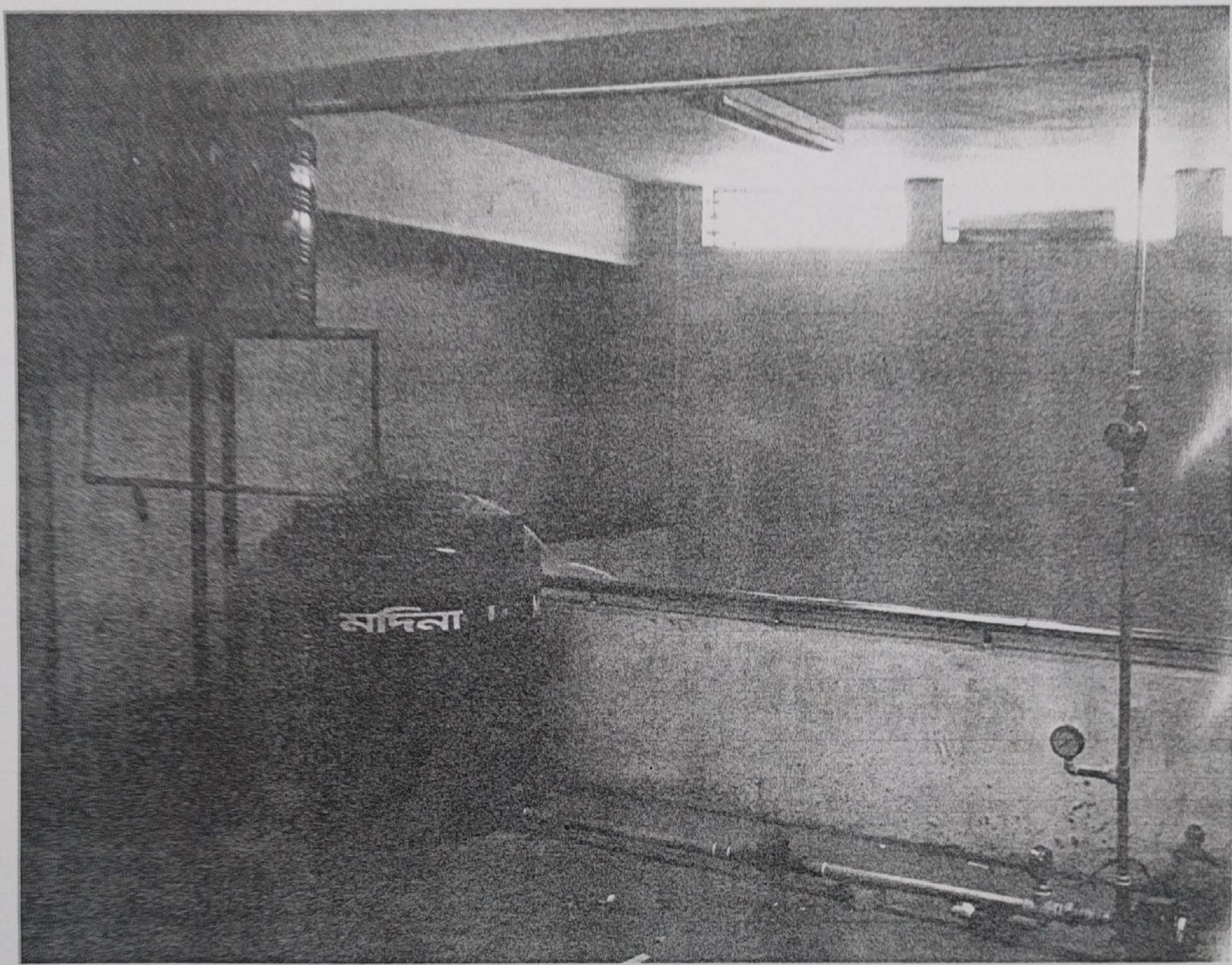


Figure 3: Centrifugal Pump Test Rig

Objective:

The objective of this experiment is to

- ✓ To do the performance test of different centrifugal pumps by varying their flow rates.
- ✓ To check the performance of centrifugal pump with different head and rpm.
- ✓ To plot the characteristics curve for different centrifugal pumps.

Apparatus:

Stopwatch, Wattmeter, Tachometer, Measuring Tape

Experimental Procedure

- ➢ Set up the centrifugal pump to the test rig.
- ➢ Wire connection to the pump.
- ➢ Measure power, voltage and current with Wattmeter.
- ➢ Measure RPM of the pump with non-contact Tachometer.
- ➢ Do this for all the pumps 0.5hp, 1hp, 1.5hp, 2hp & 3hp respectively.
- ➢ Open the gate valve at suction side of sump tank.
- ➢ Open the gate valve at delivery side of measuring tank.
- ➢ Turn on the pump.
- ➢ Take the value of flow rate at suction side and delivery side with flow meter and stopwatch.
- ➢ Take the value of pressure with pressure gauge at both sides.
- ➢ Reduce the flow of the water by controlling gate valve at delivery side step by step. Keep the flow rate of water at suction side constant.
- ➢ Now reduce the flow of the water by controlling gate valve at suction side step by step. Keep the flow rate of water at delivery side constant.
- ➢ Record all the values.
- ➢ Calculate friction in the delivery and suction side.
- ➢ Calculate the velocity head and total head.
- ➢ Calculate the pump efficiency.

Data Table:

Pipe Diameter (Suction) = 1.5 inch

Pipe Diameter (Delivery) = 1 inch

Pipe Length (Suction) = 96 inch

Pipe Length (Delivery) = 273 inch

Elevation Head, H = 2.7432 m

Height of Base = 72 cm

Width of Base = 38 cm

Pump Speed, N [r.p.m]	No Of Obs	Inlet Pressure, P_{in} [KPa]	Outlet Pressure, P_{out} [KPa]	Flow Rate, Q [m^3/s]	Inlet Velocity, V_{in} [m/s]	Outlet Velocity, V_{out} [m/s]	friction in Suction H_s [m]	friction in Delivery H_v [m]	Elevation Head,H [m]	Pressure Head [m]	Velocity Head [m]	Total Head, H_t [m]	Output Power [w]	Hydraulic Power [w]	Pump Efficiency [%]

Calculation:

Flow rate, Q = AV

Reynolds Number, $Re = \frac{\rho V D}{\mu}$

Friction, $H_f = \frac{flV^2}{2gd}$

Total Head,

$$H_m = \frac{P_2 - P_1}{\gamma} + \frac{{V_2}^2 - {V_1}^2}{2g} + Z_2 - Z_1 + H_f$$

Efficiency, $\eta = \frac{\gamma Q H_m}{P}$

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 3202: Ergonomics and Productivity Engineering
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental results and discussions (Experimental setup, Experimental conditions, Data, Graph, calculation etc.)
    - Conclusions
    - Acknowledgements
    - References
5. A quiz will be taken on the experiments at the end of the semester.
6. Marks distribution:

Total Marks		
Report	Attendance	Quiz
40	10	50

Experiment No: 1

Experiment Name: Anthropometry Measurement

Introduction

The term anthropometry is derived from two Greek words, anthropos, meaning man, and metros, meaning measurement. In other words, anthropometry is concerned with the measurements of human dimensions. Hundreds of these dimensions are possible, everything from common measurement of stature, or height, to the size of u human fingernail, but of these, a hundred or more have been defined as being useful for various purposes.

In using anthropometric measurements there are several things to bear in mind. One of these is the source of the measurements. All anthropometric tables present values that are statistical in nature. In other words they are derived as averages of multiple samples, sometimes from hundreds, sometimes from thousands of subjects. The larger the sample, the more representative it is or in statistical terms the greater is the accuracy of confidence in the measured value. The subjects in these simples are measured under standard conditions.

Objective

The objectives off this lab are:

- To know how to perform anthropometrics measurement
- To process the measurements so as to be useful
- To apply the data in the design of workplace, workstation, tools and equipment to
- fit to the human body.

Methodology

To calculate a percentile value, simply multiply the standard deviation S by a factor k, selected from table 1. Then add the product to the mean m:

$$p = m + k*S$$

If the desire d percentile is above the 50th percentile, the factor k has a positive sign and the product k*S is added to the mean m; if the p-value is below 50th percentile, k is negative and the product k*S is subtracted from the mean m. 1 the equation of mean m:

$$m = \left(\frac{\sum x}{n} \right)$$

m = mean

x = sample value

n = total of samples

The distribution of the data is described by the equation:

$$S = \sqrt{\frac{\sum (x-m)^2}{n}}$$

$$m_z = m_x - m_y$$

$$S_z = \sqrt{\left[S_z^2 + S_y^2 - 2r * S_x * S_y\right]}$$

Table 1: Percentile Values and Associated k Factors

Below Mean				Above Mean			
Percentile	Factor K	Percentile	Factor K	Percentile	Factor K	Percentile	Factor K
0.001	-4.25	26	-0.64	50	0	80	0.84
0.01	-3.72	27	-0.61	51	0.03	81	0.88
0.1	-3.09	28	-0.58	52	0.05	82	0.92
0.5	-2.58	29	-0.55	53	0.08	83	0.95
1	-2.33	30	-0.52	54	0.10	84	0.99
2	-2.05	31	-0.50	55	0.13	85	1.04
2.5	-1.96	32	-0.47	56	0.15	86	1.08
3	-1.88	33	-0.44	57	0.18	87	1.13
4	-1.75	34	-0.41	58	0.20	88	1.18
5	-1.64	35	-0.39	59	0.23	89	1.23
6	-1.55	36	-0.36	60	0.25	90	1.28
7	-1.48	37	-0.33	61	0.28	91	1.34
8	-1.41	38	-0.31	62	0.31	92	1.41
9	-1.34	39	-0.28	63	0.33	93	1.48
10	-1.24	40	-0.25	64	0.36	94	1.55
11	-1.23	41	-0.23	65	0.39	95	1.64
12	-1.18	42	-0.20	66	0.41	96	1.75
13	-1.13	43	-0.18	67	0.44	97	1.88
14	-1.08	44	-0.15	68	0.47	97.5	1.96
15	-1.04	45	-0.13	69	0.50	98	2.05
16	-0.99	46	-0.10	70	0.52	99	2.33
17	-0.95	47	-0.08	71	0.55	99.5	2.58
18	-0.92	48	-0.05	72	0.58	99.9	3.09
19	-0.88	49	-0.03	73	0.61	99.99	3.72
20	-0.84	50	0	74	0.64	99.999	4.26
21	-0.81			75	0.67		
22	-0.77			76	0.71		
23	-0.74			77	0.74		
24	-0.71			78	0.77		
25	-0.67			79	0.81		

Any percentile value p can be calculated from the mean m and the standard deviation.

<u>Result:</u> Anthropometry measurement

Dimentsion	Men				Women			
	5^{th} % ile	Mean	95^{th} % ile	SD	5^{th} % ile	Mean	95^{th} % ile	SD
Stature								
Eye Height, Standing								
Shoulder Height (Acromion), Standing								
Elbow Height, Standing								
Hip Height (Trochanter)								
Knuckle Height, Standing								
Finger Height, Standing								
Sitting Height								
Sitting Eye Height								
Sitting Shoulder Height								
Sittings Elbow Height								
Sitting Thigh Height								
Sittings Knee Height								
Sittings Popliteal Height								
Shoulder Elbow Length								
Elbow-Fingertip Length								
Overhead Grip Reach, Sitting								
Overhead Grip Reach,								
Forward Grip Reach								
Arm Length, Vertical								
Downward Grip Reach								
Chest Depth								
Abdominal Depth, Sitting								
Buttock-Knee Depth, Sitting								
Buttock-Popliteal Depth,								
Shoulder Breadth								
Shoulder Breadth (Bideltoid)								
Hip Breadth, Sitting								
Span								
Elbow Span								
Hand Length								
Hand Breadth								

See appendix for detail of anthropometric measurement

Appendix: <u>Body Dimensions</u>

The required dimensions are as follows:

1. Stature: The vertical distance from to top of the head, when standing.
2. Eye Height, Standing: The vertical distance form the floor to the outer corner of the right eye, when standing.
3. Shoulder Height (Acromion), Standing: The vertical distance from the floor to the tip (acromion) of the shoulder, when standing.
4. Elbow Height, standing: The vertical distance from the floor to the lowest point of the right elbow, when standing
5. Hip Height (Trochanter), Standing: The vertical distance from the floor to the trochanter landmark on the upper side of the right thigh, when standing.
6. Knuckle Height, Standing: The vertical distance from the floor to the knuckle (metacarpal bone) of the middle finger of the right hand, when standing.

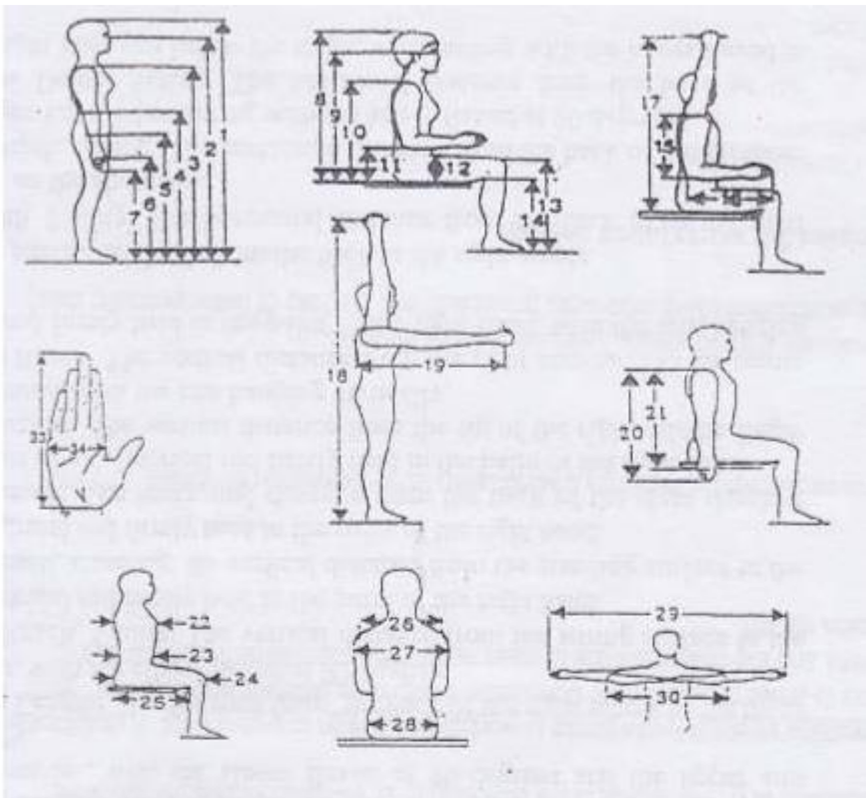


Fig: 1.1: Illustrations of Measured Body Dimensions

7. Fingertip Height, Standing: The vertical distance from the floor to the tip of the index finger of the right hand, when standing.
8. Sitting Height: the vertical distance form the sitting surface to the top of the head, when sitting.
9. Sitting Eye Height: The vertical distance from the sitting surface to the outer corner of the right eye, when sitting.

10. Sitting Shoulder Height (Acromion) : The vertical distance from the sitting surface to the tip (acromion) of the shoulder.
11. Sitting Elbow Height: The vertical distance from the sitting surface to the lowest point of the right elbow, when sitting.
12. Sitting Thigh Height (Clearance) : The vertical distance from the sitting surface to the highest point of the right thigh, when sitting.
13. Sitting Knee Height: The vertical distance from the floor to the top of the right knee cap, when sitting with knees flexed at 90 degrees.
14. Sitting Popliteal Height: The vertical distance from the floor to the underside of the thigh directly behind the right knee, when sitting with knees flexed at 90 degrees.
15. Shoulder-Elbow Length: The vertical distance from the underside of the right elbow to the right acromion., with the elbow flexed at 90 degrees and the upper arm hanging vertically.
16. Elbow-Fingertip Length: The distance from the back of the right elbow to the tip of the middle finger, with the elbow flexed at 90 degrees.
17. Overhead Grip Reach, Sitting: The vertical distance from the sitting surface to the center of a cylindrical rod firmly held in the palm of the right hand.
18. Overhead grip reach, standing: the vertical distance from the standing surface to the center of a cylindrical rod firmly held in the palm of the right hand.
19. The horizontal Forward Grip Reach distance from the back of the right shoulder blade to the center of a cylindrical rod firmly held in the palm of the right hand.
20. Arm Length, Vertical: The vertical distance from the tip of the right middle finger to the right acromion, with the arm hanging vertically.
21. Downward Grip Reach: The vertical distance from the right acromion to the center of a cylindrical rod firmly held in the palm of the right hand, with the arm hanging vertically.
22. Chest depth: the horizontal depth from the back to the right nipple.
23. Abdominal Depth, Sitting: The horizontal distance from the back of to the most protruding point on the abdomen.
24. Buttock-Knee Depth, Sitting: The horizontal distance from the back of the buttocks to the back of right knee, when sitting with the knees flexed at 90 degrees.
25. Buttock-Popliteal Depth, Sitting: The horizontal distance from the back of the buttocks to the right knee just below the thigh, when sitting with the knees flexed at 90 degrees.
26. Shoulder Breadth, Biacromial: The distance between the right and left acromion.
27. Shoulder Breadth, Bideltoid: The maximal horizontal breadth across the shoulders between the lateral margins of the right and left deltoid muscles.
28. Hip Breadth, Sitting: The maximal horizontal breadth across the hips or thighs, whatever is greater, when sitting.
29. Span: The distance between the tips of the middle fingers of the horizontally outstretched arms and hands.
30. Elbow Span: The distance between the tips of the elbows of the horizontally outstretched upper arms flexed so that the fingertips of the hands meet in front of the hunk.
31. Hand Length: The length of the right hand between the crease of the wrist and the tip of the middle finger, with right hand flat.
32. Hand Breadth: The breadth of the right hand across the knuckles of the four fingers.

Experiment No: 2

Experiment Name: Study and Design of Different Types of Hand Tools

Introduction

Hand tools extend capability of the hand. Greater capability can be more impact (hammer), more grip strength (pliers), more torque (wrench, screw-driver) or even new functions (hand saw, soldering iron). This experiment will aid one in selecting from available tools and even, in some cases, to design a new tool. The design principles are grouped into General Principles, Grip Principles, Precision Principles and Geometry Principles.

Objective

The objectives of this experiment to:

* Study ergonomic principles in designing of hand tools.
* Observe some existing hand tools and machines.
* Designing hand tools and machines using ergonomic principles. to eliminate the existing shortcoming.

Methodology

1. Identify the major components, their functions, dimensions and their relative position of the hand tools and machines mentioned in the following paragraph.
2. Use the tool or operate the machine for a typical job.
3. Carefully observe the working posture of the body and the interaction between the body and different parts of the tool or machine.
4. Conduct a survey for noting down the general feeling of the user.
5. From the above mentioned steps identify shortcomings (Geometry, dimension, alignment, material, and shape etc. of parts of the tool or machine that are not designed ergonomically resulting in discomfort and risk of musculoskeletal disorders from long time use) with reasons.
6. Propose improved design (with neat sketch) explaining the modifications made.

Tools and Machines to be studied

Hand drill, Soldering iron, Electrode Holder of Arc-welding, Cutting Torch, Chisel, Snip, Die, Hack-saw, Pliers, Jack Planner, Tanner saw, Slide Wrench, Screw driver.

Ergonomic Principles in Designing of Hand Tools

Hand Tools
Hammer, pliers, wrench, hand saw, screw driver, soldering iron, hack saw, scissors, knives, bottle opener etc.

Principles of Hand Tool & Devices Design:

* Maintain a straight wrist -
    * Avoid ulnar Deviation.

Flexion	--------> Decreasing angle at the joint
Extension	--------> opposite
Abduction	--------> movement of body segment in lateral plane away from the midline of the body.
Adduction	--------> opposite

* Avoid radial deviation with pronation & dorsiflexion.
* Design to neutral position. (wrist angle) (bent handle)

*** Grip strength is maximum at**

Neutral ↓	Supination ↓
Ulnar dev. ↓	Mid ↓
Radial dev ↓	Pronation
Dorsi flexion ↓	
Palmer flexion	

To increase high friction material, special design to gain mechanical advantage.

*** Avoid tissue compression stresses-**

- Avoid compressive force on the palm of the hand (obstructs blood flow, numbness of the fingers).
- Handles with large contact surfaces with palm so that force is distributed over larger area & is directed to less-sensitive tissues (between thumb & index finger).

* Avoid repetitive finger action -

* Avoid frequent use of index finger. Thumb operated controls should be used.
* Even better Finger-strip control (load shared by more than one finger)
* Maximum grip strength grip axis opening (axis opening) between 2.5 inch -3.5 inch

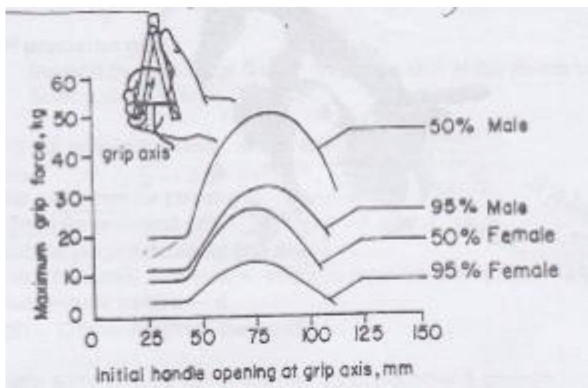


Figure 2.1: Thumb-operated and finger-strip operated pneumatic tool. Thumb operation results in overextension of the thumb. Finger strip control allows all the fingers to share the load and the thumb to grip and guide the tool

Design for safe operation -

* Eliminate pinching hazards (putting guards over pinch points, stops to prevent handles from fully closing & pinching the palm)

* Eliminate sharp corners & edges (rounding)
* Power tools --- design with brake devices.

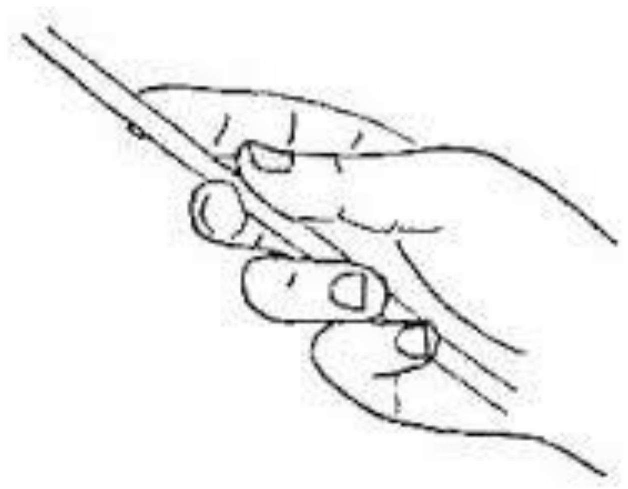


Figure2.2: Design for safe operation

Women & left handles -

* Vibration
* Gloves.

Grip Principles

Use a power grip for power. Use a precision grip for precision –

Power Grip:

1. Direction of the line of force parallel to forearm (saw).
2. Direction of the line of force at an angle to the forearm (hammer).
3. Torque about the forearm (corkscrew).

Precision Principles

1. Internal precision grips. Three characteristics

- A pinch grip by the thumb versus 1^{st} finger (or 1^{st} + 2^{nd} finger)
- Support to reduce tool tremor by the little finger & side of the hand.
- The shaft passes under the thumb.

In pushing/pulling -- tool handle parallel to the work surface.
Rotation/torque ------ tool shaft perpendicular to the work surface (screw driver).

End of the tool grip should be long enough to extend beyond the palm.

Use Spherical end.

2. External precision grip.

- Support by the side of the 2nd finger/the skin at the thumb base.
- Shaft passes over the thumb.

* Make grip the proper thickness, shape & length.
    * Thickness
    - Dia --- 40 mm for power grip.
    - >6mm for precision grip.
* Shape section perpendicular to grip axis-
    - Circular handle --- slippage, effective moment arm is less.
    - Rectangular handle --- pressure high
* Length – 125mm length of the handle.
* Design the grip surface to be compressible, nonconductive & smooth.
    - Compressible material (rubber, plastic) with high coefficient of friction.
    - Non conductive

Geometry Principles

* Angles of the forearm, grip & tool-
- Handles should be designed so that the wrist is in neutral position. (pliers, soldering iron)
* Use appropriate muscle groups.

large muscle group, (forearm vs fingers), hand closing muscles vs hand opening muscle.

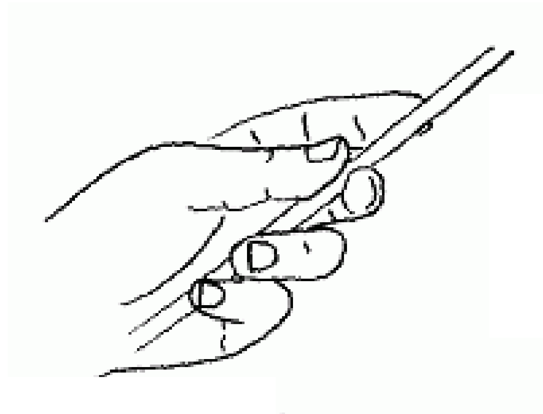


Figure2.3: Internal precision grips

Figure 2.4: External precision grips

Internal precision grips have three characteristics: (1) a pinch grip. (2) support by the little finger or side of the hand, and (3) the shaft is “internal” to the hand.

As with the power grip, thumb or little finger can be repositioned. Pointing along the top surface of a knife gives more power as well as additional precision. Patkin (1969) mentions pointing along a surgeon's needle holder with the thumb to gain additional precision.

Experiment No: 3

Experiment Name: Determination of Sound Level in different workplaces

Introduction

Sound is created by the vibrating motion of displaced molecule in an elastic medium like air, wood, steel or other materials. This vibration produces waves which radiate in all directions. As these waves travel through the medium, a small pressure change above atmospheric pressure is created. Human ear is able to sense this small change , enabling to hear. This change in pressure is known as sound pressure level. The sound pressire level is the measure of sound most commonly reffered to when discussing industrial noise control. People are able to hear sound pressure level between about 1×10^-9 psi and 15 psi (or 1atm). Since this represents 10 orders of magnitude change, logarithmic scales are used to measure sound pressure level in desibels (dB). The level of sound plays a vital role in design of workplaces. Human comfort and productivity is affected by noise level greatly. Based on job profile and other requirements, in different types of workplaces, different standards of sound level has been set to define human comfort.

Objective

In this experiment, students have to construct a noise contour map of a sound emitting source. They are also required to critically analyze the findings and comment for improvements (if any).

Apparatus

1. Sound Level Meter

Procedure

1. Using slow response setting on a sound level meter, walk around the sound source, maintaining a constant reading (e.g. 80dBA). Record your path until it closes on itself, forming a loop. Or until the path exits the area to be surveyed.
2. Trace the path followed on a plant layout or area map. This can be easily done by a second person following the surveyor.
3. Repeat the process for as many contours as desired or needed. At a minimum, seven contours forming eight hearing hazard zones are recommended.

Digital Sound Level Meter

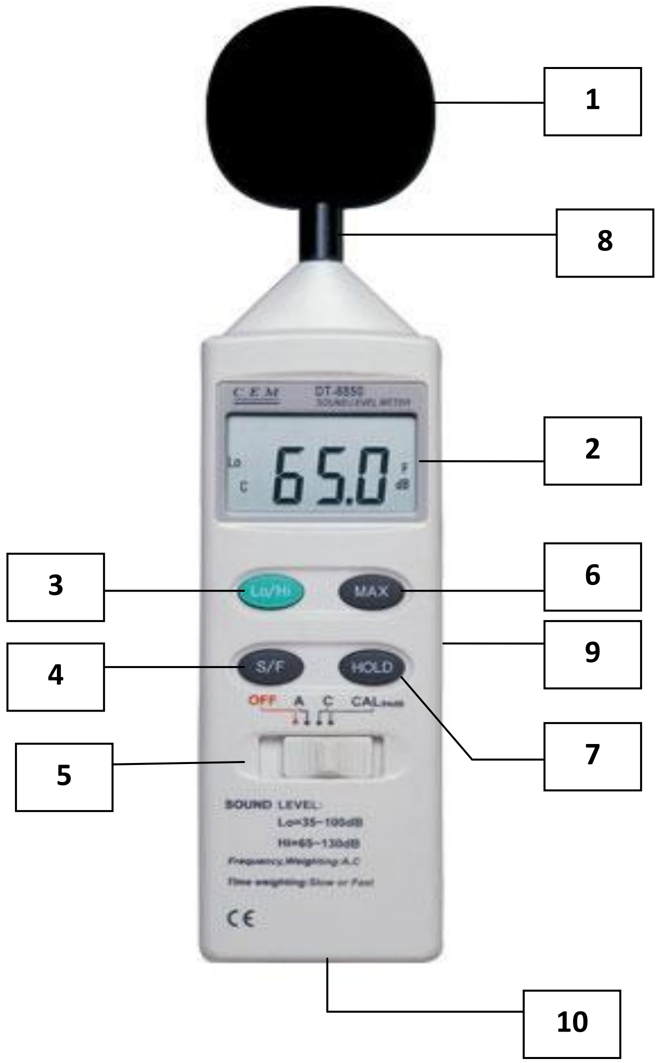


Fig: 3.1: Digital sound Level Meter

1. Windscreen
2. Display
3. Level Range Select Button: Lo: 35~100dB; Hi: 65~130dB
4. Time Weighting Select Button:
   F (Fast response): For Normal measurement.
   S (Slow response): For checking average level of fluctuating noise.
5. Power and Function Switch:
   Turn power ON/OFF and select A/C weighting & calibration function
   A: A- Weighting for general sound level measurements.
   C: C- Weighting for checking the low frequency content of noise.

6. Max Hold Button: To measure maximum level of sounds.
7. Data Hold Button: Freezes the reading in the display.
8. Microphone
9. DC, AC Output jack
10. Calibration potentiometer

Operation

1. Power the meter by pressing the power button. The meter will begin displaying sound level readings. If the LCD does not switch on, check the 9V battery located in the rear battery compartment.
2. Hold the meter away from the body.
3. View the measurement on the meter's display. If the meter is in the auto ranging mode, the display may briefly indicate "HI" or "LO" if the noise level is above or below the currently selected range. The meter will change the range as needed to display the dB level.
4. 'A' and 'C' Frequency Weighting Use the 'A/C' button to select 'A' or 'C' frequency weighting. With 'A' weighting selected, the frequency response of the meter is similar to the response of the human ear. 'A' weighting is commonly used for environmental or hearing conservation programs such as OSHA regulatory testing and noise ordinance law enforcement. 'C' weighting is a much flatter response and is suitable for the sound level analysis of machines, engines, etc. "A" or "C" icons will appear in the display. Most noise measurements are performed using 'A' Weighting and SLOW Response.
5. 'FAST' and 'SLOW' Response Time Use the 'F/S' button to select FAST (125 ms) or SLOW (1 second) response time. Select FAST to capture noise peaks and noises that occur very quickly. Select the SLOW response to monitor a sound source that has a consistent noise level or to average quickly changing levels. "FAST" or "SLOW" icons will appear in the display. Select SLOW response for most applications.
6. Max hold: In this mode the meter only updates the LCD when a higher reading than the one presently on the display is detected.
   Press the MAX HOLD button to enter the Max Hold mode. The "MAX HOLD" icon will appear in the display. Press the MAX HOLD button again to exit this mode.

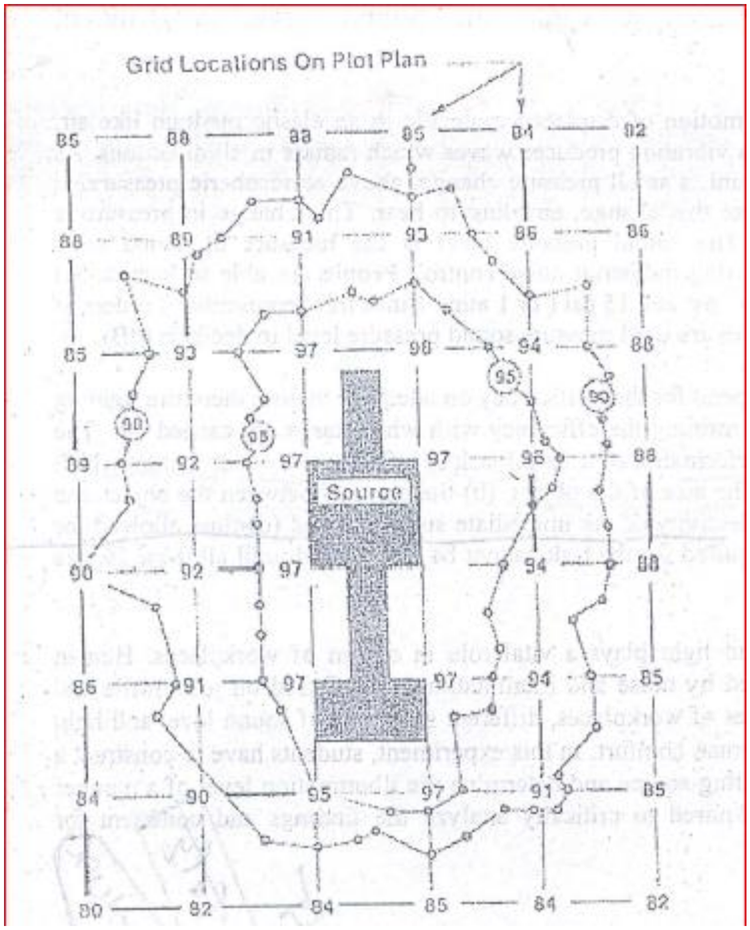


Figure 3.2: Noise Contour Map

Experiment No: 4

Experiment Name: Study of manual lifting operation and determination of the recommended weight limit using the NIOSH lifting equation

Introduction

Manual handling is an important application of ergonomic principles that particularly addresses back injury prevention. A large proportion of the accidents which occurs in industry involve the manual handling of goods. In the United Sates, the report by the National Institute for Occupational Safety and Health (NIOSH,l981) stated that back pain was attributed to overexertion by 60% of back pain sufferers. About 500,000 workers in the US suffer some type of overexertion injury per year. Approximately 60% if the overexertion injury claims involve lifting and 20% involve pushing or pulling.

The main contribution of ergonomics to the reduction of hazards in manual handling is to redesign tasks and to identify techniques and specify workloads which are safe. NIOSH has produced a work practice guide for the design of manual handling tasks and an equation for determining safe loads. In Europe, a new directive for design of these task has been issued in 1990 and the U.K. Health and Safety Commission Consultative Document (Health and Safety Commission, 1991) provides interesting proposals for the design of manual handling tasks.

Objective

The objective of this experiment is to study manual lifting operation and determination of recommended weight by using the NIOSH lifting equation.

The Revised Lifting Equation
1 Definition of Terms

1.1 Recommended Weight Limit (RWL)

The RWL is the principal product of the revised NIOSH lifting equation. The RWL is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g., up to 8 hours) without an increased risk of developing lifting-related LBP. By healthy workers, we mean workers who are free of adverse health conditions that would increase their risk of musculoskeletal injury.

The RWL is defined by the following equation:
RWL : LC X HM X VM X DM X AM X FM X CM

1.2 Lifting Index (LI)

The LI is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship of the weight of the load lifted and the recommended weight limit.

The LI is defined by the following equation:

LI= Load Weight/ Recommended weight Limit RWL = $\frac{L}{RWL}$

1.3 Terminology and Data Definitions

The following list of brief definitions is useful in applying the revised NIOSH lifting equation. For detailed descriptions of these terms, refer to the individual sections where each is discussed. Methods for measuring these variables and examples are provided in Sections 1 and 2.

Lifting Task	Defined as the act of manually grasping an object of definable size and mass with two hands, and vertically moving the object without mechanical assistance.
Load Weight (L)	Weight of the object to be lifted, in pounds or kilograms, including the container.
Horizontal	Distance of the hands away from the mid-point between the ankles, in inches
Locations (H)	or centimeter (measure at the origin and destination of lift). See Figure 1.
Vertical Location (V)	Distance of the hands above the floor, in inches or centimeters (measure at the origin and destination of lift). See Figure l.
Vertical Travel Distances (D)	Absolute value of the difference between the vertical heights at the destination and origin of the lift, in inches or centimeters.
Asymmetry Angle (A)	Angular measure of how far the object is displaced from the front (mid sagittal plane) or the worker's body at the beginning or ending of the lift, in degrees (measure at the origin and destination of lift). See Figure 2. The asymmetry angle is defined by the location of the load relative to the

	workers' mid- sagittal plane, as defined by the neutral body posture, rather than the position of the feet or the extent of body twist.
Neutral Body Position	Describes the p body and there is minimal twisting at the legs, torso, or shoulders. Position of the body when the hands are directly in front of the
Lifting Frequency (F)	Average number of lifts per minute over a 15 minute period.
Lifting Duration	Three-tiered classification of lifting duration specified by the distribution of work-time and recovery-time (work pattern). Duration is classified as earlier short (1 hour), moderate (1-2 hours), or long (2-8 hours), depending on the work pattern.
Coupling classification	Classification of the quality of the hand-to-object coupling (e.g., handles, cut- out, or grip). Coupling quality is classified as good, fair, or poor.
Significant Control	Significant control is defined as a condition requiring precision placement of the load at the destination of the lift. This is usually the case when (1) the worker has to re-grasp the load near the destination of the lift, or (2) the worker has to momentarily hold the object at the destination, or (3) the worker has to carefully position or guide the load at the destination

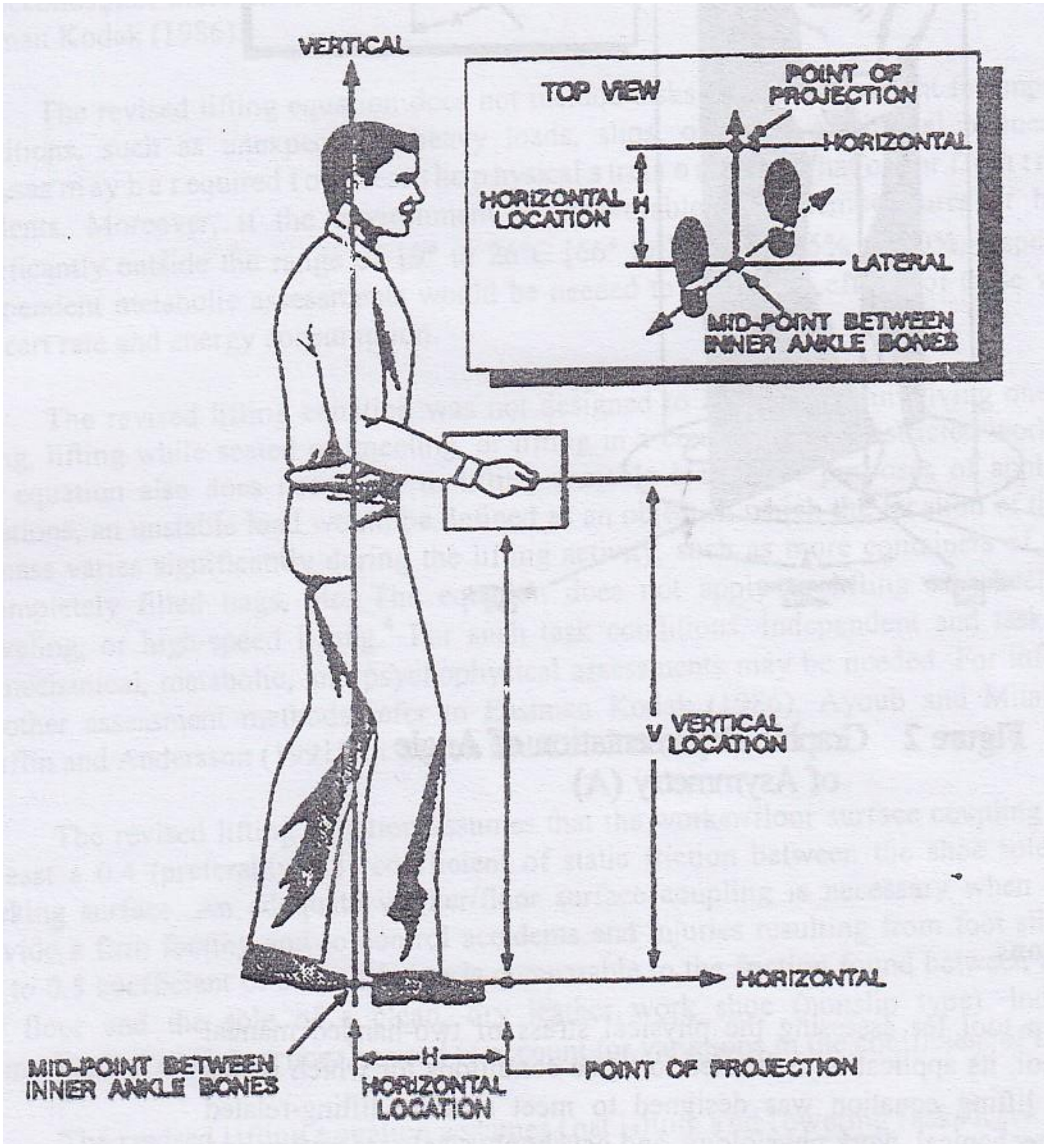


Fig: 4.1: Graphic Representation of Hand

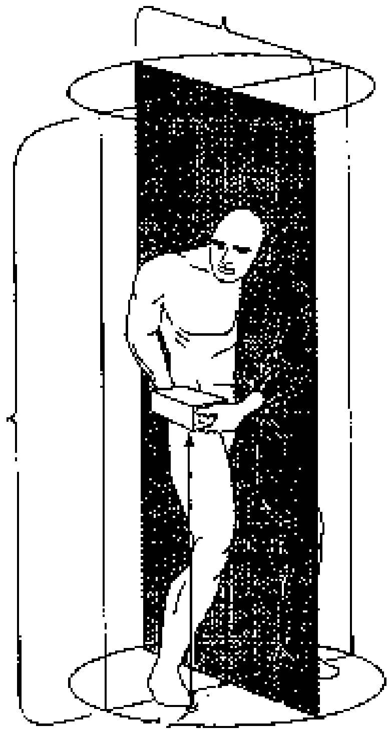


Fig: 4.2: Graphic Representation of Angle of Asymmetry (A)

2 Lifting Task Limitations

The lifting equation is a tool for assessing the physical stress of two-handed manual lifting tasks. As with any tool, its application is limited to those conditions for which it was designed. Specifically, the lifting equation was designed to meet specific lifting-related criteria that encompass biomechanical, work physiology, and psychophysical assumption and data, identified above. To the extent that a given lifting task accurately reflects these underlying conditions and criteria, this lifting equation may be appropriately applied.

The following list identified a set of work conditions in which the application of the lifting equation could either-or over-estimate the extent of physical stress associated with a particular work-related activity. Each of the following task limitations also highlight research topics in need of further research to extend the application of the lifting equation to a greater range of real world lifting tasks.

1. The revised NIOSH lifting equation is based on the assumption that manual handling activities other than lifting are minimal and do not require significant energy expenditure, especially when repetitive lifting tasks are performed. Examples of non-lifting tasks include holding, pushing, pulling, carrying, walking, and climbing. If such non-lifting activities account for more than about 10% of the total worker activity, then measures or workers' energy expenditures and/or heart rate may be required to assess the metabolic demands of the different tasks. The equation will still apply if there is a small amount of holding and carrying, but carrying should be limited to one or two steps and holding should not exceed a few seconds. For more information on assessing metabolic demand, see Garg et al. (1978) or Eastman Kodak (1986).
2. The revised lifting equation does not include tasks factors to account for unpredicted conditions, such as unexpectedly heavy loads, slips, or falls. Additional biomechanical analyses may be required to assess the physical stress on joints that occur from traumatic incidents. Moreover, if the environment is unfavorable (e.g., temperatures or humidity significantly outside the range of l9^{o} to 26^{o}C [66^{o} to 79^{o}F] or 35% to 50%, respectively), independent metabolic assessments would be needed to gauge the effects of these variables on heart rate and energy consumption.
3. The revised lifting equation was not designed to assess tasks involving one-handed lifting, lifting while seated or kneeling, or lifting in a constrained or restricted work space.[3] The equation also does not apply to lifting unstable loads, For purposes of applying the equations, an unstable load would be defined as an object in which the location of the center of mass varies significantly during the lifting activity, such as more containers of liquid or incompletely filled bags, etc. The equation does not apply to lifting of wheelbarrows, shoveling, or high-speed lifting.[4] For such task conditions, independent and task specific biomechanical, metabolic, and psychophysical assessments may be needed. For information on other assessment methods refer to Eastman Kodak (1986), Ayoub and Mital (1989), Chaffin and Andersson (1991), or Snook and Ciriellos (1991).
4. The revised lifting equation assumes that the worker/floor surface coupling provides at least a 0.4 (preferably 0.5) coefficient of static friction between the shoe sole and the working surface. An adequate worker/floor surface coupling is necessary when lifting to provide a firm footing and to control accidents and injuries resulting from foot slippage. A 0.4 to 0.5 coefficient of static friction is comparable to the friction found between a smooth, dry floor and the sole of a clean, dry leather work shoe (nonslip type). Independent biomechanical modeling may be used to account for variations in the coefficient of friction,

5. The revised lifting equation assumes that lifting and lowering tasks have the same level of risk for low back injuries (i.e. that lifting a box from a table to the floor). This assumption may not be true if the worker actually drops the box rather than lowering it all the way to the destination. Independent metabolic, biomechanical, or psychophysical assessments may be needed to assess worker capacity for various lowering conditions. (See references provided above.)

In summary, the Revised NIOSH Lifting Equation does not apply if \f any of the following occur.

* Lifting/lowering with one hand
* Lifting/lowering for over 8 hours
* Lifting/lowering while seated or kneeling
* Lifting/lowering in a restricted work space
* Lifting/lowering unstable objects
* Lifting/lowering while carrying, pushing or pulling
* Lifting/lowering with wheelbarrows or shovels
* Lifting/lowering with high speed motion (faster than about 30 inches/second)
* Lifting/lowering with unreasonable foot/floor coupling, (<0.4 coefficient of friction between the sole and the floor)
* Lifting/lowering in an unfavorable environment (i.e., temperature significantly outside 66-79^{o}F (19-26^{o}C) range; relative humidity outside 35-50% range)

For those lifting tasks in which the applications of the revised lifting equation is not appropriate, a more comprehensive ergonomic evaluation may be needed to quantify the extent of other physical stressors, such as prolonged or frequent non-neutral back postures or seated postures, cyclic loading (whole body vibration), or unfavorable environmental factors (e.g., extreme heat, cold, humidity, etc.).
Any of the above factors, alone or in combination with manual lifting, may exacerbate or initiate the onset of low back pain.

2. The Equation and Its Function

The revised lifting equation for calculating the Recommended Weight Limit (RWL) is based on a multiplicative model that provides a weighting for each of six task variables. The weightings are expressed as coefficients that serve to decrease the load constant, which represents the maximum recommended load weight to be lifted under ideal conditions. The RWL is defined by the following equation:

RWL : LC X HM X VM X DM X AM X FM X CM

Where

		METRIC	U.S. CUSTOMARY
Load Constant	LC	23 kg	51 lb
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	1-(.003 V-75)	1-(.0075 V-30)
Distance Multiplier	DM	.82 + (4.5/D)	.82 + (1.8/D)
Asymmetric Multiplier	AM	1-(.0032A)	1-(.0032A)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling Multiplier	CM	From Table 7	From Table 7

The term task variables refers to the measurable task descriptors (i.e., H, V, D, A, F, and C); whereas, the term multipliers refers to reduction coefficients in the equation (i.e., HM, VM, DM, AM, FM, and CM).

Each multiplier should be computed from the appropriate formula, but in some cases it will be necessary to use linear interpolation to determine the value of a multiplier, especially when the value of a variable is not directly Available from a table. For example, when the measured frequency is not a whole number, the appropriate multiplier must be interpolated between the frequency values in the table for the two values that are closest to the actual frequency.

3.1 Horizontal Component

3.1.1 Definition and Measurement

Horizontal Location (H) is measured from the mid-point of the line joining the inner ankle bones to a point projected on the floor directly below the mid-point of the hand grasps (i.e., load center), as defined by the large middle knuckle of the hand (Figure 1). Typically, the worker's feet are not aligned with the mid-sagittal plane, as shown in Figure l, but may be rotated inward or outward. If this is the case, then the mid-sagittal plane is defined by the worker's neutral body posture as defined above.

If significant control is required at the destination (i.e., precision placement), then H should be measured at both the origin and destination of the lift.

Horizontal Location (H) should be measured. In those situations where the H value can not be measured, then H may be approximated from the following equations:

Metric [All distances in cm]	U.S. Customary [All distances in inches]
H = 20 + W/2 for V ≥ 25 cm	H = 8 + W/2 for 10 inches
H = 25 + W/2 for V < 25 cm	H = 10 + W/2 for V<10 inches

Where: W is the width of the container in the sagittal plane and V is the vertical location of the hands from the floor.

3.1 .2 Horizontal Restrictions

If the horizontal distance is less than 10inches (25 cm), then H is set to 10 inches (25 cm). Although objects can be carried or held closer than l0 inches from the ankles, most objects that are closer than this cannot be lifted without encountering interference from the abdomen or hyper extending the shoulders. While 25 inches (63cm) was chosen as the maximum value for H, it is probably too large for shorter workers, particularly when lifting asymmetrically. Furthermore objects at a distance of more than 25 inches from the ankles normally cannot be lifted vertically without some loss of balance.

3.1.3 Horizontal Multiplier

The Horizontal Multiplier (HM) is l0/H, for H measured in inches, and HM is 25/H, for H measured in centimeters. If H is less than or equal to 10 inches (25 cm), then the multiplier is 1.0, HM decreases with an increase in H value. The multiplier for H is reduced to 0.4 when H is 25 inches (63 cm). If H is greater than 25 inches, then HM = 0. The HM value can be computed directly or determined from Table l.

Table I
Horizontal Multiplier

H	HM	H	HM
in		cm	
≤10	1.00	≤25	1.00
11	.91	28	.89
12	.83	30	.83
13	.77	32	.78
14	.71	34	.74
15	.67	36	.69
16	.63	38	.66
17	.59	40	.63
18	.56	42	.60
19	.53	44	.57
20	.50	46	.54
21	.48	48	.52
22	.46	50	.50
23	.44	52	.48
24	.42	54	.46

25	.40	56	.45
>25	.00	58	.43
		60	.42
		63	.40
		>63	.00

3.2 Vertical Component

3.2.1 Definition and Measurement

Vertical Location (V) is defined as the vertical height of the hands above the floor. V is measured vertically from the floor to the mid-point between the hand grasps, as defined by the large middle knuckle. The coordinate system is illustrated in Figure 1 (page 7).

3.2.2 Vertical Restrictions

The vertical location (v) is limited by the floor surface and the upper limit of vertical reach for lifting {i.e.,70 inches or 175 cm). The vertical location should be measured at the origin and the destination of the lift to determine the travel distance (D).

3.2.3 vertical Multiplier

To determine the vertical Multiplier (VM), the absolute value or deviation of v from an optimum height of 30 inches (75cm) is calculated. A height of 20 inches above floor revel is considered "knuckle height" (66 inches or 165 cm). The Vertical Multiplier (VM) is {1-.0075*(V-30)} for V measured in inches, and VM is {1-.003*(V-75)}, for measured in centimeters.

When v is at.3-0 inches (75 cm), the vertical multiplier (VM) is- 1.0. The value of VM decreases linearly with an increase or decrease in height from the position. At floor level, VM is 0.78, and at 70 inches (175 cm) height VM is 0.7. If V is greater than 70 inches, then VM= 0. The VM value can be computed directly or determined from Table 2.

Table 2
Vertical Multiplier

V	VM	V	VM
in		cm	
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96

35	.96	70	.99
40	.93	80	.99
45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
>70	.00	150	.78
		160	.75
		170	.72
		175	.70
		>175	.00

3.3 Distance Component

3.3.1 Definition and Measurement

The vertical Travel Distance variable (D) is defined as the vertical travel distance of the hands between the origin and destination of the lift. For lifting, D can be computed by subtracting the vertical location (V) at the origin of the lift from the corresponding V at the destination of the lift (i.e., D is equal to V at the destination minus V at the origin). For a lowering task, D is equal to V at the origin minus V at the destination.

3.3.2 Distance Restrictions

The variable (D) is assumed to be at least 10 inches (25 cm), and no greater than 70 inches [75 cm]. If the vertical travel distance is less than 10 inches (25 cm), then D should be set to the minimum distance of l0 inches (25 cm).

3.3.3 Distance Multiplier

The Distance Multiplier (DM) is (.82 + (1.8/D)) for D measured in inches, and DM is (.82 + (4.5/D)) for D measured in centimeters. For D less than 10 inches (25 cm) D is assumed to be l0 inches (25 cm), and DM is 1.0. The Distance Multiplier, therefore, decreases gradually with an increase in travel distance. The DM is 1.0 when D is set at 10 inches, (25 cm); DM is 0.85 when D = 70 inches (175 cm). Thus, DM ranges from 1.0 to 0.85 ad the D varies from 0 inches (0 cm) to 70 inches (175 cm). The DM value can be computed directly or determined from Table 3.

3.4 Asymmetry Component

3.4.1 Definition and Measurement

Asymmetry refers to a lift that begins or ends outside the mid-sagittal plane as shown in Figure 2 on page 8. In general, asymmetric lifting should be avoided. If asymmetric lifting cannot be avoided, however, the recommended weight limits are significantly less than those limits used for symmetrical lifting.5

Table 3
Distance Multiplier

D	DM	DM	DM
in		cm	
10	1.00	25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	>175	.00
>70	.00		

An asymmetric lift may be required under the following task or workplace conditions:

1. The origin and destination of the lift are oriented at an angle to each another.
4 The lifting motion is across the body, such as occurs in swinging bags or boxes from one location to another.
5 The lifting is done to maintain body balance in obstructed workplaces, on rough terrain, or on littered floors.
6 Productivity standards require reduced time per lift.

The asymmetric angle (A), which is depicted graphically in Figure 2, is operationally defined as the angle between the asymmetry the and the mid-sagittal line. The asymmetry line is defined as horizontal line that join the midpoint between the inner ankle bones and the point projected on the floor directly below the midpoint of the hand grasps, as defined by the large middle knuckle.

The sagittal line is defined as the line passing through the mid-point between the inner ankle bones and lying in the mid-sagittal plane, as defined by the neutral body position (i.e., hands directly in front of the body, with no twisting at the legs, torso, or shoulders). Note: The asymmetry angle is not defined by foot position or the angle of torso twist, but by the location of the load relative to the worker's mid-sagittal plane.

In many cases of asymmetric lifting, the worker will pivot or use a step turn to complete the lift. Since this may vary significantly between workers and between lifts, we have assumed that no pivoting or stepping occurs. Although this assumption may overestimate the reduction in acceptable load weight, it will provide the greatest protection for the worker.

The asymmetry angle (A) must always be measured at the origin of the lift. If significant control is required at the destination, however, then angle A should be measured at both the origin and the destination of the lift.

3.4.2 Asymmetry Restrictions

The angle A is limited to the range from 0^0 to 135^0 . If A> 135^0 , then AM is set equal to zero, which results in a RWL of zero, or no load.

3.4.3 Asymmetric Multiplier

The Asymmetric Multiplier (AM) is 1-(.00324). The AM has a maximum value of 1.0 when the load is lifted directly in front of the body. The AM decreases linearly as the angle of asymmetry (A) increases. The range is from a value of 0.57 at 135^0 of asymmetry to a value of 1.0 at 0^0 of asymmetry (i.e., symmetric lift).

If A is greater than 135^0 , then AM: 0, and the load is zero. The AM value can be computed directly or determined from Table 4.

