# NATIONAL OPEN UNIVERSITY OF NIGERIA

## TPM204

## WORKSHOP PRACTICE AND ENGINEERING DRAWING

**FACULTY OF MANAGEMENT SCIENCES**

**COURSE GUIDE**

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**CONTENT**

## a) Introduction

The course Workshop Practice and Engineering Drawing (TPM204) is a first semester core course, which carries thee credit units for second year level Engineering students in the Faculty of Management Sciences at the National Open University, Nigeria. This coursework will be useful in your academic pursuit by introducing you to Engineering measurement and instruments, as well as drawing, drafting and dimensioning objects from different views.

This course guide is built partially on prerequisite knowledge in Technical Drawing. However, its simplicity will make the student assimilate faster. The practice questions at the end of each unit will also prepare the student for the examination purposes. The courseware suggests some general guidelines for the amount of time required of users on each unit in order to achieve the course aim and objectives successfully. In addition, it provides users with some guidance on their tutor marked assignments (TMAs) as contained herein.

## b) Course Content

The course is made up of seventeen units (five modules) spread across eight (8) lecture hours, eight (8) hours of Drafting & Drawing and nine (9) hours of laboratory practical demonstrations/experiments covering areas such as rudiments of basic workshop practice & engineering drawing; safety practices, measuring equipment; hand and machine tools; metal and plastics materials, joining methods (including welding), presswork, primary forming, casting and moving loads. The concept of Engineering Drawing; Measuring, Lettering and Dimensioning of objects in various Positions, Principles of orthographic projections in the First Third Angle.

## Course Aims and Objectives

This courseware and lecture note have been prepared with the primary aim of introducing Basic workshop practice & Engineering Drawing course to 200 Level engineering students just entering core engineering faculty from the 100 Level basic science preparatory. The course attempts to explain the concepts and conceptual framework of workshop practice and Engineering drawing. The objective is to impart training to help the students develop engineering thinking skill. This course also aims at inculcating respect for physical work and hard labour in addition to some amount of value addition by being exposed to interdisciplinary engineering domains. In addition, the course is prepared in a way in which the users would easily enhance their previous knowledge of Technical drawing or Introductory technology. The course further aims to develop critical thinking skills in students by learning how to carry out basic workshop practice while using different tools with safety of man, machine and structure in view. It further focuses on steering up the students' ability to visualize, draft, sketch, draw and dimension engineering structures, parts, models or systems.

However, the overall objectives of the course will be achieved by:

i. Safety practices in Engineering Workshop

ii. Introducing and familiarizing with basic Engineering Workshop tools.

iii. Further explanation of the uses of Basic Hand tools and Machine tools.

iv. Discussing different drawing instruments and lettering.

v. Explaining the principles of orthographic projections in the First Third Angle

**Working through the Course**

To successfully complete this course, students/users are required to read the study units, references and other materials on the course.

Each unit contains self-assessment exercises called Student Assessment Exercises (SAE). At some points in the course, you will be required to submit assignments for assessment purposes. At the end of the course there is a final examination. This course should take about **10 weeks** to complete and some components of the course are outlined under the course material subsection.

**Course Material**

The major component of the course and what you have to do and how you should allocate your time to each unit in order to complete the course successfully on time are listed as follows:

1. Course guide
2. Study unit
3.Textbooks
4. Assignment file
5. Presentation schedule

**Study Unit**

There are 18 units covered in 5 modules in this course, which should be studied carefully and diligently.

**Module 1: Introduction to Workshop practice and Basic Tools**

Unit 1: Introduction of Workshop practice & Engineering drawing; Aim, Objectives and Synopsis of the course

Unit 2: Workshop safety practices

Unit 3: Measuring equipment

Unit 4: Basic hand and power/machine tools

**Module 2: Engineering Materials and their Properties**

Unit 1: Metal and plastics materials

Unit 2: Joining methods (including welding), presswork

Unit 3: Primary forming and casting process/techniques

**Module 3: Material Marking and Introduction to Engineering Drawing**

Unit 1: Pattern Making, Ramping and Sizing Techniques of Raw Materials

Unit 2: Sheet metal works

Unit 3: Engineering Drawing, instruments and Lettering

Unit 4: Dimensioning and Drawing layouts

**Module 4: Engineering Graphics and Intersection of Curves**

Unit 1: Engineering graphics - Geometrical figures, conics, etc.

Unit 2: Graphical calculus and applications

Unit 3: Development, intersection of curves and solids.

**Module 5: Lines and Principles of Orthographic projections**

Unit 1: Projections - lines, planes and simple solids.

Unit 2: Orthographic and isometric projections.

Unit 3: Simple examples of Orthographic and Isometric projections.

Unit 4: Principles of orthographic projections in the First Third Angle.

**References and Other Resources**

Every unit contains a list of references and further reading guide. Try to get as many as possible of those textbooks and materials listed. The textbooks and materials are meant to deepen your knowledge and understanding of the course.

**Assignment File**

There are assignments on this course and you are expected to do all of them by following the schedule prescribed for them in terms of when to attempt them and submit same for grading by your tutor. The marks you obtain for these assignments will count toward the final mark you obtain for this course. Further information on assignments will be found in the Assignment File itself and later in this Course Guide in the section on Assessment.

There are five assignments in this course. The five course assignments will cover:
Assignment 1 - All TMAs' question in Units 1 - 4 of Module 1
Assignment 2 - All TMAs' question in Units 1 - 3 of Module 2

Assignment 3 - All TMAs' question in Units 1 - 4 of Module 3

Assignment 4 - All TMAs' question in Units 1 - 3 of Module 4
Assignment 5 - All TMAs' question in Units 1 - 4 of Module 5

**Presentation Schedule**

The presentation schedule included in your course materials gives you the important dates for this year for the completion of tutor-marking assignments and attending tutorials. Remember, you are required to submit all your assignments by due date. You should guide against falling behind the schedule.

**Assessment**

There are two types of assessment of the course. First are the tutor-marked assignments; second, there is a written examination.

In attempting the assignments, you are expected to apply information, knowledge and techniques gathered during the course. The assignments must be submitted to your tutor for formal assessment in accordance with the deadlines stated in the Presentation Schedule and the Assignments File. The work you submit to your tutor for assessment will count for 30 % of your total course mark.

At the end of the course, you will need to sit for a final written examination of three hours' duration. This examination will also count for 70% of your total course mark.

**Tutor-Marked Assignments (TMAs)**

There are five tutor-marked assignments in this course. You will submit all the assignments. You are enjoined to work all the questions thoroughly. The TMAs constitute 30% of the total score.

Assignment questions for the units in this course are contained in the Assignment File. You will be able to complete your assignments from the information and materials contained in your text books, reading and study units. However, it is desirable that you demonstrate that you have read and researched more widely than the required minimum. You should use other references to have a broad viewpoint of the subject and also to give you a deeper understanding of the subject.

When you have completed each assignment, send it, together with a TMA form, to your tutor. Make sure that each assignment reaches your tutor on or before the deadline given in the Presentation File. If for any reason, you cannot complete your work on time, contact your tutor before the assignment is due to discuss the possibility of an extension. Extensions will not be granted after the due date unless there are exceptional circumstances.

**Final Examination and Grading**

The final examination will be of three hours' duration and have a value of 70% of the total course grade. The examination will consist of questions which reflect the types of self-assessment practice exercises and tutor-marked problems you have previously encountered. All areas of the course will be assessed

Use the time between finishing the last unit and sitting for the examination to revise the entire course material. You might find it useful to review your self-assessment exercises, tutor-marked assignments and comments on them before the examination. The final examination covers information from all parts of the course.

**Course Marking Scheme**

The table presented below indicate the total marks (100%) allocation.

| Assessment | Marks |
|---|---|
| Assignment (Best three assignments out of the five marked) | 30% |
| Final Examination | 70% |
| **Total** | **100%** |

**How to Get the Most from This Course**

In distance learning the study units replace the university lecturer. This is one of the great advantages of distance learning; you can read and work through specially designed study materials at your own pace and at a time and place that suit you best.

Think of it as reading the lecture instead of listening to a lecturer. In the same way that a lecturer might set you some reading to do, the study units tell you when to read your books or other material, and when to embark on discussion with your colleagues. Just as a lecturer might give you an in-class exercise, your study units provides exercises for you to do at appropriate points.

Each of the study units follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next is a set of learning objectives. These objectives let you know what you should be able to do by the time you have completed the unit.

You should use these objectives to guide your study. When you have finished the unit you must go back and check whether you have achieved the objectives. If you make a habit of doing this, you will significantly improve your chances of passing the course and getting the best grade.

The main body of the unit guides you through the required reading from other sources. This will usually be either from your text books or from a readings section. Some units require you to undertake practical overview of historical events. You will be directed when you need to embark on discussion and guided through the tasks you must do.

The purpose of the practical overview of some certain historical economic issues are in twofold. First, it will enhance your understanding of the material in the unit. Second, it will give you practical experience and skills to evaluate economic arguments, and understand the roles of history in guiding current economic policies and debates outside your studies. In any event, most of the critical thinking skills you will develop during studying are applicable in normal working practice, so it is important that you encounter them during your studies.

Self-assessments are interspersed throughout the units, and answers are given at the ends of the units. Working through these tests will help you to achieve the objectives of the unit and prepare you for the assignments and the examination. You should do each self-assessment exercises as you come to it in the study unit. Also, ensure to master some major historical dates and events during the course of studying the material.

The following is a practical strategy for working through the course. If you run into any trouble, consult your tutor. Remember that your tutor's job is to help you. When you need help, don't hesitate to call and ask your tutor to provide it.

**Read this Course Guide thoroughly.**

- Organize a study schedule. Refer to the `Course overview' for more details. Note the time you are expected to spend on each unit and how the assignments relate to the units. Important information, e.g. details of your tutorials, and the date of the first day of the semester is available from study centre. You need to gather together all this information in one place, such as your dairy or a wall calendar. Whatever method you choose to use, you should decide on and write in your own dates for working breach unit.
- Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course work. If you get into difficulties with your schedule, please let your tutor know before it is too late for help.

- Turn to Unit 1 and read the introduction and the objectives for the unit.
- Assemble the study materials. Information about what you need for a unit is given in the `Overview' at the beginning of each unit. You will also need both the study unit you are working on and one of your text books on your desk at the same time.
- Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit you will be instructed to read sections from your text books or other articles. Use the unit to guide your reading.
- Up-to-date course information will be continuously delivered to you at the study centre.
- Work before the relevant due date (about 4 weeks before due dates), get the Assignment File for the next required assignment. Keep in mind that you will learn a lot by doing the assignments carefully. They have been designed to help you meet the objectives of the course and, therefore, will help you pass the exam. Submit all assignments no later than the due date.
- Review the objectives for each study unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study material or consult your tutor.
- When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed unit by unit through the course and try to pace your study so that you keep yourself on schedule.
- When you have submitted an assignment to your tutor for marking do not wait for it return `before starting on the next units. Keep to your schedule. When the assignment is returned, pay particular attention to your tutor's comments, both on the tutor-marked assignment form and also written on the assignment. Consult your tutor as soon as possible if you have any questions or problems.
- After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives (listed in this Course Guide).

**Tutors and Tutorials**

There are some hours of tutorials (2-hours sessions) provided in support of this course. You will be notified of the dates, times and location of these tutorials. Together with the name and phone number of your tutor, as soon as you are allocated a tutorial group.

Your tutor will mark and comment on your assignments, keep a close watch on your progress and on any difficulties you might encounter, and provide assistance to you during the course. You must mail your tutor-marked assignments to your tutor well before the due date (at least two working days are required). They will be marked by your tutor and returned to you as soon as possible.

Do not hesitate to contact your tutor by telephone, e-mail, or discussion board if you need help. The following might be circumstances in which you would find help necessary.

Contact your tutor if.

- You do not understand any part of the study units or the assigned readings
- You have difficulty with the self-assessment exercises
- You have a question or problem with an assignment, with your tutor's comments on an assignment or with the grading of an assignment.

You should try your best to attend the tutorials. This is the only chance to have face to face contact with your tutor and to ask questions which are answered instantly. You can raise any problem encountered in the course of your study. To gain the maximum benefit from course tutorials, prepare a question list before attending them. You will learn a lot from participating in discussions actively.

**Summary**

This course, Workshop Practice & Engineering Drawing (TPM 204), exposes the students to the rudiments of basic workshop practice & engineering drawing; safety practices, measuring equipment; hand and machine tools; metal and plastics materials, joining methods (including welding), presswork, primary forming, casting and moving loads. It also explains the concept of engineering drawing; drafting, measuring and dimensioning; as well as orthographic projection of objects in the first third angle.

On successful completion of this course, the students would have been introduced to basic rudiments of Workshop practice & Engineering Drawing. You would have known the types, materials made with and uses of basic hand tools and machine tools in engineering workshop.

Also, you would have developed crucial thinking skills to visualize, draft and dimension objects which form part of engineered devices in a complex systems designed to solve the problem of mankind. This courseware is written in very simple language so that even an average student can easily grasp the subject matter. With detailed illustrations throughout and simple, clear language, this is a practical introduction to what can be a very complex subject.

However, to benefit maximally from the course, please try to apply anything you learn in the course to the arrangement and assembly of engineering parts in the physical projects around you and other engineering courses. We wish you success in the course and hope that you will find this material both interestingly instructive and intuitively functional.

## MODULE ONE

## INTRODUCTION TO WORKSHOP PRACTICE AND BASIC TOOLS

Unit 1: Introduction of Workshop practice & Engineering drawing; Aim, Objectives and Synopsis of the course

Unit 2: Workshop safety practices

Unit 3: Measuring equipment

Unit 4: Basic hand and machine tools

### UNIT 1: INTRODUCTION OF WORKSHOP PRACTICE & ENGINEERING DRAWING; AIM, OBJECTIVES AND SYNOPSIS OF THE COURSE

**CONTENTS**



### 1.0 Introduction

This unit is to discuss the Concept and layout of an Engineering workshop, the practices and work/operations carried out in the workshop, as well as the basic concept and use of

Engineering drawing. In other words, the basic features that differentiate Engineering workshop and drawing from other kinds of workshop and drawing respectively.

**2.0 Objectives**

At the end of this unit student should be able to

- Know the meaning and layout of Engineering workshop
- Understand the basic the features of Engineering workshop and Drawing
- Explain the basic operations in Engineering workshop

## 3.0 Main Content

### 3.1 Introduction to Workshop practice

Considering the general needs of engineering students in the country and the fact that they hardly get enough exposure to hand tools, equipment, machines and manufacturing setups, a basic course in manufacturing technology, which combine Workshop practice & Engineering drawing remains a core subject for all the branches of engineering (Singh, 2006). The complete understanding of basic technology and workshop practice is quite difficult for anyone to claim expertise over it. However, the course deals with several aspects of workshop practices for imparting the basic working knowledge of the different engineering materials, tools, equipment, characteristics and uses of various testing instruments and measuring or inspecting devices for checking components or products manufactured in various manufacturing workshops. It also describes and demonstrates the use of different hand tools (measuring, marking, holding and supporting tools, cutting etc.), equipment, machinery and various methods of manufacturing that facilitate shaping or forming the different existing raw materials into suitable usable forms. The engineering workshop is a place, where pupil engineers acquire practical knowledge on the operation of various processes in design, analysis, simulation, manufacturing and production.

Workshop layout in manufacturing or any industrial plant also forms an integral part of factory planning or plant layout. Plant layout begins with the design the position of the factory building and goes up to the location and movement of a work table of the machine. All the manufacturing facilities such as equipment, raw materials, machinery, tools, fixtures, workers, etc. are given their proper place in each workshop of the industrial plant. Plant layout of an industrial organization plays an important role in scientific management. Plant layout is a systematic and efficient functional arrangement of various departments, machines, tools, equipment and other supports services of an industrial organization that will facilitate the smooth processing of the proposed or undertaken product in the most effective, most efficient and most economical manner in the minimum possible time".

*Engineering drawing is a two dimensional representation of three-dimensional objects. In general, it provides necessary information about the shape, size, surface quality, material, manufacturing process, etc., of the object. It is the graphic language from which a trained person can visualise objects*.

Engineering drawing, particularly solid geometry is the graphic language used in the industry to record the ideas and information necessary in the form of blue prints to make machines, buildings, structures etc., by engineers and technicians who design, develop, manufacture and market the products.

The ability to read drawing is the most important requirement of all technical people in any profession. As compared to verbal or written description, this method is brief and clearer. Some of the applications are: building drawing for civil engineers, machine drawing for mechanical engineers, circuit diagrams for electrical and electronics engineers, computer graphics for one and all. The workshop practice & Engineering drawing course make students competent in handling practical work in engineering environment.

**Self Assessment Exercise:** What is the place of workshop practice & Engineering drawing in the training of engineers?

### 3.2 The basic features of workshop

All future engineers in the various spheres must know the basic requirements of workshop activities in term of;

1) Manpower, i.e. the various workmen/operators that will man, handle, operate, organize, supervise or coordinate the various tools, machines and operations and activities in the workshop

2) Machine, i.e. the use, function and care of the hand tools and machineries and appliances in the workshop.

3) Materials i.e. the characteristics of various materials in the workshop (timber, iron, steel, chemicals etc.)

4) Methods i.e. understand the best and most effective method of operating the tools and equipment, its care, safety and precautions.

5) Money, must know the value and the cost of procuring, assembling and installing the equipment and other infrastructural facilities in the workshop and therefore handle them with care.

6) A good layout with accessibility and a well-planned organization that will facilitate efficient flow of men, machineries, products and services is a necessity in workshop layout.

7) Bottlenecks and points of congestions are eliminated so that the raw material and semi-finished goods move fast from one work station to another.

8) Work stations are designed suitably to facilitate the smooth processing of the proposed or undertaken product in the most effective, most efficient and most economical manner in the minimum possible time.

9) Optimal spaces are allocated to production centres and service centres, while minimizing accidents and hazards.

**Self Assessment Exercise:** Describe the features of an engineering workshop

### 3.3 Basic Operations in Engineering Workshop

Depending on the work requirement, after selection of material(s), some of the basic operations in the workshop not in a specific/compulsory order, include:

1) Marking
2) Cutting
3) Sawing
4) Chiseling
5) Filing
6) Planning
7) Punching
8) Filling

9) Casting
10) Moulding
10) Chamfering
11) Drilling
12) Welding
13) Soldering
14) Screwing
15) Finishing
16) Labelling
17) Packaging
18) Threading
19) Forging
20) Grinding
21) Reaming

**Self Assessment Exercise:** List some operations in engineering workshop

## 4.0 Conclusion

We conclude that Workshop practice & Engineering drawing is an important course for all engineering students to prepare and familiarize them with basic tools, equipment and operations towards future analysis, design, fabrication and production.

## 5.0 Summary

In this study unit, we attempt to introduce and familiarize students with the basic workshop practice, general layout and feature of a typical engineering workshop, aimed at building the interest of students and making them competent in handling practical work in engineering environment.

## 6.0 Tutor-Marked Assignment

a) What is the place of workshop practice & Engineering drawing in the training of engineers?

b) Discuss the basic features of a typical functional engineering workshop

c) Discuss six operations from raw material of a typical finished product in engineering workshop.

## 7.0 References/Further Readings

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## UNIT 2: WORKSHOP SAFETY PRACTICES

**CONTENTS**



### 1.0 Introduction

This unit considers the general safety practices in the workshop. It deals with safety precautions in work areas. It also itemised safety precautions when using hand tools, machine tools, and appliances in the workshop. Your safety is your personal responsibility. Always follow the correct procedures. Never take shortcuts. Take responsibility and clean up if your activities results in a mess or general disorderliness. Always clean up and organize your workspace.

### 2.0 Objective

At the end of this unit student should be able to

- Know the general safety rules in workshop
- Understand safety precaution while working with tools

- Understand the power tools safety tips and the importance of personal protective equipment (PPE).

## 3.0 Main Content

### **3.1** General workshop safety maintenance

Almost everyone working in a factory has at some stage in his or her career suffered an injury requiring some kind of treatment or first aid. It may have been a cut finger or something more serious. The cause may have been carelessness by the victim or a colleague, defective safety equipment, not using the safety equipment provided or inadequate protective clothing.

Whatever the explanation given for the accident, the true cause was most likely a failure to think ahead. You must learn to work safely. Every workshop has its own safety rules so obey them at all times. Ask if you do not understand any instruction and do report anything, which seems dangerous, damaged or faulty. The general workshop safety maintenance are described below.

**Maintenance**: equipment that could fail and put workers at serious risk should be properly maintained and checked at regular intervals, as appropriate, by inspection, testing, adjustment, lubrication, repair and cleaning. Equipment, which require a system of maintenance, include emergency lighting, fencing, powered doors, fixed equipment used for window cleaning and anchorage points for safety harnesses.

**Condition of floor**: Floors and traffic routes should be sound, not uneven or slippery and should be free of obstructions and substances, which could cause a slip, trip or fall.

**Falls**: Every vessel containing a dangerous substance should be adequately fenced or covered to prevent a person falling into it. A vessel includes sumps, silos, vats, pits or tanks. Every open-sided staircase should be securely fenced. A secure and substantial handrail should be provided and maintained on at least one side of every staircase. Falls from height account for a significant number of workplace injuries and unnecessary deaths every year. Employers must ensure that all work at height is properly planned, supervised and carried out by competent people.

**Transparent surfaces**: Windows and transparent or translucent surfaces in doors, gates, walls and partitions should be made of a safety material and marked to make it apparent.

**Windows**: It should be possible to reach or operate skylights, operable windows and ventilators safely. Controls should be placed so that people are not likely to fall through or out of windows. All windows and skylights in a workplace should be able to be cleaned safely.

**Organisation of traffic routes**: There should be enough traffic routes of sufficient width and headroom to allow people on foot or vehicles to circulate safely and without difficulty. A traffic route is defined as a route for pedestrian traffic, vehicles or both, and include any stairs, staircases, fixed ladders, doorways, gateways, loading bays or ramps. Suitable warning signs should indicate potential hazards on traffic routes used by vehicles and pedestrians. Suitable road markings and signs should be used to alert drivers.

**Doors and gates**: Should be suitably constructed and if necessary be fitted with safety devices. Doors and gates, which swing in both directions, should have a transparent panel. Sliding doors should have a stop to prevent the door coming off its track. Upward opening doors should have an effective device to prevent them from falling back.

**Self Assessment Exercise:** What do you understand by general workshop safety maintenance?

## 3.2 Safety Precautions in Work Areas

### Safety Precautions

When operators enters into the workshop, he should first observe the safety of saving himself and others.

### Precautions when using machines

i. Do not lean against the machine. It is a bad practice also a dangerous one

ii. Do not work on a machine in a bad light.

iii. Never switch on a machine unless or otherwise you know all the mechanism of his operation.

iv. When using any grinding part, protect the eyes by wearing goggles or use shield.

v. Do not clean metal chips/sheets with hand, use wire mesh or wire brush.

vi. Be in a habit of cleaning tools, equipment and machines regularly.

**Precautions in workshop**

a) Keep the workshop neat and tidy. Many accidents are caused by people tipping over things loosely left or trying over gangways due to untidy/unkempt environment.

b) Do not run over/around in the workshop. Simply walk around carefully.

c) Ensure that the floor is dried and free from slippery substances.

d) Keep gangways clean and clear

e) Everything should be in place, and waste bins should be provided for waste pieces.

f) Provide fire extinguishers at strategic points in the workshop.

g) Workshop should have proper lightings and ventilation.

h) Provide first aid box in the workshop for first point of call in case of accident.

**Precautions while using hammer**

i. There should be no oil or grease on the handle

ii. Hammer head should not be project outward

iii. Hammer handle should neither be too long nor too short.

**Precautions in workshop**

a) Chisel should be handle carefully

b) Chisel must be grounded

c) Goggles must be worn while chipping

**Precautions while using files**

i. The finger of left hand should not be crooked under file, as this may injure the fingers

ii**.** Metal chips must not be removed with bare hands while working, rather use wire brush.

iii**.** Files without handle or those with broken handles should not be used for operation

**Precautions during welding**

a) Never use oxygen cylinders near inflammable substances

b) Acetylene and Oxygen cylinders must be kept separately

c) Welding must not be done in an place without adequate ventilation

d) Always use goggle to protect the eyes while welding.

e) Ensure air-tight connection of the gas by using soapy water to check leakage.

f) Do not use matches for lighting during welding.

g) After welding, ensure proper closure of the cylinder valves and release all residue/trapped gas from the regulators and hoses by opening the touch. When the regulators reads zero, release the pressure, adjust the screw and close the valves.

**Precautions on clothing**

i. Use tight-fitting coat instead of loose-fitting ones.

ii. Avoid wearing rings, long sleeve shirts and watches while working in the workshop.

iii. Hair must be combed well and kept way from danger.

iv. Clear cover footwear having thick soles and tough above.

**Self Assessment Exercise:** Explain safety precaution in selected work areas in workshop.

### 3.3 Power Tools Safety Guides and Personal Protective Equipment (PPE)

1. **Safety glasses**: These prevent dust, debris, wood shavings, shards from fiberglass, etc. from getting into the eyes. Safety glasses are one of the most basic pieces of safety equipment that must be used when working with power tools.

2. **Protection for the ears**: Power tools can generate a lot of noise, which may sound louder in the cloistered environment of a workshop; in order to minimize damage to the ears, it is advisable to wear earplugs.

3. **Knowing the right tools for the job**: It is important to know the right tools for the job in order to avoid injury to oneself and damage to the materials. To this end, it is advisable to thoroughly read the instruction manuals provided with the equipment and get familiar with the recommended safety precautions.

4. **Correct method of using tools**: Tools should not be carried by their cords; tools that are not in use should be disconnected; and while handling a tool connected to a power source, fingers should be kept away from the on/off switch.

5. **The right clothes**: Long hair should be tied and loose clothing should be avoided. Ideally, clothing that covers the entire body should be worn and heavy gloves should be used in order to avoid sharp implements and splinters from hurting the hands. Masks prevent inhalation of harmful minute particles of the material that is being worked upon. Steel-toed work boots and hard hats can also be worn.

6. **Tool inspection**: Power tools should not be employed in wet environments and should never be dipped in water; they should be checked periodically for exposed wiring, damaged plugs, and loose plug pins. Nicked cords can be taped but if a cut appears to be deep, a cord should be replaced. Tools that are damaged or those that sound and feel different when used should be checked and repaired.

7. **Cleanliness in the work area**: This should be maintained because accumulated dust particles in the air can ignite with a spark. Of course, flammable liquids should be kept covered and away from the place where power tools are being used. An uncluttered work area also makes it easy to manoeuvre the power tool; often distractions caused by a tangled cord can result in an accident.

8. **Care with particular tools**: Mitre saws and table saws should be used with a quick-release clamp and a wood push-through, respectively. Extra care should be taken while using nail guns and power belt sanders.

9. **Keep tools in place**: Power tools should be returned to their cabinets after use to prevent them from being used by an unauthorized and incapable person.

10. **Lighting**: It is important to use proper lighting while working with power tools, particularly when working in the basement and garage where lighting may not be satisfactory.

**Personal protective equipment (PPE)**

Personal Protective Equipment is defined as all equipment which is intended to be worn or held to protect against risk to health and safety. This includes most types of protective clothing and equipment such as: eye protection, safety helmets, safety footwear, gloves, high visibility clothing and safety harness. It does not include hearing protection and most respiratory equipment, which are covered by separate existing regulations.

**Self Assessment Exercise:**

Explain the safety guides of power tools and personal protective equipment (PPE) in workshop.

## 4.0 Conclusion

We established the importance of safety practices in workshop for the purpose of preventing accidents which may lead to loss of live, manpower, materials resources, money, time and other irreparable damages. Prevention they say, is always better than cure.

## 5.0 Summary

This unit explained the concept of safety practices in workshops. It presents safety guides and tips for hand and machine tools, as well as the precautions to be taking while working in many areas of the workshop to prevent avoidable but reparable and irreparable lost due to accidents and incidences. Provision of first aid, fire extinguishers, personal protective equipment (PPE) etc.

## 6.0 Tutor-Marked Assignment

a) Explain what concept of workshop safety maintenance?

b) Discuss safety precautions in selected work areas in workshop

c) Discuss the safety guides of power tools and personal protective equipment (PPE) in workshop

## 7.0 References/Further Readings

Ashby, M.F.H., Shercliff, H., & Cebon, D. (2007). Materials: Engineering, Science, Processing and Design, Butter *worthinemann Publishers*.

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## UNIT 3: MEASURING EQUIPMENT

**CONTENTS**



### 1.0 Introduction

Some form of precise measurement is necessary if parts are to fit together as intended no matter whether the parts were made by the same person, in the same factory, or in factories a long way apart. Spare parts can then be obtained with the knowledge that they will fit a part which was perhaps produced years before.

To achieve any degree of precision, the measuring equipment used must be precisely manufactured with reference to the same standard of length. That standard is the metre, which is now defined using lasers. Having produced the measuring equipment to a high degree of accuracy, it must be used correctly.

### 2.0 Objective

At the end of this unit student should be able to;

- Understand different common measuring devices used in the workshop
- Describe some length measuring simple hand tools
- Explain the use and function of Coordinate measuring machine (CMM)

## 3.0 Main Content

### 3.1 Length and angular measuring devices

In the late nineteenth century, Dr Ernst Abbe and Dr Carl Zeiss worked together to create one of the world's foremost precision optics companies. The Abbe principle resulted in observations about measurement errors.

The Abbe principle states that the reading axis and the measuring axis of a measuring instrument must be co-axial for maximum accuracy. Any separation of the two may lead to an error.

The micrometre is one instrument which complies with the Abbe principle, since the graduations are located along the same axis as the measurement being taken.

The Vernier caliper does not comply with this principle. To ensure greatest accuracy of measurement, the workpiece being measured should be moved as close to the main beam as possible. The Vernier depth gauge, however, does comply with Abbe's principle.

Many of the electronic measuring instruments outlined in this unit e.g. Vernier calipers, micrometres and dial test indicators, can be equipped to output data either through available data cables or by wireless transmitters/receivers. This data can be printed out or sent to a computer and collected and used by quality control to provide statistical information or for the generation of inspection certificates.

#### 3.1.1 Measuring Length with rules

The simplest, easiest and most common practice of length measurement is by the use of meter rule, straight edge or square, scale rule or tape rule, marking gauge, try square, bevel square (which is an adjustable try square) mortise gage. It is the safest traditional direct measuring method. Some of the devices are shown in Figure 1.1 – 1.6.

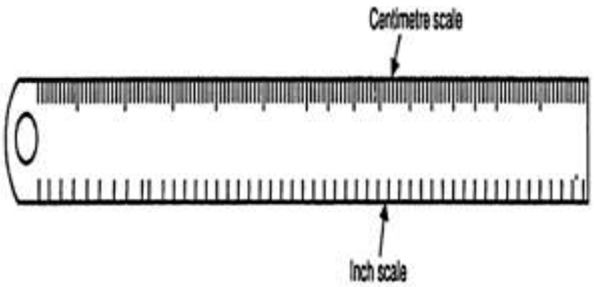


Figure 1.1: Metre rule

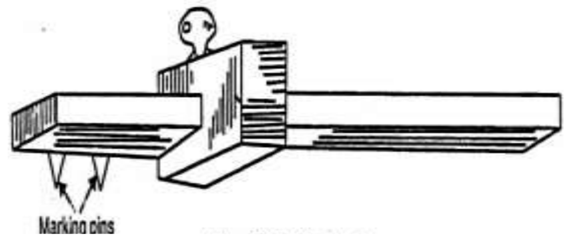


Figure 1.4: Mortise gauge

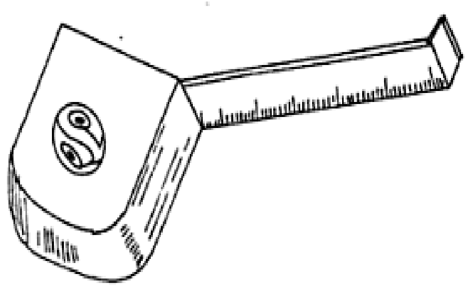

Figure 1.2: Steel measuring tape

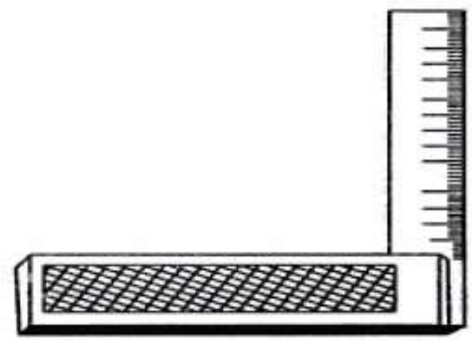

Figure 1.5: Try square

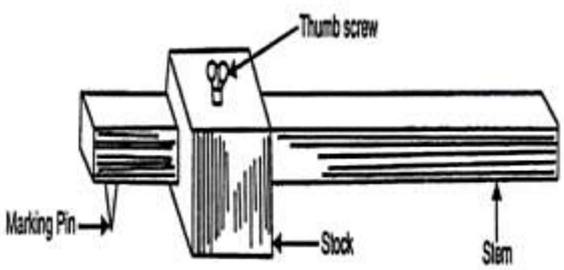


Figure 1.3: Marking gauge

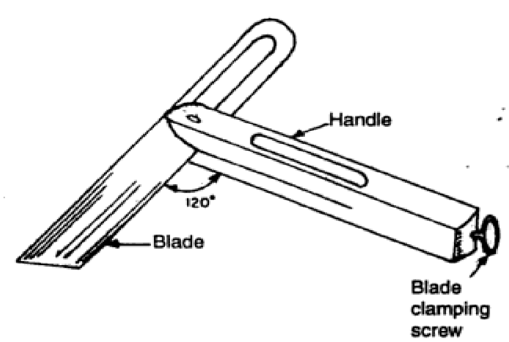


Figure 1.6: Bevel square

**Self Assessment Exercise:**

Briefly discuss some traditional length measuring devices using neat sketches

### 3.1.2 Vernier Instruments

All instruments employing a Vernier consist of two scales: one moving and one fixed. The fixed scale is graduated in millimetres, every 10 divisions equalling 10 mm, and is numbered 0, 1, 2, 3, 4 and up to the capacity of the instrument. The moving or Vernier scale is divided into 50 equal parts, which occupy the same length as 49 divisions or 49 mm on the fixed scale. This means that the distance between each graduation on the Vernier scale is 49⁄50 mm = 0.98 mm, or 0.02 mm less than each division on the fixed scale. If the two scales initially have their zeros in line and the Vernier scale is then moved so that its first graduation is lined up with a graduation on the fixed scale, the zero on the Vernier scale will have moved 0.02 mm. If the second graduation is lined up, the zero on the Vernier scale will have moved 0.04 mm and so on. If graduation 50 is lined up, the zero will have moved 50 × 0.02 = 1 mm.

Since each division on the Vernier scale represents 0.02 mm, five divisions represent 5 × 0.02 = 0.1 mm. Every fifth division on this scale is marked 1 representing 0.1 mm, 2 representing 0.2 mm and so on.

To take a reading, note how many millimetres the zero on the Vernier scale is from zero on the fixed scale. Then note the number of divisions on the Vernier scale from zero to a line, which exactly coincides with a line on the fixed scale.

#### 3.1.2.1 Vernier caliper

The most common instrument using the above principle is the Vernier caliper. Because of its capability of external, internal, step and depth measurements, its ease of operation and wide measuring range, the Vernier caliper is possibly the best general purpose measuring instrument. They are available in a range of measuring capacities from 0–150 mm to 0–1000 mm. It comes in normal, dial and digital version as shown in Figures 1.7 – 1.9. It can also be used to measure the depth or height of object as shown in Figures 1.10 – 1.13. The Vernier bevel protractor is used for angular measurements Figure 1.15.

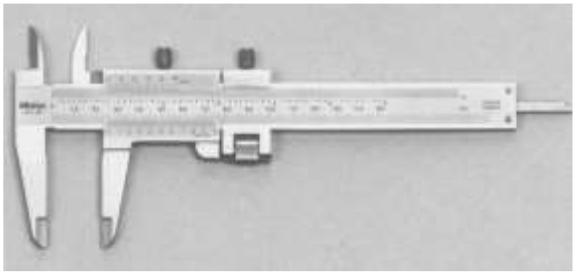

Figure 1.7: Vernier caliper

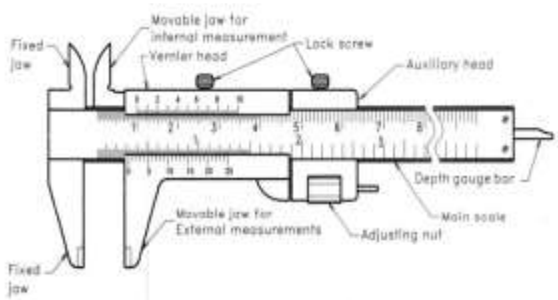


Figure 1.9: Dial caliper


Figure 1.8: Vernier caliper schematics

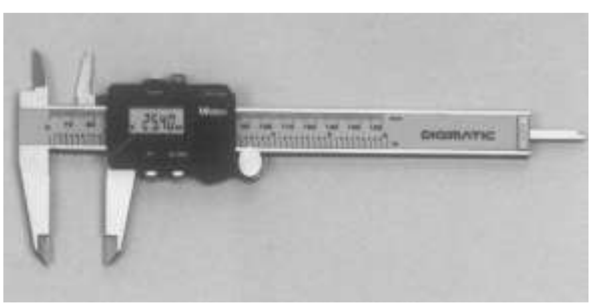


Figure 1.10: Digital caliper

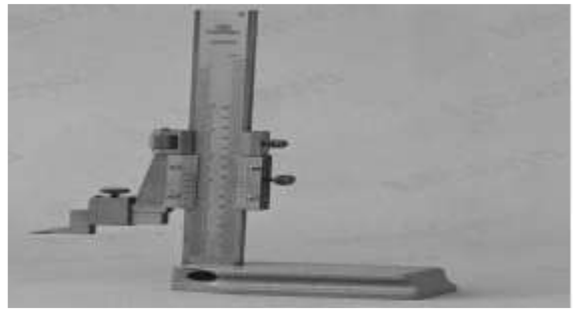

Figure 1.11: Vernier height gauge

Figure 1.12: Digital height gauge

Figure 1.13: Vernier depth gauge

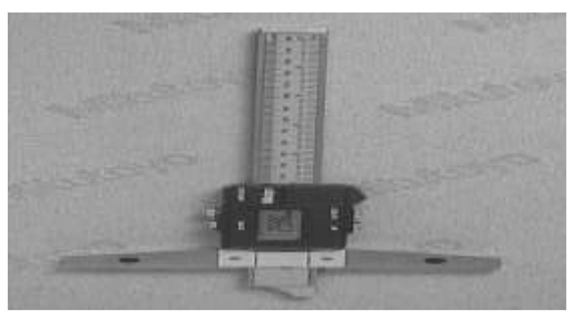

Figure 1.14: Digital depth gauge

Figure 1.15: Vernier bevel gauge

### 3.1.2.2 Micrometres

The micrometre's measuring accuracy relies on the accuracy of the spindle screw thread. The spindle is rotated in a fixed nut by means of the thimble, which opens and closes the distance between the ends of the spindle and anvil. The pitch of the spindle thread, i.e. the distance between two consecutive thread forms, is 0.5 mm. This means that, for one revolution, the spindle and the thimble attached to it will move a longitudinal distance of 0.5 mm Figure 1.16 – 1.19.

Figure 1.16: Analog Micrometre

Figure 1.17: Digital external Micrometre

Figure 1.18: Depth Micrometre

Figure 1.19: Digital 3-point Micrometre

**Self Assessment Exercise:**

Explain the importance of accurate measurement in engineering design with reference to Vernier calliper and Micrometre.

### 3.2 Lever type instrument

The lever-type of instrument is shown in below. Due to the leverage system, the range of this type is not as great as that of the plunger-type and is usually 0.5 or 0.8 mm. The dial divisions are 0.01 or 0.005 mm, and again the dial is adjustable to set zero. The greatest advantage of this type is the small space within which it can work. Another added advantage is an automatic reversal system, which results in movement above or below the contact stylus registering on the dial pointer. This facility, together with the contact stylus being able to swing at an angle, means that checks can be made under a step as well as on top.

**Lever-type dial indicator**

The lever-type of instrument is shown in figure. Due to the leverage system, the range of this type is not as great as that of the plunger-type and is usually 0.5 or 0.8 mm. The dial divisions are 0.01 or 0.005 mm, and again the dial is adjustable to set zero. The greatest advantage of this type is the small space within which it can work.

Another added advantage is an automatic reversal system, which results in movement above or below the contact stylus registering on the dial pointer. This facility, together with the contact stylus being able to swing at an angle, means that checks can be made under a step as well as on top Figure 1.20 below.

Figure 1.20: Lever-type dial indicator

**Self Assessment Exercise:**

State the advantages of lever-type measuring instrument.

### 3.3 Coordinate measuring machine (CMM)

With the advent of numerical controlled machine tools, the time required in removing metal was greatly reduced as the machine tools were controlled, initially by punched tape (NC), and subsequently, with the introduction of computers, by computer numerical control (CNC). As well as the increased speed of production, the consistent accuracy of the finished work also increased dramatically. Manufacturing tolerances had been reduced in order to satisfy improvements in product reliability and improved performance.

Checking these parts was initially carried out by inspection departments using conventional measuring techniques, which was slow and created bottlenecks in the production system. The resulting need for high-speed methods of accurate and reliable measurement brought about the introduction of the coordinate measuring machine (CMM). The introduction of computer aided design (CAD) systems together with CNC machine tools has allowed the manufacture of forms so complex that only a computer controlled CMM can economically assess the accuracy.

Basically, the CMM is a mechanical system that moves a measuring probe to determine the co-ordinates of points on the surface of a workpiece. The CMM comprises the computer-controlled machine itself, the measuring probe, the control system and the measuring software Figure 1.21 below.

Figure 1.21: Lever-type dial indicator

**Self Assessment Exercise:**

Discuss the function and merits of Coordinate measuring machine (CMM)

## 4.0 Conclusion

We conclude that to achieve any degree of precision in design, fabrication or production of workpiece, the measuring equipment used must be accurately and precisely manufactured with reference to the same standard dimensions of the machine part. We equally established that modern device with higher accuracy and precision on measured dimensions should be used.

## 5.0 Summary

In this study unit we attempt to explore traditional and modern measuring devices with different accuracies. This unit further explore the merits of coordinate measuring machine in production of workpiece in the workshop.

## 6.0 Tutor-Marked Assignment

a) Discuss some traditional length measuring devices using neat sketches.

b) Explain the importance of accurate measurement in engineering design with reference to Vernier calliper and Micrometre.

c) State the advantages of lever-type measuring instrument.

d) Discuss the function and merits of Coordinate measuring machine (CMM)

## 7.0 References/Further Readings


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## UNIT 4: BASIC HAND AND POWER (MACHINE) TOOLS

**CONTENTS**



### 1.0 Introduction

In production process, components are fabricated, formulated or produced with the help of either machines or manual efforts. The fitting operations, which usually require large number of tools and equipment, and are carried out on the workshop bench include: 1) Marking out 2) Sawing 3) Chipping 4) Filing 5) Scraping 6) Grinding 7) Drilling 8) Reaming 9) Tapping 10) Dyeing.

Working on component with hand tools and instruments, mostly on work benches is generally referred as '***Fitting work***'. The hand operation in fitting include marking, sawing, filing, scraping, grilling, tapping, grinding etc., by using hand tools, or power operated portable tools.

Generally, machining process tools can be divided into two broad groups; Hand tools and Mechanical tools. The Hand tools include Files, Saw, Chisels and Planes. The mechanical tools are those used for Grinding (Grinders), Milling (Mills), Drilling (Drills), Shaping (Scrapers) and Turning (Lathe).

## 2.0 Objective

At the end of this unit student should be able to

- Understand different common Hand tools used in the workshop
- Describe some simple power (machine) tools used in the workshop
- Understand basic workshop operations and the right tools.

## 3.0 Main Content

3.1 Basic Common Workshop Hand Tools

The tools used for Fitting works may be classified into the following groups;

i. Marking and Measuring tools
ii. Job or workpiece holding device
iii. Planing tools
iv. Cutting tools
v. Striking tools

### 3.1.1 Marking and measuring tools

a) **Rules**

Rules are used for measuring dimensions. For measuring and setting out dimensions various types of rules are used in carpentry shop. Steel Rule- Stainless Steel Rule of length 30cm and 60cm. Flexible Measuring Rule- for measuring large dimensions as well as curved or angular surface dimensions as shown in the previous unit.

b) **Straight Edge and Squares**

This is a machined flat piece wood or metal having perfectly straight and parallel edges.

c) **Steel Tape**: It is used for large dimensions, such as marking on boards and checking the overall dimensions of the work as shown in the previous unit.

e) **Gauges**

Gauges are used to mark lines parallel to the edges of a wooden piece. It mainly consists of a wooden stem sliding inside a wooden stock. The stem carries a steel point for marking lines. The stock position on the stem can be varied and fixed rigidly by tightening the thumb screw as shown in the previous unit.

f) **Try square**

Try square consists of rectangular steel blade fixed rigidly to cast iron stock. The length of blade varies from 150mm to 300mm as shown in the previous unit.

g) **Marking Knife or Scriber**

Marking Knives are used to convert the pencil lines drawn on the wooden surface into deep scratch lines on the surface. They are made of steel with a sharp point at one end and flat blade at the other end.

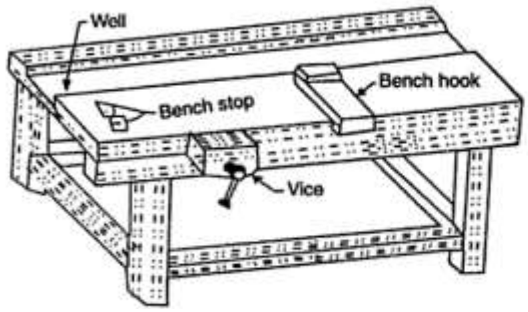
h) **Bevel Square**

This is also called sliding level. It is an adjustable try-square used for measuring/marking angles between 00 and 1800.

### 3.1.2 Job or workpiece holding tools

a) **Work Bench**

This is a table of having size and raised construction made of hard wood. The size ranges from 50- 80 cm in length and about 90cm in width. Two or four carpenters can work at a time on the work bench. The screw moves inside the fixed half nut, which can be engaged or disengaged by operating the lever. This is made up of a bar of steel. The work is clamped between jaws by rotating the screw using the handle. It is used for clamping glued pieces or holding the work piece of larger size together for various operations as shown in Figure 1.22. Carpenter bench vice is shown in Figure 1.23.



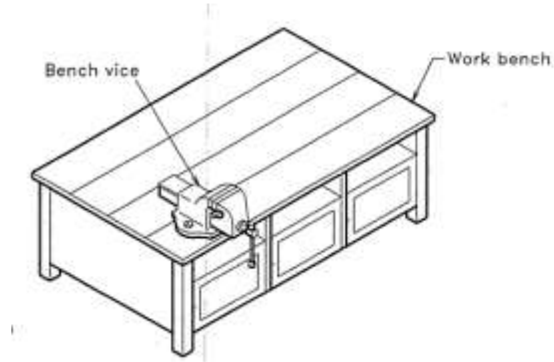




Figure 1.22: Work bench

a) **Sash-cramp**

b) **C Clamp**: The clamp of the shape of letter C or G is used to clamp short pieces together as the bar clamp. These clamps are available is sizes varying from 70 mm to 800 mm. it is used for holding the planks after gluing Figure 1.24.

**Bar or T-cramp**: it consists of a steel bar fitted with a threaded spindle and an adjustable shoe. It is used for holding the glued pieces tightly or holding firmly two or more unglued pieces for fitting dowels or doing other operations on them in assembled position Figure 1.25.

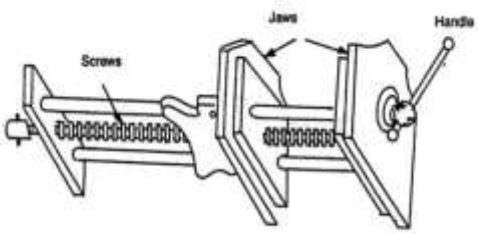



Figure 1.23: Carpenter bench vice

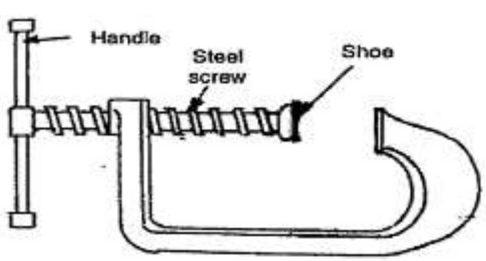



Figure 1.24: C – Clamp

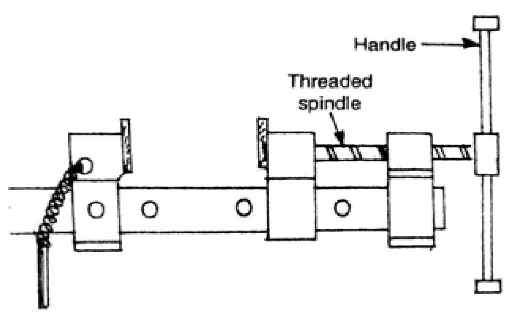



Figure 1.25: Bar or T – cramp

### 3.1.3 Planning tools

Planning tool is used to smoothen the wooden surfaces.

a) The sketch of a typical jack plane is shown in Figure 1.26.

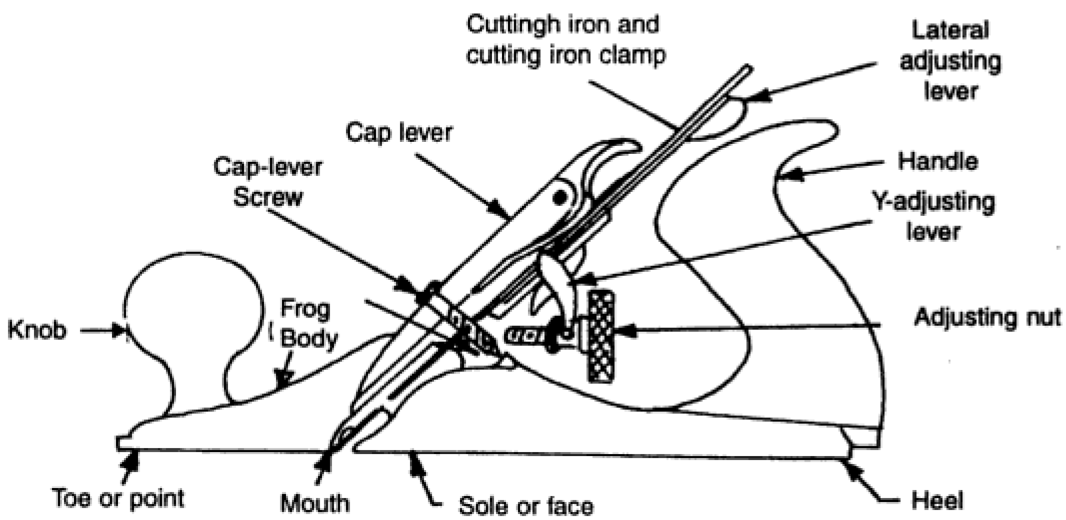



Figure 3.26: A typical jack plane

a) **Wooden jack plane**

This is the most commonly used plane in carpentry shop. The main part of a wooden jack plane is a wooden block called sole, in which steel blade having knife edge is fixed at an angle with the help of wooden edge. The angle of the blade is kept about 45 ° to bottom surface of the blade Figure 1.27.