Table 4
Asymmetric Multiplier

A	AM
deg	
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
>135	.00

3.5 Frequency Component
3.5.1 Definition and Measurement

The frequency multiplier is defined by (a) the number of lifts per minute (frequency), (b) the amount of time engaged in the lifting activity (duration), and (c) the vertical height of the lift from the floor. Lifting frequency (F) refers to the average number of lifts made per minute, as measured over a 15-minute period. Because of the potential variation in work patterns, analysis may have difficulty obtaining an accurate or representative 15-minute work sample for computing the lifting frequency (F). If significant variation exists in the frequency of lifting over the course of the day, analyst should employ standard work sampling techniques to obtain a representative work sample for determining the number of lifts per minute. For those jobs where the frequency varies from session to session, each session should be analyzed separately, but the overall work pattern must still be considered. For more information, most standard industrial engineering or ergonomics texts provide guidance for establishing a representative job sampling strategy (e.g., Eastman Kodak Company, 1986).

3.5.2 Lifting Duration
Lifting duration is classified into three categories-short-duration moderate-duration and long-duration. These categories are based on the pattern of continuous work-time and recovery-time (i.e., light work) periods. A continuous work-time period is defined as a period of uninterrupted work. Recovery-time is defined as the duration of light work activity following a period of continuous lifting. Examples of light work include activities such as sitting at a desk or table, monitoring operations, light assembly work, etc.

1. Short-duration defines lifting tasks that have a work duration of one hour of less, followed by a recovery time equal to 1.2 times the work time [i.e., at least a 1.2 recover-time to work-time ratio (RT/WT)].

For example, to be classified as short-duration, a 45-minute lifting job must be followed by at least a 54-minute recovery period prior to initiating a subsequent lifting session. If the required recovery time is not met for a job of one hour or less, and subsequent lifting session is required, then the total lifting time must be combined to correctly determine the duration category. Moreover, if the recovery period does not meet the time requirement, it is disregarded for purposes of determining the appropriate duration category.
As another example, assume a worker lifts continuously for 30 minutes, then performs a light work task for 10 minutes, and then lifts for an additional 45-minute period. In this case, the recovery time between lifting sessions (10 minutes) is less than 1.2 times the initial 30-minute work time (36 minutes). Thus, the two work times (30 minutes and 45 minutes) must be added together to determine the duration. Since the total work time (75 minutes) exceeds 1 hour, the job is classified as moderate-duration. On the other hand, if the recovery period between lifting sessions was increased to 36 minutes, then the short-duration category would apply, which would result in a larger FM value.

2.**Moderate-duration** defines lifting tasks that have a duration of more than one hour, but not more than two hours, followed by recovery period of at least 0.3 times the work time [i.e., at least a 0.3 recovery time to work-time ratio (RT/WT)].

For example, if a worker continuously lifts for 2 hours, then a recovery period of at least 36 minutes would be required before initiating a subsequent lifting session. If the recovery time requirement is not met, and a subsequent lifting session is required, then the total work time must be added together. If the total works time exceeds 2 hours, then the job must be classified as a long-duration lifting task.

3. Long-duration defines lifting tasks that have a duration of between two and eight hours, with standard industrial rest allowances (e.g., morning, lunch, and afternoon rest breaks).

Note : No weight limits are provided more than eight hours of work.

The difference in the required RT/WT ratio for the short-duration category (less than 1 hour), which is 1.2, and the moderate-duration category (1-2 hours), which is 3, is due to the difference in the magnitudes of the frequency multiplier values associated with each of the duration categories. Since the moderate-duration category results in larger reductions in the RWL than the short-duration category, there is less need for a recovery period between sessions than for the short duration category. In other words, the short duration category would result in higher weight limits than the moderate duration category, so larger recovery periods would be needed.

3.5.3 Frequency Restrictions

Lifting frequency (F) for repetitive lifting may range from 0.2 lifts/min to a maximum frequency that is dependent on the vertical location of the object (V) and the duration of lifting (Table 5). Lifting above the maximum frequency results in a RWL of 0.0. (Except for the special case of discontinuous lifting discussed above, where the maximum frequency is 15 lifts/minute.)

3.5.4 Frequency Multiplier

The FM value depends upon the average number of lifts/min (F), the vertical location (V) of the hands at the origin, and the duration of continuous lifting. For lifting tasks with a frequency less than 2 lifts per minute, set the frequency equal to 2 lifts/minute. For infrequent lifting (i.e., F > 1 lift/minute), however, the recovery period will usually be sufficient to use the 1-hour duration category. The FM value is determined from Table 5.

Table 5
Frequency Multiplier Table (FM)

Frequency Lifts/min (F)	Work Duration					
	≤1 Hour		1 but ≤ 2 Hours		2 but ≤ 8 Hours	
	V < 30 t	V ≥30	V< 30	V ≥30	V< 30	V≥ 30
≤0.2	1.00	1.00	.95	.95	85	.85
0.5	.97	.97	.92	.92	81	.81
1	.94	.94	.88	.88	75	.75
2	.91	.91	.84	.84	65	.65
3	.88	.88	.79	.79	55	.55
4	.84	.84	.72	.72	45	.45
5	.80	.80	.60	.60	35	.35
6	.75	.75	.50	.50	27	.27
7	.70	.70	.42	.42	22	.22
8	.60	.60	.35	.35	18	.18
9	.52	.52	.30	.30	00	.15
10	.45	.45	.26	.26	00	.13
11	.41	.41	.00	.23	00	.00
12	.37	.37	.00	.21	00	.00
13	.00	.34	.00	.00	00	.00
14	.00	.31	.00	.00	00	.00
15	.00	.28	.00	.00	00	.00
>15	.00	.00	.00	.00	00	.00

Va1lues of V are in inches For lifting less frequently than once per 5 minutes, set F =0. 2 lifts/minute.

3.5.5 Special Frequency Adjustment Procedure

A special procedure has been developed for determining the appropriate lifting frequency(F) for certain repetitive lifting tasks in which workers do not lift continuously during the 15 minute sampling period. This occurs when the work pattern is such that the worker lifts repetitively for a short time and then performs light work for a short time before starting another cycle, As long as the actual lifting frequency does not exceed 15 lifts per minute, the lifting frequency (F) may be determined for tasks such as this as follows:

1. Compute the total number of lifts performed for the 15 minute period (i.e., lift rate times work time).
2. Divide the total number of lifts by 15.
3. Use the resulting value as the frequency (F) to determine the frequency multiplier (FM) from Table 5.

For example, if the work pattern for a job consists of a series of cyclic sessions requiring 8 minutes of lifting followed by 7 minutes of light work, and the lifting rate during the work sessions is l0 lifts per minute, then the frequency rate (F) that is used to determine the frequency multiplier for this job is equal to (10 x 8)/15 or 5.33 lifts/minute. If the worker lifted continuously for more than 15 minutes, however, then the actual lifting frequency (10 lifts per minutes) would be used.

When using this special procedure, the duration category is based on the magnitude of the recovery periods between work sessions, not within work sessions. In other words, if the work pattern is intermittent and the special procedure applies, then the intermittent recovery periods for purposes of determining the duration category. For example, if the work pattern for a manual lifting at a rate of 10 lifts/minute, followed by 2 minutes of recovery, the correct procedure would be to adjust the frequency according to the special procedure [i.e., F = (10 lifts/minute X 5 minutes)/ 15 minutes = 50/15 = 3.4 lifts/minute/]. the 2 minute recovery periods would not count towards the WT/RT ratio, however, and additional recovery periods would have to be provided as described above.

3.6 Coupling Component

3.6.1 Definition & Measurement

The nature of the hand to object coupling or gripping method can affect not only the maximum force a worker can or must exert on the object, but also the vertical location of the hands during the lift. A good coupling will reduce the maximum grasp forces required and increase the acceptable weight for lifting, while a poor coupling will generally require higher maximum grasp forces and decrease the acceptable weight for lifting.

The effectiveness of the coupling is not static, but may vary with the distance of the object, from the ground, so that a good coupling could become a poor coupling during a single lift. The entire range of the lift should be considered when classifying hand-to-object couplings with classification based pm overall effectiveness. The analyst must classify the coupling as good, fair, or poor. The classifying a particular coupling design, the more stressful classification should be selected.

Table 6
Hand-to-Container Coupling Classification

1. For Containers of optimal design, such as some boxes, crates, etc., a "Good" hand-to-object coupling would be defined as handles or hand-hold cut-outs of optimal design [see notes 1 to 3 below]	1. For containers of optimal design, a "Fair" hand-to-object coupling would be defined as handles or hand-hold cut-outs of less than optimal design [see notes 1 to 4 below.]	1. Containers of less than optimal design or irregular objects that are bulky, hard to handle, or have sharp edges [see note 5 below.]
2. For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object [see not 6 below.]	2. For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be fixed about 90 degrees [see note 4 below.]	2. Lifting non-rigid bags (i.e., bags that sag in the middle).

1. An optimal handle design has .75 - 1.5 inches (1.9 to 3.8 cm) diameter, > 4.5 inches (11.5 cm) length, 2 inches (5 cm) clearance, cylindrical shape, and a smooth, non-slip surface.
2. An optimal hand-hold cut-out has the following approximate characteristics: ≥ 1.5 inch (3.8 cm) height, 4.5 inch (11.5 cm) length, semi-oval shape, ≥ 2 inch (5 cm) clearance, smooth non-slip surface, and ≥ 0.25 inches (0.60 cm) container thickness (e.g., double thickness cardboard)
3. An optimal container design has ≤ 16 inches (40 cm) frontal length, ≤ 12 inches (30 cm) height, and a smooth non-slip surface.
4. A worker should be capable of clamping the fingers at nearly 90^0 under the container, such as required when lifting a cardboard box from the floor.
5. A container is considered less than optimal if it has a frontal length > l6 inches (40 cm), height > 12 inches (30 cm), rough or slippery surfaces, sharp edges, asymmetric center of mass, unstable considered bulky if the load cannot easily be balances between the hand-grasps.
6. A worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations or awkward postures, and the grip should not require excessive force.

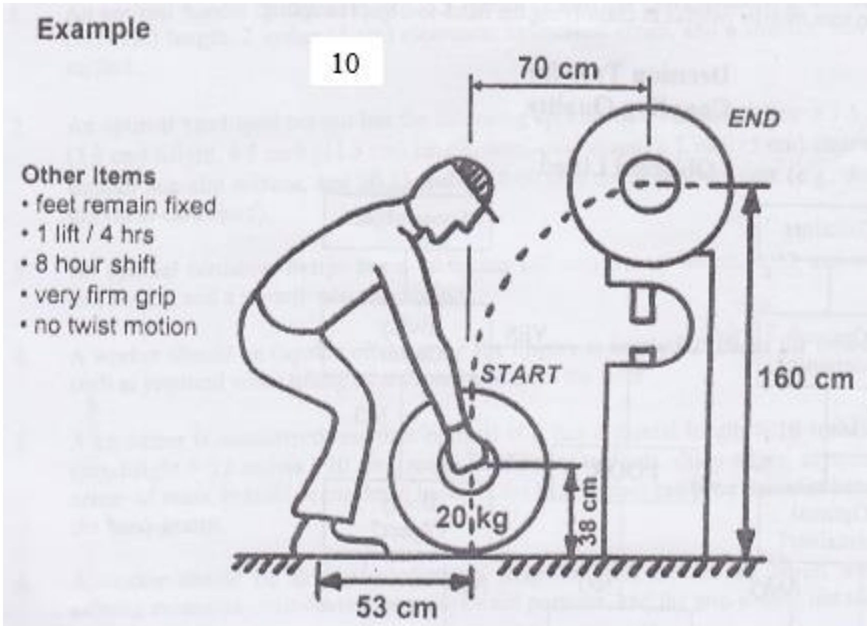
3.6.2 Coupling Multiplier 3

Based on the coupling classification and vertical location of the lift, the Coupling Multiplier (CM) is determined from Table 7.

Table 7
Coupling Multiplier

Coupling Type	Coupling Multiplier	
	V < 30 inches (75 cm)	V≥ 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Example



Job analysis Worksheet

Department.. Job Description.......................................

Job Title.. ....

Analyst's Name... ....

Date.. ....

Step 1. Measure and Record Task Variables

Object Weight		Hand Location				Vert. Dist.	Angle		Freq	Time	Object Coupling
		Origin		Dest.			Origin	Dest.	Lifts/min	HRS	
Avg	Max	H	V	H	V	D	A	A	F		C
20	20	53	38	63	160	122	0	0	0.2	8	Good

Horizontal Body-to-Hand Distance (feet are locked in place)
= 53 cm + 10 cm
= 63 cm

Total Vertical Lift
= Dest. – Origin
= 160 cm – 38 cm
= 122 cm

Minimum NIOSH Value Reportable

Step 2. Determine Multipliers and Compute RWL

RWL = LC x HM x VM x DM x AM x FM x CM

Origin RWL = 23 x 0.47 x0.889 x 0.856 x 1 x 0.85 x 1 = 7.02kg
Destination RWL = 23 x 0.4 x 0.745x 0.856 x 1 x 0.85 x 1 =4.99 kg

Origin of Lift
LC = 23 kg = fixed factor
HM = 25/H = 25/53 = 0.47
VM = 1-0.003(V-75) = 1-0.003(38-75) = 0.889
DM = 0.82 + (4.5/D) = 0.82 + (4.5/122) = 0.856
AM = 1 - 0.0032A = 1 - 0.0032(0) = 1
FM : 0.85 (since l lift/4 hrs = 0.004 lifts/min = approx. 0 on graph)
CM : 1.0, (since V = 75 cm and "good" grip)

Destination of Lift
LC = 23 kg = fixed factor
HM = 25/H = 25/63 = 0.4
VM = 1 - 0.003(V-75) = 1 - 0.003 (160 - 75) = 0.889
DM = 0.82 + (4.5/D) = 0.82 + (4.5/122)= 0.856
FM = 0.85 (since 1lift/4 hrs = 0.004 lifts/min = approx.0 on graph)
CM = 1.0, (since V = 75 cm and "good" grip

Step 3. Compute the Lifting index
Origin Lifting Index = Weight / RWL = 20/7.02 = 2.85
Destination Lifting Index : Weight / RWL. = 20/4.99 = 4

Conclusion
* Origin: the start of the lift is acceptable and safe since L1 < 3
* Destination : the end of the lift is dangerous since L1> 3. The "stress level" is LI : 4, the larger of the values. This could be the point where serious low back injury will occur. The task setup must be changed at the destination, or increased job screening, medical monitoring, and training must be introduced.

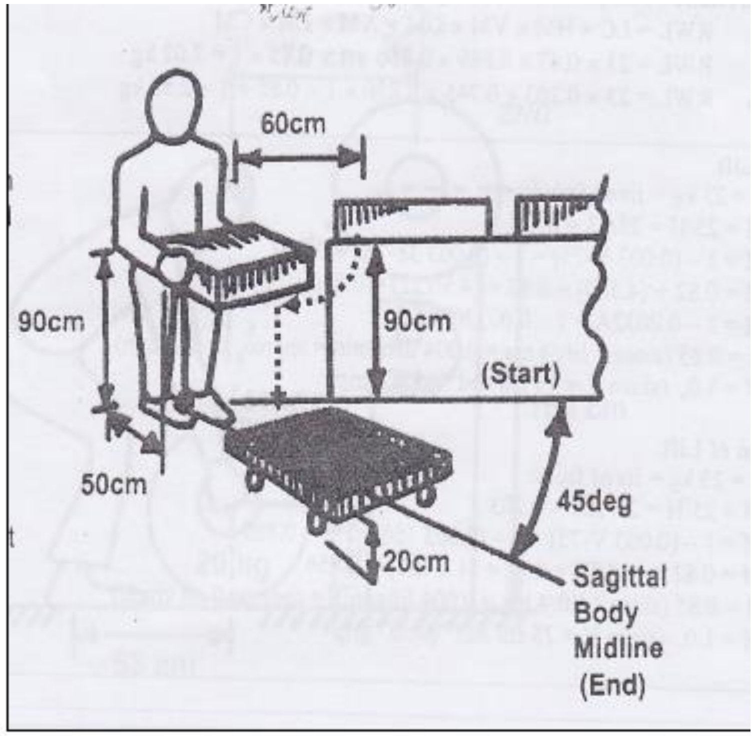
Problem 1

Task

Moving trays from conveyor belt and putting them on the cart

Other Items

* 10 kg trays
* 1 lift/min
* 4 hour shift
* feet are fixed ,
* “fair” grip
* upper body twist motion at START
* tray placed straight down onto cart at END



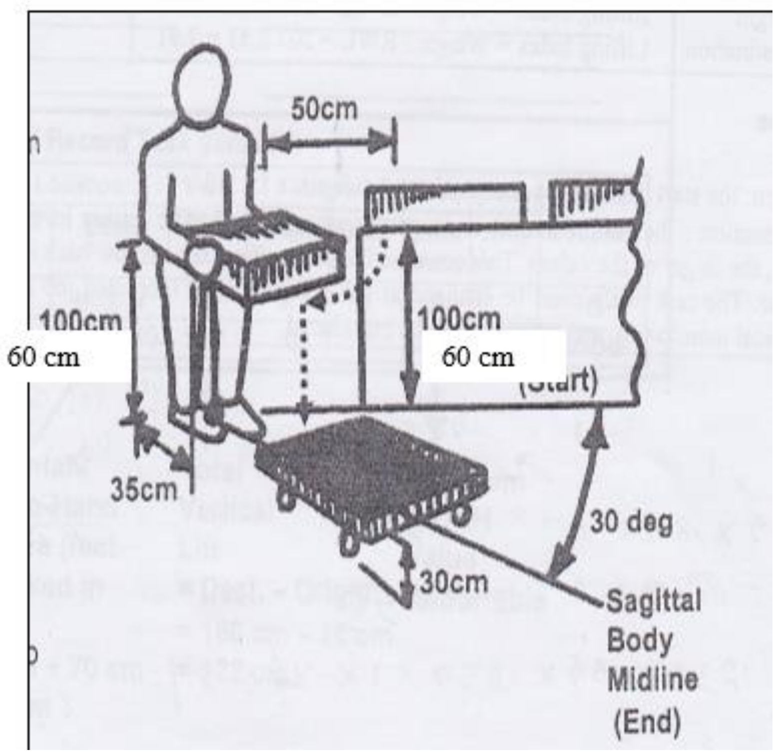
Problem 2

Task

Moving boxes from conveyor belt & placing them onto a cart

Other Items

* 15 kg boxes
* 3 lifts/min
* 3 hour shift
* feet are fixed
* “pool'” grip
* upper body twist motion at START
* boxes placed straight down onto cart at END



Job analysis Worksheet

Department... Job Description..

Job Title.. ....

Analyst’s Name.. ....

Date.. ....

Measure and Record Task Variables

Object Weight		Hand Location				Vert. Dist.	Angle		Freq	Time	Object Coupling
		Origin		Dest.			Origin	Dest.	Lifts/min	HRS	
Avg	Max	H	V	H	V	D	A	A	F		C

Experiment No: 5

Name of the experiment: Design of workstation by Applying Ergonomic Principles

Introduction

Ergonomic considerations in workspace design helps to achieve a "transparent' interface between the user and the task that users are not distracted by the equipment they are using, Distraction may be due to discomfort (e.g., numbness in the buttocks)or to workstation usability problem.

The reduction of postural stress is fundamental to worldfation design in ergonomics. A multifaceted approach is needed to arrive at appropriate workstation designs for different workers. The requirements of tasks and the characteristics of users need to be considered in relation to the options of workstation design,

Objective

The objective of this experiment is to design a workstation using ergonomic principles.

Methodology:

1. Take the relevant anthropometric measurements of the user.
2. Design the workstation using ergonomic principles (with the help of anthropometric data),

Ergonomic principles for workstation design:

Ergonomic Des Considerations-
* Product/equipment
* Job aids
* User selection
* Training of user

Follow the 14 guidelines given below for designing ergonomic workstation.

Guideline 1
Avoid Static Loads and Fixed Work postures

* Static load increases systolic and diastolic blood pressure,
* Metabolic wastes accumulate in the muscles.
* Consider increasing recovery time,

Standing

* Shoes affect center of gravity and forward bending moment,
* Have hips parallel to the floor,
* Provide bar rail to vary work posture.
* Hard floors cause standing fatigue and increase heart rate,

Falls

* Slips and falls are a major cause of unintentional injury deaths and have annual direct cost/capita of $50-400.
* **Cause of falls:**

- Slips: unexpected horizontal foot movement

- Trips: restriction of foot movement
- Stepping-on-air: unexpected vertical foot movement

Solutions for Falls

*** Prevent the fall:**

- Use well-designed ladders, scaffolds, and ramps properly.
- Provide safe steps.
- Use the three-contact rule.
- Provide good friction and reduce lubricants.

*** Reduce the consequences of the fall:**

- Interrupt the fall.
- Soften the impact.

Head Weight

* The head weighs about the same as a bowling ball.
* Keep the line of sight below the horizontal.
* Maintain forward head tilt of 100-150°
* Avoid backward and sideward tilts.

Hands/Arms

* An arm weighs about 4.4 kg.
* Avoid using the hand to hold up a tool or work piece,
* Avoid working with elevated hands,
* Support the arms on the work surface or chair arms.
* Consider using magnification.

Guideline 2

Reduce Musculoskeletal Disorders

* Set the work height at 50 mm below the elbow. Don't bend your wrist.
* Don't lift your elbow.
* Don't reach behind your back.
* Fallow guidelines for hand and arm motions.

Guideline 3

Set the Work Height at 50 mm Below the Elbow

* Work height is defined in terms of elbow height.
* Optimum height is slightly below the elbow.
* Optimum height from the elbow is the same for sitting and standing, * Work height is not table height.

Solutions for Work Height

* Change machine height.
* Adjust elbow height.
* Adjust work height on machine.

Multiple-level tables permit easy work height adjustment. In the top view, parts with the same thickness can be processed by different people using different portions of the table. In the lower view. the same person can process parts with different thicknesses using different portions of the table.

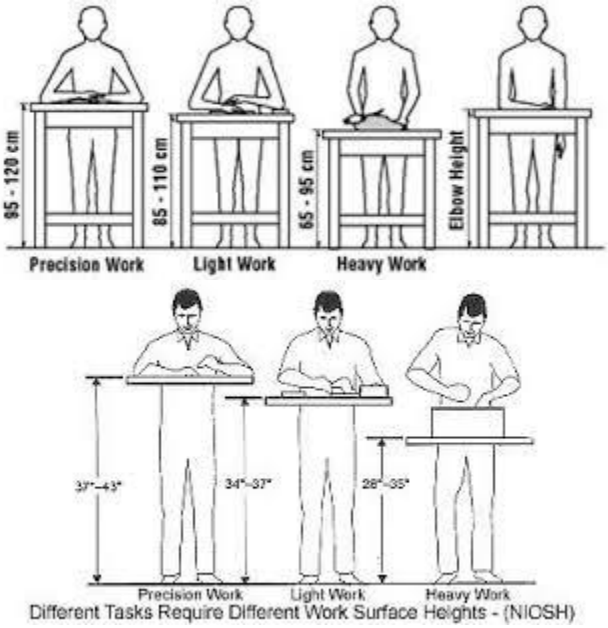


Figure 5.1: Multiple level table

VDT Workstations

- Key items: screen, keyboard, document, eyes, hands
- Workstation furniture must be adjustable.
- Locate the primary visual element first: ahead of the eye, perpendicular to the line of sight.
- Train the operation in adjusting the equipment.
- Provide a wrist rest.

Guideline 4
Furnish Every Employee with an Adjustable Chair

- The cost of an adjustable chair is very low compared to labor cost.
- Allow users to try chairs in their specific jobs.
- Buy chairs that are easily adjustable.
- Train people in proper adjustment.

Chair Design

- Seats
  - Seat height from floor
  - seat length
  - seat width
  - slope of seat
  - seat shape

Table 13.3:

Recommended dimensions for office chairs (Chaffin et al., 1999). Dimensions are in cm, angles in degrees.

FEATURE	BRITISH STD. (BS 3079 & 3893)	EUROPEAN (CEN)	DIFFERENT ET AL.	DANERO & ZELNIK	GRAND JEAN	GERMAN STD. (D EN)	SWEDISH STD. (SS)
Seat							
Height	43-51	39-54	35-52	36-51	38-53	42-54	39-51
Width (breadth)	41	40	41	43-48	40-45	40-45	42
Length (depth)	36-47	38-47	33-41	39-41	38-42	38-42	38-43
Skyic angle	0-5	0-5	0-5	0-5	4-6	0-4	0-4
Backrest							
Top height	33				48-50	32	
Botttom height	20						
Center height		17-26	23-25	19-25	30	17-23	17-22
Height		10	15-23	10-20		22	22
Width (breadth)	30-36	36-40	33	25	32-36	36-40	36-40
Horizontal radius	31-46	40mm	31-46		40-50	40-70	40-60
Vertical radios	convex						
Backrest seal	95-105		35-100	95-105			
Armtest							
Length	22	20	15-21			20-28	20
Width (breadth)	4	4	6-9				4
Height	16-23	21-25	18-25	20-25		21-25	21-25
Intearm rest	47-56	46-50	48-56	46-51		48-50	46

* Backrests

    – position of backrest
    - molded chair back position & curvature
* Armrests
* Legs/pedestals
    – clearance of feet and calves under chair

Guideline 5
Use the Feet as Well as the Hands

* The leg is slower and less dexterous than the hands.
* The legs can provide 3 times the power of the arms.
* Use pedals for power and control.

Guideline 6
Use Gravity; Don't oppose it

* Make movements horizontal or downward; avoid lifting.
* Consider using the weight of the body to increase mechanical force.
* Use gravity to move material to the work.
* Use gravity as a fixture.
* Use gravity in feeding and disposal.

Guideline 7
Conserve Momentum

* Avoid unnecessary acceleration and deceleration.
* Use circular motion for stirring and polishing.
* Follow through in disposal motions.
* Eliminate grasping motions by providing lips, rolled edges, and holes. Avoid transporting weight in the hand,

Guideline 8
Use 2-Hand Motions Rather Than 1-Hand Motions

* Cranking with 2 arms is 25% more efficient than with one.
* Using 2 hands is more productive despite taking more time and effort.
* Don't use the hand as a fixture.

Guideline 9
Use Parallel Motions for Eye Control of 2-Hand Motions

* Minimize the degree of spread rather than worry about symmetry.
* Estimate the cost of eye control with predetermined time systems.

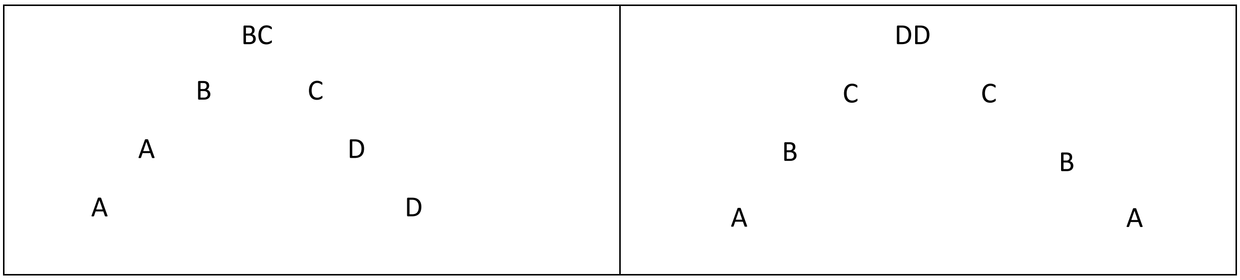


Figure 5.2: Parallel vs Symmetrical motions

Parallel motions:
- Shoulder moves
- Easy eye travel

Symmetrical motions:
- Shoulder steady
- Difficult eye

Guideline 10

Use Rowing Motions for 2-Hand Motions

* Alternation causes movement of the shoulder and twisting of the torso.
* Alternation causes higher heart rate.
* Rowing motions are more efficient and provide greater power

Guideline 11

Pivot Motions About the Elbow

* Motion time is minimized with motion about the elbow.
* Cross-body movements are more accurate than those about the elbow.
* Physiological cost is lower for movements about the elboW.

Guideline 12
Use the Preferred Hand

* The dominant hand is:
  - ✓ 10% faster for reach-type motions.
  - ✓ More accurate than the non-dominant.
  - ✓ More exposed to cumulative trauma
  - ✓ 5% to 10% stronger.
* Work should arrive from the operator's preferred side and leave from the no preferred side.

Guideline 13
Keep Arm Motions in the Normal Work Area

* Avoid long benches.
* Use swingarms and lazy Susans.
* For high use, keep it close.
* Remember the arm pivots on the shoulder, not the nose.

* The shoulder is very sensitive to small changes in workplace layout.

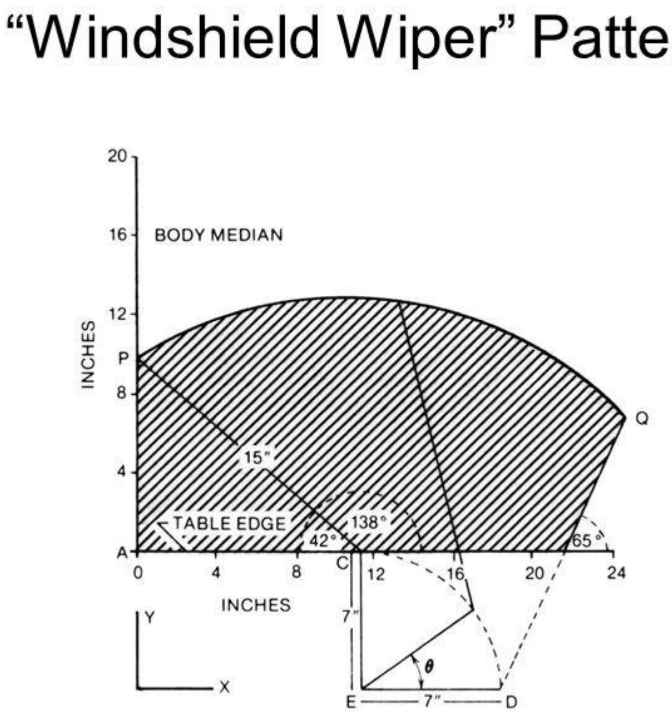


Figure 5.3: "Windshield Wiper" pattern

Guideline 14

Let the Small Person Reach; Let the Large Person Fit

* Design so most of the user population can use the design.
* Jobs must be designed for both sexes.
* Mufti person use of equipment and Station is becoming more common.
* Civilian industrial population data are not the same as military data.
* International populations be a consideration.
* The proportion to exclude depends on the seriousness of designing people out and the cost of including more people.

Ways to Exclude Few

* One size fits all
* Multiple sizes
* Adjustability

Experiment No: 6

Experiment Name: Preperation of Hazard Evaluation Worksheet (task based) for a Workstation

Introduction

A hazard analysis is one of the most important elements of the safety management program. A hazard analysis is an organized and systematic effort to identify and analyze the significance of potential hazards in work place. This analysis provides information that will assist employers and employees in making decisions for improving safety and reducing the consequences of unwanted or unplanned hazardous situation. The hazard analysis should focuses on equipment, instrumentation, utilities, human actions (routine and no routine), and external factors that might impact the process. These considerations assist in determining the hazards and potential failure points or failure modes in a process.

Objective

Objective of this experiment is to identify hazards and evaluating risks in structured and systematic way in order to prioritize decisions to reduce risks to a tolerable level.

Methodology

1. Identify potential hazards in the workplace using the hazard evaluation checklist.
2. Evaluating risk by using risk calculator.
3. Decide corrective actions.
4. Preparing the task-based Hazard Evaluation Worksheet.

Theory

Risk: Chance (Probabilty) of exposure to a hazard combined with the consequences of such exposure.
Hazard: Source or potential source.
Harm: Injury or damage to health, damage to environment, economic loss etc.
Risk: Probability of Exposure * Severity, i.e. F (likelihood* consequences)

Risk Matrix

Likelihood ↑

<table>
<tr><td>Likely</td><td rowspan="2">B</td><td rowspan="2">A</td><td rowspan="3">A</td><td rowspan="4">A</td></tr>
<tr><td>Probable</td></tr>
<tr><td>Possible</td><td rowspan="3">C</td><td rowspan="2">B</td></tr>
<tr><td>Improbable</td><td rowspan="2">B</td></tr>
<tr><td>Remote</td><td>C</td><td>B</td></tr>
<tr><td></td><td>Minor</td><td>Major</td><td>Severe</td><td>Fatal</td></tr>
</table>

→ Consequences (Severity)

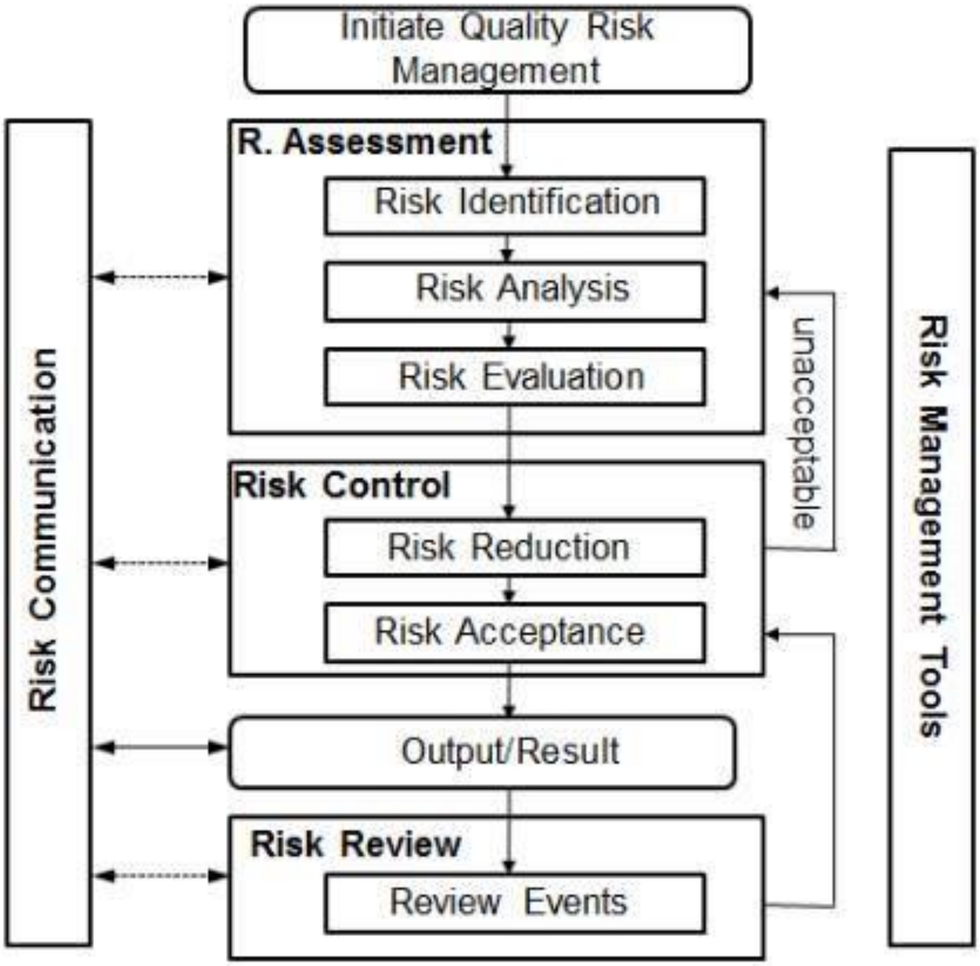


Figure 6.1: Risk Management

Hazards Identification Checklist. (Sheet 1 of 2)

TYPE OF HAZARD	SOURCE	WHO IS EXPOSED and WHEN
1. Mechanical Hazards		
1.1 Crushing		
1.2 Shearing		
1.3 Cutting/Severing		
1.4 Entanglement		
1.5 Drawing-in/Trapping		
1.6 Impact		
1.7 Stabbing/Puncture		
1.8 Friction/Abrasion		
1.9 High pressure fluid injection		
1.10 Slips/Trips/Falls		
1.11 Falling object		
1.12 Other mechanical hazards		
2. Electrical Hazards		
2.1 Direct contact		
2.2 Indirect contact		
2.3 Electrostatic phenomena		
2.4 Short circuit/overload		
2.5 Source of ignition		
2.6 Other electrical hazards		
3. Radiation Hazards		
3.1 Lasers		
3.2 Electro-magnetic effects		
3.3 Ionising/Non-ionising radiation		
3.4 Other radiation hazards		

TYPE OF HAZARD	SOURCE	WHO IS EXPOSED and WHEN
4. Hazardous Substances (THINK COSHH)		
4.1 Toxic fluids		
4.2 Toxic gas/mist/fumes/dust		
4.3 Flammable fluids		
4.4 Flammable gas/mist/fumes/dust		
4.5 Explosive substances		
4.6 Biological substances		
4.7 Other hazardous substances		
5. Work Activity Hazards		
5.1 Highly repetitive actions		
5.2 Stressful posture		
5.3 Lifting/Handling heavy items		
5.4 Mental overload/Stress		
5.5 Visual fatigue		
5.6 Poor workplace design		
5.7 Other workplace hazards		
6. Work Environment Hazards		
6.1 Localised hot surfaces		
6.2 Localised cold surfaces		
6.3 Significant noise		
6.4 Significant vibration		
6.5 Poor lighting		
6.6 Hot/Cold ambient temperature		
6.7 Other environment hazards		
Use this completed list to produce your Risk Assessment.		

Estimation/Measurement of Risks

Risk may be described in qualitative, semi-qualitativ or quantitative terms:

- Qualitative risk- no figures, judgement is used to estimate risk level
- Semi- quantitative risk- risks may be ranked on a sci·llgaiatlve scale or using .
- Quantitative risk - risk may be described sa frequency or probability in absolute terms.

The risk matrix gives a clear definition of risk. If it was estimated that the chance of the operator exposed to explosion hazard is remote, but the exposure will result in a fatality, the matrix shows this risk level as 'B '. ·

If on the other hand it was estimated that the chance of oil leaking out of a machine which would result in a person slipping is likely. This is expected to result in minor injury which is ranked by the matrix also as risk level 'B'. Therefore risk is not judged by the consequences alone.

Evaluation of Risks

One of the most important steps in risk assessment is to evaluate risks, which are to determine whether the level of risk is tolerable - or unacceptably high and would warrant some urgent attention.

Evaluation 'of risks will depend on the method used for estimating the risk. Risk evaluation could be carried out qualitatively, semi quantitative or quantitative.

- Qualitative risk- judgement is used , difficult to prioritize.
- Semi-quantitative risk - decide which area of the risk matrix.
- Quantitative risk - use the HSE criteria for tolerability of risk if a fatal accident can result from exposure to the hazards.

The Risk Matrix can be a tool to estimate and evaluate risks on a semi guantitative basis. The criteria used for risk evaluation is as follows:

- Risk level 'A' would be regarded as 'Intolerable'. Relevant activity cannot be justified on any grounds.
- Risk level 'B' is a region of uncertainty. Risk assessment is needed to ensure that risks in this region are As Low As Reasonably Practicable or '**ALARP'.**
- Risk level 'C' is broadly tolerable. No further action is necessary.

The Risk Calculator

There arc several drawbacks with the criterion described so far for the estimation and evaluation of risks, as they either focus attention on potential fatal accidents or they miss out a vital component in measuring risk. Thi s is the proportion of time person(s) are exposed to the hazard.

One of the main differences between this risk calculator and other risk matrices, is that the calculator takes into account the frequency and duration of exposure of hazards. The risk calculator is primarily based on a Normogram introduced in the British Standard BS 5304: 1988 (machinery safety) .
·
The basic elements in calculating the order of magnitude of risk are:

- The **chance** which hazard is likely to occur ('probability level') -- this ranges from frequent or 1 in 10, to extremely remote, 1 in1 million. The probabilities are used to describe the Order of magnitude of what is meant by probable, remote, ...etc.

- The **frequency and duration of exposure** to hazard -- this is measured on a scale ranging form very rare or less than 1%, to continuous exposure 100% of the time.

- The **consequences** or potential severity of injury/damage, measured on a scale ranging from category (I) minor loss/first aid, to category (VI) multiple fatalities/total loss ......etc.

By connecting th e appropriate points on each scale and using the tie line in ·the middle of the calculator, it is possible to determine the level of risk involved. The risk leve l is divided into four general categories.

- High risk (A) - which indicates that the level of risk is unacceptable and cannot be justified on any grounds.

- Moderate risk (B)- which indicates that the level of risk should be reduced to a level as low as reasonably practicable 'ALARP', and

- Low risk (C) - which indicates that the level of risk is broadly acceptable and no further precautions should be necessary.

Analysis of the Consequences

Consequences

	I	II	III	IV	V	VI
Personnel	Insignificant	minor	major	severe	fatality	Multi-fatalities
Economic	<£1000	<£10,000	<£100,000	<£1million	<£1million	Total loss
Environment	minor	Short term	major	severe	widespread	catastrophe

Catagory	Description	Examples
I	insignificant	Bruising, light abrasion etc
II	Minor	'first aid'(normally reversible)
III	Major	Lossof consciousness, burns etc. (3 days off work
IV	Severe	Serious injury/damage to health (norn1ally reversible)
V	Fatality	Permanent disability, loss of sight, amputation, respiratory damage etc (not reversible)
VI	Multi-fatalities	To in: ude delayed effects, catastrophic

Risk Assessment Case Studies

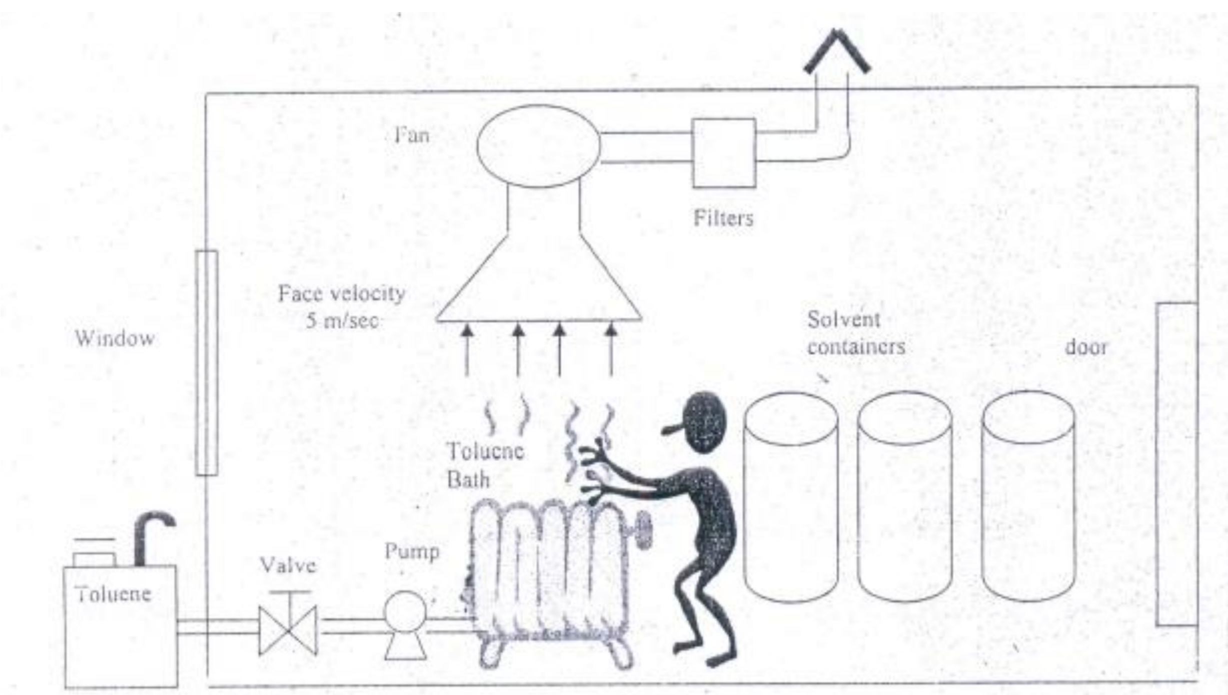


Figure 6.2: Risk Assessment Case Studies

Example of hazard identification and analysis work sheet (task based)

Machine /process/activity Metal cleaning shop		Hazard Analysis Study Reference		Sheet ……2…… of …..5……	
ACTIVITY TYPE	**Hazardous Events Error/Failure**	**POSSIBLE CAUSES**	**CONSEQUENCES**	**RISK LEVEL**	**CONTROL MEASURES/ACTION REQUIRED**
Filling cleaning tank with Toluene	Overfilling tank	Operator does not switch pump off	Increased toxic and flammable concentration	B	Action: consider high level alarm and pump trip
		Pump fails to stop (electrical fault)	Same as above	A/B	Action: same as above as well as emergency stop
Switch tank heater ON	toluene overheated	Thermostat fails	Major fire	A	Action: consider temperature indicator and alarm + procedure
	toluene not heated	Thermocouple fails	Valves not cleaned	B/C	Same as above
Dipping metallic components inside cleaning tank	Operator fails in tank	Loss of ability	fatality	A	Action: review tank height and consider mechanical handling
	Too many valves put in basket	Cut down cleaning time	Valves fall into tank/upper limb disorder	B	Action: review basket design + consider mechanical handling
		Tank topped up with other chemical	Possible reaction	B	Action: remove chemical drums from the workplace
	Toluene may be contaminated	Delivery of toluene already contaminated	Possible high level of benzene, water, etc.	B/C	Action: insure supplier compile with ISO 9000+sample
		Lack of maintenance	Explosion to high concentrations	B	Action: introduce planned preventive maintenance PPM
	Tank may leak	Impact by mobile equipment	Same as above	B	Action: remove all sources of impact

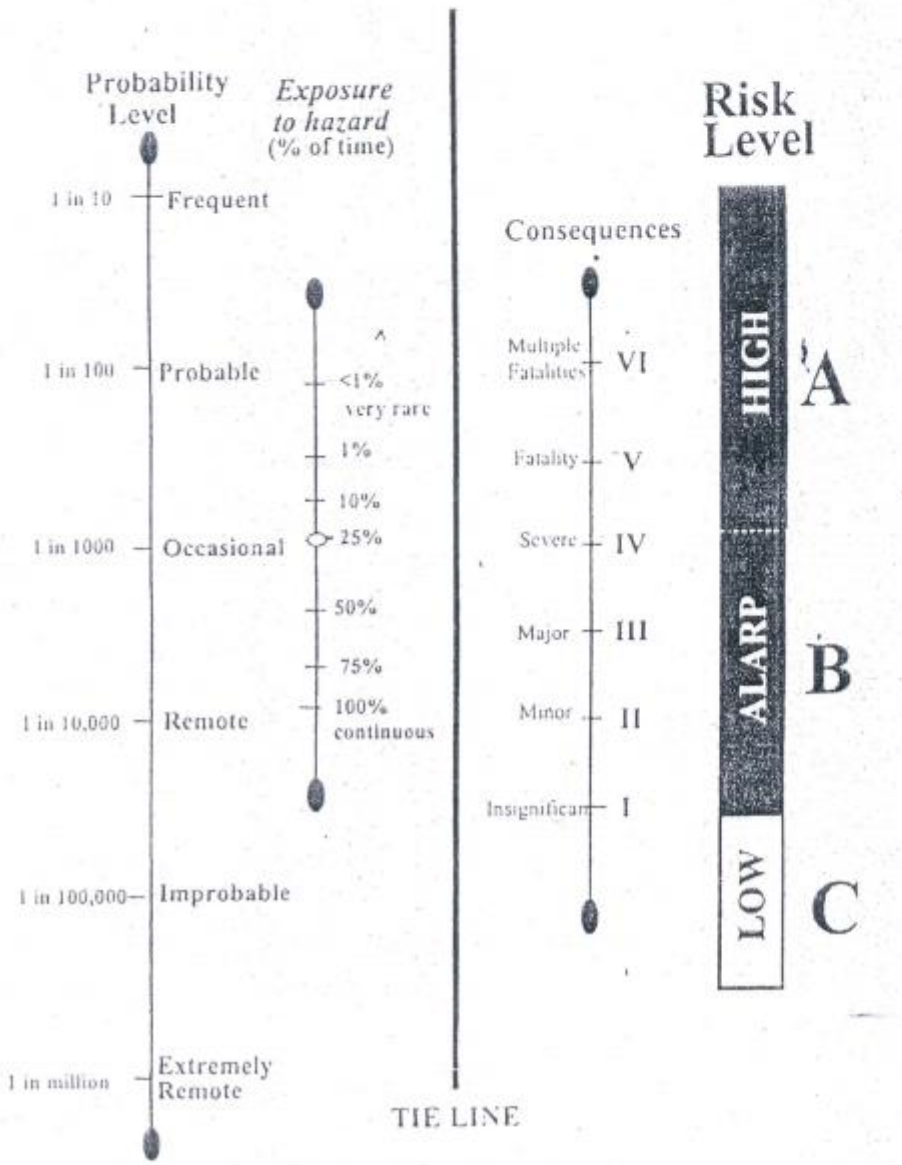


Figure 6.3: Risk level

Experiment No: 7

Experiment Name: Determination of Light Level in different workplaces

Introduction

The majority of industrial tasks depend for their effeciency on adequate vision, therefore lighting plays an important part in determining the efficiency with which tasks are carried out. The amount of light required for the performance of a visual task is influenced by four factors which are independent. These are:

I. The size of the object
II. The contrast between the object and its immediate surround
III. The reflectivity of the immediate surround
IV. Time allowed for seeing.

The amount of which is required for the task cannot be determined until all these factors have been established.

Objective

In this experiment, students have to determine the illumination level of a number of workstations.. They are also required to critically analyze the findings and comment for improvements (if any).

Apparatus

1. Light Meter

Procedure

1. Measure the light intensity of the workplace assigned.
2. Identify whether existing lighting system is adequate or not for the specific workplace.
3. Comment for improvements (if any).

Light Meter

The instrument is easy to use with pocket size and light weight, providing accurate display light level in terms of Foot Candles (FC) or LUX over wide range.

Fig 7.1: Light Meter

1. LCD Display
2. Power / function/ range switch: Turn power ON/ OFF and select measurement function and ranges.
3. Photo Detector
4. Max Hold: To hold maximum reading.
5. Data Hold: To hold the reading.
6. Function button: Select measurement functions of Lux or Fc

Operation:

1. Turn the power switch to select range to desired lux/fc range.
2. Hold the “Photo Detector” to light source in a horizontal position.
3. Read the illunination nominal from the LCD display.
4. To hold a measurement , press the “Hold” button, the reading will freeze in the display until the button is pressed again.
5. If the input signal is too strong, the instrument will display one “1” only , then a hoigher range should be selected.
6. For measurements made on the Lux 20000 or 50000 range, the displayed reading must be multiplied by 10 and 100 respectively.

Table: Range Display Multiplier

Range	Units	Multiplier
200	Fc	Direct reading
2,000	Fc & Lux	Direct reading
20,000	Lux	Reading * 10
50,000	Lux	Reading * 100

Example: If a measurement on the 20,000 Lux range displays 500, then the actual measured value is 500 * 10=5000

The table below is guidance for recommended light level in different work spaces:

Activity	Illumination *(lux, lumen/m²)*
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000
Performance of very prolonged and exacting visual tasks	5000 - 10000
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000

Assigned Workplaces

1. Machine Shop (Lathe, Milling)
2. Machine Shop (Drilling, Grinding)
3. Welding Shop
4. Measurement Lab
5. Drawing Lab
6. Computer Lab
7. Classroom
8. Departmental Office Room
9. Library

Experiment No: 8

Experiment Name: Performing time study in workplace

Introduction

Work measurement is concerned with determining the length of time it should take to complete the job. Time standard provides an indication of expected output. It reflects the amount of time it should take an average worker to do a given job working under typical condition. It is a study of the operational steps or production procedure and the time consumed by them for the purpose of devising methods of increasing efficiency or productivity of workers. This work-study aims at improving the existing and proposed ways of doing work and establishing standard times for work performance. Improving the ways in which the work is done (methods) improves productivity, work study and industrial engineering techniques and training are the areas which improve the work methods, which in term enhances the productivity.

Time study was formally introduced by Frederick Taylor in nineteenth century. It is the most widely used method of work measurement; especially appropriate for short, repetitive tasks.

Objective

In this experiment, students have to determine standard work time for workers in their assigned workplaces. They are also required to critically analyze the findings and comment for further produtivity improvements (if any).

Apparatus

1. Stop Watch

Procedure

1. Obtain and record all the job information.
2. Define the task to be studied and inform the worker(s) who will be studied.

3. Break down the operation into elements.
4. Determine the number of cycles to be observed.
5. Check that the job is being performed efficiently before setting the time standard.
6. Measure the time of the each job element using stop watch.
7. Assess the effective working speed of the operator and rate the performance.
8. Determine the allowances to be made.
9. Compute the standard time.
10. Test and review standards wherever necessary.

Standard Time

Standard time is the amount of time a qualified worker should spend to complete a specified task, working at sustainable rate, using given methods, tools and equipment, raw material and workplace arrangement.

Time study is used to develop a time standard based on observations of one worker taken over a number of cycles. However, it is very difficult to select the right person who should perform the job. Hence, average of a few properly trained workers' performed time are taken as the standard. The standard time is then applied to the work of all others in the organization who perform the same job.

Development of a time standard involves computation of 3 times:

I. Observed time (OT)
II. Normal time (NT)
III. Standard time (ST)

I. Observed Time (OT): Simply the average of the recorded times.

$$OT = \frac{\sum x_i}{n}$$

$\sum x_i =$ sum of recorded time

n = number of observations

II. Normal Time (NT): It is the observed time adjusted for worker performance.

Computed by multiplying the observed time by a performance rating of the concerned worker.

$$NT = OT * PR$$

If ratings are made on an element-by-element basis,

$$NT = \sum (OT_i * PR_i)$$

OT_i – average time for element i

PR_i – performance rating for element i

Performance Rating : Assessing the effective speed of working of the operator relative to the observer's concept of the rate corresponding to standard rating.

Time studies should be made on a number of qualified workers; and that very fast or very slow workers should be avoided.

III. Standard Time (ST): It is the normal time required for a job plus an allowance time.

$$ST = NT * AF$$

AF= Allowance factor

Allowances: Many jobs require spending of human effort and some allowance must therefore be made for recovery from fatigue and for relaxation.

Allowance must be made to allow a worker for different delays:

- Personal – drink, restroom
- Unavoidable – machine adjustment
- Material shortage
- Worker fatigue (physical / mental)

Allowance can be based on

- Job time (allowance for total job produced) $AF_{job} = 1 + A$

- Time worked (allowance for total work period) $AF_{day} = \frac{1}{1-A}$

Assignment:

1. A direct time study was taken on a manual work element. The regular cycle consisted of four elements a, b, c and d.

Work element	**a**	**b**	**c**	**d**
Observed time (min)	0.56	0.25	0.50	1.10
Performance rating	100%	80%	110%	100%

Determine Standard time for the cycle, using allowance factor of 15%.

2. Find out the standard time using the following data:
Average time for machine elements = 6 min
Average time for manual elements = 4 min
Performance rating = 110%
Allowances = 10%

3. Assuming that the total observed time for an operation of assembling an electric switch is 1.00 min. If the rating is 120%, find normal time. If an allowance of 10% is allowed for the operation, determine the standard time.

4. In attempt to increase productivity and reduce cost, a company is planning to install an incentive pay plan in its manufacturing plant. In developing standards for one operation, time study analysts observed a worker for a 30 minute period. During that time the worker completed 42 parts. The analysts rated the worker as producing at 130 percent. The base wage rate for a worker is $5 per hour and an incentive of $ 2 for each extra unit produced. The firm has established 15% as a fatigue and personal time allowance.

i. What is the standard time for the task?

ii. If the worker produced 500 units during an eight hour day, what wages would be the worker have earned?

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

1st Year, 1st Semester

Student Name :

Student ID :

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 3202: Ergonomics and Productivity Engineering
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental results and discussions (Experimental setup, Experimental conditions, Data, Graph, calculation etc.)
    - Conclusions
    - Acknowledgements
    - References
5. A quiz will be taken on the experiments at the end of the semester.
6. Marks distribution:

Total Marks		
Report	Attendance	Quiz
40	10	50

Experiment No: 1

Experiment Name: Anthropometry Measurement

Introduction:

The term anthropometry is derived from two Greek words, anthropos, meaning man, and metros, meaning measurement. In other words, anthropometry is concerned with the measurements of human dimensions. Hundreds of these dimensions are possible, everything from common measurement of stature, or height, to the size of u human fingernail, but of these, a hundred or more have been defined as being useful for various purposes.

In using anthropometric measurements there are several things to bear in mind. One of these is the source of the measurements. All anthropometric tables present values that are statistical in nature. In other words they are derived as averages of multiple samples, sometimes from hundreds, sometimes from thousands of subjects. The larger the sample, the more representative it is or in statistical terms the greater is the accuracy of confidence in the measured value. The subjects in these simples are measured under standard conditions.

Objective:

The objectives off this lab are:

* To know how to perform anthropometrics measurement
* To process the measurements so as to be useful
* To apply the data in the design of workplace, workstation, tools and equipment to fit to the human body.

Methodology:

To calculate a percentile value, simply multiply the standard deviation S by a factor k, selected from table 1. Then add the product to the mean m:

$$p = m + k*S$$

If the desire d percentile is above the 50th percentile, the factor k has a positive sign and the product k*S is added to the mean m; if the p-value is below 50th percentile, k is negative and the product k*S is subtracted from the mean m. 1 the equation of mean m:

$$m = \left(\frac{\sum x}{n} \right)$$

m = mean

x = sample value

n = total of samples

The distribution of the data is described by the equation:

$$S = \sqrt{\frac{\sum (x-m)^2}{n}}$$

$$m_z = m_x - m_y$$

$$S_z = \sqrt{[S_z^2 + S_y^2 - 2r * S_x * S_y]}$$

Table 1: Percentile Values and Associated k Factors

Below Mean				Above Mean			
Percentile	Factor K	Percentile	Factor K	Percentile	Factor K	Percentile	Factor K
0.001	-4.25	31	-0.50	50	0	85	1.04
0.01	-3.72	32	-0.47	51	0.03	86	1.08
0.1	-3.09	33	-0.44	52	0.05	87	1.13
0.5	-2.58	34	-0.41	53	0.08	88	1.18
1	-2.33	35	-0.39	54	0.10	89	1.23
2	-2.05	36	-0.36	55	0.13	90	1.28
2.5	-1.96	37	-0.33	56	0.15	91	1.34
3	-1.88	38	-0.31	57	0.18	92	1.41
4	-1.75	39	-0.28	58	0.20	93	1.48
5	-1.64	40	-0.25	59	0.23	94	1.55
6	-1.55	41	-0.23	60	0.25	95	1.64
7	-1.48	42	-0.20	61	0.28	96	1.75
8	-1.41	43	-0.18	62	0.31	97	1.88
9	-1.34	44	-0.15	63	0.33	97.5	1.96
10	-1.24	45	-0.13	64	0.36	98	2.05
11	-1.23	46	-0.10	65	0.39	99	2.33
12	-1.18	47	-0.08	66	0.41	99.5	2.58
13	-1.13	48	-0.05	67	0.44	99.9	3.09
14	-1.08	49	-0.03	68	0.47	99.99	3.72
15	-1.04	50	0	69	0.50	99.999	4.26
16	-0.99			70	0.52		
17	-0.95			71	0.55		
18	-0.92			72	0.58		
19	-0.88			73	0.61		
20	-0.84			74	0.64		
21	-0.81			75	0.67		
22	-0.77			76	0.71		
23	-0.74			77	0.74		
24	-0.71			78	0.77		
25	-0.67			79	0.81		
26	-0.64			80	0.84		
27	-0.61			81	0.88		

28	-0.58			82	0.92		
29	-0.55			83	0.95		
30	-0.52			84	0.99		

Any percentile value p can be calculated from the mean m and the standard deviation.

<u>Result:</u> Anthropometry measurement

Dimentsion	Men				Women			
	5^{th} % ile	Mean	95^{th} % ile	SD	5^{th} % ile	Mean	95^{th} % ile	SD
Stature								
Eye Height, Standing								
Shoulder Height (Acromion), Standing								
Elbow Height, Standing								
Hip Height (Trochanter)								
Knuckle Height, Standing								
Finger Height, Standing								
Sitting Height								
Sitting Eye Height								
Sitting Shoulder Height								
Sittings Elbow Height								
Sitting Thigh Height								
Sittings Knee Height								
Sittings Popliteal Height								
Shoulder Elbow Length								
Elbow-Fingertip Length								
Overhead Grip Reach,								
Overhead Grip Reach,								
Forward Grip Reach								
Arm Length, Vertical								
Downward Grip Reach								
Chest Depth								
Abdominal Depth, Sitting								
Buttock-Knee Depth, Sitting								
Buttock-Popliteal Depth,								
Shoulder Breadth								
Shoulder Breadth (Bideltoid)								
Hip Breadth, Sitting								
Span								
Elbow Span								
Hand Length								
Hand Breadth								

See appendix for detail of anthropometric measurement

Appendix: <u>Body Dimensions:</u>

The required dimensions are as follows::
1. Stature: The vertical distance from to top of the head, when standing.
2. Eye Height, Standing: The vertical distance form the floor to the outer corner of the right eye, when standing.
3. Shoulder Height (Acromion), Standing: The vertical distance from the floor to the tip (acromion) of the shoulder, when standing.
4. Elbow Height, standing: The vertical distance from the floor to the lowest point of the right elbow, when standing
5. Hip Height (Trochanter), Standing: The vertical distance from the floor to the trochanter landmark on the upper side of the right thigh, when standing.
6. Knuckle Height, Standing: The vertical distance from the floor to the knuckle (metacarpal bone) of the middle finger of the right hand, when standing.

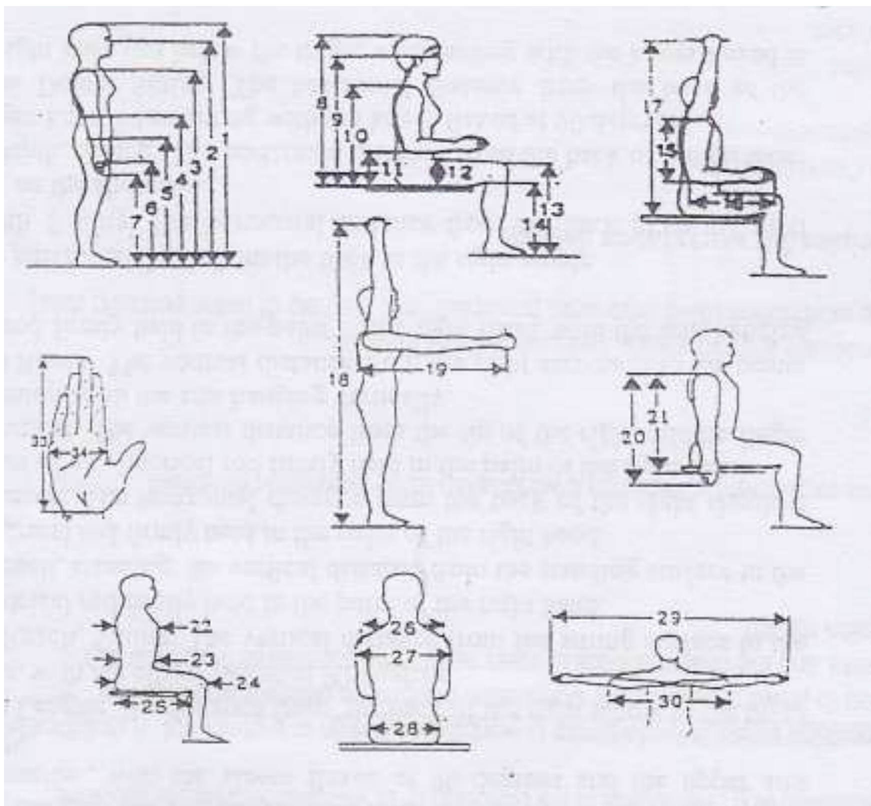


Fig: 1.1: Illustrations of Measured Body Dimensions
Fig: 1.1: Illustrations of Measured Body Dimensions

7. Fingertip Height, Standing: The vertical distance from the floor to the tip of the index finger of the right hand, when standing.
8. Sitting Height: the vertical distance form the sitting surface to the top of the head, when sitting.
9.Sitting Eye Height: The vertical distance from the sitting surface to the outer corner of the right eye, when sitting.

10. Sitting Shoulder Height (Acromion) : The vertical distance from the sitting surface to the tip (acromion) of the shoulder.
11. Sitting Elbow Height: The vertical distance from the sitting surface to the lowest point of the right elbow, when sitting.

12. Sitting Thigh Height (Clearance) : The vertical distance from the sitting surface to the highest point of the right thigh, when sitting.

13. Sitting Knee Height: The vertical distance from the floor to the top of the right knee cap, when sitting with knees flexed at 90 degrees

14. Sitting Popliteal Height: The vertical distance from the floor to the underside of the thigh directly behind the right knee, when sitting with knees flexed at 90 degrees.
15. Shoulder-Elbow Length: The vertical distance from the underside of the right elbow to the right acromion., with the elbow flexed at 90 degrees and the upper arm hanging vertically.
16. Elbow-Fingertip Length: The distance from the back of the right elbow to the tip of the middle finger, with the elbow flexed at 90 degress.
17. Overhead Grip Reach, Sitting: The vertical distance from the sitting surface to the center of a cylindrical rod firmly held in the palm of the right hand.
18. Overhead grip reach, standing: the vertical distance from the standing surface to the center of a cylindrical rod firmly held in the palm of the right hand.
19. Forward Grip Reach: The horizontal distance from the back of the right shoulder blade to the center of a cylindrical rod firmly held in the palm of the right hand.
20. Arm Length, Vertical: The vertical distance from the tip of the right middle finger to the right acromion, with the arm hanging vertically.
21. Downward Grip Reach: The vertical distance from the right acromion to the center of a cylindrical rod firmly held in the palm of the right hand, with the arm hanging vertically.
22. Chest depth: the horizontal depth from the back to the right nipple.
23.Abdominal Depth, Sitting: The horizontal distance from the back of to the most protruding point on the abdomen.
24. Buttock-Knee Depth, Sitting: The horizontal distance from the back of the buttocks to the back of right knee, when sitting with the knees flexed at 90 degrees.
25. Buttock-Popliteal Depth, Sitting: The horizontal distance from the back of the buttocks to the right knee just below the thigh, when sitting with the knees flexed at 90 degrees.
26. Shoulder Breadth, Biacromial: The distance between the right and left acromion.
27. Shoulder Breadth, Bideltoid: The maximal horizontal breadth across the shoulders between the lateral margins of the right and left deltoid muscles.
28. Hip Breadth, Sitting: The maximal horizontal breadth across the hips or thighs, whatever is greater, when sitting.
29. Span: The distance between the tips of the middle fingers of the horizontally outstretched arms and hands.
30. Elbow Span: The distance between the tips of the elbows of the horizontally outstretched upper arms flexed so that the fingertips of the hands meet in front of the hunk.
31. Hand Length: The length of the right hand between the crease of the wrist and the tip of the middle finger, with right hand flat.
32. Hand Breadth: The breadth of the right hand across the knuckles of the four fingers.

Experiment No: 2

Experiment Name: Study and Design of Different Types of Hand Tools

Introduction:

Hand tools extend capability of the hand. Greater capability can be more impact (hammer), more grip strength (pliers), more torque (wrench, screw-driver) or even new functions (hand saw, soldering iron). This experiment will aid one in selecting from available tools and even, in some cases, to design a new tool. The design principles are grouped into General Principles, Grip Principles, Precision Principles and Geometry Principles.

Objective:

The objectives of this experiment to:

* Study ergonomic principles in designing of hand tools.
* Observe some existing hand tools and machines.
* Designing hand tools and machines using ergonomic principles. to eliminate the existing shortcoming.

Methodology:

1. Identify the major components, their functions, dimensions and their relative position of the hand tools and machines mentioned in the following paragraph.
2. Use the tool or operate the machine for a typical job.
3. Carefully observe the working posture of the body and the interaction between the body and different parts of the tool or machine.
4. Conduct a survey for noting down the general feeling of the user.
5. From the above mentioned steps identify shortcomings (Geometry, dimension, alignment, material, and shape etc of parts of the tool or machine that are not designed ergonomically resulting in discomfort and risk of musculoskeletal disorders from long time use) with reasons.
6. Propose improved design (with neat sketch) explaining the modifications made.

Tools and Machines to be studied:

Hand drill, Soldering iron, Electrode Holder of Arc-welding, Cutting Torch, Chisel, Snip, Die, Hack-saw, Pliers, Jack Planner, Tanner saw, Slide Wrench, Screw driver.

Ergonomic Principles in Designing of Hand Tools

Hand Tools:
Hammer, pliers, wrench, hand saw, screw driver, soldering iron, hack saw, scissors, knives, bottle opener etc.

Principles of Hand Tool & Devices Design:

* Maintain a straight wrist -
    * Avoid ulnar Deviation.

Flexion --------> Decreasing angle at the joint
Extension --------> opposite
Abduction --------> movement of body segment in lateral plane away from the midline of the body.
Adduction --------> opposite

* Avoid radial deviation with pronation & dorsiflexion.
* Design to neutral position. (wrist angle) (bent handle)

*** Grip strength is maximum at**

Neutral ↓ Ulnar dev. ↓ Radial dev ↓ Dorsi flexion ↓ Palmer flexion } Supination ↓ Mid ↓ Pronation

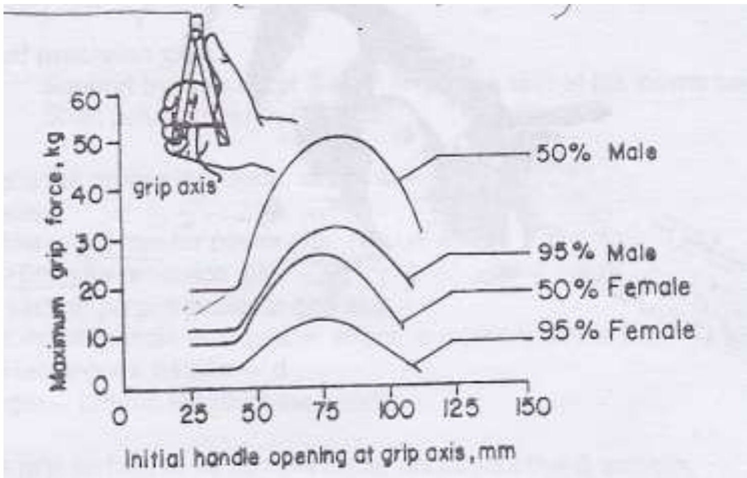
To increase high friction material, special design to gain mechanical advantage.

*** Avoid tissue compression stresses-**

- Avoid compressive force on the palm of the hand (obstructs blood flow, numbness of the fingers).
- Handles with large contact surfaces with palm so that force is distributed over larger area & is directed to less-sensitive tissues (between thumb & index finger).

* Avoid repetitive finger action -

* Avoid frequent use of index finger. Thumb operated controls should be used.
* Even better Finger-strip control (load shared by more than one finger)
* Maximum grip strength grip axis opening (axis opening) between 2.5 inch -3.5 inch



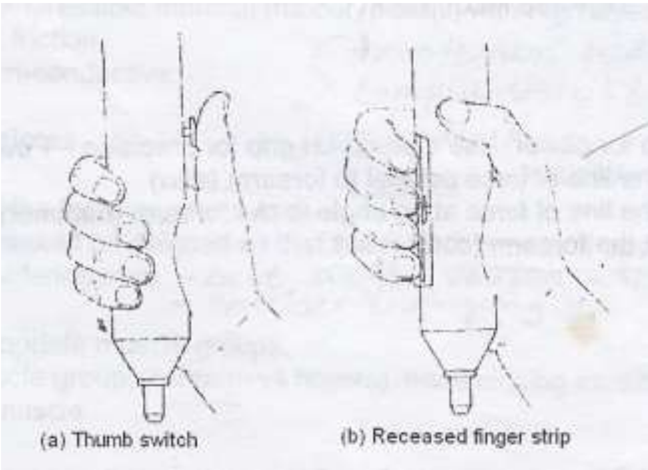
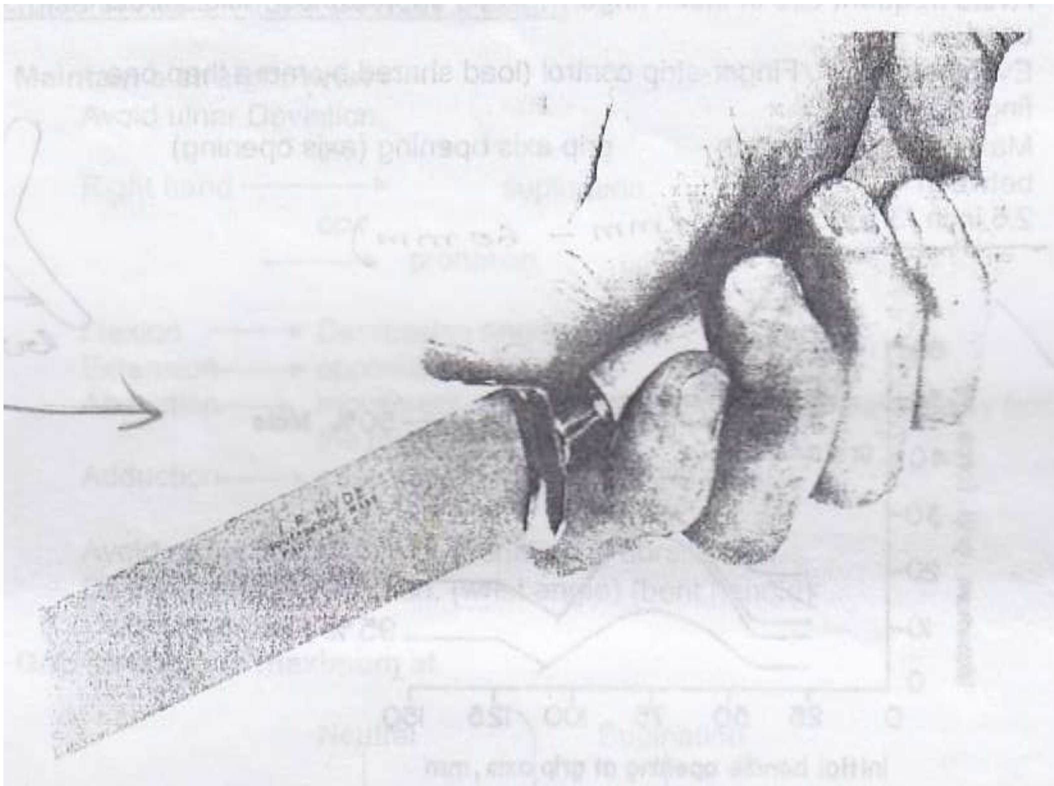


Figure: Thumb-operated and finger-strip operated pneumatic tool. Thumb operation results in overextension of the thumb. Finger strip control allows all the fingers to share the load and the thumb to grip and guide the tool

Design for safe operation -

* Eliminate pinching hazards (putting guards over pinch points, stops to prevent handles from fully closing & pinching the palm)
* Eliminate sharp corners & edges (rounding)
* Power tools --- design with brake devices.



Women & left handles -

* Vibration --- page 398 McCormick
* Gloves.

Grip Principles

Use a power grip for power. Use a precision grip for precision –

Power Grip:

1. Direction of the line of force parallel to forearm (saw).
2. Direction of the line of force at an angle to the forearm (hammer).
3. Torque about the forearm (corkscrew).

Precision Principles

1. Internal precision grips. Three characteristics

- A pinch grip by the thumb versus 1st finger (or 1st + 2nd finger)
- Support to reduce tool tremor by the little finger & side of the hand.
- The shaft passes under the thumb.

In pushing/pulling -- tool handle parallel to the work surface.
Rotation/torque ------ tool shaft perpendicular to the work surface (screw driver).

End of the tool grip should be long enough to extend beyond the palm.
Use Spherical end.

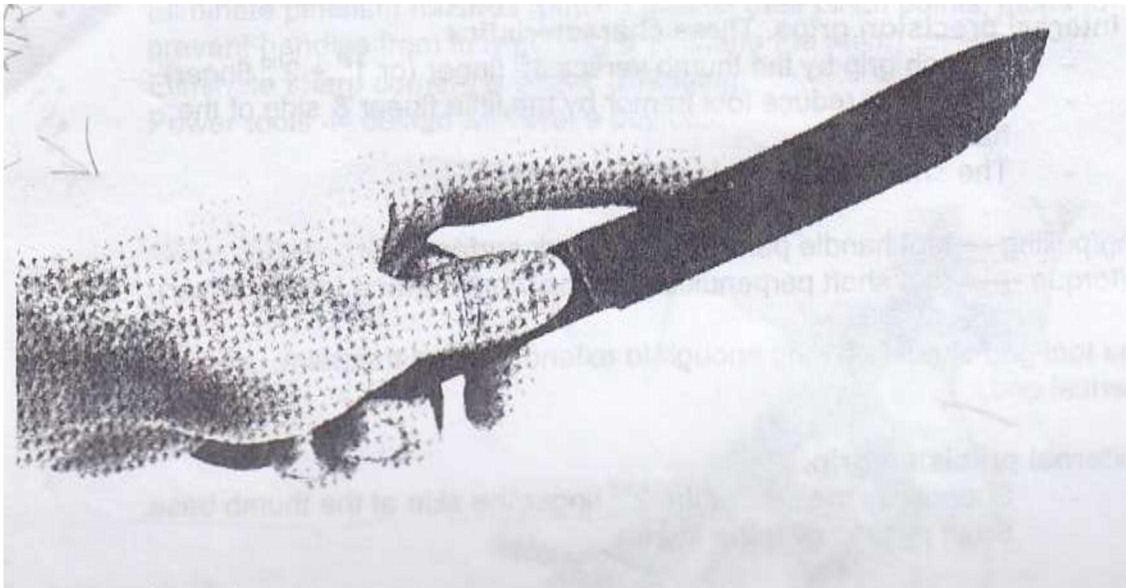
2. External precision grip.

- Support by the side of the 2nd finger/the skin at the thumb base.
- Shaft passes over the thumb.

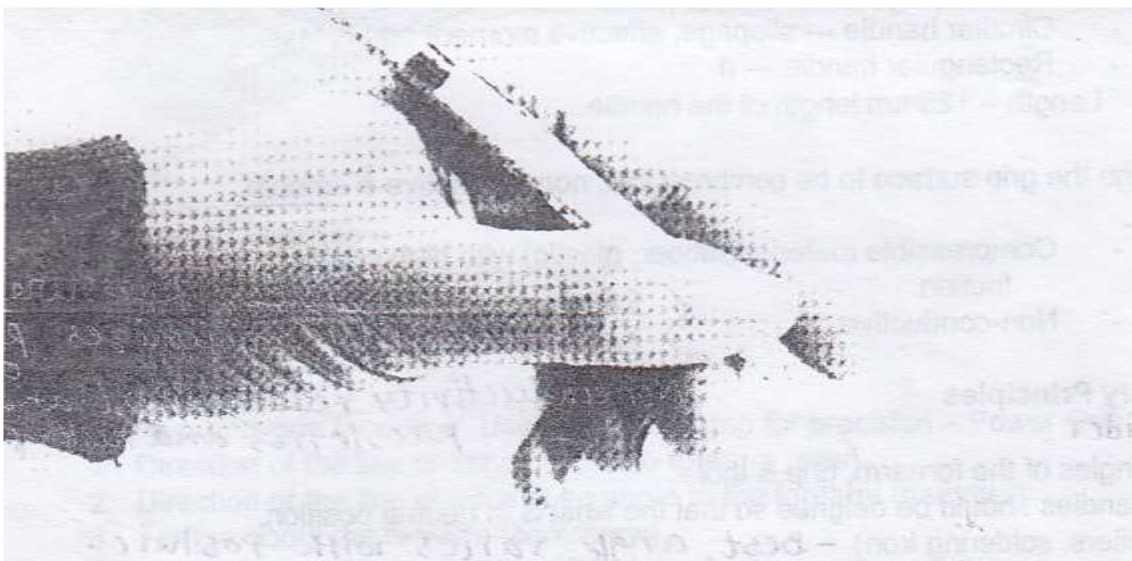
* Make grip the proper thickness, shape & length.
  * Thickness
  - Dia --- 40 mm for power grip.
  - >6mm for precision grip.
* Shape section perpendicular to grip axis-
  - Circular handle --- slippage, effective moment arm is less.
  - Rectangular handle --- pressure high
* Length – 125mm length of the handle.
* Design the grip surface to be compressible, nonconductive & smooth.
  - Compressible material (rubber, plastic) with high coefficient of friction.
  - Non conductive

Geometry Principles

* Angles of the forearm, grip & tool-
- Handles should be designed so that the wrist is in neutral position.
(pliers, soldering iron)
* Use appropriate muscle groups.
large muscle group, (forearm vs fingers), hand closing muscles vs hand opening muscle.



Internal precision grips have three characteristics: (1) a pinch grip, (2) support by the little finger or side of the hand, and (3) the shaft is "internal" to the hand.



External precision grips have three characteristics: (1) a pinch grip, (2) support by the side of the 2nd finger or skin at the thumb base, and (3) the shaft is "external" to the hand.

As with the power grip, thumb or little finger can be repositioned. Pointing along the top surface of a knife gives more power as well as additional precision. Patkin (1969) mentions pointing along a surgeon's needle holder with the thumb to gain additional precision.

Experiment No: 3

Experiment Name: Determination of Sound Level in different workplaces

Introduction:

Sound is created by the vibrating motion of displaced molecule in an elastic medium like air, wood, steel or other materials. This vibration produces waves which radiate in all directions. As these waves travel through the medium, a small pressure change above atmospheric pressure is created. Human ear is able to sense this small change , enabling to hear. This change in pressure is known as sound pressure level. The sound pressire level is the measure of sound most commonly reffered to when discussing industrial noise control. People are able to hear sound pressure level between about 1×10^-9 psi and 15 psi (or 1atm). Since this represents 10 orders of magnitude change, logarithmic scales are used to measure sound pressure level in desibels (dB). The level of sound plays a vital role in design of workplaces. Human comfort and productivity is affected by noise level greatly. Based on job profile and other requirements, in different types of workplaces, different standards of sound level has been set to define human comfort.

Objective: In this experiment, students have to construct a noise contour map of a sound emitting source. They are also required to critically analyze the findings and comment for improvements (if any).

Apparatus:

1. Sound Level Meter

Procedure:

1. Using slow response setting on a sound level meter, walk around the sound source, maintaining a constant reading (e.g. 80dBA). Record your path until it closes on itself, forming a loop. Or until the path exits the area to be surveyed.
2. Trace the path followed on a plant layout or area map. This can be easily done by a second person following the surveyor.
3. Repeat the process for as many contours as desired or needed. At a minimum, seven contours forming eight hearing hazard zones are recommended.

<u>**Digital Sound Level Meter:**</u>

1. Windscreen
2. Display
3. Level Range Select Button: Lo: 35~100dB; Hi: 65~130dB
4. Time Weighting Select Button:
    F (Fast response): For Normal measurement.
   S (Slow response): For checking average level of fluctuating noise.
5. Power and Function Switch:
   Turn power ON/OFF and select A/C weighting & calibration function
   A: A- Weighting for general sound level measurements.

C: C- Weighting for checking the low frequency content of noise.

6. Max Hold Button: To measure maximum level of sounds.
7. Data Hold Button: Freezes the reading in the display.
8. Microphone
9. DC, AC Output jack
10. Calibration potentiometer

Operation:

1. Power the meter by pressing the power button. The meter will begin displaying sound level readings. If the LCD does not switch on, check the 9V battery located in the rear battery compartment.
2. Hold the meter away from the body.
3. View the measurement on the meter's display. If the meter is in the auto ranging mode, the display may briefly indicate "HI" or "LO" if the noise level is above or below the currently selected range. The meter will change the range as needed to display the dB level.
4. 'A' and 'C' Frequency Weighting Use the 'A/C' button to select 'A' or 'C' frequency weighting. With 'A' weighting selected, the frequency response of the meter is similar to the response of the human ear. 'A' weighting is commonly used for environmental or hearing conservation programs such as OSHA regulatory testing and noise ordinance law enforcement. 'C' weighting is a much flatter response and is suitable for the sound level analysis of machines, engines, etc. "A" or "C" icons will appear in the display. Most noise measurements are performed using 'A' Weighting and SLOW Response.
5. 'FAST' and 'SLOW' Response Time Use the 'F/S' button to select FAST (125 ms) or SLOW (1 second) response time. Select FAST to capture noise peaks and noises that occur very quickly. Select the SLOW response to monitor a sound source that has a consistent noise level or to average quickly changing levels. "FAST" or "SLOW" icons will appear in the display. Select SLOW response for most applications.
6. Max hold: In this mode the meter only updates the LCD when a higher reading than the one presently on the display is detected.

   Press the MAX HOLD button to enter the Max Hold mode. The "MAX HOLD" icon will appear in the display. Press the MAX HOLD button again to exit this mode.

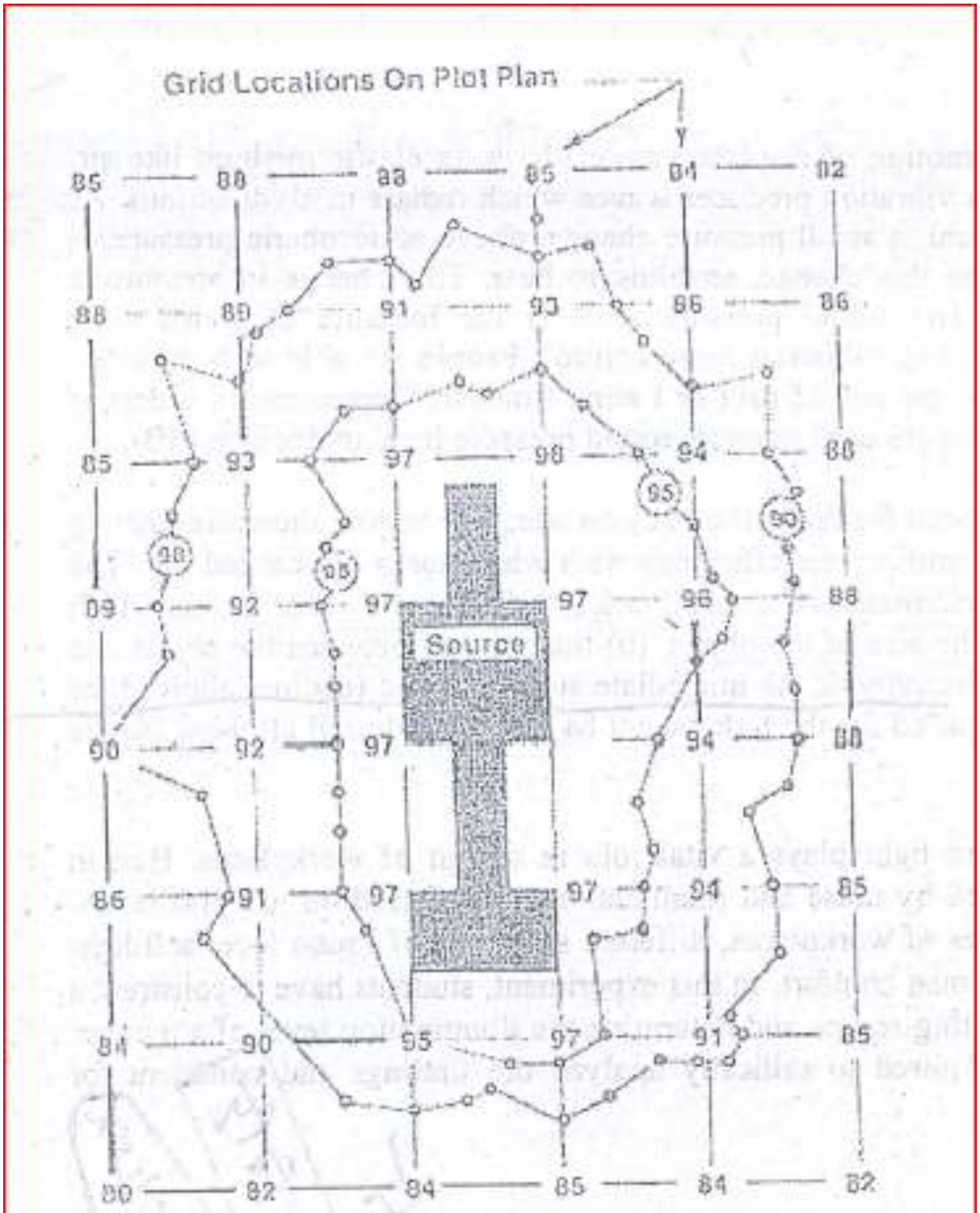


Figure 3.1: Noise Contour Map

Experiment No: 4

Experiment Name: Study of manual lifting operation and determination of the recommended weight limit using the NIOSH lifting equation

Introduction:

Manual handling is an important application of ergonomic principles that particularly addresses back injury prevention. A large proportion of the accidents which occurs in industry involve the manual handling of goods. In the United Sates, the report by the National Institute for Occupational Safety and Health (NIOSH,l981) stated that back pain was attributed to overexertion by 60% of back pain sufferers. About 500,000 workers in the US suffer some type of overexertion injury per year. Approximately 60% if the overexertion injury claims involve lifting and 20% involve pushing or pulling.
The main contribution of ergonomics to the reduction of hazards in manual handling is to redesign tasks and to identify techniques and specify workloads which are safe. NIOSH has produced a work practice guide for the design of manual handling tasks and an equation for determining safe loads. In Europe, a new directive for design of these task has been issued in 1990 and the U.K. Health and Safety Commission Consultative Document (Health and Safety Commission, 1991) provides interesting proposals for the design of manual handling tasks.

Objective:

The objective of this experiment is to study manual lifting operation and determination of recommended weight by using the NIOSH lifting equation.

The Revised Lifting Equation
1 Definition of Terms
1.1 Recommended Weight Limit (RWL)

The RWL is the principal product of the revised NIOSH lifting equation. The RWL is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g., up to 8 hours) without an increased risk of developing lifting-related LBP. By healthy workers, we mean workers who are free of adverse health conditions that would increase their risk of musculoskeletal injury.

The RWL is defined by the following equation:
RWL : LC X HM X VM X DM X AM X FM X CM

1.2 Lifting Index (LI)

The LI is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship of the weight of the load lifted and the recommended weight limit.

The LI is defined by the following equation:

LI= Load Weight/ Recommended weight Limit RWL = $\frac{L}{RWL}$

1.3 Terminology and Data Definitions

The following list of brief definitions is useful in applying the revised NIOSH lifting equation. For detailed descriptions of these terms, refer to the individual sections where each is discussed. Methods for measuring these variables and examples are provided in Sections 1 and 2.

Lifting Task Defined as the act of manually grasping an object of definable size and mass with two hands, and vertically moving the object without mechanical assistance.

Load Weight (L) Weight of the object to be lifted, in pounds or kilograms, including the container.

Horizontal Distance of the hands away from the mid-point between the ankles, in inches **Locations (H)** or centimeter (measure at the origin and destination of lift). See Figure 1.

Vertical Location (V) Distance of the hands above the floor, in inches or centimeters (measure at the origin and destination of lift). See Figure l.

Vertical Travel Distance (D) Absolute value of the difference between the vertical heights at the destination and origin of the lift, in inches or centimeters.

Asymmetry Angle (A) Angular measure of how far the object is displaced from the front (mid sagittal plane) or the worker’s body at the beginning or ending of the lift, in degrees (measure at the origin and destination of lift). See Figure 2. The asymmetry angle is defined by the location of the load relative to the workers’ mid- sagittal plane, as defined by the neutral body posture, rather than the position of the feet or the extent of body twist.

Neutral Body Describes the position of the body when the hands are directly in front of the

Position	body and there is minimal twisting at the legs, torso, or shoulders.
Lifting Frequency (F)	Average number of lifts per minute over a 15 minute period.
Lifting Duration	Three-tiered classification of lifting duration specified by the distribution of work-time and recovery-time (work pattern). Duration is classified as earlier short (1 hour), moderate (1-2 hours), or long (2-8 hours), depending on the work pattern.
Coupling Classification	Classification of the quality of the hand-to-object coupling (e.g., handles, cut-out, or grip). Coupling quality is classified as good, fair, or poor.
Significant Control	Significant control is defined as a condition requiring precision placement of the load at the destination of the lift. This is usually the case when (1) the worker has to re-grasp the load near the destination of the lift, or (2) the worker has to momentarily hold the object at the destination, or (3) the worker has to carefully position or guide the load at the destination

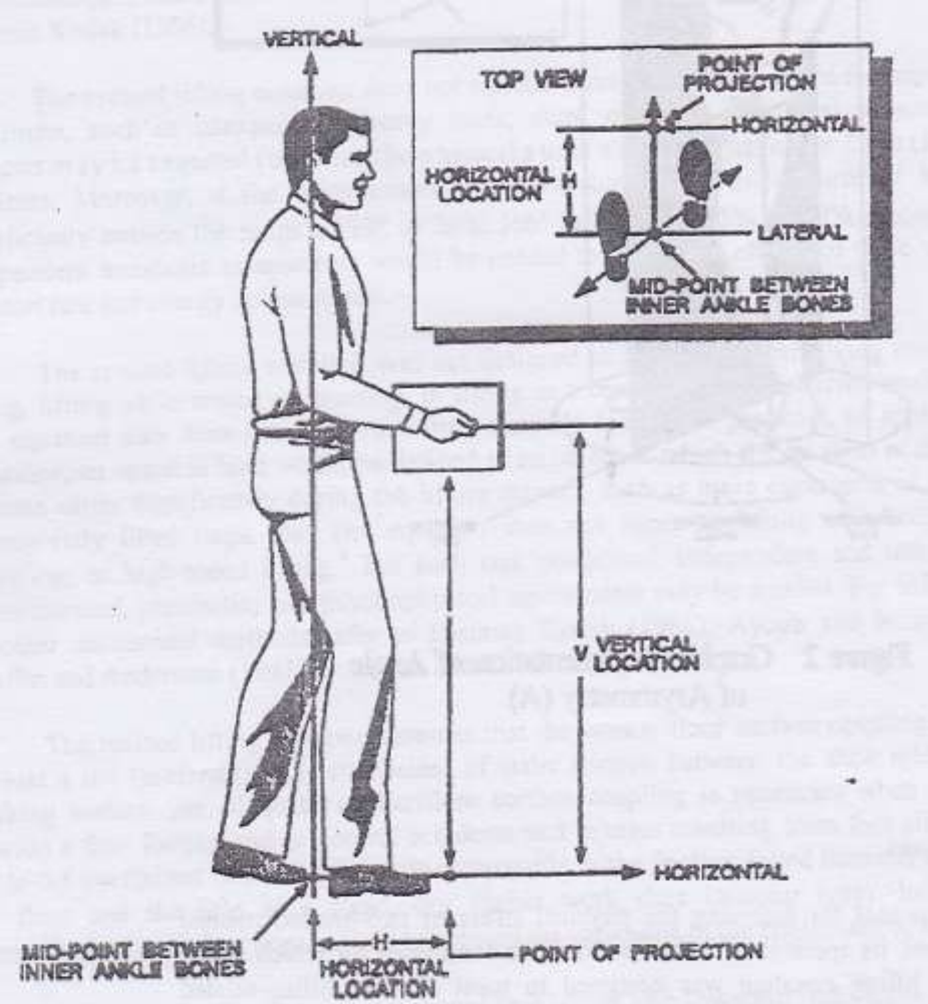


Figure 1 Graphic Representation of Hand Location

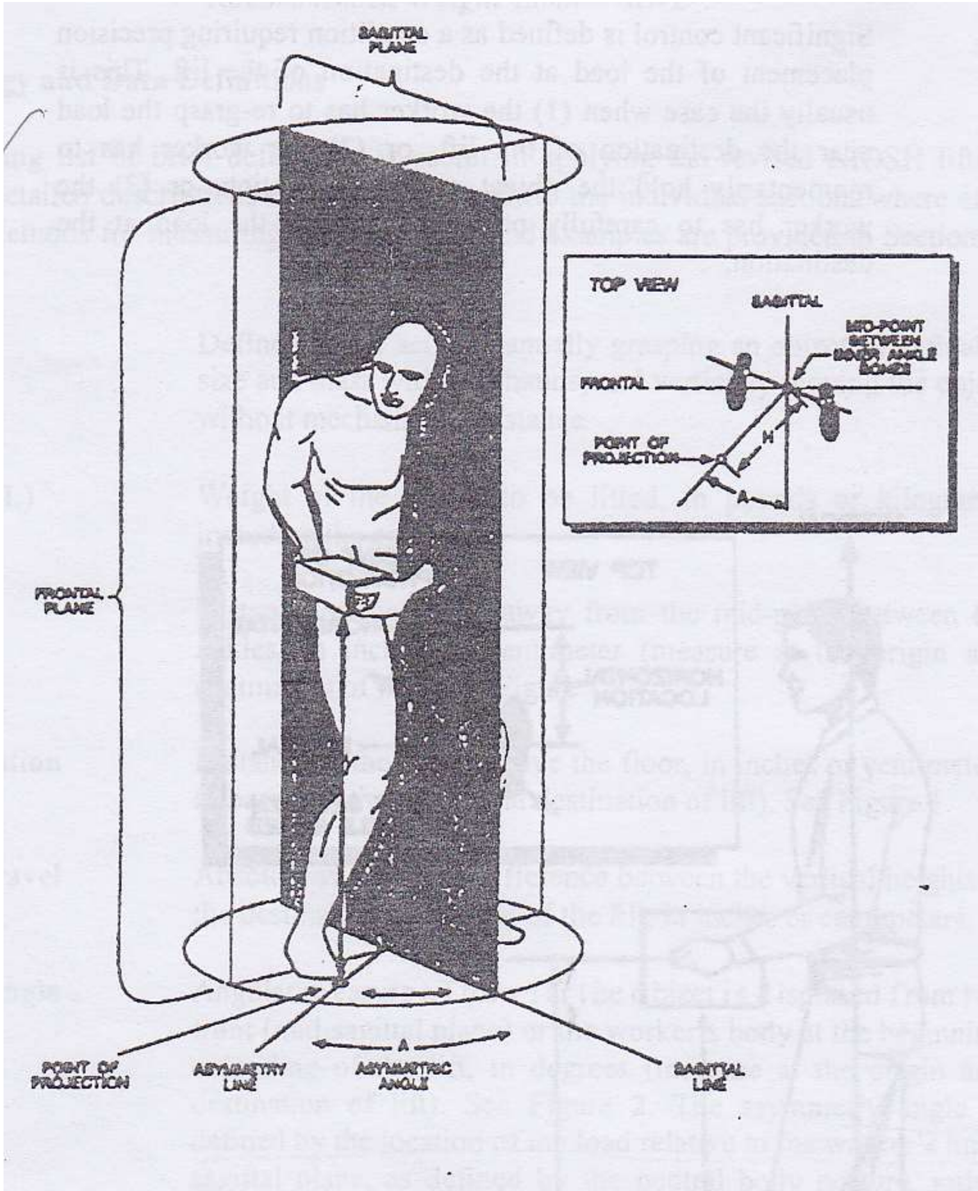


Figure 2 Graphic Representation of Angle of Asymmetry (A)

2 Lifting Task Limitations

The lifting equation is a tool for assessing the physical stress of two-handed manual lifting tasks. As with any tool, its application is limited to those conditions for which it was designed. Specifically, the lifting equation was designed to meet specific lifting-related criteria that encompass biomechanical, work physiology, and psychophysical assumption and data, identified above. To the extent that a given lifting task accurately reflects these underlying conditions and criteria, this lifting equation may be appropriately applied.

The following list identified a set of work conditions in which the application of the lifting equation could either-or over-estimate the extent of physical stress associated with a particular work-related activity. Each of the following task limitations also highlight research topics in need of further research to extend the application of the lifting equation to a greater range of real world lifting tasks.

1. The revised NIOSH lifting equation is based on the assumption that manual handling activities other than lifting are minimal and do not require significant energy expenditure, especially when repetitive lifting tasks are performed. Examples of non-lifting tasks include holding, pushing, pulling, carrying, walking, and climbing. If such non-lifting activities account for more than about 10% of the total worker activity, then measures or workers' energy expenditures and/or heart rate may be required to assess the metabolic demands of the different tasks. The equation will still apply if there is a small amount of holding and carrying, but carrying should be limited to one or two steps and holding should not exceed a few seconds. For more information on assessing metabolic demand, see Garg et al. (1978) or Eastman Kodak (1986).
2. The revised lifting equation does not include tasks factors to account for unpredicted conditions, such as unexpectedly heavy loads, slips, or falls. Additional biomechanical analyses may be required to assess the physical stress on joints that occur from traumatic incidents. Moreover, if the environment is unfavorable (e.g., temperatures or humidity significantly outside the range of l9^{o} to 26^{o}C [66^{o} to 79^{o}F] or 35% to 50%, respectively), independent metabolic assessments would be needed to gauge the effects of these variables on heart rate and energy consumption.
3. The revised lifting equation was not designed to assess tasks involving one-handed lifting, lifting while seated or kneeling, or lifting in a constrained or restricted work space.[3] The equation also does not apply to lifting unstable loads, For purposes of applying the equations, an unstable load would be defined as an object in which the location of the center of mass varies significantly during the lifting activity, such as more containers of liquid or incompletely filled bags, etc. The equation does not apply to lifting of wheelbarrows, shoveling, or high-speed lifting.[4] For such task conditions, independent and task specific biomechanical, metabolic, and psychophysical assessments may be needed. For information on other assessment methods refer to Eastman Kodak (1986), Ayoub and Mital (1989), Chaffin and Andersson (1991), or Snook and Ciriellos (1991).
4. The revised lifting equation assumes that the worker/floor surface coupling provides at least a 0.4 (preferably 0.5) coefficient of static friction between the shoe sole and the working surface. An adequate worker/floor surface coupling is necessary when lifting to provide a firm footing and to control accidents and injuries resulting from foot slippage. A 0.4 to 0.5 coefficient of static friction is comparable to the friction found between a smooth, dry floor and the sole of a clean, dry leather work shoe (nonslip type). Independent biomechanical modeling may be used to account for variations in the coefficient of friction,
5. The revised lifting equation assumes that lifting and lowering tasks have the same level of risk for low back injuries (i.e. that lifting a box from a table to the floor). This assumption may not be

true if the worker actually drops the box rather than lowering it all the way to the destination. Independent metabolic, biomechanical, or psychophysical assessments may be needed to assess worker capacity for various lowering conditions. (See references provided above.)

In summary, the Revised NIOSH Lifting Equation does not apply if \f any of the following occur.

* Lifting/lowering with one hand
* Lifting/lowering for over 8 hours
* Lifting/lowering while seated or kneeling
* Lifting/lowering in a restricted work space
* Lifting/lowering unstable objects
* Lifting/lowering while carrying, pushing or pulling
* Lifting/lowering with wheelbarrows or shovels
* Lifting/lowering with high speed motion (faster than about 30 inches/second)
* Lifting/lowering with unreasonable foot/floor coupling, (<0.4 coefficient of friction between the sole and the floor)
* Lifting/lowering in an unfavorable environment (i.e., temperature significantly outside 66-79^{o}F (19-26^{o}C) range; relative humidity outside 35-50% range)

For those lifting tasks in which the applications of the revised lifting equation is not appropriate, a more comprehensive ergonomic evaluation may be needed to quantify the extent of other physical stressors, such as prolonged or frequent non-neutral back postures or seated postures, cyclic loading (whole body vibration), or unfavorable environmental factors (e.g., extreme heat, cold, humidity, etc.).
Any of the above factors, alone or in combination with manual lifting, may exacerbate or initiate the onset of low back pain.

2. The Equation and Its Function

The revised lifting equation for calculating the Recommended Weight Limit (RWL) is based on a multiplicative model that provides a weighting for each of six task variables. The weightings are expressed as coefficients that serve to decrease the load constant, which represents the maximum recommended load weight to be lifted under ideal conditions. The RWL is defined by the following equation:

RWL : LC X HM X VM X DM X AM X FM X CM

Where

		METRIC	U.S. CUSTOMARY
Load Constant	LC	23 kg	51 lb
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	1-(.003 V-75)	1-(.0075 V-30)
Distance Multiplier	DM	.82 + (4.5/D)	.82 + (1.8/D)
Asymmetric Multiplier	AM	1-(.0032A)	1-(.0032A)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling Multiplier	CM	From Table 7	From Table 7

The term task variables refers to the measurable task descriptors (i.e., H, V, D, A, F, and C); whereas, the term multipliers refers to reduction coefficients in the equation (i.e., HM, VM, DM, AM, FM, and CM).

Each multiplier should be computed from the appropriate formula, but in some cases it will be necessary to use linear interpolation to determine the value of a multiplier, especially when the value of a variable is not directly Available from a table. For example, when the measured frequency is not a whole number, the appropriate multiplier must be interpolated between the frequency values in the table for the two values that are closest to the actual frequency.

3.1 Horizontal Component

3.1.1 Definition and Measurement

Horizontal Location (H) is measured from the mid-point of the line joining the inner ankle bones to a point projected on the floor directly below the mid-point of the hand grasps (i.e., load center), as defined by the large middle knuckle of the hand (Figure 1). Typically, the worker's feet are not aligned with the mid-sagittal plane, as shown in Figure l, but may be rotated inward or outward. If this is the case, then the mid-satittal plane is defined by the worker's neutral body posture as defined above.

If significant control is required at the destination (i.e., precision placement), then H should be measured at both the origin and destination of the lift.

Horizontal Location (H) should be measured. In those situations where the H value can not be measured, then H may be approximated from the following equations:

Metric [All distances in cm]	U.S. Customary [All distances in inches]
H = 20 + W/2 for V ≥ 25 cm	H = 8 + W/2 for 10 inches
H = 25 + W/2 for V < 25 cm	H = 10 + W/2 for V<10 inches

Where: W is the width of the container in the sagittal plane and V is the vertical location of the hands from the floor.

3.1 .2 Horizontal Restrictions

If the horizontal distance is less than 10inches (25 cm), then H is set to 10 inches (25 cm). Although objects can be carried or held closer than l0 inches from the ankles, most objects that are closer than this cannot be lifted without encountering interference from the abdomen or hyper extending the shoulders. While 25 inches (63cm) was chosen as the maximum value for H, it is probably too large for shorter workers, particularly when lifting asymmetrically. Furthermore objects at a distance of more than 25 inches from the ankles normally cannot be lifted vertically without some loss of balance.

3.1.3 Horizontal Multiplier

The Horizontal Multiplier (HM) is l0/H, for H measured in inches, and HM is 25/H, for H measured in centimeters. If H is less than or equal to 10 inches (25 cm), then the multiplier is 1.0, HM decreases with an increase in H value. The multiplier for H is reduced to 0.4 when H is 25 inches (63 cm). If H is greater than 25 inches, then HM = 0. The HM value can be computed directly or determined from Table l.

Table I
Horizontal Multiplier

H	HM	H	HM
in		cm	
≤10	1.00	≤25	1.00
11	.91	28	.89
12	.83	30	.83
13	.77	32	.78
14	.71	34	.74
15	.67	36	.69
16	.63	38	.66
17	.59	40	.63
18	.56	42	.60
19	.53	44	.57
20	.50	46	.54
21	.48	48	.52
22	.46	50	.50
23	.44	52	.48
24	.42	54	.46
25	.40	56	.45

>25	.00	58	.43
		60	.42
		63	.40
		>63	.00

3.2 Vertical Component

3.2.1 Definition and Measurement

Vertical Location (V) is defined as the vertical height of the hands above the floor. V is measured vertically from the floor to the mid-point between the hand grasps, as defined by the large middle knuckle. The coordinate system is illustrated in Figure 1 (page 7).

3.2.2 Vertical Restrictions

The vertical location (v) is limited by the floor surface and the upper limit of vertical reach for lifting {i.e.,70 inches or 175 cm). The vertical location should be measured at the origin and the destination of the lift to determine the travel distance (D).

3.2.3 vertical Multiplier

To determine the vertical Multiplier (VM), the absolute value or deviation of v from an optimum height of 30 inches (75cm) is calculated. A height of 20 inches above floor revel is considered “knuckle height” (66 inches or 165 cm). The Vertical Multiplier (VM) is {1-.0075*(V-30)} for V measured in inches, and VM is {1-.003*(V-75)}, for measured in centimeters.

When v is at.3-0 inches (75 cm), the vertical multiplier (VM) is- 1.0. The value of VM decreases linearly with an increase or decrease in height from the position. At floor level, VM is 0.78, and at 70 inches (175 cm) height VM is 0.7. If V is greater than 70 inches, then VM= 0. The VM value can be computed directly or determined from Table 2.

Table 2
Vertical Multiplier

V	VM	V	VM
in		cm	
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96
35	.96	70	.99
40	.93	80	.99

45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
>70	.00	150	.78
		160	.75
		170	.72
		175	.70
		>175	.00

3.3 Distance Component

3.3.1 Definition and Measurement

The vertical Travel Distance variable (D) is defined as the vertical travel distance of the hands between the origin and destination of the lift. For lifting, D can be computed by subtracting the vertical location (V) at the origin of the lift from the corresponding V at the destination of the lift (i.e., D is equal to V at the destination minus V at the origin). For a lowering task, D is equal to V at the origin minus V at the destination.

3.3.2 Distance Restrictions

The variable (D) is assumed to be at least 10 inches (25 cm), and no greater than 70 inches [75 cm]. If the vertical travel distance is less than 10 inches (25 cm), then D should be set to the minimum distance of l0 inches (25 cm).

3.3.3 Distance Multiplier

The Distance Multiplier (DM) is (.82 + (1.8/D)) for D measured in inches, and DM is (.82 + (4.5/D)) for D measured in centimeters. For D less than 10 inches (25 cm) D is assumed to be l0 inches (25 cm), and DM is 1.0. The Distance Multiplier, therefore, decreases gradually with an increase in travel distance. The DM is 1.0 when D is set at 10 inches, (25 cm); DM is 0.85 when D = 70 inches (175 cm). Thus, DM ranges from 1.0 to 0.85 ad the D varies from 0 inches (0 cm) to 70 inches (175 cm). The DM value can be computed directly or determined from Table 3.

3.4 Asymmetry Component

3.4.1 Definition and Measurement

Asymmetry refers to a lift that begins or ends outside the mid-sagittal plane as shown in Figure 2 on page 8. In general, asymmetric lifting should be avoided. If asymmetric lifting cannot be avoided, however, the recommended weight limits are significantly less than those limits used for symmetrical lifting.5

Table 3
Distance Multiplier

D	DM	DM	DM
in		cm	
10	1.00	25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	>175	.00
>70	.00		

An asymmetric lift may be required under the following task or workplace conditions:

1.The origin and destination of the lift are oriented at an angle to each another.
4 The lifting motion is across the body, such as occurs in swinging bags or boxes from one location to another.
5 The lifting is done to maintain body balance in obstructed workplaces, on rough terrain, or on littered floors.
6 Productivity standards require reduced time per lift.

The asymmetric angle (A), which is depicted graphically in Figure 2, is operationally defined as the angle between the asymmetry the and the mid-sagittal line. The asymmetry line is defined as horizontal line that join the midpoint between the inner ankle bones and the point projected on the floor directly below the midpoint of the hand grasps, as defined by the large middle knuckle.