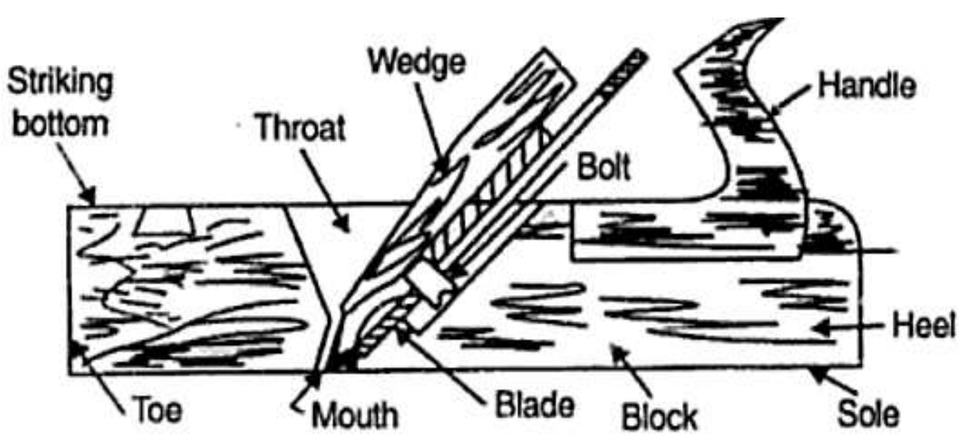



Figure 1.27: Wooden jack plane

b) **Metal Jack Plane**

It serves the same purpose as the wooden jack plane but facilitates a smoother operations and better finish. The body of a metal jack plane is made from a grey iron casting with the side and sole machined and ground to better finish as shown in Figure 1.28.

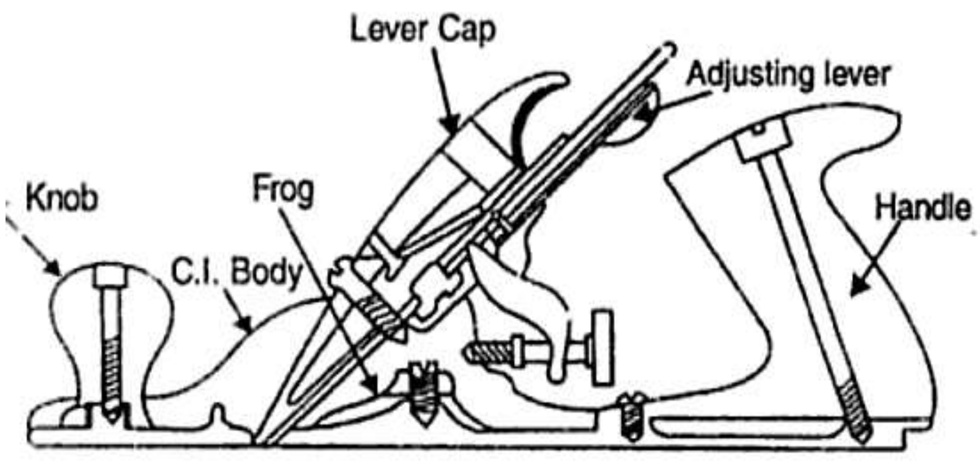



Figure 1.28: Metal jack plane

**3.1.4**

**Cutting tools**

a) **Saw**

Saw is a cutting tool which has teeth on one edge and cutting is affected by reciprocating motion of the edge relative to the work piece. Cutting occurs during the forward motion; such a saw is called push type saw, the cutting occurs during the backward motion.

i. Hand Saw- This saw is used for short straight cuts. It has a blade of 25-40cm length 6-10cm width. The number of teeth per cm length ranges from 3-5.

ii. Tenon Saw (Back Saw) - It has a parallel blade of 25-40cm length and 6-10cm width. The number of teeth per cm length ranges from 5-8. The types and parts of a saw are shown in Figures 1.29 – 1.30 respectively.

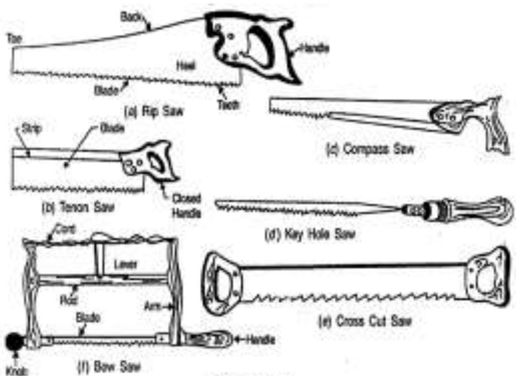



Figure 1.29: Different types of saw

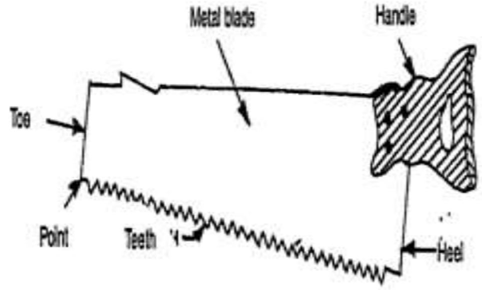



Figure 1.30: Parts of a saw

b) **Chisel**

The common type of chisels used is briefly explained below.

i. Firmer Chisels- they are most common and general purpose chisel used by a carpenter. They have flat blade of 15-50mm width and 125mm length.

ii. Dove Tail Chisel (bevelled edge firmer chisel) - These chisels are used for fine and delicate works as well as for cutting corners.

iii. Mortise chisel – These chisels are used for heavy and deep cut to remove large quantity of wood. These chisels have width of about 15mm but the blade thickness may range from 6-15mm. The types and parts of a chisel are shown in Figures 1.31 – 1.32 respectively.

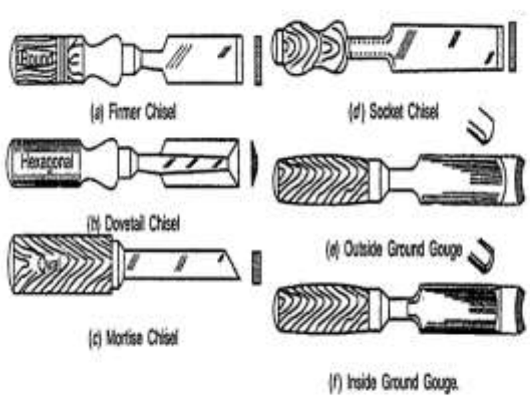



Figure 1.31: Different types of chisel

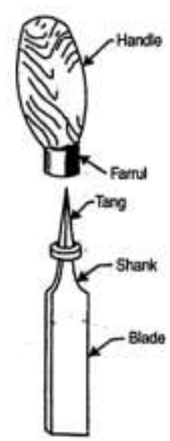



Figure 1.32: Parts of a chisel

### 3.1.5 Striking tools

Striking tools include Hammers, Chisels and Scribers. They are described in other units of this courseware.

a) **Hammers**

A hammer consists of four parts namely; Peen, Head, Eye and Face. The eye is normally made oval or elliptical in shape and it accommodate the handle or shaft or stem. The face is hardened and polished well, and is slightly convex instead of flat to avoid spoilage of the surface of the metal to be hammered by the sharp edge of the flat surface. There are;

i. Ball peen hammer

ii. Cross-peen hammer

Straight peen hammer

Double faced hammer

Soft hammer

**Self Assessment Exercise:**

Briefly state the basic hand tools in the workshop and their uses.

## 3.2 Basic Power (machine) Tools in Workshop

A power tool is a tool that is actuated by an additional power source and mechanism other than the solely manual labour used with hand tools. The most common types of power tools use electric motors. Internal combustion engines and compressed air are also commonly used. Other power sources include steam engines, direct burning of fuels and propellants or even natural power sources like wind or moving water.

Power tools are used in industry, in construction, and around the house for purposes of driving (fasteners), drilling, cutting, shaping, sanding, grinding, routing, polishing, painting, heating and more.

Power tools are classified as either stationary or portable, where portable means hand-held. Portable power tools have obvious advantages in mobility. Stationary power tools however often have advantages in speed and accuracy and some stationary power tools can produce objects that cannot be made in any other way. Stationary power tools for metalworking are usually called machine tools.

### 3.2.1 Various types of power tools

a**) Impact Drivers**

An **impact driver** is a tool that delivers a strong, sudden rotational and downward force. In conjunction with toughened screwdriver bits and socket sets, they are often used by mechanics to loosen larger screws (bolts) and nuts that are corrosively "frozen" or over-torque. The direction can also be reversed for situations where screws have to be tightened with torque greater than a screwdriver can reasonably provide Figure 1.33.

Figure 1.33: Impact driver

b) **Chain saw**

A **chainsaw** (or **chain saw**) is a portable mechanical saw, powered by electricity, compressed air, hydraulic power, or most commonly a two-stroke engine. It is used in activities such as tree felling, limbing, bucking, pruning, by tree surgeons to fell trees and remove branches and foliage, to fell snags and assist in cutting firebreaks in wild land fire suppression, and to harvest firewood. Chainsaws with specially designed bar and chain combinations have been developed as tools for use in chainsaw art. Specialist chainsaws are used for cutting concrete Figure 1.34.

Figure 1.34: Chain saw

c) **Angle/Side/Disc Grinder**

An angle grinder, also known as a side grinder or disc grinder, is a handheld power tool used for cutting, grinding and polishing. Angle grinders can be powered by an electric motor, petrol engine or compressed air. The motor drives a geared head at a right-angle on which is mounted an abrasive disc or a thinner cut-off disc, either of which can be replaced when worn. Angle grinders typically have an adjustable guard and a side-handle for two-handed operation. Certain angle grinders, depending on their speed range, can be used as sanders, employing a sanding disc with a backing pad or disc. The backing system is typically made of hard plastic, phenolic resin, or medium-hard rubber depending on the amount of flexibility desired.

Angle grinders may be used for both removing excess material from a piece and simply cutting into a piece. There are many different kinds of discs that are used for various materials and tasks, such as cut-off discs (diamond blade), abrasive grinding discs, grinding stones, sanding discs, wire brush wheels and polishing pads. The angle grinder has large bearings to counter side forces generated during cutting, unlike a power drill, where the force is axial.

Angle grinders are widely used in metalworking and construction, as well as in emergency rescues. They are commonly found in workshops, service garages and auto body repair shops as shown in Figure 1.35.

Figure 1.35: Angle grinder

d) **Drilling Machine**

A drill is a tool fitted with a cutting tool attachment or driving tool attachment, usually a drill bit or driver bit, used for drilling holes in various materials or fastening various materials together with the use of fasteners. The attachment is gripped by a chuck at one end of the drill and rotated while pressed against the target material. The tip, and sometimes edges, of the cutting tool does the work of cutting into the target material. This may be slicing off thin shavings (twist drills or auger bits), grinding off small particles (oil drilling), crushing and removing pieces of the work piece, countersinking, counter boring, or other operations.

Drills are commonly used in woodworking, metalworking, construction and do-it-yourself projects. Specially designed drills are also used in medicine, space missions and other applications. Drills are available with a wide variety of performance characteristics, such as power and capacity Figure 1.36.

Figure 1.36: Drilling machine

e) **Nail Gun**

A nail gun, nailgun or nailer is a type of tool used to drive nails into wood or some other kind of material. It is usually driven by electromagnetism, compressed air (pneumatic), highly flammable gases such as butane or propane, or, for powder-actuated tools, a small explosive charge. Nail guns have in many ways replaced hammers as tools of choice among builders as shown in Figure 1.37.

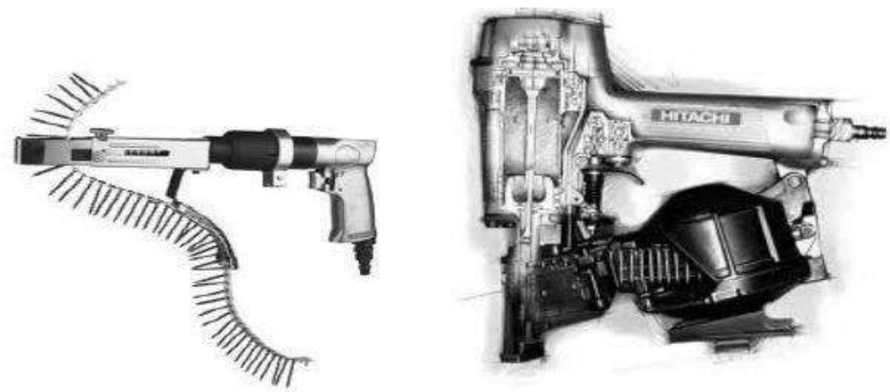



Figure 1.37: Nail gun

f) **Impact Wrench**

An impact wrench (also known as an impactor, air wrench, air gun, rattle gun, torque gun, windy gun) is a socket wrench power tool designed to deliver high torque output with minimal exertion by the user, by storing energy in a rotating mass, then delivering it suddenly to the output shaft. Compressed air is the most common power source, although electric or hydraulic power is also used, with cordless electric devices becoming increasingly popular in recent times.

Impact wrenches are widely used in many industries, such as automotive repair, heavy equipment maintenance, product assembly (often called "pulse tools" and designed for precise torque output), major construction projects, and any other instance where a high torque output is needed as shown in Figure 1.38.

Figure 1.38: Impact wrench

**g) Cut off machine**

An abrasive saw, also known as a cut-off saw or metal chop saw, is a power tool which is typically used to cut hard materials, such as metals. The cutting action is performed by an abrasive disc, similar to a thin grinding wheel. The saw generally has a built-in vice or other clamping arrangement, and has the cutting wheel and motor mounted on a pivoting arm attached to a fixed base plate.

They typically use composite friction disk blades to abrasively cut through the steel. The disks are consumable items as they wear throughout the cut. The abrasive disks for these saws are typically 14 in (360 mm) in diameter and 7⁄64 in (2.8 mm) thick. Larger saws use 410 mm (16 in) diameter blades. Disks are available for steel and stainless steel as shown in Figure 1.39.


Figure 1.39: Cut off machine

h) **Jigsaw**

Although jigsaws cut more slowly than circular saws, they can cut curved shapes into materials such as timber, metal and plastic. They're commonly found in joinery workshops but can also be useful on site for cutting holes in, for example, kitchen worktops for sinks. Most models now have a variable speed control so that you can select the best speed for the job. Fast speeds are more suitable for cutting timber and slower speeds for cutting metal. The base plate of a jigsaw can be tilted to allow bevelled cuts. The teeth of a jigsaw point upward, so the cutting is done during the up-stroke. This can result in damage to the surface of the timber, especially on sheet materials such as plywood. If necessary, clearance must be allowed for the edges to be cleaned up afterwards. There are blades available with teeth which point downwards and these are useful when cutting material such as plastic laminates.

However, you must take extreme care when using this type of blade as it can cause the saw to 'lift' away from the work surface. To prevent this, always maintain downward pressure on the saw. Some models have a mechanism, which produces an orbital motion in the blade. This means that the blade moves forward on the up-cut and pulls back for the down-cut which results in a faster (but possibly rougher) cut. A control allows the orbital motion to be reduced to zero for clean cutting as shown in Figure 1.40.

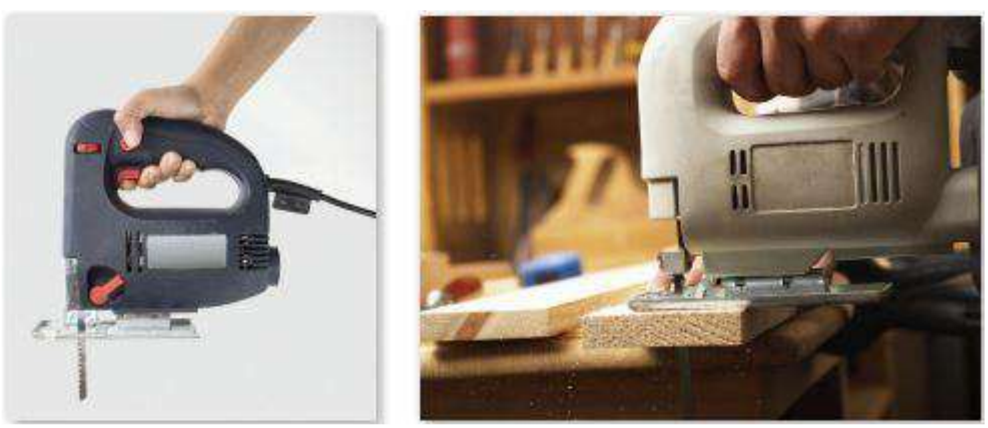


Figure 1.40: Jigsaw

i) **Power plane**

Electric planes are regularly used on construction sites for planning the edges of doors during the fitting process. They can also be used to perform operations such as chamfering (removing the corner of a piece of timber on an angle) and rebating (taking a square recess out of the corner of a piece of timber). Although electric planes vary from model to model, they are all very similar in appearance and have many of the same features as shown in Figure 1.41.

Figure 1.41: Power planes

j) **Circular Saw**

No other power tool has given carpenters a greater advantage over old hand-powered methods than the portable circular saw (also known as a skill saw). It is widely used on construction sites for cutting timber and sheet materials such as plywood and chipboard.

The circular saw is used primarily for ripping and cross-cutting, but it can also be adjusted to perform a number of other operations such as grooving, rebating and trenching as well as making bevelled and compound cuts Figure 1.42.

Figure 1.42: Circular saw

k) **Router cutter or bit**

There are many different router cutters and/or bits available. Some are used for forming rebates and grooves for jointing and other practical purposes, and others are used for forming decorative mouldings. All router bits are secured into the router with a collet – a sleeve with a split in the side. When the chuck is tightened, the collet is squeezed tight and grips the shaft of the bit. Incorrect fitting of the collet or bits can result in very serious injury to the operator. Most router bits have a 6 mm or 12 mm shaft. A 12 mm shaft fits directly into the chuck, but a 6 mm shaft needs a reduction sleeve.

l) **Orbital Sander**

Orbital sanders (also known as finishing sanders) sand in a circular motion, and are used to achieve a fine, smooth finish on timber surfaces. They are not suitable for 'flushing off' joints or removing wood quickly. A reciprocating sander is very similar to the orbital sander but its motion is back and forth rather than circular. The base of the sander has a soft rubber pad and a spring clip holds the abrasive paper to it. This paper can be bought in packs of pre-cut pieces or cut to size from standard sized sheets or rolls. The base of the sander rotates in a circular motion at approximately 12 000 rpm. The circular motion of the abrasive paper can leave swirl marks on the timber surface, which may only become visible after you have stained or polished the timber. If a very fine finish is required, you should carry out a final sanding by hand in the direction of the grain as shown in Figure 1. 43.

Figure 1.43: Orbital sander

**Self Assessment Exercise:**

Mention some power tools and state their uses in the workshop

### 3.3 Power Tools Safety Tips

1. **Safety glasses**: These prevent dust, debris, wood shavings, shards from fiberglass etc., from getting into the eyes. Safety glasses are one of the most basic pieces of safety equipment that must be used when working with power tools.

2. **Protection for the ears**: Power tools can generate a lot of noise, which may sound louder in the cloistered environment of a workshop; in order to minimize damage to the ears, it is advisable to wear earplugs.

3. **Knowing the right tools for the job**: It is important to know the right tools for the job in order to avoid injury to oneself and damage to the materials. To this end, it is advisable to thoroughly read the instruction manuals provided with the equipment and get familiar with the recommended safety precautions.

4. **Correct method of using tools**: Tools should not be carried by their cords; tools that are not in use should be disconnected; and while handling a tool connected to a power source, fingers should be kept away from the on/off switch.

5. **The right clothes**: Long hair should be tied and loose clothing should be avoided. Ideally, clothing that covers the entire body should be worn and heavy gloves should be used in order to avoid sharp implements and splinters from hurting the hands. Masks prevent inhalation of harmful minute particles of the material that is being worked upon. Steel-toed work boots and hard hats can also be worn.

6. **Tool inspection**: Power tools should not be employed in wet environments and should never be dipped in water; they should be checked periodically for exposed wiring, damaged plugs, and loose plug pins. Nicked cords can be taped but if a cut appears to be deep, a cord should be replaced. Tools that are damaged or those that sound and feel different when used should be checked and repaired.

7. **Cleanliness in the work area**: This should be maintained because accumulated dust particles in the air can ignite with a spark. Of course, flammable liquids should be kept covered and away from the place where power tools are being used. An uncluttered work area also makes it easy to manoeuvre the power tool; often distractions caused by a tangled cord can result in an accident.

8. **Care with particular tools**: Mitre saws and table saws should be used with a quick-release clamp and a wood push-through, respectively. Extra care should be taken while using nail guns and power belt sanders.

9. **Keep tools in place**: Power tools should be returned to their cabinets after use to prevent them from being used by an unauthorized and incapable person.

10. **Lighting**: It is important to use proper lighting while working with power tools, particularly when working in the basement and garage where lighting may not be satisfactory.

**Self Assessment Exercise:**

State the essential safety tips for power tools in the workshop?

## 4.0 Conclusion

Parts or workpieces require the use of both hand tools and power (machine) tools. These tools did not only remove drudgery, fatigue but also make the work easier, smoother, faster, and allows for precision and mass production. Specific tools (hand or power/machine) should be used for the specific intended purpose for maximum efficiency. Safety tips for these tools must also be known and observed by workmen and other technicians.

## 5.0 Summary

These days, power tools have largely replaced hand tools, because they allow site workmen and bench joiners to work with increased speed, more efficiency and greater accuracy. Power tools are available with a variety of power sources including mains power, battery and compressed air. Workmen use a range of power tools to cut, shape and install timber in building construction and fit-out. There are several categories of power tools, each designed to carry out specific functions. They’re usually available in a range of shapes and sizes.

**6.0 Tutor-Marked Assignment**

a) Briefly state the basic hand tools in the workshop and their uses.

b) Mention some power (machine) tools and state their uses in the workshop

c) Explain the safety tips for maximum utilization and efficiency of power (machine) tools in the workshop

**7.0 References/Further Readings**


Ashby, M.F.H., Shercliff, H., & Cebon, D. (2007). Materials: Engineering, Science, Processing and Design, Butter *worthinemann Publishers*.

Bruce, J.B. (2015). Workshop Processes, Practices and Materials, 5th edition, *Routledge Publisher*.

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# MODULE TWO

# ENGINEERING MATERIALS AND THEIR PROPERTIES



## UNIT 1: METAL AND NON-METALLIC MATERIALS

**CONTENTS**



### 1.0 Introduction

The important properties of an engineering material determine the utility of the material which influences quantitatively or qualitatively the response of a given material to imposed stimuli and constraints. A wide range of materials is used in engineering, and it is important to be aware of the ways in which these are applied and of the properties which make them suitable for these applications.

## 2.0 Objective

At the end of this unit student should be able to

- Identify different engineering materials used in the workshop
- Understand the properties engineering materials.
- Relate the properties of engineering materials to their functions and application
- Know the reasons behind the choice of material engineering materials

## 3.0 Main Content

### 3.1 Classification of Engineering Materials

A large numbers of engineering materials exists in the universe such as metals and non-metals (leather, rubber, asbestos, plastic, ceramics, organic polymers, composites and semiconductor). Some commonly used engineering materials are broadly classified as shown in Table 2.1. ***Rubber*** is highly flexible and can easily withstand against considerable wear under suitable conditions. Rubber is commonly employed as packing material, belt drive as an electric insulator. ***Asbestos*** is basically utilized for lagging round steam pipes and steam pipe and steam boilers because it is poor conductor of heat, so avoids loss of heat to the surroundings.

Engineering materials may also be categorized into metals and alloys, ceramic materials, organic polymers, composites and semiconductors. The metal and alloys have tremendous applications for manufacturing the products required by the customers.

#### 3.1.1 Metals and Alloys

Metals are polycrystalline bodies consisting of a great number of fine crystals. Pure metals possess low strength and do not have the required properties. Therefore, alloys are produced by melting or sintering two or more metals or metals and a non-metal, together. Alloys may consist of two more components. Metals and alloys are further classified into two major kind namely ferrous metals and non-ferrous metals.

(a) *Ferrous metals* are those, which have the iron as their main constituent, such as pig iron, cast iron, wrought iron and steels.

(b) *Non-ferrous metals* are those, which have a metal other than iron as their main constituent, such as copper, aluminium, brass, bronze, tin, silver zinc, invar etc.

**Table 2.1: Classification of Engineering Materials**

| **Engineering Materials** | | | | |
|---|---|---|---|---|
| **Metallic Materials** | | | **Non-metallic Materials** | |
| **Ferrous** | | **Non-ferrous** | **Organic** | **Inorganic** |
| **Steel** | Cast iron | | | |
| | | Aluminium | | |
| **Plain** | Grey | Copper | Plastic | Minerals |
| **Carbon** | White | Magnesium | Wood | Cement |
| **Alloy** | Malleable | Tin | Paper | Glass |
| | Ductile | Zinc | Rubber | Ceramics |
| | Nodular | Lead | Leather | Graphite |
| | | Nickel and their alloy | Petroleum | |

## 3.2 Properties of Engineering Materials

Properties of materials can be divided into two groups: physical and mechanical. Physical properties are those properties of a material, which do not require the material to be deformed or destroyed in order to determine the value of the property. Mechanical properties indicate a material's reaction to the application of forces. These properties require deformation or destruction tests in order to determine their value. The value of these properties can be altered by subjecting the material to heat treatment and cold or hot working.

**Self Assessment Exercise:**

Discuss physical and mechanical properties of engineering materials.

### 3.3 Non-destructive Testing of Materials and Choice of Materials

Tests of a different nature and purpose are used to examine manufactured components and assemblies for internal flaws and faults and surface cracks and defects without destroying the component. These tests are known as non-destructive tests (NDT), since the component is not physically damaged as a result of the test and therefore remains 'fit for purpose'. These tests are carried out to check possible defects produced during machining, welding, casting and heat treatment and are also carried out on 'in-service components, e.g. jet engine turbine blades and aircraft components.

Non-destructive evaluation (NDE) is a term often used together with NDT. However, NDE is used to describe measurements that are more quantitative in nature, i.e. detection of the defect is not enough, quantitative information is required regarding flaw size, shape and orientation, information which could be used to determine the component's suitability for use.

**Self Assessment Exercise:**

Discuss Non-destructive test methods for metallic and non-metallic materials

#### 3.3.1 Choice of materials for the engineering application

The choice of materials for the engineering purposes depends upon the following factors:

1 Availability of the materials,

2 Properties needed for meeting the functional requirements,

3 Suitability of the materials for the working conditions in service, and

4 The cost of the materials.

**Self Assessment Exercise:**

State some factors to be consider in the choice of materials for engineering applications

## 4.0 Conclusion

A wide range of materials used in engineering application has been explored. Physical and chemical properties of these materials has also been explored with a view to understand their behaviour understand different conditions. The knowledge of their properties from laboratory probes, which make them suitable for engineering applications will guide in the choice and preference for these materials.

## 5.0 Summary

Brief classification of engineering materials has been done in order to make learners appreciate their importance. Physical and chemical properties of engineering materials, as well as the tests to ascertain their properties for better understanding of their behaviour and choice as materials in the fabrication or production industry.

## 6.0 Tutor-Marked Assignment

d) Discuss the physical and chemical properties of engineering materials.

e) Discuss some Non-destructive test methods for metallic and non-metallic materials

f) Briefly classify engineering materials, and state some factors to be considered for materials for engineering applications

## 7.0 References/Further Readings

Ashby, M.F.H., Shercliff, H., & Cebon, D. (2007). Materials: Engineering, Science, Processing and Design, Butter *worthinemann Publishers*.

Bruce, J.B. (2015). Workshop Processes, Practices and Materials, 5th edition, *Routledge Publisher*.

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## UNIT 2: JOINING METHODS: WELDING, PRESSWORK

**CONTENTS**



### 1.0 Introduction

Some method of joining parts together is used throughout industry, to form either a complete product or an assembly. The method used depends on the application of the finished product and whether the parts have to be dismantled for maintenance or replacement during service. Welding is widely used as a fabrication and repairing process in industries. Some of the typical applications of welding include the fabrication of ships, pressure vessels, automobile bodies, off-shore platform, bridges, welded pipes, sealing of nuclear fuel and explosives, etc.

### 2.0 Objective

At the end of this unit student should be able to;

- Understand the different methods of joining parts in the workshop.
- Understand the purpose and types of welding
- Know the application/importance of wedding
- Understand the concept of presswork in the workshop.

## 3.0 Main Content

### 3.1 Joining methods/operations in the workshop

There are five methods by which parts may be joined:

1. mechanical fasteners – screws, bolts, nuts, rivets;
2. soldering;
3. brazing;
4. welding;
5. adhesive bonding.

Mechanical fasteners are most widely used in applications where the parts may need to be dismantled for repair or replacement. This type of joint is known as non-permanent. The exception would be the use of rivets, which have to be destroyed to dismantle the parts and so form a permanent joint. Welding and adhesives are used for permanent joints, which do not need to be dismantled – any attempt to do so would result in damage to or destruction of the joints and parts.

Although soldered and brazed joints are considered permanent, they can be dismantled by heating for repair and replacement.

#### 3.1.1 Mechanical fasteners

Mechanical fasteners can be made from many materials but most bolts, nuts and washers are made from carbon steel, alloy steel, or stainless steel depending upon their industrial use. Carbon steel is the cheapest and most common for general use.

To prevent corrosion, mechanical fasteners may be plated or coated in some way, again depending on the application. The most common surface treatments are zinc, nickel and cadmium. Phosphate coatings are also used but have limited corrosion resistance.

a) ***Machine screws***

These are used for assembly into previously tapped holes, are manufactured in brass, steel, stainless steel and plastics (usually nylon), and threaded their complete length. Various head shapes are available.

Depending on the style, thread diameters are generally available up to 10 mm, with lengths up to 50 mm. For light loading conditions where space is limited, a headless variety known as a grub screw is available. A typical application would be to retain a knob or collar on a shaft.

Although Figure 2.1 shows head types with slotted head drives, these screws are available with a variety of head drives with Phillips, Pozidriv and Torx the most common.

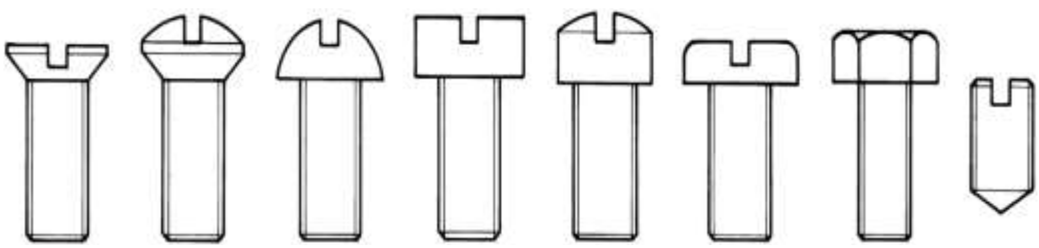
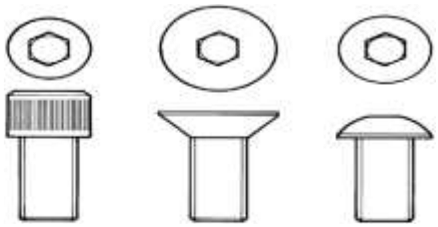


Figure 2.1: Types of screw head

b) ***Socket screws***

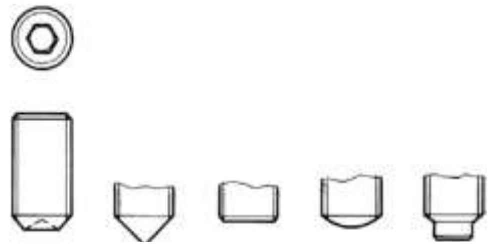
Manufactured in high-grade alloy steel with rolled threads, this type of screw is used for higher strength applications than machine screws. Three head shapes are available, all of which contain a hexagon socket for tightening and loosening using a hexagon key, Figure 2.2.

Headless screws of this type – known as socket set screws – are available with different shapes of point. These are used like grub screws, where space is limited, but for higher strength applications. Different points are used either to bite into the metal surface to prevent loosening or, in the case of a dog point, to tighten without damage to the work, Figure 2.3.



Socket cap Socket countersunk Socket button

Figure 2.2: Socket screw heads



Cup Cone Flat Oval Dog

Figure 2.3: Socket set screws

c) ***Self-tapping screws***

Self-tapping screws are used for fast-assembly work. They also offer good resistance to loosening through vibration. These screws are specially hardened and produce their own threads as they are screwed into a prepared pilot hole, thus eliminating the need for a separate tapping operation.

There are two types:

✓ the ***thread-forming type***, which produces its mating thread by displacing the work material and is used on softer ductile materials, Figure 2.4(a);

✓ the ***thread-cutting type***, which produces its mating thread by cutting in the same way as a tap. This type has grooves or flutes to produce the cutting action, Figure 3.47(b), and is used on hard brittle materials, especially where thin wall sections exist, as this type produces less bursting force.

Figure 2.4: Self-tapping screws (a) thread-forming (b) thread-cutting (c) self-piercing-and-tapping

d) ***Bolts***

Bolts are used in conjunction with a nut for heavier applications than screws. Unlike screws, bolts are threaded for only part of their length, usually twice the thread diameter.

Bright hexagon-head bolts are used in engineering up to 36 mm diameter by 150 mm long. Larger sizes are available in high-tensile materials for use in structural work.

e) ***Nuts***

Standard hexagon nuts are used with bolts to fasten parts together. Where parts require to be removed frequently and hand tightness is sufficient, wing nuts are used, Figure 2.5 (a). If a decorative appearance is required, a dome or acorn nut can be fitted, Figure 2.5 (b).

Where thin sheets are to be joined and access is available from only one side, rivet bushes or rivet nuts are used. These provide an adequate length and strength of thread, which is fixed and therefore allows ease of assembly, Figure 2.5 (c).

Available in thread sizes up to 12 mm for lighter applications, blind nuts of the type shown in Figure 2.5 (d) can also be used. The nut is enclosed in a plastics body, which is pressed into a predrilled hole. A screw inserted into the nut pulls it up and, in so doing, expands and traps the plastics body.

Spring-steel fasteners are available which as well as holding also provide a locking action. If access is available from both sides, a flat nut can be used, Figure 2.5 (e), or from a J-type nut can be used, Figure 2.5 (f). In their natural state these nuts are arched, but they are pulled flat when the screw is tightened.

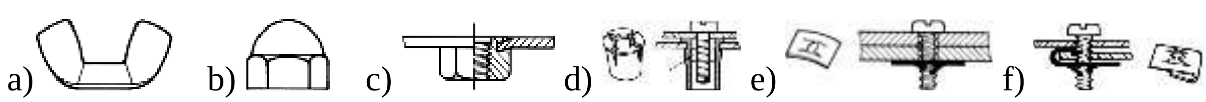



Figure 2.5: Types of nut (a) wing (b) dome or acorn (c) rivet bush or nut (d) blind (e) flat spring steel fastener and (f) J type fastener

f) ***Washers***

Washers distribute the tightening load over a wider area than does a bolt head, screw head or nut. They also keep the surface of the work from being damaged by the fastener.

Plain flat washers spread the load and prevent damage to the work surface. Flanged nuts are available with a plain flange at one end which acts as an integrated, non-slipping washer. The flange face may be serrated to provide a locking action but can only be used where scratching of the work surface is acceptable Figure 2.6.

Figure 2.6: Flange nuts

g) ***Spring tension pins***

These pins are made from spring steel wrapped round to form a slotted tube, Figure 2.7. The outside diameter is produced larger than the standard-size drilled hole into which it is to be inserted. When inserted in the hole, the spring tension ensures that the pin remains securely in position and cannot work loose. A chamfer at each end of the pin enables it to be easily inserted in the hole, where it can be driven home using a hammer.

Pins of this type are now being used to replace solid hinge pins, split pins, rivets and screws, eliminating the need for reaming, tapping, counter-boring and countersinking. They are available in a range of diameters from 1 mm to 12 mm and lengths from 4 mm to 100 mm.

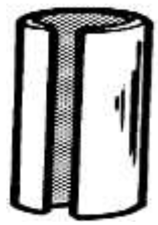


Figure 2.7: Spring tension pin

h) ***Screw threads***

Since 1965, British industry has been urged to adopt the ISO (International Organization for Standardization) metric thread as a first-choice thread system, with the ISO inch (unified) thread as the second choice. The British Standard Whitworth (BSW), British Standard Fine (BSF), and British Association (BA) threads would then become obsolete. The British Standard Pipe (BSP) thread is to be retained. The changeover has been extremely slow in taking place, and all these threads are available and still in use. There are ISO metric thread, Unified thread, British Standard Whitworth thread (BSW), British Association (BA) thread etc.

i) ***Self-locking screw and bolts***

These screws and bolts eliminate the need for nuts and washers and so provide cost savings. Common types incorporate a nylon insert, either as a small plug or as a strip along the length of the thread, Figure 2.8(a). A development of this principle is the application of a layer of nylon over a patch of thread. As the screw is engaged in the mating part, the nylon is compressed and completely fills the space between thread forms. This provides an interference, which will resist rotation of the screw, Figure 2.8(b). A more recent development is the application to an area of thread of a chemical adhesive, which is completely dry to the touch, Figure 2.8(c). The liquid adhesive is encapsulated within the film. When the two threaded parts are assembled, the micro-capsules of adhesive are broken, releasing the adhesive, which hardens and provides a reliably sealed and locked thread.

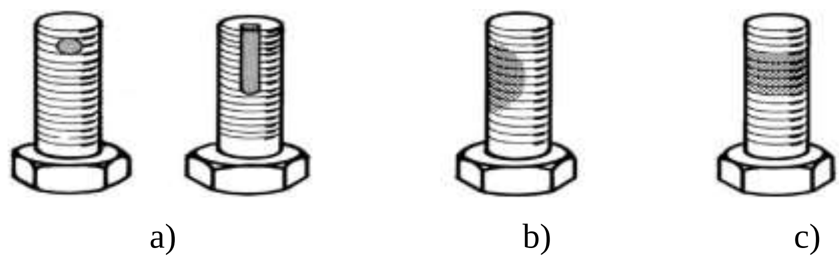



Figure 2.8: Self-locking screws and bolts (a) nylon insert (b) nylon layer (c) adhesive film

j) ***Riveting***

Riveting as a means of fastening is used because of its speed, simplicity, dependability and low cost. Light riveting, used for general assembly work up to about 6 mm diameter, is carried out in industry using high-speed rivet-setting machines having cycle times as short as 1/3 second. Rivets are used on assemblies where parts do not normally have to be dismantled, i.e. permanent joints. They may also be used as pivots, electrical contacts and connectors, spacers or supports.

The cost of riveting is lower than that of most other methods of fastening, due to the absence of plain washers, locking washers, nuts or split pins; also, the use of self-piercing rivets eliminates the need to predrill holes. Rivets are available in steel, brass, copper and aluminium in a variety of types. The more standard head types used are shown in Figure 2.9. Solid rivets are strong but require high forces to form the end. In riveting, forming the end is known as clinching. Solid rivets are used in applications where the high forces used in clinching will not damage the work being fastened. Tubular rivets are designed for application where lighter clinching forces are used. Short-hole tubular rivets, Figure 3.53(a), have the advantage of a solid rivet with easier clinching. These have a parallel hole and can be used for components of varying thicknesses.

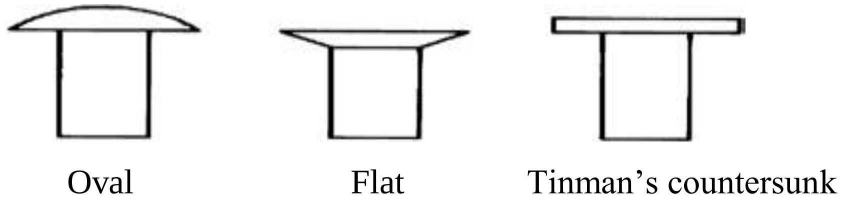



Figure 2.9: Solid-rivet head types

a) b) c) d)

Figure 2.10: Tubular rivets (a) short-hole (b) double-taper semi-tubular (c) bull-nose semi-tubular (d) self-piercing

Double-taper semi-tubular rivets, Figure 2.10 (b), have a taper hole to minimise shank expansion during clinching and are used to join brittle materials.

Bull-nose semi-tubular rivets, Figure 2.10 (c), are used where maximum strength is required. The rivet shank is intended to expand during the setting operation in order to fill the predrilled hole in the work. This ensures a very strong joint. Self-piercing rivets, Figure 2.10 (d), have been specially developed to pierce thicker metal and clinch in the same operation. For metal up to 4.7 mm thick, the self-piercing rivet is made from special steel and is heat-treated to give the required hardness for piercing and ductility for clinching. One use of this type of rivet is automatic riveting in the production of garage doors.

j) ***Soft soldering***

Soft soldering is a process of joining metal parts by heating and running a low-melting-point alloy between the two surfaces being joined. When cooling takes place, the alloy solidifies, resulting in a secure joint. For most purposes, the low melting- point solder alloy is a composition of tin and lead. Solder melts at a temperature less than 300 °C, which is far below the melting temperature of the metal being joined, and produces a low-strength joint Figure 2.11.

a) b) c)

Figure 2.11: Soldering-joint design (a) interlocking (b) winding round a pillar (c) bending through a tab connector

k) ***Solders***

Soft solders are alloys of tin and lead. All the plain tin/lead solders become solid at 183 °C. The temperature at which they become completely liquid depends on the composition, the temperature increasing as the lead content increases.

i) **Fluxes**

Fluxes used in soft soldering are either active or passive. An active flux chemically removes the oxide film, has an acid base, and is highly corrosive. These fluxes are usually hydrochloric acid in which zinc has been dissolved to form zinc chloride, known as ‘killed spirits’. Any joint prepared using an active flux must be thoroughly washed in warm water when soldering is completed, to remove any flux residue. For this reason, an active flux is not suitable for electrical applications.

ii) **Heating**

The type of heat source used for soldering depends largely on the size of the parts to be joined. The greatest problem is usually heat loss to the surrounding area by conduction through the metal. The temperature in the joint area must be high enough to melt the solder and allow it to flow and combine with the surfaces to be joined.

Where the conduction of heat is likely to cause damage, e.g. to electrical insulation or electronic components, a piece of bent copper can be placed in contact with the conductor, positioned between the joint and the insulation or component. The copper readily absorbs the heat before it can do any damage and is known as a ‘heat sink’.

Welding as a joining method shall be discussed in the next unit.

l) ***Brazing***

*Brazing* is defined as a process of joining metals in which, during or after heating, molten filler metal is drawn by capillary action into the space between closely adjacent surfaces of the parts being joined. In general, the melting point of the filler metal is above 450 °C but always below the melting temperature of the metals being joined. Brazing is used to join any combination of similar or dissimilar metals and results in a high-strength joint of good reliability. To form a strong joint, the surfaces must be free of any rust, grease or oxide film.

m) ***Adhesive bonding***

*i.* ***Adhesive bonding as a joining technique***

*Bonding* is the surface-to-surface joining of similar or dissimilar materials using a substance which usually is of a different type, and which adheres to the surfaces of the two adherents to be joined, transferring the forces from one adherent to the other. According to DIN EN 923, an adhesive is a non-metallic substance capable of joining materials by surface bonding (adhesion), and the bond possessing adequate internal strength (cohesion). Bonding is a material joining technique that, in the traditional sense, cannot be broken without destruction of the bond. Recently, specific bonding-on- demand techniques have been developed for example as an assembly tool without further function, or for recycling based on a separation of materials, a method that today is becoming increasingly important.

Bonding is by far the universal joining technique. Virtually all technically useful materials can be joined with each other, and one with another, by means of this surface-to-surface and material-joining technique.

*ii.* ***Characteristic features of Adhesive bond***

Bonding rarely competes with other joining techniques used in industry. For example, one would not consider bonding a steel bridge or a gantry, but for the lightweight construction of car bodies using steel, aluminium, glass and plastics, adhesive joining offers extremely interesting applications. Adhesive joining is particularly well suited to the joining of large-sized surfaces of different materials, such as in the construction of sandwich assemblies.

One important disadvantage of adhesive bonding, however, is the relatively poor heat resistance of the bond-line as compared to inorganic materials such as metal or glass. Hence, in order to obtain high-performance assemblies, the production parameters must meet the specific requirements of the material used. This applies not only to the manufacturing sequences but also to the ambient conditions in which the joints are produced, because adhesion generally develops only during the production process, and the production parameters can have a decisive effect on the quality of the bond. The same more often than not applies to the cohesion of the adhesive layer. The technical properties of cohesion only develop during the course of the production process (with the exception of pressure-sensitive adhesives) after different setting processes. In this case, too, the production parameters mostly have a considerable effect on the quality of the final joint. By way of contrast, the joining process itself has only a minimally significant effect on the quality of traditional joining techniques, such as screw joints.

**Table 1.2**: **Characteristic features of adhesive joints**

| **Disadvantages** | **Advantages** |
|---|---|
| ▪ The adherents are not affected by heat | ▪ Limited stability to heat |
| ▪ Uniform stress distribution | ▪ Long-term use may affect the properties of the bon-line |
| ▪ Possibility to join large surfaces | |
| ▪ Possibility to join different materials | ▪ Cleaning and surface preparation of the adherents is necessary in many cases |
| ▪ Gas-proof and liquid-tight | ▪ Specific clamping devices are often required to fix the joint |
| ▪ Possibility to join very thin adherents | ▪ Specific production requirements to be met |
| ▪ No crevice corrosion | ▪ Non-destructive quality testing is only possible to a certain extent |
| ▪ No contact corrosion | |
| ▪ No precise fits of the adherent surfaces are necessary | |
| ▪ Good damping properties | |
| ▪ High dynamic strength | |

**Self-Assessment Exercise:**

Discuss the five methods by which parts can be joined in the workshop.

### 3.2 Welding operations and procedure

Welding is a process for joining two similar or dissimilar metals by fusion. It joins different metals/alloys, with or without the application of pressure and with or without the use of filler metal. The fusion of metal takes place by means of heat. The heat may be generated either from combustion of gases, electric arc, electric resistance or by chemical reaction.

Most of the metals and alloys can be welded by one type of welding process or the other. However, some are easier to weld than others. To compare this ease in welding term 'weldability' is often used. The *weldability* may be defined as property of a metal, which indicates the ease with which it can be welded with other similar or dissimilar metals. Elements of welding process used with common welding joints such as base metal, fusion zone, weld face, root face, root opening toe and root are shown in Figure 2.12, while welding terminologies are shown in Figure 2.13.

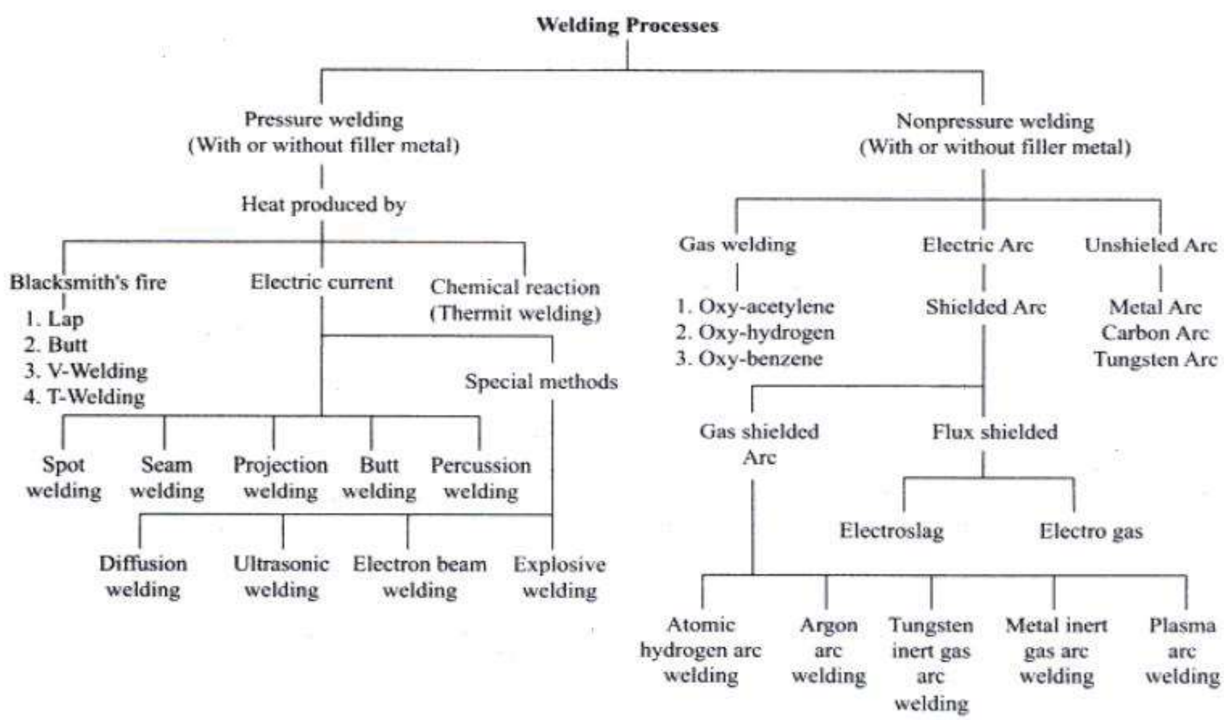



Figure 2.12: Welding processes

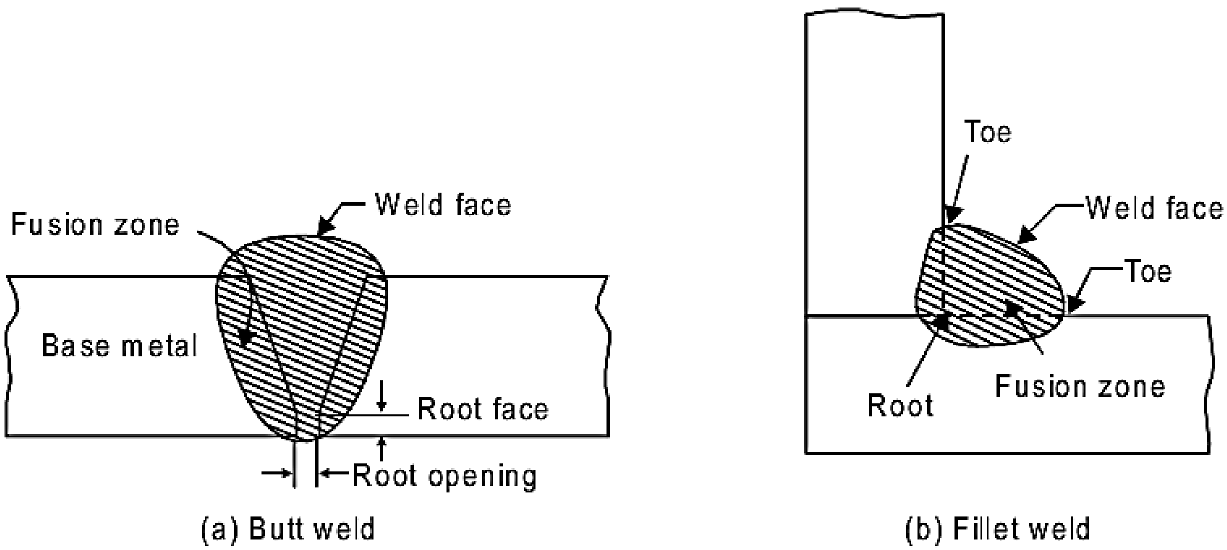



Figure 2.13: Welding terminologies

3.2.1 ***Edge preparations***

For welding, the edges of joining surfaces of metals are prepared first. Different edge preparations may be used for welding butt joints, which are discussed below.