The sagittal line is defined as the line passing through the mid-point between the inner ankle bones and lying in the mid-sagittal plane, as defined by the neutral body position (i.e., hands directly in front of the body, with no twisting at the legs, torso, or shoulders). Note: The asymmetry angle is not defined by foot position or the angle of torso twist, but by the location of the load relative to the worker's mid-sagittal plane.

In many cases of asymmetric lifting, the worker will pivot or use a step turn to complete the lift. Since this may vary significantly between workers and between lifts, we have assumed that no pivoting or stepping occurs. Although this assumption may overestimate the reduction in acceptable load weight, it will provide the greatest protection for the worker.

The asymmetry angle (A) must always be measured at the origin of the lift. If significant control is required at the destination, however, then angle A should be measured at both the origin and the destination of the lift.

3.4.2 Asymmetry Restrictions

The angle A is limited to the range from 0^0 to 135^0 . If A> 135^0 , then AM is set equal to zero, which results in a RWL of zero, or no load.

3.4.3 Asymmetric Multiplier

The Asymmetric Multiplier (AM) is 1-(.00324). The AM has a maximum value of 1.0 when the load is lifted directly in front of the body. The AM decreases linearly as the angle of asymmetry (A) increases. The range is from a value of 0.57 at 135^0 of asymmetry to a value of 1.0 at 0^0 of asymmetry (i.e., symmetric lift).

If A is greater than 135^0 , then AM: 0, and the load is zero. The AM value can be computed directly or determined from Table 4.

Table 4
Asymmetric Multiplier

A	AM
deg	
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
>135	.00

3.5 Frequency Component
3.5.1 Definition and Measurement

The frequency multiplier is defined by (a) the number of lifts per minute (frequency), (b) the amount of time engaged in the lifting activity (duration), and (c) the vertical height of the lift from the floor. Lifting frequency (F) refers to the average number of lifts made per minute, as measured over a 15-minute period. Because of the potential variation in work patterns, analysis may have difficulty obtaining an accurate or representative 15-minute work sample for computing the lifting frequency (F). If significant variation exists in the frequency of lifting over the course of the day, analyst should employ standard work sampling techniques to obtain a representative work sample for determining the number of lifts per minute. For those jobs where the frequency varies from session to session, each session should be analyzed separately, but the overall work pattern must still be considered. For more information, most standard industrial engineering or ergonomics texts provide guidance for establishing a representative job sampling strategy (e.g., Eastman Kodak Company, 1986).

3.5.2 Lifting Duration

Lifting duration is classified into three categories-short-duration moderate-duration and long-duration. These categories are based on the pattern of continuous work-time and recovery-time (i.e., light work) periods. A continuous work-time period is defined as a period of uninterrupted work. Recovery-time is defined as the duration of light work activity following a period of continuous lifting. Examples of light work include activities such as sitting at a desk or table, monitoring operations, light assembly work, etc.

1. Short-duration defines lifting tasks that have a work duration of one hour of less, followed by a recovery time equal to 1.2 times the work time [i.e., at least a 1.2 recover-time to work-time ratio (RT/WT)].

For example, to be classified as short-duration, a 45-minute lifting job must be followed by at least a 54-minute recovery period prior to initiating a subsequent lifting session. If the required recovery time is not met for a job of one hour or less, and subsequent lifting session is required, then the total lifting time must be combined to correctly determine the duration category. Moreover, if the recovery period does not meet the time requirement, it is disregarded for purposes of determining the appropriate duration category.
As another example, assume a worker lifts continuously for 30 minutes, then performs a light work task for 10 minutes, and then lifts for an additional 45-minute period. In this case, the recovery time between lifting sessions (10 minutes) is less than 1.2 times the initial 30-minute work time (36 minutes). Thus, the two work times (30 minutes and 45 minutes) must be added together to determine the duration. Since the total work time (75 minutes) exceeds 1 hour, the job is classified as moderate-duration. On the other hand, if the recovery period between lifting sessions was increased to 36 minutes, then the short-duration category would apply, which would result in a larger FM value.

2. **Moderate-duration** defines lifting tasks that have a duration of more than one hour, but not more than two hours, followed by recovery period of at least 0.3 times the work time [i.e., at least a 0.3 recovery time to work-time ratio (RT/WT)].

For example, if a worker continuously lifts for 2 hours, then a recovery period of at least 36 minutes would be required before initiating a subsequent lifting session. If the recovery time requirement is not met, and a subsequent lifting session is required, then the total work time must be added together. If the total works time exceeds 2 hours, then the job must be classified as a long-duration lifting task.

3. Long-duration defines lifting tasks that have a duration of between two and eight hours, with standard industrial rest allowances (e.g., morning, lunch, and afternoon rest breaks).

Note : No weight limits are provided more than eight hours of work.

The difference in the required RT/WT ratio for the short-duration category (less than 1 hour), which is 1.2, and the moderate-duration category (1-2 hours), which is 3, is due to the difference in the magnitudes of the frequency multiplier values associated with each of the duration categories. Since the moderate-duration category results in larger reductions in the RWL than the short-duration category, there is less need for a recovery period between sessions than for the short duration category. In other words, the short duration category would result in higher weight limits than the moderate duration category, so larger recovery periods would be needed.

3.5.3 Frequency Restrictions

Lifting frequency (F) for repetitive lifting may range from 0.2 lifts/min to a maximum frequency that is dependent on the vertical location of the object (V) and the duration of lifting (Table 5). Lifting above the maximum frequency results in a RWL of 0.0. (Except for the special case of discontinuous lifting discussed above, where the maximum frequency is 15 lifts/minute.)

3.5.4 Frequency Multiplier

The FM value depends upon the average number of lifts/min (F), the vertical location (V) of the hands at the origin, and the duration of continuous lifting. For lifting tasks with a frequency less than 2 lifts per minute, set the frequency equal to 2 lifts/minute. For infrequent lifting (i.e., F > 1 lift/minute), however, the recovery period will usually be sufficient to use the 1-hour duration category. The FM value is determined from Table 5.

Table 5
Frequency Multiplier Table (FM)

Frequency Lifts/min (F)	Work Duration					
	≤1 Hour		1 but ≤ 2 Hours		2 but ≤ 8 Hours	
	V < 30 t	V ≥30	V< 30	V ≥30	V< 30	V≥ 30
≤0.2	1.00	1.00	.95	.95	85	.85
0.5	.97	.97	.92	.92	81	.81
1	.94	.94	.88	.88	75	.75
2	.91	.91	.84	.84	65	.65
3	.88	.88	.79	.79	55	.55
4	.84	.84	.72	.72	45	.45
5	.80	.80	.60	.60	35	.35
6	.75	.75	.50	.50	27	.27
7	.70	.70	.42	.42	22	.22
8	.60	.60	.35	.35	18	.18
9	.52	.52	.30	.30	00	.15
10	.45	.45	.26	.26	00	.13
11	.41	.41	.00	.23	00	.00
12	.37	.37	.00	.21	00	.00

13	.00	.34	.00	.00	00	.00
14	.00	.31	.00	.00	00	.00
15	.00	.28	.00	.00	00	.00
>15	.00	.00	.00	.00	00	.00

Va1lues of V are in inches For lifting less frequently than once per 5 minutes, set F =0. 2 lifts/minute.

3.5.5 Special Frequency Adjustment Procedure

A special procedure has been developed for determining the appropriate lifting frequency(F) for certain repetitive lifting tasks in which workers do not lift continuously during the 15 minute sampling period. This occurs when the work pattern is such that the worker lifts repetitively for a short time and then performs light work for a short time before starting another cycle, As long as the actual lifting frequency does not exceed 15 lifts per minute, the lifting frequency (F) may be determined for tasks such as this as follows:

1. Compute the total number of lifts performed for the 15 minute period (i.e., lift rate times work time).
2. Divide the total number of lifts by 15.
3. Use the resulting value as the frequency (F) to determine the frequency multiplier (FM) from Table 5.,

For example, if the work pattern for a job consists of a series of cyclic sessions requiring 8 minutes of lifting followed by 7 minutes of light work, and the lifting rate during the work sessions is l0 lifts per minute, then the frequency rate (F) that is used to determine the frequency multiplier for this job is equal to (10 x 8)/15 or 5.33 lifts/minute. If the worker lifted continuously for more than 15 minutes, however, then the actual lifting frequency (10 lifts per minutes) would be used.

When using this special procedure, the duration category is based on the magnitude of the recovery periods between work sessions, not within work sessions. In other words, if the work pattern is intermittent and the special procedure applies, then the intermittent recovery periods for purposes of determining the duration category. For example, if the work pattern for a manual lifting at a rate of 10 lifts/minute, followed by 2 minutes of recovery, the correct procedure would be to adjust the frequency according to the special procedure [i.e., F = (10 lifts/minute X 5 minutes)/ 15 minutes = 50/15 = 3.4 lifts/minute/]. the 2 minute recovery periods would not count towards the WT/RT ratio, however, and additional recovery periods would have to be provided as described above.

3.6 Coupling Component

3.6.1 Definition & Measurement

The nature of the hand to object coupling or gripping method can affect not only the maximum force a worker can or must exert on the object, but also the vertical location of the hands during the lift. A good coupling will reduce the maximum grasp forces required and increase the acceptable weight for lifting, while a poor coupling will generally require higher maximum grasp forces and decrease the acceptable weight for lifting.

The effectiveness of the coupling is not static, but may vary with the distance of the object, from the ground, so that a good coupling could become a poor coupling during a single lift. The entire range of the lift should be considered when classifying hand-to-object couplings with classification based pm overall effectiveness. The analyst must classify the coupling as good, fair, or poor. The classifying a particular coupling design, the more stressful classification should be selected.

Table 6
Hand-to-Container Coupling Classification

1. For Containers of optimal design, such as some boxes, crates, etc., a "Good" hand-to-object coupling would be defined as handles or hand-hold cut-outs of optimal design [see notes 1 to 3 below]	1. For containers of optimal design, a "Fair" hand-to-object coupling would be defined as handles or hand-hold cut-outs of less than optimal design [see notes 1 to 4 below.]	1. Containers of less than optimal design or irregular objects that are bulky, hard to handle, or have sharp edges [see note 5 below.]
2. For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object [see not 6 below.]	2. For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be fixed about 90 degrees [see note 4 below.]	2. Lifting non-rigid bags (i.e., bags that sag in the middle).

1. An optimal handle design has .75 - 1.5 inches (1.9 to 3.8 cm) diameter, > 4.5 inches (11.5 cm) length, 2 inches (5 cm) clearance, cylindrical shape, and a smooth, non-slip surface.

2. An optimal hand-hold cut-out has the following approximate characteristics: ≥ 1.5 inch (3.8 cm) height, 4.5 inch (11.5 cm) length, semi-oval shape, ≥ 2 inch (5 cm) clearance, smooth non-slip surface, and ≥ 0.25 inches (0.60 cm) container thickness (e.g., double thickness cardboard)

3. An optimal container design has ≤ 16 inches (40 cm) frontal length, ≤ 12 inches (30 cm) height, and a smooth non-slip surface.

4. A worker should be capable of clamping the fingers at nearly 90^0 under the container, such as required when lifting a cardboard box from the floor.

5. A container is considered less than optimal if it has a frontal length > l6 inches (40 cm), height > 12 inches (30 cm), rough or slippery surfaces, sharp edges, asymmetric center of mass, unstable considered bulky if the load cannot easily be balances between the hand-grasps.

6. A worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations or awkward postures, and the grip should not require excessive force.

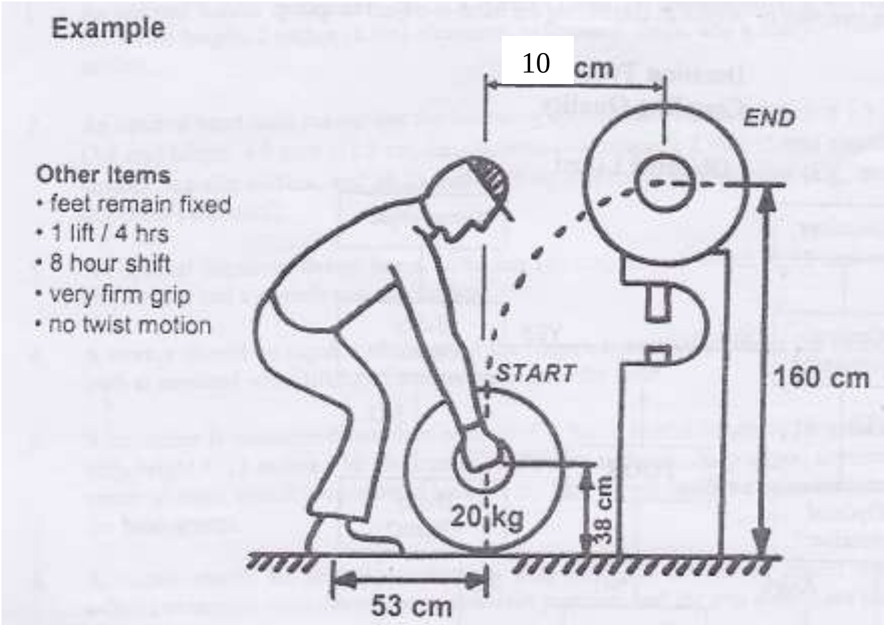
3.6.2 Coupling Multiplier 3

Based on the coupling classification and vertical location of the lift, the Coupling Multiplier (CM) is determined from Table 7.

Table 7
Coupling Multiplier

Coupling Type	Coupling Multiplier	
	V < 30 inches (75 cm)	V ≥ 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Example



Other Items

* feet remain fixed
* 1 lift/4 hrs
* 8 hour shift
* very firm grip
* no twist motion

Job analysis Worksheet

Department.. Job Description.......................................

Job Title... ....

Analyst's Name.. ....

Date.. ....

Step 1. Measure and Record Task Variables

Object Weight		Hand Location				Vert. Dist.	Angle		Freq	Time	Object Coupling
		Origin		Dest.			Origin	Dest.	Lifts/min	HRS	
Avg	Max	H	V	H	V	D	A	A	F		C
20	20	53	38	63	160	122	0	0	0.2	8	Good

Horizontal Body-to-Hand Distance (feet are locked in place)
= 53 cm + 10 cm

Total Vertical Lift
= Dest. – Origin
= 160 cm – 38 cm
= 122 cm

Minimum NIOSH Value Reportable

= 63 cm

Step 2. Determine Multipliers and Compute RWL

	RWL = LC x HM x VM x DM x AM x FM x CM
Origin	RWL = 23 x 0.47 x0.889 x 0.856 x 1 x 0.85 x 1 = 7.02kg
Destination	RWL = 23 x 0.4 x 0.745x 0.856 x 1 x 0.85 x 1 =4.99 kg

Origin of Lift
LC = 23 kg = fixed factor
HM = 25/H = 25/53 = 0.47
VM = 1-0.003(V-75) = 1-0.003(38-75) = 0.889
DM = 0.82 + (4.5/D) = 0.82 + (4.5/122) = 0.856
AM = 1 - 0.0032A = 1 - 0.0032(0) = 1
FM : 0.85 (since l lift/4 hrs = 0.004 lifts/min = approx. 0 on graph)
CM : 1.0, (since V = 75 cm and "good" grip)

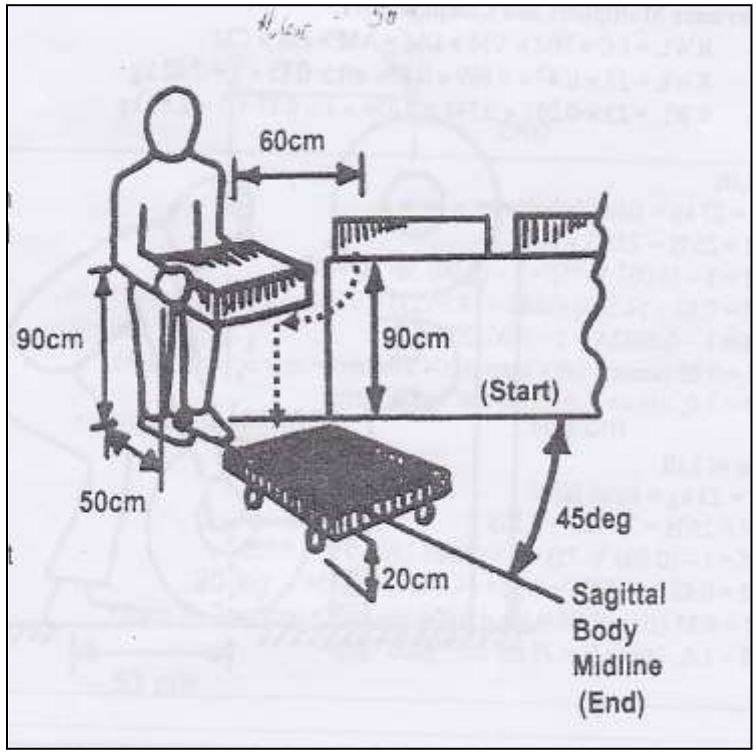
Destination of Lift
LC = 23 kg = fixed factor
HM = 25/H = 25/63 = 0.4
VM = 1 - 0.003(V-75) = 1 - 0.003 (160 - 75) = 0.889
DM = 0.82 + (4.5/D) = 0.82 + (4.5/122)= 0.856
FM = 0.85 (since 1lift/4 hrs = 0.004 lifts/min = approx.0 on graph)
CM = 1.0, (since V = 75 cm and "good" grip

Step 3. Compute the Lifting index
Origin Lifting Index = Weight / RWL = 20/7.02 = 2.85
Destination Lifting Index : Weight / RWL. = 20/4.99 = 4

Conclusion
* Origin: the start of the lift is acceptable and safe since L1 < 3
* Destination : the end of the lift is dangerous since L1> 3. The "stress level" is LI : 4, the larger of the values. This could be the point where serious low back injury will occur. The task setup must be changed at the destination, or increased job screening, medical monitoring, and training must be introduced.

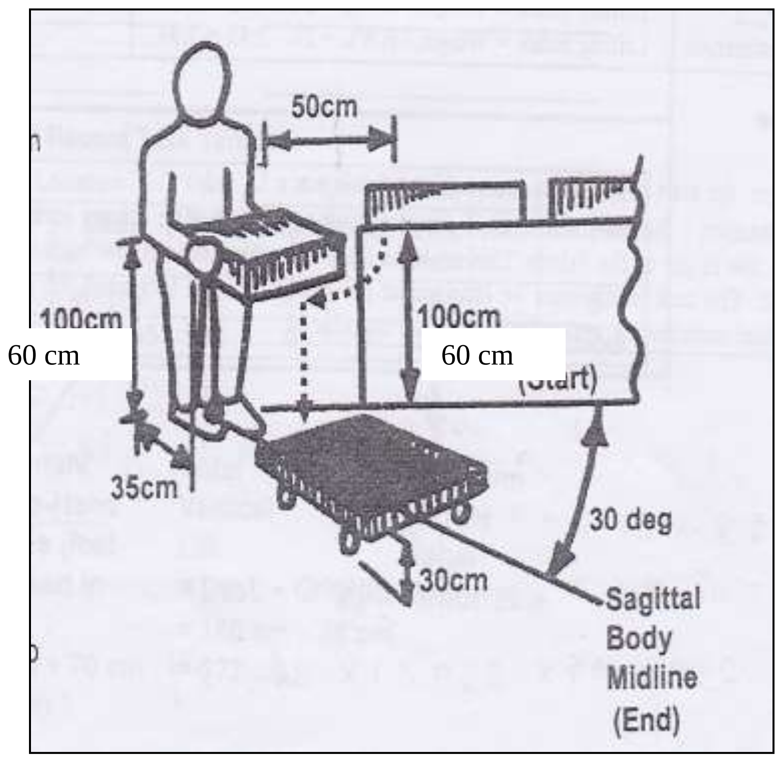
Problem 1

Task
Moving trays from conveyor belt and putting them on the cart
Other Items
* 10 kg trays
* 1 lift/min
* 4 hour shift
* feet are fixed ,
* "fair" grip
* upper body twist motion at START
* tray placed straight down onto cart at END



Problem 2

Task
Moving boxes from conveyor belt & placing them onto a cart
Other Items
* 15 kg boxes
* 3 lifts/min
* 3 hour shift
* feet are fixed
* "pool'" grip
* upper body twist motion at START
* boxes placed straight down onto cart at END



Job analysis Worksheet

Department.. Job Description..
Job Title... ....
Analyst's Name... ....
Date... ....

Measure and Record Task Variables

Object Weight		Hand Location				Vert. Dist.	Angle		Freq	Time	Object Coupling
		Origin		Dest.			Origin	Dest.	Lifts/min	HRS	
Avg	Max	H	V	H	V	D	A	A	F		C

Experiment No: 5

Experiment Name: Design of workstation by Applying Ergonomic Principles

Introduction:

Ergonomic considerations in workspace design helps to achieve a "transparent' interface between the user and the task that users are not distracted by the equipment they are using, Distraction may be due to discomfort (e.g., numbness in the buttocks)or to workstation usability problem.

The reduction of postural stress is fundamental to workstation design in ergonomics. A multifaceted approach is needed to arrive at appropriate workstation designs for different workers. The requirements of tasks and the characteristics of users need to be considered in relation to the options of workstation design.

Objective:

The objective of this experiment is to design a workstation using ergonomic principles.

Methodology:

1. Take the relevant anthropometric measurements of the user.
2. Design the assigned workstation using ergonomic principles (with the help of anthropometric data)

Ergonomic principles for workstation design:

Ergonomic Design Consideration:

- Product/ Equipment
- Job aids
- User selection
- Training of user

Follow the 14 guidelines given below for designing ergonomic workstation:

<u>Guideline 1:</u>

Avoid Static Loads and Fixed Work Postures:

- ✓ Static load increases systolic and diastolic blood pressure,
- ✓ Metabolic wastes accumulate in the muscles
- ✓ Consider increasing recovery time,

Standing:

- ✓ Shoes affect center of gravity and forward bending moment,
- ✓ Have hips parallel to the floor,
- ✓ Provide bar rail to vary work posture.
- ✓ Hard floors cause standing fatigue and increase heart rate,

Falls

- ✓ Slips and falls are a major cause of unintentional injury deaths and have annual direct cost/capita of $50-400.

Causes of falls:

- Slips: unexpected horizontal foot movement
- Trips: restriction of foot movement
- Stepping-on-air: unexpected vertical foot movement

Solutions for fall:

* **Prevent the fall:**
  - -Use well-designed ladders, scaffolds, and ramps properly.
  - - Provide safe steps.
  - -Use the three-contact rule.
  - -Provide good friction and reduce lubricants.
* **Reduce the consequences of the fall:**
  - - Interrupt the fall.
  - - Soften the impact.

Head Weight

* The head weighs about the same as a bowling ball.
* Keep the line of sight below the horizontal.
* Maintain forward head tilt of 100-150°
* Avoid backward and sideward tilts.

Hands/Arms

* An arm weighs about 4.4 kg.

* Avoid using the hand to hold up a tool or work piece,
*Avoid working with elevated hands,
* Support the arms on the work surface or chair arms.
* Consider using magnification.

<u>Guideline 2</u>

Reduce Musculoskeletal Disorders

* Set the work height at 50 mm below the elbow.
* Don't bend your wrist.
* Don't lift your elbow.
* Don't reach behind your back.
* Fallow guidelines for hand and arm motions.

<u>Guideline 3</u>

Set the Work Height at 50 mm below the Elbow

* Work height is defined in terms of elbow height.
* Optimum height is slightly below the elbow.
* Optimum height from the elbow is the same for sitting and standing
* Work height is not table height.

Solutions for Work Height

* Change machine height.
* Adjust elbow height.
* Adjust work height on machine.

Multiple-level tables permit easy work height adjustment. In the top view, parts with the same thickness can be processed by different people using different portions of the table. In the lower view. The same person can process parts with different thicknesses using different portions o the table.

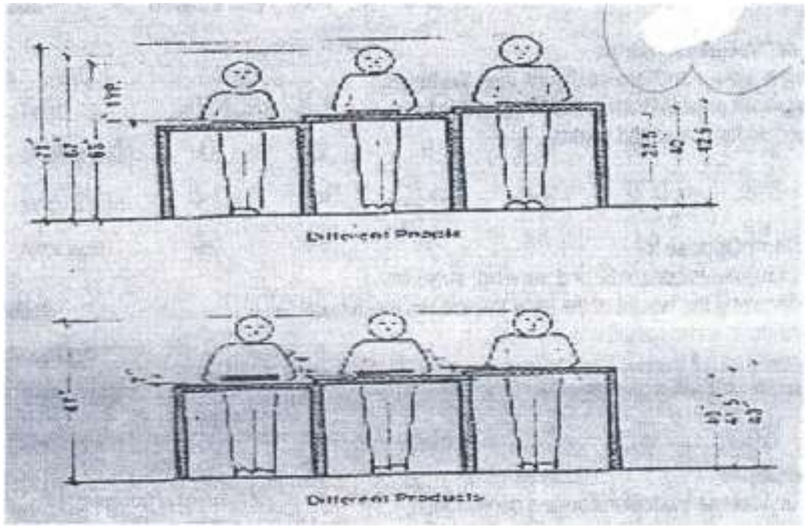


Fig: Multiple Level Tables

VDT Workstations:

* Key items: screen, keyboard, document, eyes, hands
* Workstation furniture must be adjustable.
* Locate the primary visual element first: ahead of the eye, perpendicular to the line of sight.
* Train the operation in adjusting the equipment.
* Provide a wrist rest.

Guideline 4:

Furnish Every Employee with an Adjustable Chair

* The cost of an adjustable chair is very low compared to labor cost.
* Allow users to try chairs in their specific jobs.
* Buy chairs that are easily adjustable.
* Train people in proper adjustment.

Chair Design:

* Seats
  - seat height from floor
  - seat length
  - seat width
  - seat slope
  - seat shape

Recommended dimensions for office chairs (Chaffin eta!., 1999). Dimensions are in cm, angles in degrees.

FEATURE	BRITISH STD. (BS 3079&	EUROPEA N (CEN)	DIFFERENT ET AL.	DANERO & ZELNI	GRAND JEAN	GERMAN STD. (DEN)	SWEDISH STD.
Seat							
Height	43-51	39-54	35-52	36-51	38-53	42-54	39-51
Width	4	40	4	43-48	40-45	40-45	42
Length	*36-41*	38-47	33-41	39-41	38-42	38-42	38-43
Skyic angle	0-5	0-5	0-5	0-5	4-6	0-4	0-4
Backtest							
Top height	3				48-50	32	
Botttom	20						
Center height		17-26	23-25	19-25	30	17-23	17-22
Height		10	15-23	10-20		22	22
Width	30-36	36-40	33	25	32-36	36-40	36-40
Horizontal	31-46	40mm	31-46		40-50	40-70	40-60
Vertical	convex						
Backrest seal angle	95-105		35-100	95-105			
Armtest							
Length	22	20	15-21			20-28	20
Width (breadth)	4	4	6-9 .				4
Height	16-23	21-25	18-25	20-25		21-25	21-25
Intearm rest	47-56	46-50	48-56	46-51		48-50	46

*Backrests

- position of backrest
- molded chair back position & curvature

*Armrests

* Legs/pedestals

- clearance of feet and calves under chair

Guideline 5

Use the Feet as Well as the Hands

* The leg is slower and less dexterous than the hands.
* The legs can provide 3 times the power of the arms.
* Use pedals for power and control.

Guideline 6

Use Gravity; Don't oppose it

* Make movements horizontal or downward; avoid lifting.
* Consider using the weight of the body to increase mechanical force.
*Use gravity to move material to the work.
*Use gravity as a fixture.
* Use gravity in feeding and disposal.

Guideline 7

Conserve Momentum

* Avoid unnecessary acceleration and deceleration.
* Use circular motion for stirring and polishing.
*Follow through in disposal motions.
*Eliminate grasping motions by providing lips, rolled edges, and holes.

Avoid transporting weight in the hand,

Guideline 8

Use 2-Hand Motions Rather Than 1-Hand Motions·

* Cranking with 2 arms is 25% more efficient than with one.
*Using 2 hands is more productive despite taking more time and effort
* Don't use the hand as a fixture.

Guideline 9

Use Parallel Motions for Eye Control of 2-Hand Motions

* Minimize the degree of spread rather than worry about symmetry.
* Estimate the cost of eye control with predetermined time systems.

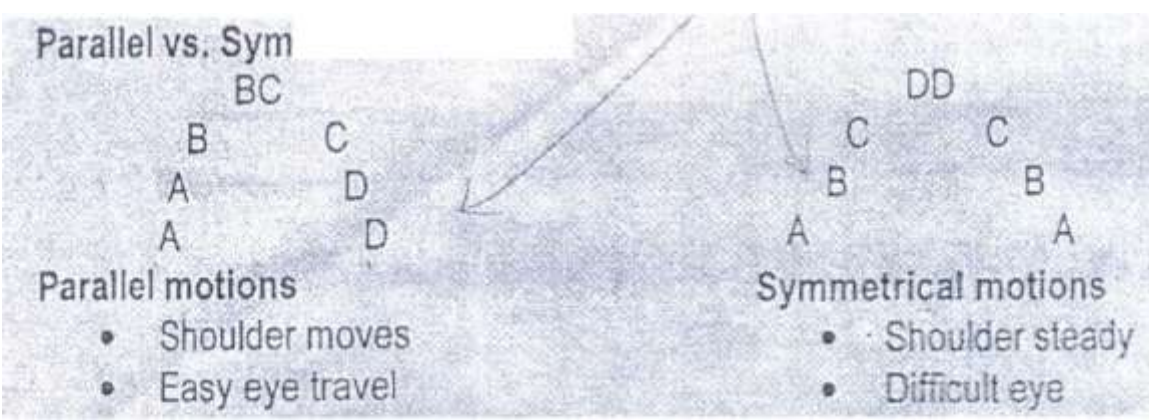


Fig: Parallel vs Symmetrical motions

<u>Guideline 10</u>

Use Rowing Motions for 2-Hand Motions

- * Alternation causes movement of the shoulder and twisting of the torso.
- * Alternation causes higher heart rate.
- * Rowing motions are more efficient and provide greater power

<u>Guideline 11</u>

Pivot Motions about the Elbow

*Motion time is minimized with motion about the elbow.

*Cross-body movements are more accurate than those about the elbow.

*Physiological cost is lower for movements about the elbow.

<u>Guideline 12</u>

Use the Preferred Hand

*The dominant hand is:

- 10% faster for reach-type motions
- More accurate than the non-dominant
- More exposed to cumulative trauma
- 5% to 10% stronger

*Work should arrive from the operator's preferred side and leave from the no preferred side.

<u>Guideline 13</u>

Keep Arm Motions in the Normal Work Area

*Avoid long benches.

*Use swingarms and lazy Susans.

* For high use, keep it close.

*Remember the arm pivots on the shoulder, not the nose.

* The shoulder is very sensitive to small changes in workplace layout.

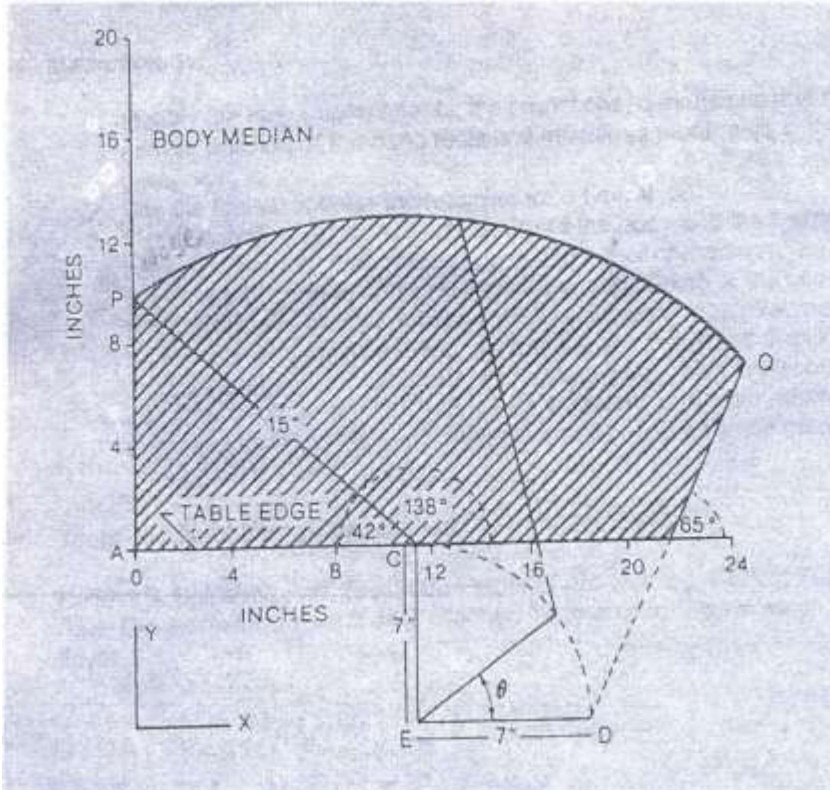


Fig: Windshield Wiper" pattern

Guideline 14

Let the Small Person Reach; Let the Large Person Fit

* Design so most of the user population can use the design.
* Jobs must be designed for both sexes.
* Multipurpose use of equipment functions is becoming more common.
* Civilian industrial population data are not the same as military data.
* International populations be a consideration.
* The proportion to exclude depends on the seriousness of designing people out and the cost of including more people.

Ways to Exclude Few

* One size fits all
* Multiple sizes
* Adjustability

Assigned Workstations

Group 1: A call center operator

Group 2: A student’s workstation

Group 3: An office workstation

Group 4: Private car driver’s seat

Group 5: Doctor’s chamber

Group 6: Wall painter’s workstation

Group 7: Watch mechanic’s workstation

Group 8: Cobbler’s workstation

Experiment No: 6

Experiment Name: Preperation of Hazard Evaluation Worksheet (task based) for a Workstation

Introduction:

A hazard analysis is one of the most important elements of the safety management program. A hazard analysis is an organized and systematic effort to identify and analyze the significance of potential hazards in work place. This analysis provides information that will assist employers and employees in making decisions for improving safety and reducing the consequences of unwanted or unplanned hazardous situation. The hazard analysis should focuses on equipment, instrumentation, utilities, human actions (routine and no routine), and external factors that might impact the process. These considerations assist in determining the hazards and potential failure points or failure modes in a process.

Objective:

Objective of this experiment is to identify hazards and evaluating risks in structured and systematic way in order to prioritize decisions to reduce risks to a tolerable level.

Methodology:

1. Identify potential hazards in the workplace using the hazard evaluation checklist.
2. Evaluating risk by using risk calculator.
3. Decide corrective actions.
4. Preparing the task-based Hazard Evaluation Worksheet.

Theory:

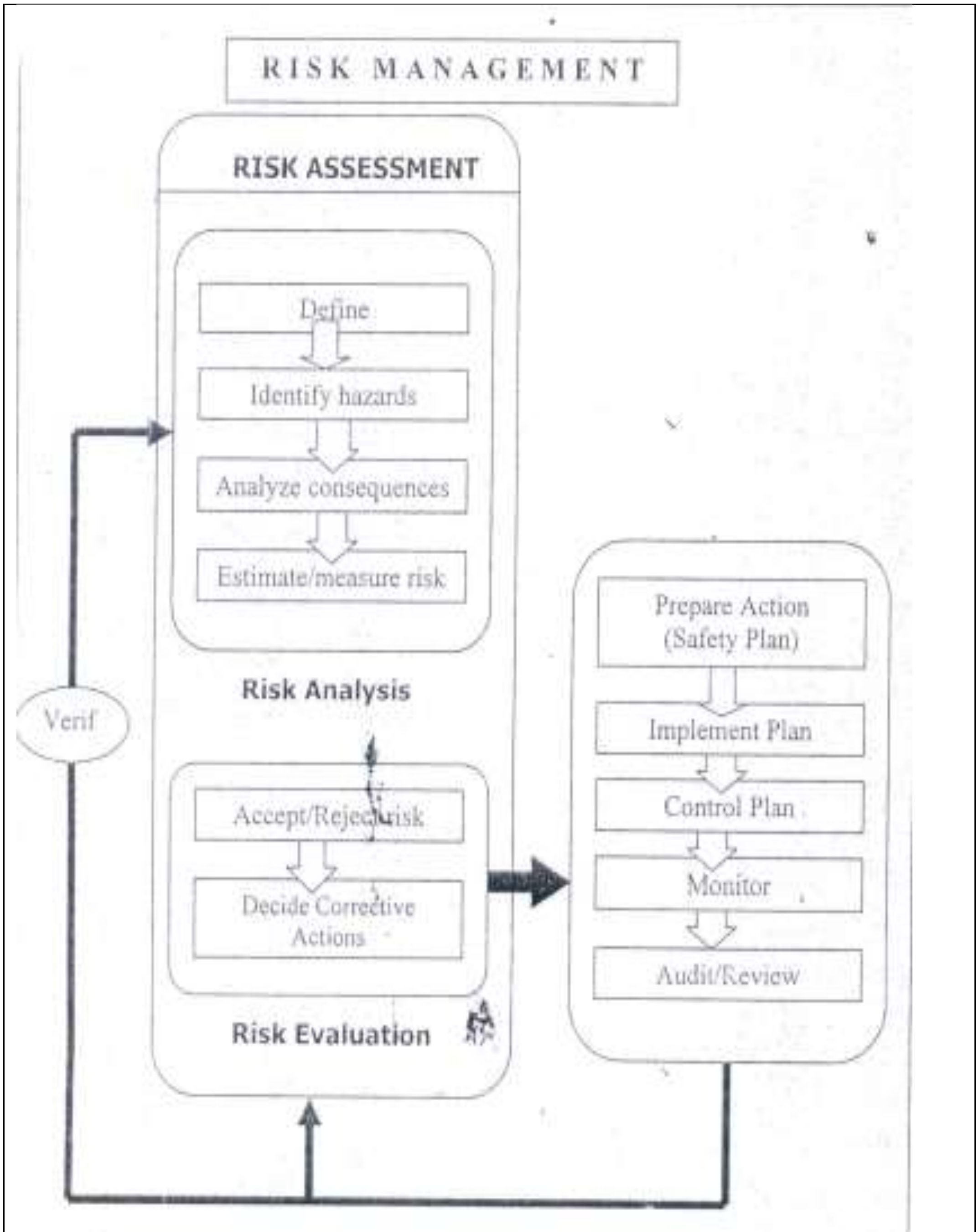
Risk: Chance (Probabilty) of exposure to a hazard combined with the consequences of such exposure.
Hazard: Source or potential source.
Harm: Injury or damage to health, damage to environment, economic loss etc.
Risk: Probability of Exposure * Severity, i.e. F (likelihood* consequences)

Risk Matrix

Likelihood ↑

<table>
<tr><td>Likely</td><td rowspan="2">B</td><td rowspan="2">A</td><td rowspan="3">A</td><td rowspan="4">A</td></tr>
<tr><td>Probable</td></tr>
<tr><td>Possible</td><td rowspan="3">C</td><td rowspan="2">B</td></tr>
<tr><td>Improbable</td><td rowspan="2">B</td></tr>
<tr><td>Remote</td><td>C</td><td>B</td></tr>
<tr><td></td><td>Minor</td><td>Major</td><td>Severe</td><td>Fatal</td></tr>
</table>

Consequences (Severity) →


RISK MANAGEMENT
RISK ASSESSMENT
Define
Identify hazards
Analyze consequences
Estimate/measure risk
Risk Analysis
Accept/Reject risk
Decide Corrective Actions
Risk Evaluation
Verif
Prepare Action (Safety Plan)
Implement Plan
Control Plan
Monitor
Audit/Review

Hazards Identification Checklist. (Sheet 1 of 2)

TYPE OF HAZARD	SOURCE	WHO IS EXPOSED and WHEN
1. Mechanical Hazards		
1.1 Crushing		
1.2 Shearing		
1.3 Cutting/Severing		
1.4 Entanglement		
1.5 Drawing-in/Trapping		
1.6 Impact		
1.7 Stabbing/Puncture		
1.8 Friction/Abrasion		
1.9 High pressure fluid injection		
1.10 Slips/Trips/Falls		
1.11 Falling object		
1.12 Other mechanical hazards		
2. Electrical Hazards		
2.1 Direct contact		
2.2 Indirect contact		
2.3 Electrostatic phenomena		
2.4 Short circuit/overload		
2.5 Source of ignition		
2.6 Other electrical hazards		
3. Radiation Hazards		
3.1 Lasers		
3.2 Electro-magnetic effects		
3.3 Ionising/Non-ionising radiation		
3.4 Other radiation hazards		

TYPE OF HAZARD	SOURCE	WHO IS EXPOSED and WHEN
4. Hazardous Substances (THINK COSHH)		
4.1 Toxic fluids		
4.2 Toxic gas/mist/fumes/dust		
4.3 Flammable fluids		
4.4 Flammable gas/mist/fumes/dust		
4.5 Explosive substances		
4.6 Biological substances		
4.7 Other hazardous substances		
5. Work Activity Hazards		
5.1 Highly repetitive actions		
5.2 Stressful posture		
5.3 Lifting/Handling heavy items		
5.4 Mental overload/Stress		
5.5 Visual fatigue		
5.6 Poor workplace design		
5.7 Other workplace hazards		
6. Work Environment Hazards		
6.1 Localised hot surfaces		
6.2 Localised cold surfaces		
6.3 Significant noise		
6.4 Significant vibration		
6.5 Poor lighting		
6.6 Hot/Cold ambient temperature		
6.7 Other environment hazards		
Use this completed list to produce your Risk Assessment.		

Estimation/Measurement of Risks

Risk may be described in qualitative, semi-qualitativ or quantitative terms:

- Qualitative risk- no figures, judgement is used to estimate risk level
- Semi- quantitative risk- risks may be ranked on a sci·llgaiatlve scale or using .
- Quantitative risk - risk may be described sa frequency or probability in absolute terms.

The risk matrix gives a clear definition of risk. If it was estimated that the chance of the operator exposed to explosion hazard is remote, but the exposure will result in a fatality, the matrix shows this risk level as 'B '. ·

If on the other hand it was estimated that the chance of oil leaking out of a machine which would result in a person slipping is likely. This is expected to result in minor injury which is ranked by the matrix also as risk level 'B'. Therefore risk is not judged by the consequences alone.

Evaluation of Risks

One of the most important steps in risk assessment is to evaluate risks, which are to determine whether the level of risk is tolerable - or unacceptably high and would warrant some urgent attention.

Evaluation 'of risks will depend on the method used for estimating the risk. Risk evaluation could be carried out qualitatively, semi quantitative or quantitative.

- Qualitative risk- judgement is used , difficult to prioritize.

- Semi-quantitative risk - decide which area of the risk matrix.

- Quantitative risk - use the HSE criteria for tolerability of risk if a fatal accident can result from exposure to the hazards.

The Risk Matrix can be a tool to estimate and evaluate risks on a semi guantitative basis. The criteria used for risk evaluation is as follows:

- Risk level 'A' would be regarded as 'Intolerable'. Relevant activity cannot be justified on any grounds.
- Risk level 'B' is a region of uncertainty. Risk assessment is needed to ensure that risks in this region are As Low As Reasonably Practicable or '**ALARP'.**

- Risk level 'C' is broadly tolerable. No further action is necessary.

The Risk Calculator

There arc several drawbacks with the criterion described so far for the estimation and evaluation of risks, as they either focus attention on potential fatal accidents or they miss out a vital component in measuring risk. Thi s is the proportion of time person(s) are exposed to the hazard.

One of the main differences between this risk calculator and other risk matrices, is that the calculator takes into account the frequency and duration of exposure of hazards. The risk calculator is primarily based on a Normogram introduced in the British Standard BS 5304: 1988 (machinery safety) .
·
The basic elements in calculating the order of magnitude of risk are:

- The **chance** which hazard is likely to occur ('probability level') -- this ranges from frequent or 1 in 10, to extremely remote, 1 in1 million. The probabilities are used to describe the Order of magnitude of what is meant by probable, remote, ...etc.

- The **frequency and duration of exposure** to hazard -- this is measured on a scale ranging form very rare or less than 1%, to continuous exposure 100% of the time.

- The **consequences** or potential severity of injury/damage, measured on a scale ranging from category (I) minor loss/first aid, to category (VI) multiple fatalities/total loss ......etc.

By connecting th e appropriate points on each scale and using the tie line in ·the middle of the calculator, it is possible to determine the level of risk involved. The risk leve l is divided into four general categories.

- High risk (A) - which indicates that the level of risk is unacceptable and cannot be justified on any grounds.

- Moderate risk (B)- which indicates that the level of risk should be reduced to a level as low as reasonably practicable 'ALARP', and

- Low risk (C) - which indicates that the level of risk is broadly acceptable and no further precautions should be necessary.

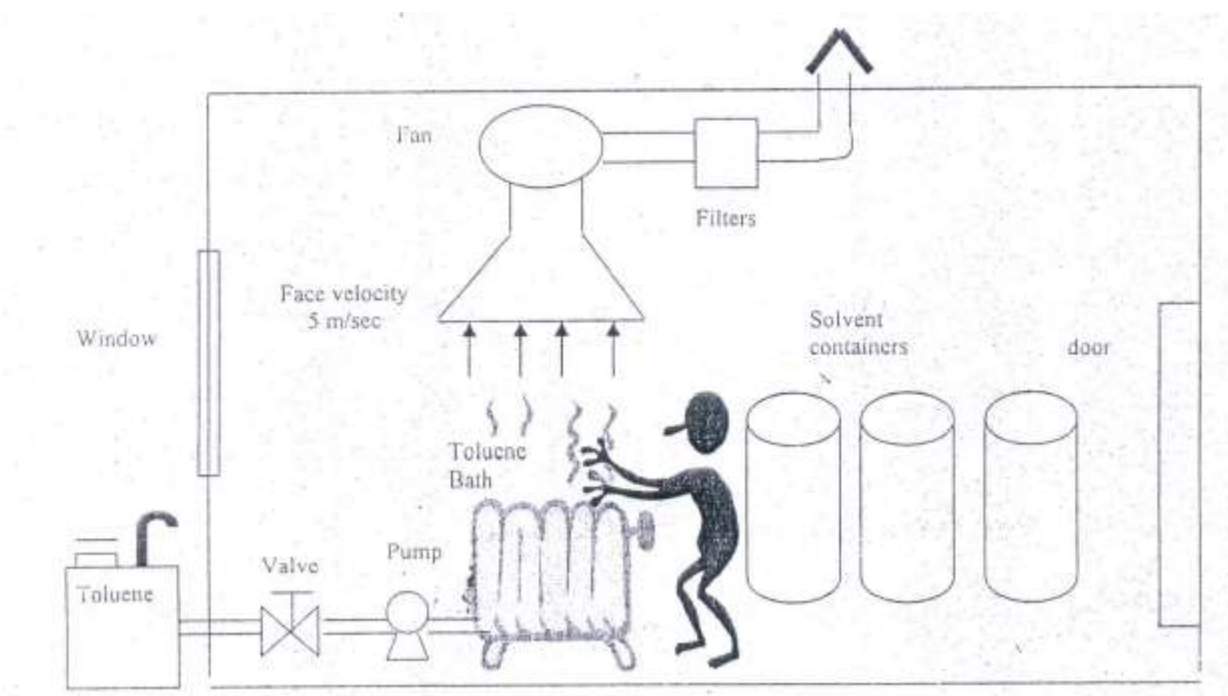
Analysis of the Consequences

Consequences

	I	II	III	IV	V	VI
Personnel	Insignificant	minor	major	severe	fatality	Multi-fatalities
Economic	<£1000	<£10,000	<£100,000	<£1million	<£1million	Total loss
Environment	minor	Short term	major	severe	widspread	catastrophe

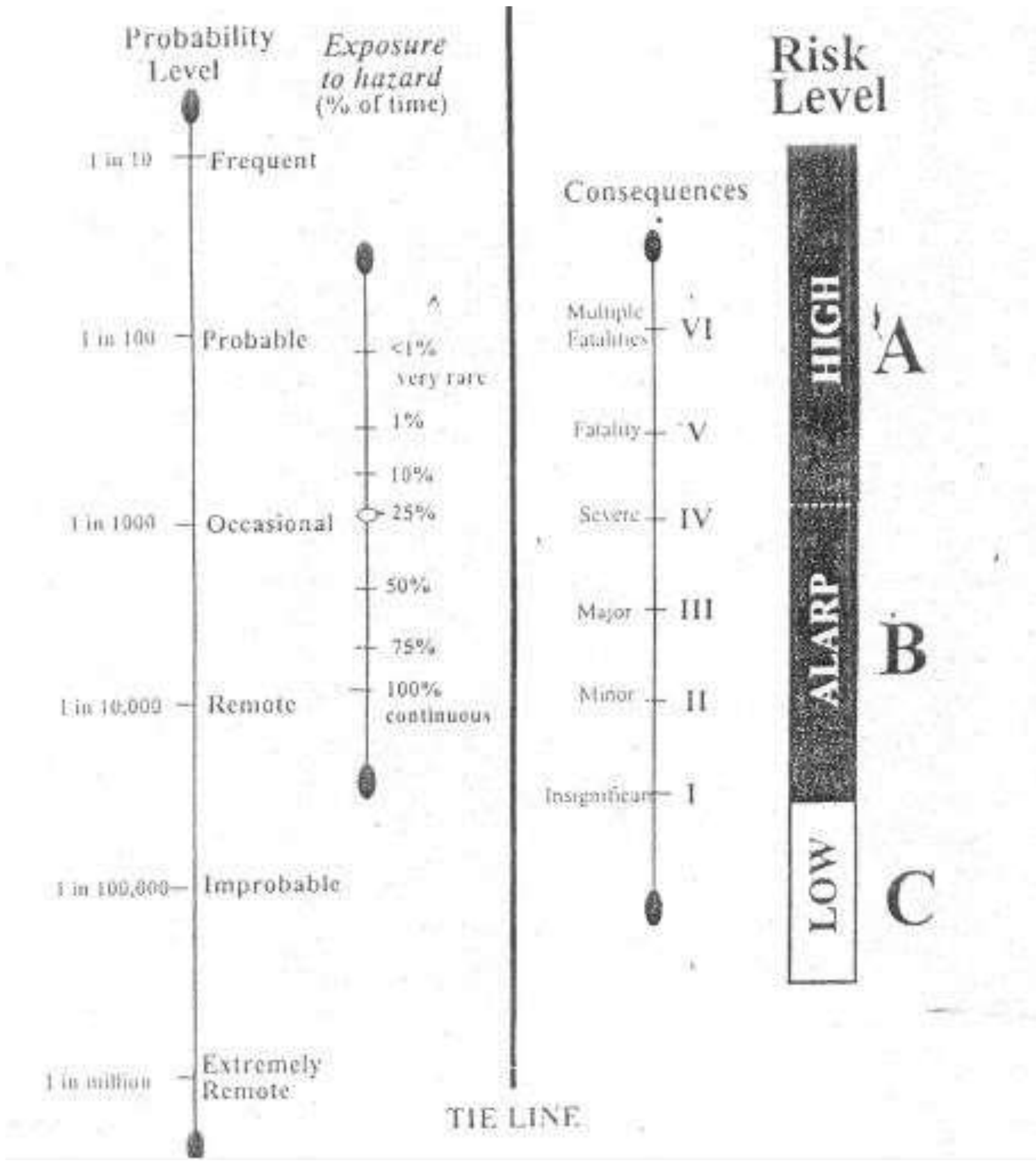
Catagory	Description	Examples
I	insignificant	Bruising, light abrasion etc
II	Minor	‘first aid’(normally reversible)
III	Major	Lossof consciousness, burns etc. (3 days off work
IV	Severe	Serious injury/damage to health (norn1ally reversible)
V	Fatality	Permanent disability, loss of sight, amputation, respiratory damage etc (not reversible)
VI	Multi-fatalities	To in: ude delayed effects, catastrophic

Risk Assessment Case Studies



Example of hazard identification and analysis work sheet (task based)

Machine /process/activity Metal cleaning shop		**Hazard Analysis Study Reference**		**Sheet ……2…… of …..5……**	
ACTIVITY TYPE	**Hazardous Events Error/Failure**	**POSSIBLE CAUSES**	**CONSEQUENCES**	**RISK LEVEL**	**CONTROL MEASURES/ACTION REQUIRED**
Filling cleaning tank with Toluene	Overfilling tank	Operator does not switch pump off	Increased toxic and flammable concentration	B	Action: consider high level alarm and pump trip
		Pump fails to stop (electrical fault)	Same as above	A/B	Action: same as above as well as emergency stop
Switch tank heater ON	toluene overheated	Thermostat fails	Major fire	A	Action: consider temperature indicator and alarm + procedure
	toluene not heated	Thermocouple fails	Valves not cleaned	B/C	Same as above
Dipping metallic components inside cleaning tank	Operator fails in tank	Loss of ability	fatality	A	Action: review tank height and consider mechanical handling
	Too many valves put in basket	Cut down cleaning time	Valves fall into tank/upper limb disorder	B	Action: review basket design + consider mechanical handling
		Tank topped up with other chemical	Possible reaction	B	Action: remove chemical drums from the workplace
	Toluene may be contaminated	Delivery of toluene already contaminated	Possible high level of benzene, water, etc.	B/C	Action: insure supplier compile with ISO 9000+sample
		Lack of maintenance	Explosion to high concentrations	B	Action: introduce planned preventive maintenance PPM
	Tank may leak	Impact by mobile equipment	Same as above	B	Action: remove all sources of impact



Probability Level
Exposure to hazard (% of time)
Risk Level
1 in 10 Frequent
1 in 100 Probable
1 in 1000 Occasional
1 in 10,000 Remote
1 in 100,000 Improbable
1 in million Extremely Remote
<1% very rare
1%
10%
25%
50%
75%
100% continuous
Consequences
Multiple Fatalities VI
Fatality V
Severe IV
Major III
Minor II
Insignificant I
HIGH
A
ALARP
B
LOW
C
TIE LINE

Experiment No: 7

Experiment Name: Determination of Light Level in different workplaces

Introduction:

The majority of industrial tasks depend for their effeciency on adequate vision, therefore lighting plays an important part in determining the efficiency with which tasks are carried out. The amount of light required for the performance of a visual task is influenced by four factors which are independent. These are:

I. The size of the object
II. The contrast between the object and its immediate surround
III. The reflectivity of the immediate surround
IV. Time allowed for seeing.

The amount of which is required for the task cannot be determined until all these factors have been established.

Objective: In this experiment, students have to determine the illumination level of a number of workstations.. They are also required to critically analyze the findings and comment for improvements (if any).

Apparatus:

1. Light Meter

Procedure:

1. Measure the light intensity of the workplace assigned.
2. Identify whether existing lighting system is adequate or not for the specific workplace.
3. Comment for improvements (if any).

Light Meter:

The instrument is easy to use with pocket size and light weight, providing accurate display light level in terms of Foot Candles (FC) or LUX over wide range.

Fig: Light Meter

1. LCD Display
2. Power / function/ range switch: Turn power ON/ OFF and select measurement function and ranges.
3. Photo Detector
4. Max Hold: To hold maximum reading.
5. Data Hold: To hold the reading.
6. Function button: Select measurement functions of Lux or Fc

Operation:

1. Turn the power switch to select range to desired lux/fc range.
2. Hold the “Photo Detector” to light source in a horizontal position.
3. Read the illunination nominal from the LCD display.
4. To hold a measurement , press the “Hold” button, the reading will freeze in the display until the button is pressed again.
5. If the input signal is too strong, the instrument will display one “1” only , then a hoigher range should be selected.
6. For measurements made on the Lux 20000 or 50000 range, the displayed reading must be multiplied by 10 and 100 respectively.

Table: Range Display Multiplier

Range	Units	Multiplier
200	Fc	Direct reading
2,000	Fc & Lux	Direct reading
20,000	Lux	Reading * 10
50,000	Lux	Reading * 100

Example: If a measurement on the 20,000 Lux range displays 500, then the actual measured value is 500 * 10=5000

The table below is guidance for recommended light level in different work spaces:

Activity	Illumination *(lux, lumen/m^2)*
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000
Performance of very prolonged and exacting visual tasks	5000 - 10000
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000

Assigned Workplaces

1. Machine Shop (Lathe, Milling)
2. Machine Shop (Drilling, Grinding)
3. Welding Shop
4. Measurement Lab
5. Drawing Lab
6. Computer Lab
7. Classroom
8. Departmental Office Room
9. Library

Experiment No: 8

Experiment Name: Performing time study in workplace

Introduction:

Work measurement is concerned with determining the length of time it should take to complete the job. Time standard provides an indication of expected output. It reflects the amount of time it should take an average worker to do a given job working under typical condition. It is a study of the operational steps or production procedure and the time consumed by them for the purpose of devising methods of increasing efficiency or productivity of workers. This work-study aims at improving the existing and proposed ways of doing work and establishing standard times for work performance. Improving the ways in which the work is done (methods) improves productivity, work study and industrial engineering techniques and training are the areas which improve the work methods, which in term enhances the productivity.

Time study was formally introduced by Frederick Taylor in nineteenth century. It is the most widely used method of work measurement; especially appropriate for short, repetitive tasks.

Objective: In this experiment, students have to determine standard work time for workers in their assigned workplaces. They are also required to critically analyze the findings and comment for further produtivity improvements (if any).

Apparatus:

1. Stop Watch

Procedure:

1. Obtain and record all the job information.
2. Define the task to be studied and inform the worker(s) who will be studied.
3. Break down the operation into elements.

4. Determine the number of cycles to be observed.
5. Check that the job is being performed efficiently before setting the time standard.
6. Measure the time of the each job element using stop watch.
7. Assess the effective working speed of the operator and rate the performance.
8. Determine the allowances to be made.
9. Compute the standard time.
10. Test and review standards wherever necessary.

Standard Time

Standard time is the amount of time a qualified worker should spend to complete a specified task, working at sustainable rate, using given methods, tools and equipment, raw material and workplace arrangement.

Time study is used to develop a time standard based on observations of one worker taken over a number of cycles. However, it is very difficult to select the right person who should perform the job. Hence, average of a few properly trained workers' performed time are taken as the standard. The standard time is then applied to the work of all others in the organization who perform the same job.

Development of a time standard involves computation of 3 times:

I. Observed time (OT)
II. Normal time (NT)
III. Standard time (ST)

I. Observed Time (OT): Simply the average of the recorded times.

$$OT = \frac{\sum x_i}{n}$$

$\sum x_i =$ sum of recorded time

n = number of observations

II. **Normal Time (NT):** It is the observed time adjusted for worker performance.

Computed by multiplying the observed time by a performance rating of the concerned worker.

$$NT = OT * PR$$

If ratings are made on an element-by-element basis,

$$NT = \sum \left(OT_i * PR_i\right)$$

OT_i – average time for element i

PR_i – performance rating for element i

Performance Rating *:* Assessing the effective speed of working of the operator relative to the observer's concept of the rate corresponding to standard rating.

Time studies should be made on a number of qualified workers; and that very fast or very slow workers should be avoided.

III. **Standard Time (ST):** It is the normal time required for a job plus an allowance time.

$$ST = NT * AF$$

AF= Allowance factor

Allowances: Many jobs require spending of human effort and some allowance must therefore be made for recovery from fatigue and for relaxation.

Allowance must be made to allow a worker for different delays:

- Personal – drink, restroom
- Unavoidable – machine adjustment
- Material shortage
- Worker fatigue (physical / mental)

Allowance can be based on

- Job time (allowance for total job produced) $AF_{job} = 1 + A$
- Time worked (allowance for total work period) $AF_{day} = \frac{1}{1 - A}$

Assignment:

1. A direct time study was taken on a manual work element. The regular cycle consisted of four elements a, b, c and d.

Work element	**a**	**b**	**c**	**d**
Observed time (min)	0.56	0.25	0.50	1.10
Performance rating	100%	80%	110%	100%

Determine Standard time for the cycle, using allowance factor of 15%.

2. Find out the standard time using the following data:
Average time for machine elements = 6 min
Average time for manual elements = 4 min
Performance rating = 110%
Allowances = 10%

3. Assuming that the total observed time for an operation of assembling an electric switch is 1.00 min. If the rating is 120%, find normal time. If an allowance of 10% is allowed for the operation, determine the standard time.

4. In attempt to increase productivity and reduce cost, a company is planning to install an incentive pay plan in its manufacturing plant. In developing standards for one operation, time study analysts observed a worker for a 30 minute period. During that time the worker completed 42 parts. The analysts rated the worker as producing at 130 percent. The base wage rate for a worker is $5 per hour and an incentive of $ 2 for each extra unit produced. The firm has established 15% as a fatigue and personal time allowance.

i. What is the standard time for the task?

ii. If the worker produced 500 units during an eight hour day, what wages would be the worker have earned?

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 3204: Material Handling and Maintenance Engineering Sessional
Credit Hour: 1.5

Objective:

To get familiar with different types of conveyor and product handling equipment. Designing concepts of common handling and transfer equipment. Concept of maintenance plan and maintenance management.

General Instructions:

1. Attend to the lab 5 minutes prior to the scheduled time and be prepared for the experiment.
2. Sessional grade will be calculated in the following way:

Total Marks: 100			
Attendance	**Lab Reports**	**Viva**	**Quiz**
10	40	20	30

3. Students must bring the necessary instruments, data sheet (for particular experiment), calculator, graph papers (Cartesian, Semi-log, log-log).
4. Report should be submitted in the following week during the sessional time.
5. Write report on one side of an 80 gram A4 paper and follow the following format
    a) Top sheet
    b) Objective
    c) Apparatus (including technical specification)
    d) Figure/Experimental Setup
    e) Data Sheets/Result
    f) Sample calculation
    g) Graph
    h) Discussion
        i) Discuss the graphs and results
        ii) Discuss about the experimental setup if it could be improved
        iii) Discuss the different parameters that could affect the result
        iv) Discuss any assumption made
        v) Discuss any discrepancies in the experimental procedure and result
        vi) Discuss what you have learnt and the practical application of this knowledge
    i) Finally, add the data sheet with the report.

Suggested Reading:

1. Conveyors and Related Equipment – A. Spivakovsky and V. Dyachkov
2. Material Handling – Siddharta Ray

Name of the Experiments:

1. Study of angle of repose (static and dynamic) for different materials
2. Determination of bulk weight of different material
3. Determination of the capacity of a belt conveyor
4. Study of a bucket conveyor and determination of optimum capacity
5. Determination of the capacity of an apron conveyor
6. Determination of the capacity of a Screw conveyor and power loss
7. Study of layout plan of AUST central Machine shop
8. Study of the replacement plans of tube lights in AUST campus
9. Determination of power loss of the roller conveyor
10. Study the impact of angle change of roller conveyors

Equipment List

1. **Screw Conveyor with hopper feeder**
2. **Belt Conveyor with speed control**
3. **Bucket Conveyor with speed control**
4. **Apron Conveyor**
5. **Roller Conveyor with angle adjustment**
6. **Weighing Scale (0~10 kg)**
7. **Stopwatch**
8. **Cylindrical pipe**
9. **Container**
10. **Different Types of Granular Materials (Wheat, Rice, Gram, Paddy, PVC Granules, Lentils)**

Experiment No: 1

DETERMINATION OF ANGLE OF REPOSE (STATIC AND DYNAMIC) FOR DIFFERENT MATERIALS

Objectives:

i. To determine the static and dynamic angle of repose for different bulk materials
ii. To study how long they vary at different working conditions, their implication on the selection and design of material handling equipment

Theory:

Angle of Repose:

When a loose material (bulk load) unobstructedly spills on a horizontal plane, it assumes a slope. The angle of the slope with the horizontal plane is called the angle of repose (φ).

The magnitude of the angle of repose depends on the mutual mobility of the particles. The larger their mobility the smaller their angle.

The angle of repose may be static (φ) or dynamic (φ_{dyn}). Dynamic angle of repose is approximately 0.7 times the static angle of repose.

The static angle of repose can be determined with various simple devices, a hollow cylinder, for example. The material is filled into the hollow cylinder and when the latter is carefully raised, the material pour out and from a cone on the horizontal surface. The cone forms an angle with the surface which is called static angle of repose. The angle is measured with angle gauge of different types. The dynamic angle of repose is obtained when the horizontal supporting surface vibrates vertically.

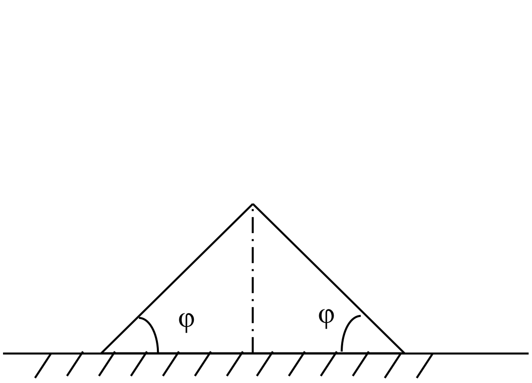


Figure 1.1: Natural slope assumed by a free – flowing material spilled on a horizontal surface

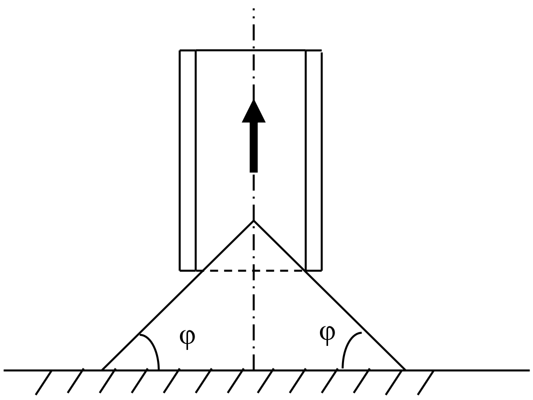


Figure 1.2: Determination of angle of repose with a hollow cylinder

Determination of angle of repose:

Procedure:

To determine static angle of repose, the bulk material should be filled into a hollow cylinder and then the cylinder should be raised carefully. The material would pour out and from a cone on the horizontal surface. The angle of the generatrix of the cone is the static angle of repose.

To determine the dynamic angle of repose, vertical vibration on the surface should be given while raising the hollow cylinder.

Determine the angle of repose by varying

i. Diameter and material of the cylinder
ii. Bulk material
iii. Type of the surface (such as floor table, cloth etc)

Data Sheet: (for determination of angle of repose)

Serial No.	Surface Condition	Material	Angle of Repose		Radius of Expansion		% of Static Angle
			Static	Dynamic	Static	Dynamic	

Questions:

1. What is the impact of angle of repose in conveying material?
2. Angle of repose changes with the mobility of the material, why?
3. How angle of repose can be changed for the same material?
4. Should we consider the coefficient of the bulk material on working surface in determining angle of repose? If yes, why?

Experiment No: 2

DETERMINATION OF BULK WEIGHT OF DIFFERENT MATERIAL

Objectives:

i. To determine the bulk weight of different bulk materials
ii. To study the impact of bulk weight in conveying materials

Theory:

Bulk or heaped weight γ is the weight of the material per unit of volume in bulk. It is usually measured in tons per cubic meter (or kg per liter), sometimes in kg per cubic meter. The bulk weight of granular and powdered materials is usually determined with a special device consisting of container of a definite given volume; rod attached to the container and revolving frame secured on rod. The larger the lump size of the material, the larger should be the volume of the container.

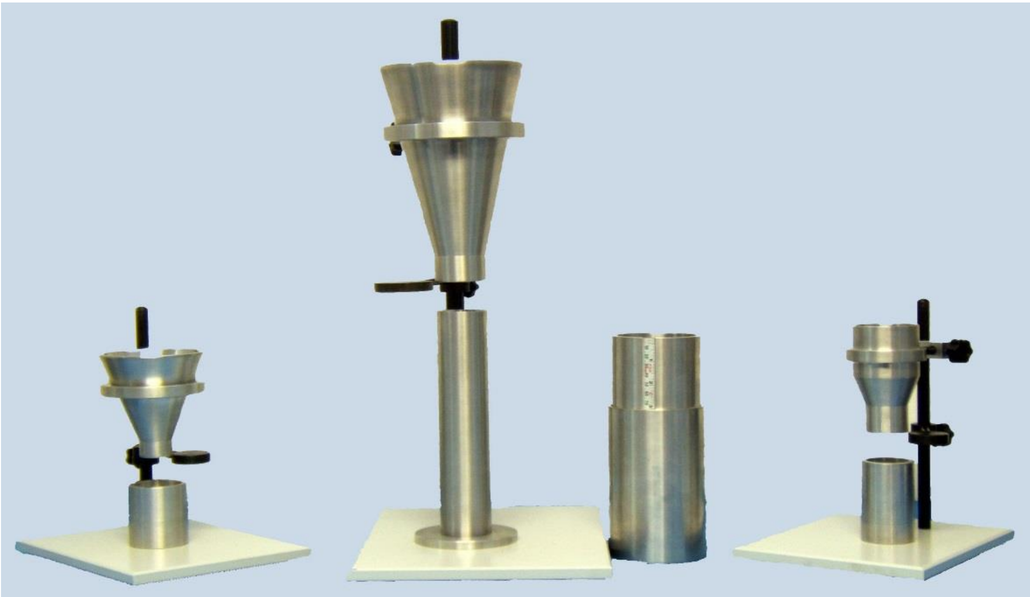


Figure 2.1: Bulk weight of material

Procedure:

i. Measure the weight of the empty container.
ii. Bulk material is poured into the container through the frame until the container is full.
iii. A turn of the frame removes excess material and leaves the container full to the rim.
iv. Then contained is weighted with bulk material.
v. The difference between the final weight and the initial container weight is the net weight of the material.
vi. Divide the net weight of the material by the container volume is the bulk weight of that material.

Data Sheet:

Radius of the container: __________________ m

Height of the container: __________________ m

Volume of the container: _________________ m^3

Initial weight of the container (kg)	Final weight of the container including bulk material (kg)	Net weight of the material (kg)	Bulk weight, γ (kg/ m^3)

Questions:

1) What is the impact of moisture in bulk weight measurement?
2) Significance of bulk weight.
3) While designing a material handling system what type of bulk weight should be calculated? (γ or γ_{packed})

Experiment No: 3

DETERMINATION OF THE CAPACITY OF A BELT CONVEYOR

Objectives:

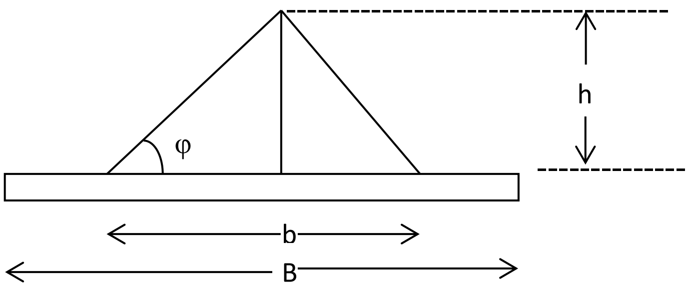
i. Study Different Parts of the Belt Conveyor
ii. To find the capacity of a belt conveyor (theoretical and actual)
iii. To find tensions at different points of the belt
iv. To calculate the required horsepower of the drive motor

Determination of theoretical capacity:

Cross sectional area of bulk load over the belt,

$F_1 = ½ bhC_1 = ½ (0.8B) (0.5 b \tan\varphi_1) C_1$

$= 0.16 B^2 C_1 \tan (0.35 \varphi)$



Capacity of the belt conveyor, $Q_{theoretical} = 3600 F_1 v\gamma$ tons/hour

Where, v =belt speed, m/sec

γ = bulk weight of material, tons/m^3

φ = static angle of repose

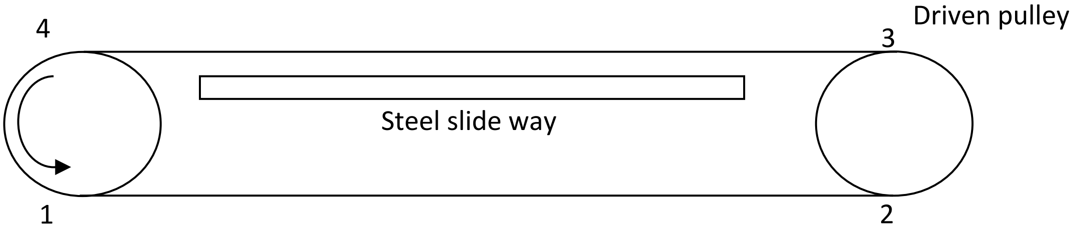
C_1 = correction factor for possible spillage of the load on an inclined belt. (For horizontal belt its value is taken as 1.)

Determination of actual capacity:

Determination the actual capacity of the conveyor, Q_{actual} by taking weight of the material at the discharge end for a certain period of time (measured by stop watch)

Observation	Weight of material discharged (kg)	Time (sec)	Capacity, Q_{actual}, (tons/hr)	Average value
1				
2				
3				
4				
5				

Determination of required Horse power of Motor:



Let the conveyor outline be divided into separate sections of the different resistance, neglecting the resistance on the deflecting rollers; and number them from 1 to 4.

The tension S_1 in point 1, where the belt leaves the driving pulley is assumed to be equal to S_{s1}.

- The tension in point 2,

  $S_2 = S_1 + W_{1,2} = S_1 + 0 = S_1$

  [Where, $W_{1,2}$ is the resistance on the section between point 1 & 2]

- The tension in point 3,

  $S_3 = S_2 + W_{curve} = S_2 + kS_2 = (1+k)\ S_2 = KS_2$

  [Where, the resistance W_{curve} consists of the resistance set up by the stiffness of the pulling member when it bends entering the curve and straightens out leaving it and of the frictional resistance on the hub of the pulley or that of the shaft carrying the pulley. These resistances are generally proportional to S_2. The value of K lies between 1.05 and 1.07]

- The tension in point 4,

$$S_4 = S_3 + W_{3,4} = S_3 + (q+q_b)L\mu_1 = KS_2 + (q+q_b)L\mu_1 = KS_1 + (q+q_b)L\mu_1$$

[Where, q = weight of the load per meter of belt length, kg/m

q_b = weight of the belt per meter of its length, kg/m

= 1.1B ($\delta_i + \delta_1 + \delta_2$)

{Assume, δ (thickness of one ply) = 1.25mm

δ_1 (cover thickness on the loaded side) = 1.5 mm

δ_2 (cover thickness on the return side) = 1.0 mm

i (number of plies) = 4}

L = length of the section between points 3 &4,

μ_1 = belt friction factor on steel runway = 0.35 to 0.67]

- Now it is known from friction drive theory that there will be no belt slip on the pulley when

$$S_t = S_4 \leq S_{sl} \times e^{\mu\alpha} \leq S_1 \times e^{\mu\alpha}$$

[α is the wrap angle of the belt on the driving pulley in radian, μ is the friction factor between belt and pulley (= 0.3 for cast iron or steel pulley and dry atmosphere and dusty)]

Or, $KS_1 + (q+q_b) L\mu_1 = S_1 \times e^{\mu\alpha}$

Or, $S_1 = (q+q_b) L\mu_1 / (e^{\mu\alpha} - K)$

- Thus, S_2, S_3, S_4 can be found
- Now, the resistance on the driving pulley, $W_{dr} = 0.05 (S_t + S_{sl})$
- The effective tension $W_0 = S_{st} - S_{sl} + W_{dr}$
- The required motor power for the conveyor, $N = (W_0 \times v)/102\eta$ Kilowatt [Assume v = 4m/sec]

Questions:

1. Why the tension differs from slack to tight side of the belt conveyor?
2. Can the resistance factor be changed of the “roller & belt” & “belt & pulley”? If yes, then how?
3. Is it possible to have a value of μ=0.9 for the belt and slideway friction?
4. With net sketches classify belt conveyor according to the path of motion.
5. Briefly describe different types of drive arrangements used for belt conveyor.
6. What are the factors those influence the magnitude of the pull transmitted by the driving pulley?
7. How can the magnitude of the pull be enhanced?

Experiment No: 4

STUDY OF A BUCKET CONVEYOR AND DETERMINATION OF OPTIMUM CAPACITY

Objectives:

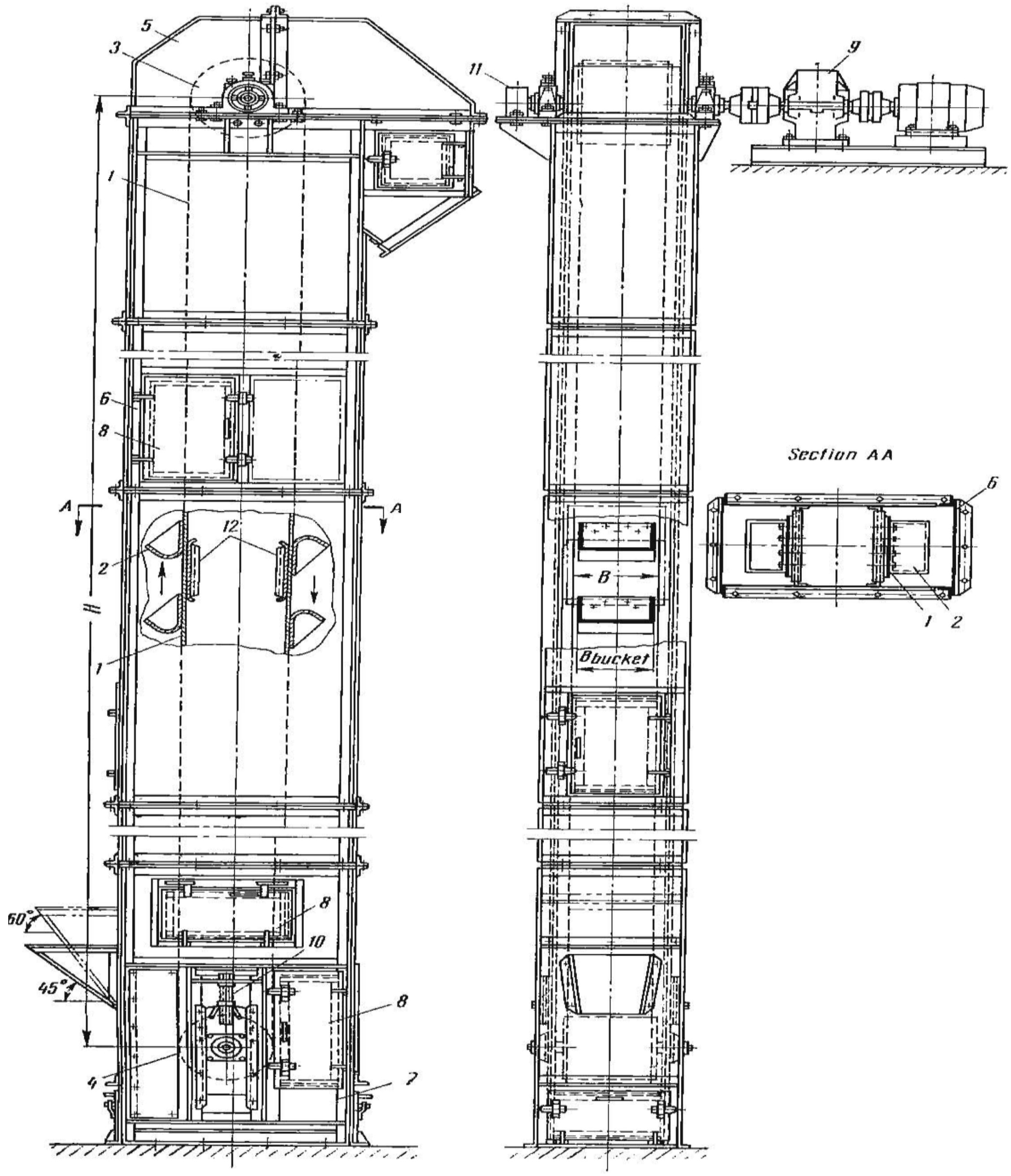
i. To study different components and the operation of the bucket conveyor
ii. To determine both the theoretical and actual capacity
iii. To determine the optimum capacity

Theory:

Definition, descriptive specifications and use:

These are powered equipment for conveying bulk materials in a vertical or steep inclined path, consisting of an endless belt, or chain/s to which metallic buckets are fixed. With the flexible belt/chain, the buckets move unidirectionally within a casing and collects bulk materials at bottom end of the equipment and delivers it at the top end.

A typical bucket elevator with different constructional parts is shown in Figure. The different major parts constituting a bucket elevator are as follows:
(*i*) An endless pulling member- flat belt or chain.
(*ii*) Driving and take up pulleys or sprockets at top and bottom respectively, mounted on bearings and blocks.
(*iii*) Metal casing covering the entire elevator. It consists of **head** at the top, **boot** at the bottom and intermediate sections, all joined at flanges by fasteners.
(*iv*) Buckets, generally made out of sheet metal, which are attached at definite pitch to the pulling member by fasteners (screw and nuts, riveted etc.)
(*v*) Drive at the top consisting of an electric motor, gearbox, and couplings.
(*vi*) Hold back brake attached to the top pulley/sprocket shaft, to prevent reverse motion of the elevator when drive is stopped.
vii) Feed hopper attached to the boot for feeding materials to the elevator.
(*viii*) Delivery/ discharge spout fixed with the top part of the casing, through which the material is discharged.
(*ix*) Manholes are provided at the casing to check operations of the elevator.
(*x*) Guides and guide sprockets are provided for belt and chain respectively to keep them in a straight path.



1-belt; 2-bucket; 3-driving pulley; 4-take-up pulley; 5-upper casing section; 6-intermediate casing sections; 7-lower casing section (boot); 8-manholes; 9-drive unit; 10-take-up; 11- holdback brake; 12-guides.

Figure 4.1: A vertical belt-and-bucket elevator

Types of bucket elevators:

Bucket elevators are classified based on bucket spacing and mode of discharge of materials.

Centrifugal discharge elevators:

In a centrifugal discharge elevator, the buckets are spaced at a regular pitch to avoid interference in loading and discharging. The charging of buckets is by scooping action and the discharge is by centrifugal action. These elevators are generally used in vertical configuration and used for practically all types of free flowing, small lump materials like grain, coal, sand, clay, sugar, dry chemicals etc. Both belt and chain may be used and the speed of these elevators range between 1.1 to 2 mpm.

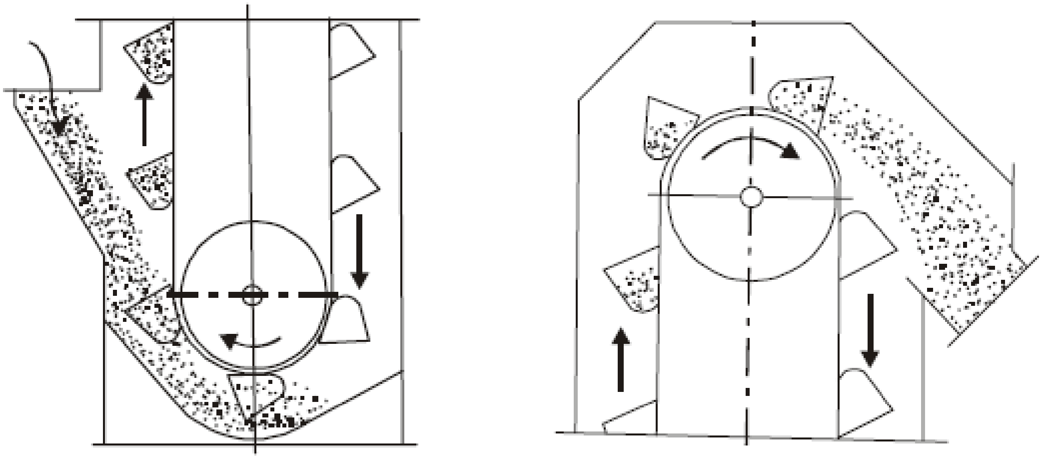


Figure 4.2: Charging and discharging of buckets of centrifugal discharge elevator

Positive discharge elevators:

These are similar to centrifugal discharge type excepting that the buckets are side-mounted on two strands of chains (i.e. buckets lie between two strands of chains), and are provided with a pair of two snub sprockets under the head sprockets to invert the buckets for complete discharge. The speed of the elevator may be slow in the range of 0.6 to 0.67 mpm. These elevators are used for light, fluffy, sluggish and slightly sticky materials. The feeding is through scooping or digging by the buckets. Fig.4.3 shows the discharging of these elevators. An inclined elevator is particularly suitable for perfect gravity discharge.

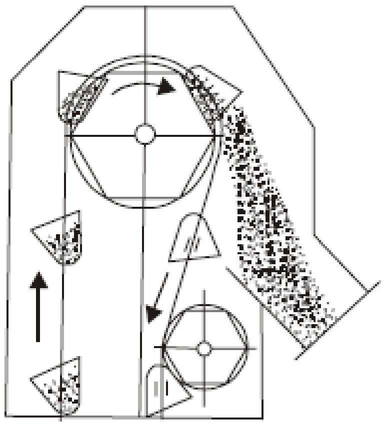


Figure 4.3: Discharging of positive discharge elevator

Continuous discharge elevators:

In these elevators, V-type buckets are used without any gap between them. These elevators are employed for handling larger lumps and materials that may be difficult to handle by centrifugal discharge. The charging of the buckets are by direct filling. The discharge is by directed gravity i.e. when the buckets pass over head wheel, the flanged end of the preceding bucket act as a chute to deliver materials gently to the discharging spout. This type of charging and discharging is particularly effective for handling fragile materials.

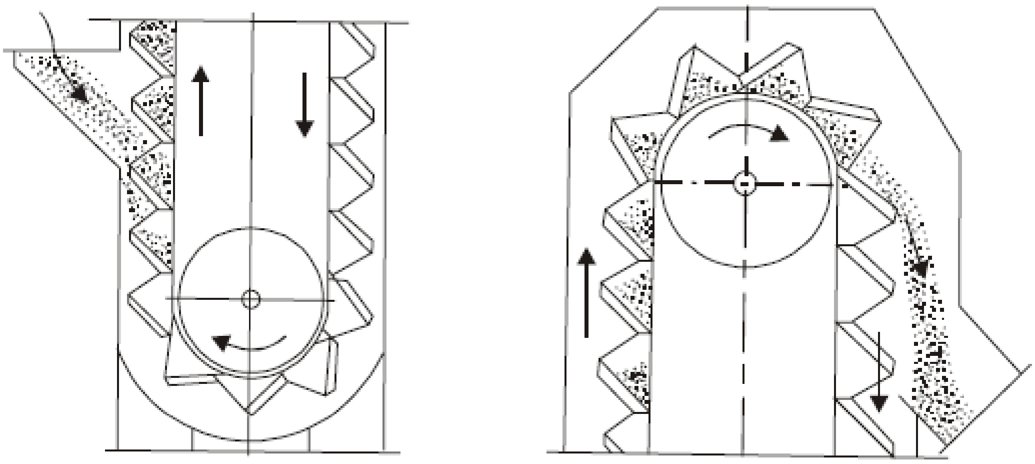


Figure 4.4: Charging and discharging of a continuous bucket elevator

Determination of theoretical capacity:

Capacity of the bucket conveyor, $Q = 3.6\ \psi\ \gamma\ V\ (i_o/a)$ ton/hr

Where,

i_o = capacity of the bucket, liter

a = distance between bucket, m

v = belt or chain speed, m/sec

γ = bulk weight, ton/m^3

ψ = loading efficiency

Determination of actual capacity:

Determination the actual capacity of the conveyor, Q_{actual} by taking weight of the material at the discharge end for a certain period of time (measured by stop watch)

rpm: ____________

Observation	Weight of material discharged (kg)	Time (sec)	Capacity, Q_{actual}, (tons/hr)	Average value
1				
2				
3				

rpm: ____________

Observation	Weight of material discharged (kg)	Time (sec)	Capacity, Q_{actual}, (tons/hr)	Average value
1				
2				
3				

rpm: ____________

Observation	Weight of material discharged (kg)	Time (sec)	Capacity, Q_{actual}, (tons/hr)	Average value
1				
2				
3				

Questions:

1) How the power consumption varies with inclination angle of bucket conveyor?
2) Which kind of discharge is required? Gravity or centrifugal? Explain.
3) Differentiate between scoop type and direct feeding charging.

Experiment No: 5

DETERMINATION OF THE CAPACITY OF AN APRON CONVEYOR

Objectives:

i. To study different components and the operation of the apron conveyor
ii. To determine both the theoretical and actual capacity
iii. To determine the optimum capacity

Theory:

Definition:

The term chain conveyor means a group of different types of conveyors used in diverse applications, characterized by one or multiple strands of endless chains that travel entire conveyor path, driven by one or a set of sprockets at one end and supported by one or a set of sprockets on the other end.

General Characteristics

Different types of chain conveyors are used in wide varieties of applications. Chain, compared to belts of a belt conveyor, have certain advantages as well as disadvantages. The major advantages are that the chain easily wraparound sprockets of small diameter, and the drive is positive i.e. no slippage takes place between chain and sprocket. The chain stretch is also little. The disadvantages of chain are its high weight, high initial cost, higher maintenance cost and most importantly, limited running speed because of dynamic loading that come into play in chain-sprocket drive causing intensive wear at high speeds.
Maximum length and maximum lift of chain conveyors are limited by the maximum allowable working tension of the chain used.

Figure 5.1: Apron Conveyor

Power Calculation:

Sprocket diameter, d = 8 in

N = 70 rev/min

Velocity, V = $\frac{\pi d N}{1000}$ m/min

Apron width, B =?

Slat material weight, q_o = (60B+A) kg/m

Table: Approximate values of factor A for flanged aprons

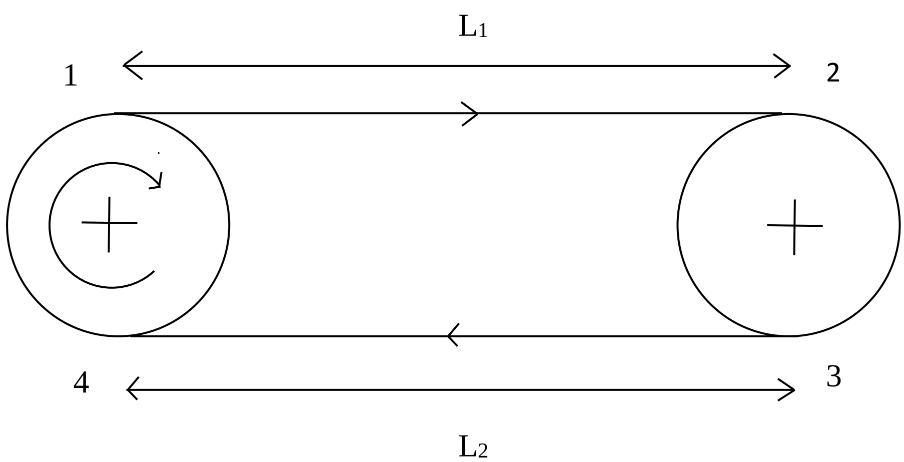
Type of Apron	Factor A for an apron having a width of		
	B<0.5m	B<0.8m	B>0.8m
Light	40	50	70
Medium	60	70	100
Heavy	80	110	150

For unflanged aprons the corresponding value of factor A is decreased by 10 to 15 percent.

Considering the maximum weight, G = 4 kg per load

Distance between two load, a=?

Weight of the material per meter, q = $\frac{G}{a}$ kg/m



From the above figure,

Least tension will be at point 3 or point 1

Let, S_1 = 100 kg [the minimum pull of apron conveyor is between 100-300 kg]

For rolling bearing,

Resistance factor, $\omega' = 0.045$ [Adverse operation condition]

$S_2 = S_1 + (q_o+q)\ L_1.\ \omega'$ kg

[L_1 = length of the section between points 1 & 2]

$S_3 = k.S_2$ kg

$S_4 = S_3 + q_o.\ L_2.\ \omega'$ kg

[L_2 = length of the section between points 3 & 4]

The resistance on the driving pulley $W_{dr} = k\ (S_{4+}\ S_1)$

Peripheral pull, $W_o = S_4 - S_1 + W_{dr}$ kg

Considering the efficiency of bevel gear, $\eta_g = 75\%$

Power required, $N = (W_o * v)/\ 102\ \eta_g$

Efficiency of motor, η = ?

Capacity:

Capacity, Q = 3.6 qv ton/hr

Where, q = Weight of the material in kg per meter

v = velocity, m/s

Questions:

1) What is the basic difference between belt and slat conveyors?
2) When it is appropriate to use slat conveyors?
3) What are the ways to increase the efficiency of slat conveyor?

Experiment No: 6

DETERMINATION OF THE CAPACITY OF A SCREW CONVEYOR AND POWER LOSS

Objectives:

i. To study different components and the operation of the screw conveyor
ii. To determine both the theoretical and actual capacity
iii. To investigate the possible causes of deviations of the result and ways to improve the overall efficiency of the conveyor

Theory:

Screw conveyor:

Screw conveyor consists of a spiral member, which advances around a circular shaft. Material is advanced by the action of the helical screw as it is turned by the shaft in a trough. As the shaft rotates the material fed to it is moved forward by the thrust of the screw or flights.

The screw conveyor is of simple design, easy to maintain, of small width, permit intermediate discharge of the material at several points, is readily made dust tight by jacketing the trough. They are relatively inexpensive means of conveying pulverized or granular materials.

Thrust reaction force on screw is opposite to the direction in which the material flows. When the setup is such that the trust is taken at discharge end, the conveyor is in tension and if thrust is taken at receiving end- the conveyor is under compression.

Standard pitch conveyors are used for handling materials horizontally or inclined up to 20^0. Longer pitches are for high capacity, free flowing material. Shorter pitches are for materials which are fed slowly, as for cooling, drying etc.

The spiral may be mounted to run in either open or covered troughs, usually made of steel.

The total resistance to motion in a screw conveyor is made up of –

i. Friction of the material against the trough
ii. Friction of the material against the surface of the screw
iii. Friction in the intermediate and terminal bearings
iv. Friction in the axial thrust bearings
v. Packing in the axial thrust bearings
vi. Mixing of the materials
vii. Friction on the edges of the screw against the particles in the clearance

Applications of screw conveyors are limited. Materials that can be satisfactorily handled by it are few. It is effective only when there is uniform feeding. It cannot be used for easily crushed, large lumped, abrasive, and sticking materials. Overloads cause bottlenecks near the intermediate bearings obstruct the shaft revolving and stop the screw. Friction of the material against screw and trough is responsible for high power consumption, wear of the conveyor part and crushing of the material. Therefore, screw conveyors are used for low medium capacity (up to 100 m^3/hr).

Parts of screw conveyor:

1. Screw and shaft
2. Trough (generally made of sheet steel)
3. Intermediate hanger bearing (generally located at discharge end other conveyor. It is a thrust bearing taking up the force of frictional resistance directed along the longitudinal axis of the conveyor).
4. Loading spout
5. Discharge spout
6. Intermediate discharge spout
7. Drive unit

The inner diameter of the cylinder trough section is slightly larger than that of screw, so that a certain clearance is left between them. The clearance should be such that there is less breaking up of the material and less power consumption. Recommended clearance is 6 to 9.5 mm. the clearance increases with screw diameter.

Theoretical capacity of the screw conveyor:

$Q = V\,\gamma$

$Q = 60.\pi\,(D^2/4)\,S.\,n.\,\psi.\,\gamma$ tons/hr

Where, Q = capacity of the conveyor, tons/hr

V = volumetric capacity, m^3/hr

γ = bulk weight of the material, tons/m^3

C = factor that takes into account the inclination of the conveyor

D = screw diameter, m

S = screw pitch, m

n = speed of the shaft of screw conveyor

ψ = loading efficiency of the vertical cross sectional are of the screw

In typical design the screw pitch equals D. for slow flowing and abrasive material it is 0.8D.

Loading efficiency, ψ = 0.125 for slow flowing abrasive material

= 0.25 for slow flowing mildly abrasive material

= 0.32 for free flowing mildly abrasive material

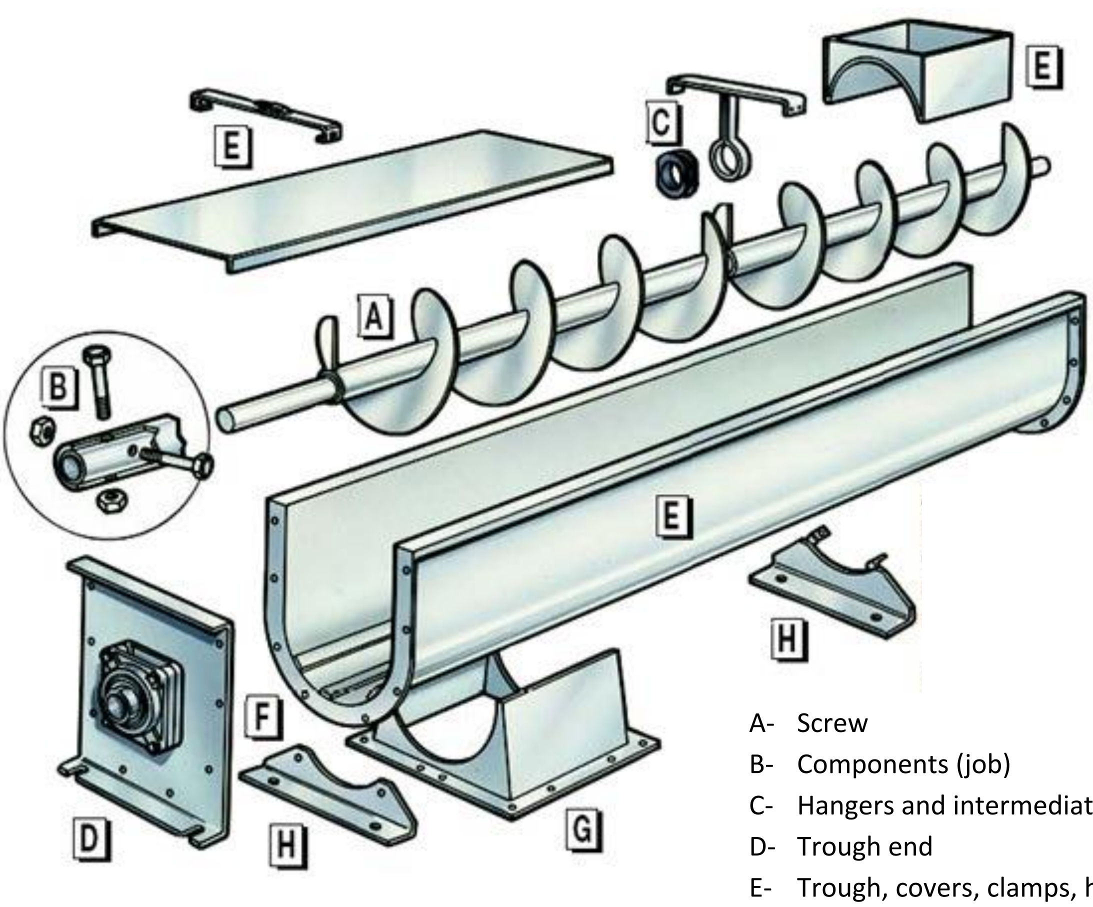
= 0.4 for free flowing non-abrasive material

Ψ is taken relatively low to obviate risk of bottlenecks near the intermediate bearings. It is large for free flowing, non-highly abrasive material and vice-versa.

β = angle of inclination

For horizontal conveyor, C=1.0

β	0^0	5^0	10^0	15^0	20^0
C	1	0.9	0.8	0.7	0.65



A- Screw
B- Components (job)
C- Hangers and intermediate bearing
D- Trough end
E- Trough, covers, clamps, hopper inlet
F- Flange
G- Discharge spout
H- Supporting feet and saddle

Figure 6.1: Schematic diagram of screw conveyor

Determination of actual capacity:

Determination the actual capacity of the conveyor, Q_{actual} by taking weight of the material at the discharge end for a certain period of time (measured by stop watch)

Observation	Weight of material discharged (kg)	Time (sec)	Capacity, Q_{actual}, (tons/hr)	Average value
1				
2				
3				
4				
5				

Procedure:

i. Start the motor and hereby start the operation of the screw conveyor.
ii. Start feeding bulk material into the loading spout of the conveyor.
iii. Wait some time until the flow-rate of bulk material becomes steady.
iv. Determine the weight of the accumulated bulk material in a certain time at the discharge spout. Measure time by stopwatch.
v. Calculate amount of accumulation of bulk material per unit time, this is the capacity of the conveyor.
vi. Calculate capacity of the conveyor using the conveyor using the formula given above. Measure value of D, S, n. Take the value of γ from the chart, for wheat it is 0.65 to 0.83 tons/m^3
vii. Compare both the capacities.

Questions:

1. Why the value ψ changes for different bulk materials?
2. What is the relationship between β and C both for
   i) increasing rate of β ii) decreasing rate of β
3. Bulk weight of the material γ, why changes for different bulk materials? Explain, why it taken from a range?
4. What type of bearing will you select for designing screw conveyor? Explain.
5. Under which circumstances you will choose screw conveyors for material handling?

6. What are the basic types of screws normally used in screw conveyors? For conveying the following types of materials what type of screws will you choose:
    i. Lumpy and clinging materials
    ii. Dry granular or powdered materials
    iii. For blending, churning and homogenous mixing of two or more grades of materials

Experiment No: 7

STUDY OF THE LAYOUT PLAN OF AUST CENTRAL MACHINE SHOP

Objectives:

i. To study different types of layout of production floor
ii. To study the influence of layout on the material handling system
iii. To study the selection of layout type depending on the manufacturing process involved in order to optimize the material handling system as well as the overall process

Plant Layout:

Plant layout refers to arrangement of physical facilities in a production plan

A layout suited to flow-type mass production is not appropriate for job-shop production and vice-versa.

There are three types of plant layout:

i. Product flow layout
ii. Process flow layout
iii. Fixed position layout

In **Product Flow layout** (also called Flow – Shop layout), the plant specializes in the production of one product or one class of products in large volumes. The processing and the assembly facilities are placed along the line of flow of the product. This type of layout is suitable for flow-type mass production.

In **Process layout** (also called Job Shop layout), the production machines are arranged into groups according to general type of manufacturing process. The layout provides flexibility. This layout is typical in job shops and batch production.

In **Fixed Position layout**, the product remains in one location, and the equipment is brought to it.

In **Group Technology (GT) or Cellular layout**, dissimilar machines are grouped into work centers or cells to work on products that have similar shapes and processing requirements. A GT layout is similar to process layout in that cells are designed to perform specific set of processes, and it is similar to product layout in that the cells are dedicated to a limited range of products.

Effect of plant layout on material handling:

Plant layout is an important factor influencing the design of a material handling system. In case of a new plant, the design of the handling system should be considered as a part of the layout design.

The plant layout should provide the following information for use in the design of the handling system:

- Location where materials must be picked up (load stations)
- Location where materials must be delivered (unload station)
- Possible route between the locations
- Distances that must be traveled to move materials
- Flow patterns, opportunities to combine deliveries, possible places where congestion might occur
- Total area of the facility and area within specific departments in the layout
- Arrangement of equipment in the layout

How different layout types influence the selection of the material handling system:

The product flow layout usually involves the production of a standard (or nearly identical types of) product in relatively high volumes. The handling system typically exhibits the following:

i. Fixed installation
ii. Fixed route and
iii. Mechanized for automated

It is often a delivery and storage system (to reduce the effects of downtime between production areas along the line of production flow). Conveyor systems are often used to transport the product in product-flow layouts. Delivery of component parts for stocking at the various workstations a long path in assembly plants is accomplished by trucks and similar unit load vehicles.

In process layout, there are a variety of products manufactured and the quantities made per product are medium or small. The handling system must be flexible and programmable to deal with the variations. Considerable in process inventory is usually one of the characteristics of this type of manufacturing and the handling (and storage) system must be capable of holding this inventory.

In case of the fixed position layout, the product is large and heavy and therefore remains in a single location during most of its fabrication. Heavy components and subassemblies must be moved to the product. Handling systems used for these moves in fixed-position layouts are larger and often mobile. Cranes, hoists and trucks are common in this situation.

Data requirement to prepare a plant layout:

1. The area of each department expressed in square feet or as a number of unit squares
2. The rectilinear distances between candidate locations or between departments usually measured between their centers
3. Departmental relationship measures that can be expressed either quantitatively in a from-to chart or qualitatively in relationship chart
4. A scale for plotting the layout by the computer.

Preparing plant layout of machine shop, AUST:

i. Go to Machine shop, AUST
ii. Measure the area of the machine shop
iii. Measure the areas required for different types of machine
iv. Study the flow of materials as well as people inside the machine shop
v. Draw a current layout of the machine shop
vi. Suggest any changes required for the machine shop with relevant information

Questions:

1. What are the objectives of layout designing?
2. Differentiate Product layout from Process layout.
3. What are the benefits and limitations of GT or Cellular layout?
4. Which type of layout should be used in a machine shop or workshop where different types of automobile parts are manufactured?
5. When Fixed Position layout should be used and why? Explain with example.

Experiment No: 8

STUDY OF THE REPLACEMENT PLANS OF TUBE LIGHTS IN AUST CAMPUS

Objectives:

i. To study and know about different replacement policies
ii. To develop a model of replacement for different equipment based on reliability, at house as well as in industrial level
iii. To solve the model to get the optimum replacement policy

Sample problem:

Following is the data available on the failure of 10 identical special-purpose bulbs being used in a plant:

Time in months	Failure Probability
1	Nil
2	Nil
3	Nil
4	0.05
5	0.15
6	0.30
7	0.25
8	0.15
9	0.10

The cost of replacing the bulbs individually, when they fail, is Tk. 100 (per bulb). The cost of replacing all the 10 bulbs together is Tk. 500. Four different replacement policies are possible:

a) *Independent Breakdown Replacement,* i.e. replace bulb/bulbs as and when they fail to function.
b) *Group Breakdown Replacement,* i.e. as soon as one bulb fails, all the ten bulbs are replaced.
c) *Individual Preventive Replacement,* i.e. each bulb is replaced when it is n (some number) months of age, even though it does not fail.
d) *Group Preventive Replacement,* i.e. at fixed intervals, all bulbs is replaced; but within the interval, independent breakdown replacement is undertaken if bulb/bulbs fail.

The cost of independent preventive replacement of a bulb is Tk. 70. Which will be the best policy?

Solution:

<u>Case (a): Independent Breakdown Replacement Policy</u>

Mean life of a bulb = (4×0.05)+(5×0.15)+(6×0.30)+(7×0.25)+(8×0.15)+(9×0.10) = 6.6 months.

$$\therefore\ cost\ per\ month, for\ the\ policy = \frac{Tk.100}{6.6} \times 10\ (bulbs) = 151.5\ per\ month.$$

Case (b): Group Breakdown Replacement Policy

Cost of replacing all 10 parts together = Tk. 500.

$$Per\ month\ cost = \frac{500}{Average\ life\ (for\ 1st\ failure)}$$

Average life = $4\begin{bmatrix} Probability\ that\ the \\ failure \\ occurs\ at\ month\ 4 \end{bmatrix} + 5\begin{bmatrix} Probability\ that\ the \\ failure \\ occurs\ at\ month\ 5 \end{bmatrix} + 6\begin{bmatrix} Probability\ that\ the \\ failure \\ occurs\ at\ month\ 6 \end{bmatrix}$

$+7\begin{bmatrix} Probability\ that\ the \\ failure \\ occurs\ at\ month\ 7 \end{bmatrix} + 8\begin{bmatrix} Probability\ that\ the \\ failure \\ occurs\ at\ month\ 8 \end{bmatrix} + 9\begin{bmatrix} Probability\ that\ the \\ failure \\ occurs\ at\ month\ 9 \end{bmatrix}$

Now, the probability of surviving up to the 4^{th} month = 1- 0.05 =0.95

Therefore, probability of all 10 bulbs surviving up to the 4^{th} month = $(0.95)^{10}$ =0.599

So, probability that any one of the bulbs fails for the first time at month 4 = 1- $(0.95)^{10}$ = 0.401

We can find the other probabilities as follows:

Probability of all 10 bulbs surviving up to the 5^{th} month = $(0.80)^{10}$ = 0.107

Probability of any one bulb failing either in the 4^{th} or the 5^{th} month = 1- $(0.80)^{10}$ = 0.893.

Probability that the first failure occurs in the 5^{th} month = $[1-(0.80)^{10}] – [1- (0.95)^{10}]$ = 0.492.

Similarly,

Probability that the first failure occurs at,

6^{th} month = $[1- (0.5)^{10}] – [1- (0.8)^{10}]$ = 0.999 – 0.893 = 0.106

7^{th} month = $[1- (0.25)^{10}] – [1- (0.5)^{10}]$ = 1.000 – 0.999 = 0.001

8^{th} month = $[1- (0.1)^{10}] – [1- (0.25)^{10}]$ = negligible.

9^{th} month = $[1] – [1- (0.10)^{10}]$ = negligible.

Therefore, the average life = 4(0.401) + 5(0.492) + 6(0.106) + 7(0.001) + 8(0.000) + 9(0.000)

= 4.707 months.

Hence, per month cost = $\frac{500}{4.707}$ = Tk. 106.22

Case (c): Individual Preventive Replacement Policy

Let us consider,

Preventive replacement period of 5 months:

The total cost per unit replacement comprises two components: a) the possibility that the bulb may fail before the replacement age needing breakdown replacement; and b) the possibility that the bulb may not fail till its replacement age.

Component (a) = Tk. 100 × (0.05 + 0.15) = Tk. 20.00

Component (b) = Tk. 70 × (0.80) = Tk. 56.00

So, total cost of unit replacement = Tk. 76.00

Now, cost per month = $\frac{total\ cost\ of\ replacement}{expected\ life\ of\ a\ bulb} = \frac{76 \times 10}{expected\ life\ of\ a\ bulb} = \frac{760}{4.95} = Tk. 153.53$

Where, expected life of a bulb = (4×0.05) + (5×0.95) = 4.95 months.

Preventive replacement period of 6 months:

Then, Component (a) = Tk. 100 × (0.05 + 0.15 + 0.30) = Tk. 50.00

Component (b) = Tk. 70 × 0.50 = Tk. 35.00

Total cost of unit replacement = Tk. 85.00

Expected life of a bulb = (4×0.05) + (5×0.15) + (6×0.80) = 5.75 months.

Cost per month = $\frac{total\ cost\ of\ replacement}{expected\ life\ of\ a\ bulb} = \frac{85 \times 10}{expected\ life\ of\ a\ bulb} = \frac{850}{5.75} = Tk. 147.83$

Preventive replacement period of 7 months:

Component (a) =Tk. 100 × 0.75 = Tk. 75

Component (b) =Tk. 70 × 0.25 = Tk.17.5

Total cost of unit replacement = Tk. 92.5

Expected life of a bulb = (4 × 0.05) + (5 × 0.15) + (6 × 0.30) + (7 × 0.50) = 6.25 months.

Cost per month = $\frac{total\ cost\ of\ replacement}{expected\ life\ of\ a\ bulb} = \frac{92.5 \times 10}{expected\ life\ of\ a\ bulb} = \frac{925}{6.25} = Tk. 148.00$

Preventive replacement period of 4 months:

Component (a) =Tk. 100 × 0.05 = Tk. 5.0

Component (b) =Tk. 70 × 0.95 = Tk.66.5

Total cost of unit replacement = Tk. 71.5

Expected life of a bulb = 4 months.

Cost per month = $\frac{total\ cost\ of\ replacement}{expected\ life\ of\ a\ bulb} = \frac{71.5\times 10}{expected\ life\ of\ a\ bulb} = \frac{715}{4} = Tk. 178.75$

With this policy, the replacement period of 6 month is found to be optimal.