3.2.2 ***Welding joints***

Some common welding joints are shown in Figure 2.14. Welding joints are of generally of two major kinds namely ***lap joint*** and ***butt joint***. The main types are described below.

i) ***Lap weld joint***

***Single-Lap Joint***

This joint, made by overlapping the edges of the plate, is not recommended for most work. The single lap has very little resistance to bending. It can be used satisfactorily for joining two cylinders that fit inside one another.

***Double-Lap Joint***

This is stronger than the single-lap joint but has the disadvantage that it requires twice as much welding.

***Tee Fillet Weld***

This type of joint, although widely used, should not be employed if an alternative design is possible.

ii) ***Butt weld joint***

a. *Single-Vee Butt Weld*

It is used for plates up to 15.8 mm thick. The angle of the vee depends upon the technique being used, the plates being spaced approximately 3.2 mm.

b. *Double-Vee Butt Weld*

It is used for plates over 13 mm thick when the welding can be performed on both sides of the plate. The top vee angle is either 60° or 80°, while the bottom angle is 80°, depending on the technique being used. Butt weld joints are shown in Figure 2.14.

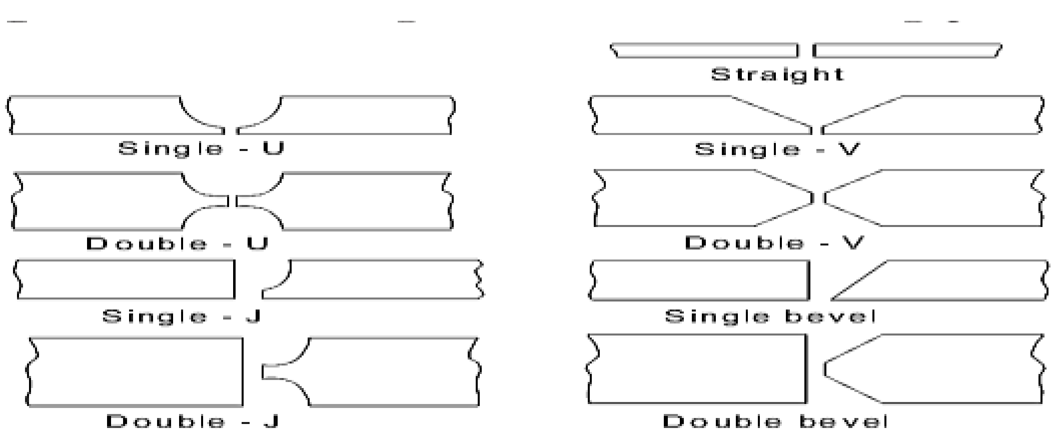



Figure 2.14: Types of butt weld joint

3.2.3 ***Welding positions***

As shown in Figure 2.15, there are four types of welding positions, which are given as:

a. Flat or down hand position

b. Horizontal position

c. Vertical position

d. Overhead position

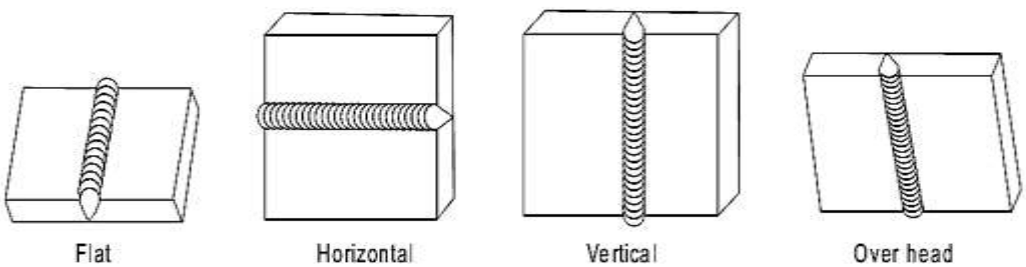



Figure 2.15: Welding positions

*Flat or Down-hand Welding Position*

The flat position or down hand position is one in which the welding is performed from the upper side of the joint and the face of the weld is approximately horizontal.

*Horizontal Welding Position*

In horizontal position, the plane of the workpiece is vertical and the deposited weld head is horizontal. This position of welding is most commonly used in welding vessels and reservoirs.

*Vertical Welding Position*

In vertical position, the plane of the work-piece is vertical and the weld is deposited upon a vertical surface. It is difficult to produce satisfactory welds in this position due to the effect of the force of gravity on the molten metal.

*Overhead Welding Position*

The overhead position is probably even more difficult to weld than the vertical position. Here the pull of gravity against the molten metal is much greater.

### 3.2.4 **Arc Welding Processes**

The process, in which an electric arc between an electrode and a work-piece or between two electrodes is utilized to weld base metals, is called an *arc welding process*. The basic principle of arc welding is shown in Figure 2.16. However, the basic elements involved in arc welding process are shown in Figure 2.17. Most of these processes use some shielding gas while others employ coatings or fluxes to prevent the weld pool from the surrounding atmosphere.

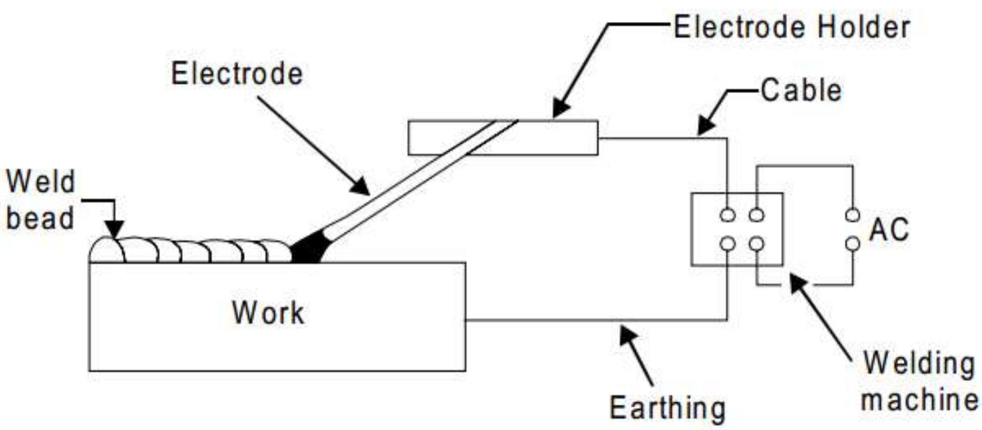
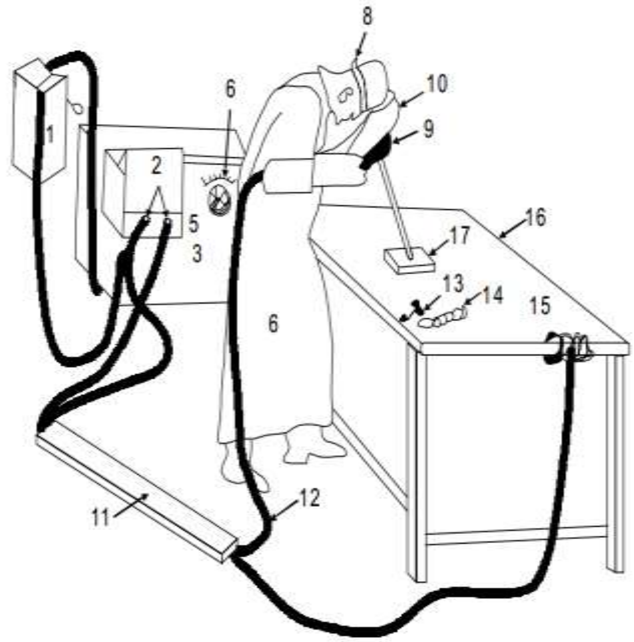



Figure 2.16: The basic principle of arc welding




1) Switch box
2) Secondary terminals
3) Welding machine
4) Current reading scale
5) Current regulating hand wheel
6) Leather apron
7) Asbestos hand gloves
8) Protective glasses strap
9) Electrode holder
10) Hand shield
11) Cable protection channel
12) Welding table
13) Chipping hammer
14) Wire brush
15) Earth clamp
16) Working table (metallic)
17) Workpiece/job

Figure 2.17: The basic principle of arc welding

a) ***Arc welding equipment***

Arc welding equipment, setup and related tools and accessories are discussed below. However, some common tools of arc welding are shown separately in the Figures below. Few of the important components of arc welding setup are also described below.

1**. *Arc welding power source***

Both direct current (DC) and alternating current (AC) are used for electric arc welding, each having its particular applications. DC welding supply is usually obtained from generators driven by electric motor or if no electricity is available by internal combustion engines. For AC welding supply, transformers are predominantly used for almost all Arc-welding where mains electricity supply is available. They have to step down the usual supply voltage (200-400 volts) to the normal open circuit welding voltage (50-90 volts). The following factors influence the selection of a power source:

a. Type of electrodes to be used and metals to be welded
b. Available power source (AC or DC)
c. Required output
d. Duty cycle
e. Efficiency
f. Initial costs and running costs
g. Available floor space
h. Versatility of equipment

2. ***Welding cables***

Welding cables are required for conduction of current from the power source through the electrode holder, the arc, the work piece and back to the welding power source. These are insulated copper or aluminium cables.

3. ***Electrode holder***

Electrode holder is used for holding the electrode manually and conducting current to it. These are usually matched to the size of the lead, which in turn matched to the amperage output of the arc welder. Electrode holders are available in sizes that range from 150 to 500 Amps Figure 2.18.

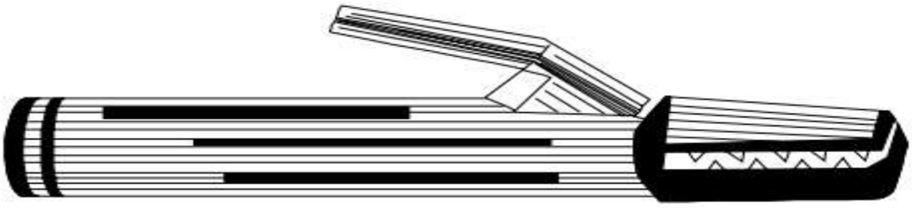


Figure 2.18: Electrode holder

4. ***Welding Electrodes***

An electrode is a piece of wire or a rod of a metal or alloy, with or without coatings. An arc is set up between electrode and workpiece. Welding electrodes are classified into following types-

i) *Consumable Electrodes*

(a) Bare Electrodes (b) Coated Electrodes

Consumable electrode is made of different metals and their alloys. The end of this electrode starts melting when arc is struck between the electrode and workpiece. Thus, consumable electrode itself acts as a filler metal. Bare electrodes consist of a metal or alloy wire without any flux coating on them. This coating on melting performs many functions like prevention of joint from atmospheric contamination, arc stabilizers etc. Figure 2.19.

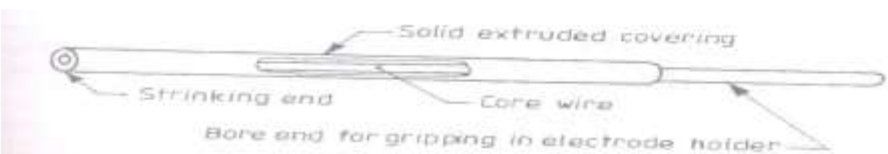



Figure 2.19: Part of Electrode

(ii) *Non-consumable Electrodes*

(a) Carbon or Graphite Electrodes (b) Tungsten Electrodes

Non-consumable electrodes are made up of high melting point materials like carbon, pure tungsten or alloy tungsten etc. These electrodes do not melt away during welding. However, practically, the electrode length goes on decreasing with the passage of time, because of oxidation and vaporization of the electrode material during welding. The materials of non-consumable electrodes are usually copper-coated carbon or graphite, pure tungsten, thoriated or zirconated tungsten.

5. *Hand Screen*

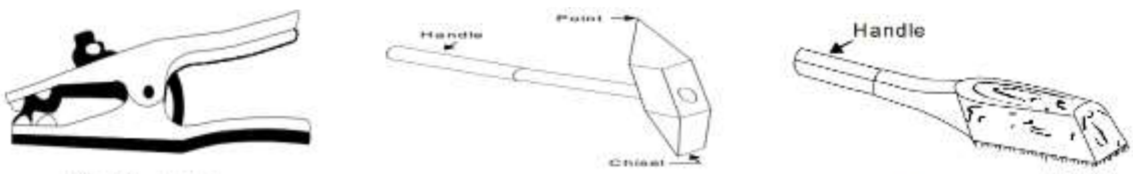
Hand screen used for protection of eyes and supervision of weld bead.

6. *Chipping hammer*

Chipping Hammer is used to remove the slag by striking.

7. *Wire brush*

Wire brush is used to clean the surface to be weld. Some welding accessories are shown in Figure 2.20.




a) b) c)

Figure 2.20: Some arc welding equipment a) Earth clamp b) Chipping hammer c) Wire brush

8. *Protective clothing*

Operator wears the protective clothing such as apron to keep away the exposure of direct heat to the body.

9) ***Safety Recommendations for ARC Welding***

The beginner in the field of arc welding must go through and become familiar with these general safety recommendations given below.

1. The body or the frame of the welding machine shall be efficiently earthed. Pipe lines containing gases or inflammable liquids or conduits carrying electrical conductors shall not be used for a ground return circuit All earth connections shall be mechanically strong and electrically adequate for the required current.

2. Welding arc is a source of infra-red and ultra-violet light. Consequently, the operator must use either helmet or a hand-shield fitted with a special filter glass to protect eyes

3. Excess ultra-violet light can cause an effect similar to sunburn on the skin of the welder

4. The welder’s body and clothing are protected from radiation and burns caused by sparks and flying globules of molten metal with the help of the following:

5. Gloves protect the hands of a welder.

6. Leather or asbestos apron is very useful to protect welder’s clothes and his trunk and thighs while seated he is doing welding.

7. For overhead welding, some form of protection for the head is required

8. Leather skullcap or peaked cap will do the needful.

9. Leather jackets and 1ather leggings are also available as clothes for body protection.

10. Welding equipment shall be inspected periodically and maintained in safe working order at all times.

11. Arc welding machines should be of suitable quality.

12. All parts of welding set shall be suitably enclosed and protected to meet the usual service conditions.

**Self Assessment Exercise:**

Discuss welding procedure in joining operations

### 3.3 Presswork operation in workshop

The term 'presswork' is used here to describe the process in which force is applied to sheet metal with the result that the metal is cut, i.e. in blanking and piercing, or is formed to a different shape, i.e. in bending.

The press working process is carried out by placing the sheet metal between a punch and die mounted in a press. The punch is attached to the moving part – the slide or ram – that applies the necessary force at each stroke. The die, correctly aligned with the punch, is attached to the fixed part or bedplate of the press. The press used may be manually operated by hand or by foot and used for light work or it may be power operated, usually by mechanical or hydraulic means, and capable of high rates of production.

#### 3.3.1 **Presses**

a) ***The fly press***

Blanking, piercing and bending of light work where the required force is small and the production rate is low may be carried out on a fly press. A hand-operated bench-type fly press is shown in Figure 2.21. The body is a C-shaped casting of rigid proportions designed to resist the forces acting during the press working operation. The C shape gives an adequate throat depth to accommodate a range of work sizes. (The throat depth is the distance from the centre of the slide to the inside face of the body casting.) The bottom part of the casting forms the bed to which tooling is attached. The top part of the casting is threaded to accept the multi-start square-threaded screw, which carries the handle at its top end and the slide at its bottom end.

Figure 2.21: Fly press

In operation, the vertical handle is grasped and the handle is partially rotated. This provides, through the multi-start thread, a vertical movement of the slide. A punch and die fitted in the slide and on the bed, and correctly aligned with each other, are used to carry out the required press working operation.

b) ***Power presses***

Power presses are used where high rates of production are required. A power press may be identified by the design of the frame and its capacity – i.e. the maximum force capable of being delivered at the work, e.g. 500 kN ('50 tons'). The source of power may be mechanical or hydraulic. Different types of press are available in a wide range of capacities, the choice depending on the type of operation, the force required for the operation and the size and type of tooling used.

One of the main types of power press is the open-fronted or gap-frame type. This may be rigid or inclinable. The inclinable feature permits finished work to drop out the back by gravity. A mechanical open-fronted rigid press is shown in Figure 3.65. The model shown has a capacity of1000 kN ('100 tons') and operates at 60 strokes per minute (it is shown without guards for clarity). The open nature of this design gives good accessibility of the tools and allows the press to be operated from either side or from the front.

The limitation of the open-fronted press is the force, which can be applied. High forces have a tendency to flex the frame and so open the gap between the slide and the bedplate. This flexing of the frame can be overcome on the large-capacity presses by fitting tie-rods between the bedplate and the top of the frame as shown in Figure 2.22.

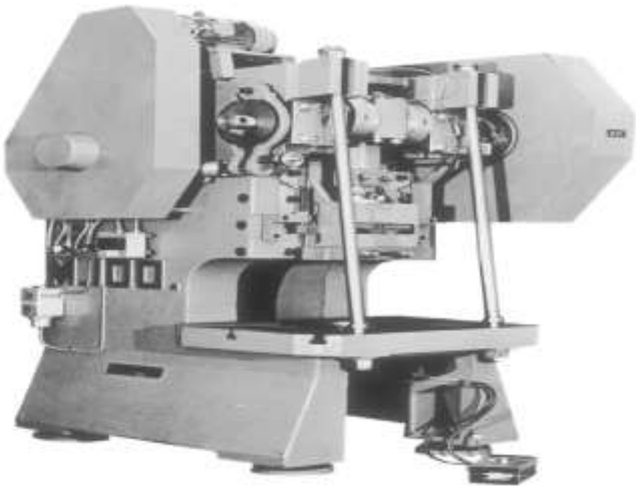


Figure 2.22: Mechanical open-fronted rigid power press

c) ***Mechanical presses***

Mechanical power presses derive their energy for operation from a constantly rotating flywheel driven by an electric motor. The flywheel is connected to a crankshaft through a clutch, which can be set for continuous or single stroking. In the single-stroke mode, the clutch is automatically disengaged at the end of each stroke and the press will not restart until activated by the operator. A connecting rod is attached at one end to the crankshaft and at its other end to the slide. Adjustment is provided to alter the position of the slide, and in some presses, the length of stroke can also be adjusted by means of an eccentric on the crankshaft. A brake is fitted to bring the crankshaft to rest at the correct position.

d) ***Hydraulic presses***

Hydraulic power presses derive their power from high-pressure hydraulic pumps, which operate the ram. The load applied is completely independent of the length and stroke, i.e. full load can be applied at any point in the stroke. The applied load is controlled by a relief valve, which gives automatic protection against overload. Again, by means of valves, the ram can be made to approach the work rapidly and then be shifted to a lower speed before contacting the work, thus prolonging the life of the tool but still giving fast operating speeds.

Figure 2.23: Hydraulic straight-sided power press

**Self Assessment Exercise:**

Discuss presswork process in the workshop

**4.0 Conclusion**

We conclude that various metallic and non-metallic materials in the can be joined to form the desired components by various joining methods. However, this unit has been written in a way that learner will find it easy to understand and retained the different ways materials and components parts or workpieces can be joined.

**5.0 Summary**

Different joining methods for different materials and equipment as well as presswork operations were explained and illustrated. This concept of materials joining and presswork operations were clearly explained and distinguished, in order to drive home the point for clearer understanding of the student.

**6.0 Tutor-Marked Assignment**

a) Discuss the five methods by which parts can be joined in the workshop.

b) Discuss welding procedure in joining operations

c) Discuss the process of press work in the workshop

**7.0 References/Further Readings**

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## UNIT 3: PRIMARY FORMING AND CASTING PROCESS/TECHNIQUES

**CONTENTS**



### 1.0 Introduction

The main aim of this unit is to provide a broad understanding of manufacturing processes associated with primary forming. It will give learners a broad understanding of casting process and techniques in manufacturing and production processes.

### 2.0 Objective

Under this unit student should be able to

- Understand the processes involved in forming of metals and non-metallic materials.
- Understand the processes involved in primary forming
- Understand the rudiments and techniques of casting of metals and non-metallic materials.

## 3.0 Main Content

### 3.1 Primary Metal Forming Operations

Metal forming is a very important manufacturing operation. It enjoys industrial importance among various production operations due to its advantages such as cost effectiveness, enhanced mechanical properties, flexible operations, higher productivity, considerable material saving.

The objects and articles that we use in our daily life are man-made, engineered parts, which are obtained from some raw material through some manufacturing process. All these objects are made of a number of small components assembled into finished product. The pen that we use for writing, for example is made of several small parts, assembled together. An automobile is supposed to be an assembly of more than 15000 parts, produced through various manufacturing operations. Manufacturing of finished parts and components from raw materials is one of the most important steps in production.

Production encompasses all types of manufacturing processes. Manufacturing refers to the conversion of raw materials into finished products employing suitable techniques. There are several methods of manufacturing such as metal casting, metal forming, metal machining, metal joining and finishing. Some of the modern methods of manufacturing include micro machining, Nano fabrication, ultra-precision manufacturing etc.

Metal forming is a general term for a large group, which includes a wide variety of manufacturing processes. Metal forming processes are characteristic in that the metal being processed is plastically deformed to shape it into a desired geometry. In order to plastically deform a metal, a force must be applied that will exceed the yield strength of the material. When low amounts of stress are applied to a metal, it will change its geometry slightly, in correspondence to the force that is exerted.

Computers and robots play important role in modern manufacturing techniques, today. Modelling and simulation of the process prior to mass production helps the manufacturing engineer fix up the best operating parameters and hence achieve the finished product to the utmost level of quality and cost-effectiveness.

The present sub-unit is focused on one of the important methods of manufacturing, namely, metal forming.

### 3.1.1 Manufacturing Operations

Materials are converted into finished products though different manufacturing processes. Manufacturing processes are classified into shaping [casting], forming, joining, and coating, dividing, machining and modifying material property as shown in Figure 2.24 below.

Of these manufacturing processes, forming is a widely used process, which finds applications in automotive, aerospace, defence and other industries. Wrought forms of materials are produced through bulk or sheet forming operations. Cast products are made through shaping – moulding and casting. A typical automobile uses formed parts such as wheel rims, car body, valves, rolled shapes for chassis, stamped oil pan, etc. In our daily life, we use innumerable formed products e.g. cooking vessels, toothpaste containers, bicycle body, chains, tube fitting, fan blades etc.

Forming is the process of obtaining the required shape and size on the raw material by subjecting the material to plastic deformation through the application of tensile force, compressive force, bending or shear force or combinations of these forces.

### 3.1.2 Classification of metal forming processes

Typically, metal forming processes can be classified into two broad groups. One is ***bulk forming*** and the other is ***sheet metal forming***. Bulk deformation refers to the use of raw materials for forming which have low surface area to volume ratio. Rolling, forging, extrusion and drawing are bulk forming processes. In bulk deformation processing methods, the nature of force applied may be compressive, compressive and tensile, shear or a combination of these forces. Bulk forming is accomplished in forming presses with the help of a set of tool and die. Examples for products produced by bulk forming are *gears, bushed, valves, engine parts such as valves, connecting rods, hydraulic valves*, etc.

Sheet metal forming involves application of tensile or shear forces predominantly. Working upon sheets, plates and strips mainly constitutes sheet forming. Sheet metal operations are mostly carried out in presses – hydraulic or pneumatic. A set of tools called die and punch are used for the sheet working operations. Bending, drawing, shearing, blanking, punching are some of the sheet metal operations.

A new class of forming process called powder forming is gaining importance due to its unique capabilities. One of the important merits of powder forming is its ability to produce parts very near to final dimensions with minimum material wastage. It is called near-net-shape forming. Material compositions can be adjusted to suit the desirable mechanical properties. Formability of sintered metals is greater than conventional wrought materials. However, the challenge in powder forming continues to be the complete elimination or near-complete elimination of porosity. Porosity reduces the strength, ductility and corrosion resistance and enhances the risk of premature failure of components.

### 3.1.3 Brief Description of Forming Operations

***a) Bulk forming processes***

***i) Rolling***

Rolling is a compressive deformation process, which is used for producing semi-finished products such as bars, sheets, plates and finished products such as angles, channels, sections. Rolling can be carried out both in hot and cold conditions.

**ii)** ***Forging***

Forging is a bulk forming process in which the work piece or billet is shaped into finished part by the application of compressive and tensile forces with the help of a pair of tools called die and punch. Forging can be done in open dies or closed dies. Open die forging is usually used for preliminary shaping of raw materials into a form suitable for subsequent forming or machining.

***Open die forging closed die forging***

Open die forming is done using a pair of flat faced dies for operations such as drawing out, thinning, etc.

Closed die forming is performed by squeezing the raw material called billet inside the cavity formed between a pair of shaped dies. Formed products attain the shape of the die cavity. Valve parts, pump parts, small gears, connecting rods, spanners, etc. are produced by closed die forming.

iii) ***Coining***

Coining is the process of applying compressive stress on surface of the raw material in order to impart special shapes on to the surface from the embossing punch – e.g. coins, medallions.

***iv) Extrusion***

Extrusion involves forcing the raw material through a narrow opening of constant cross-section or varying cross-section in order to reduce the diameter and increase the length. Extrusion can be done hot or cold. Extruded products include shafts, tubes, cans, cups, and gears.

Basically, there are two methods of extrusion, forward and backward extrusions. In forward extrusion, the work and the extrusion punch move along the same direction. In backward extrusion, the punch moves opposite to the direction of movement of the work piece.

***v) Drawing***

Wire drawing process is used for producing small diameter wires from rods by reducing their diameter and stretching their length through the application of tensile force. Musical strings are produced by wire drawing process. Seamless tubes can be produced by tube drawing process.

*Deep drawing: a sheet metal process*

Deep drawing is a sheet metal process the process in which a sheet metal is forced into cup of hollow shape without altering its thickness – using tensile and compressive forces. Complex shapes can be produced by deep drawing of blanks in stages – redrawing, multiple draw deep drawing etc.

Hydro mechanical deep drawing uses both punch force and hydrostatic force of a pressurized fluid for achieving the shape. Flanges and collars are formed by flanging process. Spinning transforms a sheet metal into a hollow shape by compressive and tensile stresses. Spinning mandrel of given shape is used against a roll head. Embossing imparts an impression on the work piece by means of an embossing punch. Bending of sheets includes rotary bending, swivel bending, roll bending using rotary die. Die bending using flat die or shaped die is used for bending of sheets, or die coining of sheets.

### 3.1.4 Forming Tools

Forming i.e. shaping of the sheet metal such as folding, bending, curling, etc., are done by using the following types of forming tools.

***1. Stakes***

Stakes are the sheet metal anvils used for bending, seaming and forming by using a hammer or mallet. They work as the supporting tool as well as the forming tools. They are made in different sizes and shapes depending upon the job requirement. Commonly used stakes are shown in Figure 2.24.

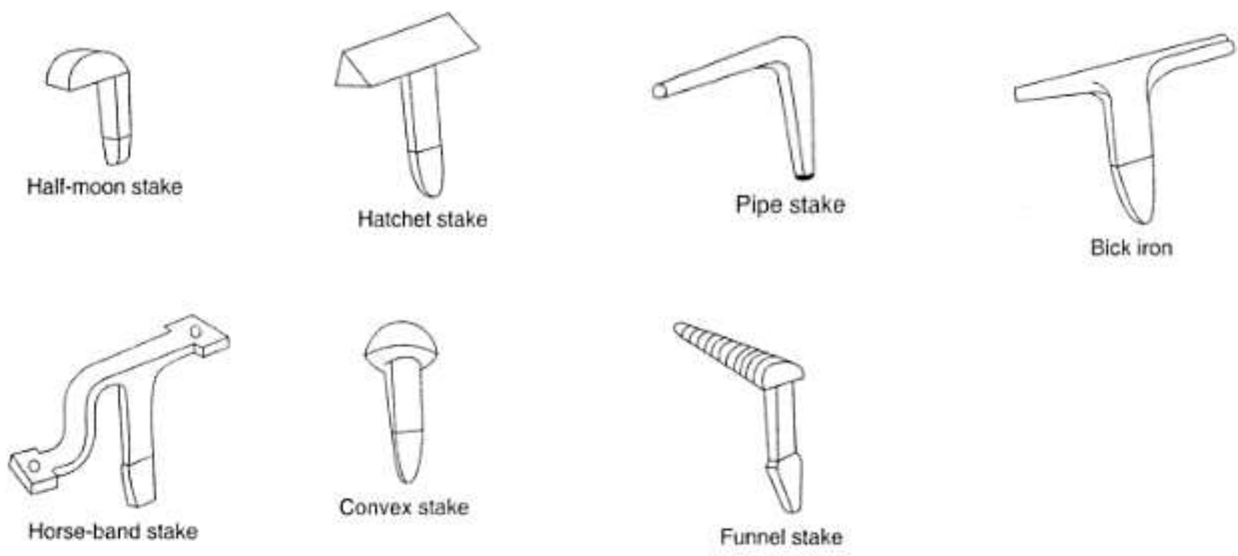


Figure 2.24: Commonly used stakes

2 Stake Holder

The stake holder used in sheet metal shop is a rectangular bench plate as shown in Figure 2.25.

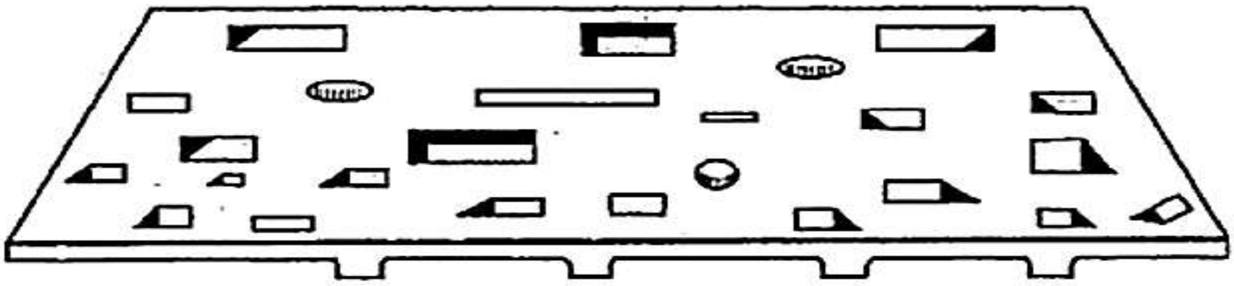

Figure 2.35: Stake holder

***3. Hammers***

The sheet metal is shaped by hammering or striking with mallet, after keeping the work on suitable form of stake. The hammers used for sheet metal work are (a) Setting hammer, for setting down the edge while making double seam, (b) Raising hammer for forming curved or hollow shape from flat piece, and (c) Riveting hammer for riveting purpose. Mallets are soft hammers used to give soft blows which will not damage the sheet at the same time will shape them. The commonly used types of hammers and mallets are shown in Figure 2.26.

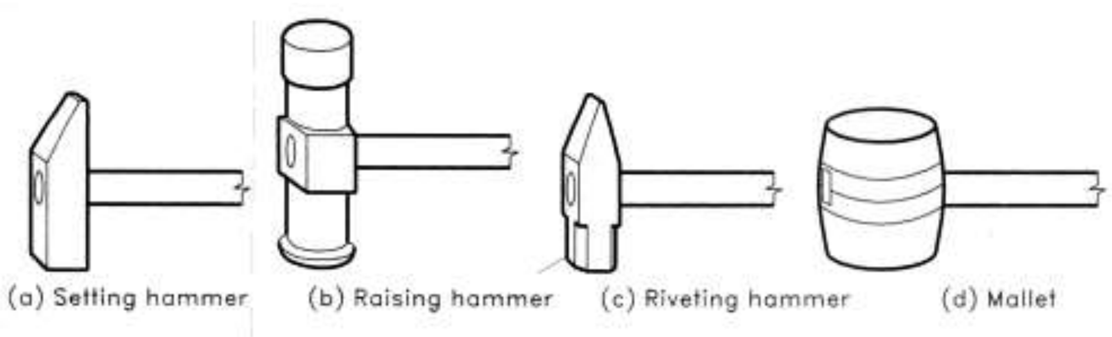


Figure 2.36: Hammer types for forming

**Self Assessment Exercise:**

What is metal forming, and what are the categories of metal forming

**3.2 Casting Process/Techniques**

Casting is one of the oldest manufacturing process. It is the first step in making most of the products. The casting process involves pouring of liquid metal into a mould cavity and allowing it to solidify to obtain the final casting. The flow of molten metal into the mould cavity depends on several factors like minimum section thickness of the part, presence of corners, non-uniform cross-section of the cast, and so on.

### 3.2.1 Introduction to Casting processes

Metal casting process begins by creating a mould, which is the 'reverse' shape of the part we need. The mould is made from a refractory material, for example, sand. The metal is heated in an oven until it melts, and the molten metal is poured into the mould cavity. The liquid takes the shape of cavity, which is the shape of the part. It is cooled until it solidifies. Finally, the solidified metal part is removed from the mould.

A large number of metal components in designs we use every day are made by casting. The reasons for this include:

(a) Casting can produce very complex geometry parts with internal cavities and hollow sections.

(b) It can be used to make small (few hundred grams) to very large size parts (thousands of kilograms).

(c) It is economical, with very little wastage: the extra metal in each casting is re-melted and re-used.

(d) Cast metal is isotropic – it has the same physical/mechanical properties along any direction.

Common examples: door handles, locks, the outer casing or housing for motors, pumps, etc., wheels of many cars. Casting is also heavily used in the toy industry to make parts, e.g. toy cars, planes, and so on.

In all casting processes, a metal alloy is melted and then poured or forced into a mould where it takes the shape of the mould and is allowed to solidify. Once it has solidified, the casting is removed from the mould. Some castings require finishing due to the cast appearance, tolerance, or surface finish requirements.

During solidification, most metals shrink (grey cast iron is an exception) so moulds must be made slightly oversize in order to accommodate the shrinkage and still achieve the desired final dimensions.

There are two basic types of moulds used in castings, namely, expendable moulds (sand casting and investment casting) that are destroyed to remove the part, and permanent moulds (die casting). Expendable moulds are created using either a permanent pattern (sand casting) or an expendable pattern (investment casting). Permanent moulds, of course, do not require a pattern.

Two of the major advantages for selecting casting as the process of choice for creating a part are the wide selection of alloys available and the ability, as in injection moulding, to create complex shapes. However, not all alloys can be cast by all processes.

**Steps involved in metal casting**

Generally, steps involved in metal casting include:

- Making mould cavity
- Material is first liquefied by properly heating it in a suitable furnace.
- Liquid is poured into a prepared mould cavity
- allowed to solidify
- product is taken out of the mould cavity, trimmed and made to shape

The most common metal casting processes are sand casting, investment casting, and die casting.

### 3.2.2 Sand Casting

Sand casting is a process in which a sand mould is formed by packing a mixture of sand, a clay binder, and water around a wood or metal pattern that has the same external shape as the part to be cast. A pattern can come in two halves: a top half (called a cope) and a bottom half (called a drag). Each half is placed in a moulding box, and the sand mixture is then poured all around the pattern. After the sand is packed, holes, which are used to pour the molten metal into the mould (sprue) and to be used as a reservoir of molten metal (risers), are formed in the sand. Vents are also created in order to allow the escape of gases from the melt. Then the pattern is removed and a runner system or small passageway is created inside the die through which the melt can flow and be distributed. Gates are the sections where the melt enters the impression. Thus, sprues feed the runners, and the runners feed the gates.

Sand casting also results in parts with internal porosity that causes leaking and reduces part strength. Porosity is the result of voids or pores caused by trapped air, liquids, or gases that come about during freezing of the melt. Trapped air and liquids are a result of the dendrites (a crystal that has a treelike branching pattern) that occur when the cooling rate is relatively slow, as in sand casting. Because the trapped liquids and gases continue to freeze and shrink, holes are created.

### 3.2.3 Investment Casting

Investment casting is typically used when low production volumes are expected (e.g., less than 10,000 pieces), whereas die casting tends to be used when high production volumes are expected. Investment casting can produce parts of similar geometric shapes and size.

Investment cast parts can be made of a wide range of metal alloys including aluminium and copper alloys, carbon and low alloy steels, stainless steels, tool steels, and nickel and cobalt alloys. In investment casting, a metal die or mould is made by either machining or casting. The more complicated the shape (because of undercuts, for example), the more costly the metal dies.

To make parts, the mould cavity is filled with molten metal that is allowed to solidify. To facilitate filling of the mould the melt is poured while the mould is still hot. When the part has cooled, the mould is destroyed and the part removed. The tolerances and surface finishes achievable by investment casting are such that machining is not generally required. The investment-casting process, also called the lost-wax process, was first used during the period 4000-3500 B.C. The pattern is made of wax or a plastic such as polystyrene.

### 3.2.4 Die Casting

Like injection moulding, die casting is a process in which a melt is injected under pressure into a metal mould. The melt then cools and solidifies, conforming to the internal shape of the mould.

As in injection moulding, as the part geometry becomes more complex, the cost of the mould increases. In addition, as the wall thickness increases, the cycle time required to produce the part also increases. While the thin film, called flashing, that extrudes out through the spaces between parts of a mould is easily removed by hand in the case of injection-moulded parts, the same cannot be said for die-cast parts. Hence, because of the difficulty of flash removal, internal undercuts are not generally die cast. Nevertheless, both injection moulding and die casting can economically produce parts of great complexity.

There are two types of die casting machines: a hot chamber machine and a cold chamber machine. Both have four main elements:

(1) a source of molten metal, (2) an injection mechanism, (3) a mould, and (4) a clamping system.

In a hot chamber machine, the injection mechanism is submerged in the molten metal. Because the plunger is submerged in the molten metal, only alloys such as zinc, tin, and lead, (which do not chemically attack or erode the submerged injection system) can be used. Aluminium and copper alloys are not suitable for hot chamber machines.

When the die is opened and the plunger retracted the molten metal flows into the pressure chamber (gooseneck). After the mould (die) is closed, the hydraulic cylinder is actuated and the plunger forces the melt into the die at pressures between 14 and 28 MPa (2,000-4,000psi). After the melt solidifies, the die is opened, the part ejected, and the cycle repeated. In Die casting the metal is injected into the mould under high pressure.

### 3.2.5 Other Casting Processes

Die casting, investment casting, and sand casting are the most commonly used casting processes. However, other casting processes, such as *centrifugal casting*, *carbon dioxide mould casting*, *permanent mould casting*, *plaster mould casting*, *shell mould casting*, and *ceramic casting* are also used.

In ***centrifugal casting***, molten metal is poured into a mould that is revolving about a horizontal or vertical axis. Horizontal centrifugal casting is used to produce rotationally symmetric parts, such as pipes, tubes, bushings, and other parts. Vertical centrifugal casting can be used to produce both symmetrical as well as non-symmetrical parts. However, since only a reasonable amount of imbalance can be tolerated for a non-symmetrical part, the most common shapes produced are cylinders and rotationally symmetric flanged parts. Centrifugal casting of metal produces a finer grain structure and thinner ribs and webs than can be achieved in ordinary static mould casting.

In ***carbon dioxide mould casting***, sodium silicate (water glass) is used as a binder in place of the clay binders used in conventional sand moulds and cores. In this process, a low strength mould is made with a mixture of sodium silicate and sand. When CO: gas is sent through the mixture the mould is hardened. The pattern can then be removed and the melt added. CO: moulds are used when closer tolerances than those attainable through sand casting are needed.

In ***permanent mould casting,*** also referred to as gravity die casting, molten metal is poured by gravity into a reusable permanent mould made of two or more parts. This process is closely related to die casting; however, the tolerances and surface finishes achievable by this process are not as good as those obtainable by "pressure" die casting. Because of the high pressures used during filling of the mould during die casting, die casting can produce more complex shapes than achievable via permanent mould casting. Gravity die casting accounts for less than 5 % of all die castings produced.

In ***plaster mould casting***, moulds are made by coating a pattern with plaster and allowing it to harden. The pattern is then removed and the plaster mould baked.

Ceramic moulding is similar to plaster moulding. In ceramic moulding, a fine grain slurry is poured over the pattern and allowed to set chemically.

***Shell mould casting*** is a process in which an expendable mould is formed by pouring a resin-coated sand onto a heated pattern. The sand bonds together to form a hardened shell that corresponds to the outer shape of the pattern. Two shell halves are put together to form the single-use mould. This process is used for the production of small parts that require a finer tolerance than is obtainable via sand casting. If better tolerances and surface finishes are required, then investment casting and pressure die casting are necessary.

**Self Assessment exercise:**

Explain casting process and techniques in parts manufacturing.

## 4.0 Conclusion

Forming and casting are the first steps in the manufacturing of metallic components. Casting as a production process enables wide selection of available alloys, and especially in injection moulding for the creation of complex shapes of parts/accessories. Efficient metal forming and casting lead to cost effectiveness, enhanced mechanical properties, flexible operations, higher productivity, considerable material saving.

## 5.0 Summary

Students have been exposed and taught the various metal forming operations and techniques. Various casting methods, peculiarities of these techniques have been explained and illustrated to students to prepare them for the required knowledge in parts forming and casting in manufacturing technology.

## 6.0 Tutor-Marked Assignment

a) Discuss the primary metal forming processes and operations,

b) Describe material behaviour when forming metals.

c) Describe the types of casting and their peculiarities.

## 7.0 References/Further Readings


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## MODULE THREE

## MATERIAL MARKING AND INTRODUCTION TO ENGINEERING DRAWING



### UNIT 1: PATTERN MAKING, RAMPING AND MANUFACTURING PROCESSES

**CONTENTS**



#### 1.0 Introduction

This unit looked at pattern marking and core making on materials being prepared for part manufacturing.

#### 2.0 Objective

At the end of this unit student should be able to

- Know the purpose, type and uses of pattern in parts' production.
- Explain different type of materials for pattern making and their peculiarities
- Understand the different types of tool used for manufacturing.
- Know the characteristics of available engineering materials used for production.

**3.0 Main Content**

**3.1`Pattern making and core prints**

A pattern is a model or the replica of the object (to be casted). It is embedded in moulding sand and suitable ramming of moulding sand around the pattern is made. The pattern is then withdrawn for generating cavity (known as mould) in moulding sand. Thus, it is a mould-forming tool. Pattern can be said as a model or the replica of the object to be cast except for the various al1owances a pattern exactly resembles the casting to be made. It may be defined as a model or form around which sand is packed to give rise to a cavity known as mould cavity in which when molten metal is poured, the result is the cast object. When this mould/cavity is filled with molten metal, molten metal solidifies and produces a casting (product). Therefore, the pattern is the replica of the casting.

A pattern prepares a mould cavity for the purpose of making a casting. It may also possess projections known as core prints for producing extra recess in the mould for placement of core to produce hol1owness in casting. It may help in establishing seat for placement of core at locating points on the mould in form of extra recess. It establishes the parting line and parting surfaces in the mould. It may help to position a core in case a part of mould cavity is made with cores, before the moulding sand is rammed. It should have finished and smooth surfaces for reducing casting defects. Runner, gates and risers used for introducing and feeding molten metal to the mould cavity may sometimes form the parts of the pattern. The first step in casting is pattern making. The pattern is a made of suitable material and is used for making cavity called mould in moulding sand or other suitable mould materials. When this mould is filled with molten metal and it is allowed to solidify, it forms a reproduction of the, pattern which is known as casting.

***Objectives of a pattern***

1. Pattern prepares a mould cavity for the purpose of making a casting.

2. Pattern possesses core prints, which produces seats in form of extra recess for core placement in the mould.

3. It establishes the parting line and parting surfaces in the mould.

4. Runner, gates and riser may form a part of the pattern.

5. Properly constructed patterns minimize overall cost of the casting.

6. Pattern may help in establishing locating pins on the mould and therefore on the casting with a purpose to check the casting dimensions.

7. Properly made pattern having finished and smooth surface reduce casting defects.

Patterns are generally made in pattern making shop. Proper construction of pattern and its material may reduce overall cost of the castings.

### 3.1.1 Pattern making materials

The common materials used for making patterns are wood, metal, plastic, plaster, wax or mercury. There are some important pattern materials are discussed below.

#### 1. Wood

Wood is the most popular and commonly used material for pattern making. It is cheap, easily available in abundance, repairable and easily fabricated in various forms using resin and glues. It is very light and can produce highly smooth surface. Wood can preserve its surface by application of a shellac coating for longer life of the pattern. However, in spite of its above qualities, it is susceptible to shrinkage and warpage and its life is short because of the reasons that it is highly affected by moisture of the moulding sand. After some use, it warps and wears out quickly as it is having less resistance to sand abrasion. It cannot withstand rough handily and is weak in comparison to metal. In the light of above qualities, wooden patterns are preferred only when the numbers of castings to be produced are less. The main varieties of woods used in pattern making are shisham, kail, deodar, teak and mahogany.

***Shisham***

It is dark brown in colour having golden and dark brown stripes. It is very hard to work and blunts the cutting tool very soon during cutting. It is very strong and durable. Besides making pattern, it is also used for making good variety of furniture, tool handles, beds, cabinets, bridge piles, plywood etc.

***Kail***

It has too many knots. It is available in Himalayas and yields a close grained, moderately hard and durable wood. It can be very well painted. Besides making pattern, it is also utilized for making wooden doors, packing case, cheap furniture etc.

***Deodar***

It is white in colour when soft but when hard, its colour turns toward light yellow. It is strong and durable. It gives fragrance and has some quantity of oil and therefore it is not easily attacked by insects. It is available in Himalayas at a height from 1500 to 3000 meters. It is used for making pattern, manufacturing of doors, furniture, patterns, railway sleepers etc. It is a soft wood having a close grain structure unlikely to warp. It is easily workable and its cost is low. It is preferred for making pattern for production of small size castings in small quantities.

***Teak Wood***

It is hard, very costly and available in golden yellow or dark brown colour. Special stripes on it add to its beauty. In India, it is found in M.P. It is very strong and durable and has wide applications. It can maintain good polish. Besides making pattern, it is used for making good quality furniture, plywood, ships etc. It is a straight-grained lightwood. It is easily workable and has little tendency to warp. Its cost is moderate.

***Mahogany***

This is a hard and strong wood. Patterns made of this wood are more durable than those mentioned above are and they are less likely to warp. It has a uniform straight grain structure and it can be easily fabricated in various shapes. It is costlier than teak and pine wood. It is generally not preferred for high accuracy for making complicated pattern. It is also preferred for production of small size castings in small quantities. The other Indian woods, which may also be used for pattern making, are deodar, walnut**,** kail, maple, birch, cherry and shisham.

***Advantages of wooden patterns***

1 Wood can be worked easily.

2 It is light in weight.

3 It is easily available.

4 It is very cheap.

5 It is easy to join.

6 It is easy to obtain good surface finish.

7 Wooden laminated patterns are strong.

8 It can be repaired easily.

***Disadvantages***

1 It is susceptible to moisture.

2 It tends to warp.

3 It wears out quickly due to sand abrasion.

4 It is weaker than metallic patterns.

**2. Metal**

Metallic patterns are preferred when the number of castings required is large enough to justify their use. These patterns are not much affected by moisture as wooden pattern. The wear and tear of this pattern is very less and hence possess longer life. Moreover, metal is easier to shape the pattern with good precision, surface finish and intricacy in shapes. It can withstand against corrosion and handling for longer period. It possesses excellent strength to weight ratio. The main disadvantages of metallic patterns are higher cost, higher weight and tendency of rusting.

It is preferred for production of castings in large quantities with same pattern. The metals commonly used for pattern making are cast iron, brass, bronzes, and aluminium alloys.

***Cast Iron***

It is cheaper, stronger, tough, and durable and can produce a smooth surface finish. It also possesses good resistance to sand abrasion. The drawbacks of cast iron patterns are that they are hard, heavy, brittle and get rusted easily in presence of moisture.

***Advantages***

1. It is cheap

2. It is easy to file and fit

3. It is strong

4. It has good resistance against sand abrasion

5. Good surface finish

***Disadvantages***

1 It is heavy

2 It is brittle and hence it can be easily broken

3 It may rust

***Brasses and Bronzes***

These are heavier and expensive than cast iron and hence are preferred for manufacturing small castings. They possess good strength, machinability and resistance to corrosion and small castings. They possess good strength, machinability and resistance to corrosion and

wear. They can produce a better surface finish. Brass and bronze pattern is finding application in making match plate pattern

***Advantages***

1. Better surface finish than cast iron.

2. Very thin sections can be easily casted.

***Disadvantages***

1. It is costly

2. It is heavier than cast iron.

***Aluminium Alloys***

Aluminium alloy patterns are more popular and best among all the metallic patterns because of their high light ness, good surface finish, low melting point and good strength. They also possesses good resistance to corrosion and abrasion by sand and thereby enhancing longer life of pattern. These materials do not withstand against rough handling. These have poor repair ability and are preferred for making large castings.