Case (d): Group Preventive Replacement Policy

Let us consider a replacement period of 8 months to start with.

The total cost under this policy comprises of two components:

a) Cost of group replacement = Tk. 500
b) Cost of individual breakdown replacement = Tk. 100 × number of failures within 8 months

Now, the number of failures within 8 months = for the 4^{th} month (10×0.05) + for the 5^{th} month (10×0.15) + for the 6^{th} month (10×0.3) + for the 7^{th} month [(10×0.05) × 0.05 + (10×0.25)] + for the 8^{th} month [(10×0.15)×0.05 + (10×0.05)×0.15+(10×0.15)] = 9.175

Cost per month = $\frac{500+100\times 9.175}{8} = Tk. 177.20$

For other months, the similar calculations are shown in the Table.1

Table 1: Group Replacement Cost

Replacement Period	Breakdown Replacement costs in Different Periods: 4	5	6	7	8	9	Total Costs, Tk.	Average Cost, Tk.
3							500	166.66
4	100×0.5						550	137.50
5	100×0.5	100×1.5					700	140.00
6	100×0.5	100×1.5	100×3.0				1000	166.66
7	100×0.5	100×1.5	100×3.0	100× 2.525			1252.5	178.92
8	100×0.5	100×1.5	100×3.0	100× 2.525	100× 1.65		1417.5	177.20
9	100×0.5	100×1.5	100×3.0	100× 2.525	100× 1.65	100× 1.525	1570	174.44

Summarizing the costs for different policies:

Independent Breakdown Replacement	Tk. 151.50 per month
Group Breakdown Replacement	Tk. 106.22 per month
Individual Preventive Replacement	Tk. 147.83 per month
Group Preventive Replacement	Tk. 137.50 per month

Answer: We choose group breakdown replacement policy.

Procedure:

i. Specify the area (i.e. 5^{th} floor, 6^{th} floor, Arts/Science faculty, MPE) for which you want to develop the replacement model.
ii. Collect information of tube lights. (i.e. total number of lights, price of one piece, lot price, charge for set up).
iii. Determine the failure probability of each light.

Solve the model to get the optimum replacement policy among the above four policies.

Experiment No: 9

DETERMINATION OF POWER LOSS OF THE ROLLER CONVEYOR

Objectives:

i. To study different components and the operation of the roller conveyor
ii. To determine both the theoretical and actual power required
iii. To investigate the possible causes of deviations of the result and ways to improve the overall efficiency of the conveyor

Theory:

Roller Conveyor:

Roller conveyors also known as roller runways or roller tracks serve to convey piece goods (ingots, plates, molding boxes, rolled stock, pipes, boxes etc.) horizontally and up or down slight inclines. The articles are conveyed on rollers evenly spaced on the conveyor frame. The articles to be moved must have a smooth bottom or straight longitudinal ribs. Wedged and cylindrical articles may also be conveyed on the conveyor.

Classification:

According to the principle of action roller conveyors are classified as powered and unpowered roller conveyors. The rollers of live (powered) roller conveyors are driven by a motor and revolve around their axes. They transmit motion to the articles conveyed by friction. In unpowered roller conveyors the motive force is applied directly to the load and the rollers are rotated by friction of the article as it moves along the roller bed. Unpowered roller conveyors commonly have a slight incline, sufficient for the force of gravity to overcome the slight frictional resistance.

Calculation of a Powered Roller Conveyor:

The rollers of a powered conveyor rotate continuously no matter whether a load passes over them or not. Unloaded rollers having diameter D rotate with a resistance factor equal to

$$w' = \frac{\mu d}{D}$$

Where μ = friction factor in the bearing reduced to the journal diameter d

A transport roller conveyor with a design capacity of Q tons per hour (with the irregularities of feed taken into account), a length of L m, a length of the horizontal projection L_{hor} m, elevation of H m, a total of z rollers having a weight (of the rotating parts) of p kg and with the load moving at a rate of v m/sec will require a motor rated at

$$N = \left(\frac{QH}{367} + \frac{QL_{hor}\omega'}{367} + \frac{zp\omega_1'v}{102}\right)\frac{1}{\eta_g}\ kW$$

Where $\boldsymbol{\omega'}$ = resistance factor of the weight of the conveyed load G determined from equation

$$\boldsymbol{\omega'} = \frac{\mu d + 2k}{D};$$

Where, k = rolling friction factor of the load on the rollers, cm

D = roller diameter, cm

μ = friction factor in the journal reduced to the roller axel journal diameter d, cm

$\boldsymbol{\omega_1'}$ = resistance factor of the weight of the roller rotating parts p_1 determined from the equation no. 1

For a horizontal conveyor H = 0 and L_{hor} = L, hence

$$N = \left(\frac{QL\omega'}{367} + \frac{zp\omega_1'v}{102}\right)\frac{1}{\eta_g} kW$$

Procedure:

i. Start the motor and hereby start the operation of the roller conveyor.
ii. Start feeding material into the loading zone of the conveyor.
iii. Determine the weight of the material in a certain time at the discharge zone. Measure time by stopwatch.
iv. Calculate amount of conveyed material per unit time, this is the capacity of the conveyor.
v. Calculate capacity and the power required by the conveyor using the formula given above.
vi. Compare the actual and theoretical power.
vii. Discuss the causes of the variation between both the powers.

Questions:

1. Distinguish between powered and unpowered roller conveyors.
2. Write some potential applications of powered and unpowered roller conveyor.
3. How to keep gravity sag of the article conveyed to minimum?
4. Discuss the reasons behind the variation between theoretical and actual power.
5. Discuss the role of friction in roller conveyor.

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 3210: Metal Forming and Sheet metal Working Sessional
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. The report should include the following:
   - Objectives
   - Apparatus (with specifications if any)
   - Machine used (with specifications)
   - Schematic diagram
   - Data sheet
   - Sample calculation
   - Graphs (if any)
   - Discussion (in passive form)
   - Assignment
   - References
5. Viva & quiz will be taken on the experiments at the end of the semester.
6. Marks distribution:

Total Marks			
Job/project	Report	Attendance and Viva	Quiz
05	30	30	35

Sheet metal:

Sheet metal is metal formed by an industrial process into thin, flat pieces. It is one of the fundamental forms used in metalworking and it can be cut and bent into a variety of shapes. Countless everyday objects are constructed with sheet metal. Thicknesses can vary significantly; extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate.

The thickness of sheet metal is commonly specified by a traditional, non-linear measure known as its gauge. The larger the gauge number, the thinner the metal. Commonly used steel sheet metal ranges from 30 gauge to about 8 gauge. Gauge differs between ferrous (iron based) metals and a non-ferrous metal such as aluminum or copper; copper thickness, for example is measured in ounces (and represents the thickness of 1 ounce of copper rolled out to an area of 1 square foot).There are many different metals that can be made into sheet metal, such as aluminum, brass, copper, steel, tin, nickel and titanium. For decorative uses, important sheet metals include silver, gold, and platinum (platinum sheet metal is also utilized as a catalyst).

Sheet metal is available in flat pieces or coiled strips. The coils are formed by running a continuous sheet of metal through a roll slitter.During the rolling process the rollers bow slightly, which results in the sheets being thinner on the edges. So, a tolerance is specified by the manufacturer of sheet metal i.e. deviation from the nominal size.

Sheet metal forming processes:

Bending:

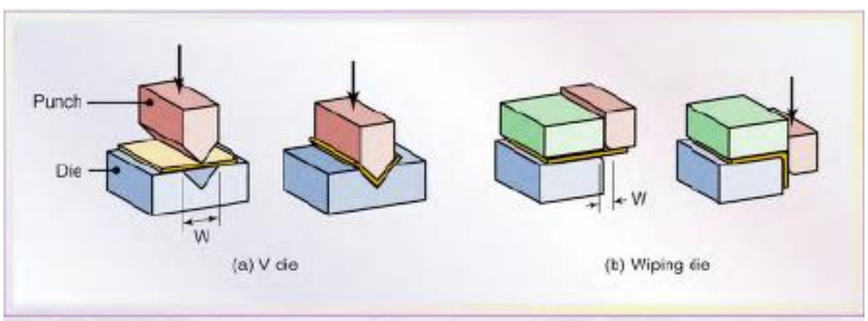


Figure 16.21 Common die-bending operations showing the die-opening dimension, *W*, used in calculating bending forces.

Bending is a manufacturing process that produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials, most commonly sheet metal. Commonly used equipment includes box and pan brakes, *brake presses*, and other specialized machine presses. Typical products that are made like this are boxes such as electrical enclosures and rectangular ductwork. Bending forces can be estimated by assuming that the process is one of simple bending of a rectangular beam. The bending force in that case is a function of the strength of the material, the length L of the bend, the thickness T of the sheet, and the size W of the die opening (fig 16.21). Excluding friction, the maximum bending force P is,

$$P = \frac{kYLT^2}{W}$$

Where the factor *k* ranges from about 0.3 for a wiping die, to about 0.7 for a U-die, to about 1.3 for a V-die, and Y is the yield stress of the material.

For a V-die, this equation can often be approximated as,

$$P = \frac{(UTS)LT^2}{W}$$

Where UTS is the ultimate tensile strength of the material. This equation applies well to situations in which the punch radius and the sheet thickness are small compared to the die opening W.

Press brake forming:
In press brake forming, a work piece is positioned over the *die block* and the die block presses the sheet to form a shape. Usually bending has to overcome both tensile stresses and compressive stresses. When bending is done, the *residual stresses* cause the material to *spring back* towards its original position, so the sheet must be over-bent to achieve the proper bend angle. The amountof spring back is dependent on the material, and the type of forming. When sheet metal is bent, it stretches in length. The *bend deduction* is the amount the sheet metal will stretch when bent as measured from the outside edges of the bend. The *bend radius* refers to the inside radius. The formed bend radius is dependent upon the dies used, the material properties, and the material thickness.

Types:
There are *three basic types of bending on a press brake;* each is defined by the relationship of the end tool position to the thickness of the material. These three are Air Bending, Bottoming and Coining. The configuration of the tools for these three types of bending is nearly identical. A die with a long rail form tool with a radiused tip that locates the inside profile of the bend is called a *punch.* Punches are usually attached to the ram of the machine by clamps and move to produce the bending force. A die with a long rail form tool that has concave or V shaped lengthwise channel that locates the outside profile of the form is called a *die*. Dies are usually stationary and located under the material on the bed of the machine. Note that some locations do not differentiate between the two different kinds of dies (punches and dies.) The other types of bending listed use specially designed tools or machines to perform the work.

Air bending:
This bending method forms material by pressing a punch (also called the upper or top die) into the material, forcing it into a bottom V-die, which is mounted on the press. The punch forms the bend so that the distance between the punch and the side wall of the V is greater than the material thickness (T).Either a V-shaped or square opening may be used in the bottom die (dies are frequently referred to as tools or tooling). A set of top and bottom dies are made for each product or part produced on the

press. Because it requires less bend force, air bending tends to use smaller tools than other methods. Some of the newer bottom tools are adjustable, so, by using a single set of top and bottom tools and varying press-stroke depth, different profiles and products can be produced. Different materials and thicknesses can be bent in varying bend angles, adding the advantage of flexibility to air bending. There are also fewer tool changes, thus, higher productivity.A disadvantage of air bending is that, because the sheet does not stay in full contact with the dies, it is not as precise as some other methods, and stroke depth must be kept very accurate. Variations in the thickness of the material and wear on the tools can result in defects in parts produced.

Air bending's angle accuracy is approximately ±0.5 deg. Angle accuracy is ensured by applying a value to the width of the V opening, ranging from 6 T (six times material thickness) for sheets to 3 mm thick to 12 T for sheets more than 10 mm thick. *Springback* depends on material properties, influencing the resulting bend angle.Depending on material properties, the sheet may be overbended to compensate for *springback*.

Air bending does not require the bottom tool to have the same radius as the punch. Bend radius is determined by material elasticity rather than tool shape.

The flexibility and relatively low tonnage required by air bending are helping to make it a popular choice. Quality problems associated with this method are countered by angle-measuring systems, clamps and crowning systems adjustable along the x and y axes, and wear-resistant tools.

The K-Factor approximations given below are more likely to be accurate for air bending than the other types of bending due to the lower forces involved in the forming process.

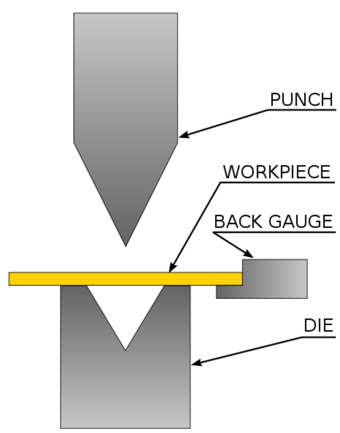


Fig: A schematic of air bending with a *backgauge*.

Coining:
In coining, the top tool forces the material into the bottom die with 5 to 30 times the force of air bending, causing permanent deformation through the sheet. There is little, if any, springback. Coining can produce an inside radius is as low as 0.4 T, with a 5 T width of the V opening. While coining can attain high precision, higher costs mean that it is not often used in metal working.

Three point bending:

Three-point bending is a newer process that uses a die with an adjustable-height bottom tool, moved by a servo motor. The height can be set within 0.01 mm. Adjustments between the ram and the upper tools are made using a hydraulic cushion, which accommodates deviations in sheet thickness. Three-point bending can achieve bend angles with 0.25 deg. precision. While three-point bending permits high flexibility and precision, it also entails high costs and there are fewer tools readily available. It is being used mostly in high-value niche markets.

Roll bending:
A Roll bender is a mechanical jig having three rollers used to form a metal bar into a circular arc. The rollers freely rotate about three parallel axes, which are arranged with uniform horizontal spacing. Two outer rollers, usually immobile, cradle the bottom of the material while the inner roller, whose position is adjustable, presses on the topside of the material. Generally the rolling machine consists of three rollers, one driver and other two driven rollers.

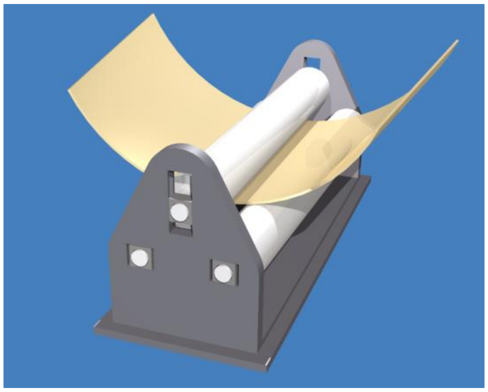


Fig: Roll bending

Calculations:

Legends-

BA=Bending allowance
BD=Bend allowance
R=Inside bend radius
K=K-factor=t/T
T=Material thickness
t=Distance from inside face to the neutral line
A=Bend angle in *degrees*(the angle through which material is bent)

The neutral line (also called the neutral axis) is an imaginary line that can be drawn through the cross-section of the workpiece that represents the lack of any internal forces. Its location in the material is a function of the forces used to form the part and the material yield and tensile strengths. The position of the *neutral axis* depends on the radius and angle of bend. For *ideal case* the neutral axis is the center of the sheet thickness and k=0.5. In the bend region, the material between the neutral line and the inside radius will be under compression during the bend. The material between the neutral line and the outside radius will be under tension during the bend.Because of the Poisson’s ratio, the width of the part (bend length, L) in the outer region is smaller and in the inner region it is larger. (Figure 16.16)

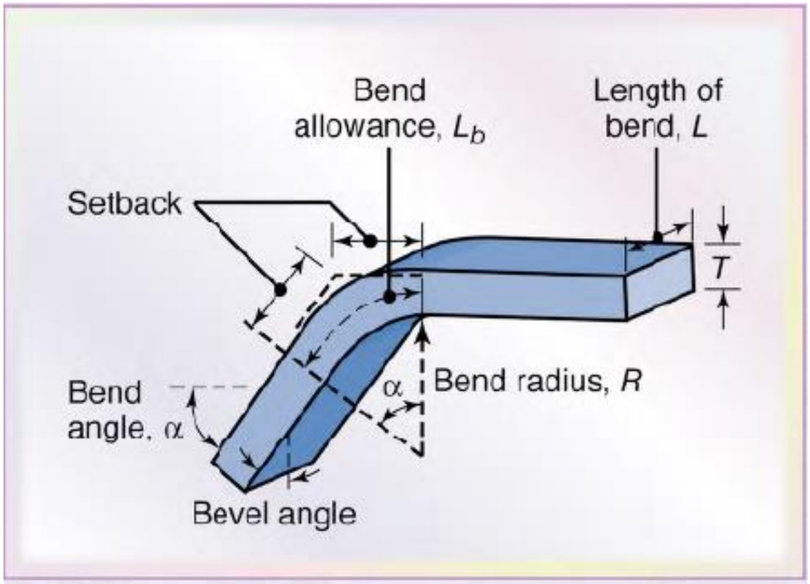


Figure 16.16 Bending terminology. Note that the bend radius is measured to the inner surface of the bent part.

Both bend deduction and bend allowance represent the difference between the neutral line or unbent flat pattern (the required length of the material prior to bending) and the formed bend. Subtracting them from the combined length of both flanges gives the flat pattern length. The question of which formula to use is determined by the dimensioning method used to define the flanges as shown in the two diagrams below.

<u>Bend Allowance:</u>

The bend allowance (BA) is the length of the arc of the neutral line between the tangent points of a bend in any material. Adding the length of each flange taken between the center of the radius to the BA gives the Flat Pattern length. This bend allowance formula is used to determine the flat pattern length when a bend is dimensioned from (1) the center of the radius, (2) a tangent point of the radius or (3) the outside tangent point of the radius on an acute angle bend.

The BA can be calculated using the following formula:

$$BA = A\left(\frac{\pi}{180}\right)(R + K \times T)$$

Bend deduction:

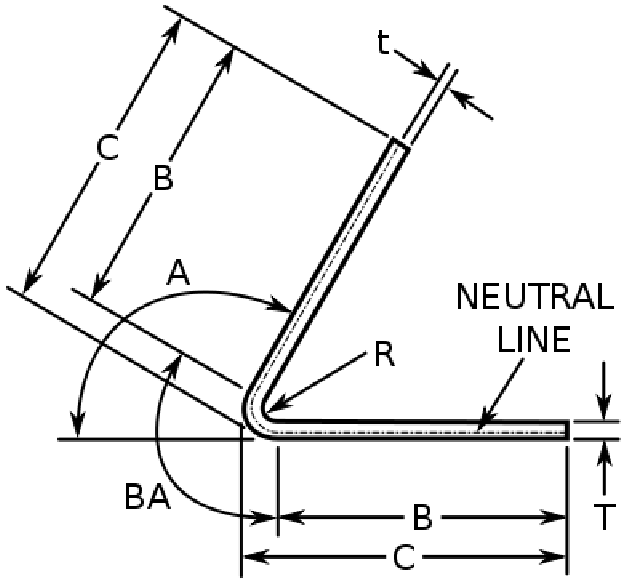


Fig: Diagram showing standard dimensioning scheme when using Bend Allowance formulas. Note that when dimensions "C" are specified, dimension B = C - R – T

Example:

Angle	90^0
pi	3.1416
Radius	1.5
K-factor	0.33
Thickness	6
Bend allowance	5.46708

Bend deduction:

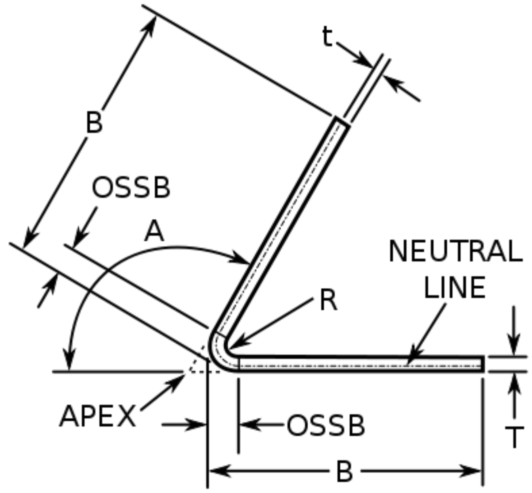


Fig: Diagram showing standard dimensioning scheme when using Bend Deduction formulas.

The outside set back (OSSB) is the length from the tangent point of the radius to the apex of the outside of the bend. The bend deduction (BD) is twice the outside setback minus the bend allowance. BD is calculated using the following formula.

$$BD = 2\,(R + T)\tan\frac{A}{2} - BA$$

The above formula works only for right angles. For bend angles 90 degrees or greater the following formula works, where A is the angle in radians (=degrees*π/180).

$$BD = R\,(A - 2) + T\,(kA - 2)$$

$$BD = 2 \times OSSB - BA$$

K-factor:

K-factor is a ratio of location of the neutral line to the material thickness as defined by t/T where t = location of the neutral line and T = material thickness. The K-Factor formulation does not take the forming stresses into account but is simply a geometric calculation of the location of the neutral line after the forces are applied and is thus the roll-up of all the unknown (error) factors for a given setup. The K-factor depends on many factors including the material, the type of bending operation (coining, bottoming, air-bending, etc.) the tools, etc. and is typically between 0.33(for $R<2T$) to 0.5(for $R>2T$).For *ideal case* k=0.5. The following equation relates the K-factor to the bend allowance:

$$K = \frac{-R + \frac{BA}{\pi A/180}}{T}$$

The following table is a "Rule of Thumb". Actual results may vary remarkably:

Generic K-Factors	**Aluminum**		**Steel**
Radius	**Soft Materials**	**Medium Materials**	**Hard Materials**
Air Bending			
0 to Thickness	0.33	0.38	0.40
Thickness to 3 x Thickness	0.40	0.43	0.45
Greater than 3 x Thickness	0.50	0.50	0.50
Bottoming			
0 to Thickness	0.42	0.44	0.46
Thickness to 3 x Thickness	0.46	0.47	0.48
Greater than 3 x Thickness	0.50	0.50	0.50
Coining			
0 to Thickness	0.38	0.41	0.44
Thickness to 3 x Thickness	0.44	0.46	0.47
Greater than 3 x Thickness	0.50	0.50	0.50

The following formula can be used in place of the table as a good approximation of the K-Factor for Air Bending:

$$K=\log(\min(100,\max(20 \times R,T) / T)) / \log(100) / 2$$

Flat pattern length (L_f): Total length of the flat sheet required can be computed by any of the following two formulas:

$$L_f=B+B+BA$$

Or

$$L_f=C+C-BD$$

Where the alphabets represent the conventions in the above figures.

Springback:

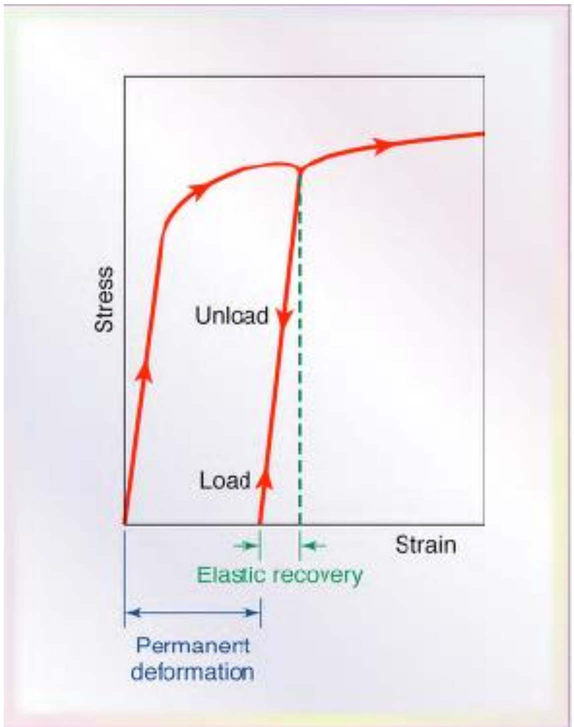


Fig 2.3: Schematic illustration of the loading and unloading of tensile-test specimen. Note that during unloading the curve follows a path parallel to the original elastic slope

Because all materials have a finite modulus of elasticity, plastic deformation is followed, when the load is removed, by some elastic recovery (See figure 2.3). In bending, this recovery is called springback; you can easily observe it by bending and then releasing a piece of sheet metal or wire. As noted in the figure the final bend angle after springback smaller and the final bend radius is larger than before bending. Springback occurs not only in flat sheets and plate, but also in rod, wire and bar with any cross section.

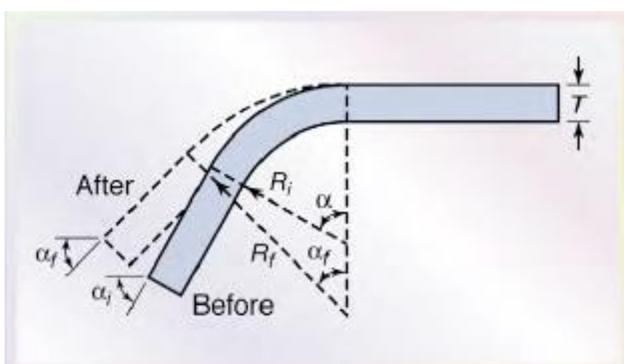


Fig 16.19: Sringback in bending

Springback can be calculated approximately in terms of the radii R_i and R_f (See figure 16.19) as,

$$\frac{R_i}{R_f} = 4\left(\frac{R_iY}{ET}\right)^3 - 3\left(\frac{R_iY}{ET}\right) + 1$$

Note from this formula that springback increases (a) as the R/T ratio and the yield stress Y of the material increase and (b) as the elastic modulus E decreases. In V-die bending it is possible for the material to exhibit *negative,* as well as positive springback. This condition is caused by the nature of the deformation which is occurring just as the punch completes the bending operation at the end of the stroke. *Negative springback* does not occur in air bending (free bending) because of the lack of the constraints that a V-die imposes.

Compensation for springback:

In forming operations, springback is usually compensated for by overbending the part (Figure 16.20 a and b); several trials may be necessary to obtain the desired results. Another method is to use *coin* the bend area by subjecting it to high localized compressive stresses between the technique tip of the punch and the die surface (16.20 c and d); this technique is known as *bottoming* the punch. Another method is *stretch bending* in which the part is subjected to tension while being bent. In order to reduce springback bending may also be carried out at elevated temperatures.

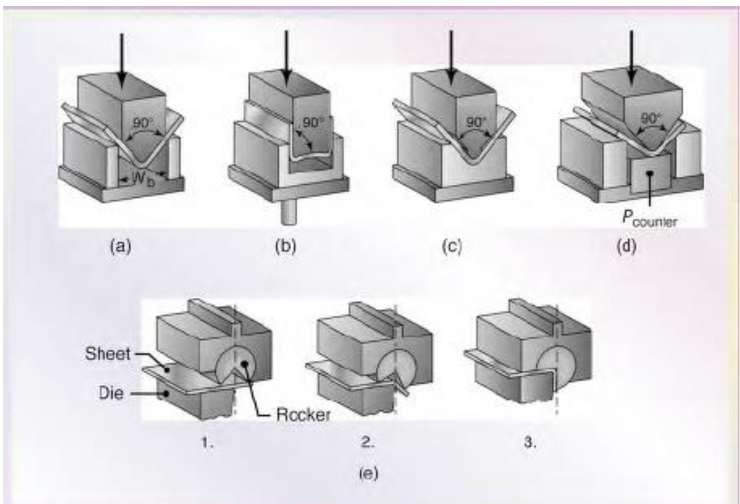


Fig 16.20: Method of reducing or eliminating springback in bending

References:

1. Manufacturing engineering and technology by Serope Kalpakjian.
2. www.wikipedia.org

Bending tube without a mandrel:

Principle of stretching and compressing: When a tube is bent, two things happen to metal (***Figure 1-a***). The outside wall is reduced in thickness due to the stretching of the material and the inside wall becomes thicker due to the compressing of the material (***Figure 1***). The material actually is formed approximately about the centerline of the tube. The material that forms the outside of the bend has further to travel and therefore is stretched; the inside of the bend has less distance to travel and is compressed.

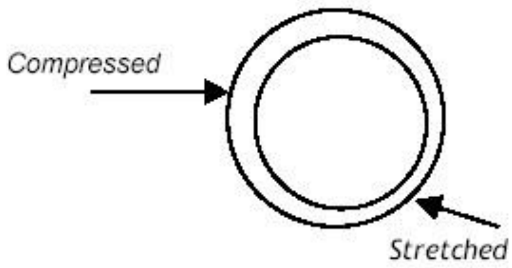


Figure 1-a

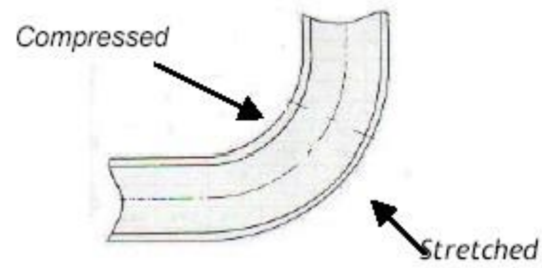


Figure 1

Functions of bend die: When the ratio of the tube diameter to wall thickness is small enough, the tube can be bent on a relatively small radius (Centerline radius CLR= 4* tube thickness). Excessive flattening or wrinkling of the bent should not occur. The outside and inside of the bend tend to pull towards the centerline of the tube (flattening). Two factors that help prevent this from happening are a grooved bend die, which supports the tube along the centerline and the natural strength of the tube; round or square (figure 2). **Little or no support is needed within the tube when the tube diameter is small and the wall is thick.** As the size of the tube diameter is increased, the tube becomes weaker. If the wall thickness of the tube is decreased, it also becomes weaker. The forces acting on the tube also becomes greater as the radius of the bend becomes smaller.

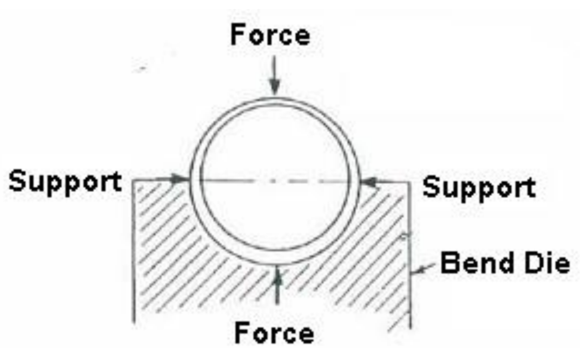


Figure 2

Basic primary tooling: A bend die, clamp die, and pressure die are the minimum essentials for bending tube (***Figure 3***). The bend die helps to prevent the tube from flattening and forms a given radius of bend. The clamp die holds the tube in position while bending. The pressure die forces the tube into the bend die.

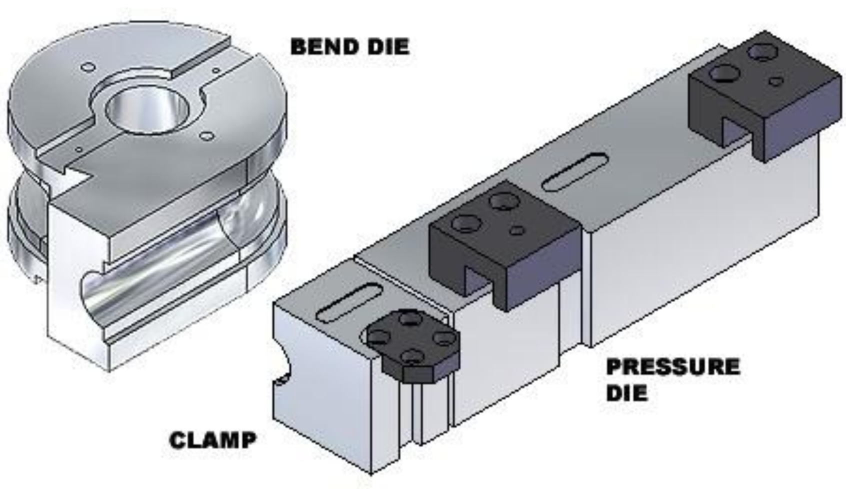


Figure 3

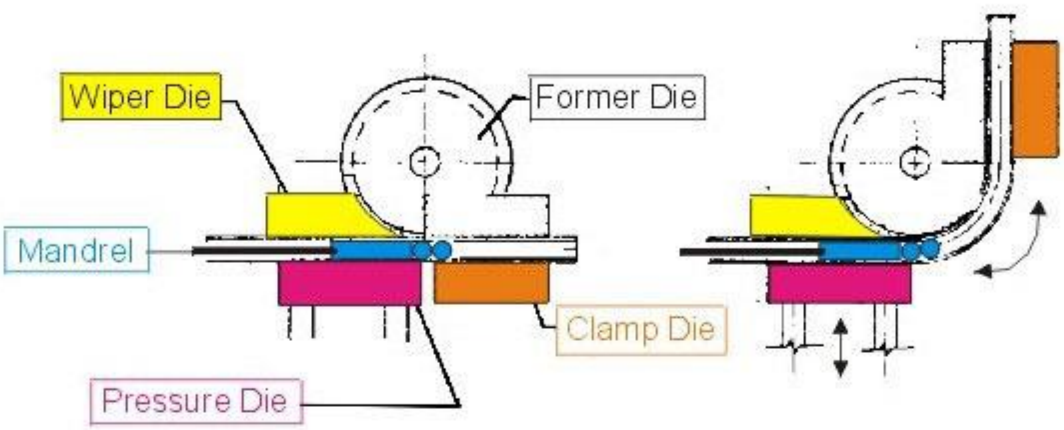


Fig 3 (a)

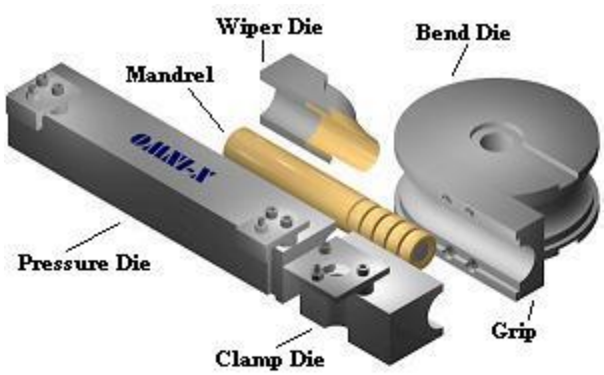


Figure 3 (b)

Control of springback: Springback is excessive when a mandrel is not used. This should be considered when selecting a bend die. Springback is the term used to describe the tendency of metal that has been formed to return to its original shape. Springback will cause the tube to unbend from two to ten degrees depending on the radius of bend, and may increase the bend radius of the tube. The smaller the radius of bend the smaller the springback.

Kinked or Buckled bends: The tube may kink or buckle as shown in **Figure 4**. This may be due to hard material, which will not compress on the inside radius of the bend. The material, not being able to compress, pushes in toward the centerline of the tube. This condition can be corrected (provided the tube is not too hard) by proper set up of the tooling. A plug mandrel (**Figure 5)** is indicated if the tube buckles and is still within the wall factor and the diameter of the bend.

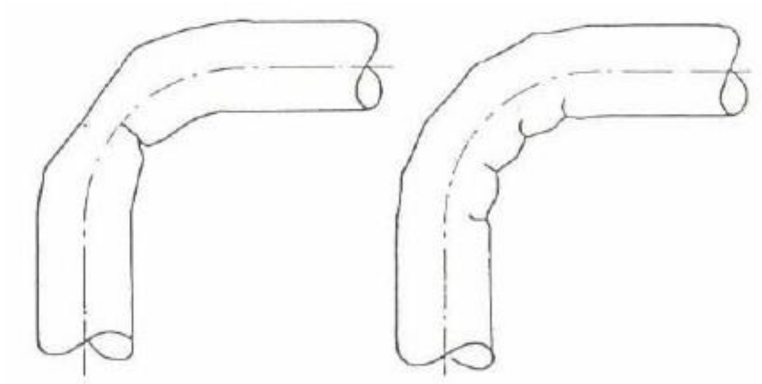


Figure 4

Bending tube with a plug mandrel:

Balanced pressures: **The purpose of a plug mandrel is to prevent the tube from flattening and to bend without wrinkles or kinks.** The mandrel is held in a fixed position while the tube is pulled over it. The tube stretching process is localized on the outer radius of the bend and the material is work-hardened to retain its shape and not flatten. The material stretching is done on the forward tip of the mandrel **(Figure 5).** This force, acting on the mandrel tip, supports the inner radius of the bend, holding it firmly into the bend die groove.A plug mandrel can be used to produce relatively good quality bends for tubing 10mm diameter and smaller. Exceptions to this are thin wall tubing or a centerline radius that is less than 2 x tube O.D. There also are certain limitations for tubes larger than 10mm diameter.

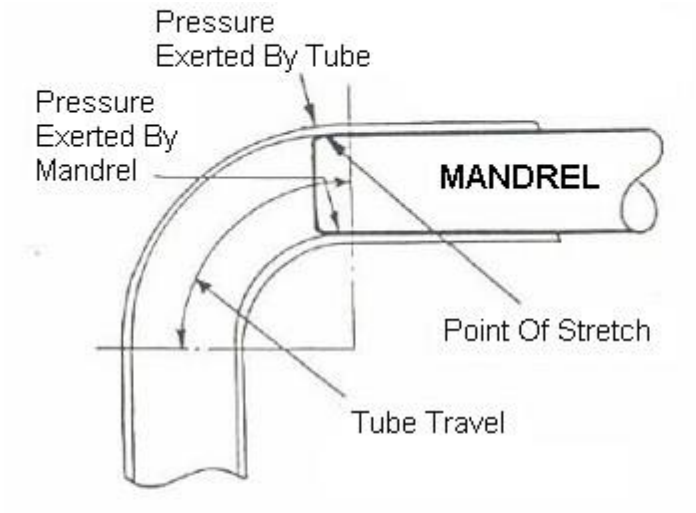


Figure 5

Unbalanced pressures: The pressure die should be adjusted for a light pressure against the tube. **The purpose of the pressure die is to keep the tube against the bend die through the duration of bending.** The pressure die also keeps the mandrel from bending and maintains a straight tube between tangent points of bends (the portion of tubing left on the mandrel after bending). The location of the mandrel affects the amount of springback. The mandrel in a forward position (toward tangent) will stretch the material on the outside of the bend more than is necessary. This increases the length of material on the outside beyond that which is required to make a bend. When the bent tube is removed from the bend die, it will conform to the die and there will be little or no springback. **Figure 6** is an overstated example. The outside of the bend actually is in compression with forces acting at points A and B. Counteracting forces occur at C and D. Forces A and B tend to close the bend while forces C and D act to open the bend.

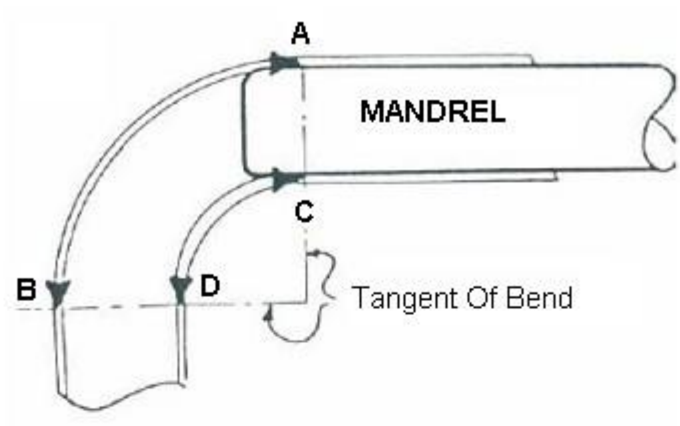


Figure 6

The mandrel in a position away from tangent will not stretch the material on the outside of the bend enough; consequently, there is not enough material to reach from A to B, putting a tension in the material. The forces at A and B are now the reverse of those shown in **Figure 6**, tending to open up the bend. Thus, mandrel location can cause excessive springback, which reduces the angel of bend and also may increase the radius. The mandrel should be brought forward (toward tangent) when the radius is increased. **There is no given formula for correct mandrel setting.** One thing is clear; when the angle of springback is more than 3 degrees, the mandrel is too retarded and the tube's radius of bend will be larger than the bending die.

When the tube breaks repeatedly, **it may indicate that the material is too hard**. Hard material does not have the ability to stretch sufficiently**. Working with recently fully annealed material will rule out this likelihood**. **When the mandrel is set too far forward or the tube slips in the clamp die, breakage may occur also.**

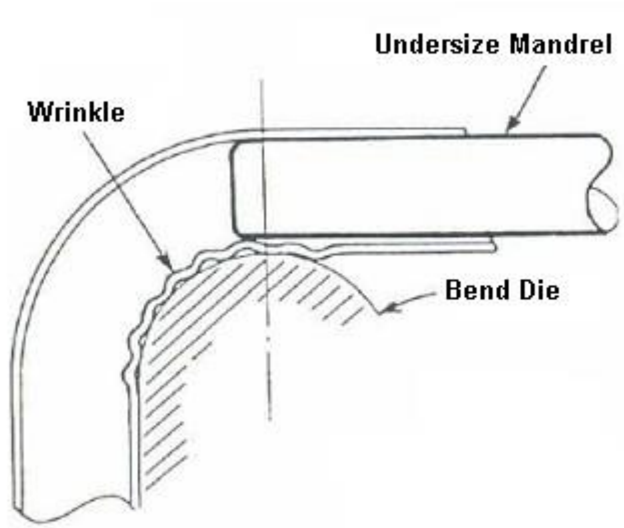


Figure 7

Mandrel too far back: Advancing the mandrel slightly forward, the wrinkles may stop forming in front and begin to form in back of tangent. **The mandrel at this point is still not far enough forward to generate the necessary pressure on the inside of the bend and compress the material.** The bend may start out smooth, but as it progresses past approximately 20 degrees, the material pushes back, forming a ripple or wave at point A (**Figure 8)**. This ripple is forming and being flattened continually betweenthe mandrel and the bend die. The ripple, however, does not entirely disappear. When the bent tube is removed from the bend die, there is a large buckle at point A. **It is necessary to continue to advance the mandrel until the material can't squeeze back between the bend die and mandrel. Figure 9** shows what occurs when the mandrel is not full advanced.

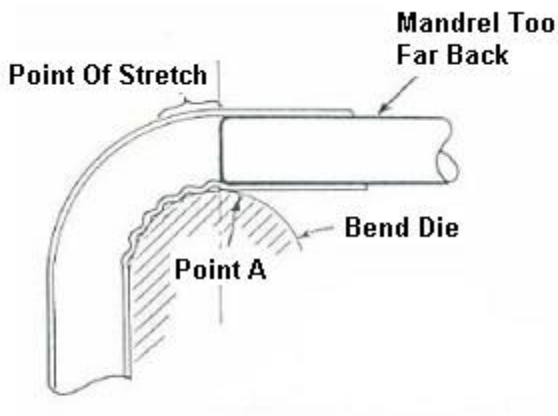


Figure 8

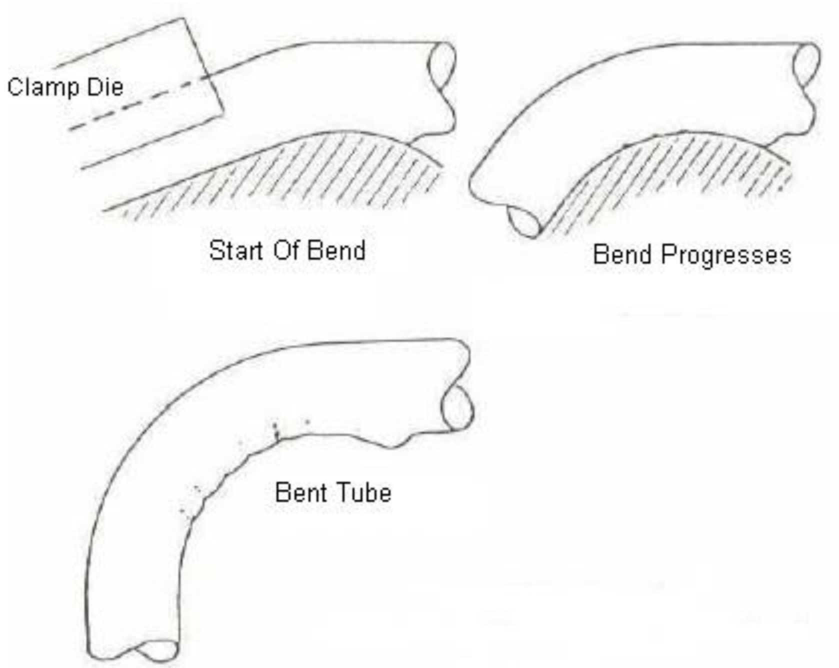


Figure 9

Mandrel too far forward: When the mandrel is too far forward **(Figure 10)** bumps appear on the outside of the bend at the terminal tangent and a step on the inside of the bend at the starting tangent. These are shown on the same tube. They will not always appear at the same time, depending upon shape of the mandrel and bend radius. The bump, obviously, is caused by the mandrel. The end of the mandrel prying the tube away from the bend die forms the step.

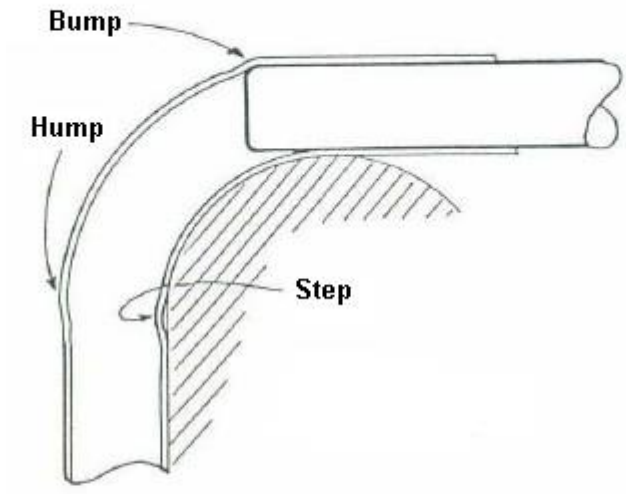


Figure 10

Plug mandrels are inexpensive, easy to maintain and cause little drag. **Ball-type mandrels, however, should be employed for small radius bends, thin wall tubes or where high quality is desired.** The clamp die should have a minimum length of three times the tube diameter when using a plug mandrel.

<u>Bending with ball mandrel and wiper die:</u> When the radius of the bend is smaller and/or the wall is thinner, it becomes necessary to use a ball mandrel and wiper die. The wiper die is used to prevent wrinkles. The ball mandrel performs like a plug mandrel. The balls are used to keep the tube from collapsing after it leaves the mandrel shank.

Bending issues are enlarged when making tight bends or with thin wall tubing. It becomes more difficult to retain the material during compression. The pressure is so intense the material is squeezed back past tangent and buckles. **This area must be supported so that the material will compress rather than buckle; this is the prime purpose of the wiper die. Note, the wiper die cannot flatten wrinkles after they are formed; it can only prevent them.**

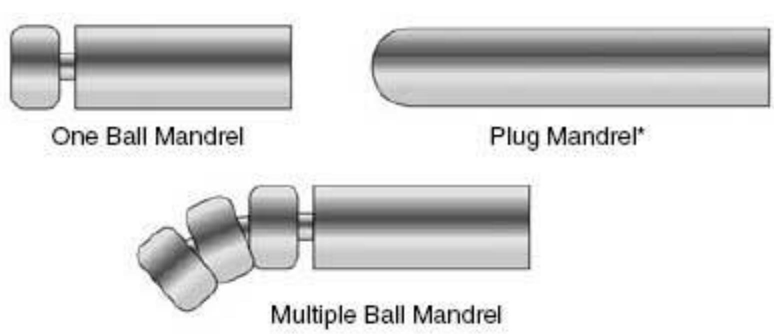


Figure 11: Ball and plug mandrel

Tubes and structural shape bending:

Stretch bending or forming: The work piece is pulled at both ends while being bent over a form block. The method is slow but almost eliminates springback. It is used to make large irregular and noncircular bends without mandrels.

Draw bending: It is dome with the work piece clamped against a form block, which rotates and pulls the material around the bend. The work going into the bend is supported by a pressure bar. A mandrel may be inserted in a tube to restrain flattening. Flexible ball, laminated, cable mandrel etc. are used to provide support around the bend length for delicate work. Draw bending is best for small radii and thin walls and most versatile.

Compression bending or forming: the work piece is clamped to and wrapped around a fixed form block by a wiper shoe. Flat sheet metal is commonly bent in the same way on ungrooved blocks in an operation called wing or tangent bending. Bending radius may be very small. Compression bending can make series of bends with almost no spaces between them. A combination of stretch and compression forming is called radial draw forming and is advantageous for difficult curved parts.

Roll extrusion bending: It is for piper over 130mm O.D. and walls to 16mm thick. A head is rotated inside the pipe with wide thrust rollers on one side and a narrow work roller on the other. The pipe is enclosed by work rings outside of the head. The work roller is cammed in and out as the head rotates to apply pressure to extrude metal in the pipe wall on the side to make it bend. As the material is worked, the pipe is advanced past the head. The method is repeated 10 times faster than others for larger pipes.

Ram or press bending: It is done by pressing the work piece between a moving ram block and two swinging pressure dies as indicated in the figure. A fixed stroke punch press may be used, but an adjustable stroke bending press is better. Equipment cost is little more than for draw bending and angles are limited to about 165^0 but press bending is 3 to 4 times faster than other methods. A different press setup is required for each different bend so the process is suitable only for quantity production, such as furniture factories.

Roll bending: It is done for plates, bars, structural shapes and thick walled tubes using three rolls as shown in the figure. One roll is adjusted between the other two for the desired radius of bend. Continuous coils can be made in this way. Bend radius can be changed easily and the operation is suitable for job work, but angle control is difficult.

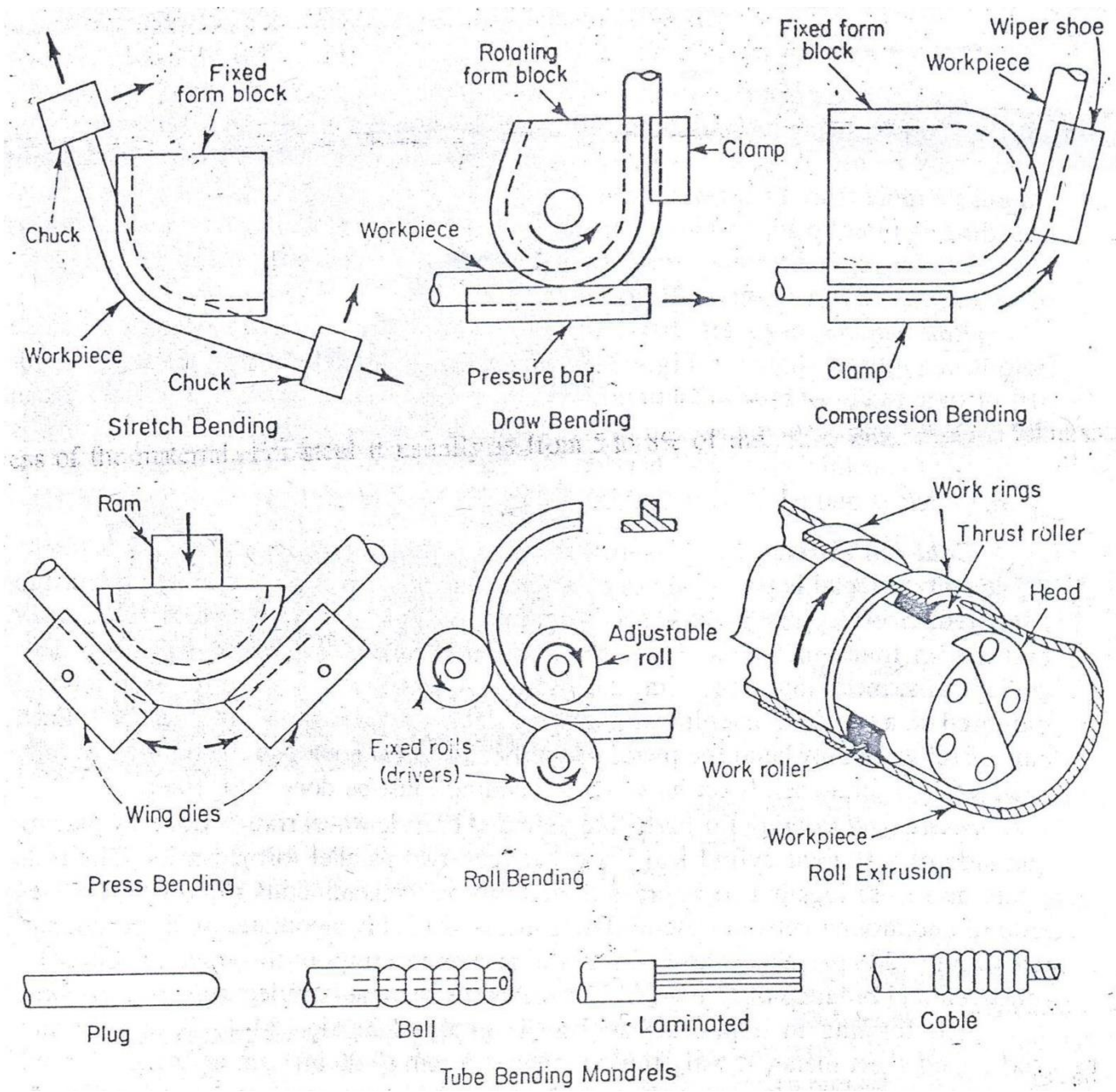


Figure 12: Methods for bending pipes, tubes and structural shape

References:

1. Manufacturing processes and materials for engineers by Doyle
2. R. K. Jain
3. Kalpakgian

Assignment:

1. Write down the causes and suggest ways to eliminate followings:
   (a) Tube breakage (b) Tube wrinkling
2. Explain with neat sketches different tube bending operations.
3. Discuss tube bending mechanism with necessary sketches.
4. Relate tube thickness with different tube bending operations.
5. What are the typical components required for tube bending? Write down their functions.

Experiment 1: Determination of bend allowance and bend deduction for mild steel specimen.

Procedure:

1. Prepare four 4 inch x 1 inch specimen from mild steel sheet.
2. Bend each specimen to 90, 120, 135 and 150 degrees of bend angle separately.
3. Calculate bend radius for each bend angle.
4. Calculate bend allowance, bend deduction and flat pattern length for each bend angle.
5. Plot bend allowance vs. bend angle and bend deduction vs. bend angle in graph paper.

Table:

Bend angle	Bend radius	Bend allowance (BA)	Bend deduction (BD)	Flat pattern length (using BA)	Flat pattern length (using BD)

Formulas:

To calculate bend allowance:

$$BA = A\left(\frac{\pi}{180}\right)(R + K \times T)$$

To calculate bend deduction for bend angle up-to 90 degree bend angle:

$$BD = 2(R + T)\tan\frac{A}{2} - BA$$

For bend angle greater than 90 degrees:

$$BD = R(A - 2) + T(kA - 2)$$

To calculate unbent flat pattern length (L_f):

Using BA: L_f= B +B + Bend allowance

Using BD: L_f= C + C- Bend deduction

Assignment:

1. Calculate the value of bend allowance and bend deduction for the following specimen configuration:

Angle	90^0
pi	3.1416
Radius	1.5 mm
K-factor	Variable for each student
Thickness	6 mm

2. Why do you need to calculate bend allowance and bend deduction? What are the factors that governs the values of those two variables for a certain specimen?
3. Deduce a relationship between bend radiuses and bend deduction, bend radius and bend allowance.

Report writing:

- Objectives
- Apparatus (with specifications if any)
- Machine used (with specifications)
- Schematic diagram
- Data sheet
- Sample calculation
- Graphs (if any)
- Discussion (in passive form)
- Assignment
- References

Experiment 2: Determination of springback and shearing force required for mild steel specimen.

Procedure:

1. Prepare four 4 inch x 1 inch specimen from mild steel sheet.
2. Bend each specimen to 90, 120, 135 and 150 degrees of bend angle separately.
3. Calculate bend radius for each bend angle. This is initial bend radius R_i.
4. Calculate the bend radius again on the next day. This is final bend radius R_f.
5. Calculate the actual and theoretical spring back.
6. Measure the die opening in the bending machine (w) and bend length (L).
7. Calculate bend force required for each specimen.
8. Plot actual springback and theoretical springback vs. bend angle.
9. Plot bending force vs. die opening in graph paper.

Table 1:

Bend angle	Initial radius (R_i)	Final radius (R_f)	Actual springback	Theoretical springback

Table 2:

Bend length (L)	Die opening (w)	Bending force (P)
L_1=	W_1=	P_1=
	W_2=	P_2=
	W_3=	P_3=
	W_4=	P_4=
L_2=	W_1=	P_1=
	W_2=	P_2=
	W_3=	P_3=
	W_4=	P_4=
L_3=	W_1=	P_1=
	W_2=	P_2=
	W_3=	P_3=
	W_4=	P_4=
L_4=	W_1=	P_1=
	W_2=	P_2=
	W_3=	P_3=
	W_4=	P_4=

Formulas:

To calculate springback:

$$\frac{R_i}{R_f} = 4\left(\frac{R_iY}{ET}\right)^3 - 3\left(\frac{R_iY}{ET}\right) + 1$$

To calculate bending force:

$$P = \frac{kYLT^2}{W}$$

For ‘V’ die, this formula can be approximate as:

$$P = \frac{(UTS)LT^2}{W}$$

For mild steel, yield stress, Y= 350 MPa, UTS= 460 MPa.

Assignment:

1. Deduce relationship between bend angle and springback. Also discuss the relationship between material thickness and springback.
2. Deduce relationship between bending force and material strength.
3. Discuss some measures how you can eliminate/reduce springback in bending.
4. Why do you need to calculate springback for a certain specimen?

Report writing:

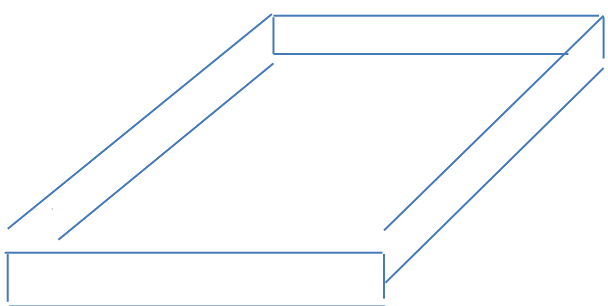
- Objectives
- Apparatus (with specifications if any)
- Machine used (with specifications)
- Schematic diagram
- Data sheet
- Sample calculation
- Graphs (if any)
- Discussion (in passive form)
- Assignment
- References

Experiment no. 3: To be familiarized with different types of sheet metal forming operations and to make a rectangular/square box with sheet metal specimen.

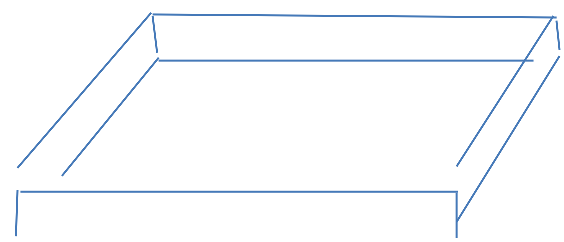
Procedure:

1. Calculate the dimension of required flat sheet to make the box (follow the 'unfolding' technique to do this).
2. Mark on the stocked sheet with scriber.
3. Cut the stocked sheet in the shearing machine along the markings.
4. Mark on the flat sheet on places where to be bent.
5. Connect the diagonals produced on each corner of the flat sheet.
6. Cut the sheet with snip along the diagonals maintaining proper allowances.
7. Bend the flat sheet in the bending machine following 'opposite edge to be the next' technique. Each bend angle should be 90^0.
8. Implement 'cornering operation' on each of the bended corner.
9. Measure the final dimension and compare it with designed one.
10. Discuss reasons behind discrepancy in values, if any.

Figure:



Dimension: 12x8x2 inch (rectangular)



Dimension: 12x12x2 inch (square)

Assignment:

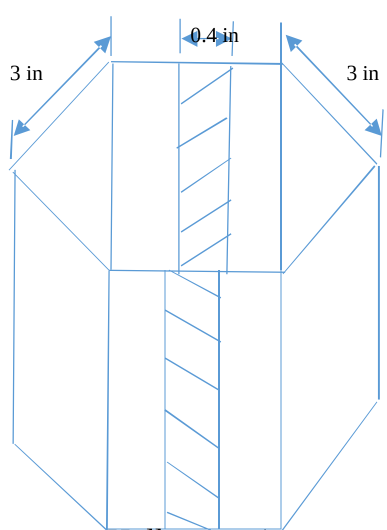
1. What do you mean by 'sheet metal' and 'sheet metal work'?
2. Write down any four characteristics of 'sheet metal'.
3. Discuss different types of sheet metal forming operations.
4. Define the term 'springback'. Which property of the material is responsible for 'springback'?
5. What will be the value of springback for a brittle material like 'glasses'? Justify your answer.

Experiment no. 4: To be familiarized with different sheet metal joining operations and to make a regular hexagonal box with sheet metal specimen.

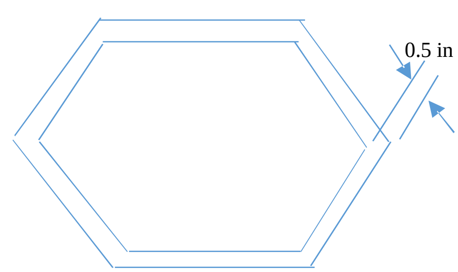
Procedure:

1. Calculate the flat sheet dimension to make the box (follow the 'unfolding' procedure to do this). Divide the box into two equally dimensioned parts.
2. Mark on the stocked sheet with scriber.
3. Cut the stocked sheet in the shearing machine along the markings.
4. Mark on the flat sheet on places where to be bent.
5. Bend the flat sheet in the bending machine. Firstly bend the extreme edges where seam joint to be produced (bend angle should be nearly 180^0).
6. Produce three bends with bend angle of 60^0 on each parts to make the arms of hexagon. Be careful with the direction of bend, so that opposite parts match together to lock the seam.
7. Lock the seam joint and complete the hollow section.
8. Scribe the outer circumference of the hollow box on a flat sheet.
9. Offset the circumference as required.
10. Join the edges of outer and inner hexagon and cut along the joined line maintaining proper allowance, with the help of snip.
11. Set the hollow box on top of the cap prepared.
12. Implement 'finishing operations' on each component.
13. Measure the final dimension and compare it with designed one.
14. Discuss reasons behind discrepancy in values, if any.

Figure:



Hollow section



Lower cap

Assignment:

1. Describe different sheet metal joining operations. Explain with neat sketch: Soldering, Brazing and Resistance welding.
2. Discuss different types of bending operations with neat sketch.
3. Discuss different types of seam joints with illustrations.
4. Write down advantage, limitations and application areas of seam joint.

Report writing:

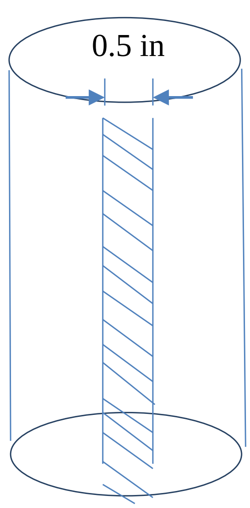
- Objectives
- Apparatus (with specifications if any)
- Machine used (with specifications)
- Schematic diagram
- Data sheet
- Sample calculation
- Graphs (if any)
- Discussion (in passive form)
- Assignment
- References

Experiment no 5: To be familiarized with sheet metal roll bending process and to make a cylindrical box using sheet metal specimen.

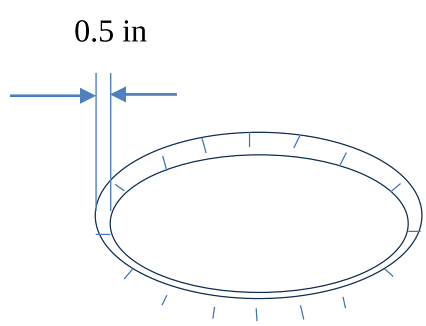
Procedure:

1. Calculate the flat sheet dimension to make the box (follow the 'unfolding' procedure to do this).
2. Mark on the stocked sheet with scriber.
3. Cut the stocked sheet in the shearing machine along the markings.
4. Mark on the flat sheet on places where to be bent.
5. Bend the flat sheet in the bending machine. Firstly bend the extreme edges where seam joint to be produced (bend angle should be nearly 180^0).
6. Bend the flat sheet in sheet rolling machine. Be careful in setting clearance between rollers in the machine. Remember the 'rule of thumb': the closer the clearance, the smaller will be the radius of the cylinder.
7. Lock the seam joint and complete the hollow section.
8. Scribe the outer circumference of the hollow box on a flat sheet.
9. Offset the circumference as required with the help of a divider.
10. Divide the circle into 16 (sixteen) equal parts and mark on the sheet.
11. Cut the sheet along the markings between the outer and inner circle maintaining proper allowance with the help of snip.
12. Bend the split portions with the help of tong.
13. Set the hollow box on top of the cap prepared.
14. Implement 'finishing operations' on each component.
15. Measure the final dimension and compare it with designed one.
16. Discuss reasons behind discrepancy in values, if any.

Figure:



Hollow section



Lower Cap

Problem: Find the radius and height of the hollow cylinder having a volume of 64π/27π/72π inch^3. Given that, minimum and maximum radius that can be formed in the rolling machine is 2 inch a 10 inch respectively.

Assignment:

1. Elaborate with neat sketch 'Roll bending processes.
2. Can you recommend any alternative method to make a cylinder except 'roll bending'? Discuss.
3. Will the values of 'bend allowance' and 'bend deduction' be larger for 'roll bending' than 'V-die bending'? Justify your answer.
4. How can you find the 'center' of an already drawn circle? What is the value of bend angle for a 'cylinder'?
5. Discuss gas welding process and its advantages, disadvantages.

Report writing:

- Objectives
- Apparatus (with specifications if any)
- Machine used (with specifications)
- Schematic diagram (Rolling machine and job)
- Data sheet
- Sample calculation
- Graphs (if any)
- Discussion (in passive form)
- Assignment
- References

Experiment no 6: To be familiarized with different types of pipe bending operations and various defects in bended pipe.

Procedure:

17. Prepare two pipe specimens from the stocked pipe. Specimen configuration should be: length/Outer diameter/Thickness= (2.5’/1”/1mm) and (2.5’/$\frac{3}{4}$”/1mm). Use hand grinding machine to cut the stocked pipe and finish the cut parts.
18. Set the first specimen on the pipe bending machine. Be sure to pass the pipe in between pressure die & bend die and secure one end of the pipe in the clamp die.
19. Clamp the pipe such that it may flow inside the clam die while pressure is applied to bend the pipe, otherwise the pipe may be distorted if pipe material is not tough enough. Be sure to keep some extra pipe extended further from the clam die in the direction opposite to bend direction; this will facilitate the bending process.
20. Tighten the pressure die with the help of lead screw in the pressure handle. Apply moment in the pressure handle to bend the pipe.
21. Unfasten the pipe from the machine and remove it from the machine. Cut the bended portion in radial direction with the help of hand grinding machine or hacksaw and analyze the bended portion. Make sure if any flattening or wrinkle is present.
22. Repeat from step 2 to 5 for the second specimen.
23. Insert mandrel (sand) in the specimen and repeat from step 2 to 5.
24. Compare observations on the bended pipe without and with mandrel.

Figure:

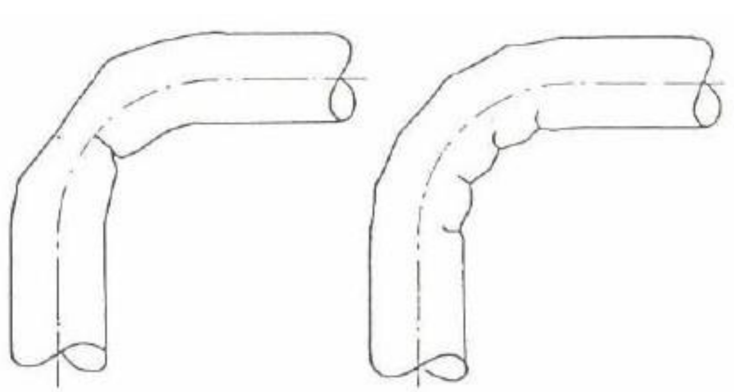


Figure: Actual shape of bended pipe

Assignment:

6. Write down the causes and suggest ways to eliminate followings:
   (b) Tube breakage (b) Tube wrinkling
7. Explain with neat sketches different tube bending operations.
8. Discuss tube bending mechanism with necessary sketches.
9. Relate tube thickness with different tube bending operations.
10. What are the typical components required for tube bending? Write down their functions.

Report writing:

- Objectives
- Apparatus (with specifications if any)
- Machine used (with name of the different components)
- Schematic diagram (Experimental setup)
- Data sheet (Pipe configurations)
- Graphs (if any)
- Discussion (in passive form)
- Assignment
- References

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

4th Year, 1st Semester

Student Name :

Student ID :

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 4102: Machine Tools and Machining Sessional
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. Viva for each experiment will be taken on the next day with the report.
5. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental setup, Experimental conditions
    - Data Sheets
    - Sample calculation
    - Result
    - Graph
    - Discussion
        i) Discuss the graphs and results
        ii) Discuss about the experimental setup if it could be improved
        iii) Discuss the different parameters that could affect the result
        iv) Discuss any assumption made
        v) Discuss any discrepancies in the experimental procedure and result
        vi) Discuss what you have learnt and the practical application of this knowledge
        vii) Finally, add the data sheet with the report.
    - Conclusions
    - Acknowledgements
    - References
6. A quiz will be taken on the experiments at the end of the semester.
7. Marks distribution:

Total Marks: 100			
Attendance	**Lab Reports**	**Viva**	**Quiz**
10	40	20	30

List of the Experiments:

1. Study of Chips and Determination of Chip Reduction Co-efficient in Turning Medium Carbon Steel by coated Carbide Insert.
2. Study of Cutting Zone Temperature in Turning Medium Carbon Steel by coated Carbide Insert.
3. Study of the Alignment test of a Lathe Machine, Milling Machine, Drilling Machine and Grinding Machine.
4. Study of Gear Indexing and Manufacturing of a Spur Gear on a Knee/Column Type Milling Machine.
5. Study of Gear Indexing and Manufacturing of a Helical Gear on a Knee/Column Type Milling Machine.
6. Study of Kinematic Diagram of Engine Lathe.
7. Determination of surface roughness of workpiece at different machining operations.
8. Determination of tool wear of cutting tool.

Books of References:

(i) Elements of Machine Tools by M. Anwarul Azim
(ii) Machine Tools by N. Chernov
(iii) Production Technology by Er. R.K. Jain
(iv) Fundamentals of Machining and Machine Tools by Boothroyd G. & Knight
(v) Introduction to Manufacturing Processes by Kalpakjian S.
(vi) Material and Process Engineering by DeGarmo E. Paul

Experiment No: 01

STUDY OF CHIPS AND DETERMINATION OF CHIP REDUCTION CO-EFFICIENT IN TURNING MEDIUM CARBON STEEL BY COATED CARBIDE INSERT.

Objectives:

i. To study different types of chip (type, shape and color)

ii. To determine chip reduction co-efficient (ξ)

Theory:

Chip Formation:

When force is applied by cutting tool against the workpiece, the uncut layer deforms first elastically followed by plastic deformation due to the shearing action near the cutting edge of the tool. Shearing takes place along a shear zone and shear is of maximum at the shear plane. After passing out of the shear plane, the deformed material slides along the tool face as chip as cutting progresses.

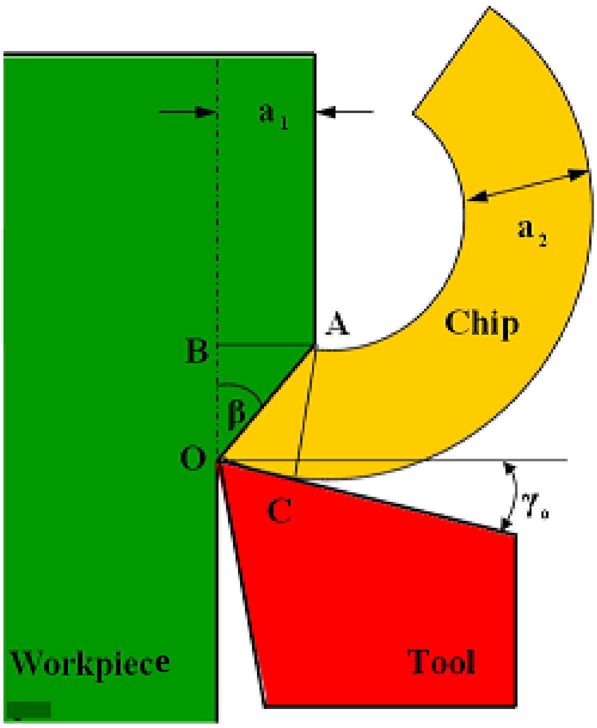


Fig.1.1: Schematic Representation of Chip Formation

Four main categories of chips (as shown in Fig. 2) are:

Discontinuous chips:

These chips are small segments, which adhere loosely to each other. They are formed when the amount of deformation to which chips undergo is limited by repeated fracturing. Hard and brittle materials like bronze, brass and cast iron will produce such chips.

Continuous or 'ribbon' chips:

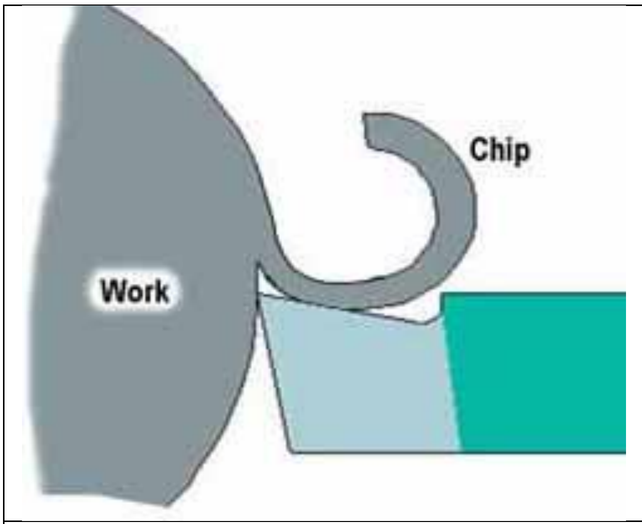
In continuous chip formation, the pressure of the work piece builds until the material fails by slip along the plane. The inside on the chip displays steps produced by the intermittent slip, but the outside is very smooth. It has its elements bonded together in the form of long coils and is formed by the continuous plastic deformation of material without fracture ahead of the cutting edge of the tool and is followed by the smooth flow of chip up the tool face.

Continuous chip with built up edge:

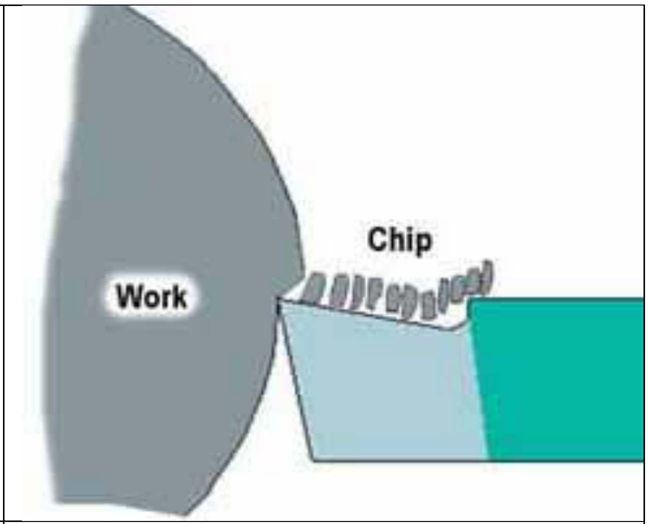
These types of chips are very similar to that of continuous type, with the difference that it is not as smooth as the previous one. This type of chip is associated with poor surface finish, but protects the cutting edge from wear due to movement of chips and the action of heat causing the increase in tool life.

Serrated chips:

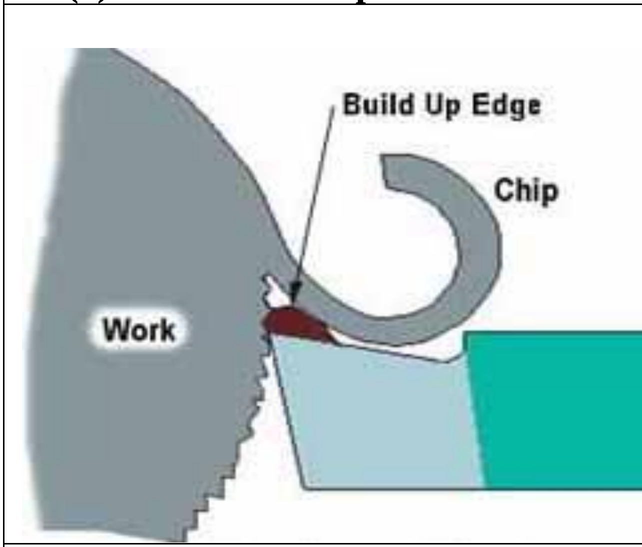
These chips are semi-continuous in the sense that they possess a saw-tooth appearance that is produced by a cyclical chip formation of altering high shear strain followed by low shear strain. This chip is most closely associated with certain difficult-to-machine metals such as titanium alloys, nickel-based super-alloys and aesthetic stainless steels when they are machined at higher cutting speeds. However, the phenomenon is also found with more common work metals (e. g. steel), when they are cut at high speeds.



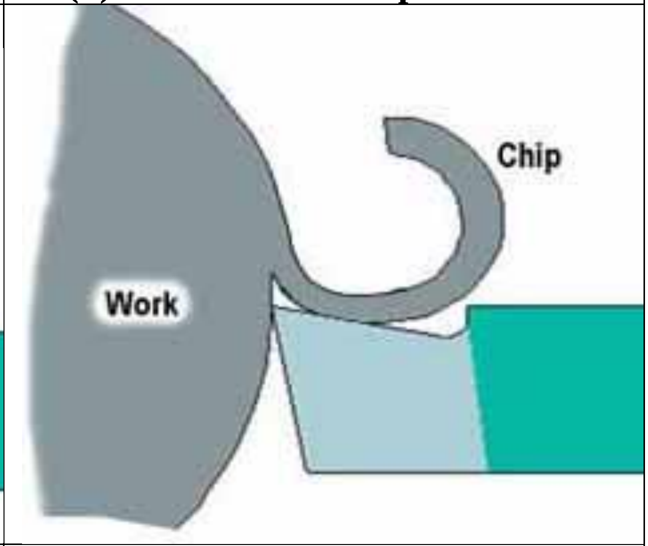
(a) Continuous chip



(b) Discontinuous chip



(c) Continuous with built-up edge

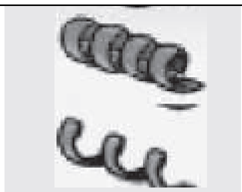


(d) Serrated chip

Fig.1.2: Four types of chip formation in metal cutting

Chip Shape:

Chip shape depends in the state of chip curling. Chip shape may be ribbon-like, helical (tubular), spiral, one turn, half turn etc.

Chip Shape				
Group	Half Turn	Tubular/ Helical	Spiral	Ribbon-like

Chip Color:

Chip color depends generally on the cutting conditions (cutting velocity, depth of cut, feed rate etc). In dry cutting the chip color is generally blue or burned blue. In wet conditions chip color generally in metallic, golden, or blue.

Chip Reduction Co-efficient:

Chip reduction co-efficient (ξ) is the ratio of chip thickness (a_2) to uncut chip thickness (a_1), (as shown in Fig.1). Mathematically,

$$\xi = \frac{a_2}{a_1} = \frac{a_2}{s_0 \, Sin \, \emptyset}$$

The inverse of ξ is known as cutting ratio, r_c. ξ is an important index which indicates the degree of deformation and hence the force required. ξ is affected by process parameters (i.e. V_c, S_o, t, γ etc) and other variables (i.e. friction at too-chip interface, cutting fluid, tool material, work material etc).

Machine, Equipment and Work Material:

i. Lathe machine
ii. Work material (medium carbon steel)
iii. Cutting tool (coated carbide)
iv. Slide calipers

Procedure:

i. Turn the work material in an engine lathe with three different cutting velocities (V_c) at a constant feed rate (S_o) and constant depth of cut.
ii. Repeat the above procedure for three different feed rates.
iii. Collect the chips obtained
iv. Study them to identify their types, shapes and colors.
v. Calculate the chips reduction coefficient for each chip.
vi. Plot the graphs ξ vs V_c, ξ vs S_o

DATA SHEET

Study of chips in turning medium carbon steel by coated carbide insert

Work material :
Diameter :
Cutting tool :
Material :
Cutting conditions
Cutting velocity :
Feed rate :
Depth of cut :
Environment :

S_0 (mm/rev)	N (rpm)	V_c (m/min)	a_1 (mm)	a_2 (mm)	ξ	Chip		
						type	shape	color

Question/Answer:

1. What is the significance of ξ?
2. Will ξ be greater than 1 always? Why?
3. What is the difference in chips when r.p.m is high?

Experiment No: 02

STUDY OF CUTTING ZONE TEMPERATURE USING TOOL-WORK THERMOCOUPLE IN TURNING MEDIUM CARBON STEEL BY COATED CARBIDE INSERT.

Objective:

i. To determine temperature (θ) at chip tool interface

Theory:

Machining is a material removal process that typically involves the cutting of metals using different types of cutting tools in which a tool removes material from the surface of a less resistant body through relative movement of the tool and application of force and is particularly useful due to its high dimensional accuracy, flexibility of process, and cost-effectiveness in producing limited quantities of parts. Due to removal of material in the form of chips, new surfaces are cleaved from the workpiece accompanied by a large consumption of mechanical energy which in turn transformed into heat, leading to conditions of high pressure, high temperature and severe thermal conditions at the tool-chip interface. The greater the energy consumption, the greater are the temperature and frictional forces at the tool–chip interface and consequently the higher is the tool wear.

During machining heat is generated at the (a) primary deformation zone due to shear and plastic deformation (b) chip-tool interface due to secondary deformation and sliding and (c) work-tool interface due to rubbing during machining of any ductile materials. Maximum temperature has been produced at the chip-tool interface by all such heat sources which substantially influence the chip formation mode, cutting forces and tool life. The magnitude of this cutting temperature increases, though in different degree, with the increase of cutting speed, feed and depth of cut, as a result, high production machining is constrained by rise in temperature.

The average chip-tool interface cutting temperature has to measure under dry and wet conditions undertaken by simple but reliable tool-work thermocouple technique with proper calibration. This method is very useful to specify the effects of the cutting speed, feed rate and cutting parameters on the temperature. Thermocouples are conductive, rugged and inexpensive and can operate over a wide temperature range. To record emf as milivolt a digital multi-meter has been used where one end of multi-meter has been connected to the workpiece and other end to the tool.

Machine, Equipment and Work Material:

i. Lathe machine
ii. Work material (medium carbon steel)
iii. Cutting tool (coated carbide)
iv. Mica sheet
v. Millivoltmeter

Procedure:

i. Turn the work material in an engine lathe with three different cutting velocities (V_c) at a constant feed rate (S_o).
ii. Repeat the above procedure for three different feed rates.
iii. Take the mV reading from the Millivoltmeter and then determine temperature (θ) at chip-tool interface from $\theta = 75.28 + 63.05\ mV - 0.57\ mV^2$
iv. Plot θ vs V_c; and θ vs S_0

Experimental Setup for Temperature Measurement

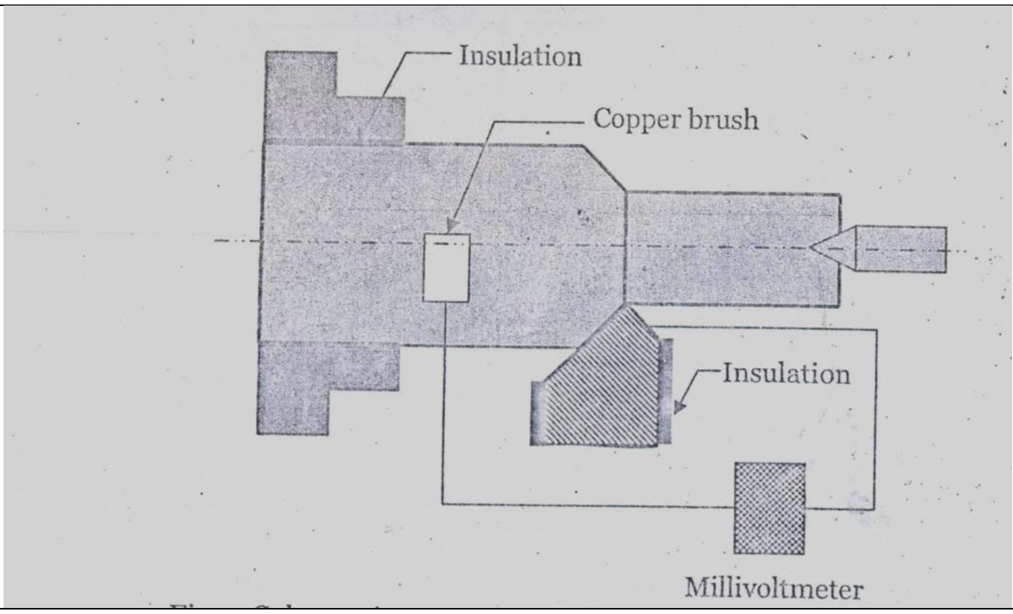


Fig.2.1: Schematic representation of temperature measurement

DATA SHEET

Study of cutting zone temperature in turning medium carbon steel by coated carbide insert

Work material :
Diameter :
Cutting tool :
Material :
Cutting conditions
- **Cutting velocity :**
- **Feed rate :**
- **Depth of cut :**

Environment :

S_0 (mm/rev)	N (rpm)	V_c (m/min)	mV	θ (^0C)

Question/Answer:

1. Explain seebeck effect.
2. What is the insulation procedure in this experiment? Why it is necessary?
3. What is EMF?
4. What is the relationship between cutting zone temperature and cutting velocity?

Experiment No: 03

STUDY OF THE ALIGNMENT TEST OF A LATHE MACHINE, MILLING MACHINE, DRILLING MACHINE AND GRINDING MACHINE.

Objectives:

i. To study the alignment test of a lathe machine (Chuck, tail stock, and slide ways)
ii. To study the alignment test of a Milling machine (Spindle, arbor and slide ways)
iii. To study the alignment test of a Drilling machine (Spindle and column)
iv. To study the alignment test of a Grinding machine (Magnetic chuck and worktable)

Theory:

Alignments are a crucial step in setting up a machine to cut accurate parts. Alignment test are carried out to check the accuracy of machine tool.

Machine tools are very sensitive to impact or shock, even heavy casting standards are not always solid and rigid enough to withstand stresses due to falling during transportation, and deformations may be set up. Although the machine is always carefully adjusted and aligned when on the test stand or in the assembly department of the manufacturer, it is well known from experience that erection in the workshop is not always done with sufficient care and thus inaccuracies of the work may result from the faulty erection of the machine.

Machine tools for the workshop must be able to produce workpieces of given accuracy within prescribed limits, consistently and without requiring artistic skill on the part of the operator.

For acceptance test of a machine, its alignment test is performed and to see its dynamic stability, which may be poor though alignment tests are right, certain specific jobs are prepared and their accuracy checked.

Various tests on any machine tool are carried out, it is very essential that it should be installed in truly horizontal and vertical planes. In horizontal plane, both longitudinal and transverse directions are equally important. If, say, any long lathe bed is not installed truly horizontal the bed will undergo a deflection, thereby producing a simple bend and undesirable stresses will be introduced. If the bed is not installed truly horizontal in transverse direction, twist will be introduced. Thus, the movement of the saddle can't be in a straight line and true geometric cylinder can't be generated. For proper installation and maintenance of its accuracy, a special concrete foundation of considerable depth must be prepared. Also, this must be insulated from the surrounding floor by introducing some form of damping.

Machine, Equipment and Work Material:

i. Lathe machine
ii. Milling machine
iii. Drilling machine
iv. Grinding machine
v. Dial gauge
vi. Slide calipers
vii. Measuring tape

Procedure:

i. Clamp the dial gauge at different places of the machine tool.
ii. Take the reading of deflection at different places of the machine tool using dial indicator.
iii. Repeat the above procedure for other machines.
iv. Plot deflection vs distance graph.

Assignment:

1. Why alignment test of a machine tool is necessary?
2. What occurs if spindle alignment in lathe/ milling machine is not correct?
3. What occurs if slideway alignment in lathe/ milling machine is not correct?
4. Draw the graph and discuss about the pattern of alignment test at lathe/ milling/drilling machine in the experiment?

Experiment No: 04

STUDY OF GEAR INDEXING AND MANUFACTURING OF A SPUR GEAR ON A KNEE TYPE MILLING MACHINE

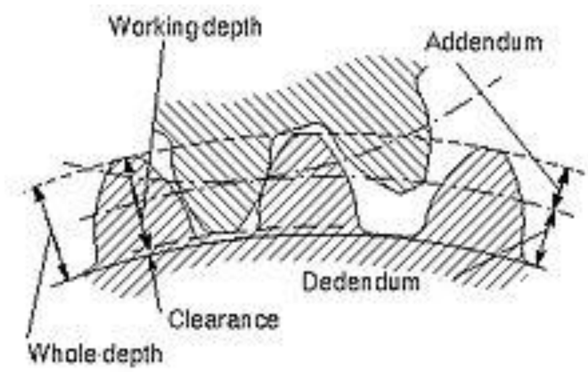
Objective:

i. To study the indexing a spur gear
ii. To manufacture a spur gear

Theory:
Introduction:

Gear is a widely used mechanical component whose primary use is to transmit power from one shaft to another. These gears are of many types namely spur gears, helical gears, worm gears etc. gear drives are used to various kinds of machines like automobiles, metal cutting tools, rolling mills, material handling equipments etc. the friction and other losses in this type of power transmission equipment is comparatively very low.

Gear Nomenclature:



Addendum: The **addendum** is the height by which a tooth of a gear projects beyond (outside for external, or inside for internal) the standard pitch circle or pitch line; also, the radial distance between the pitch circle and the addendum circle.

Dedendum:
is the depth of a tooth space below the pitch line. It is normally greater than the addendum of the mating gear to provide clearance.

Dividing Heads
A dividing head is a tool that is used to divide a circle into equal divisions. Dividing heads are employed in operations on knee type milling machine for setting the work

piece at the required angle to the table of the machine, turning the work piece through a pre-determined angle, diving circle into the required number of parts (indexing) and also for continuous rotation of the work piece in milling helical grooves with a large lead.

Fig.4.1: Dividing Head

Types of dividing heads:

There are dividing heads for direct indexing (called plain dividing heads), optical dividing heads and universal dividing heads. Universal dividing heads are classified as heads with and without an index plate. Index plate dividing heads are more widely used. Universal dividing heads are setup for:

a. **Simple indexing:** It consists in turning the spindle through the required angle by rotating the index crank.
b. **Differential indexing:** It is employed where simple indexing cannot be effected i.e. where an index plate with the number of holes required for simple indexing is not available.
c. Cutting helical grooves: In milling helical grooves, a complex helical movement is imparted to the work piece, which involves a straight movement along the work piece axis and rotation of the work about the same axis.

Machine, Equipment and Work Material:

i. Milling machine
ii. Work material (Gear Blank)
iii. Cutting tool (Gear Cutter)

Necessary Calculations:

i. Outside diameter O.D = $\frac{T+2}{P_d}$ here, T= Number of teeth to be cut

P_d = Diametral Pitch

D_p = Pitch Diameter

ii. $P_d = \frac{T}{Dp}$

iii. Addendum, $a = \left[\frac{1}{Pd}\right]$

iv. Clearance, $c = \left[\frac{0.157}{Pd}\right]$

v. Dedendum, $b = a+c = \left[\frac{1.157}{Pd}\right]$

vi. Full depth or Depth of cut = $a+b = \left[\frac{2.157}{Pd}\right]$

Procedure:

Sr. No.	Operation	Tools / Equipment
01	Mount and align the dividing head and tailstock on machine table.	Dividing head, tail stock, dial indicator.
02	Mount the gear-milling cutter on the arbor and test for concentricity.	Gear cutter.
03	Hold the work piece on the mandrel and adjust the mandrel between centers.	Try square, slip gauges
04	Adjust the work piece to the center of cutter.	
05	Set the revolutions, and feed for milling.	
06	In the beginning the cutter should shave slightly on the work piece.	
07	Withdraw the work piece out of range of the cutter and lift the milling table by the height of the tooth depth.	
08	Milling of first tooth space.	
09	Withdraw the work piece from the cut and turn the indexing handle by the tooth pitch & mill next tooth space.	
10	Repeat the procedure for next tooth.	

Questions:

1. What are the other options that can be used other than milling to manufacture a gear?
2. Differentiate simple and differential indexing.
3. What is the requirement of indexing plate or dividing plate?
4. How can you produce a spur gear having less than 40 teeth with this indexing plate?

Experiment No: 05

STUDY OF GEAR INDEXING AND MANUFACTURING OF A HELICAL GEAR ON A KNEE TYPE MILLING MACHINE

Objective:

i. To study the indexing a helical gear
ii. To manufacture a helical gear

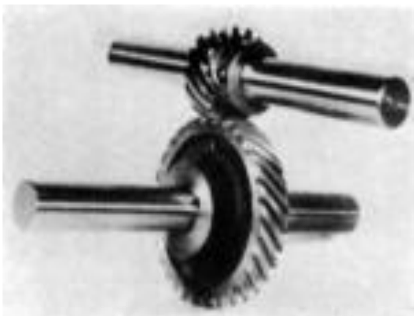
Theory:

Helical Gear

Helical gears are similar to spur gears except that their teeth are cut at an angle to the hole (axis) rather than straight and parallel to the hole like the teeth of a spur gear. Helical gears are used to connect non-intersecting shafts. Helical gears are manufactured as both *right and left-hand gears*. The teeth of a left-hand helical gear lean to the left when the gear is placed on a flat surface. The teeth of a right-hand helical gear lean to the right when placed on a flat surface. Opposite hand helical gears run on parallel shafts. Gears of the same hand operate with shafts of 90º.

Right Hand Helical Gear

Left Hand Helical Gear



Helical Gears on Non-Parallel Shafts Shaft Angle 90°
Both Gears Right Hand

Setting up a universal diving head for milling helical grooves:

In milling helical grooves, a complex helical movement is imparted to the work piece, which involves a straight movement along the work piece axis and rotation of the work about the same axis. The work piece receives the straight movement with the work table of the machine, and rotation, from the work-table lead screw through the change gears. The table is set to the spindle axis at an angle ω equal to the helix angle of the groove being cut. In milling a left-hand groove, the table is swiveled clockwise at an angle ω, and in cutting a right hand groove, counterclockwise.

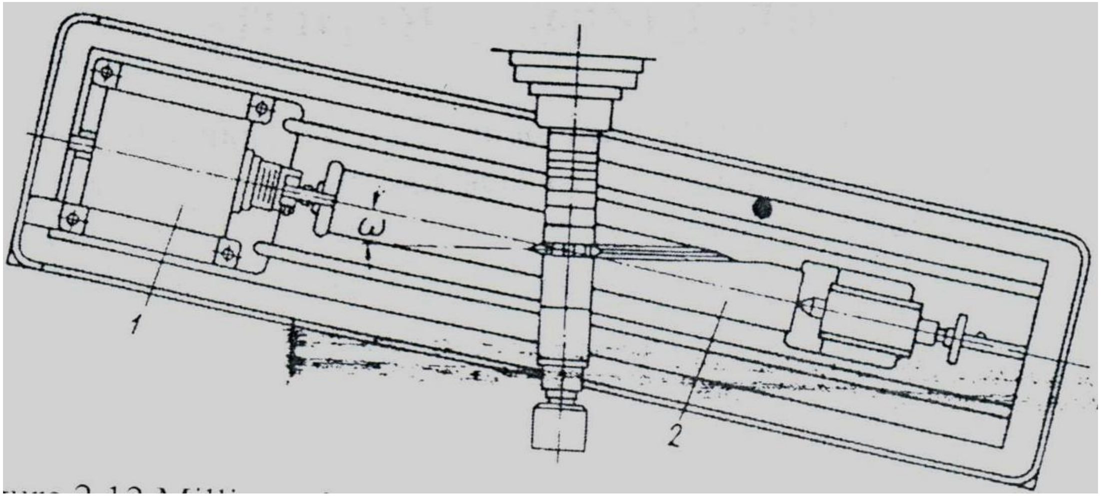


Fig.5.1: Milling of helical grooves; 1. Diving head; 2. Work piece

The set for the table is,

$\boldsymbol{\omega}=\arctan \frac{\pi D}{P\ h.g}$

Where, D = diameter of the work piece being cut; $P_{h.g}$ = Lead of the helical groove.

If the helix ids determined by the lead angle α, the table should be set at an angle of 90^0-α. Slow rotation is imparted to the dividing head spindle along the kinematic chain shown in figure.

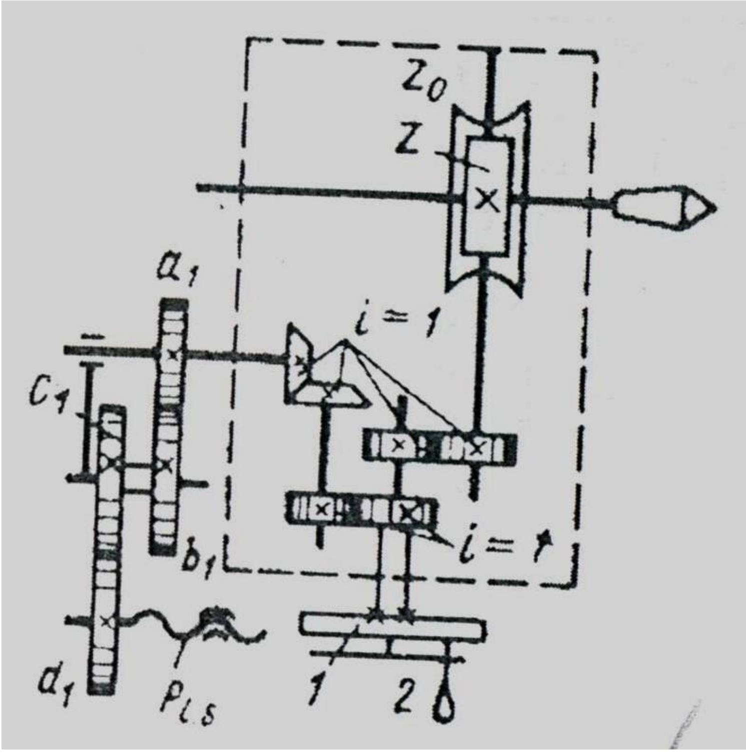


Fig.5.2: Diagram of Universal Dividing Head set-up

The kinematic balance equation of this chain for setting up change-gear train $\frac{a1}{b1}\frac{c1}{d1}$ is worked out provided that for every revolution of the work piece the work table of the machine travels by an amount equal to the lead $P_{h.g}$ of the groove being cut.

$$1\frac{Z0}{Z}1.1.1\frac{a1}{b1}\frac{c1}{d1}P_{l.s} = P_{h.g}$$

With Z=1, we obtain

$$\frac{a1}{b1}\frac{c1}{d1}=\frac{Ph.g}{Z0Pl.s}$$

Where, $P_{l.s}$ is the lead of work table lead screw, mm.

Question/Answer:

1. Why helical gears are better than spur gear?
2. How you cut the helical gear in vertical milling machine?
3. Name some other machine except milling in which helical gears can be cut.

Experiment No: 06

STUDY OF KINEMATIC DIAGRAM OF AN ENGINE LATHE.

Objective:

i. To study the kinematic diagram of an engine lathe

Theory:

Movement of the machine:

There are basically three types of movements of an engine lathe. They are-

a. Principle movement: Rotation of the spindle with the workpiece.
b. Feed movement: Longitudinal travel of the carriage and the cross traverse of the cross slide and
c. Auxiliary movement: Rapid traverse of the carriage and the cross slide in the same direction from an individual drive.

Machine, Equipment and Work Material:

i. Lathe machine
ii. Screw driver
iii. Wrench

Question/Answer:

1. Draw the kinematic diagram of the engine lathe that you have studied.
2. What are the types of gears you have seen in this experiment? Describe them all with necessary figures.

Experiment No: 07

DETERMINATION OF SURFACE ROUGHNESS OF WORKPIECE AT DIFFERENT MACHINING OPERATIONS.

Objective:

- **i.** To obtain the value of the roughness of a specimen by using Roughness Tester
- **ii.** To see the surface quality of a specimen

Theory:

Surface roughness, often shortened to **roughness**, is a component of surface texture. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces.

Although a high roughness value is often undesirable, it can be difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

Roughness can be measured by manual comparison against a "surface roughness comparator", a sample of known surface roughness, but more generally a Surface profile measurement is made with a profilometer that can be contact (typically a diamond styles) or optical (e.g. a white light interferometer).

However, controlled roughness can often be desirable. For example, a gloss surface can be too shiny to the eye and too slippery to the finger (a touchpad is a good example) so a controlled roughness is required.

Why do we measure surface roughness?

The shape and size of irregularities on a machined surface have a major impact on the quality and performance of that surface, and on the performance of the end product. The quantification and management of fine irregularities on the surface, which is to say, measurement of surface roughness, is necessary to maintain high product performance.

There are two ways to measure surface roughness:

The instruments for measuring surface roughness can be broadly divided between two types.

i. contact and
ii. non-contact types

Contact Type:

Overview

i. The degree of roughness in the surface is measured over an arbitrary rectangular range

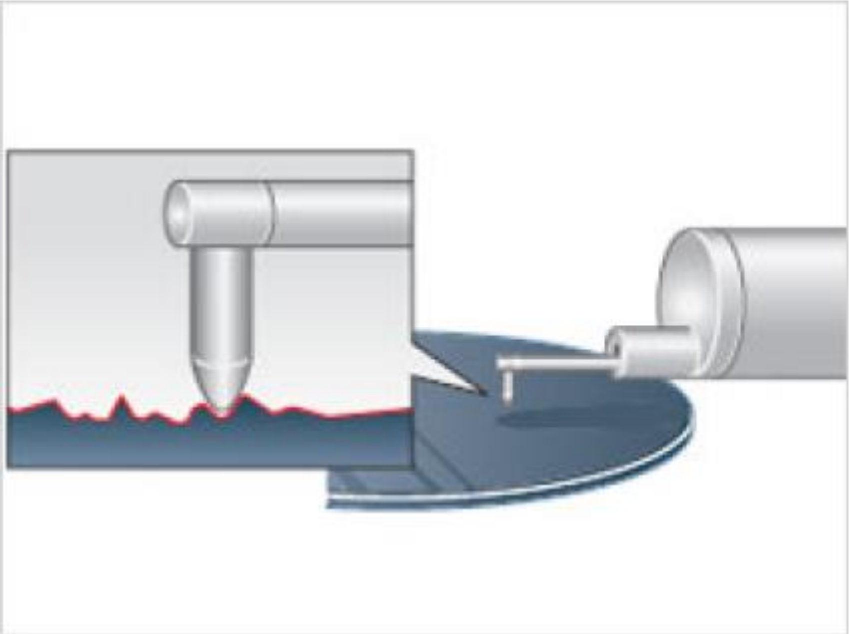


Fig.7.1: Contact-type roughness instrument

With this type, the tip of the stylus directly touches the surface of the sample. As the stylus traces across the sample, it rises and falls together with the roughness on the sample surface. This movement in the stylus is picked up and used to measure surface roughness. The stylus moves closely with the sample surface, so data is highly reliable.

Non-Contact Type:

The leading method of this type is light. Light emitted from the instrument is reflected and read, to measure without touching the sample. Various non-contact systems include the focus detection type, the confocal microscope type, and the interferometer type.

As they are non-contact, these systems never harm the sample and can even measure soft or viscous materials.

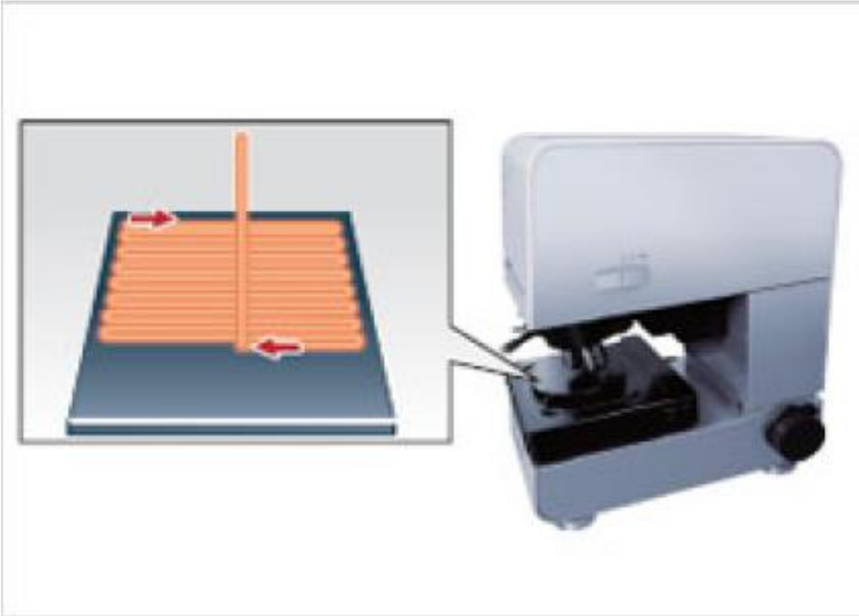


Fig.7.2: Laser microscope (focus detection system)

Data Sheet:

Operation Name	S_0 (mm/rev)	t	N (rpm)	V_c (m/min)	Roughness Value, R_a			Average
					1	2	3	

Question/Answer:

1. Which method is best, contact type or non-contact type?
2. How can you reduce surface roughness?

Experiment No: 08

DETERMINATION OF TOOL WEAR OF CUTTING TOOL.

Objective:

- **i.** To determine the value of tool wear by using Inverted Microscope
- **ii.** To learn different types of tool wear

Theory:

Tool Wear:

Productivity and economy of manufacturing by machining are significantly affected by life of the cutting tools. Cutting tools may fail by brittle fracture, plastic deformation or gradual wear. Turning carbide inserts having enough strength, toughness and hot hardness generally fail by gradual wears. With the progress of machining the tools attain crater wear at the rake surface and flank wear at the clearance surfaces, (as schematically shown in following figure.1) due to continuous interaction and rubbing with the chips and the work surfaces respectively. Among the *aforesaid* wears, the principal flank wear is the most important because it raises the cutting forces and the related problems.

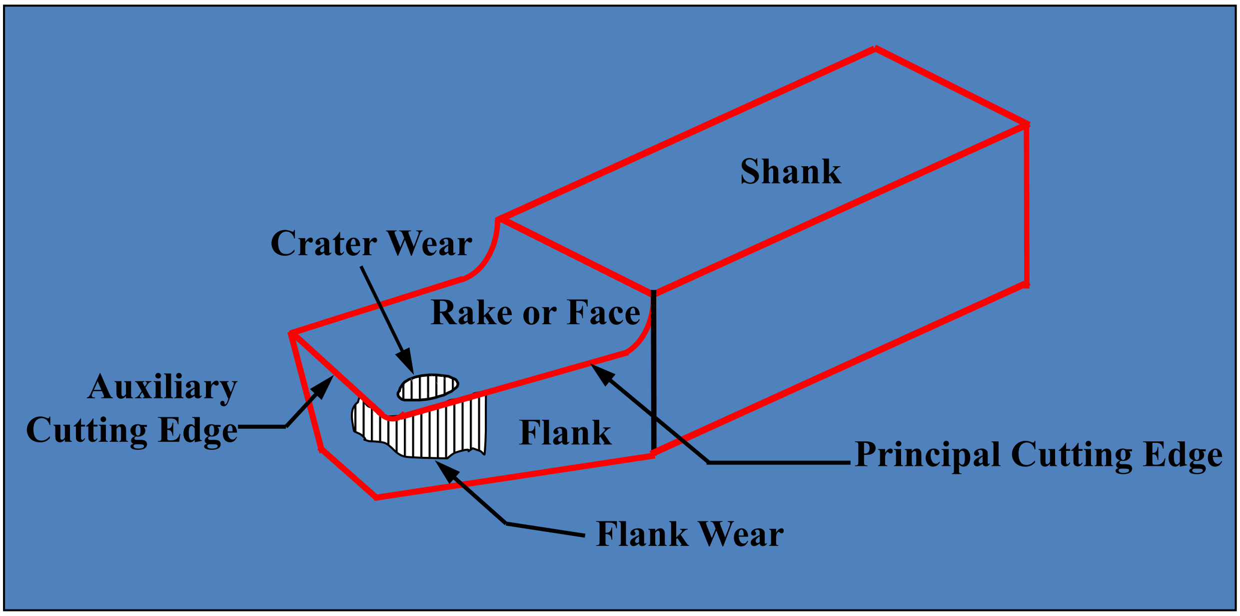


Fig.8.1: Tool Wear

Tool wear describes the gradual failure of cutting tools due to regular operation.

Types of wear include:

i. **flank wear** in which the portion of the tool in contact with the finished part erodes.

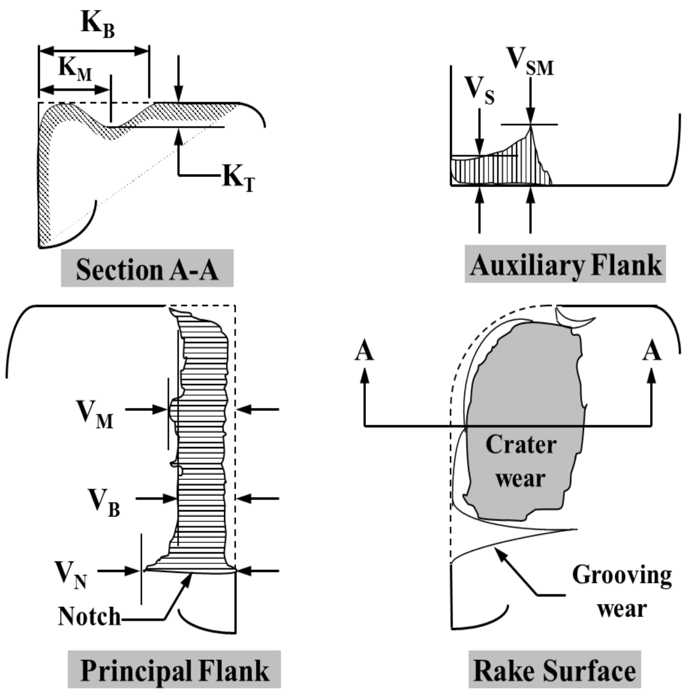
ii. **crater wear** in which contact with chips erodes the rake face. This is somewhat normal for tool wear, and does not seriously degrade the use of a tool until it becomes serious enough to cause a cutting-edge failure. Can be caused by spindle speed that is too low or a feed rate that is too high. In orthogonal cutting this typically occurs where the tool temperature is highest.

iii. **glazing** occurs on grinding wheels, and occurs when the exposed abrasive becomes dulled. It is noticeable as a sheen while the wheel is in motion.

iv. **edge wear**, in drills, refers to wear to the outer edge of a drill bit around the cutting face caused by excessive cutting speed. It extends down the drill flutes, and requires a large volume of material to be removed from the drill bit before it can be corrected.