***Advantages***

1. Aluminium alloys pattern does not rust.

2. They are easy to cast.

3. They are light in weight.

4. They can be machined easily.

***Disadvantages***

1. They can be damaged by sharp edges.

2. They are softer than brass and cast iron.

3. Their storing and transportation needs proper care.

***White Metal (Alloy of Antimony, Copper and Lead)***

***Advantages***

1. It is best material for lining and stripping plates.

2. It has low melting point around 260°C

3. It can be cast into narrow cavities.

***Disadvantages***

1. It is too soft.

2. Its storing and transportation needs proper care

3. It wears away by sand or sharp edges.

**3. Plastic**

Plastics are getting more popularity now a days because the patterns made of these materials are lighter, stronger, moisture and wear resistant, non-sticky to moulding sand, durable and they are not affected by the moisture of the moulding sand. Moreover, they impart very smooth surface finish on the pattern surface. These materials are somewhat fragile, less resistant to sudden loading and their section may need metal reinforcement. The plastics used for this purpose are thermosetting resins. Phenolic resin plastics are commonly used. These are originally in liquid form and get solidified when heated to a specified temperature. To prepare a plastic pattern, a mould in two halves is prepared in *Plaster of Paris* with the help of a wooden pattern known as a master pattern. The phenolic resin is poured into the mould and the mould is subjected to heat. The resin solidifies giving the plastic pattern. Recently a new material has stepped into the field of plastic, which is known as *foam plastic*. Foam plastic is now being produced in several forms and the most common is the expandable polystyrene plastic category. It is made from benzene and ethyl benzene.

**4. Plaster**

This material belongs to gypsum family, which can be easily cast and worked with wooden tools and preferable for producing highly intricate casting. The main advantages of plaster are that it has high compressive strength and is of high expansion setting type, which compensate for the shrinkage allowance of the casting metal. Plaster of Paris pattern can be prepared either by directly pouring the slurry of plaster and water in moulds prepared earlier from a master pattern or by sweeping it into desired form by the sweep and strickle method. It is also preferred for production of small size intricate castings and making core boxes.

**5. Wax**

Patterns made from wax are excellent for investment casting process. The materials used are blends of several types of waxes, and other additives, which act as polymerizing agents, stabilizers, etc. The commonly used waxes are paraffin wax, shellac wax, bees-wax, cerasin wax, and microcrystalline wax. The properties desired in a good wax pattern include low ash content up to 0.05 per cent, resistant to the primary coat material used for investment, high tensile strength and hardness, and substantial weld strength. The general practice of making wax pattern is to inject liquid or semi-liquid wax into a split die. Solid injection is also used to avoid shrinkage and for better strength. Waxes use helps in imparting a high degree of surface finish and dimensional accuracy castings. Wax patterns are prepared by pouring heated wax into split moulds or a pair of dies. The dies after having been cooled down are parted off. Now the wax pattern is taken out and used for moulding. Such patterns need not to be drawn out solid from the mould. After the mould is ready, the wax is poured out by heating the mould and keeping it upside down. Such patterns are generally used in the process of investment casting where accuracy is linked with intricacy of the cast object.

### 3.1.2 Factors affecting selection of pattern materials

The following factors must be taken into consideration while selecting pattern materials:

1. Number of castings to be produced. Metal pattern are preferred when castings are required large in number.

2. Type of mould material used.

3. Kind of moulding process.

4. Method of moulding (hand or machine).

5. Degree of dimensional accuracy and surface finish required.

6. Minimum thickness required.

7. Shape, complexity and size of casting.

8. Cost of pattern and chances of repeat orders of the pattern

### 3.1.3 Types of pattern

The types of the pattern and the description of each are given below.

1. One piece or solid pattern

2. Two piece or split pattern

3. Cope and drag pattern

4. Three-piece or multi- piece pattern

5. Loose piece pattern

6. Match plate pattern

7. Follow board pattern

8. Gated pattern

9. Sweep pattern

10. Skeleton pattern

11. Segmental or part pattern

***1. Single-piece or solid pattern***

Solid pattern is made of single piece without joints, partings lines or loose pieces. It is the simplest form of the pattern as shown in Figure 3.1.

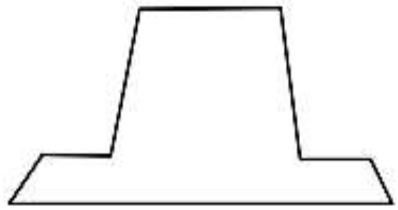

Figure 3.1: Single piece or pattern

***2. Two-piece or split pattern***

When solid pattern is difficult for withdrawal from the mould cavity, then solid pattern is splited in two parts. Split pattern is made in two pieces, which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the withdrawal of the pattern as shown in Figure 3.2.

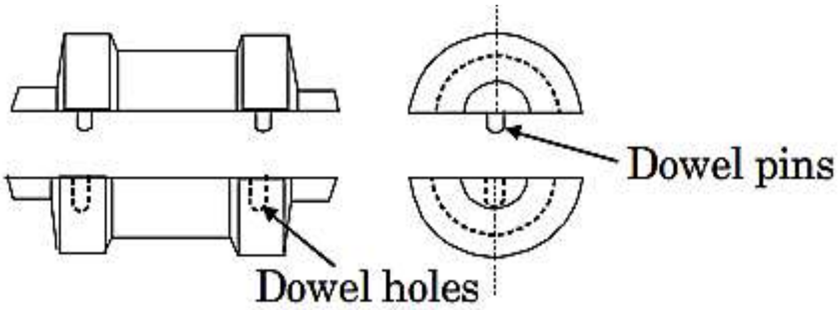


Figure 3.2: Two-piece or split pattern

***3. Cope and drag pattern***

In this case, cope and drag part of the mould are prepared separately. This is done when the complete mould is too heavy to be handled by one operator. The pattern is made up of two halves, which are mounted on different plates.

***4. Three-piece or multi-piece pattern***

Some patterns are of complicated kind in shape and hence cannot be made in one or two pieces because of difficulty in withdrawing the pattern. Therefore, these patterns are made either in three pieces or in multi-pieces. Multi moulding flasks are needed to make mould from these patterns.

***5. Loose-piece Pattern***

Loose piece pattern is used when pattern is difficult for withdrawal from the mould. Loose pieces are provided on the pattern and they are the part of pattern. The main pattern is removed first leaving the loose piece portion of the pattern in the mould. Finally the loose piece is withdrawal separately leaving the intricate mould.

***6. Match plate pattern***

This pattern is made in two halves and is on mounted on the opposite sides of a wooden or metallic plate, known as match plate. The gates and runners are also attached to the plate. This pattern is used in machine moulding.

***7. Follow board pattern***

When the use of solid or split patterns becomes difficult, a contour corresponding to the exact shape of one half of the pattern is made in a wooden board, which is called a follow board and it acts as a moulding board for the first moulding operation.

***8. Gated pattern***

In the mass production of casings, multi cavity moulds are used. Such moulds are formed by joining a number of patterns and gates and providing a common runner for the molten metal. These patterns are made of metals and metallic pieces to form gates and runners are attached to the pattern.

***9. Sweep pattern***

Sweep patterns are used for forming large circular moulds of symmetric kind by revolving a sweep attached to a spindle. Actually, a sweep is a template of wood or metal and is attached to the spindle at one edge and the other edge has a contour depending upon the desired shape of the mould. The pivot end is attached to a stake of metal in the centre of the mould.

***10. Skeleton pattern***

When only a small number of large and heavy castings are to be made, it is not economical to make a solid pattern. In such cases, however, a skeleton pattern may be used. This is a ribbed construction of wood, which forms an outline of the pattern to be made. This framework is filled with loam sand and rammed. The surplus sand is removed by strickle board. For round shapes, the pattern is made in two halves, which are joined with glue or by means of screws etc.

***11. Segmental pattern***

Patterns of this type are generally used for circular castings, for example wheel rim, gear blank etc. Such patterns are sections of a pattern so arranged as to form a complete mould by being moved to form each section of the mould. The movement of segmental pattern is guided by the use of a central pivot.

### 3.1.4 Pattern allowances

Pattern may be made from wood or metal and its colour may not be same as that of the casting. The material of the pattern is not necessarily same as that of the casting. Pattern carries an additional allowance to compensate for metal shrinkage. It carries additional allowance for machining. It carries the necessary draft to enable its easy removal from the sand mass. It carries distortions allowance also. Due to distortion allowance, the shape of casting is opposite to pattern. Pattern may carry additional projections, called core prints to produce seats or extra recess in mould for setting or adjustment or location for cores in mould cavity. It may be in pieces (more than one piece) whereas casting is in one piece. Sharp changes are not provided on the patterns. These are provided on the casting with the help of machining. Surface finish may not be same as that of casting.

The size of a pattern is never kept the same as that of the desired casting because of the fact that during cooling the casting is subjected to various effects and hence to compensate for these effects, corresponding allowances are given in the pattern. These various allowances given to pattern can be enumerated as, allowance for shrinkage, allowance for machining, allowance for draft, allowance for rapping or shake, allowance for distortion and allowance for mould wall movement. These allowances are discussed below.

*1. Shrinkage Allowance*

In practice, it has been discovered that, all common cast metals shrink a significant amount when they are cooled from the molten state. The total contraction in volume is divided into the following parts:

a. Liquid contraction, i.e. the contraction during the period in which the temperature of the liquid metal or alloy falls from the pouring temperature to the liquid temperature.

b. Contraction on cooling from the liquid to the solid temperature, i.e. solidifying contraction.

c. Contraction that results there after until the temperature reaches the room temperature. This is known as solid contraction.

The first two of the above are taken care of by proper gating and risering. Only the last one, i.e. the solid contraction is taken care by the pattern makers by giving a positive shrinkage allowance. This contraction allowance is different for different metals. The contraction allowances for different metals and alloys such as Cast Iron 10 mm/mt. Brass 16 mm/mt., Aluminium Alloys. 15 mm/mt., Steel 21 mm/mt., Lead 24 mm/mt. In fact, there is a special rule known as the pattern marks contraction rule in which the shrinkage of the casting metals is added. It is similar in shape as that of a common rule but is slightly bigger than the latter depending upon the metal for which it is intended.

*2. Machining Allowance*

It is a positive allowance given to compensate for the amount of material that is lost in machining or finishing the casting. If this allowance is not given, the casting will become undersize after machining. The amount of this allowance depends on the size of casting, methods of machining and the degree of finish. In general, however, the value varies from 3 mm. to 18 mm.

*3. Draft or Taper Allowance*

Taper allowance is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier. The normal amount of taper on the external surfaces varies from 10 mm to 20 mm/mt. On interior holes and recesses which smaller in size, the taper should be around 60 mm/mt. These values are greatly affected by the size are of the pattern and the moulding method. In machine moulding its, value varies from 10 mm to 50 mm/mt.

*4. Rapping or Shake Allowance*

Before withdrawing the pattern, it is rapped and thereby the size of the mould cavity increases. Actually, by rapping, the external sections move outwards increasing the size and internal sections move inwards decreasing the size. This movement may be insignificant in the case of small and medium size castings, but it is significant in the case of large castings. This allowance is kept negative and hence the pattern is made slightly smaller in dimensions 0.5-1.0 mm

*5. Distortion Allowance*

This allowance is applied to the castings, which have the tendency to distort during cooling due to thermal stresses developed. For example, a casting in the form of U shape will contract at the closed end on cooling, while the open end will remain fixed in position. Therefore, to avoid the distortion, the legs of U pattern must converge slightly so that the sides will remain parallel after cooling.

*6. Mould wall Movement Allowance*

Mould wall movement in sand moulds occurs as a result of heat and static pressure on the surface layer of sand at the mould metal interface. In ferrous castings, it is also due to expansion due to graphitisation. This enlargement in the mould cavity depends upon the mould.

### 3.1.5 Method of marking

Marking means setting out dimensions with the help of a working drawing or directly transferring them from a similar part. Marking metal surfaces is usually done by means of scriber or other gauge as shown in Figures 3.3 – 3.4. The procedure of marking is as follows:

1. The surface to be marked is smoothen with jackplane.

2. Then the work is held in a holding device depending on the shape.

3. Lines in horizontal direction are scribed by means of a marking gauge. Lines at right angles can be drawn by try square and then using the scriber, if true surface is available.

4. The centre on the end of a wood log can be located by using an odd leg calliper, surface gauge etc.

5. The circles and arcs on a flat surface are marked by means of a divider.

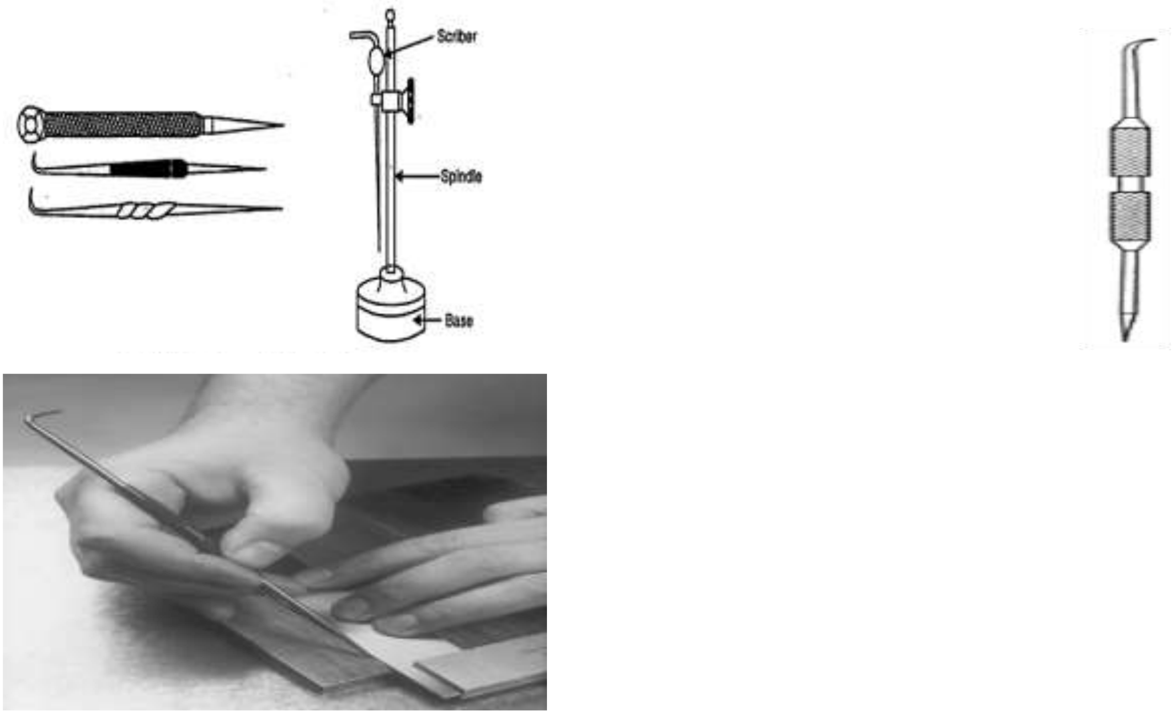


Figure 3.3: Scriber

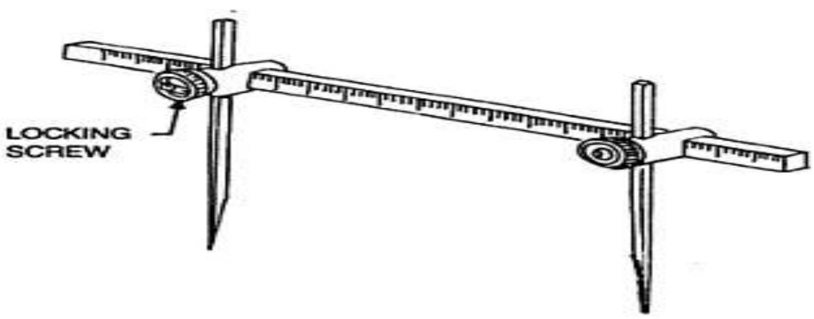


Figure 3.4: Trammel point

### 3.1.2 Core box and core print

Cores are compact mass of core sand that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting. The environment in which the core is placed is much different from that of the mould. In fact, the core has to withstand the severe action of hot metal, which surrounds it. Cores are classified according to shape and position in the mould.

There are various types of cores such as horizontal core, vertical core, balanced core, drop core and hanging core.

***a) Functions of core***

There are various functions of cores, which include;

1. Core is used to produce hollowness in castings in form of internal cavities.

2. It may form a part of green sand mould

3. It may be deployed to improve mould surface.

4. It may provide external undercut features in casting.

5. It may be used to strengthen the mould.

6. It may be used to form gating system of large size mould.

7. It may be inserted to achieve deep recesses in the casting.

***b) Core box Allowance***

Materials used in making core generally swell and increase in size. This may lead to increase the size of core. The larger cores sometimes tend to become still larger. This increase in size may not be significant in small cores, but it is quite significant in large cores and therefore certain amount of allowance should be given on the core boxes to compensate for this increase the cores. It is not possible to lay down a rule for the amount of this allowance as this will depend upon the material used, but it is customary to give a negative allowance of 5 mm /mt.

***c) Colour codification for patterns and core boxes***

There is no set or accepted standard for representing of various surfaces of pattern and core boxes by different colours. The practice of representing of various pattern surfaces by different colours varies with from country to country and sometimes with different manufactures within the country. Out of the various colour codifications, the American practice is the most popular. In this practice, the colour identification is as follows. Surfaces to be left unfinished after casting are to be painted as black. Surface to be machined are painted as red. Core prints are painted as yellow. Seats for loose pieces are painted as red stripes on yellow background. Stop-offs is painted as black stripes on yellow base.

***d) Core prints***

When a hole blind or through is needed in the casting, a core is placed in the mould cavity to produce the same. The core has to be properly located or positioned in the mould cavity on pre-formed recesses or impressions in the sand. To form these recesses or impressions for generating seat for placement of core, extra projections are added on the pattern surface at proper places. These extra projections on the pattern (used for producing recesses in the mould for placement of cores at that location) are known as core prints. Core prints may be of horizontal, vertical, balanced, wing and core types. Horizontal core print produces seats for horizontal core in the mould. Vertical core print produces seats to support a vertical core in the mould. Balanced core print produces a single seat on one side of the mould and the core remains partly in this formed seat and partly in the mould cavity, the two portions balancing each other. The hanging portion of the core may be supported on chaplets. Wing core print is used to form a seat for a wing core. Cover core print forms seat to support a cover core.

***e) Wooden pattern and wooden core box making tools***

When a hole blind or through is needed in the casting, a core is placed in the mould cavity to produce the same. The core has to be properly located or positioned in the mould cavity on pre-formed recesses or impressions in the sand. The job of patternmaker is basically done by a carpenter. The tools required for making patterns, therefore do not much differ from those used by a carpenter, excepting the special tools as per the needs of the trade.

In addition to tools used by a carpenter, there is one more tool named as the contraction rule, which is a measuring tool of the patternmaker's trade. All castings shrinks during cooling from the molten state, and patterns have to be made correspondingly larger than the required casting in order to compensate for the loss in size due to this shrinkage. Various metals and alloys have various shrinkages. The allowance for shrinkage, therefore, varies with various metals and according to particular casting conditions, and hence the size of the pattern is proportionally increased. A separate scale is available for each allowance, and it enables the dimensions to be set out directly during laying out of the patterns. The rule usually employed the one that has two scales on each side, the total number of scales being four for four commonly cast metals namely, steel, cast iron, brass and aluminium. To compensate for contraction or shrinkage, the graduations are oversized by a proportionate amount, e.g. on 1 mm or 1 per cent scale each 100 cm is longer by 1 cm. The general tools and equipment used in the pattern making shop are listed below.

***1. Measuring and Layout Tools***

1. Wooden or steel scale or rule
2. Dividers
3. Callipers
4. Try square
5. Calliper rule
6. Flexible rule
7. Marking gauge
8. T-bevel
9. Combination square

***2. Sawing Tools***

1. Compass saw
2. Rip saw
3. Coping saw
4. Dovetail saw
5. Back saw
6. Panel saw
7. Mitre saw

***3. Planning Tools***

1. Jack plane
2. Circular plane

3. Router plane
4. Rabbet plane
5. Block plane
6. Bench plane
7. Core box plane

***4. Boring Tools***

1. Hand operated drills
2. Machine operated drills
3. Twist drill
4. Countersunk
5. Brace
6. Auger bit
7. Bit gauge

***5. Clamping Tools***

1. Bench vice
2. C-clamp
3. Bar clamp
4. Hand screw
5. Pattern maker's vice
6. Pinch dog

***f) Wooden pattern and wooden core box making machines***

Modern wooden pattern and wooden core making shop requires various wood working machines for quick and mass production of patterns and core boxes. Some of the commonly machines used in making patterns and core boxes of various kinds of wood are discussed below.

1. *Wood Turning Lathe*. This lathe makes patterns for cylindrical castings.

2. *Abrasive Disc Machine*. It is used for shaping or finishing flat surfaces on small pieces of wood.

3. *Abrasive Belt Machine*. It makes use of an endless abrasive belt. It is used in shaping the patterns.

4. *Circular Saw*. It is used for ripping, cross cutting, bevelling and grooving.

5. *Band Saw*. It is designed to cut wood by means of an endless metal saw band.

6. *Jig or Scroll Saw*. It is used for making intricate irregular cuts on small work.

7. *Jointer*. The jointer planes the wood by the action of the revolving cutter head.

8. *Drill Press*. It is used for drilling, boring, mortising, shaping etc.

9. *Grinder*. It is used for shaping and sharpening the tools.

10. *Wood Trimmer*. It is used for metering the mouldings accurately.

11. *Wood Shaper*. It is used for imparting the different shapes to the wood.

12. *Wood Planer*. Its purpose is similar to jointer but it is specially designed for planning larger size.

13. *Tennoner*. These are used for sawing (accurate shape and size).

14. *Mortiser*. It is used to facilitate the cutting of mortise and tenon.

**Self Assessment Exercise:**

Discuss common materials used for pattern making. State their merits and demerits

### 3.2 Manufacturing processes

Manufacturing process is that part of the production process which is directly concerned with the change of form or dimensions of the part being produced. It does not include the transportation, handling or storage of parts, as they are not directly concerned with the changes into the form or dimensions of the part produced.

#### 3.2.1 Classification of manufacturing processes

For producing of products, materials are needed. It is therefore important to know the characteristics of the available engineering materials. Raw materials are used for the manufacturing of products, tools, machines and equipment in factories or industries are extracted from ores. The ores are suitably converted to metal in a molten form by reducing or refining processes in foundries. This molten metal is poured into moulds for providing commercial castings, called *ingots*. Such ingots are then processed in rolling mills to obtain market form of material supply in form of bloom, billets, slabs and rods. These forms of material supply are further subjected to various manufacturing processes towards getting usable metal products of different shapes and sizes in various manufacturing shops. All these processes used in manufacturing involve changing the ingots into usable products may be classified into six major groups, namely; primary shaping processes, secondary machining processes, metal forming processes, joining processes, surface finishing processes and processes of effecting a change in properties. These are discussed below.

### 3.2.2 Primary Shaping Processes

Primary shaping processes are manufacturing of a product from an amorphous material.

Some processes produces finish products or articles into its usual form whereas others do not, and require further working to finish component to the desired shape and size. Castings need re-melting of scrap and defective ingots in cupola or in some other melting furnace and then pouring of the molten metal into sand or metallic moulds to obtain the castings. Thus the intricate shapes can be manufactured. Typical examples of the products that are produced by casting process are machine beds, automobile engines, carburettors, flywheels etc. The parts produced through these processes may or may not require to undergo further operations.

Some of the important primary shaping processes include: (1) Casting, (2) Powder metallurgy, (3) Plastic technology, (4) Gas cutting, (5) Bending and (6) Forging

### 3.2.3 Secondary or Machining Processes

As large number of components require further processing after the primary processes. These components are subjected to one or more number of machining operations in machine shops, to obtain the desired shape and dimensional accuracy on flat and cylindrical jobs. Thus, the jobs undergoing these operations are the roughly finished products received through primary shaping processes. The process of removing the undesired or unwanted material from the workpiece or job or component to produce a required shape using a cutting tool is known as machining. This can be done by a manual process or by using a machine called machine tool (traditional machines namely lathe, milling machine, drilling, shaper, planner, slotter). In many cases these operations are performed on rods, bars and flat surfaces in machine shops.

These secondary processes are mainly required for achieving dimensional accuracy and a very degree of surface finish. The secondary processes require the use of one or more machine tools, various single or multi-point cutting tools (cutters), job holding devices, marking and measuring instruments, testing devices and gauges etc. for getting desired dimensional control and required degree of surface finish on the workpieces. The example of parts produced by machining processes includes hand tools, machine tools instruments, automobile parts, nuts, bolts and gears etc. Lot of material is wasted as scrap in the secondary or machining process. Some of the common secondary or machining processes include:

(1) Turning, (2) Threading, (3) Knurling, (4) Milling, (5) Drilling, (6) Boring, (7) Planning, (8) Shaping, (9) Slotting, (10) Sawing, (11) Broaching, (12) Hobbing, (13) Grinding, (14) Gear cutting, (15) Thread cutting and (16) Unconventional machining processes namely machining with Numerical Control (NC) machines tools or Computer Numerical Control (CNC) machines tools using ECM, LBM, AJM, USM setups etc.

**Self Assessment Exercise:**

Discuss both primary and secondary machining operations

**4.0 Conclusion**

We conclude that a pattern is a mould-forming tool, a model or the replica of the object to be cast. It establishes seat for placement of core at locating points on the mould in form of extra recess. It also establishes the parting line and parting surfaces in the mould. It may help to position a core in case a part of mould cavity is made with cores, before the moulding sand is rammed. Marking means setting out dimensions with the help of a working drawing or directly transferring them from a similar part. Manufacturing process is that part of the production process which is directly concerned with the change of form or dimensions of the part being produced

**5.0 Summary**

We discussed what is pattern and the types of materials used for pattern making and core prints. Design considerations, the layout and construction of pattern were also discussed. We also discussed different types of machines for making wooden pattern and wooden boxes. Primary and secondary processes in the production of parts and components were also covered.

**6.0. Tutor-Marked Assignment**

a) What is pattern? How does it different from the actual product to be made from it.

b) Discuss common materials used for pattern making. State their merits and demerits.

c) Briefly list and explain some machines used for wooden patterns and wooden core boxes.

d) Briefly discuss primary and secondary machining processes in parts production

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## UNIT 2: SHEET METAL WORKS

**CONTENTS**



### 1.0 Introduction

In sheet metal work, there is no need for further machining as required for casting and forging works. The time taken in sheet-metal working is approximately half of that required in the machining process. For carrying out sheet metal work, the knowledge of geometry, mensuration and properties of metal is most essential because nearly all patterns come from the development of the surfaces of a number of geometrical models such as cylinder, prism, cone, and pyramid.

In sheet metal work, various operations such as shearing, blanking, piercing, trimming, shaving, notching, forming, bending, stamping, coining, embossing etc. are to be performed on sheet metal using hand tools and press machines to make a product of desired shape and size. Generally, metals used in sheet metal work are black iron, galvanized iron, stainless steel, copper, brass, zinc, aluminium, tin plate and lead.

Sheet metal work has its own significance in the engineering work. Many products, which fulfil the household needs, decoration work and various engineering articles, are produced from sheet metals. Common examples of sheet metal work are hoopers, canisters, guards, covers, pipes, hoods, funnels, bends, boxes etc. Such articles are found less expensive, lighter in weight and in some cases sheet metal products replace the use of castings or forgings.

## 2.0 Objective

At the end of this unit student should be able to

- Understand different metal used for sheet metal works
- Explain the different operations involved in sheet metal works
- Understand the basic tools used in sheet metal works

## Main Content

### 3.1 Metals used in Sheet Metal Works

A metal plate of thickness less than 4 mm is considered as sheet. The size of the sheet is specified by its length, width and thickness in mm. In British system, the thickness of sheet is specified by a number called Standard Wire Gauge (SWG). The commonly used gauge numbers and the equivalent thickness in mm are given in Table 3.1

**Table 3.1: Common standard wire gauges**

| **SWG (No)** | 16 | 17 | 18 | 19 | 20 | 22 | 24 | 27 | 30 |
|---|---|---|---|---|---|---|---|---|---|
| **Thickness (mm)** | 1.62 | 1.42 | 1.22 | 1.02 | 0.91 | 0.71 | 0.56 | 0.42 | 0.37 |

The following metals are generally used in sheet metal work:

### i. Black Iron Sheet

It is the cheapest among ail. It has a bluish-black appearance and is uncoated sheet. Being uncoated, it corrodes rapidly. It is prepared by rolling to the desired thickness, then annealed by pleasing in a furnace and then set aside to cool gradually. The use of this metal is limited to articles that are to be painted or enamelled such as stovepipes, tanks, pans etc.

**ii. Galvanized Iron**

It is soft steel coated with molten zinc. This coating resist rust, improves appearances, improves solderability, and improves water resistance. It is popularly known as G.I. sheets. Articles such as pans, buckets, furnaces, cabinet etc. are made from Gl sheets.

**iii. Stainless Steel**

It is an alloy of steel with nickel, chromium and traces of other metals. It has good corrosive resistance. The cost of stainless steel is very high but tougher than Gl sheets. It is used in kitchenware, food handling equipment, chemical plants etc.

**iv. Copper**

It is a reddish coloured metal and is extremely malleable and ductile. Copper sheets have good corrosion resistance as well as good appearances but costs are high as compared to Gl and stainless steel. Because of high thermal conductivity, it is used for the radiator of automobiles, domestic heating appliances etc.

**v. Aluminium**

Aluminium cannot be used in its pure form, but is used in alloy form. Common additions are copper, silicon, manganese and iron. It has many qualities like high ratio of strength to weight, corrosion resistant qualities, and ease in fabrication and whitish in colour. It is used in manufacturing of a number of products such as refrigerator trays, household appliances, lighting fixtures, window work, construction of airplanes and in many electrical and transportation industries.

**vi. Tin Plates**

It is an iron sheet coated with the tin to protect it against rust. This metal has a very bright silvery appearance and is used principally in making food containers, cans and pans.

**vii. Lead**

It is a very soft, malleable, low melting point and possesses high resistance to acid corrosion. It is having low mechanical strength so it is used to provide lining to the highly corrosive acid tanks. It is also used in radiation shielding.

**Self Assessment Exercise:**

Mention the metals commonly used for sheet metal work and describe them.

## 3.2 Tools used in Sheet Metal Works

Most of tools used for sheet metal works have already been described in Modules 1 and 2, the following tools are commonly used for general sheet-metal work:

(i) Hand shears or snips

(ii) Hammers

(iii) Stakes and stake holder

(iv) Cutting tools

(v) Measuring tools

(vi) Miscellaneous hand tools such as chisels, groovers, seamers, rivet sets and hand punches.

Some of the important sheet metal tools are described below.

a) **Hand shears or snips**

Figure 3.5 shows the types of hand shears or snips. They resemble with pair of scissors and are used like them to cut thin soft metal sheets of 20 gauge or thinner. They are required to size and shape the sheets. They can make straight or circular cuts. Different types of hand shears are:

(1) *Straight hand shear*: It is used for general purpose cutting, making straight cuts and trimming away extra metal.

(2) *Universal shear*: Its blades are designed for universal cutting straight line or internal and external cutting of contours. It may be of right hand or left hand type, easily identifiable, as the top blade is either on the right of on the left.

(3) *Curved or bent hand shear*: It is used for cutting circular or irregular curved shapes ranging from 20 to 35 cm.

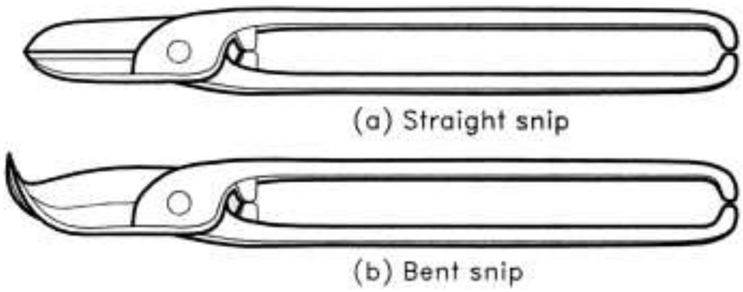

Figure 3.5: Hand shears or snips

b) Hammers

*(a) Smoothing hammer*. Smoothing hammer is used for levelling and smoothing a sheet metal joint.

*(b) Stretching hammer*. Stretching hammer is used for stretching sheet.

*(c) Creasing hammer*. Creasing hammer is used to close down joint edges of sheets metal part.

*(d) Hollowing hammer*. Hollowing hammer is used for hollowing sheet metal part. It is used for generating sharp radii also.

*(e) Riveting hammer*. Riveting hammer is used for forming riveted heads.

*(f) Planishing hammer*. Planishing hammer is used for removing small marks or indentations from the sheet metal job surface and to true the shape of the work. It smoothens off the finished sheet metal work.

*(g) Soft hammer or Mallets.* Mallets used during working with soft metal sheets. They may be of wood, rubber or raw hide. A mallet strikes a blow with the minimum damage to the surface. In sheet metal work, the commonly used mallets are bossing mallet, tinman's mallet and rawhide mallet.

However, hammers for sheet metal works can be grouped under four type, namely (a) Setting hammer, for setting down the edge while making double seam, (b) Raising hammer for forming curved or hollow shape from flat piece, and (c) Riveting hammer for riveting purpose. Mallets are soft hammers used to give soft blows which will not damage the sheet at the same time will shape them as shown in Figure 3.6.

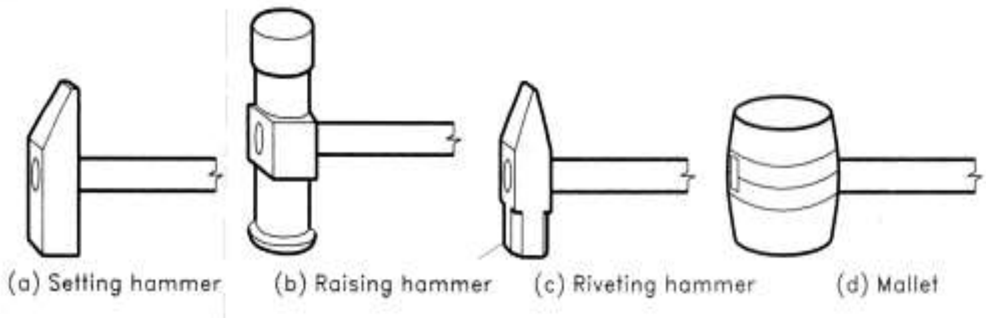


Figure 3.6: Hammers used for sheet metal works

**c) Stakes**

Stakes are used to form the metal sheets into various shapes. It is a sort of anvil, which supports the sheet for sheet metal work. It consists of a shank and a head or horn. The shank of stake is designed to fit into a tapered bench socket. The head or horn of stake is available in a number of varieties of sizes and shapes. Their working faces of stakes are machined or ground to needed shape. With the help of a hammer, operations such as bending, seaming or forming can be easily performed on these stakes. Some stakes are made of forged mild steel faced with cast steel. Whereas the better class stakes are made either of cast iron or cast as discussed below:

1. *Beak horn stake*. Beak horn is basically used for forming, riveting and seaming articles made of sheet metal part. It is not much suitable like blow horn stake. It has a thick tapered horn at one end and a rectangular shaped horn at the other.

2. *Funnel stake*. Funnel stake is commonly used for planished tapered work and hand forming of funnels and similar conical shapes of sheet metal.

3. *Half-moon stake*. Half-moon stake is basically used for throwing up edges of curved sheet metal work and for preliminary stages of wiring curved edges.

4. *Round bottom stake*. Round bottom stake is commonly used for squaring up edges and setting up the bottom of cylindrical jobs made up of sheets.

5. *Bick iron*. Bick iron stake is mainly used for forming taper handles, spouts and tubular work in general. The narrow flat anvil end of bick iron is very useful on rectangular work.

6. *Hatchet stake*. Hatchet stake is generally used for making sharp bends, bending edges and forming boxes and pans of sheet metal by hand. This stake has a sharp straight edge bevelled along one side.

7. *Creasing with horn stake*. Creasing horn stake has a round horn used for forming conical shaped pieces in sheets. The other end has a tapering square horn with grooved slots for wiring and beading.

8. *Needle case stake*. Needle case stake is generally used for bending of sheets. It has a round slender horn for forming wire rings and tubes.

9. *Candle mould stake*. Candle mould stake has two horns for different tapers when forming, seaming and riveting long flaring articles made up of sheet metal.

10. *Blow horn stake*. Blow horn stake is generally used in forming, riveting and seaming tapered articles such as funnels.

11. *Conductor stake*. Conductor stake has two cylindrical horns of different diameters. It is used for forming, riveting, and seaming small sized pipes and tubes.

12. *Double seaming stake*. Double seaming stake consists of two cylindrical horns of different diameters and it is commonly used for riveting forming, and seaming tubes and small pipes.

The pictorial illustration of stakes, stake holders, cutting tools and measuring tools have been discussed in modules 1 and 2 in the previous sections of this courseware.

d) **Miscellaneous tools for sheet metal works**

1. Steel square

2. Straight edge

3. Divider

4. Scriber

5. Trammel points

6. Soldering iron

7. Pliers

Other hand tools or instruments used in sheet metal shop include rivet sets, soldering iron, scrapers clamps, screw drivers, spanners and wrenches, chisels, different types of calipers and dividers, Vernier caliper, micrometres, standard wire and thickness gauges, files for softer metals, conventional types of metal files including needle files and round files.

### 3.3.1 Folding terminology of sheet metal joint

a) ***Edge***

The edges on part need to be folded to increase the strength and to eliminate the sharp edges of sheet metal component.

*Types of folded edges*.

The common types of folded edges are: (i) single hem, (ii) double hem and (iii) wired edge as shown in Figure 3.7.

1. *Single hem*. It is made by folding the edge over. To layout such a hem, a line is drawn at a distance equal to the desired hem width.

2. *Double hem*. It is a single hem with its end bent under. To layout such a hem, draw two parallel lines each equal to the width of the hem.

3. *Wired edge*. It consists of an edge, which has been wrapped around a piece of wire.

This edge is used where more strength is needed. To layout wired edge the diameter of wire is to be determined. The steel metal will be needed to roll around the wire.

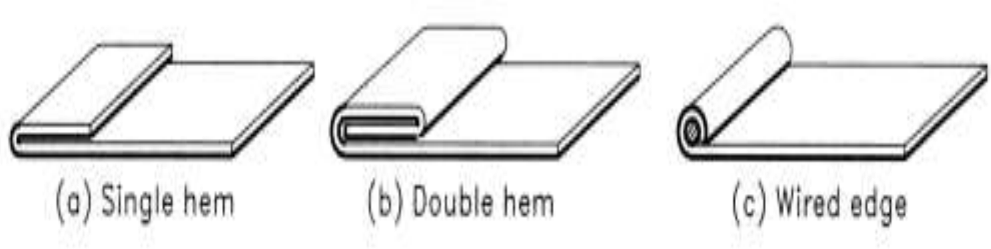


Figure 3.7: Types of hems in sheet metal works

b) ***Seam***

A seam is the section where pieces of sheet metal are joined together. Most common types of seams are: (a) Single seam, (b) Double seam, (c) Grooved seam, (d) Lap seam, (e) Dovetail seam, and (f) Burred bottom seam

1. *Single seam*

It is used to join a bottom to vertical bodies of various shapes. To layout such a seam, draw a line parallel to one edge of the sheet metal body stretch out at a distance equal to the width of the seam. Now draw two lines parallel to the edges of the bottom stretch out. The first line should be drawn at the distance from the edge of sheet metal equal to the width of the seam minus 1 mm. approx. Second line should be drawn at a distance from the first equal to the width to the seam on sheet metal plus 1 mm approx. The plus and minus dimensions of 1 mm is used to prevent the folded bottom edge of sheet metal from interfering with the body's folded bottom edge. If the bottom is round, then mark the lines on sheet metal part.

2. *Double seam*

The layout process for this seam on sheet metal part is similar to that used for a single seam on sheet metal part. It differs from single seam in a manner that its formed edge is bent upward against the body.

3. *Grooved seam*

It is made by booking two folded edges of sheet metal part together and then off-setting the seam. On one piece draw one line equal to half the width of the seam from outer edge. Then draw second line at a distance equal to the width of the seam from the first line. Same way draw two lines on the other piece of sheet metal part.

4. *Lap seam*

It is the simplest type of seam made on sheet metal part because one edge laps over another and is soldered or riveted. To layout lap seam on sheet metal part, draw line on the edge of piece at a distance equal to the width of the required seam.

5. *Dovetail seam*

It is used to join a flat plate to a cylindrical piece. To layout such a seam, draw a line parallel to one edge of sheet metal component at a distance of 6 to 20 mm. depending upon the size of the hole of sheet metal part. Then draw lines to indicate where the sheet metal part is to be slit. The width of the piece between slits ranges from 6 to 26 mm.

6. *Flanged or burred bottom seam*

It is used to fasten the bottom of a container made of sheet metal to its body in which upper part is the sheet metal body and lower bottom of a container. To layout such a seam on sheet metal part, draw a circle, which represents the outline of the bottom on sheet metal part. If it is square or rectangular component, draw the bottom shape on the sheet metal part. Then draw a second line to show the width of the flange. The width of this flange may range from 3 to 6 mm on sheet metal part.

c) ***Notches***

In the process of laying out on sheet metal part, some provision is to be made for bent sections when they have folded edges. The opening left at corners of seams and edges of sheet metal part are called notches. Five common types of notches are: (1) Straight notch, (2) V-notch (3) Square-notch and (4) Slanting-notch.

1. *Straight notch.* It is prepared by making a straight cut where the bend is to occur in sheet metal part.

2. *V-notch*. It is used where the corners of a flange should fit together in sheet metal part. It is used for laying out 90° and other than 90° angle on the sheet metal part

3. *Square-notch*. It is applicable where square or rectangular box (made up of sheet metal) is formed.

4. *Slant-notch*. It is used where single hems are to meet at right angles. In this process they should be clipped at 45° angle on the sheet metal part.

**Self Assessment Exercise:**

Describe various tools used for sheet metal work, use neat sketches where necessary

### 3.3 Sheet Metal Joints

The line of joint on a sheet me ml pieces is called seam. The most common types of seams are as follows:

1. *Lap seam*: This is the simplest seam used in sheet metal work Figure 3.8 (a). This consists of one edge lapping over the other and joint is made by soldering or riveting.

2. *Grooved seam*: A grooved seam is made by hooking two-folded edges together and then off setting them as shown in Figure 3.8 (b). This joint is self-locking and stronger to some extent than lap seam.

3. *Single seam*: This seam is used to join a bottom portion to a vertical body as shown in Figure (c). The bottom edge is hooked over the bent edge of the vertical body. This method of joint can be used for square, rectangular or round containers.

4. *Double seam*: This seam is similar lo single scam with the difference that the formed edge is bent upwards against the body as shown in Figure 3.8 (d).

5. *Dove-tail seam*: This seam is used to connect a cylindrical piece to a flat as shown in Figure 3.8 (e). The edge of the cylindrical part to be joined is slit at short distance and is bent so that alternate pieces come inside and outside of the joint. Permanent joint is obtained by soldering or riveting.

6. *Flanged (burred) bottom seam*: This seam is used to fasten the bottom of a container to its body. The flange of a cylindrical job is often called a burr. The joint consists of a narrow flange which may be joined to inside or outside of the vessel. The illustrations of these joints are shown in Figure 3. 8.

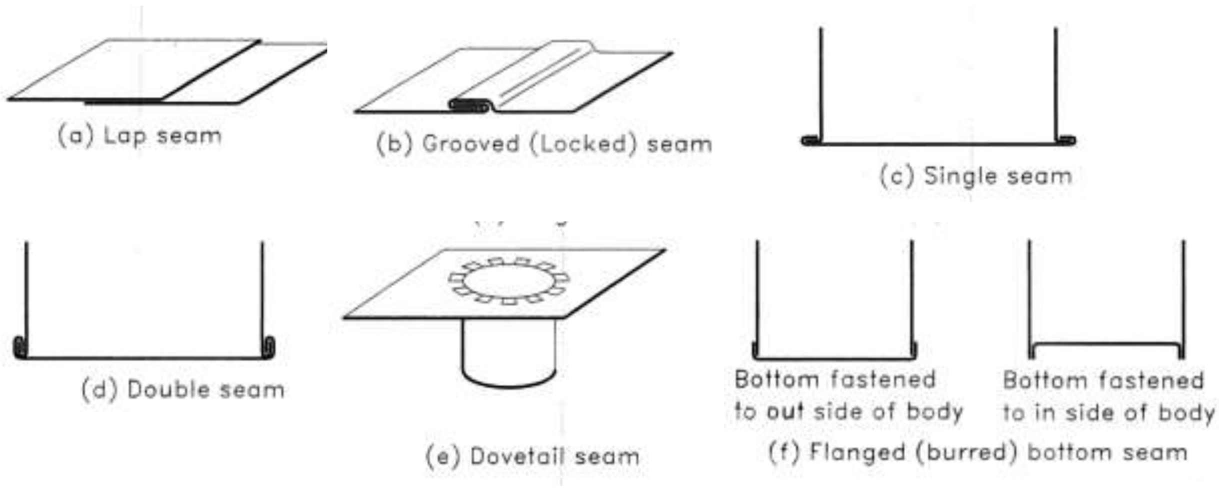


Figure 3.8: Sheet metal joints

**Self Assessment Exercise:**

Discuss the various types of joints in sheet metal works

## 4.0 Conclusion

Sheet metal processing is a useful trade in engineering works to meet our day-to-day requirements. Many products, which fulfil the household needs, decoration work and various engineering parts, are produced from sheet meta1s. A good product properly developed with the prescribed tools may lead to saving of time and money.

## 5.0 Summary

This study unit looked into the concept of materials and tools used for sheet metal works. This study further revealed the types of joints that is used to connect, elongate, shape and achieve the desirable components and parts.

## 6.0 Tutor-Marked Assignment

a) Mention the metals commonly used for sheet metal work and describe them.

b) Describe various tools used for sheet metal work, use neat sketches where necessary

c) With the ai of neat sketches describes the types of joints in sheet metal works.

## 7.0 References/Further Readings


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## UNIT 3: ENGINEERING DRAWING, INSTRUMENTS AND LETTERING

**CONTENTS**



### 1.0 Introduction

Engineering drawing is a two dimensional representation of three dimensional objects. In general, it provides necessary information about the shape, size, surface quality, material, manufacturing process, etc., of the object. It is the graphic language from which a trained person can visualise objects.

### 2.0 Objective

At the end of this unit student should be able to

- Understand the modes and illustrations in Engineering drawing
- Understand information provided on the shape, size, and pattern of objects.
- Understand Engineering drawing as the universal language of engineers.

### 3.0 Main Content

### 3.0 Introduction to Engineering Drawing

Drawing is one of the oldest forms of communicating, dating back even farther than verbal communication. The drawing itself is a way of communicating all necessary information about an abstract, such as an idea or concept or a graphic representation of some real entity, such as a machine part, house or tools.

An engineering drawing is an advanced technical drawing, which is a means of clearly and concisely communicating all of the information necessary to transform an engineered idea or concept in to reality. Therefore, an engineering drawing often contains more than just a graphic representation of its subject. It also contains dimensions, notes and specifications.

Drawings prepared in one country may be utilised in any other country irrespective of the language spoken. Hence, engineering drawing is called the universal language of engineers. Any language to be communicative, should follow certain rules so that it conveys the same meaning to everyone. Similarly, drawing practice must follow certain rules, if it is to serve as a means of communication.

### 3.1.1 Role of Engineering Drawing

The ability to read drawing is the most important requirement of all technical people in any profession. As compared to verbal or written description, this method is brief and clearer. Some of the applications are: building drawing for civil engineers, machine drawing for mechanical engineers, circuit diagrams for electrical and electronics engineers, computer graphics for one and all.

The subject in general is designed to impart the following skills.

1. Ability to read and prepare engineering drawings.
2. Ability to make free - hand sketching of objects.
3. Power to imagine, analyse and communicate, and
4. Capacity to understand other subjects:

### 3.1.2 Types of Technical drawing

***a) Design Sketches*** - which comprise of:

- i. Initial Ideas and Requirements
- ii. Calculations and Concepts

***b) Layout Drawings*** - which comprise of:

- i. development of initial design
- ii. used to create detailed or assembly drawings

***c) Assembly Drawings*** - which comprise of:

- i. parts +/or sub-assemblies = component / machine

***d) Detail Drawings -*** which comprise of:

i information to make or purchase

ii Include shape, dimensions, tolerances, surface finish etc.

### 3.1.3 Drawing layout

According to BS 8888, the layout of engineering drawing sheet and paper sizes are shown in Figure 3. 9 – 3.10.