Major Features of Wear of Turning Tool:

V_B	= Average flank wear
V_N	= Flank notch wear
V_M	= Maximum flank wear
V_S	= Average auxiliary flank wear
V_{SM}	= Maximum auxiliary flank wear
K_T	= Crater depth
K_M	= Distance from center of crater
K_B	= Crater width



A cutting tool was rejected and further machining stopped based on one or a combination of rejection criteria:

i.	Average Flank Wear	≥	0.3 mm
ii.	Maximum Flank Wear	≥	0.4 mm
iii.	Nose Wear	≥	0.3 mm
iv.	Notching at the depth of cut line	≥	0.6 mm
v.	Average surface roughness value	≥	1.6 μm
vi.	Excessive chipping (flanking) or catastrophic fracture of cutting edge.		

Some General effects of tool wear include:

I. increased cutting forces
II. increased cutting temperatures
III. poor surface finish
IV. decreased accuracy of finished part
V. May lead to tool breakage

Reduction in tool wear can be accomplished by using lubricants and coolants while machining. These reduce friction and temperature, thus reducing the tool wear.

Data Sheet:

(machine: lathe machine, operation: turning)

Obs. No.	rpm, N	depth of cut, t	Feed rate, s_o	Operation Time or Distance	Flank Wear			Average Flank Wear	Crater Wear			Average Crater Wear
					1	2	3		1	2	3	
1.												
2.												
3.												
4.												

Draw the figure of rake surface, principal flank and auxiliary flank with possible wear:

Figure: Rake Surface with possible wear

Figure: Auxiliary Flank Surface with possible wear

Figure: Principal Flank Surface with possible wear

Question/Answer:

1. Is it possible to eliminate or reduce tool wear? Explain.
2. What is the effect of tool wear on machined surface?
3. Plot the graph tool wear vs time.

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

4^{th} Year, 2^{nd} Semester

Student Name :

Student ID :

Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering (MPE)
IPE 4206: Industrial Simulation Sessional
Credit Hour: 1.5

General Guidelines:

1. Students must be prepared for the experiment prior to the class.
2. Report of an experiment must be submitted in the next class.
3. A quiz will be taken on the experiments at the end of the semester.
4. Marks distribution:

Total Marks: 100		
Attendance	**Assignment**	**Quiz**
10	20	70

Introduction:

A simulation is the imitation of the operation of a real-world process or system over time. Whether done by hand or on a Computer, simulation involves the generation of an artificial history of a system.

The behavior of a system as it evolves over time is studied by developing a simulation model. This model usually takes the form of a set of assumptions concerning the operation of the system.

Objective

Objective of this sessional is to observe how simulation modeling can be used both as an analysis tool for predicting the effect of changes to existing systems (Material handling, Scheduling, assembly, inventory, queuing etc.) & as a design tool to predict the performance of a new systems under varying sets of circumstances.

Briefing-1: Introduction to simulation systems, Models & Simulation

Consider a manufacturing firm that is contemplating building a large extension onto one of its plants but is not sure if the potential gain in productivity would justify the construction cost. It certainly would not be cost-effective to build the extension and then remove it later if it does not work out. However, a careful simulation study could shed some light on the question by simulation the operation of the plant as it currently exists and as it would be if the plant were expanded.

Application areas for simulation are numerous and diverse. Below is a list of some particular kinds of problems for which simulation has been found to be a useful and powerful tool:

* Designing and analyzing manufacturing systems
* Evaluating hardware and software requirements for a computer system
* Evaluating a new military weapons system or tactic
* Determining ordering policies for an inventory system
* Designing communications systems and message protocols for them
* Designing and operating transportation facilities such as freeways, airports, subways, or Ports
* Evaluating designs for service organizations such as hospitals, post offices, or fast-food restaurants
* Analyzing financial or economic systems

A system is defined to be a collection of entities, e.g., people or machines, that act an interact together toward the accomplishment of some logical end. In practice, what is meant by "the system" depends on the objectives of a particular study. The collection of entities that compose a system for one study might be only a subset of the overall system for another. For example, if one wants to study a bank to determine the number of tellers needed to provide adequate service for customers who want just to cash a check or make a savings deposit, the system can be defined to be that portion of the bank consisting of the tellers and the customers waiting in line or being served. If, on the other hand, the Joan officer and the safety deposit boxes are to be included, the definition of the system must be expanded in an obvious way. We define the state of a system to be that collection of variables necessary to describe a system at a particular time, relative to the objectives of a study. In a study of a bank, exam pies of possible state variables are the number of busy tellers, the number of customers in the bank, and the time of arrival of each customer in the bank.

Discrete-event simulation concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time. (In more mathematical terms, we might say that the system can change at only a countable number of points in time.) These points in time are the ones at which an event occurs, where an event is defined as an instantaneous occurrence that may change the state of the system. Although discrete-event simulation could conceptually be done by hand calculations the amount of data that must be stored and manipulated for most real world systems dictates that discrete-event simulations be done on a digital computer.

Briefing-2: Simulation of Queuing Systems

Example: A small grocery store has only one checkout counter. Customers arrive at this checkout counter at random from 1 to 8 minutes apart. Each possible value of inter arrival time is the same probability of occurrence, as shown in Table 1. The service times vary from 1 to 6 minutes with the probabilities shown in Table 2. The problem is to analyze the system by simulation for the arrival and service of 20 customers.

Table 1

Time between Arrivals (Minutes)	Probability	Cumulative Probability	Random Digit Assignment
1	0.125	0.125	001-125
2	0.125	0.250	126-250
3	0.125	0.375	251-375
4	0.125	0.500	376-500
5	0.125	0.625	501-625
6	0.125	0.750	626-750
7	0.125	0.875	751-875
8	0.125	1.000	876-000

Table 2

Service Time (Minutes)	Probabiliy	Cumulative Probability	Random Digit Assignment
1	0.10	0.10	01-10
2	0.20	0.30	11-30
3	0.30	0.60	31-60
4	0.25	0.85	61-85
5	0.10	0.95	86-95
6	0.05	1.00	96-00

Find out the following:

- The average waiting time of a customer
- The probability that a customer has to wait in the queue
- The proportion of idle time of the server
- The average service time of the server
- The average time between arrival
- The average waiting time of those who wait
- The average time a customer spends in the system

Assignment:

In the above exercise let the service distribution be changed to the following

Service Time (Minutes)	1	2	3	4	5	6
Probability	0.05	0.10	0.20	0.30	0.25	0.10

Develop the simulation table and the analysis for 20 customers. What is the effect of changing the service-time distribution?

Briefing-3: Simulation of Inventory System

Example: Suppose that the maximum inventory level M is 11 units and the review period N is 5 days. The problem is to estimate by simulation (for 5 Cycle) the average ending units in inventory and the number of days when a shortage condition existed. The distribution of the number of units demanded per day is shown in table. Lead time is random variable also shown in table. Assume that the orders are placed at the close of business. Beginning inventory is 3 units and an order of 8 units is scheduled to arrive in 2 days' time.

Table 1: Random Digit Assignment for Daily Demand

Demand	Probability	Cumulative Probability	Random Digit Assignment
0	0.10	0.10	01-10
1	0.25	0.35	11-35
2	0.35	0.70	36-70
3	0.21	0.91	71-91
4	0.09	1.00	92-00

Table 2: Random Digit Assignments for Lead Time

Lead Time (Days)	Probability	Cumulative Probability	Random Digit Assignment
1	0.6	0.6	1-6
2	0.3	0.9	7-9
3	0.1	1.0	0

Find the following:

- Average ending inventory
- Number of days' shortage condition existed

Assignment: rework the above example for 10 cycles with M=10

Briefing-4: Simulation on reliability problem

Example: A large milling machine has three different bearings that fall in service. The cumulative distribution function of the life of each bearing is identical as shown in the table. When a bearing fails, the mills stops, a repairperson is called, and a new bearing is installed. The delay time of the repairperson's arriving at the milling machine is also a random variable, with the distribution given in table 2. Downtime for the mill is estimated at $5 per minute. The direct on site cost of the repairperson is $15 per hour. It takes 20 minutes to change one bearing, 30 minutes to change two bearings, and 40 minutes to change three bearings. The bearings cost $16 each. A proposal has been made to replace all three bearings whenever a bearing fails. Management needs an evaluation of this proposal.

Table 1: Random Digit Assignment for Bearing life

Bearing life (Hours)	Probability	Cumulative Probability	Random Digit Assignment
1000	0.10	0.10	01-10
1100	0.13	0.23	11-23
1200	0.25	0.48	24-48
1300	0.13	0.61	49-61
1400	0.09	0.70	62-70
1500	0.12	0.82	71-82
1600	0.02	0.84	83-84
1700	0.06	0.90	85-90
1800	0.05	0.95	91-95
1900	0.05	1.00	96-00

Table 2: Random Digit Assignments for Delay Time

Delay Time (Minutes)	Probability	Cumulative Probability	Random Digit Assignment
5	0.6	0.6	1-6
10	0.3	0.9	7-9
15	0.1	1.0	0

Simulate the problem for 20000 hours of operation. It will be assumed in this problem that the times are never exactly the same and thus no more than 1 bearing is changed at any breakdown. 16 bearings changes were made for bearings 1 and 2 but only 14 bearings were required for bearing 3.

Assignment: Rework the simulation of the proposed method using new random digits and 30000 hours.

Briefing-5: Simulation of Newspaper seller problem

Example: A paper seller buys the papers for 33 cents each and sells them for 50 cents each. Newspapers not sold at the end of the day are sold as scrap for 5 cents each. Newspaper can be purchased in the bundles of 10. Thus the paper seller can buy 50, 60, and so on. There are three types of news days, “good”, “fair” and “poor” of 0.35, 0.45 and 0.20. The distribution of papers demanded on each of these days is given below:

Table 1: Distribution of paper demand and the respective probability distribution

Demand	Demand probability distribution		
	Good	Fair	poor
40	0.13	0.23	11-23
50	0.25	0.48	24-48
60	0.13	0.61	49-61
70	0.09	0.70	62-70
80	0.12	0.82	71-82
90	0.02	0.84	83-84
100	0.06	0.90	85-90

The profits are given by the following relationships

Profit = revenue from sales- cost of newspapers- loss profit from excess demand+ salvage from sales of scarp papers

Determine the optimum number of papers the seller should purchase. This will be accomplished by simulating demands for 20 day and recording profits from sales each day. (Simulate for 40 newspaper)

Table 2: Random Digit Assignments for Type of Newsday

Types of News days	Probability	Cumulative Probability	Random Digit Assignment
Good	0.35	0.35	01-35
Fair	0.45	0.80	36-80
Poor	0.20	1.00	81-00

Table 3: Random digit assignment of Newspaper demanded

Demand	Cumulative distribution			Random Digit Assignment		
40	0.03	0.1	0.44	01-03	01-10	01-44
50	0.08	0.28	0.66	04-08	11-28	45-66
60	0.23	0.68	0.82	09-23	29-68	67-82
70	0.43	0.88	0.94	24-43	69-88	83-94
80	0.78	0.96	1	44-78	89-96	95-00
90	0.93	1	1	79-93	97-00	
100	1	1	1	94-00		

Assignment: Simulate the above example for 50 & 60 newspaper.

Lab Manual of Computer Simulation

Briefing 1: Variables, script and operations

MATLAB can be thought of as a super-powerful graphing calculator: Remember the TI-83 from calculus? With many more buttons (built-in functions). In addition it is a programming language MATLAB is an interpreted language, like Java Commands executed line by line

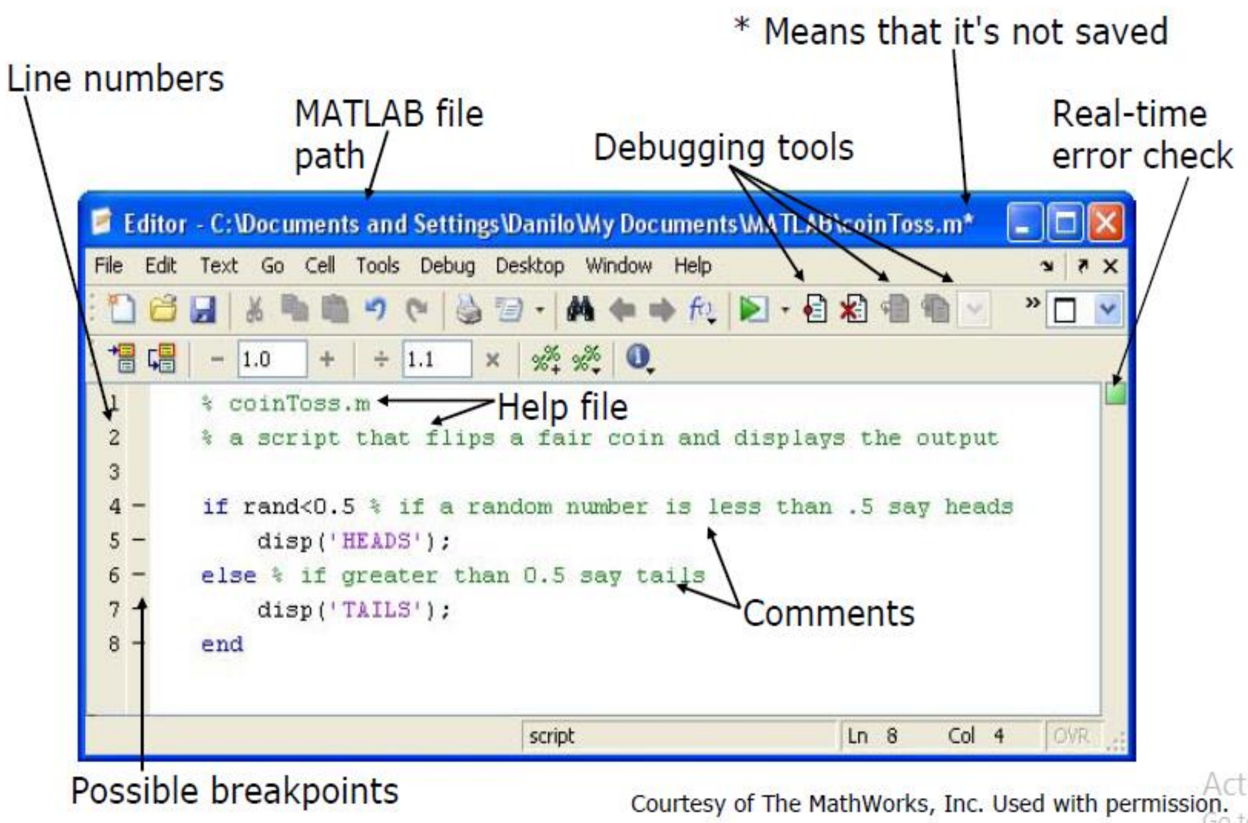
Help/Docs: help: The most important function for learning MATLAB on your own and to get info on how to use a function: »help sin**>>**Help lists related functions at the bottom and links to the doc**:** To get a nicer version of help with examples and easy-to- read descriptions: doc sin

To search for a function by specifying keywords: »doc + Search tab

Scripts: Overview

- Scripts are collection of commands executed in sequence written in the MATLAB editor saved as MATLAB files (.m extension)
- To create an MATLAB file from command-line
- »edit helloWorld.m
- COMMENT: Anything following a % is seen as a comment. The first contiguous comment becomes the script's help file. Comment thoroughly to avoid wasting time later note that scripts are somewhat static, since there is no input and no explicit output. All variables created and modified in a script exist in the workspace even after it has stopped running.
- Exercise: Scripts
- Make a helloWorld script
    - When run, the script should display the following text:
- Hello World!
- I am going to learn MATLAB!
- Hint: use disp to display strings. Strings are written between single quotes, like 'This is a string'.

Scripts: the Editor



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Variable Types

- MATLAB is a weakly typed language. No need to initialize variables! MATLAB supports various types, the most often used are
- »3.84=64-bit double (default)
- »‘a’=16-bit char
- Most variables you’ll deal with will be vectors or matrices of doubles or chars
- Other types are also supported: complex, symbolic, 16-bit and 8 bit integers, etc. You will be exposed to all these types through the homework.
- Naming variables
- To create a variable, simply assign a value to a name: »var1=3.1 »myString=‘hello world’

- Variable names: first character must be a LETTER, after that, any combination of letters, numbers and CASE SENSITIVE! (var1 is different from Var1)
- Built-in variables. Don't use these names!
- i and j can be used to indicate complex numbers
- pi has the value 3.1415926…
- ans stores the last unassigned value (like on a calculator)
- Inf and -Inf are positive and negative infinity
- NaN represents 'Not a Number'.

Row Vectors

- Row vector: comma or space separated values between brackets

```
» row = [1 2 5.4 -6.6]
» row = [1, 2, 5.4, -6.6];
```

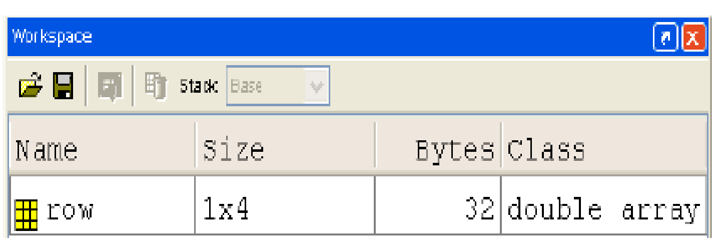
- Command window:

```
>> row=[1 2 5.4 -6.6]

row =

    1.0000    2.0000    5.4000   -6.6000
```

- Workspace:



Column Vectors

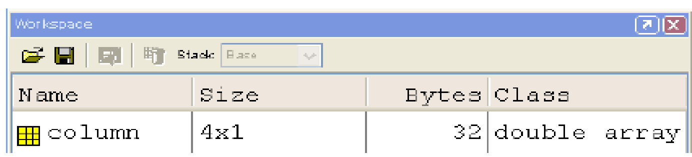
- Column vector: semicolon separated values between brackets
  ```
  » column = [4;2;7;4]
  ```

- Command window:
  ```
  >> column=[4;2;7;4]

  column =

       4
       2
       7
       4
  ```

- Workspace:



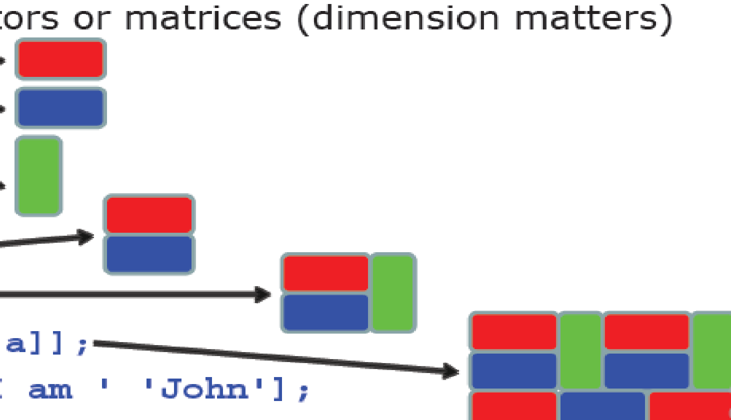
Matrices

- Make matrices like vectors

- Element by element
  ```
  » a= [1 2;3 4];
  ```
  $$a = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

- By concatenating vectors or matrices (dimension matters)
  ```
  » a = [1 2];
  » b = [3 4];
  » c = [5;6];

  » d = [a;b];
  » e = [d c];
  » f = [[e e];[a b a]];
  » str = ['Hello, I am ' 'John'];
  ```
  ➢ Strings are character vectors



Basic Scalar Operations:

- Arithmetic operations (+,-,*,/) »7/45 »(1+i)*(2+i) »1 / 0 »0 / 0
- Exponentiation (^) »4^2 »(3+4*j)^2
- Complicated expressions, use parentheses »((2+3)*3)^0.1
- Multiplication is NOT implicit given parentheses »3(1+0.7) gives an error
- To clear command window »clc

Built-in Functions:

- MATLAB has an enormous library of built-in functions
- Call using parentheses – passing parameter to function »sqrt(2) »log(2), log10(0.23) »cos(1.2), atan(-.8) »exp(2+4*i) »round(1.4), floor(3.3), ceil(4.23) »angle(i); abs(1+i);

Transpose:

- The transpose operators turns a column vector into a row vector and vice versa
- »a = [1 2 3 4+i]
- »transpose(a)
- »a'
- »a.'

Addition and Subtraction

- Addition and subtraction are element-wise; sizes must match (unless one is a scalar):

$$\begin{array}{r} [12 \quad 3 \quad 32 \quad -11] \\ +[2 \quad 11 \quad -30 \quad 32] \\ \hline =[14 \quad 14 \quad 2 \quad 21] \end{array}$$

$$\begin{bmatrix} 12 \\ 1 \\ -10 \\ 0 \end{bmatrix} - \begin{bmatrix} 3 \\ -1 \\ 13 \\ 33 \end{bmatrix} = \begin{bmatrix} 9 \\ 2 \\ -23 \\ -33 \end{bmatrix}$$

- The following would give an error

```
» c = row + column
```

- Use the transpose to make sizes compatible

```
» c = row' + column
» c = row + column'
```

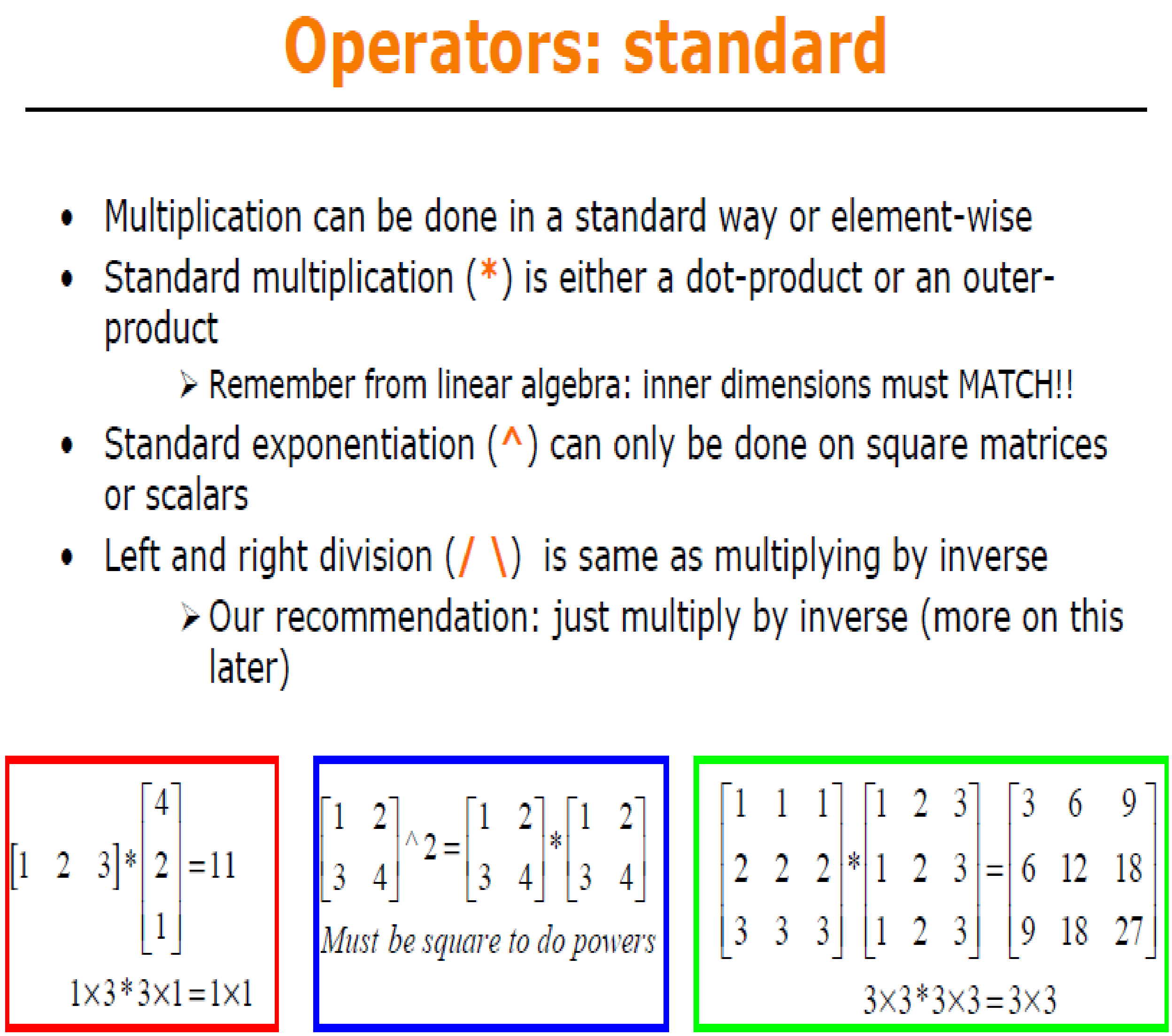
- Can sum up or multiply elements of vector

```
» s=sum(row);
» p=prod(row);
```

Operators: element-wise

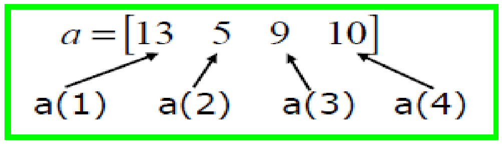
To do element-wise operations, use the dot: . (.*, ./, .^). BOTH dimensions must match (unless one is scalar)!

- »a=[1 2 3];b=[4;2;1];
- »a.*b, a./b, a.^b Æ all errors
- »a.*b', a./b’, a.^(b’) Æ all valid



Vector Indexing

- MATLAB indexing starts with **1**, not **0**
  - We will not respond to any emails where this is the problem.
- a(n) returns the n^{th} element

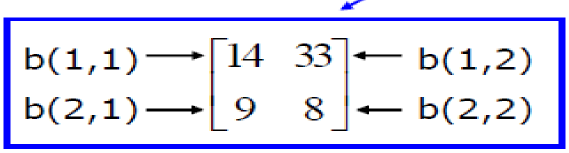


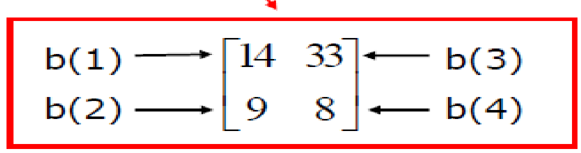
- The index argument can be a vector. In this case, each element is looked up individually, and returned as a vector of the same size as the index vector.

```
» x=[12 13 5 8];
» a=x(2:3);          →  a=[13 5];
» b=x(1:end-1);      →  b=[12 13 5];
```

Matrix Indexing

- Matrices can be indexed in two ways
  - using **subscripts** (row and column)
  - using linear **indices** (as if matrix is a vector)
- Matrix indexing: subscripts or linear indices





- Picking submatrices

```
» A = rand(5)  % shorthand for 5x5 matrix
» A(1:3,1:2)  % specify contiguous submatrix
» A([1 5 3], [1 4])  % specify rows and columns
```

Advanced Indexing 1

- To select rows or columns of a matrix, use the **:**

$$c = \begin{bmatrix} 12 & 5 \\ -2 & 13 \end{bmatrix}$$

```
» d=c(1,:); ──────────► d=[12 5];
» e=c(:,2); ──────────► e=[5;13];
» c(2,:)=[3 6];  %replaces second row of c
```

Advanced Indexing 2

- MATLAB contains functions to help you find desired values within a vector or matrix

```
» vec = [5 3 1 9 7]
```

- To get the minimum value and its index:

```
» [minVal,minInd] = min(vec);
```

  - `max` works the same way

- To find any the indices of specific values or ranges

```
» ind = find(vec == 9);
» ind = find(vec > 2 & vec < 6);
```

  - **find** expressions can be very complex, more on this later

- To convert between subscripts and indices, use **ind2sub**, and **sub2ind**. Look up **help** to see how to use them.

Plotting:

What does plot do?

- **plot** generates dots at each (x,y) pair and then connects the dots with a line
- To make plot of a function look smoother, evaluate at more points

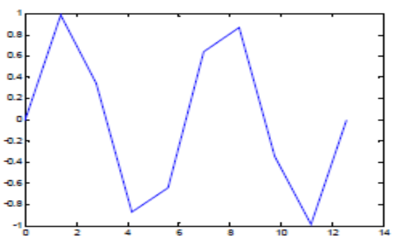
```
» x=linspace(0,4*pi,1000);
» plot(x,sin(x));
```

- x and y vectors must be same size or else you'll get an error

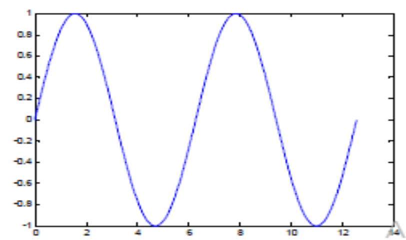
```
» plot([1 2], [1 2 3])
```

  - error!!

10 x values:



1000 x values:



Plot Options

- Can change the line color, marker style, and line style by adding a string argument

```
» plot(x,y,'k.-');
```

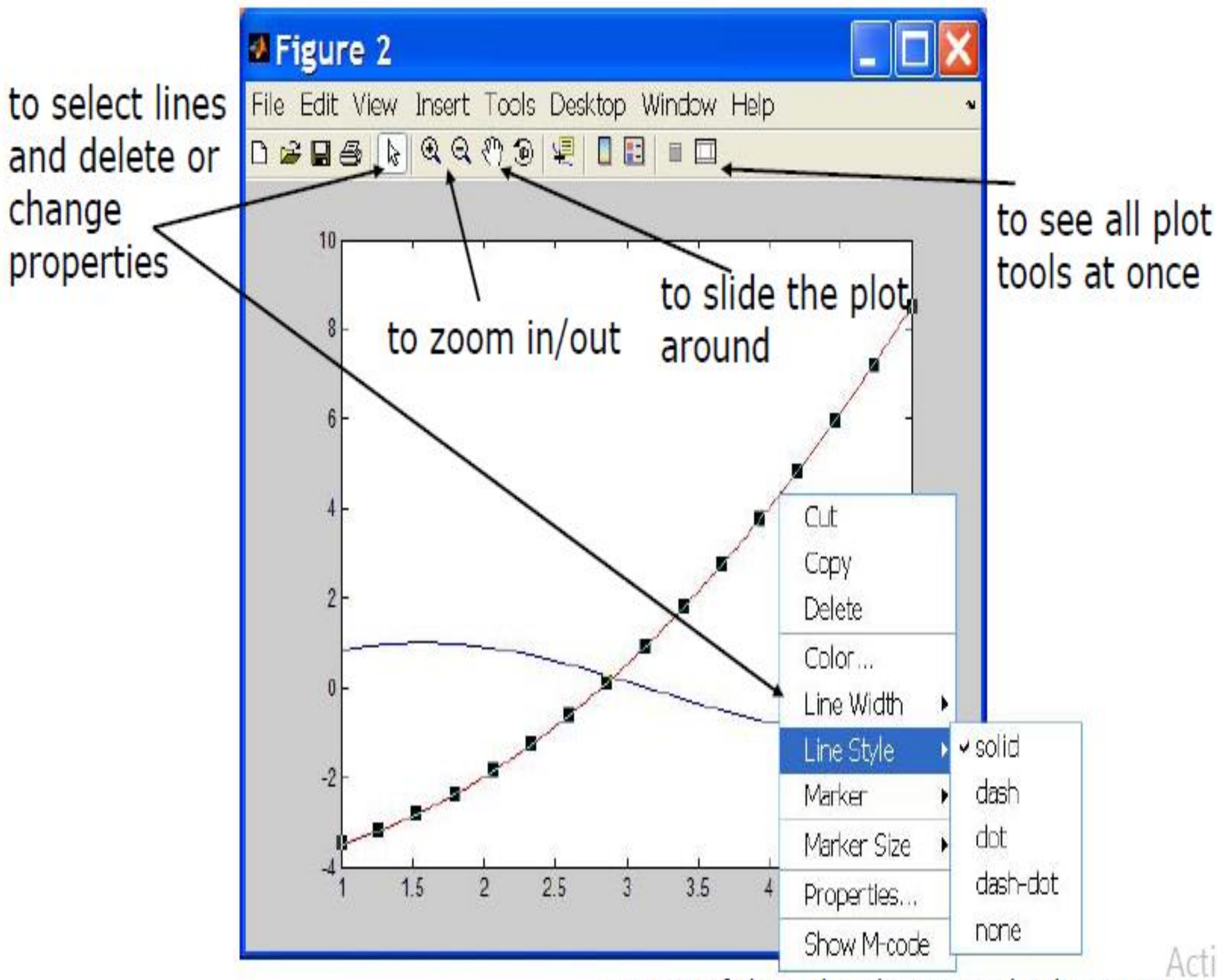
color marker line-style

- Can plot without connecting the dots by omitting line style argument

```
» plot(x,y,'.')
```

- Look at **help plot** for a full list of colors, markers, and linestyles

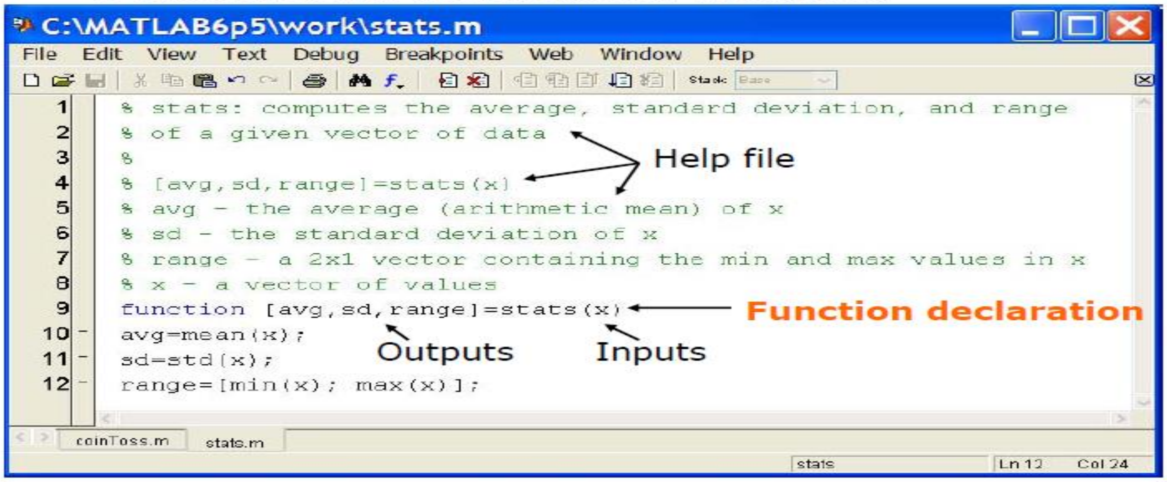
Playing with the Plot



Briefing 2: Visualization and Programming

User-defined Functions

- Functions look exactly like scripts, but for **ONE** difference
  - Functions must have a function declaration



User-defined Functions

- Some comments about the function declaration

Inputs must be specified

function [x, y, z] = funName(in1, in2)

Must have the reserved word: function

Function name should match MATLAB file name

If more than one output, must be in brackets

- No need for return: MATLAB 'returns' the variables whose names match those in the function declaration
- Variable scope: Any variables created within the function but not returned disappear after the function stops running

Relational Operators

- MATLAB uses *mostly* standard relational operators
  - equal ==
  - **not** equal ~=
  - greater than >
  - less than <
  - greater or equal >=
  - less or equal <=
- Logical operators

	elementwise	short-circuit (scalars)
And	&	&&
Or	|	||
Not	~	
Xor	xor	
All true	all	
Any true	any	

- Boolean values: zero is false, nonzero is true
- See **help .** for a detailed list of operators

if/else/elseif

- Basic flow-control, common to all languages
- MATLAB syntax is somewhat unique

IF

```
if cond
    commands
end
```

Conditional statement: evaluates to true or false

ELSE

```
if cond
    commands1
else
    commands2
end
```

ELSEIF

```
if cond1
    commands1
elseif cond2
    commands2
else
    commands3
end
```

- No need for parentheses: command blocks are between reserved words

for

- **for** loops: use for a known number of iterations
- MATLAB syntax:

Loop variable

```
for n=1:100
    commands
end
```

Command block

- The loop variable
  - Is defined as a vector
  - Is a scalar within the command block
  - Does not have to have consecutive values (but it's usually cleaner if they're consecutive)
- The command block
  - Anything between the **for** line and the **end**

while

- The while is like a more general for loop:
  - Don't need to know number of iterations

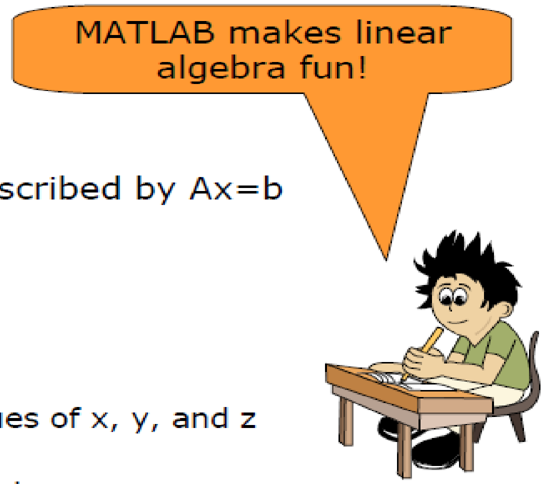
WHILE

```
while cond
    commands
end
```

- The command block will execute while the conditional expression is true
- Beware of infinite loops!

Briefing 3: Solving Equation and curve fitting

Systems of Linear Equations



- Given a system of linear equations
  - x+2y-3z=5
  - -3x-y+z=-8
  - x-y+z=0
- Construct matrices so the system is described by Ax=b

```
» A=[1 2 -3;-3 -1 1;1 -1 1];
» b=[5;-8;0];
```

- And solve with a single line of code!

```
» x=A\b;
```

  - x is a 3x1 vector containing the values of x, y, and z

- The \ will work with square or rectangular systems.
- Gives least squares solution for rectangular systems. Solution depends on whether the system is over or underdetermined.

Exercise: Linear Algebra

- Solve the following systems of equations:
  - System 1:

$$x + 4y = 34$$
$$-3x + y = 2$$

```
» A=[1 4;-3 1];
» b=[34;2];
» rank(A)
» x=inv(A)*b;
```

  - System 2:

$$2x - 2y = 4$$
$$-x + y = 3$$
$$3x + 4y = 2$$

```
» A=[2 -2;-1 1;3 4];
» b=[4;3;2];
» rank(A)
```

  - rectangular matrix

```
» x1=A\b;
```

  - gives least squares solution

```
» error=abs(A*x1-b)
```

Polynomials

- Many functions can be well described by a high-order polynomial
- MATLAB represents a polynomials by a vector of coefficients
  - if vector P describes a polynomial

    ax^3+bx^2+cx+d

    P(1) P(2) P(3) P(4)

- P=[1 0 -2] represents the polynomial x^2-2
- P=[2 0 0 0] represents the polynomial $2x^3$

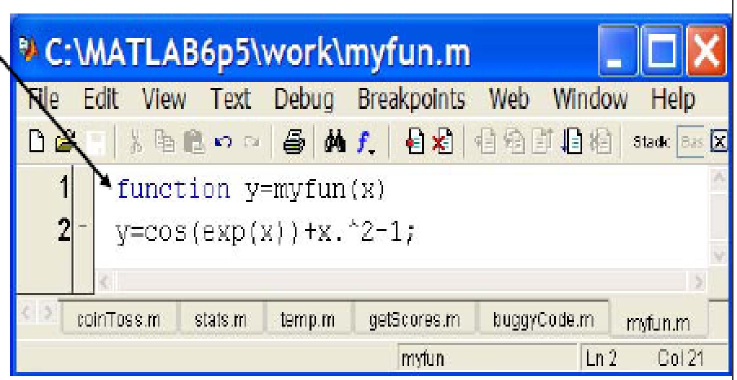
Polynomial Operations

- P is a vector of length N+1 describing an N-th order polynomial
- To get the roots of a polynomial
  - » `r=roots(P)`
    - r is a vector of length N
- Can also get the polynomial from the roots
  - » `P=poly(r)`
    - r is a vector length N
- To evaluate a polynomial at a point
  - » `y0=polyval(P,x0)`
    - x0 is a single value; y0 is a single value
- To evaluate a polynomial at many points
  - » `y=polyval(P,x)`
    - x is a vector; y is a vector of the same size

Nonlinear Root Finding

- Many real-world problems require us to solve f(x)=0
- Can use **fzero** to calculate roots for *any* arbitrary function

- **fzero** needs a function passed to it.
- We will see this more and more as we delve into solving equations.
- Make a separate function file
  - » `x=fzero('myfun',1)`
  - » `x=fzero(@myfun,1)`
    - ➢ 1 specifies a point close to where you think the root is



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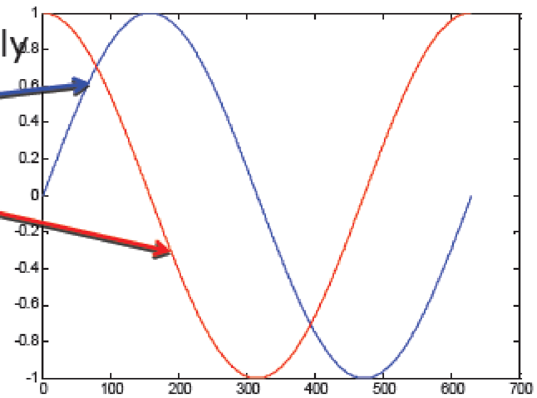
Minimizing a Function

- **fminbnd**: minimizing a function over a bounded interval
  - » `x=fminbnd('myfun',-1,2);`
    - ➢ myfun takes a scalar input and returns a scalar output
    - ➢ myfun(x) will be the minimum of myfun for $-1 \leq x \leq 2$
- **fminsearch**: unconstrained interval
  - » `x=fminsearch('myfun',.5)`
    - ➢ finds the local minimum of myfun starting at x=0.5

Optimization Toolbox

- If you are familiar with optimization methods, use the optimization toolbox
- Useful for larger, more structured optimization problems
- Sample functions (see `help` for more info)
  - » `linprog`
    - ➢ linear programming using interior point methods
  - » `quadprog`
    - ➢ quadratic programming solver
  - » `fmincon`
    - ➢ constrained nonlinear optimization

Numerical Differentiation



- MATLAB can 'differentiate' numerically
  - » `x=0:0.01:2*pi;`
  - » `y=sin(x);`
  - » `dydx=diff(y)./diff(x);`
    - ➢ diff computes the first difference
- Can also operate on matrices
  - » `mat=[1 3 5;4 8 6];`
  - » `dm=diff(mat,1,2)`
    - ➢ first difference of mat along the 2^{nd} dimension, dm=[2 2;4 -2]
    - ➢ see **help** for more details
    - ➢ The opposite of `diff` is the cumulative sum `cumsum`
- 2D gradient
  - » `[dx,dy]=gradient(mat);`

Numerical Integration

- MATLAB contains common integration methods
- Adaptive Simpson's quadrature (input is a function)
  - » `q=quad('myFun',0,10);`
    - ➢ q is the integral of the function `myFun` from 0 to 10
  - » `q2=quad(@(x) sin(x)*x,0,pi)`
    - ➢ q2 is the integral of `sin(x)*x` from 0 to pi
- Trapezoidal rule (input is a vector)
  - » `x=0:0.01:pi;`
  - » `z=trapz(x,sin(x));`
    - ➢ z is the integral of sin(x) from 0 to pi
  - » `z2=trapz(x,sqrt(exp(x))./x)`
    - ➢ z2 is the integral of $\sqrt{e^x}/x$ from 0 to pi

ODE Solvers: MATLAB

- MATLAB contains implementations of common ODE solvers

- Using the correct ODE solver can save you lots of time and give more accurate results
  - » `ode23`
    - ➢ Low-order solver. Use when integrating over small intervals or when accuracy is less important than speed
  - » `ode45`
    - ➢ High order (Runge-Kutta) solver. High accuracy and reasonable speed. Most commonly used.
  - » `ode15s`
    - ➢ Stiff ODE solver (Gear's algorithm), use when the diff eq's have time constants that vary by orders of magnitude

ODE Solvers: Standard Syntax

- To use standard options and variable time step

```
» [t,y]=ode45('myODE',[0,10],[1;0])
```

ODE integrator: 23, 45, 15s — ODE function — Time range — Initial conditions

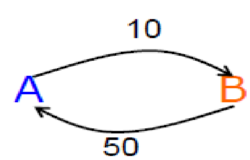
- Inputs:
  - ODE function name (or anonymous function). This function takes inputs (t,y), and returns dy/dt
  - Time interval: 2-element vector specifying initial and final time
  - Initial conditions: column vector with an initial condition for each ODE. This is the first input to the ODE function
- Outputs:
  - t contains the time points
  - y contains the corresponding values of the integrated variables.

ODE Function

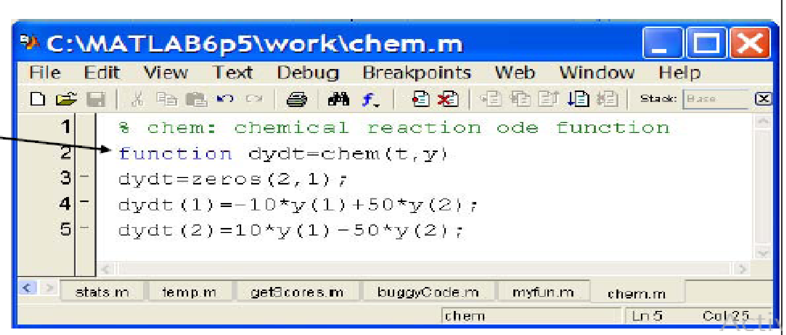
- The ODE function must return the value of the derivative at a given time and function value
- Example: chemical reaction
  - Two equations

$$\frac{dA}{dt} = -10A + 50B$$

$$\frac{dB}{dt} = 10A - 50B$$



  - ODE file:
    - y has [A;B]
    - dydt has [dA/dt;dB/dt]



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ODE Function: viewing results

- To solve and plot the ODEs on the previous slide:

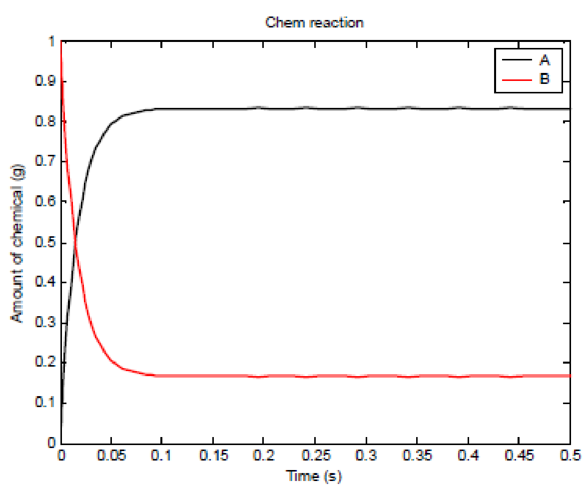
```
» [t,y]=ode45('chem',[0 0.5],[0 1]);
```

  - ➢ assumes that only chemical B exists initially

```
» plot(t,y(:,1),'k','LineWidth',1.5);
» hold on;
» plot(t,y(:,2),'r','LineWidth',1.5);
» legend('A','B');
» xlabel('Time (s)');
» ylabel('Amount of chemical (g)');
» title('Chem reaction');
```

ODE Function: viewing results

- The code on the previous slide produces this figure



Briefing 4: Advance Method

Statistics

- Whenever analyzing data, you have to compute statistics

```
» scores = 100*rand(1,100);
```

- Built-in functions
    - mean, median, mode

- To group data into a histogram

```
» hist(scores,5:10:95);
```

  - makes a histogram with bins centered at 5, 15, 25…95

```
» N=histc(scores,0:10:100);
```

  - returns the number of occurrences between the specified bin *edges* 0 to <10, 10 to <20…90 to <100. you can plot these manually:

```
» bar(0:10:100,N,'r')
```

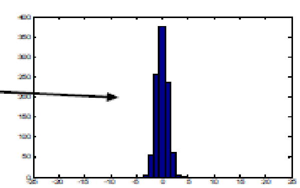
Random Numbers

- Many probabilistic processes rely on random numbers
- MATLAB contains the common distributions built in
  - » `rand`
    - ➢ draws from the uniform distribution from 0 to 1
  - » `randn`
    - ➢ draws from the standard normal distribution (Gaussian)
  - » `random`
    - ➢ can give random numbers from many more distributions
    - ➢ see **doc random** for help
    - ➢ the docs also list other specific functions
- You can also seed the random number generators

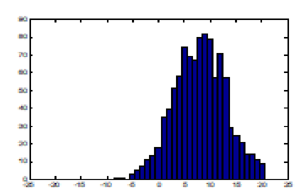
```
» rand('state',0); rand(1); rand(1);
  rand('state',0); rand(1);
```

Changing Mean and Variance

- We can alter the given distributions
  - » `y=rand(1,100)*10+5;`
    - ➢ gives 100 uniformly distributed numbers between 5 and 15
  - » `y=floor(rand(1,100)*10+6);`
    - ➢ gives 100 uniformly distributed integers between 10 and 15. floor or ceil is better to use here than round



  - » `y=randn(1,1000)`
  - » `y2=y*5+8`
    - ➢ increases std to 5 and makes the mean 8



Briefing 5: Symbolic

Symbolic Variables

- Symbolic variables are a type, like **double** or **char**
- To make symbolic variables, use `sym`
  - » `a=sym('1/3');`
  - » `b=sym('4/5');`
  - » `mat=sym([1 2;3 4]);`
    - fractions remain as fractions
  - » `c=sym('c','positive');`
    - can add tags to narrow down scope
    - see **help sym** for a list of tags
- Or use `syms`
  - » `syms x y real`
    - shorthand for x=sym('x','real'); y=sym('y','real');

Cleaning up Symbolic Statements

» `pretty(ans)`

- makes it look nicer

```
                 2
1/9 - 2/3 c + c
```

» `collect(3*x+4*y-1/3*x^2-x+3/2*y)`

- collects terms

```
ans =
2*x+11/2*y-1/3*x^2
```

» `simplify(cos(x)^2+sin(x)^2)`

- simplifies expressions

```
ans =
1
```

» `subs('c^2',c,5)`

```
ans=
25
```

- Replaces variables with numbers or expressions. To do multiple substitutions pass a cell of variable names followed by a cell of values

» `subs('c^2',c,x/7)`

```
ans=
1/49*x^2
```


Symbolic Expressions

- Multiply, add, divide expressions

» `d=a*b`

```
d =
4/15
```

- does 1/3*4/5=4/15;

» `expand((a-c)^2);`

- multiplies out

```
ans =
1/9-2/3*c+c^2
```

» `factor(ans)`

```
ans =
1/9*(3*c-1)^2
```

- factors the expression

» `matInv=inv(mat)`

```
ans =
[   -2,     1]
[  3/2,  -1/2]
```

- Computes inverse symbolically

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 4208: Business Communication Seminar
Credit Hour: 1.5

General Guidelines:

1. Students will not be allowed to remain present in the class without formal attire
2. Students have to speak in English in the class
3. Students must submit their assignment weekly
4. A Mock Interview will be taken at the end of the semester

Learning Objective:

This course is designed for the students of Engineering and Technology who need English for specific purposes in specific situations. It aims at imparting the communication skills that are needed in their academic and professional pursuits. This is achieved through an amalgamation of traditional lecture-oriented approach of teaching with the task based skill oriented methodology of learning.

Marks distribution

Total Marks			
Class Performance	Assignment	Presentation	Mock Interview
10	30	30	30

Contents

Introduction

Students will get to know the learning objective of this course and they will be given some crucial tips to increase their fluency while speaking in English. Each student will get 2 minutes to say something about them to get accustomed to the environment. They will get an idea about how to introduce them in a positive manner to leave a longer lasting impression. On the very next day, they have to submit an assignment on where they want to see them after 10 years within 150 words.

Writing a complaint and adjustment letter

This section covers two closely related types of business letters: *complaint letters*, which request compensation for problems with purchases or services, and *adjustment letters*, which are the responses to complaint letters. A complaint letter requests some sort of compensation for defective or damaged merchandise or for inadequate or delayed services. While many complaints can be made in person, some circumstances require formal business letters. The complaint may be so complex that a phone call may not effectively resolve the problem; or the writer may prefer the permanence, formality, and seriousness of a business letter. The essential rule in writing a complaint letter is to maintain your poise and diplomacy, no matter how justified your gripe is. Avoid making the recipient an adversary. Replies to complaint letters, often called letters of "adjustment," must be handled carefully when the requested compensation cannot be granted. Refusal of compensation tests your diplomacy and tact as a writer.

Report Writing

Students will get a detail demonstration of how to write a formal report on this topic, they have to prepare a business plan on basis of these learning following the steps of a formal report writing

Preparing an effective presentation

The key to effective presentations lies in careful preparation. You need to know about your audience and their expectations; you need to identify your own objectives (do you intend to inform or persuade your audience?); you need to sequence your information in a logical way and you need to know the best ways to create and keep the audience's interest. You should also have your audio-visual aids ready and in the right sequence and should check that the equipment is in working order. After this demonstration of how to deliver an effective presentation, students will be assigned to prepare a presentation. Students have to give a formal presentation on that particular within a week

Effective Resume Writing

A resume, or résumé, is a concise document typically not longer than one or two pages as the intended the reader will not dwell on your document for very long. The goal of a resume is to make an individual stand out from the competition. This is essential for any type of job position. The objective of this section is to introduce students with effective resume writing which will help them to prepare their own resume in their near future career.

In this session, students will be taught detail about resume/ cv writing, different types of formats, different sections of an effective resume and so on.

After the session, the student will be given an assignment to prepare their own resume along with cover letter for a real job circular.

Preparing a Tender

The ability to write a successful tender is, arguably, your most important business skill. It is worth investing the time and energy in learning how to do it properly. It is a skill that you will draw on for all of your working life. But also, your company or your job may depend on your ability to write winning tenders; such is the direction that business is taking. More and more, people and businesses are demanding a fair and transparent means of appointing suppliers. Putting work out to competitive tender is the only way to guarantee fairness and transparency. Here, Students will learn the steps of writing a successful tender

LC opening

Letters of credit are a payment mechanism, particularly used in international trade. The Seller gets paid, not after the Buyer has inspected the goods and approved them, but when the Seller presents certain documents (typically a bill of lading evidencing shipment of the goods, an insurance policy for the goods, commercial invoice, etc.) to his bank. The bank does not verify that the documents presented are true, but only whether they “on their face” appear to be consistent with each other and comply with the terms of the credit. After examination the bank will pay the Seller (or in LC terms the beneficiary of the letter of credit). In this section, students will learn various stage of opening LC.

Business Plan Presentation & Report Submission

A “Business Plan” is a written document describing the nature of the business, the sales and marketing strategy, and the financial background, and containing a projected profit and loss statement. It is a “Selling Document” that conveys the excitement and promise of a business to any potential backers and stakeholders.

The objective of this session is to introduce students about how to write a business plan, what are the major components of it such as - marketing strategy, financial strategy, operational plan, organizational management and so on. In this section, students are given a detail lecture on business plan, its definition, types of business plan, major contents of a plan etc.

At the end of the brief session, students have to submit a detail business plan on a particular assigned topic with a report and formal presentation under a fixed budget limit.

Interview tips and tricks

In this portion, students will develop an in depth idea about approaching a job interview. Pros and cons of cracking an interview will be the prime concern in this segment. By following some easy steps, one can increase the chances of success at interviews. First, remember that job interviews should be a process of two-way communication. Not only are they a tool for employers to use to evaluate a person, but they are also an opportunity for aspirant to assess the job, the organization, and to see if there is a "fit." The keys to a successful interview are preparation and practice. **Self-evaluation** is most important for you to think about yourself and your past experiences in order to be ready to articulate what you have to offer an employer. Some most frequently asked interview questions and their tricky answers will also be discussed. In the very next class a mock interview will be conducted to give students a complete overview of nailing a job interview.