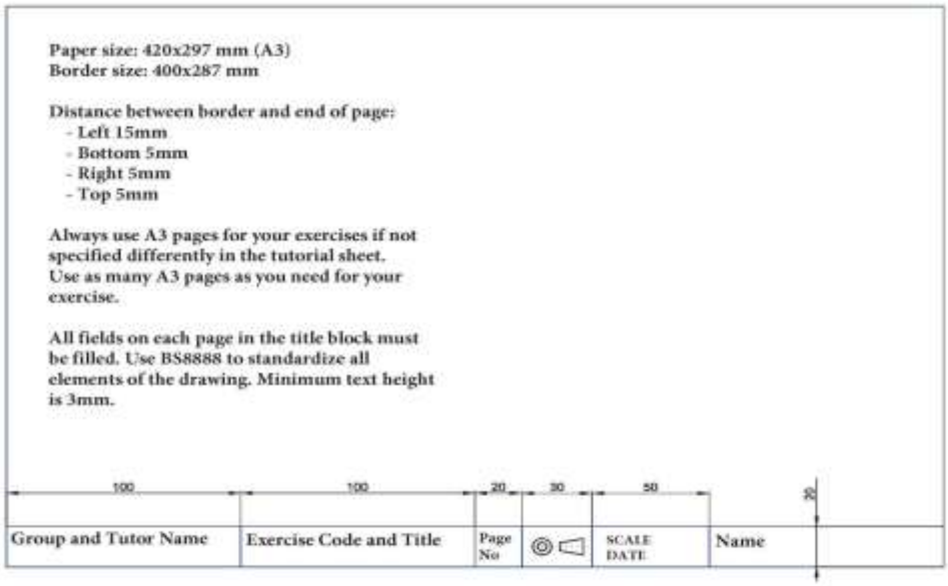



Figure 3.9: Layout of engineering drawing sheet

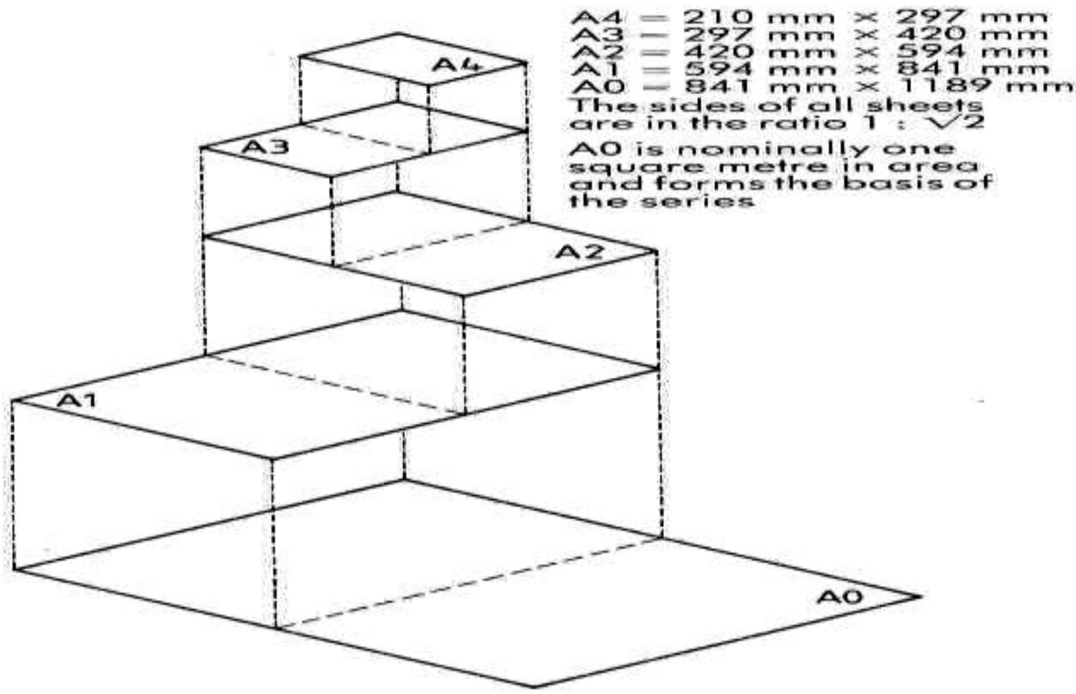



Figure 3.10: Engineering drawing paper sizes

### 3.1.4 Elements of Title Block

The elements title block in engineering drawing are shown in Figure 3. 11 – 3.13 and Table 3.2. The title block text should be 4-6 mm. Text should not be smaller than 3mm. the title block itself is 170 x 65 mm length and width respectively.

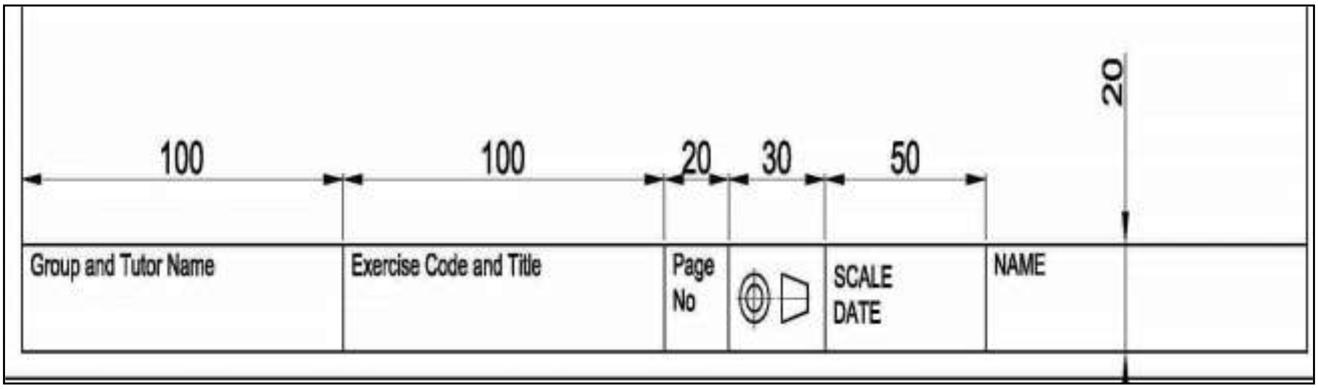



Figure 3.11: Title block element

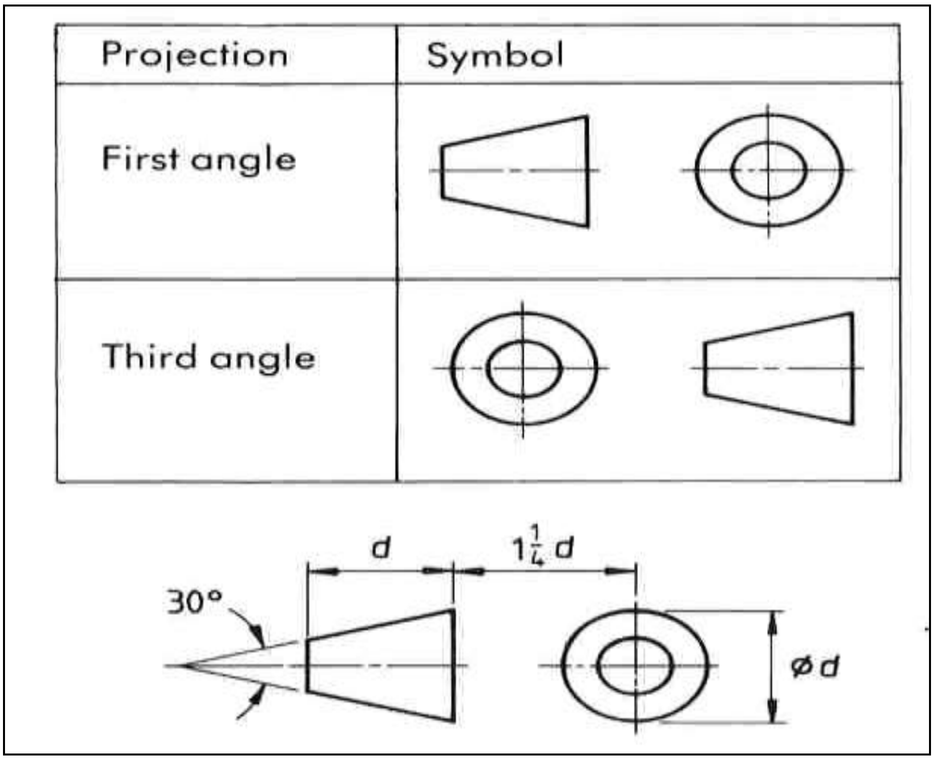



Figure 3.12: Projection symbols in the title block

Table 3.2: Scale of drawing in the title block

| | | | |
|---|---|---|---|
| On drawings smaller than full size (reduction scales): | | | |
| | 1:2 | 1:5 | 1:10 |
| | 1:20 | 1:50 | 1:100 |
| | 1:200 | 1:500 | 1:1000 |
| On drawings larger than full size (enlargement scales): | | | |
| | 2:1 | 5:1 | 10:1 |
| | 20:1 | 50:1 | |


Figure 3.13: Graphics/Alphabets character template

**Self Assessment Exercise:**

Explain the role of engineering drawing the design and execution of engineering projects.

### 3.2 Drawing Instruments and Accessories

To record information on paper instruments and equipment are needed. Engineering drawing is entirely a graphic language hence instruments are essentially needed. Drawing must be clear, neat and legible in order to serve its purpose. Hence it is extremely important for engineers to have good speed, accuracy, legibility and neatness in the drawing work. All drawings are made by means of various instruments. The quality of drawing depends to a large extent on the quality, adjustment and care of the instrument. Depending on the job requirement, the instruments and other aids used in drafting woks include a) Drawing board b) Mini draughter c) Instrument box d) Set squares e) Protractor f) Set of scales g) French curves h) Drawing sheets i) Pencils j) Templates

#### 3.2.1 Drawing Instruments

***i. Drawing Paper***

Drawing paper is the paper, on which drawing is to be made. All engineering drawings are made on sheets of paper of strictly defined sizes, which are set forth in the U.S.S.R standards. The use of standard size saves paper and ensures convenient storage of drawings. Now a day, A3 and A4 are the most commonly used paper sizes. The U.S.S.R standard establishes five preferred sizes for drawings as shown in Table 3.3.

**Table 3.3**: **Description of drawing paper size**

| **Size designation** | **11** | **12** | **22** | **24** | **44** |
|---|---|---|---|---|---|
| **Designation of paper sheet** | **A4** | **A3** | **A2** | **A1** | **A0** |
| **Sheet dimensions (mm)** | 297x210 | 297x420 | 594x420 | 594x841 | 1189x841 |

***ii. Triangles (setsquares)***

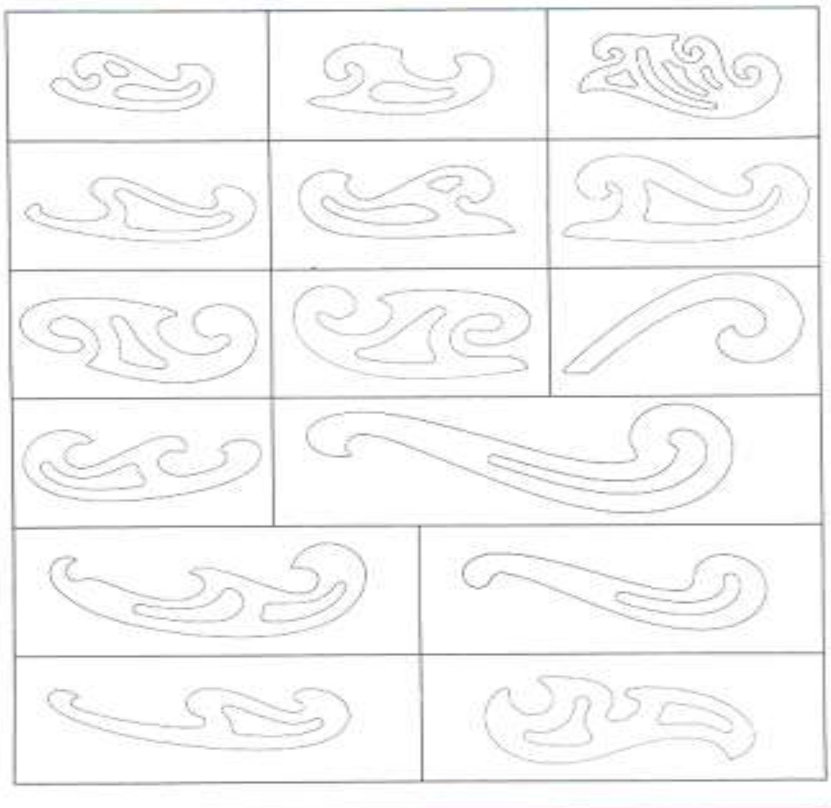
They are used to construct the most common angles (i.e. $30^0$, $45^0$, $60^0$) in engineering and other technical drawings. The $45^0$ x $45^0$ and $30^0$ x $60^0$ triangles are the most commonly used for ordinary work.

***iii. T- square***

It is used primarily to draw horizontal lines and for guiding the triangles when drawing vertical and inclined lines. It is manipulated by sliding the working edge (inner face) of the head along the left edge of the board until the blade is in the required position.

***iv. French curve***

It is used to draw irregular curves that are not circle arcs. The shape varies according to the shape of irregular curve. French curves are available in different shape. First, a series of points are plotted along the desired path and then the most suitable curve is made along the edge of the curve. A flexible curve consists of a lead bar inside rubber which bends conveniently to draw a smooth curve through any set of points as shown in Figure 3.14.



Assortment of French curves

Figure 3.14: French curves

***v. Protractor***

It is used for laying out and measuring angle as shown in Figure 3.15.

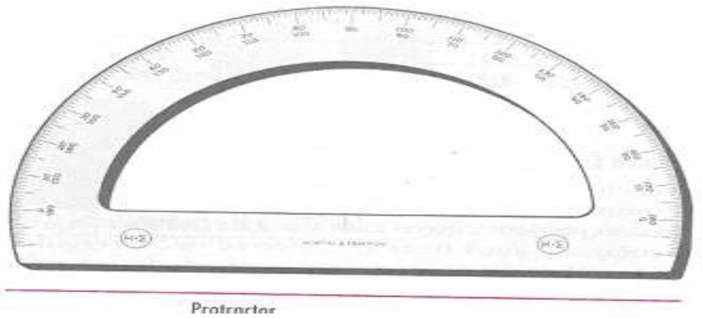



Figure 3.15: Protractor

***vi. Scale Rule or Scale ruler***

A number of kinds of scales are available for varied types of engineering design. There are scales with bevelled edges graduated in mm usually used for precision measurement as shown in Figure 3.16.

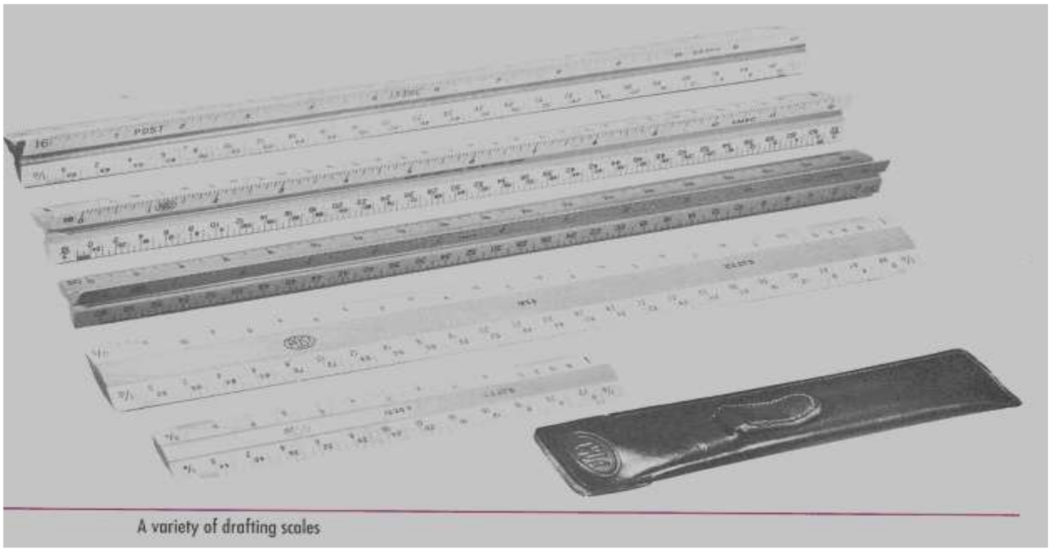



Figure 3.16: Scale rules

***vii. Pencils***

The engineered trainees, technicians and professionals involved in the design of structures/infrastructures should be equipped with a selection of good, well-sharpened pencil with leads of various degrees of hardness such as: 9H, 8H, 7H, and 6H (hard); 5H& 4H (medium hard); 3H and 2H (medium); and H& F (medium soft). The grade of pencil to be used for various purposes depends on the type of line desired, the kind of paper employed, and the humidity, which affects the surface of the paper. Standards for line quality usually will govern the selection. For instance, various uses of pencils include:

♦ 6H is used for light construction line.

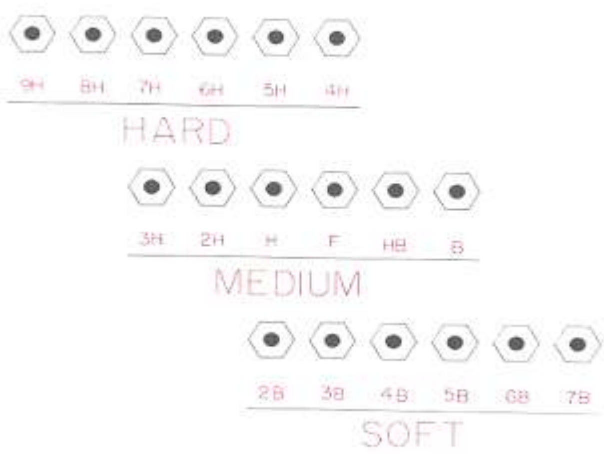
♦ 4H is used for re-pencilling light finished lines (dimension lines, centre lines, and invisible object lines)

♦ 2H is used for visible object lines

♦ F and H are used for all lettering and freehand work. Other use of pencils according to the grade is shown in Table 3.4.

Table 3.4: Grades of pencils used in drawing

| TASK | LEAD |
|---|---|
| CONSTRUCTION LINES | 3H , 2H |
| GUIDE LINES | 3H , 2H |
| LETTERING | H, F, HB |
| DIMENSION LINES | 2H , H |
| LEADERLINES | 2H , H |
| HIDDEN LINES | 2H , H |
| CROSSHATCHING LINES | 2H , H |
| CENTERLINES | 2H , H |
| PHANTOM LINES | 2H , H |
| STITCH LINES | 2H , H |
| LONG BREAK LINES | 2H , H |
| VISIBLE LINES | H, F, HB |
| CUTTING PLANE LINES | H, F, HB |
| EXTENSION LINES | 2H , H |
| FREEHAND BREAK LINES | H, F, HB |




Grades of lead (left) and lead-lines chart (right)

***viii. Compass***

It is used to draw circles and arcs both in pencil and ink. It consists of two legs pivoted at the top. One leg is equipped with a steel needle attached with a screw, and other shorter leg is, provided with a socket for detachable inserts as shown in Figure 3.17.

***ix. Divider***

Used chiefly for transferring distances and occasionally for dividing spaces into equal parts. i.e. for dividing curved and straight lines into any number of equal parts, and for transferring measurements as shown in Figure 3.17.

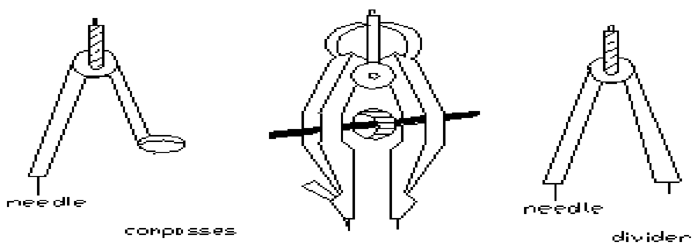



Figure 3.17: Compass and Divider

***x. Template***

A template is a thin, flat piece of plastic containing various cut-out shapes. It is designed to speed the work of the drafter and to make the finished drawing more accurate. Templates are available for drawing circles, ellipses, plumbing's, fixtures etc. Templates come in many sizes to fit the scale being used on the drawing. And it should be used wherever possible to increase accuracy and speed.

***xi. Mini-Drafter***

Mini-drafter consists of an angle formed by two arms with scales marked and rigidly hinged to each other. It combines the functions of T-square, set-squares, scales and protractor. It is used for drawing horizontal, vertical and inclined lines, parallel and perpendicular lines and for measuring lines and angles.

***xii. Instrument Box***

Instrument box contains 1. Compasses, 2. Dividers and 3. Inking pens. What is important is the position of the pencil lead with respect to the tip of the compass.

***xi. Others***

***i. Drawing board*** is a board whose top surface is perfectly smooth and level on which the drawing paper is fastened.

***ii. Clinograph*** (Adjustable set square)-its two sides are fixed at 900 and the third side can be adjusted at any angle. Rubber or eraser- extra lines or curves which are not required in the drawing are to be rubbed out or erased. Hence a rubber or eraser are required in the drawing work. Erasers are available in many degrees of hardness, size and shape.

***iii. Eraser shield*** –it is an important device to protect lines near those being erased. It is made up of thin metal plate in which gaps of different widths and lengths are cut.

***iv. Tracing paper*** – it is a thin transparent paper. Figures below it can be seen easily and traced out in pencil ink.

***v. Drawing ink***- it is used for making drawings in ink on tracing paper.

**Self Assessment Exercise:**

Explain the use of different drawing equipment.

### 3.3 Techniques of Lettering

Lettering is defined as writing of titles, sub-titles, dimensions, etc., on a drawing. "Any normal person can learn to letter if he is persistent and intelligent in his efforts." While it is true that" Practice makes perfect," it must be understood that practice alone is not enough; it must be accompanied by continuous effort to improve.

There are three necessary steps in learning to letter:

1. Knowledge of the proportions and forms of the letters, and the order of the strokes.
2. Knowledge of composition- the spacing of the letters and words.
3. Persistent practice, with continuous effort to improve.

#### 3.3.1 Guidelines of Good Lettering

Extremely light horizontal guidelines are necessary to regulate the height of letters. In addition, light vertical or inclined guidelines are needed to keep the letters uniformly vertical or inclined Figure 3.18. Guidelines are absolutely essential for good lettering, and should be regarded as a welcome aid, not as an unnecessary requirement. Make guidelines light, so that they can be erased after the lettering has been completed. Use a relatively hard pencil such as a 4H to 6H, with a long, sharp, conical point.

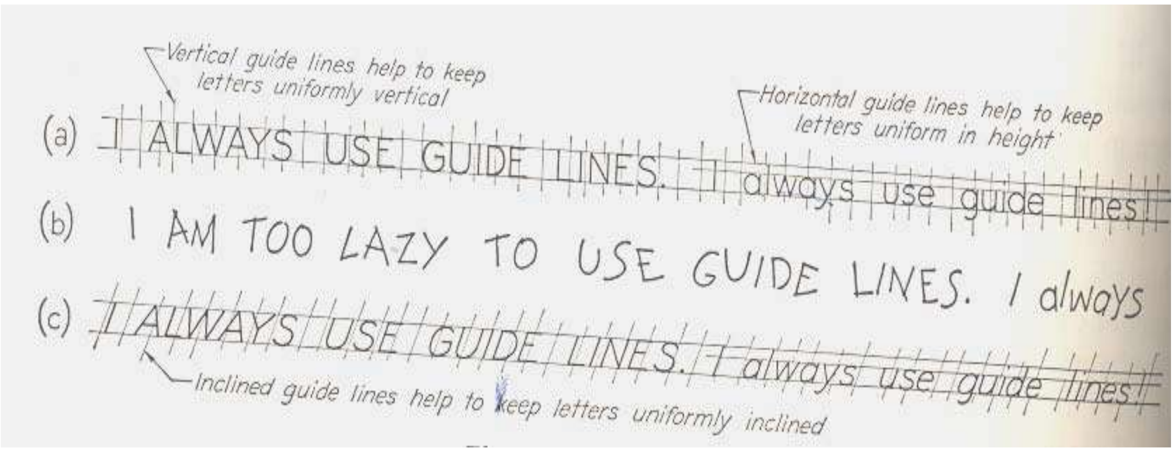



Figure 3.18: Guidelines to lettering

*a) Guidelines for Capital (Upper case) Letters*

On working drawings, capital letters are commonly made 3mm high, with the space between lines of lettering from ¾ th to the full height of the letters. The vertical guidelines are not used to space the letters (as this should always be done by eye while lettering), but only to keep the letters uniformly vertical, and they should accordingly be drawn at random Figure 3.19.

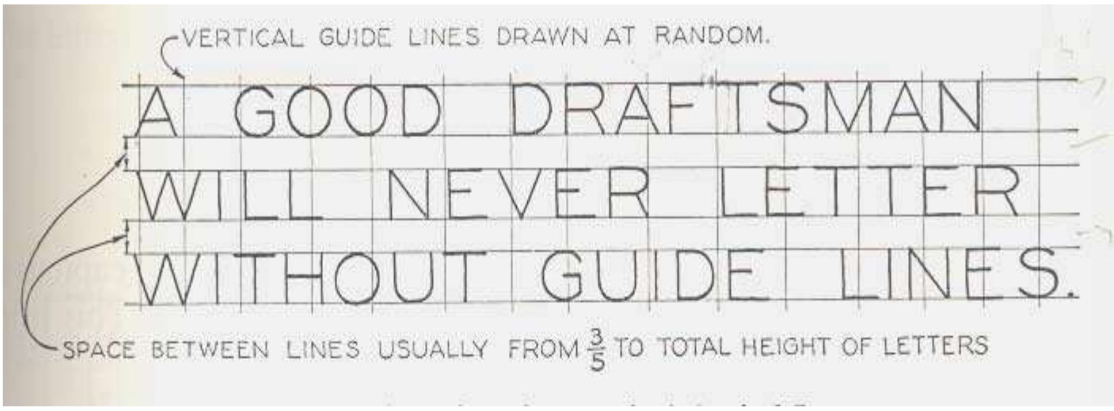



Figure 3.19: Guidelines for capital letters

*b) Guidelines for Inclined Capital (Upper case) Letters*

A guideline for inclined capital letters is somewhat different. The spacing of horizontal guidelines is the same as for vertical capital lettering. The American Standard recommends slope of approximately $68.2^0$ with the horizontal and may be established by drawing a "sloped triangle", and drawing the guidelines at random with T-square and triangles as shown in Figure 3.20.

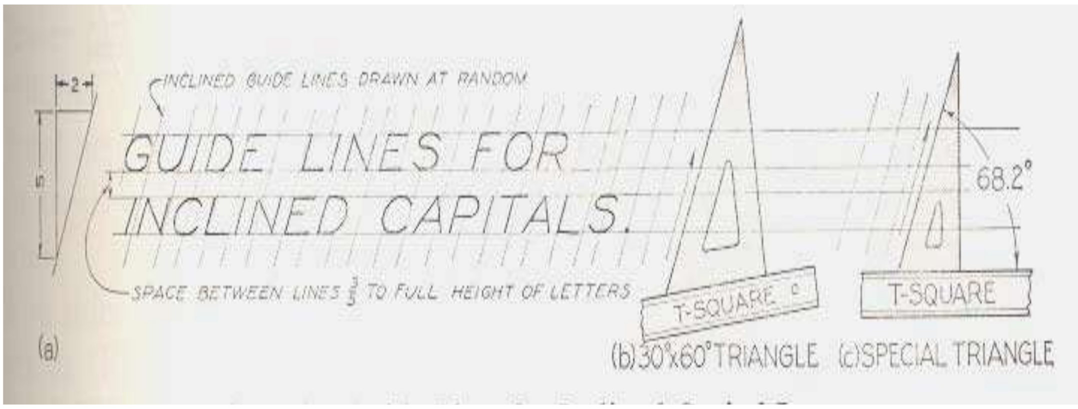



Figure 3.20: Guidelines for inclined capital letters

*c) Guidelines for Lower-Case Letters*

Lower-case letters have four horizontal guidelines, called the cap line, waistline, and base line and drop line. Strokes of letters that extend up to the cap line are called ascenders, and those that extend down to the drop line, descenders. Since there are only five letters (p, q, g, j, and y) that have descenders, the drop lines are little needed and are usually omitted. In spacing guidelines, space "a" may vary from 3/5to 2/3 of space "b".

The term single stoke or one stoke does not mean that the entire letter is made without lifting the pencil. But the width of the stroke is the width of the stem of the letter.

***Single stoke lettering***

The salient features of this type of lettering are:

- Greatest amount of lettering on drawings is done in a rapid single stroke letter i.e. either vertical, or inclined.

- The ability to letter and perfectly can be acquired only by continued and careful practice

- It is not a matter of artistic talent or event of dexterity in hand writing.

***Order of strokes***

They are necessary to have legible and accurate letter styles. In the following description an alphabet of slightly extended vertical capitals has-been arranged in-group. Study the slope of each letter with the order and direction of the storks forming it. The proportion of height and width of various letters must be known carefully to letter them perfectly.

***The I-H-T Group***

- The letter I is The Foundation Stroke.

- The top of T is drawn first to the full width of the square and the stem is started accurately at its mid-point.

***The L-E-F Group***

- The L is made in two strokes.

- The first two strokes of the E are the same for the L, the third or the upper stoke is lightly shorter than the lower and the last stroke is the third as long as the lower

- F has the same proportion as E

***The V-A-K Group***

- V is the same width as A, the A bridge is one third up from the bottom.

- The second stroke of K strikes stem one third up from the bottom and the third stroke branches from it.

***The M-W Group***

- are the widest letters

- M may be made in consecutive strokes of the two verticals as of N

- W is made with two V's

***The O-Q-C-G Group***

- The O families are made as full circles and made in two strokes with the left side a longer arc than the right.

- A large size C and G can be made more accurately with an extra stroke at the top.

***The D- U-J Group***

- The top and bottom stokes of D must be horizontal, fail line to observe this is a common fault with beginners

- U is formed by two parallel strokes to which the bottom stroke be added.

- J has the same construction as U, with the first stroke omitted.

***The P-R-B Group***

- The number of stokes depends up on the size of the letter.

- The middle line of P and R are on centreline of the vertical line.

The orders of stroke for capital (upper case) for capital letters is shown in Figure 3.21 – 3.22.

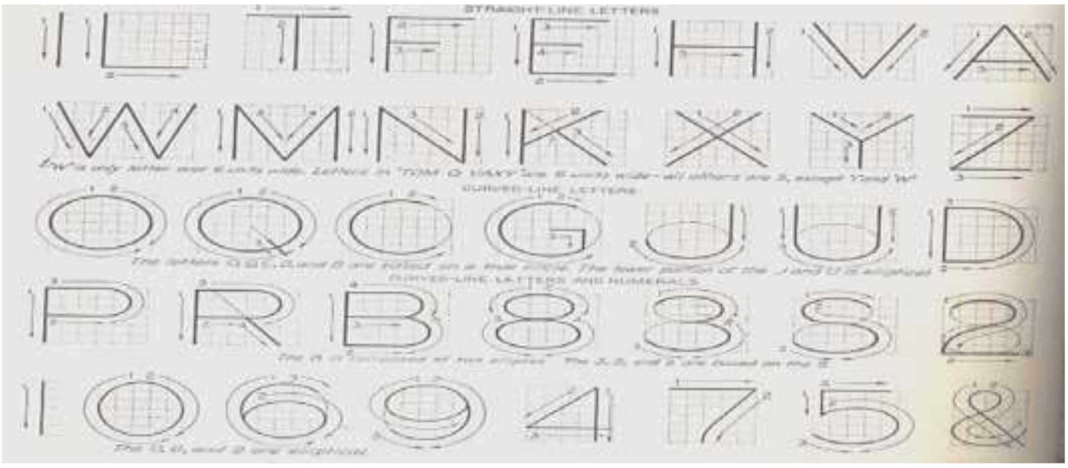


Figure 3.21: Order of stroke for capital letters

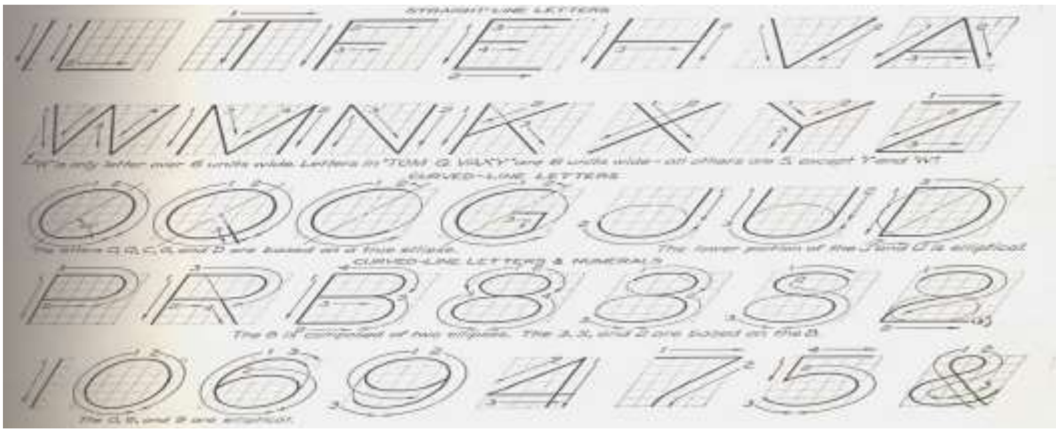


Figure 3.22: Order of stroke for inclined capital letters

**3.3.2 Spacing of Letters**

Uniformity in spacing of letters is a matter of equalizing spaces by eye. The background area between letters, not the distance between them, should be approximately equal. Some combinations, such as LT and VA, may even have to be slightly overlapped to secure good spacing. In some cases the width of a letter may be decreased. For example, the lower stroke of the L may be shortened when followed by A.

Words are spaced well apart, but letters with in words should be spaced closely. Make each word a compact unit well separated from the adjacent words. For either upper case or lower-case lettering, make the spaces between words approximately equal to a capital O. Avoid spacing letters too far apart and words too close together.

**Self Assessment Exercise:**

Describe the lettering techniques in presentation of engineering drawing.

## 4.0 Conclusion

This unit concludes with the significance of engineering drawing. For desired precision, the design draft and final drawing must be produced with the appropriate instrument.  It further concludes that for effective communication of the design to the relevant professional in the built environment, appropriate lettering techniques, size and style must be used.

## 5.0 Summary

This study unit introduced and familiarized the students with engineering drawing, different drawing equipment, technical standards and procedures for construction of geometric figures. The unit also explained the concept of graphic communication among Engineers, technicians, architects, draftsmen, builders and other professionals in built environment. In addition, the unit further explained the techniques of lettering in technical drawing communications.

## 6.0 Tutor-Marked Assignment

a) Explain the role of engineering drawing the design and execution of engineering projects.

b) Explain the use of different drawing equipment.

c) Describe the lettering techniques in presentation of engineering drawing.

## 7.0 References/Further Readings


Bhatt, N.D. (2018). Engineering Drawing, 5th edition, *Chrotar Publishing House,* India.

MRCET (2017). Engineering Drawing, Special Edition-MRCET, *McGrahill Publishers*.

Shah, P.J. (2008). A Textbook of Engineering drawing. 1st edition, *S.Chand Publishers,* India.

Venkata, R.K. (2008). Textbook of Engineering Drawing, Second Edition. *BS Publications*, Hyderabad.

## UNIT 4: DIMENSIONING AND DRAWING LAYOUTS

**CONTENTS**



### 1.0 Introduction

The purpose of dimensioning is to provide a clear and complete description of an object. A complete set of dimensions will permit only one interpretation needed to construct the part. Drawing of a component, in addition to providing complete shape description, must also furnish information regarding the size description. These are provided through the distances between the surfaces, location of holes, nature of surface finish, type of material, etc. The expression of these features on a drawing, using lines, symbols, figures and notes is called dimensioning.

### 2.0 Objective

At the end of this unit student should be able to

- Understand the purpose and significance of dimensioning of drawings
- Explain the different operations involved in sheet metal works
- Understand the basic tools used in sheet metal works

### 3.0 Main Content

### 3.1 Principles of Dimensioning

Some of the basic principles of dimensioning are given below.

1. All dimensional information necessary to describe a component clearly and completely shall be written directly on a drawing.

2. Each feature shall be dimensioned once only on a drawing, i.e., dimension marked in one view need not be repeated in another view.

3. Dimension should be placed on the view where the shape is best seen.

4. As far as possible, dimensions should be expressed in one unit only preferably in millimetres, without showing the unit symbol (mm).

5. As far as possible dimensions should be placed outside the view.

6. Dimensions should be taken from visible outlines rather than from hidden lines.

7. No gap should be left between the feature and the start of the extension line.

8. Crossing of centre lines should be done by a long dash and not a short dash.

**3.1.1 Definitions in Dimensioning**

***i. Dimension line*** is a thin line, broken in the middle to allow the placement of the dimension value, with arrowheads at each end as shown in Figure 3.23.

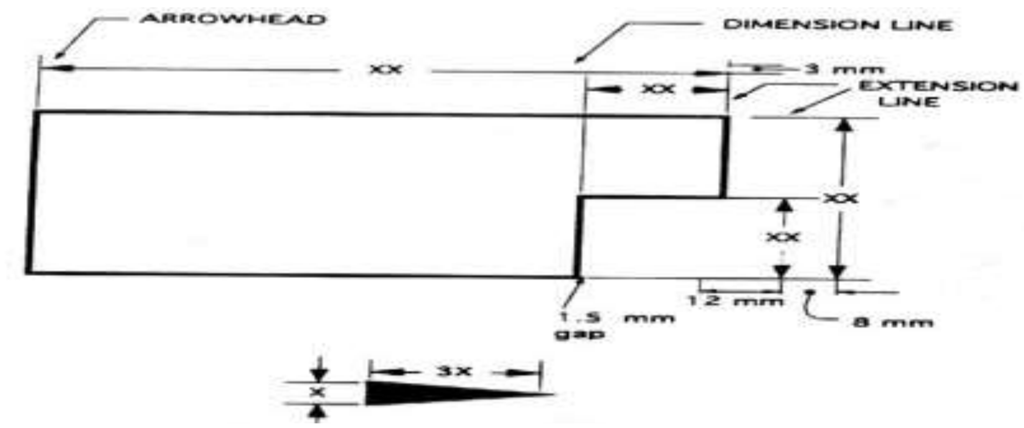



Figure 3.23: Dimension lines

***ii. Arrowhead*** **-** an arrowhead is approximately 3 mm long and 1 mm wide. That is, the length is roughly three times the width.

***iii. An extension line*** **-** a line, which extends a line on the object to the dimension line. The first dimension line should be approximately 12 mm (0.6 in) from the object. Extension lines begin 1.5 mm from the object and extend 3 mm from the last dimension line.

***iv. A leader is*** **-** a thin line used to connect a dimension with a particular area as shown in Figure 3.24, with Dimension lines showing 26, 16 and 2xØ 6 are all leader lines. A leader may also be used to indicate a note or comment about a specific area. When there is limited space, a heavy black dot may be substituted for the arrows. Also in this drawing, two holes are identical, allowing the "2x" notation to be used and the dimension to point to only one of the circles.

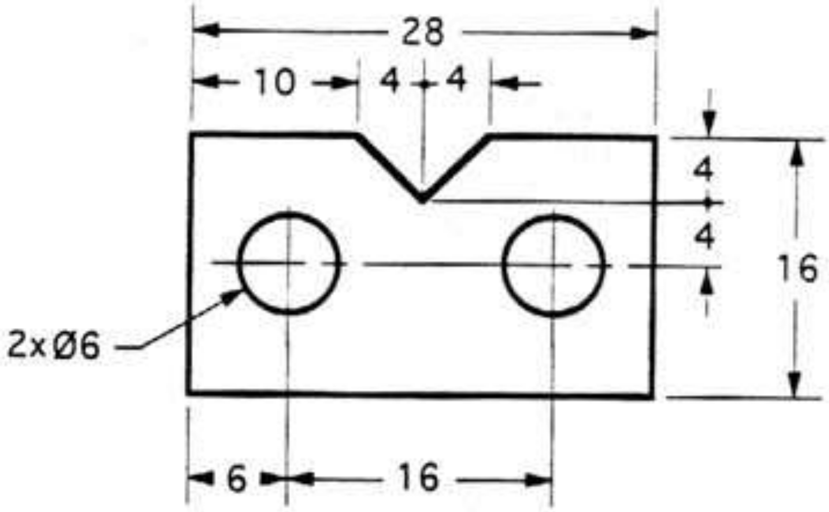



Figure 3.24: Examples of leader dimension lines

### *3.1.2 Steps in Dimensioning*

There are two basic steps in dimensioning objects, regardless of the type of object.

STEP 1: Apply the size dimensions. These are dimensions, which indicate the overall sizes of the object and the various features, which make up the object.

STEP 2: Apply the location dimensions. Location dimensions are dimensions, which locate various features of an object from some specified datum or surface as shown in Figure 3.25.

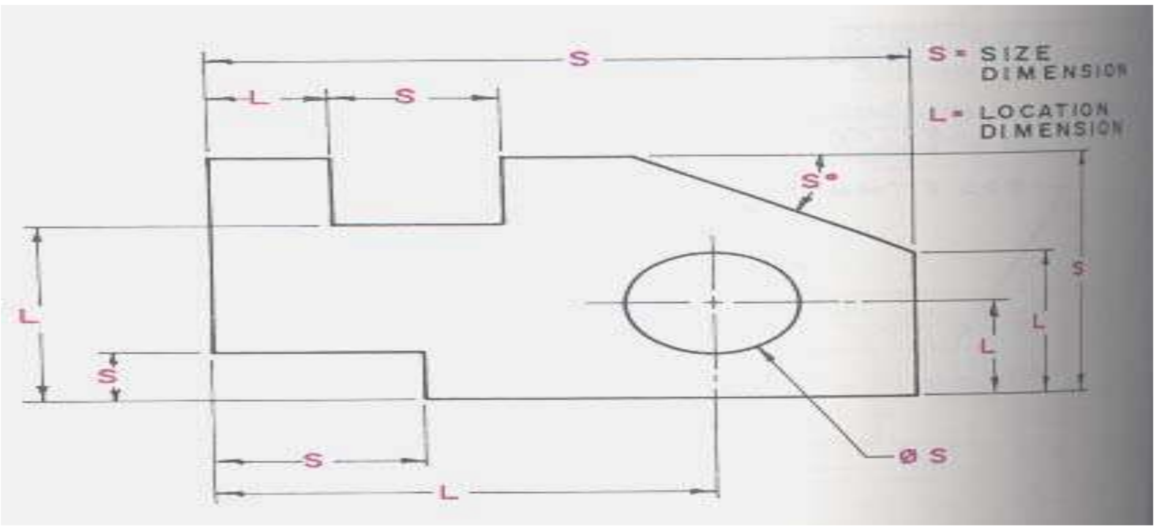



Figure 3.25: Dimensioning steps

### 4.1 Where to put Dimensions in Drawing

The dimensions should be placed on the face that describes the feature most clearly. Examples of appropriate and inappropriate placing of dimensions are shown in Figure 3.26.

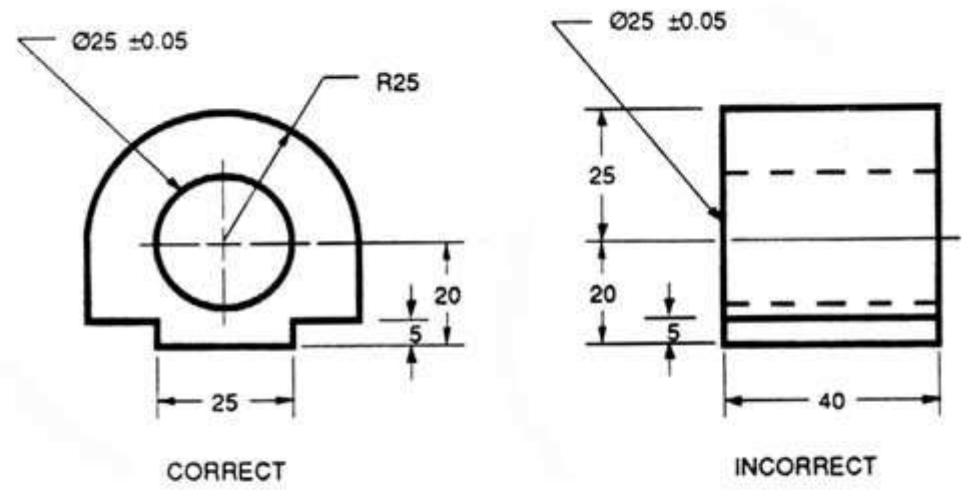



Figure 3.26: Appropriate and in appropriate placement of dimension

***Illustration of Dimensioning***

We have to make some choices when we dimension a block with a notch or cut-out (Figure 3.27). It is usually best to dimension from a common line or surface. This can be called the datum line of surface. This eliminates the addition of measurement or machining inaccuracies that would come from "chain" or "series" dimensioning. Note how the dimensions originate on the datum surfaces. We chose one datum surface in Figure 3.27, and another in Figure 3.28. As long as we are consistent, it makes no difference. (We are just showing the top view). In Figure 3.29 we have shown a hole that we have chosen to dimension on the left side of the object. The Ø stands for "diameter".

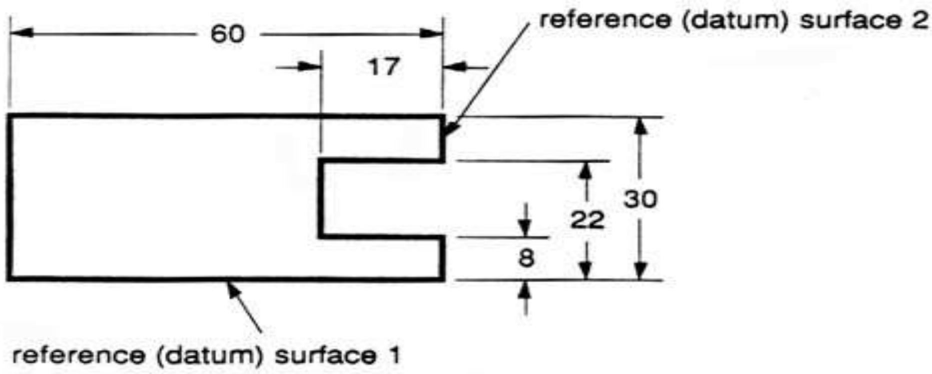



*Figure 27 Surface datum example*

Figure 3.27: Surface datum example

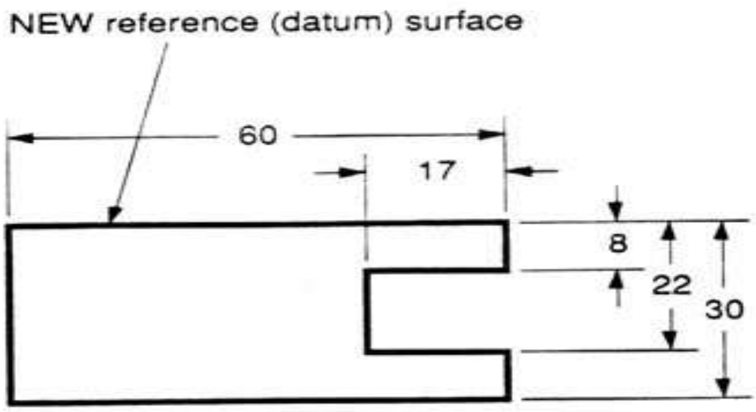



Figure 3.28: Surface datum examples

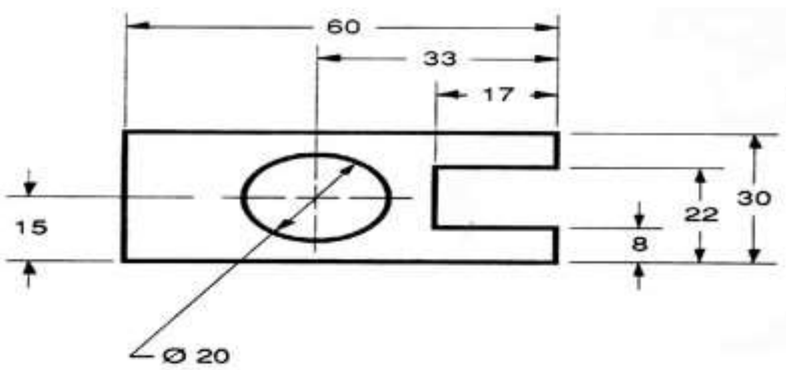



Figure 3.29: Examples of a dimensioned hole

**4.2 Drawing Layouts**

Most of tools used for sheet metal works have already been described in Modules 1 and 2, the following tools are commonly used for general sheet-metal work.

**4.2.1 Drawing Sheets**

The standard drawing sheet sizes are arrived at on the basic Principal of x: y = 1: $\sqrt{2}$ and xy = 1 where x and yare the sides of the sheet. For example AO, having a surface area of 1 Sq.m; x = 841 mm and y = 1189 mm. The successive sizes are obtained by either by halving along the length or doubling the width, the area being in the ratio 1: 2. Designation of sizes is given in Figure 3.l0 and their sizes are given in Table 3.3. For class work use of A2 size drawing sheet is preferred. See Figure 3.10 and Table 3.3 in unit 3.

**4.2.2 Drawing Layout**

For the typical layout of drawing, title block, dimensions and other details, see sections 3.1.3 and 3.1.4 of Unit 3 in this module.

**Self Assessment exercise:**

List the different paper types/designations and discuss a typical drawing layout.

## 4.0 Conclusion

The description of the shape and size of the object expressed in terms of the distances between the surfaces, location of holes, nature of surface finish, type of material, etc. on a drawing by using lines, symbols, figures and notes, which is known as dimensioning is of utmost importance if precision, accuracy, ease of work and meeting desired target is desired. Ambiguity, implied interpretation and unnecessary assumption, which could be costly are easily avoided by use of correct and proper dimensioning and by use of acceptable layout for the drawings.

## 5.0 Summary

This study unit looked into the significance of proper dimensioning of engineering drawing. It established that a complete set of dimensions will permit only one interpretation needed to construct the part. This study further revealed that proper layout of drawn objects must be ensured for proper communication to other professionals involved in the course of, cutting, shaping, making, building etc. of the desirable components, parts or entire project.

## 6.0 Tutor-Marked Assignment

a) Discuss the purpose of dimensioning

b) Explain the difference among dimension line, extension line and leaders

c) List the different paper types/designations and discuss a typical drawing layout.

## 7.0 References/Further Readings


Bhatt, N.D. (2018). Engineering Drawing, 5th edition, *Chrotar Publishing House*, India.

MRCET (2017). Engineering Drawing, (2017) Special Edition-MRCET, *McGrahill Publishers*.

Shah, P.J. (2008). A Textbook of Engineering drawing. 1st edition, *S.Chand Publishers,* India.

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Venugopal, K., & Prabhu, R.V. (2020). Engineering Drawing and Graphics. *New Age Publishers*, United Kingdom.

## MODULE FOUR

## ENGINEERING GRAPHICS AND INTERSECTION OF CURVES

Unit 1: Engineering graphics - Geometrical figures, conical sections etc.

Unit 2: Graphical calculus and applications

Unit 3: Development, intersection of curves for solids

### UNIT 1: ENGINEERING GRAPHICS – GEOMETRICAL FIGURES: CONICAL SECTIONS

**CONTENTS**



### 1.0 Introduction

Engineering drawing is a graphical two dimensional representation of three dimensional objects. In general, it provides necessary information about the shape, size, surface quality, material, manufacturing process, etc., of the object. It is the graphic language from which a trained person can visualize objects and transform it to reality.

### 2.0 Objective

At the end of this unit student should be able to

- Learn to sketch and take field dimensions.
- Learn to take data and transform it into graphic drawings.

- Learn basic engineering drawing formats

## 3.0 Main Content

## 3.1 Engineering graphics

The graphics of engineering design and construction is one of the most important courses of all studies for an engineering or technical career. The indisputable reason why graphics or drawing is extremely important is that, it is the language of the technicians, designers and engineers, used to communicate designs and construction details to others. The language of graphics is written in the form of drawings that represent the shape, size, and specifications of physical objects. The language is read by interpreting the drawings, so that physical objects can be constructed exactly as originally conceived by the designer. The technicalities of engineering drawing, make it more peculiar and distinguish it from other drawings.

### *3.1.1 Graphics in Engineering Communication*

A drawing is a graphic representation of an object, or a part of it, and is the result of creative thought by an engineer or technician. When one person sketches a rough map in giving direction to another, this is graphic communication. Graphic communication involves using visual materials to relate ideas.

Drawings, photographs, slides, transparencies, and sketches are all forms of graphic communication. Any medium that uses a graphic image to aid in conveying a message, instructions, or an idea is involved in graphic communication. One of the most widely used forms of graphic communication is the drawing.

Technically, engineering drawing can be defined as “a graphic representation of an idea, a concept or an entity which actually or potentially exists in life. Drawing is one of the oldest forms of communicating, dating back even farther than verbal communication. The drawing itself is a way of communicating all necessary information about an abstract, such as an idea or concept or a graphic representation of some real entity, such as a machine part, house or tools.

Unlike technical drawing, engineering drawing is a means of clearly and concisely communicating all of the information necessary to transform an idea or a concept in to reality. Therefore, engineering drawing often contains more than just a graphic representation of its subject. It also contains dimensions, notes and specifications.

**Self Assessment Exercise:**

What is graphic communication?

### 3.2 Geometrical Figures

Precise interpretation of geometric construction allows use of only the compass and an instrument for drawing straight lines, and with these, the geometer, following mathematical theory, accomplishes his solutions. In engineering drawing, the principles of geometry are employed constantly. However, instruments used are not limited to the basic. T-squares, triangles, scales, curves etc. are used to make constructions with speed and accuracy. Since there is continual application of geometric principles, the methods given in this unit should be mastered thoroughly. It is assumed that students using this courseware understand the elements of plane geometry and will be able to apply their knowledge.

Remember that the results you obtain will be only as accurate as your skill in making them. Take care in measuring and drawing so that your drawings will be accurate, precise and professional even in appearance (aesthetics).

#### *3.2.1 Techniques of Geometric Construction*

To construct the above mentioned geometric figures, we have to know some principles and procedures of geometric construction. Thus, the remaining of this unit is devoted to illustrate step-by-step geometric construction procedures used by drafters and technicians to develop various geometric forms.

*A. How to Bisect a Line or an Arc*

To bisect a line means to divide it in half or to find its centre point. In the given process, a line will also be constructed at the exact centre point at exactly $90^0$.

Given: Line A-B

Step 1: Set the compass approximately two-thirds of the length of line A-B and swing an arc from point A.

Step 2: Using the exact same compass setting, swing an arc from point B.

Step 3: At the two intersections of these arcs, locate points D and E

Step 4: Draw a straight-line connecting point D with point E.

Where this line intersects line A-B, it bisects line A-B. Line D-E is also perpendicular to line A-B at the exact centre point as shown in Figure 4.1.

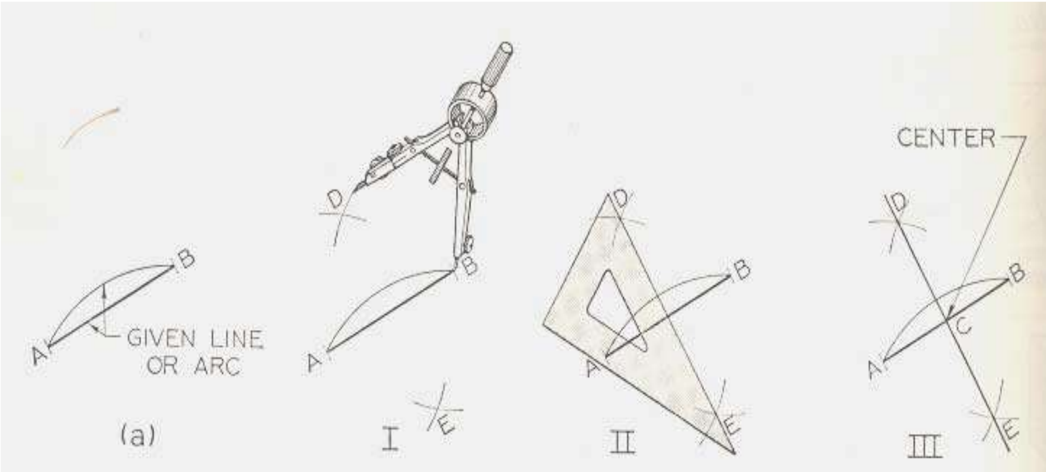


Figure 4.1: Example of how to bisect a line or an arc

*B. How to divide a Line to a number of equal parts*

Given: Line A-B

Step 1: Draw a construction line AC that starts at end A of given line AB. This new line is longer than the given line and makes an angle of not more than 300 with it.

Step 2: Find a scale that will approximately divide the line AB in to the number of parts needed (11 in the example below), and mark these divisions on the line AC.

There are now ‘n’ equal divisions from A to D that lie on the line AC (11 in this example).

Step 3: Set the adjustable triangle to draw a construction line from point D to point B. Then draw construction lines through each of the remaining ‘n-1’ divisions parallel to the first line BD by sliding the triangle along the straight edge. The original line AB will now be accurately divided as shown in Figure 4.2.

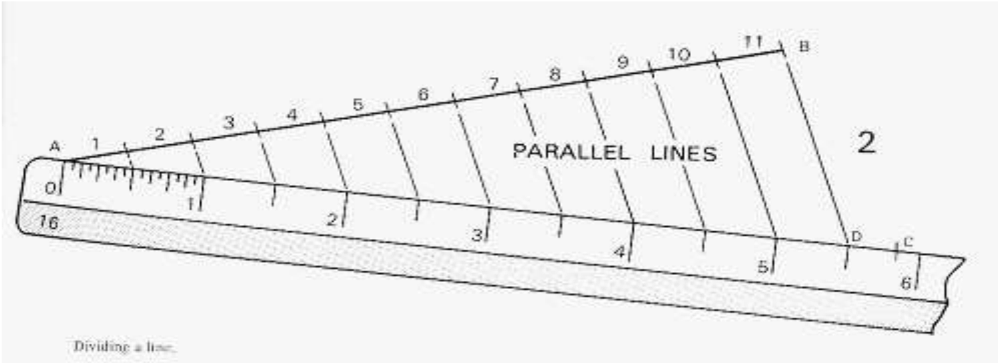


Figure 4.2: How to divide a line to a number of equal parts

*C. How to Bisect an Angle*

To bisect an angle means to divide it in half or to cut it in to two equal angles.

Given: Angle BAC

Step 1: Set the compass at any convenient radius and swing an arc from point A

Step 2: Locate points E and F on the legs of the angle, and swing two arcs of the same identical length from points E and F, respectively.

Step 3: Where these arcs intersect, locate point D. Draw a straight line from A to D. This line will bisect angle BAC and establish two equal angles: CAD and BAD as shown in Figure 4.3.

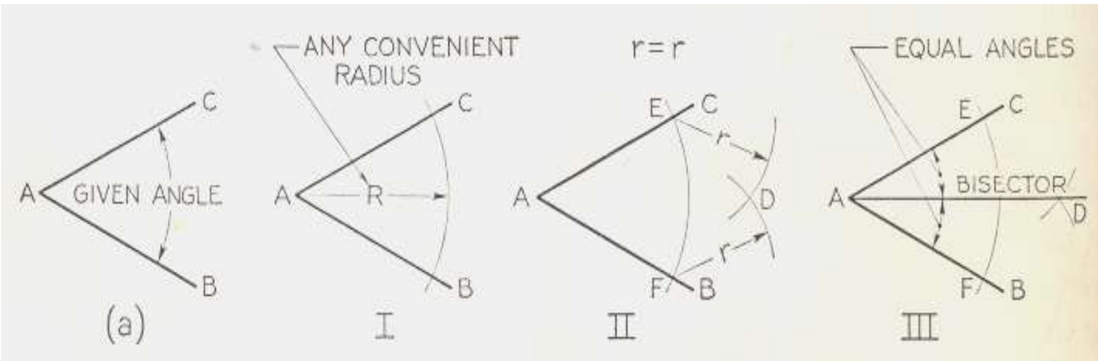


Figure 4.3: Example of how to bisect an angle

*D. How to Draw an Arc or Circle (Radius) Through Three Given Points*

Given: Three points in space at random: A, Band C.

Step 1: With straight line, lightly connect points A to B, and B to C,

Step 2: Using the method outlined for bisecting a line, bisect lines A-B and B-C

Step 3: Locate point X where the two extended bisectors meet. Point X is the exact centre of the arc or circle.

Step 4: Place the point of the compass on point X and adjust the lead to any of the points A, B, or C (they are the same distance), and swing the circle. If all work is done correctly, the arc or circle should pass through each point as shown in Figure 4.4.

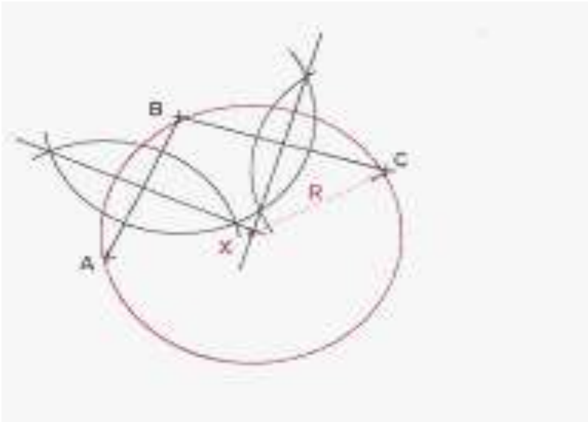


Figure 4.4: How to draw an arc/circle through three given points

*E. How to Draw a Line Parallel to a Straight Line at a Given Distance*

Given: Line A-B, and a required distance to the parallel line.

Step 1: Set the compass at the required distance to the parallel line. Place the point of the compass at any location on the given line, and swing a light arc whose radius is the required distance.

Step 2: Adjust the straight edge of either a drafting machine or an adjusted triangle so that it line align with line A-B, slide the straight edge up or down to the extreme high point, which is the tangent point, of the arc, then draw the parallel line as shown in Figure 4.5.

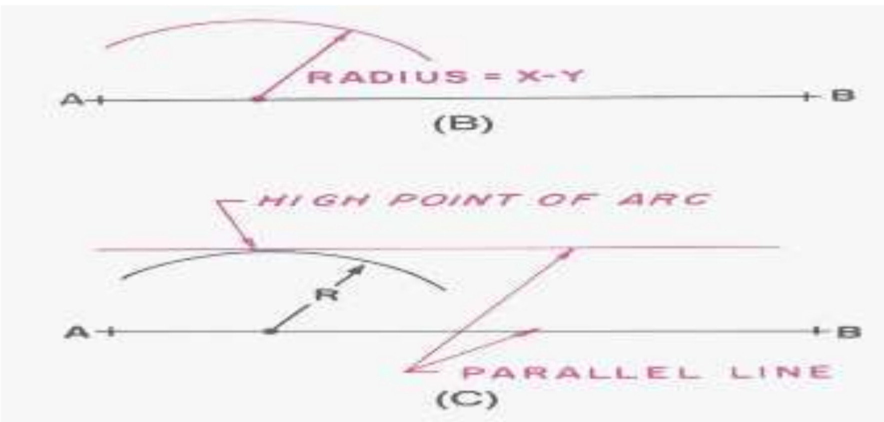


Figure 4.5: How to Draw a Line Parallel to a Straight Line at a Given Distance

*F. How to Draw a Line Parallel to a Curved Line at a Given Distance*

Given: Curved line A-B, and a required distance to the parallel line, Step 1: Set the compass at the required distance to the parallel line. Starting from either end of the curved line, place the point of the compass on the given line, and swing a series of light arcs along the given line.

Step 2: using an irregular curve, draw a line along the extreme high points of the arcs.

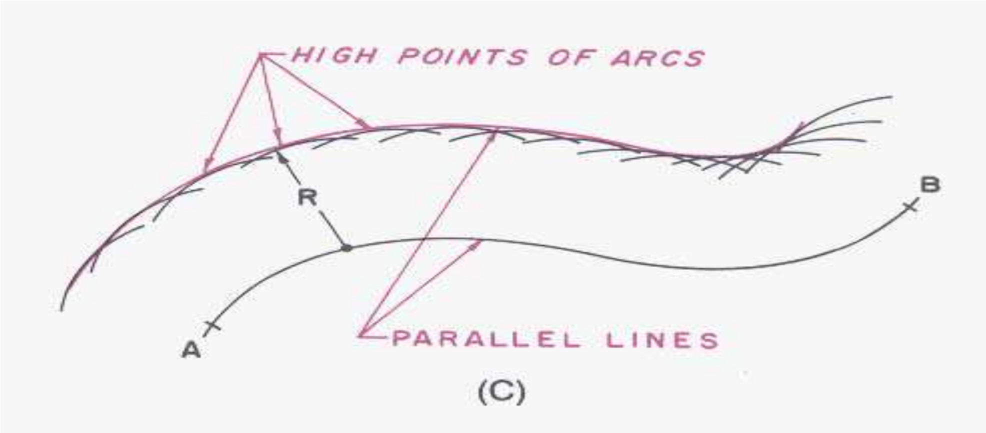


Figure 4.6: How to draw a line parallel to a curved line at a given distance

*G. How to Draw a Perpendicular Lines to a Line at a Point*

*Method 1*

Given: Line A-B with point P on the same line.

Step 1: Using P as a centre, make two arcs of equal radius or more continuous arc (R1) to intercept line A-B on either side of point P, at points S and T.

Step 2: Swing larger but equal arcs (R2) from each of points S and T to cross each other at point U.

Step 3: A line from P to U is perpendicular to line A-B at point P

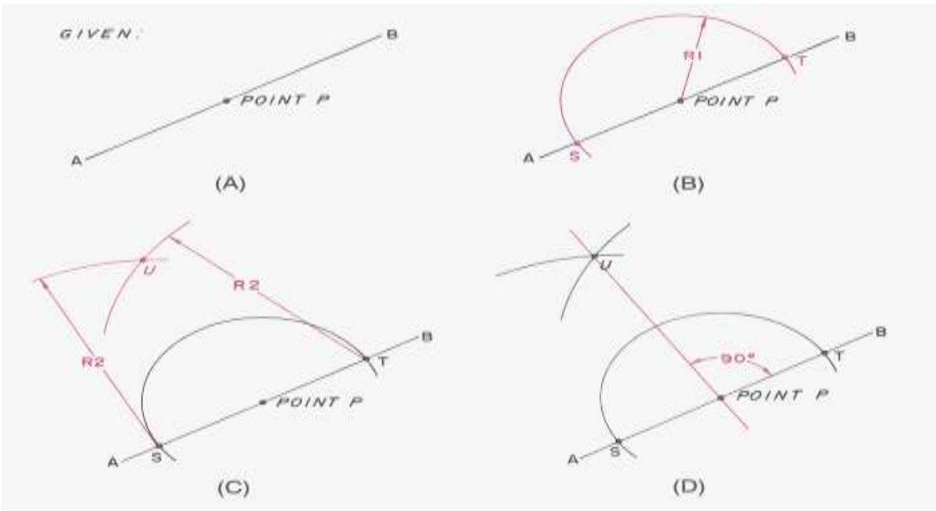


Figure 4.7: How to draw a perpendicular line to a line at a point outside the line

*Method 2*

Given: Line A-B with point P on the line.

Step 1: Swing an arc of any convenient radius whose centre O is at any convenient location NOT online A-B, but positioned to make the arc cross line A-B at points P and Q

Step 2: A line from point Q through centre O intercepts the opposite side of the arc at point R

Step 3: Line R-P is perpendicular to line A-B (A right angle has been inscribed in a semi-circle)

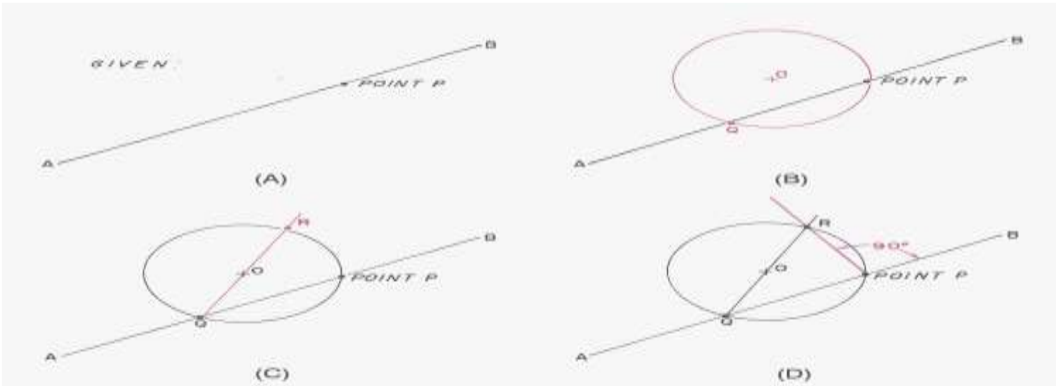


Figure 4.8: Example on how to draw a perpendicular line, to a point on the line

*H. How to Draw a Triangle with Known Lengths of Sides*

Given: lengths 1, 2, and 3.

Step 1: Draw the longest length line, in this example length 3, with ends A and B. Swing an arc (R1) from point A whose radius is either length 1 or length 2; in this example length 1.

Step 2; using the radius length not used in step 1, swing an arc (R2) from point B to intercept the arc swung from point A at point

Step 3: Connect A to C and B to C to complete the triangle as shown in Figure 4.9.

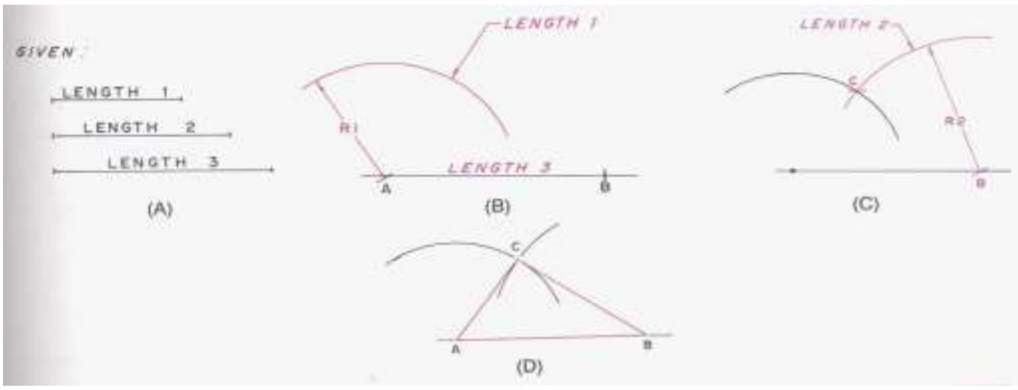


Figure 4.9: How to draw a triangle with known lengths of sides

*I. How to Draw a Square*

*Method-1*

Given: The locations of the centre and the required distance across the sides of a square.

Step 1: Lightly draw a circle with a diameter equal to the distance around the sides of the square. Set the compass at half the required diameter.

Step 2: Using triangles, lightly complete the square by constructing tangent lines to the circle. Allow the light construction lines to project from the square, without erasing them.

Step 3: Check to see that there are four equal sides and, if so, darken in the actual square using the correct line thickness as shown in Figure 4.10.

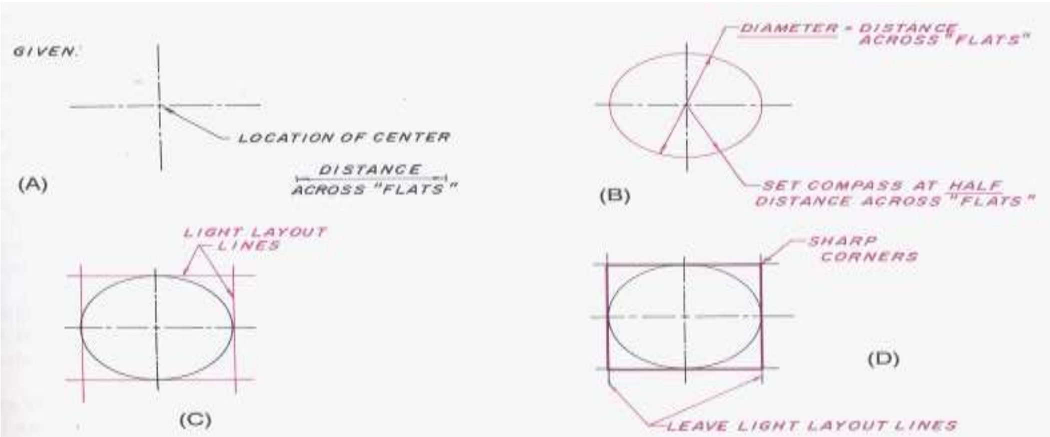


Figure 4.10: How to draw a square with given side, M1

Method-2

Given one side AB. Through point A, draw a perpendicular. With A as a centre, and AB as radius; draw the arc to intersect the perpendicular at C. With B and C as centres, and AB as radius, strike arcs to intersect at D. Draw line CD and BD as shown in Figure 4.11.

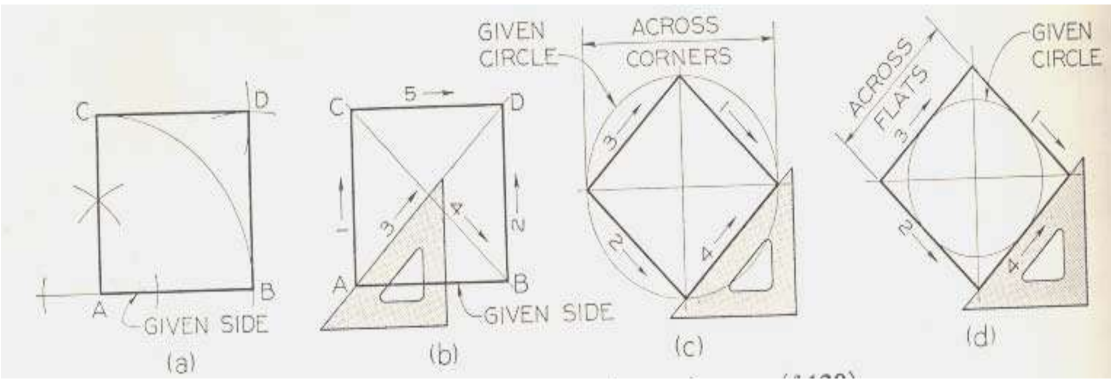


Figure 4.11: How to draw square with given side, M2

*L. How to Draw a Pentagon (5 Sided polygon)*

Given: The locations of the pentagon centre and the diameter that will circumscribe the pentagon.

Step 1: Bisect radius OD at C.

Step 2: With C as centre, and CA as radius, strike arc AE.

With A as centre, and AE as radius, strike arc EB.

Step 3: Draw line AB, then set off distances AB around the circumference of the circle, and draw the sides through these points as shown in Figure 4.12.

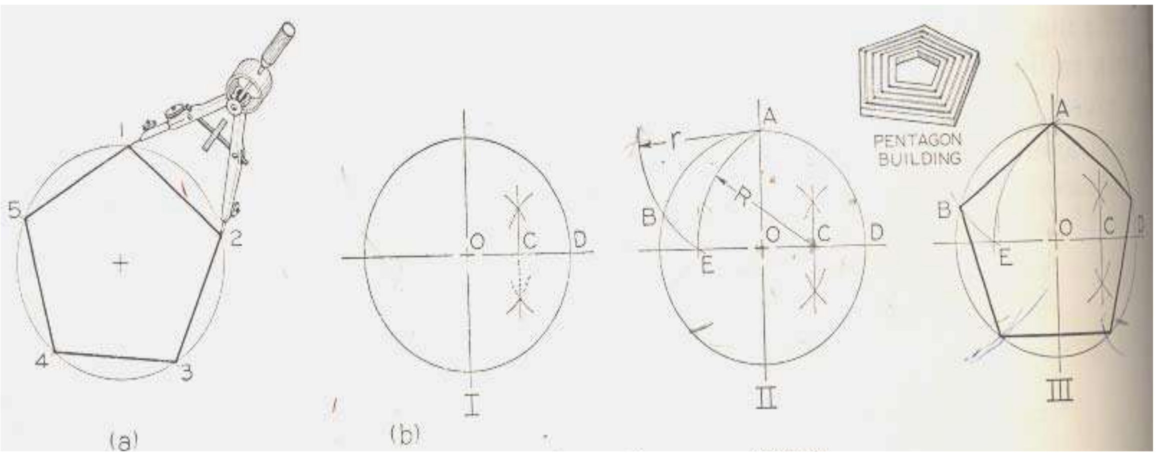


Figure 4.12: How to draw a pentagon (5-sided polygon)

*K. To Draw Any Sided Regular Polygon*

To construct a regular polygon with a specific number of sides, divide the given diameter using the parallel line method as shown in Figure 4.12 below. In this example, let us assume seven sided (Heptagon) regular polygon. Construct an equilateral triangle (0-7-8) with the diameter (0-7) as one of its sides.

1). Draw a line from the apex (point 8) through the second point on the line (point

2). Extend line 8-2 until it intersects the circle at point 9. Radius 0-9 will be the size of each side of the figure. Using radius 0-9 step off the corners of the seven-sided polygon and connect the points as shown in Figure 4.13.

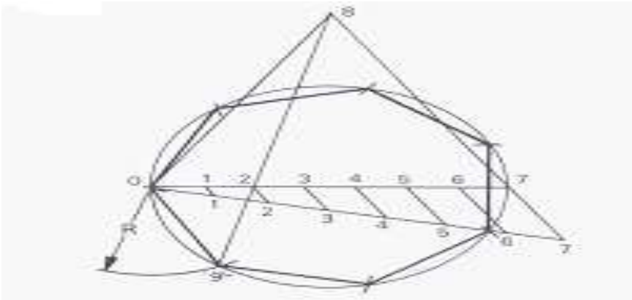


Figure 4.13: How to draw regular polygon of any side

**Self Assessment Exercise:**

Show the procedure how to divide a line in to number of equal parts.

### 3.3 Conical sections

Cone is formed when a right angled triangle with an apex and angle $\theta$ is rotated about its altitude as the axis. The length or height of the cone is equal to the altitude of the triangle and the radius of the base of the cone is equal to the base of the triangle. The apex angle of the cone is $2\theta$. When a cone is cut by a plane, the curve formed along the section is known as a conic.

*a) Circle*

When a cone is cut by a section plane A-A making an angle $\alpha$ = 90° with the axis, the section obtained is a circle.

*b) Ellipse*

When a cone is cut by a section plane B-B at an angle, $\alpha$ more than half of the apex angle i.e., $\theta$ and less than 90°, the curve of the section is an ellipse. Its size depends on the angle $\alpha$ and the distance of the section plane from the apex of the cone. In physical world, parabola are found in the main cables on simple suspension bridge, as parabolic reflectors in satellite dish antennas, vertical curves in roads, trajectory of a body, automobile head light, parabolic receivers.

*c) Parabola*

If the angle $\alpha$ is less than $\theta$ (section plane D-D), the curve at the section is hyperbola. The curve of intersection is hyperbola, even if $\alpha = \theta$, provided the section plane is not passing through the apex of the cone. However if the section plane passes through the apex, the section produced is an isosceles triangle. If the angle $\alpha$ is equal to $\theta$ i.e., when the section plane C-C is parallel to the slant side of the cone the curve at the section is a parabola. This is not a closed figure like circle or ellipse. The size of the parabola depends upon the distance of the section plane from the slant side of the cone.

*d) Hyperbola*

If the angle $\alpha$ is less than $\theta$ (section plane D-D), the curve at the section is hyperbola. The curve of intersection is hyperbola, even if $\alpha = \theta$, provided the section plane is not passing through the apex of the cone. However if the section plane passes through the apex, the section produced is an isosceles triangle. Lampshades, gear transmission, cooling towers of nuclear reactors are some of the applications of Hyperbola. The shapes are shown in Figure 4.14

Eccentricity (e):

a. If e = 1, it is parabola

b. If e < 1, it is an ellipse

c. If e > 1, it is hyperbola

Where eccentricity e is the ratio of distance of the point from the focus to the distance of the point from the directrix.

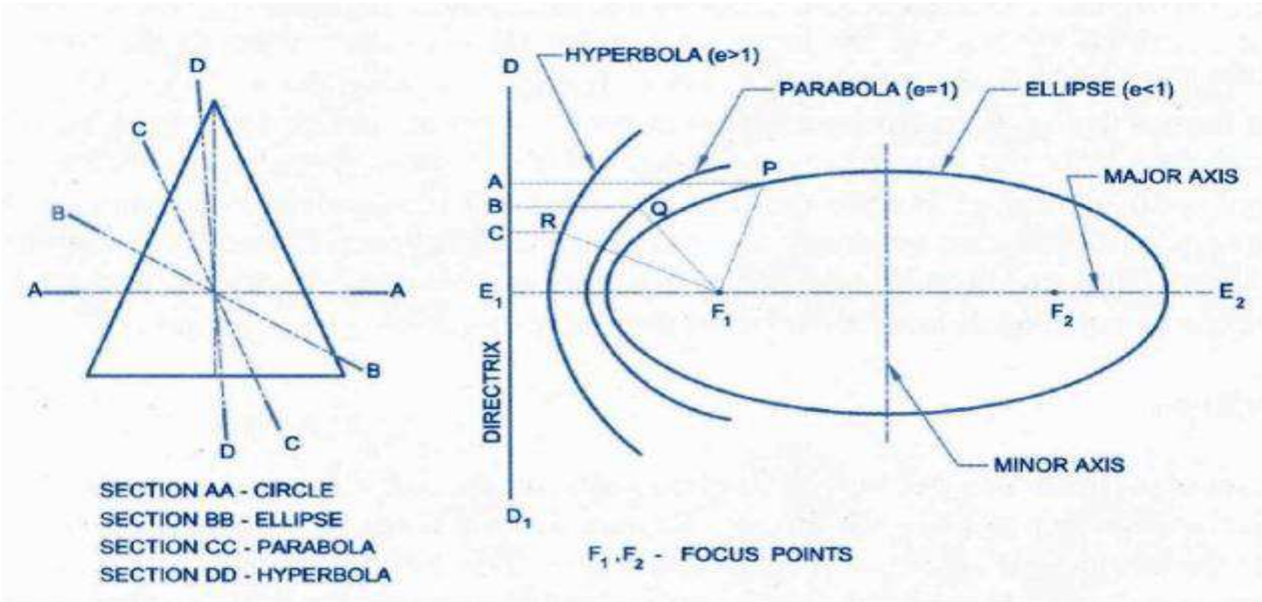


Figure 4.14: Hyperbola

*Exercise*

To draw a parabola with the distance of the focus from the directrix at 50mm (Eccentricity method)

Construction:

1. Draw the axis AB and the directrix CD at right angles to it:

2. Mark the focus F on the axis at 50mm.

3. Locate the vertex V on AB such that AV = VF

4. Draw a line VE perpendicular to AB such that VE = VF

5. Join A, E and extend. Now, VE/VA = VF/VA = 1, the eccentricity.

6. Locate number of points 1, 2, 3, etc., to the right of V on the axis, which need not be equidistant.

7. Through the points 1, 2, 3, etc., draw lines perpendicular to the axis and to meet the line AE extended at 1',2',3' etc.

8. With centre F and radius 1-1', draw arcs intersecting the line through 1 at P1 and P`1

9. Similarly, locate the points P2, P`2, P3, P`3 etc., on either side of the axis. Join the points by smooth curve, forming the required parabola Figure 4.15.

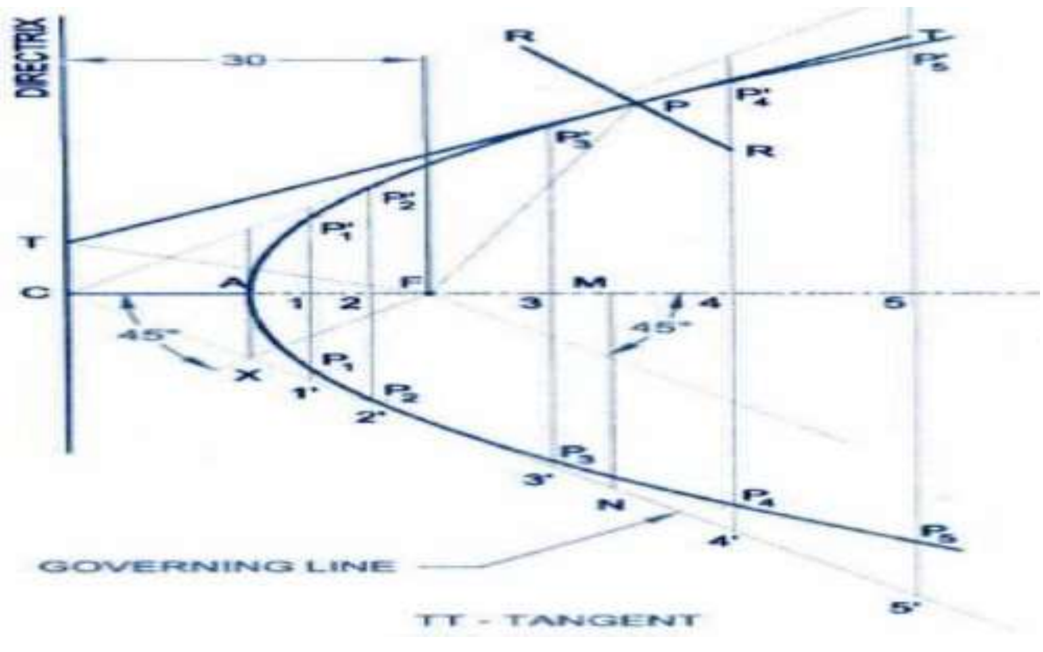


Figure 4.15: How to draw a parabola from a give directrix

**Self Assessment exercise:**

Construct a parabola if the distance between its focus and directrix is 60 mm. Also draw a tangent to the curve.

## 4.0 Conclusion

Engineering graphics provides necessary information about the shape, size, surface quality, material, manufacturing process, etc., of the object. Geometrical constructions and conical sections involved in engineering drawing have been x-rayed in this unit. A few methods of geometry have been illustrated, but of course, without mathematical proofs.

## 5.0 Summary

From this unit we find out that engineering drawing, which is the graphic language provides an avenue, from where a trained person (Engineers, builders, technicians and other professional in the built environment) can visualize objects and transform it to reality. The unit established simple steps of drawing selected geometrical shapes, which are encountered in our day-to-day interactions in engineered systems.

## 6.0 Tutor-Marked Assignment

a. What is graphic communication?

b. Show the procedure how to divide a line in to number of equal parts.

c. Construct a regular pentagon of 25 mm side, by two different methods.

d. Construct a parabola if the distance between its focus and directrix is 60 mm. Also draw a tangent to the curve.

## 7.0 References/Further Readings


Bhatt, N.D. (2018). Engineering Drawing, 5th edition, *Chrotar Publishing House*, India.

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## UNIT 2: GRAPHICAL CALCULUS AND APPLICATIONS

**CONTENTS**



### 1.0 Introduction

The geometric solutions of three-dimensional forms require an understanding of the space relations that points, lines, and planes share in forming any given shape. Problems which many times require mathematical solutions can often be solved graphically with accuracy that will allow manufacturing and construction. Thus, basic descriptive geometry is one of the designer's methods of thinking through and solving problems.

### 2.0 Objective

At the end of this unit student should be able to

- Develop the ability to communicate engineering and other general information using mathematical principles of calculus;
- Explore and appreciate the significance of engineering drawing and graphical communication in a rapidly changing technological society;
- Understand the design process and graphical calculus for the communication of tangible data or abstract information in engineering design.

### 3.0 Main Content

### 3.1 Graphical Calculus

#### *3.1.1 Curve fitting and Volume of Containers*

How could we estimate the volume? One way would be to simply fill the container with a liquid and then pour the liquid into a measuring device.

Another way, using calculus and the curve fitting or regression feature of a graphing calculator, would be to turn the urn on its side, as shown below, take a series of vertical measurements from the centre to the top, use regression, and then integrate (either by hand or with the aid of the calculator).

*Example*

Find the area of the region bounded by the ***parabola*** $y = x^2$ and the line $y = x + 2$.

Explanation: The parabola and the line divide the plane into five regions – four of them are unbounded (R1; R2; R3 and R5) and one of them is bounded (R4, the required one) Figure 4.16.

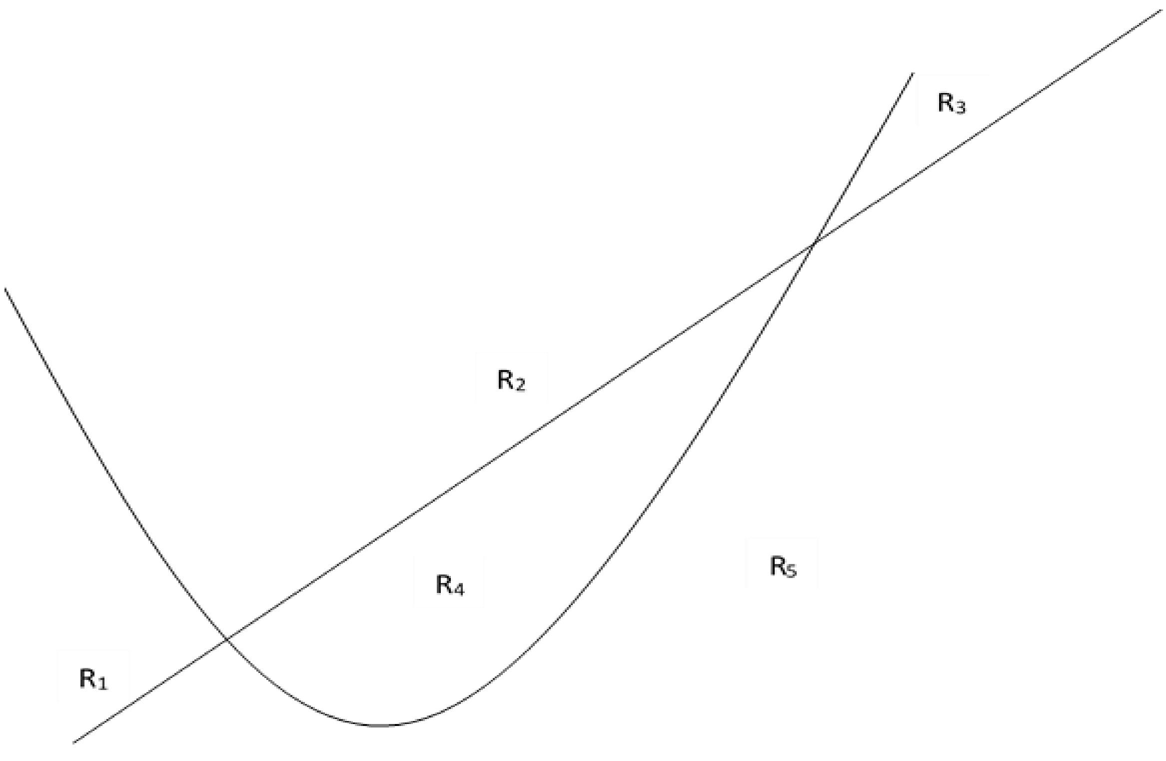


Figure 4.16: The parabola and the planes

*Solution*

Solving for the x-coordinates of the intersection points of the parabola and the line:

$x^2 = x + 2$
$x^2 - x - 2 = 0$
$(x - 2)(x + 1) = 0$
we get $x_1 = -1, and\ x_2 = 2$.

The region under consideration lies below the graph of y = x + 2, above that of $y = x^2$ (and between the vertical lines x = -1 and x = 2). The area A of the region below is shown is Figure 4.17: Area bound by the parabola.

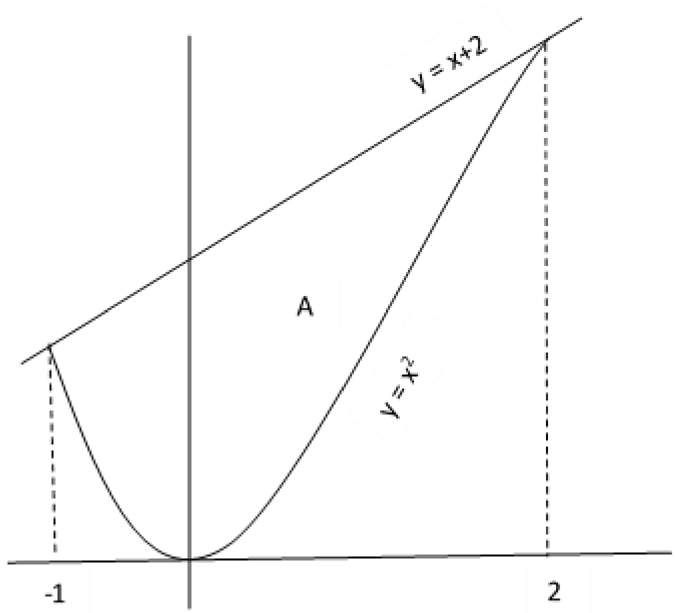


Figure 4.17: Area bound by the parabola

**Self Assessment Exercise:**

Explain how calculus can be used in area determination and sketching.

**3.2 Application of Calculus in Engineering Drawing**

1. Hydraulic engineering (fitting data with power functions and properties of log and exponential functions sketches)

2. Bridge project (sketches of piecewise functions and differentiability of a function)

3. Automobile velocity data (fitting polynomial functions to velocity data and testing models sketches)

4. Optimization of an irrigation channel (plane geometry, trigonometry, and minimization of functions sketches).

***1. Hydraulic Engineering (Torricelli's Principle)***

Let f denote the volume flow rate of a liquid through a restriction, such as an opening or a valve, out of a tank. Torricelli's principle states that f is proportional to the square root of the volume V of liquid in the tank. Thus

$$f = r\sqrt{v}$$

where r is a constant. The idea is to use regression to fit a curve of the form

$$f = V^m$$

to the given data.

To use linear regression, transform the variables using logarithms to base 10 first, giving a linear equation between the variables $x = \log_{10} V$ and $b = \log_{10} r$.

***Exercise 4a: Hydraulic fittings***

A 15-cup coffee pot was placed under a water faucet and filled to the 15-cup line. With the outlet valve open, the faucet's flow rate was adjusted until the water level remained constant at 15 cups, and the time for one cup to flow out of the pot was measured. This experiment was repeated with the pot filled to the various levels shown in Table 4.1.'

If t equals the time for one cup to flow out of the pot, then the flow rate equals 1 = t. During class we first found the linear regression line $f = C_1V + C_2$ to the given data, without transforming the variables.

Later we compared this fit with the one obtained by transforming the variables. Matlab was used to find and plot the regression curves, along with the data, and then to extrapolate from the data. It was emphasized to the class that it is important not to use software blindly, and to understand some of the underlying mathematical principles. In this case, one must understand the of logarithms and exponential functions.

We also emphasized the importance of knowing some theory as well as the given data.

In this case, the theory is Torricelli's principle, which says that $f = r\sqrt{v}$. Of course, for experimental, the relationship is approximately $f = rV^{1/2}$. Here is where theory meets practice. The fit obtained without transforming the variables is $f = 0.0062V + 0718$, as shown by the linear regression of Figure 4.18. If one transforms the variables first, the

Matlab commands are: $L_2$ = polyfit (log10 (cups), log10 (flow), 1), which gives $L_2$ = 0.4331, -1.3019; So, m≅ 0.4331, b = -1.3019.

To obtain f, $10^{\log f} = 10^{b+mx} = 10^b 10^{mx} = 10^b (10^{\log V})^m = 10^b V^m = rV^m$, where $r = 10^b$. For this example, f = `10. ^ (-1.3019).*v. ^0.4331', or $f = 0.0499V^{0.4331}$. A plot of both fits together (see Figure 4.18) shows that the line diverges from the power function as *V* becomes larger. Hence the power function is the better estimate as *V* grows large.

Table 4.1: Flow rate of filling the cups and time

| **Unit** | **Readings** | | | |
|---|---|---|---|---|
| **V (cups)** | 15 | 12 | 9 | 6 |
| **t(sec)** | 6 | 7 | 8 | 9 |

This was demonstrated several holes in a plastic container (Figure 4. 19). For a given opening size, the time to fill a cup, t, was recorded for constant water levels. (*V* = 6, 9, 12, 15 cups) in the container. The constant water level was maintained by adjusting the faucet water entering the container. Each team received a set of four data values for t. The values remained the same as in the sample done in class. The teams were asked to do what was done for the sample in class, and were encouraged to use Matlab.

Table 4.1: Flow rate of filling the cups and time

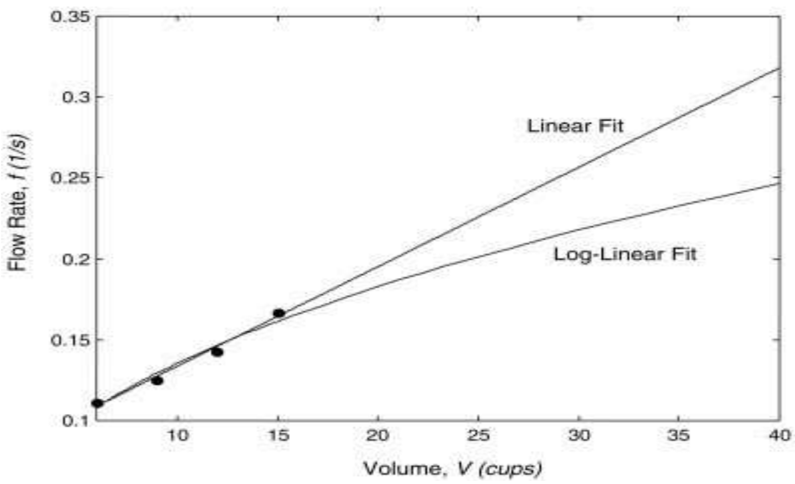


Figure 4.18: Flow rate of filling the cups and time

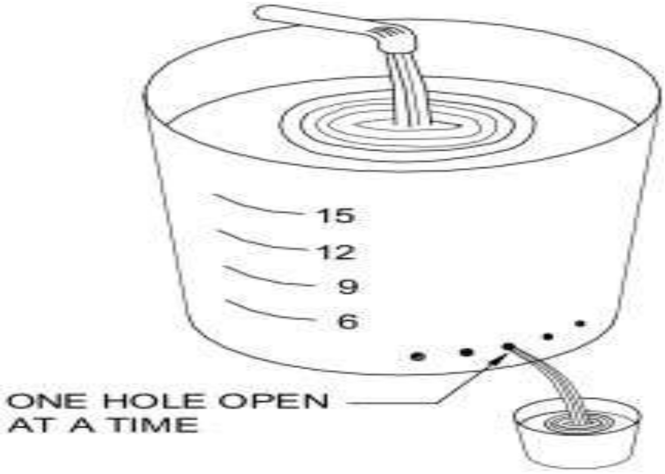


Figure 4.18: Hydraulic engineering experimental set up

***Exercise 4b Optimization of an irrigation channel***

Figure 4.19 shows the cross-section of an irrigation channel, which is a trapezoidal region. To maintain a certain volume flow rate, we want the cross-sectional area, A, to be fixed, to say A = 100 sq. ft. The objective is to minimize the amount of concrete that must be used to line the channel. To do this one minimizes the length, L, of the channel's perimeter, excluding the top. For the classroom example, we assumed that $\theta_1 = \theta_2 = \theta$, $h_1 = h_2 = h$, and $e_1 = e_2 = e$. Using geometry and trigonometry, one can express L as a function of $\theta$ and d alone.

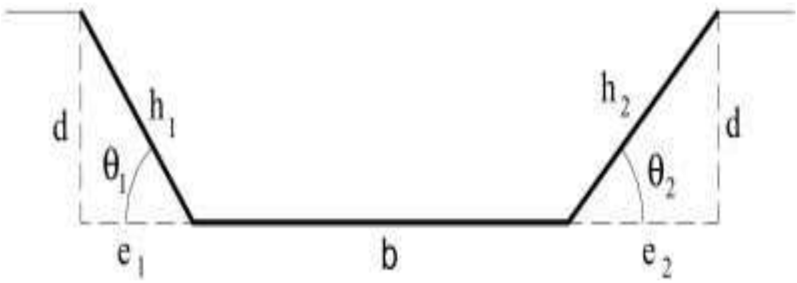


Figure 4.19: Channel cross section for the irrigation project

$$L = \frac{100}{d} - \frac{d}{tan\theta} + \frac{2d}{\sin\theta}$$

Minimizing L as a function of both $\theta$ and d requires multivariable calculus, something that the students had not yet learned. We first reduced the problem to single variable calculus by specifying either $\theta$ or d.

**Self Assessment Exercise:**

Discuss the application of calculus in engineering drawing.

## 4.0 Conclusion

All geometric shapes are composed of points and their connectors, lines. In descriptive geometry points are the most important geometric element and the primary building block for any graphical projection of a form. All projections of lines, planes, or solids can be physically located and manipulated by identifying a series of points that represent the object. Shapes of movement of machine part can be determined and plotted using calculus applications.

## 5.0 Summary

The unit established how Calculus notions are applied in professional contexts in engineering drawing. Mechanical design, in particular, requires extensive use of graphics, not only conventional orthographic drawings, but also sketches, solid models, graphical representations of various analyses and experiments, prototypes, and other graphical and physical models to communicate design concepts and outcomes effectively.

## 6.0 Tutor-Marked Assignment

a) Explain how calculus can be used in area determination and sketching.

b) Discuss some application of calculus in engineering drawing

## 7.0 References/Further Readings


Bhatt, N.D. (2018). Engineering Drawing, 5th edition, *Chrotar Publishing House*, India.

Horwitz, A., & Ebrahimpour, A. (2002). Engineering Applications in Differential and Integral Calculus, *Int. Jour. of Engineering*, Ed. Vol. 18, No. 1, pp. 78-88.

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**UNIT 3: DEVELOPMENT, INTERSECTION OF CURVES AND SOLIDS**

**CONTENTS**



## 1.0 Introduction

Development of surfaces is an aspect of workshop drawing that often arises when, for example, we need to cut out sheet metal which can be rolled into a specific shape, or when we need to cut a hole in a container - boiler or tank - which will be a close fit to a branching piece.

A development is no more than the shape of the piece of flat sheet metal before folding and jointing. An intersection is the profile of the curve formed when two sections meet. You will find six of these on every nut where the cone of the chamfer meets the six flats. Normally we do not need to draw these accurately, but there can be occasions when this is necessary.

## 2.0 Objective

At the end of this unit student should be able to

- Understand the significance of surface development in sheet metal work.
- Understand how materials are shaped before cutting and sizing out in article/parts fabrication

- Understand the importance of dimension especially the true length, with or diameter in material handling in the production process.

## 3.0 Main Content

### 3.1 Development of surfaces

A layout of the complete surface of a three dimensional object on a plane surface is called its development or pattern. Development is term frequently used in sheet metal work, where it means the unfolding or unrolling of a detail into a flat sheet called a pattern. A layout of the complete surface of a three dimensional object on a plane is called the development of the surface or flat pattern of the object. The development of surfaces is very important in the fabrication of articles made of sheet metal.

The objects such as containers, boxes, boilers, hoppers, vessels, funnels, trays etc., are made of sheet metal by using the principle of development of surfaces. In making the development of a surface, an opening of the surface should be determined first. Every line used in making the development must represent the true length of the line (edge) on the object.

#### *3.1.1. Steps for development of surface*

The steps to be followed for making objects, using sheet metal are given below:

1. Draw the orthographic views of the object to full size.

2. Draw the development on a sheet of paper.

3. Transfer the development to the sheet metal.

4. Cut the development from the sheet.

5. Form the shape of the object by bending.

6. Join the closing edges.

**Note**: *In actual practice, allowances have to be given for extra material required for joints and bends. These allowances are not considered in this unit.*

### *3.1.2 Methods of Development*

The method to be followed for making the development of a solid depends upon the nature of its lateral surfaces. Based on the classification of solids, the methods of pattern/surface development are: 1) Parallel line ii) Radial line iii) Triangulation.

### *i. Parallel Line Method*

This method can only be used to develop objects (or parts thereof) having a constant cross-section for their full length, for example, prisms and cylinders and related forms. Parallel lines, parallel to the axis of the detail, are shown on a view, which shows them as their true lengths as shown in Figures 4. 21 – 4.22.

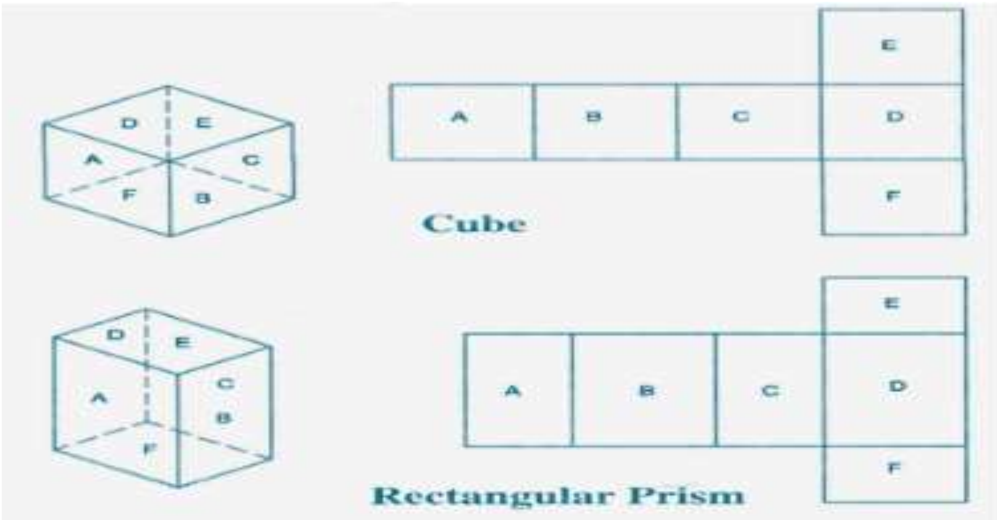



Figure 4.21: Parallel development of prism

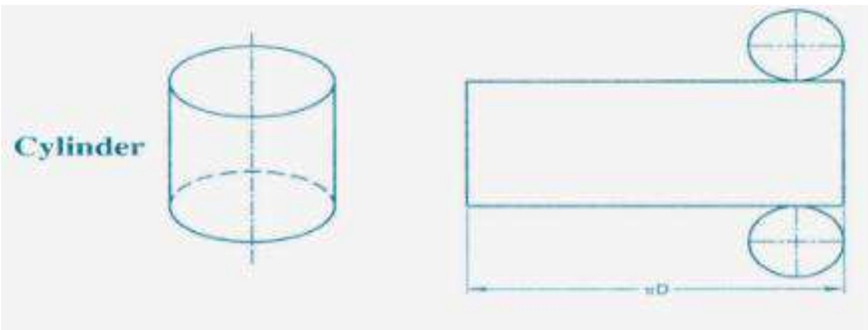



Figure 4.22: Parallel development of cylinder

### *ii. Radial Line Method*

This method of development is used for right and oblique pyramids and cones. It employs radial lines, which are slant edges from the vertex to base corner point for pyramids and radial surface lines on the cone surface from the vertex to the base as shown in Figure 4.23.

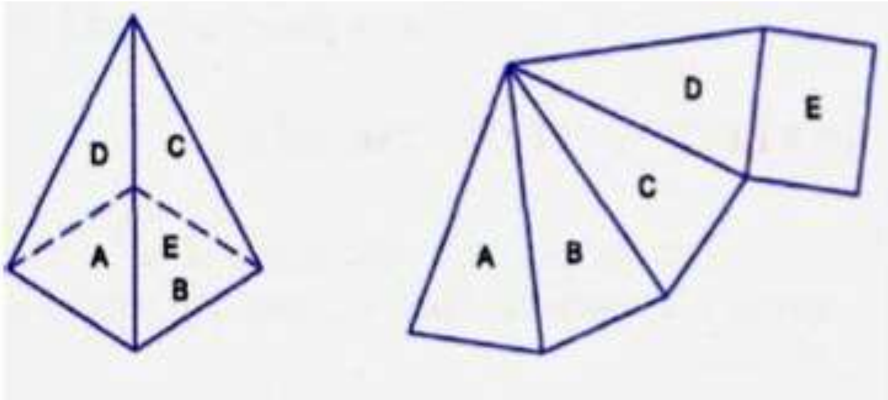



Figure 4.23: Radial line development of cone and pyramid

***iii. Triangulation developments method***

Triangulation developments are made from polyhedrons, single curved surfaces, and wrapped surfaces. Examples are tetrahedron and other polyhedrons.

***iv. Approximate development method***

In approximate development, the shape obtained is only approximate. After joining, the part is stretched or distorted to obtain the final shape. Example is sphere.

*3.1.3 Development of Prism*

Prisms: A prism is a polyhedron having two equal ends called the bases parallel to each other. The two bases are joined by faces, which are rectangular in shape. The imaginary line passing through the centres of the bases is called the axis of the prism.

A prism is named after the shape of its base. For example, a prism with square base is called a square prism, the one with a pentagonal base is called a pentagonal prism, and so on as shown Figure 4.24.

1. Assume the prism is resting on its base on H.P. with an edge of the base parallel to V.P and draw the orthographic views of the square prism.

2. Draw the stretch-out line 1-1 (equal in length to the circumference of the square prism) and off the sides of the base along this line in succession i.e. 1-2, 2-3, 3-4 and 4-1.

3. Erect perpendiculars through 1, 2, 3 etc., and mark the edges (folding lines) 1-A, 2-B, etc., equal to the height of the prism 50 mm.

4. Add the bottom and top bases 1234 and ABCD by the side of any of the base edges.

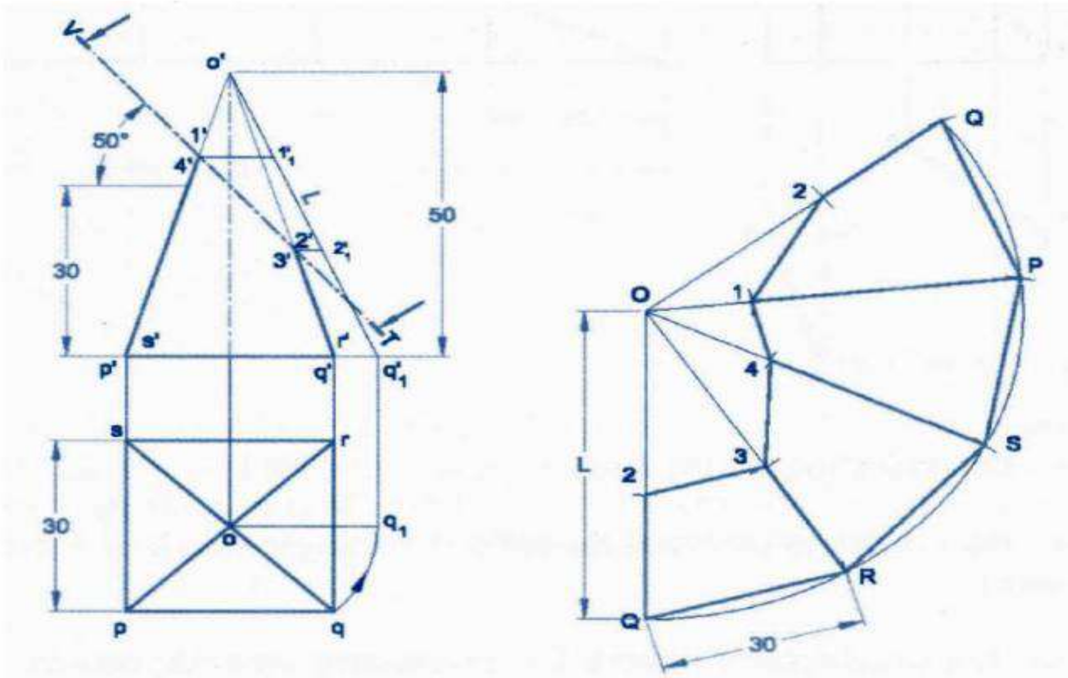


Figure 4.24: Development of a Prism

*3.1.4 Development of a Cylinder*

A cylinder of diameter of base 40 mm and height 50 mm is standing on its base on

HP. A cutting plane inclined at 45° to the axis of the cylinder passes through the left extreme point of the top base. Develop the lateral surface of the truncated cylinder as shown in Figure 4.25. The steps are as follows;

1. Draw the views of the truncated cylinder.

2. Divide the circle (top view) into an equal number of parts.

3. Draw the generators in the front view corresponding to the above division points.

4. Mark the points of intersection a′, b′, c′, d′, etc., between the truncated face and the generators.

5. Draw the stretch-out line of length equal to the circumference of the base circle.

6. Divide the stretch-out line into the same number of equal parts as that of the base circle and draw the generators through those points.

7. Project the points a, b, c, etc., and obtain A, B, C, etc., respectively on the corresponding generators 1, 2, 3 etc., in the development.

8. Join the points A, B, C etc., by a smooth curve.

*Note*

(i) The generators should not be drawn thick as they do not represent the folding edges on the surface of the cylinder.

(ii) The figure bounded by 1A-$A_1$, 1 represents the development of the complete cylinder.

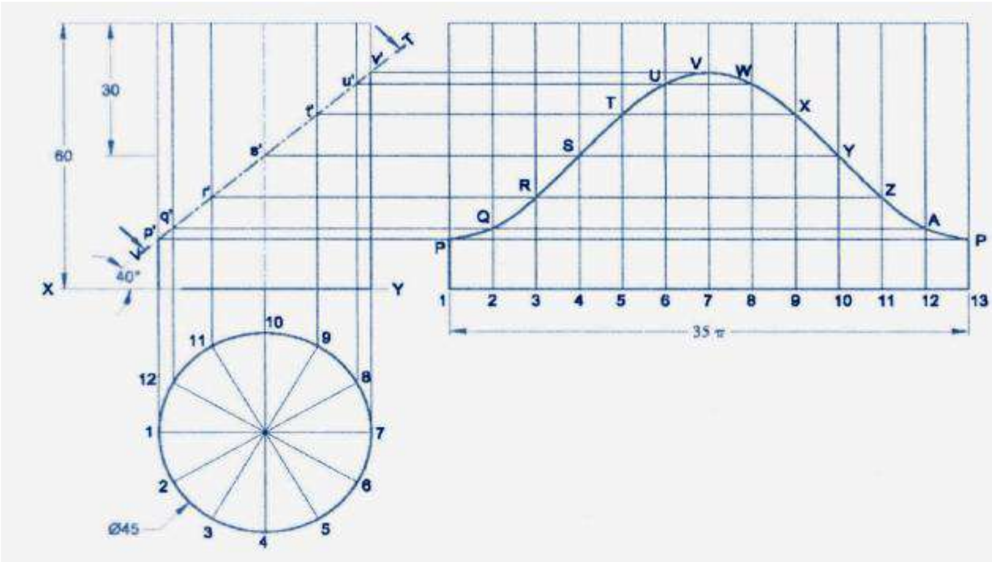



Figure 4.25: Development of Cylinder

**Self Assessment exercise:**

State the steps involved in the development of conic and cylindrical surfaces.

**3.2 Projection of Solids**

A solid is a three dimensional object having length, breadth and thickness. It is completely bounded by a surface or surfaces, which may be curved or plane. The shape of a solid is described orthographically by its two orthographic projections, usually, on the two principal planes of projection i.e. Horizontal plane (HP) and Vertical plane (VP) as shown in Figure 4.26.

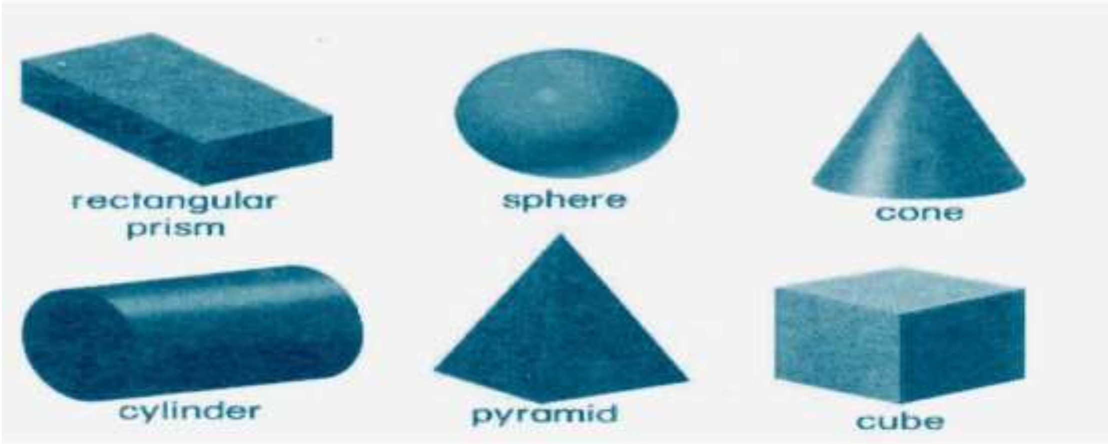



Figure 4.26: Shapes of solids sections

### 3.2.1 Types of solid

To understand and remember various solids in this subject properly, they are classified & arranged in to two major groups. Group A and Group B.

Group A: Solids having top and base of same shape as shown in Figure 4.27. Group B, Solids having base of some shape and just a point as a top, called apex as shown in Figure 4.28.

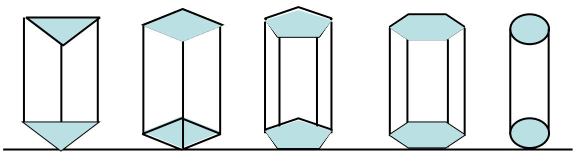


Figure 4.27: Solids with same top and base

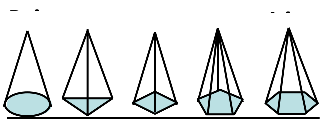


Figure 4.28: Solids with same top and base

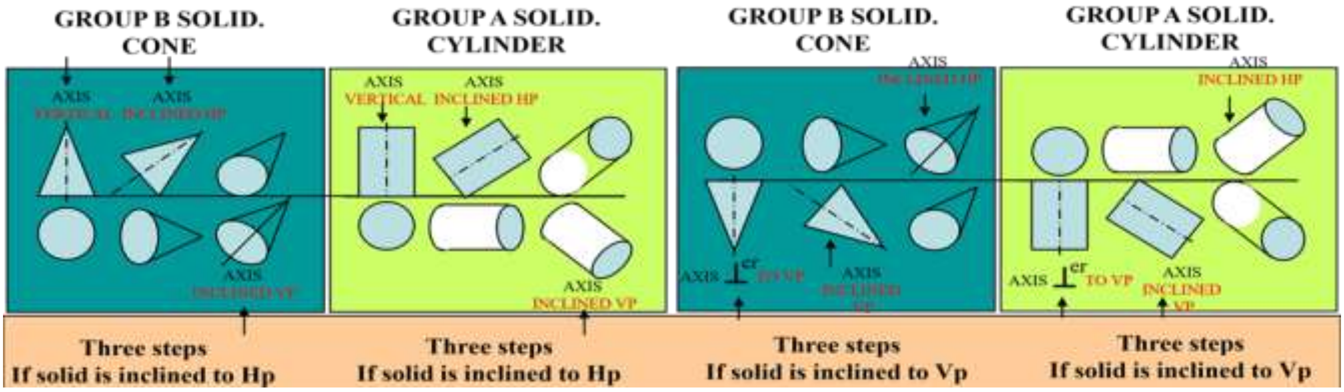



Figure 4.29: The two groups of solids

*Exercise 4.3b*

Draw the projections of a cone, base 45 mm diameter and axis 50 mm long, when it is resting on the ground on a point on its base circle with (a) the axis making an angle of 30º with the HP and 45º with the VP (b) the axis making an angle of 30º with the HP and its top view making 45º with the VP.

*Solution to Exercise 4.3b*

Steps

(1) Draw the TV & FV of the cone assuming its base on the HP

(2) To incline axis at 30º with the HP, incline the base at 60º with HP and draw the FV and then the TV.

(3) For part (a), to find β, draw a line at 45º with XY in the TV, of 50 mm length. Draw the locus of the end of axis. Then cut an arc of length equal to TV of the axis when it is inclined at 30º with HP. Then redraw the TV, keeping the axis at new position. Then draw the new FV

(4) For part (b), draw a line at 45º with XY in the TV. Then redraw the TV, keeping the axis at new position. Again draw the FV. See Figure 4.30 and the addendum below it.

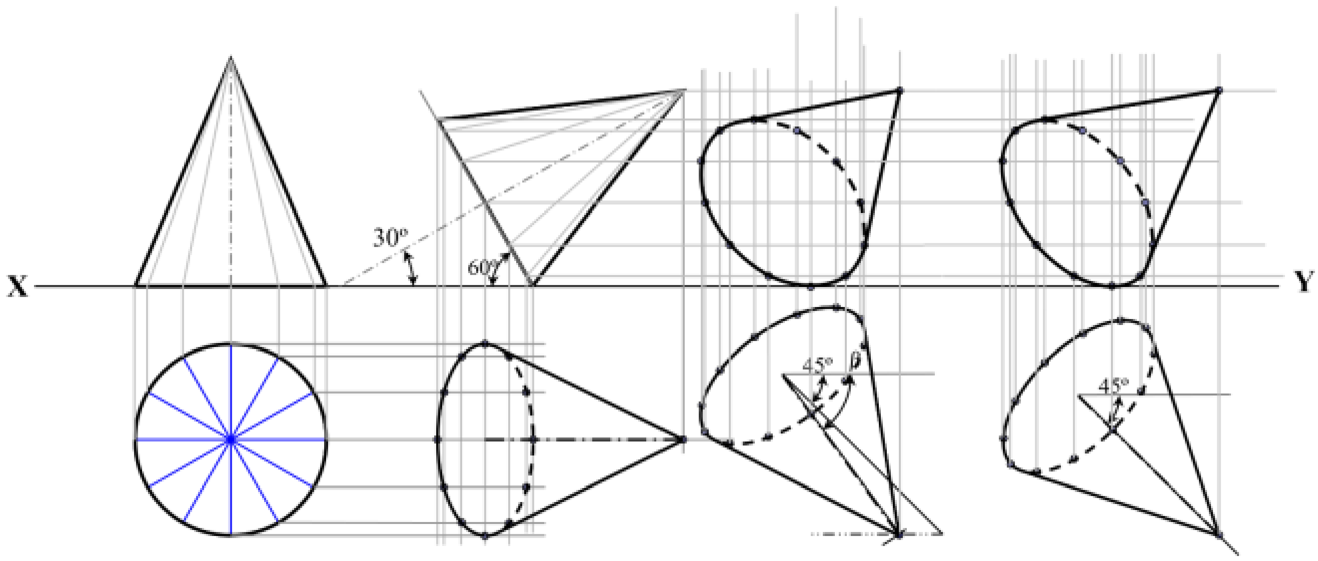
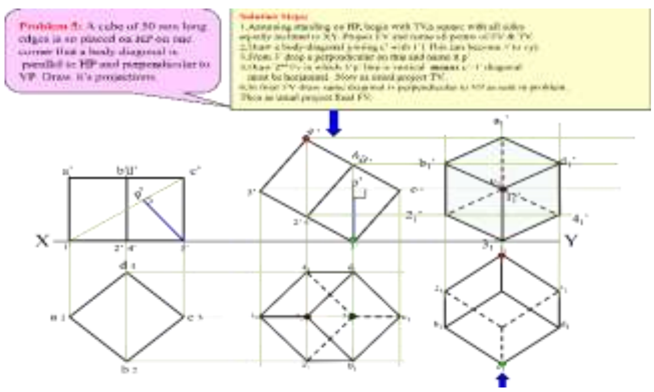



Figure 4.30: Projection of a cone



**Self Assessment exercise:**

Draw the projections of a cone, base 45 mm diameter and axis 50 mm long, when it is resting on the ground on a point on its base circle with (a) the axis making an angle of 30° with the HP and 45° with the VP (b) the axis making an angle of 30° with the HP and its top view making 45° with the VP.

### 3.3 Intercession of Surfaces

Whenever two or more solids combine, a definite curve is seen at their intersection. This curve is called the curve of intersection (COI). Ducts, pipe joints, smoke stacks, boilers, containers, machine castings etc., involve intersection of surfaces. Sheet metal work required for the fabrication of the above objects necessitate the preparation of the development of the joints in solids members. Orthographic drawings of lines and curves of intersection of surfaces must be prepared first for the accurate development of objects. Methods of obtaining the lines and curves of intersection of surfaces of cylinder and prism are covered in this unit.

### *3.3.1 Cases of Intersection*

The cases of intersection depend on the type of intersecting solids and the manner in which they intersect. Two intersecting solids may be of the same type (e.g., prism and prism) or of different types (e.g., prism and pyramid). The possible combinations are shown in Table 4.2 below.

Table 4.2: Cases of Intersection

| | | **1st Solid** | | | | |
|---|---|---|---|---|---|---|
| | | *Prism* | *Pyramid* | *Cylinder* | *Cone* | *Sphere* |
| | *Prism* | Case 1 | | | | |
| | *Pyramid* | Case 2 | Case 6 | | | |
| | *Cylinder* | Case 3 | Case 7 | Case 10 | | |
| | *Cone* | Case 4 | Case 8 | Case 11 | Case 13 | |
| **2nd Solid** | *Sphere* | Case 5 | Case 9 | Case 12 | Case 14 | Case 15 |

The two solids may intersect in different ways. The axes of the solids may be parallel, inclined or perpendicular to each other. The axes may be intersecting, offset or coinciding. Therefore, the following sub-cases exist:

(i) Axes perpendicular and intersecting

(ii) Axes perpendicular and offset

(iii) Axes inclined and intersecting

(iv) Axes inclined and offset

(v) Axes parallel and coinciding

(vi) Axes parallel and offset

### *3.3.2 Methods of Intercession*

There are two methods of Intersections; 1) Line method 2) Cutting plane method *a) Line method Line method:* A number of lines are drawn on the lateral surface of one of the solids and in the region of the line of intersection. Points of intersection of these lines with the surface of the other solid are then located. These points will lie on the required line of intersection. They are more easily located from the view in which the lateral surface of the second solid appears edgewise (i.e. as a line). The curve drawn through these points will be the line of intersection.

*b) Cutting-plane method:* The two solids are assumed to be cut by a series of cutting planes. The cutting planes may be vertical (i.e. perpendicular to the H.P.), edgewise (i.e. perpendicular to the V.P.) or oblique. The cutting planes are so selected as to cut the surface of one of the solids in straight lines and that of the other in straight lines or circles.

### ***3.3.3 Intercession of horizontal Cylinder penetrating a vertical cylinder***

Step of drawing the intersecting surface/curve

1. Draw three views of standing solid.
2. Name views as per the illustrations.
3. Beginning with side view draw three views of penetrating solids also.
4. On it Sv, mark number of points And name those (either letters or nos.)
5. The points which are on standard generators or edges of vertical solid, (in S.V.) can be marked on respective generators in Fv and Tv.
6. Other points from Sv should be brought to Tv first and then projecting upward To Fv.
7. Dark and dotted line’s decision should be taken by observing side view from it right side as shown by arrow. Points from SV should be brought to Tv first and then projecting upward to Fv.
8. Accordingly, those should be joined by curvature or straight lines

**Note:**

In case cone is penetrating solid Side view is not necessary. Similarly in case of penetration from top it is not required.

*Problem*: A cylinder 50mm dia. and 70mm axis is completely penetrated by another of 40 mm dia. and 70 mm axis horizontally. Both axes intersect and bisect each other. Draw projections showing curves of intersections. See the construction in Figure 4.31

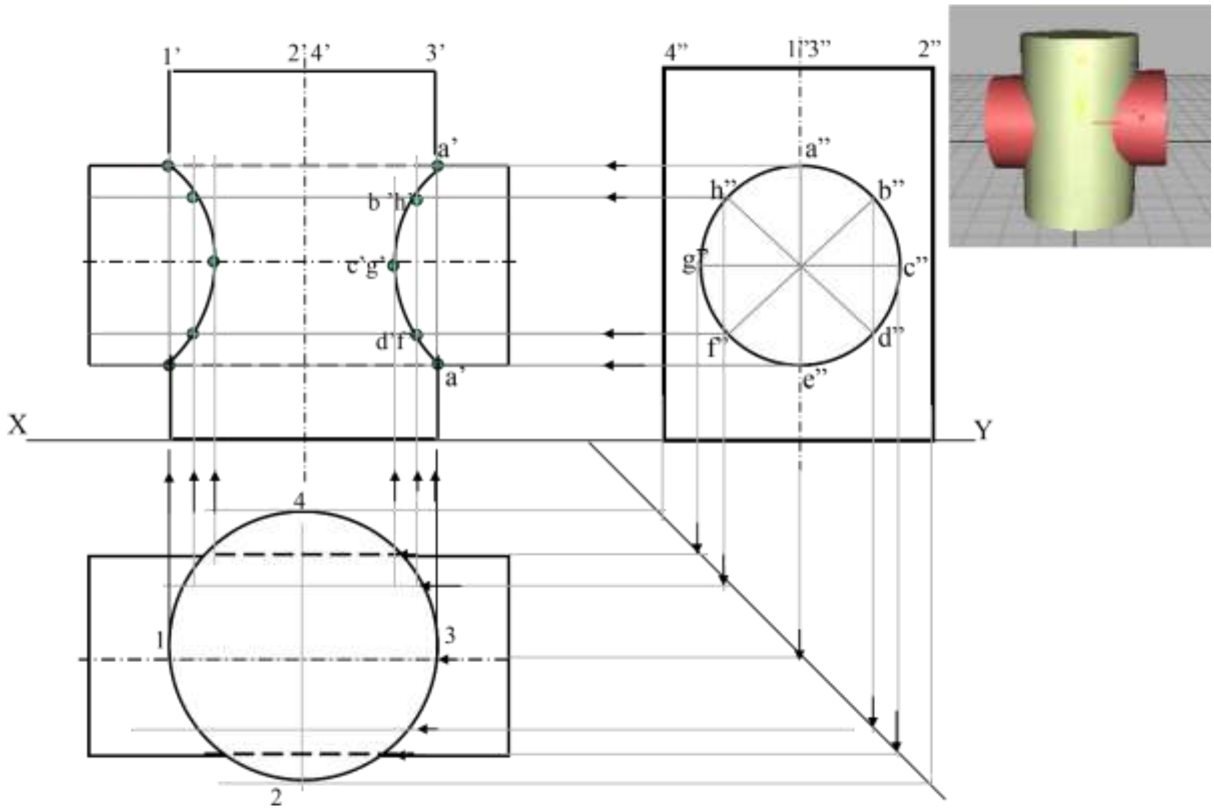



Figure 4.31: Intersection curve of cylinder penetrating another cylinder

*Problem*: A square prism 30 mm base sides and 70mm axis is completely penetrated by another square prism of 25 mm sides and 70 mm axis, horizontally. Both axes Intersects & bisect each other. All faces of prisms are equally inclined to Vp. Draw the projections showing curves of intersections. See the construction in Figure 4.32.

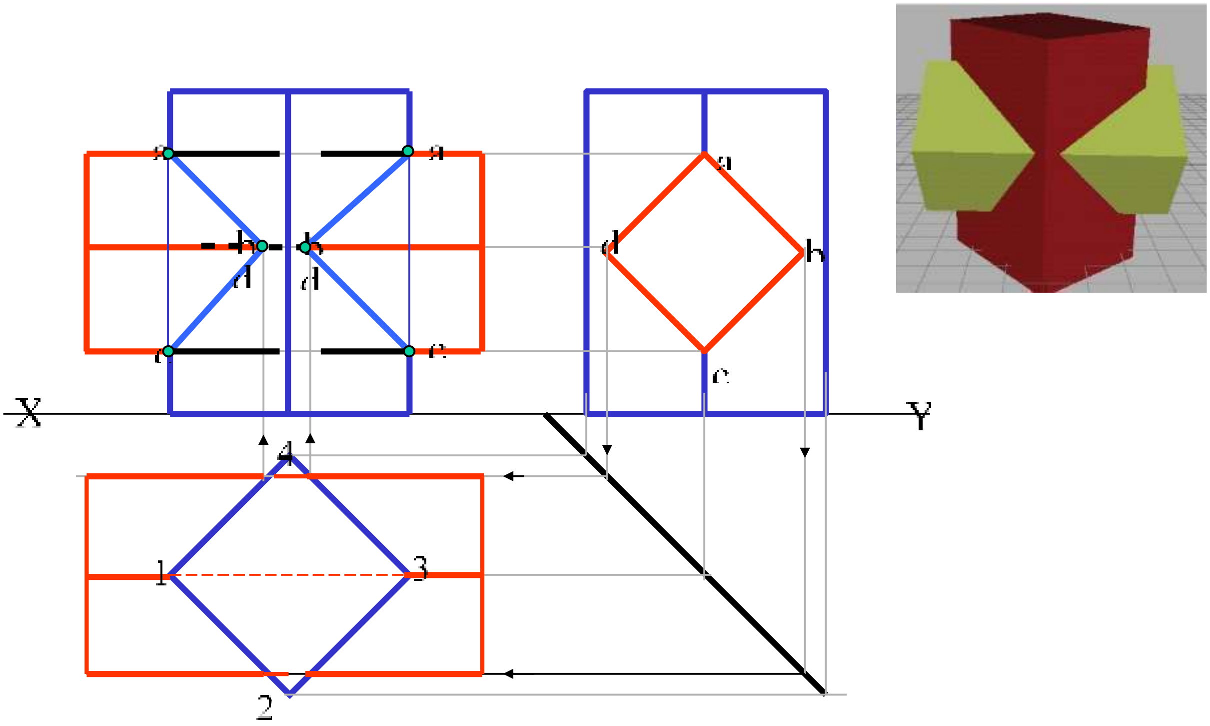



Figure 4.32: Intersection curve of a square prism penetrating another

**Self Assessment Exercise:**

Draw the projections of a cone, base 45 mm diameter and axis 50 mm long.

## 4.0 Conclusion

When two objects are to be joined together, maximum surface contact between both becomes a basic requirement for strongest and leak-proof joint. Curves of Intersections being common to both Intersecting solids, show exact & maximum surface contact of both solids. When one solid penetrates another solid then their surfaces intersect and at the junction of intersection a typical curve is formed, which remains common to both solids. This curve is called curve of intersection and it is a result of interpenetration of the contacting solids.

## 5.0 Summary

The Methods of obtaining the lines and curves of intersection of surfaces of cylinder, prism and pyramids are covered in this unit. Whenever two or more solids combine, a definite curve is seen at their intersection. This curve is called the curve of intersection (COI). Curves of intersection are useful in the design and fabrication of machine components such as industrial dust collectors, pipeline network, industrial feeding hoppers, connecting rods etc.

## 6.0 Tutor-Marked Assignment

a. State the steps involved in the development of conic and cylindrical surfaces.

b. The comparative cost advantage resulted to advancement of Classical thought. Draw the projections of a cone, base 45 mm diameter and axis 50 mm long, when it is resting on the ground on a point on its base circle with (a) the axis making an angle of 30º with the HP and 45º with the VP (b) the axis making an angle of 30º with the HP and its top view making 45º with the VP.

c. A square prism 30 mm base sides and 70mm axis is completely penetrated by another square prism of 25 mm sides and 70 mm axis, horizontally. Both axes Intersects & bisect each other. All faces of prisms are equally inclined to Vp. Draw the projections showing curves of intersections.

## 7.0 References/Further Readings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**MODULE FIVE**

**LINES AND PRINCIPLES OF ORTHOGRAPHIC PROJECTIONS**

Unit 1: Projections - lines, planes and simple solids.

Unit 2: Orthographic and isometric projections.

Unit 3: Simple examples of Orthographic and Isometric projections.

Unit 4: Principles of orthographic projections in the First Third Angle.

## UNIT 1: PROJECTIONS - LINES, PLANES AND SIMPLE SOLIDS

**CONTENTS**



### 1.0 Introduction

The shortest distance between two points is called a straight line. The projectors of a straight line are drawn therefore by joining the projections of its end points. Information regarding a line means its length, position of its ends with HP & VP. It's inclinations with HP & VP will be given.

Basic terminologies in point, line, plane and solids projection. The terminologies are shown in Figure 5.1.

HP – Horizontal plane; VP – Vertical plane; PP – both Horizontal and Vertical planes; FV – Front view; TV –Top view

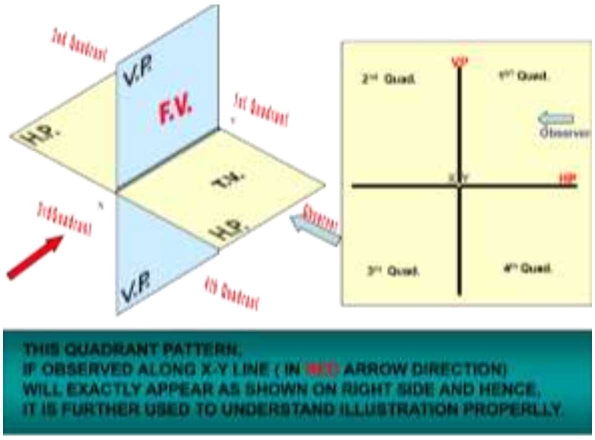


Figure 5.1: Basic terminologies in projections

## 2.0 Objective

At the end of this unit student should be able to

- Explain the concept of point projection in plane geometry
- Understand the traces of points and edge in principal planes
- Understand the pattern and shape of line projection in both Front and Top views

## 3.0 Main Content

### 3.1 Projection of Lines

The shortest distance between two points is called a straight line. The projectors of a straight line are drawn therefore by joining the projections of its end points. The possible projections of straight lines with respect to V.P and H.P in the first quadrant are as follows as shown in Figures 5.2 – 5.4:

I. A vertical line (line perpendicular to Hp & parallel to Vp)

2. Line Parallel to both principal planes (Hp & Vp).

3. Line inclined to Hp and parallel to Vp.

4. Line inclined to Vp and parallel Hp.

5. Line inclined to both Hp and Vp

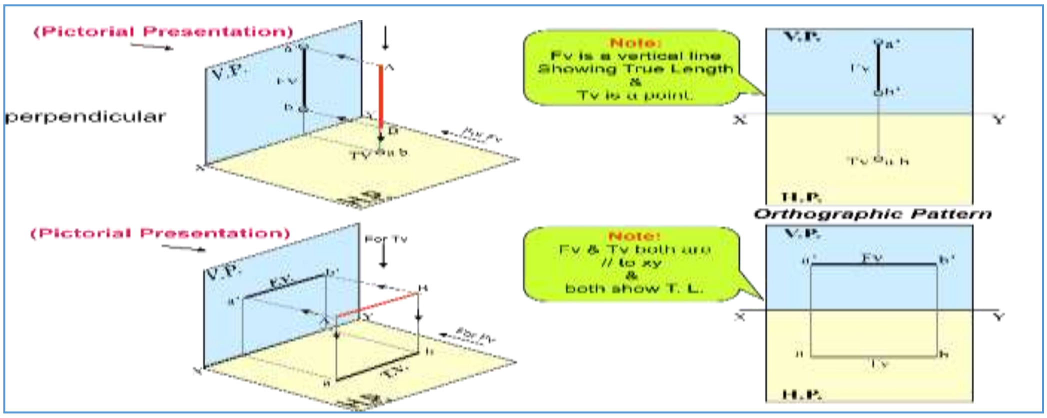


Figure 5.2: Vertical line perpendicular to principal planes Hp or Vp

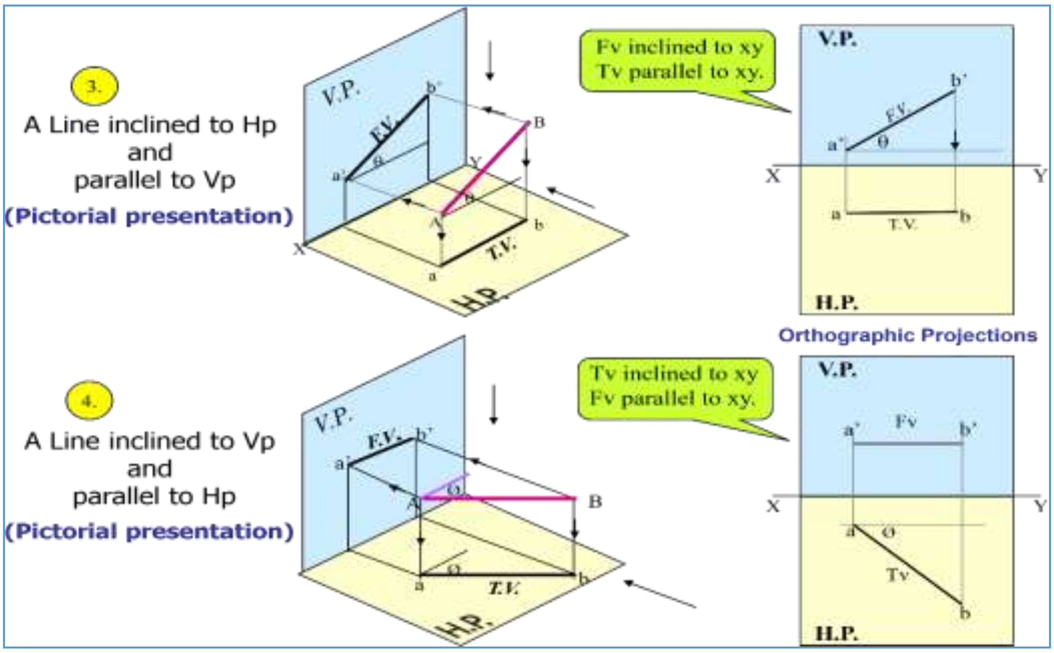


Figure 5.3: Line inclined to one of the principal plane and parallel to other principal plane Hp or Vp

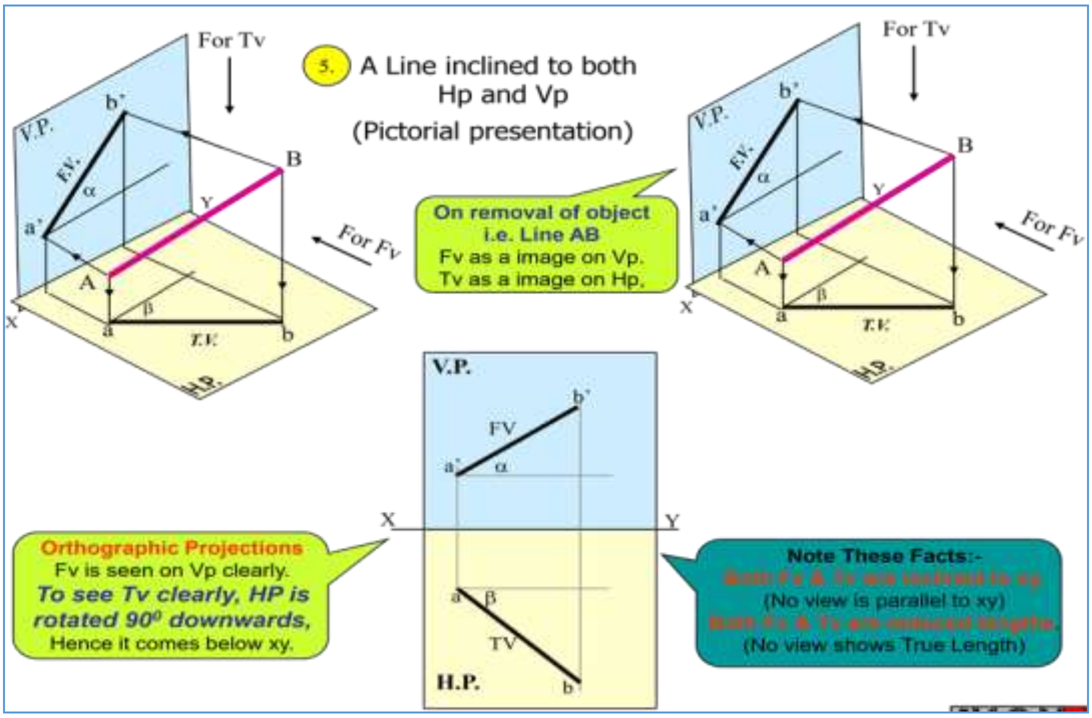


Figure 5.4: Vertical line perpendicular to principal planes Hp or Vp

*Exercise*: Line AB 75mm long makes $45^0$ inclination with Vp while it's Fv makes $55^0$. End A is 10 mm above Hp and 15 mm in front of Vp. If line is in 1st quadrant, draw its projections and find it's inclination with Hp.

*Solution* Steps:-

1. Draw x-y line.

2. Draw one projector for a' & a 3.Locate a' 10mm above x-y & Tv a 15 mm below xy.

4. Draw a line 450 inclined to xy from point a and cut TL 75 mm on it and name that point b1 Draw locus from point b1

5. Take 550 angle from a' for Fv above xy line.

6. Draw a vertical line from b1 up to locus of a, and name it 1. It is horizontal component of TL & is LFV.

7. Continue it to locus of a' and rotate upward up to the line of Fv and name it b'. This a' b' line is Fv.

8. Drop a projector from b' on locus from point b1 and name intersecting point b.

Line a b is Tv of line AB.

9. Draw locus from b' and from a' with TL distance cut point b1'10. Join a' b1' as TL and measure its angle at a'.

It will be true angle of line with Hp, see Figure 5.5.

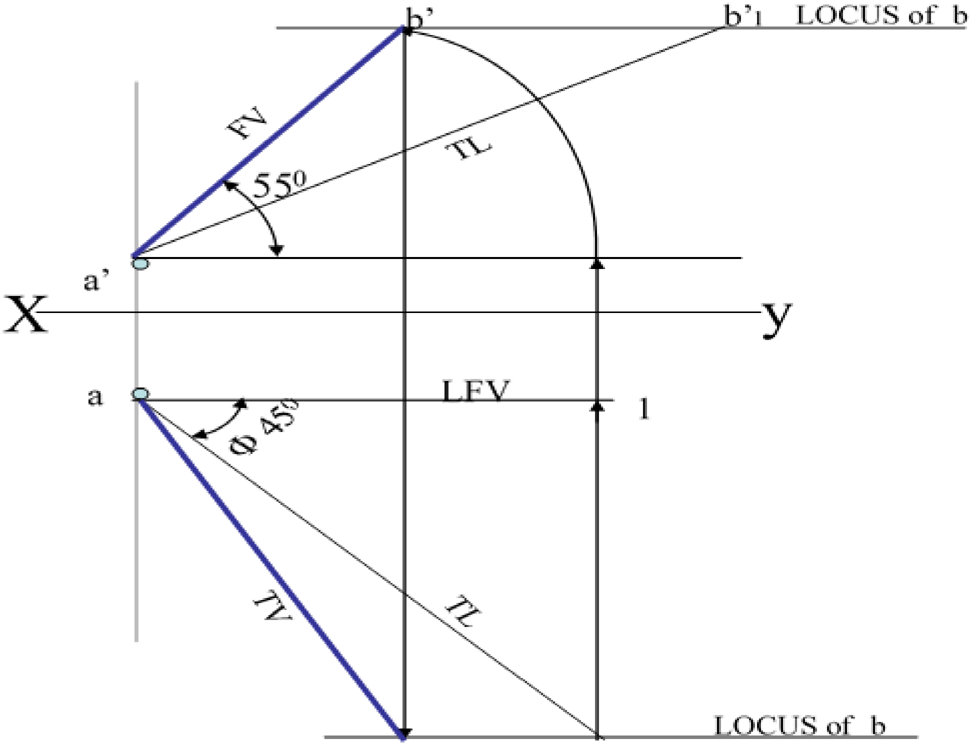

Figure 5.5: Projection of Line AB

**Self Assessment Exercise:**

Line AB 75mm long makes $45^0$ inclination with Vp while its Fv makes $55^0$. End A is 10 mm above Hp and 15 mm in front of Vp. If line is in 1st quadrant, draw its projections and find it's inclination with Hp.

**3.2 Projection of Planes**

Planes are described based on their surface and side inclination to the principal planes. There are three cases that mostly occur in the projection of paths of planes; a) surface parallel to Hp b) surface inclined to Hp c) One small side inclined to Vp as shown in Figure 4.37.

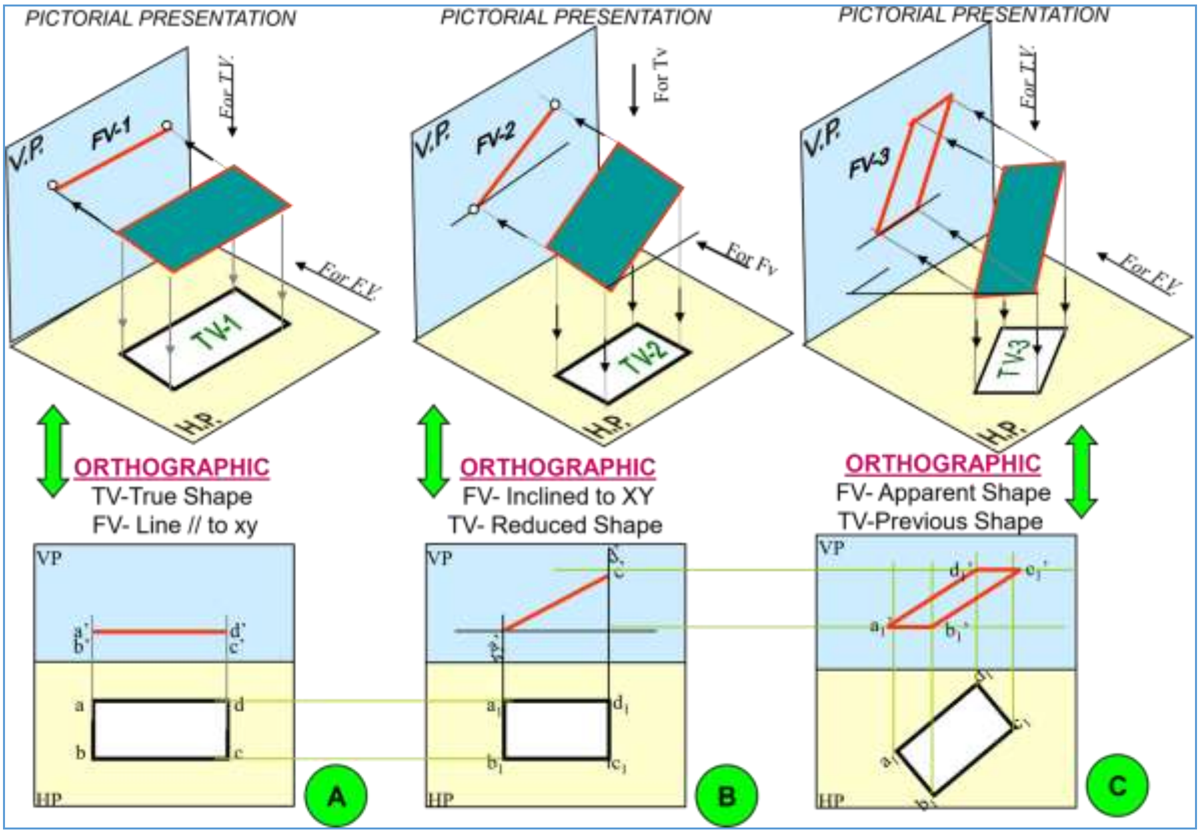


Figure 5.6: Cases of plane projection

### *3.2.1 Procedure for drawing projection of plane*

There steps:

STEP 1. Assume suitable conditions & draw Fv & Tv of initial position.

STEP 2. Now consider surface inclination & draw 2nd Fv & Tv.

STEP 3. After this, consider side/edge inclination and draw 3rd (final) Fv & Tv.

Assumptions for initial position:

(Initial Position means assuming surface // to HP or VP)

1. If in problem surface is inclined to HP – assume it // HP or If surface is inclined to VP – assume it // to VP
2. Now if surface is assumed // to HP- Its TV will show True Shape. And if surface is assumed // to VP – Its FV will show True Shape.
3. Hence begin with the drawing of TV or FV as True Shape.

4. While drawing this True Shape – keep one side/edge (which is making inclination) perpendicular to xy line.

**Hint: As the plane is inclined to HP, it should be kept parallel to HP with one edge perpendicular to VP**

Exercise: A regular pentagon of 25mm side has one side on the ground. Its plane is inclined at 45º to the HP and perpendicular to the VP. Draw its projections and show its traces. See the solution in Figure 5.7.

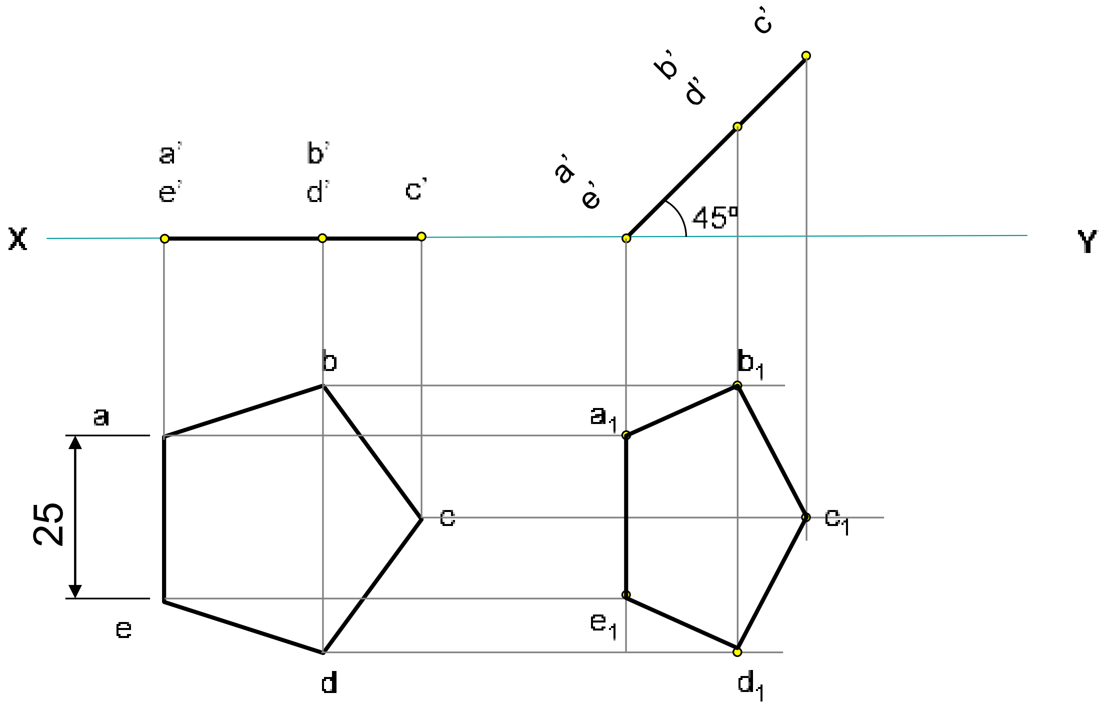


Figure 5.7: Projection of the plane of a regular pentagon

**Self Assessment Exercise:**

State the procedure for drawing projection of planes

**3.3 Projection of Simple Solids**

A solid consists of a' number "Planes. A plane consists of a number of lines and a line in turn consists of number of points:-'from this, it is obvious that a solid may be generated by a plane.

*Exercise.* Draw the projections of a circle of 5 cm diameter having its plane vertical and inclined at 30º to the V.P. Its centre is 3cm above the H.P. and 2cm in front of the V.P. Show also its traces. See the solution in Figure 5.8

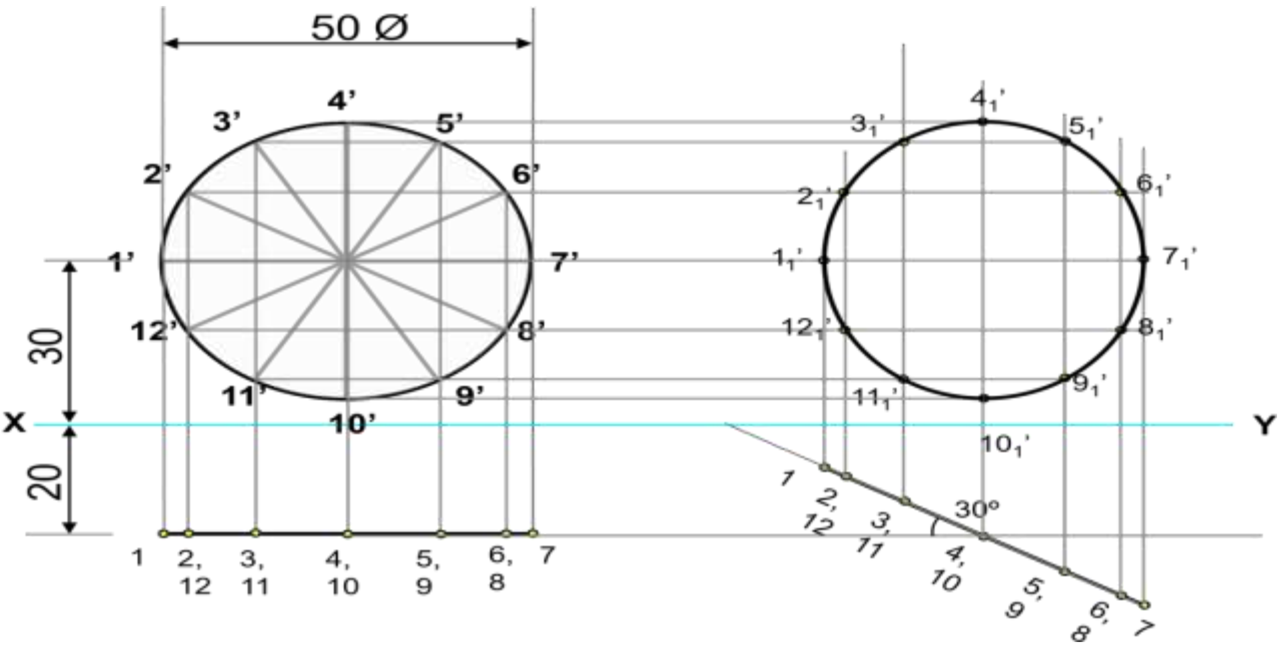


Figure 5.8: Projection of circle

*Problem*: Draw a regular hexagon of 40 mm sides, with its two sides vertical. Draw a circle of 40 mm diameter in its centre. The figure represents a hexagonal plate with a hole in it and having its surface parallel to the VP. Draw its projections when the surface is vertical abd inclined at 30° to the VP. See the solution in Figure 5.9

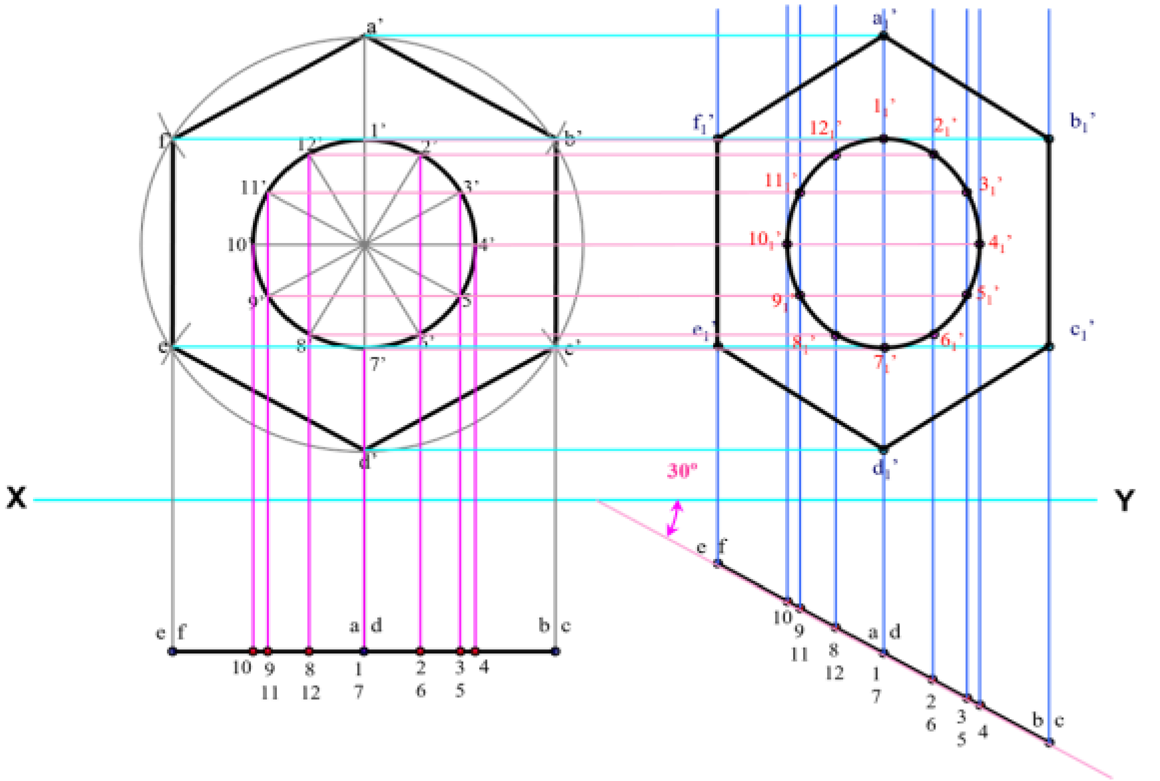


Figure 5.9: Projection of a hexagon

**Self Assessment Exercise:**

Draw the projections of a circle of 5 cm diameter having its plane vertical and inclined at 30º to the V.P. Its centre is 3cm above the H.P. and 2cm in front of the V.P. Show also its traces.

**4.0 Conclusion**

The theory of projection is the basis of background information necessary to shape representation in graphics. A plane is a two dimensional object having length and breadth only. The trace of a plane is the line of intersection or meeting of the plane surface with the reference plane; if necessary, the plane surface is extended to intersect the reference plane. A solid may be represented by orthographic views, the number of which depends on the type of solid and its orientation with respect to the planes of projection.

**5.0 Summary**

The figure or view formed by joining, in correct sequence, the points at which these lines meet the plane is called the projection of the object. The lines or rays drawn from the object to the plane are called projectors. The transparent plane on which the projections are drawn is known as plane of projection.

**6.0 Tutor-Marked Assignment**

a. Line AB 75mm long makes $45^0$ inclination with Vp while its Fv makes $55^0$. End A is 10 mm above Hp and 15 mm in front of Vp. If line is in 1st quadrant, draw its projections and find it's inclination with Hp.

b. State the procedure for drawing projection of planes

c. Draw the projections of a circle of 5 cm diameter having its plane vertical and inclined at 30º to the V.P. Its centre is 3cm above the H.P. and 2cm in front of the V.P. Show also its traces.

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**UNIT 2: ORTHOGRAPHIC AND ISOMETRIC PROJECTIONS**



**1.0 Introduction**

Projection is defined as an Image or drawing of the object made on a plane. The lines form the object to the Plane are called projectors. Orthographic projection is the method of representing the exact shape of an object by dropping perpendiculars from two or more sides of the object to planes, generally at right angles to each other; collectively, the views

on these planes describe the object completely. Isometric projection is a type of pictorial projection in which the three dimensions of a solid are not only shown in one view but their actual sizes can be measured directly from it.

**2.0 Objective**

At the end of this unit student should be able to

- Understand the position objects or parts take when projected in planes
- Know how projection of the path of object affect their views in different plane
- Understand that projected views of objects on planes describe the object more vividly and completely.

## 3.0 Main Content

## 3.1 Orthographic projection of objects

When the projectors are parallel to each other and also perpendicular to the plane the projection is called orthographic projection. Basically, Orthographic projection could be defined as any single projection made by dropping perpendiculars to a plane. In short, orthographic projection is the method of representing the exact shape of an object by dropping perpendiculars from two or more sides of the object to planes, generally at right angles to each other; collectively, the views on these planes describe the object completely Figure 5.10.

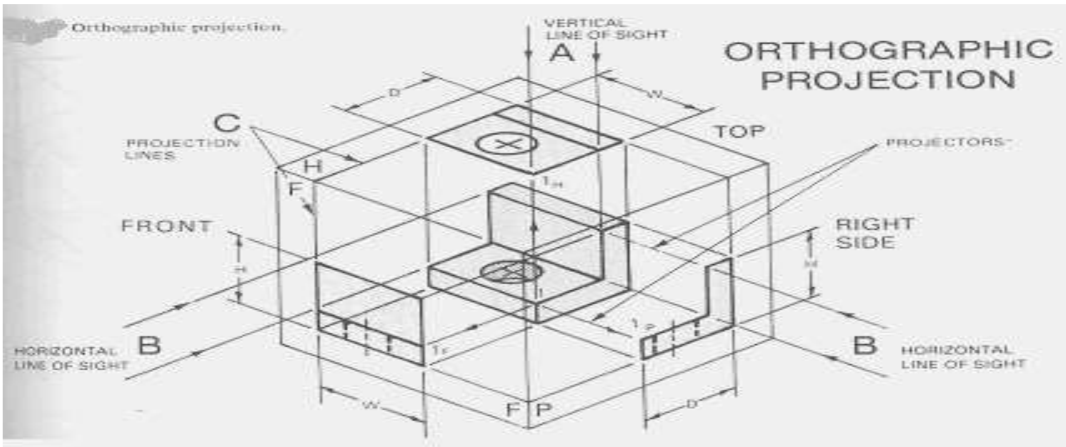


Figure 5.10: Orthographic projection

### *3.1.1 Orthographic Views*

It is the picture or view or thought of as being found by extending perpendiculars to the plane from all points of the object. This picture, or projection on a frontal plane, shows the shape of the object when viewed from the front but it does not tell the shape or distance from front to real. Accordingly, more than one protection is required to describe the object. If transparent plane is placed horizontally above the object, the projection on this plane found by extending perpendiculars to it from the object, will give the appearance of the object as if viewed from directly above and will show the distance from frontal plane. Then the horizontal plane is now rotated into coincidence with the frontal plane. Now again a third plane, perpendicular to the first two called profile plane are used to view an object from the side.

### *3.1.2 The Six Principal Views*

Let us surround the object entirely by asset of six planes, each at right angles to each other. On these planes, views of the object can be obtained as is seen from the top, front, and right side, left side, bottom and rear. Think now of the six sides, or the plane of the paper. The front is already in the plane of the paper, and the other sides are, as it were, hinged and rotated in position as shown. The projection on the frontal plane is the front view vertical projection, or front elevation, that on the horizontal plane, the top view, horizontal projection, or plan, that on the side, profile view, side view, profile projection, or side elevation. By reversing the direction of sight, a bottom view is obtained instead of a top view, or a rear view instead of a front view Figure 5.11.

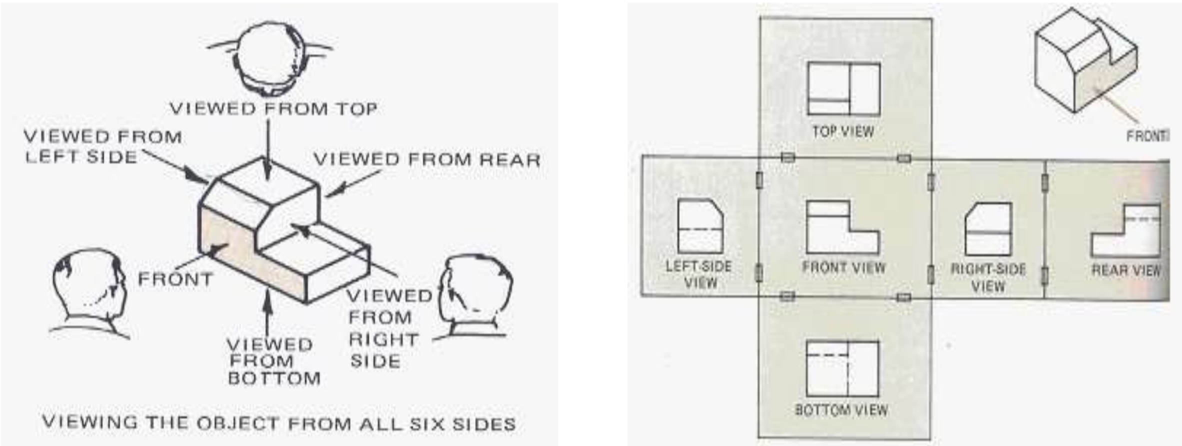


Figure 5.11: Orthographic principal views

**Self Assessment exercise**:

Discuss the orthographic projection of objects.

## 3.2 Isometric projection of objects

Isometric projection is often constructed using isometric scale which gives dimensions smaller than the true dimensions. To produce an isometric projection (Isometric means "equal measure"), it is necessary to place the object so that its principal edges or axes, make equal angles with the plane of projection, and are therefore foreshortened equally. In this position the edges of a cube would be projected equally and would make equal angles with each other ($120^0$) Figure 5.12.

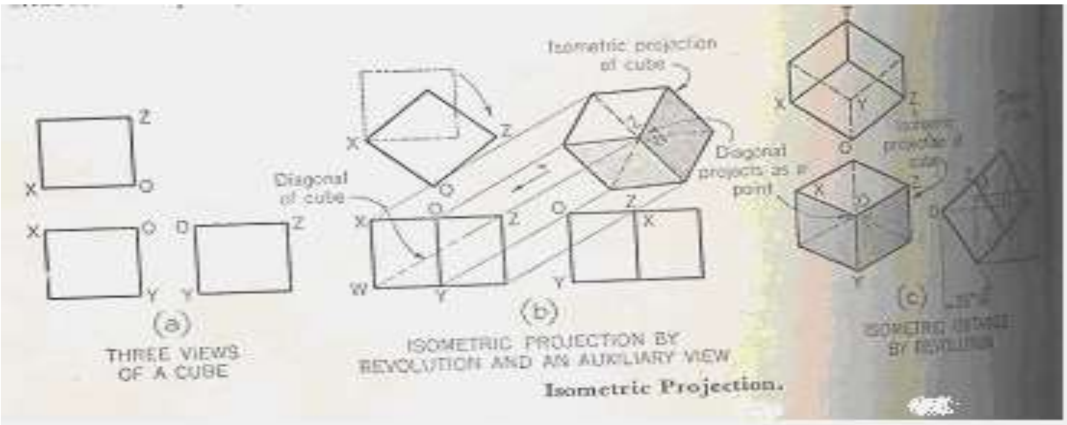


Figure 5.12: Isometric projection

In Figure 5.12 above, the projections of the axes OX, OY and OZ make angles of $120^0$ with each other, and are called the isometric axes. Any line parallel to one of these is called an Isometric line; a line which is not parallel is called a non-isometric line. It should be noted that the angles in the isometric projection of the cube are either $120^0$ or $60^0$ and that all projections of $90^0$ angles. In an isometric projection of a cube, the faces of the cube or any planes parallel to them are called Isometric planes.

***3.2.1 Isometric Drawing***

When a drawing is prepared with an isometric scale or otherwise as the object is actually projected on a plane of projection, it is an isometric projection. But when it is prepared with an ordinary scale, it is an isometric drawing. The isometric drawing is 22.5% larger than the isometric projection, but the pictorial value is obviously the same in both.

Since the isometric projection is foreshortened and an isometric drawing is full size, it is customary to make an isometric drawing rather than an isometric projection, because it is so much easier to execute and, for all practical purposes, is just as satisfactory as the isometric projection.

**Self Assessment Exercise:**

Explain the importance of isometric projection in the development of objects

**4.0 Conclusion**

Orthographic projection is a way of drawing a 3D object from different directions. Usually a front, side and plan view is drawn so that a person looking at the drawing can see all the important sides. Orthographic drawings are useful especially when a design has been developed to a stage whereby it is almost ready to manufacture.

## 5.0 Summary

This unit discussed the purpose and theory of multi view projections. It described the “Glass Box Method” of orthographic projection. It also explain the principal views and combination of view. It further explain how to convert pictorial drawings to orthographic or multi view projection in orthographic projection. The isometric drawing is 22.5% larger than the isometric projection, but the pictorial value is obviously the same in both.

## 6.0 Tutor-Marked Assignment

a. Discuss the orthographic projection of objects.

b. Discuss the six principal plane and orthographic views of objects.

c. Explain the importance of isometric projection in the development of objects

## 7.0 References/Further Readings


Agrawal, Basant Agrawal, C.M. (2013). Engineering Drawing, 2nd Edition, *Tata McGraw Hill*.

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## UNIT 3: CONSTRUCTION OF ORTHOGRAPHIC AND ISOMETRIC PROJECTIONS OF OBJECTS

**CONTENTS**



### 1.0 Introduction

Frequently it is necessary to prepare drawings that are accurate and scientifically correct, and that can be easily understood by persons without technical training. Such drawings show several faces of an object at once, approximately as they appear to the observer. 'ORTHO' means right angle and orthographic means right angled drawing. When the projectors are perpendicular to the plane on which the projection is obtained, it is known as orthographic projection. Isometric drawing is a drawing, which shows the 3 dimensional view of an object. The perpendicular edges of an object are drawn on 3 axes at $120^o$ to each other, with the actual distances drawn and shown on the axes.

### 2.0 Objective

At the end of this unit student should be able to

- Understand the concept of tracing the projected path of objects in the six principal planes
- Explain the steps involved in drawing both orthographic and isometric projections of objects

### 3.0 Main Content

### 3.1 Drawing Orthographic Projection of Objects

The most common means of understanding orthographic projection is the Glass Box method as shown in Figure 5.13. The lines of sight representing the direction from which the object is viewed. In Figure 5.13, the vertical lines of sight (A) and horizontal lines of sight (B) are assumed to originate at infinity. The line of sight is always perpendicular to the image plane, represented by the surfaces of the glass box (top, front, and right side). Projection lines(c) connect the same point on the image plane from view to view, always at right angle.

A point is projected up on the image plane where its projector, or line of sight, pierces that image plane. In Figure 5.13, point 1, which represents a corner of the given object, has been projected on to the three primary image planes. Where it is intersects the horizontal plane (top image plane), it is identified as 1H, when it intersects the frontal plane (front image plane), it is identified as 1F, and where it intersects the profile plane (right side image plane), it is labelled 1P.

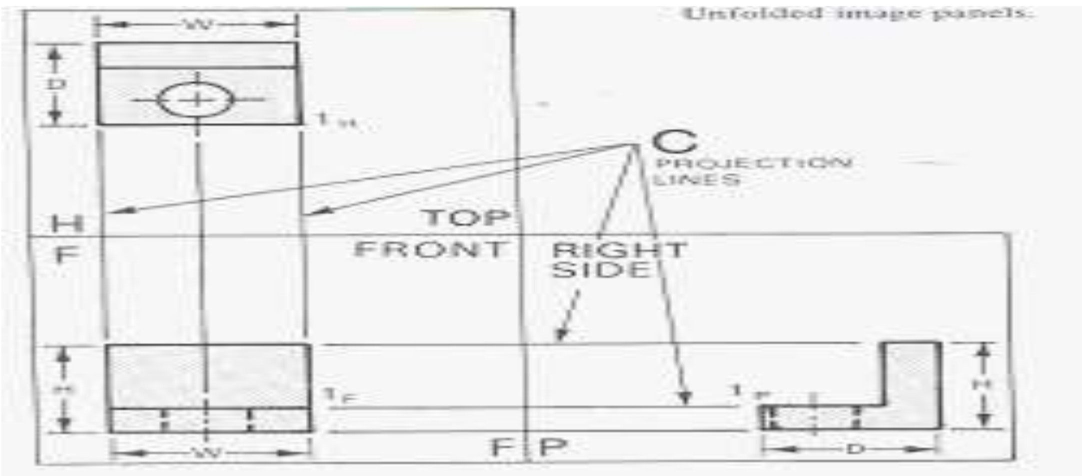


Figure 5.13: Orthographic projection of objects

#### *3.1.1 Combination of views*

The most usual combination selected from the six possible views consists of the *top, front*, and *right side* views sometimes the left- side view helps to describe an object more clearly than the right- side view.

N.B: The side view of the front face of the object is adjacent to the front view and the side view of a point will be at the same distance from the front surface as its distance from the front surface on the top view. Hp – Horizontal plane; Vp – Vertical plane; Fv – Front view;

Fv is a view projected on Vp; Tv – Top view, Tv is a view projected on Hp; Sv – Side view, Sv is a view projected on Pp; Pp – Profile plane;

### *3.1.2 Methods of Drawing Orthographic projection*

There are basically two methods of drawing orthographic projection; i) First angle projection ii) Third angle projection with the symbols shown in Figure 5.14.

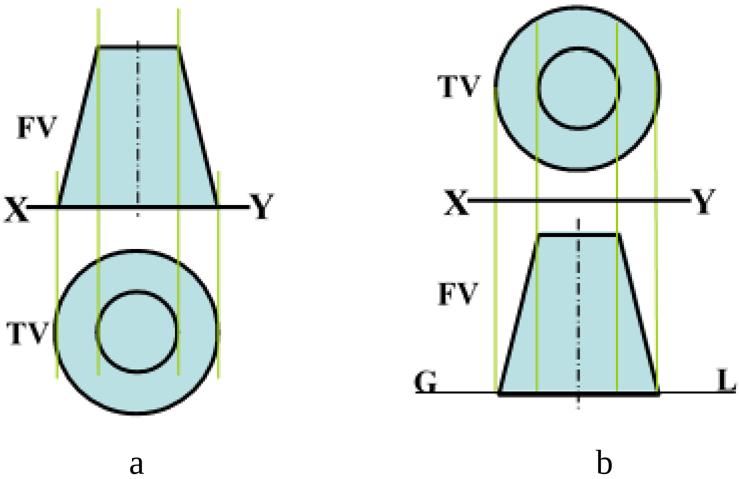


Figure 5.14: Orthographic projection: a-First angle; b- Third angle

**Self Assessment Exercise:**

Explain the steps involved in the construction of orthographic drawing of objects

### 3.2 Construction of Isometric Drawing of Objects

The steps in constructing an isometric drawing of an object composed only of normal surfaces, as illustrated in Figure 5.15. Notice that all measurements are made parallel to the main edges of enclosing box, that is, parallel to isometric axes. No measurement along a diagonal (non-isometric line) on any surface or through the object can be set off directly with the scale. The object may be drawn in the same position by beginning at the corner Y or any other corner, instead of at the corner X.

The method of constructing an isometric drawing of an object composed partly of inclined surface (and oblique edges) is shown in Figure 5.15. Notice that inclined surfaces are located by offset measurements along isometric lines. For example, dimensions E and F are setoff to locate the inclined surface M, and dimensions A and B are used to locate surface N.

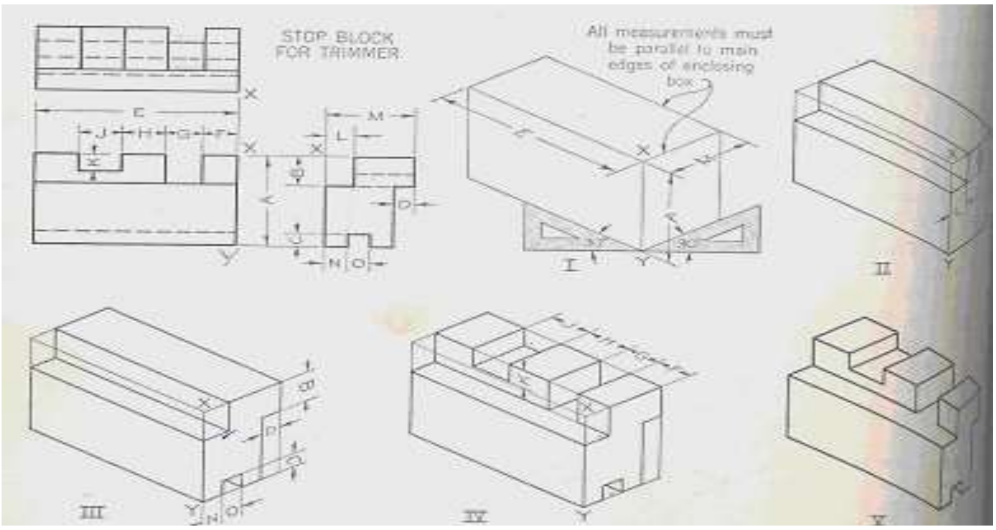


Figure 5.15: Isometric drawing of normal surfaces

### *3.2.2 Box Construction*

Objects of rectangular shape may be more easily drawn by means of box construction, which consists simply in imagining the object to be enclosed in a rectangular box whose sides coincide with the main faces of the object. For example, in Figure 4.46 below, the object shown in two views is imagined to be enclosed in a construction box. This box is then drawn lightly with construction lines, I, the irregular features are then constructed, II, and finally, III, the required lines are made heavy.

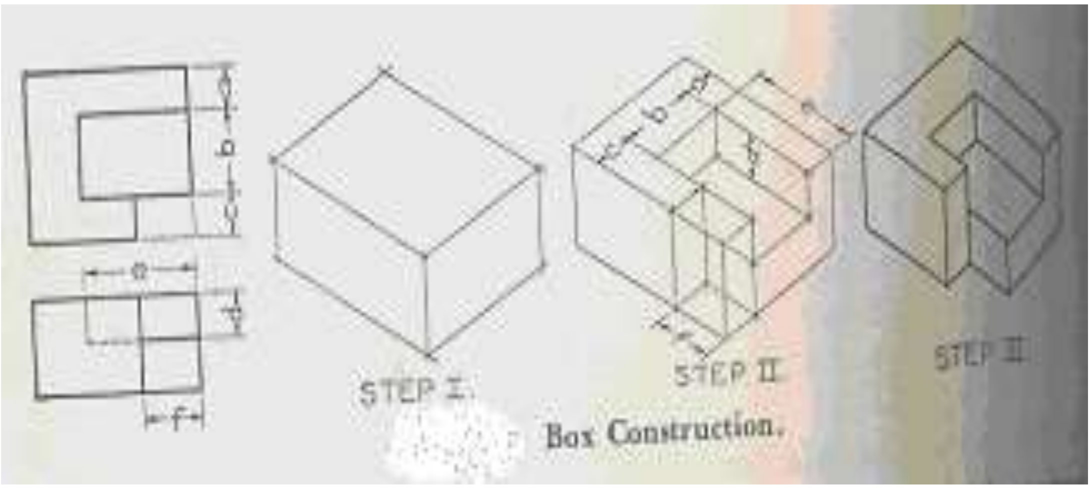


Figure 5.16: Isometric box construction

*Exercise 1*

Giving the F.V. & T.V. of object 1, draw its isometric view. See Figure 5.17 below.

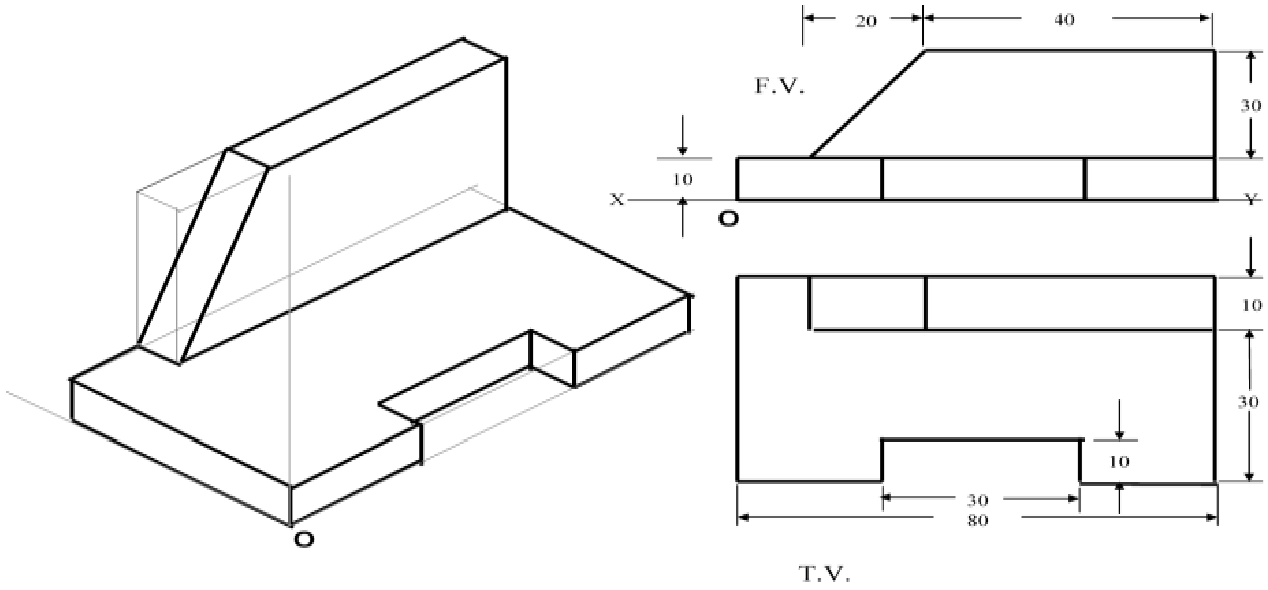


Figure 5.17: Orthographic and Isometric view of object 1

*Exercise 2*

Giving the isometric view of the object below, draw it orthographic views or vice versa

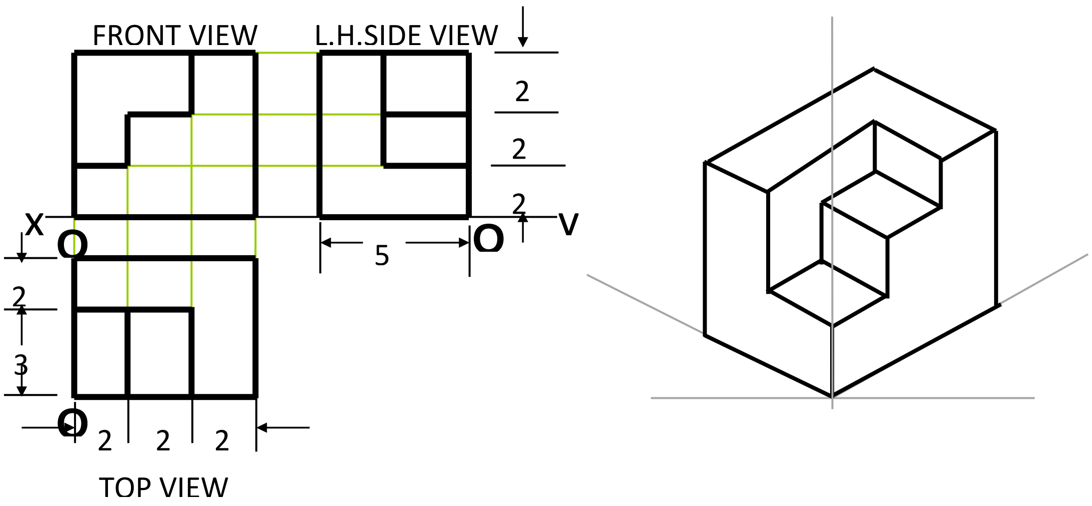


Figure 5.18: Orthographic and Isometric view of object 2

**Self Assessment Exercise:**

Construct a box for isometric and oblique drawings based on the technical drawing procedure.

## 4.0 Conclusion

This unit concludes that, to fabricate, construct and produced part or whole of structure or device, it must be viewed in all principal planes, so that every details can be captured and included in the designed. Orthographic and Isometric drawings help the engineering to have clear view of the object from all sides, so that it can be properly dimensioned, and details that may be hidden from one viewpoint, may be seen and accommodated in other views.

## 5.0 Summary

In summary this unit discussed the rudiments of both orthographic and isometric projections. In orthographic projection, Front view (Fv) is projected on the Vp, Top view (Tv) is projected on Hp, while the Side view (Sv) is projected on the Pp. It explains the two methods of orthographic projections; first angle projection (with object projected in the first quadrant) and third angle projection (with object projected in the third quadrant). It further explain Isometric drawing, as a drawing, which shows the 3 dimensional view of an object for precision and accuracy during machining or other processes.

## 6.0 Tutor-Marked Assignment

a. Explain the steps involved in the construction of orthographic drawing of objects
b. Construct a box for isometric and oblique drawings based on the technical drawing procedure.

## 7.0 References/Further Readings


Agrawal, Basant Agrawal, C.M. (2013). Engineering Drawing, 2nd Edition, *Tata McGraw Hill*.

Bhatt, N.D. (2018). Engineering Drawing, 5th edition, *Chrotar Publishing House*, India.

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## UNIT 4: PRINCIPLES OF ORTHOGRAPHIC PROJECTIONS IN THE FIRST-THIRD ANGLE

**CONTENTS**



### 1.0 Introduction

To describe an object with complex internal features completely, a drawing should contain lines representing all the edges, intersections, and surface limits of the objects. In any view there will be some parts of the object that cannot be seen from the position of the observer, as they will be covered by the location of the object closer to the observer's eye. 'ORTHO' means right angle and orthographic means right angled drawing. When the projectors are perpendicular to the plane on which the projection is obtained, it is known as orthographic projection.

### 2.0 Objective

At the end of this unit student should be able to

- Understand the concept of objects projected from the first and third quadrant
- Explain the steps involved in drawing orthographic projections of objects in both first and third quadrants.

## 3.0 Main Content

## 3.1 Orthographic Projection in First angle

In this form of projection, the object is assumed to be in front of the image plane. Each view is formed by projecting through the object and on to the image plane as shown in Figures 5.19 – 5.20.

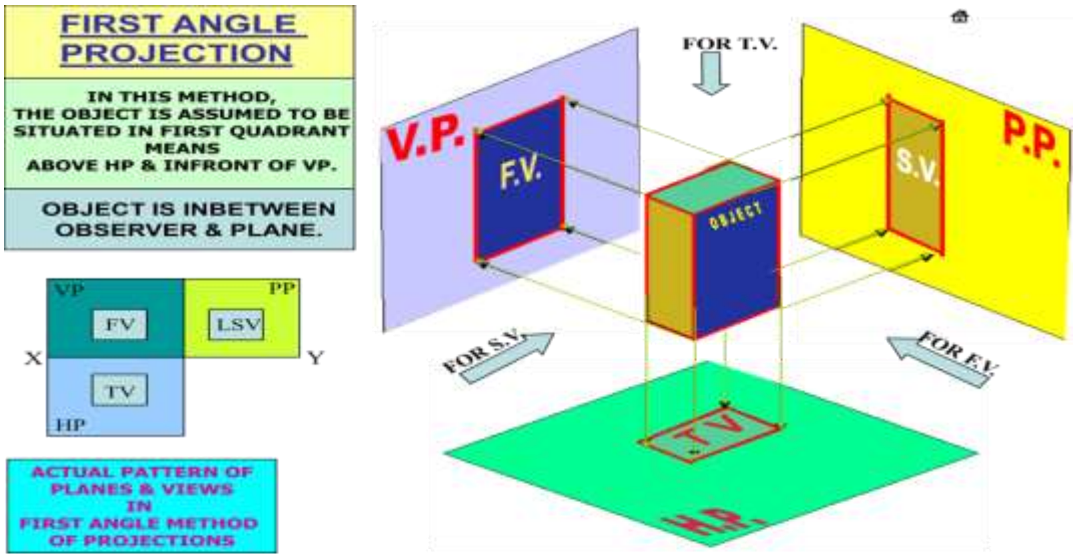


Figure 5.19: First angle orthographic projection

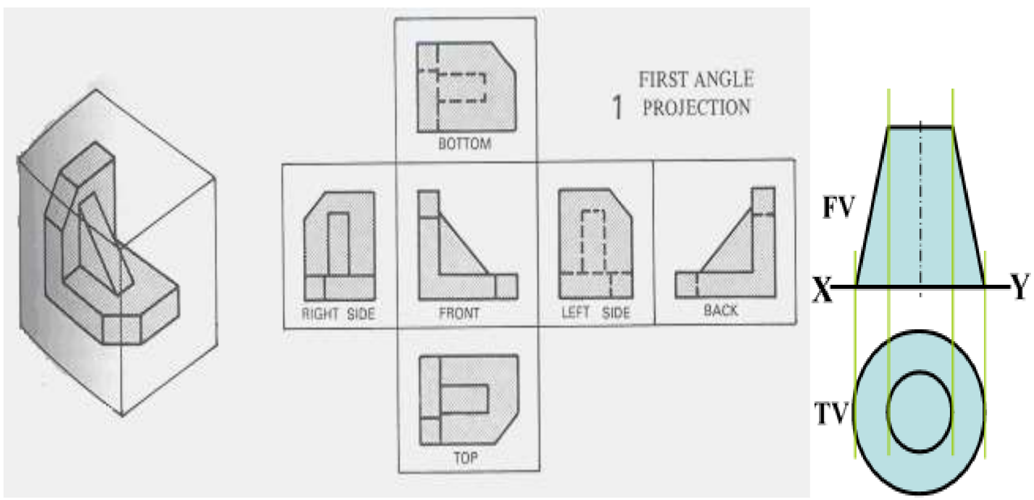


Figure 5.20: First angle orthographic projection views

### *3.1.1 First Angle Projection Principles*

When the object is situated in First Quadrant, that is, in front of Vp and above Hp, the projections obtained on these planes is called First angle projection. (Fv is above X-y, while Tv below X-y)

(i) The object lies in between the observer and the plane of projection.

(li) The front view is drawn above the xy line and the top view below xy. (above xy line is Vp and below xy line is Hp).

(iii) In the front view, Hp coincides with xy line and in top view Vp coincides with xy line.

(iv) Front view shows the length (L) and height (H) of the object and Top view shows the length (L) and breadth (B) or width (W) or thickness (T) of it.

**Self Assessment Exercise:**

State and sketch the arrangement of views in First angle projection.

## 3.2 Orthographic Projection in Third angle

The steps in constructing an orthographic projection of an object in the third quadrant using only the normal surfaces, as illustrated below.

### *3.2.1 Third Angle Projection*

In this, the object is situated in Third Quadrant. The Planes of projection lie between the object and the observer. The front view comes below the xy line and the top view above it. (Fv is below X-y, while Tv above X-y) as shown in Figure 5.21 - 5.22.

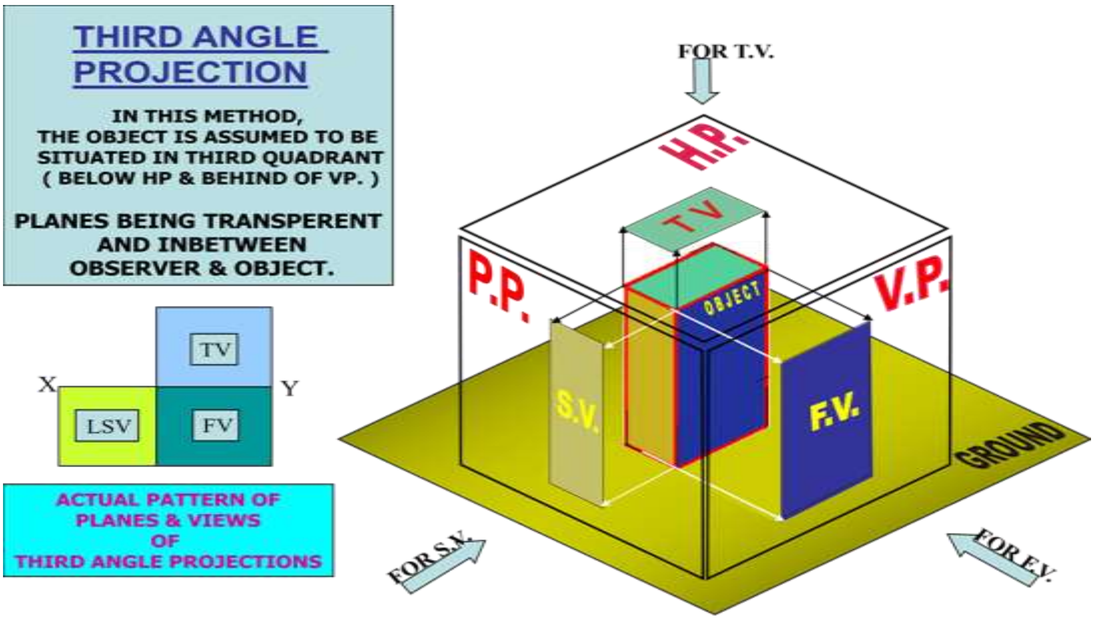


Figure 5.21: Third angle orthographic projection

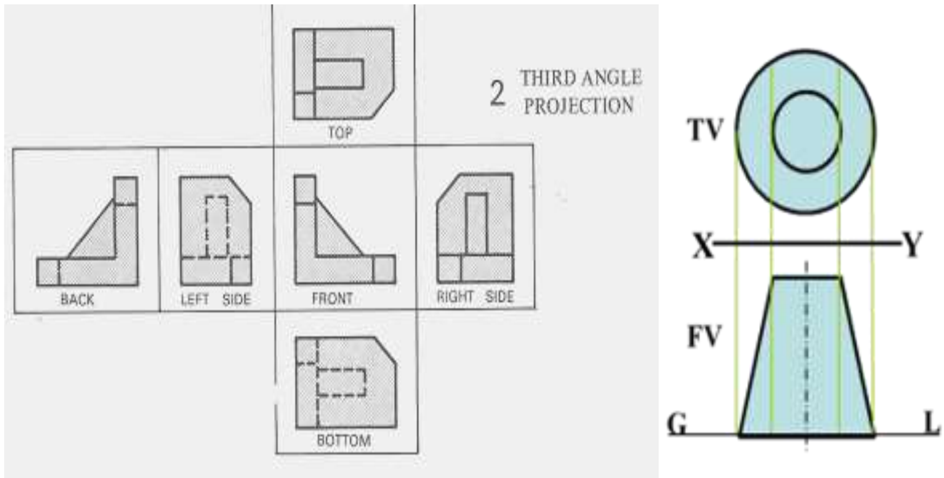


Figure 5.22: Third angle orthographic projection views

*Exercise 1*

Draw three views of the object shown below using first angle projection method. See Figure 5.23 below.

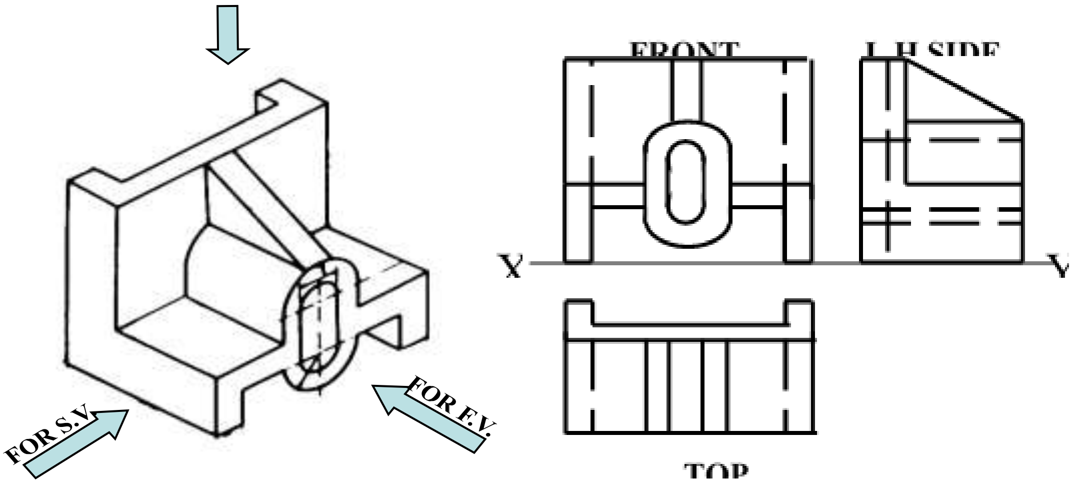


Figure 5.23: Orthographic views of object 1

*Exercise 2*

Draw two views of the object shown below using first angle projection method. See Figure 5.24 below.

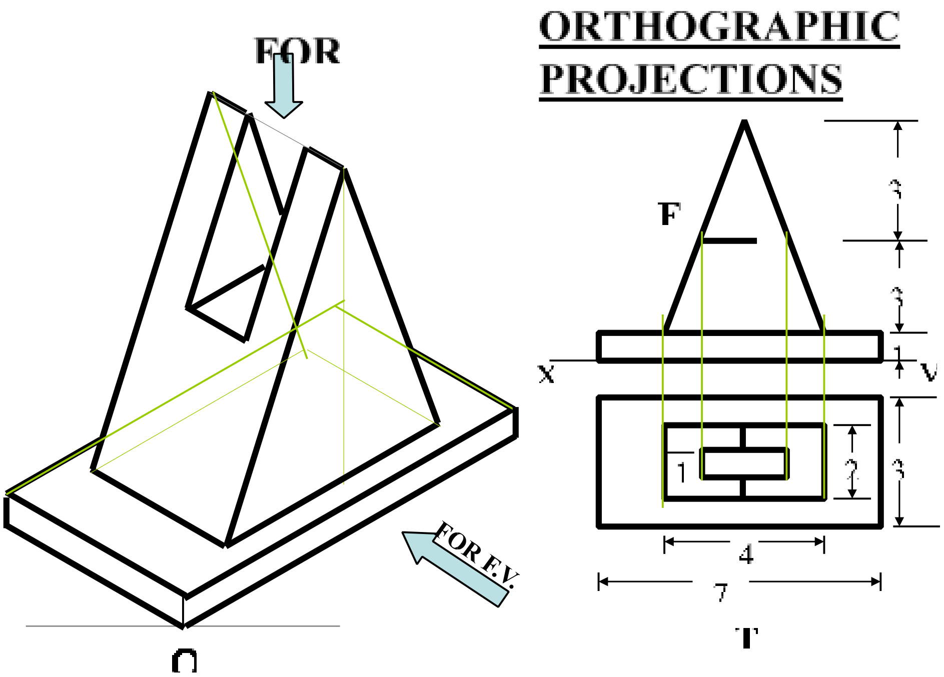


Figure 5.24: Orthographic and Isometric view of object 2

**Self Assessment exercise:**

Draw three views of the objects shown in Figure 4.53 using first angle projection

## 4.0 Conclusion

An object in space may be imagined as surrounded by six mutually perpendicular planes. So, it is possible to obtain six different views by viewing the object along the six directions, normal to the six planes. Orthographic drawings, especially the ones projected from the first and third angle help the designer have clear view of the object from all sides, so that it can be properly dimensioned, and details that may be hidden from one viewpoint, may be seen and accommodated in other views.

## 5.0 Summary

In summary this unit discussed the rudiments of orthographic projections of objects in the principal planes. It explains two methods of orthographic projections; first angle projection (with the object projected in the first quadrant) and third angle projection (with object projected in the third quadrant). It further explain the import of projection of objects in these quadrants (first and third) for a wider and better views, where more details can be seen in other to achieve a more accurate finished product.

## 6.0 Tutor-Marked Assignment

a. State the principle of first angle projection in orthographic drawing.
b. State and sketch the arrangement of views in First angle projection.
c. Draw three views of selected objects using first and third angle methods of orthographic projections.

## 7.0 References/Further Readings


Agrawal, Basant Agrawal, C.M. (2013). Engineering Drawing, 2nd Edition, *Tata McGraw Hill*.

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