JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY

BACHELOR OF SCIENCE IN ELECTRICAL AND COMPUTER ENGINEERING

SPH 2206 TECHNICALDRAWING

COURSE NOTES

ENG. OJWANG CHARITY
(Department of Mechanical Engineering)

2021

SPH 2206 TECHNICAL DRAWING

Contact hours: 45

Prerequisites: None

Purpose of the course

The course is intended to introduce students to basic geometry; perspective, oblique and isometric projections and free hand printing of characters and use of printing aids.

Learning Outcomes

By the end of the course, the student should be able to:

i. Use freehand and drawing aids to print characters
ii. Construct plane figures and profiles in three dimension
iii. Assemble pictorial drawings from given views

Course description

Basic Geometry. Free hand printing of characters and use of printing aids. Title block. Types of lines: Line instructions. Construction of plane figures and cum profiles in three dimensional geometry. Presentation Of Objects. Pictorial drawings to include perspective, oblique and isometric projections. Orthographic Projection. First and third angle projections. Sectioning. Auxiliary view. Pictorial drawing from given views.

Teaching methodologies

2 hour lecture, 1 hour tutorial and one three hour practical session per week and assignments.

Instructional materials/equipment

White/black board, marker pens, chalk, duster, projectors, laptops, internet.

Apparatus/Equipment relevant to the course experiments.

Course assessment

CAT 30%: (Tests 15%, Practicals 10% and Assignments 5%), and final university examination 70%.

Course Textbook

Simmons, C. H., Phelps, N. and Maguire, D. E., “Manual of Engineering Drawing” 4th Ed., Butterworth-Heineman, 2012. ISBN: 978-0-08-096652-6.

Reference books

1. Bielefeld, B. and Skiba, I., “Basics Technical Drawing” Birkhauser Architecture, 2013. ISBN-10: 3034613261, ISBN-13: 978-3034613262.
2. Goetsch, D. E., Rickman, R. L. and Chalk, W. S., “Technical Drawing for Engineering Communication” 7th Edition, Delmar Cengage Learning, 2015. ISBN-10: 1285173015, ISBN-13: 978-1285173016.

Course Journals

1. International Journal of Mechanical Engineering Education, ISSN: 1573-1979 (electronic version).
2. Journal for Geometry and Graphics, ISSN: 1434-8411.

Reference Journal

Instruction materials/equipment

1. Drawing office;
2. Drawing instruments;
3. Computer Laboratory.

Grading Policy

1. Continuous Assessment: 50%
    - CATs: 20%
    - Assignments: 30%
2. Written Exam: 70%

Topics coverage

1. Graphic Language
2. Introduction to Technical Drawing
3. Loci
4. Orthographic Projection
5. Three Dimensional views
6. Conventional representation of features
7. Free hand sketching
8. Gear tooth profiles, thread forms and fasteners
9. Aspects of Engineering design

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Chapter 1

Introduction

1.1 Graphics Language

Graphics are visual presentations on some surface such as a wall, paper, canvas, computer screen, etc, to inform (communicate) or to entertain. Examples of graphics are:

- pictures
- photographs
- visual art
- diagrams
- engineering drawings, etc

The **graphic language** is the idea of communicating thoughts from one person to another by means of graphics. The role of the graphics language is:

i. To communicate ideas

ii. To communicate feelings

iii. To convey information

Written language is essential for discussing concepts, meanings or feelings, the things that do not have form, whereas things that have form are better explained or captured with the graphic language. Just as a person must be literate in order to to understand the written language, visual literacy is also important in order to understand information in graphic form.

Communication by use of graphics has developed along two distinct paths:

- Artistic drawing
- Technical drawing

1.1.1 Artistic Drawing

Artistic drawings are used to express aesthetic, philosophic or other abstract ideas. They can also be used to portray decorative aspects, to express joy, sorrow, political or religious beliefs. It can be carried out on almost any surface and allows many interpretations. Common tools for artistic drawing are:

- graphite pencils

- inked brushes
- crayons
- charcoal
- markers
- waxed colored pencils, etc.

1.1.2 Introduction to Technical Drawing

Technical drawing (drafting) is the practice of creating accurate descriptions and representations of existing or imagined physical objects for technical, architectural and engineering needs. They are used in development of ideas for designs and to convey technical information. Aspects of a technical drawing include:

- shape
- size
- material
- assembly
- finish

Essential requirements for a technical drawing include:

- Clear and unambiguous
- Language independent
- accurate
- Conform to standards
- suitable for duplication

There are three types of technical drawings:

1. Multi-view drawings (orthographic); one or more views (projections) systematically arranged.
2. Pictorial; one view drawn in 3D at a specified angle as it would appear in real life.
3. Schematic (diagrammatic); simplified functional drawing.

Drawing conventions (drawing grammar) allow people to communicate more effectively and with clarity. These conventions are set by various standards organizations such as:

- **ISO** International Organization for Standardization
  - ISO 128: Technical Drawings - General principles of presentation.
  - ISO 129: Technical Drawings - Dimensioning
  - ISO 3098/1: Technical Drawings - Lettering
  - ISO 8048: Technical Drawings - Construction Drawings - Representation of views, sections, cuts.
- **KEBS** Kenya Bureau of Standards
  - KS 06-325. Year 1986. Title: Engineering drawing practice. scope: Specifies the general principles of presentation and practice to be applied to engineering drawings. Subject: Engineering drawings
  - KS 06-1334 Year 1996. Title: Specification for engineer's squares.
- **ANSI** American National Standards Institute
- **BS** British Standards

These standards ensure quality, safety and interchangeability of products and information. Standards are updated periodically rendering the old ones obsolete.

Technical drawing is referred to as the universal language for Engineering since it can be interpreted in any part of the world.

1.1.3 Drawing Equipment

List of equipment for technical drawing

1. Drawing board or drafting table (508×610)
2. T-square
3. Set of instruments (draughtsman set)
4. Triangle 45^o-45^o-90^o or adjustable sets square.
5. Triangle 60^o-60^o-90^o
6. Protractor
7. Pencils HB, H, 2H, 4H

8. Eraser (Staedtler)
9. Drafting tape (masking tape)
10. Drawing paper (A2)
11. Dry piece of cloth

Optional equipment:

1. Erasing shield
2. Irregular curve (French curve)
3. Lettering guide
4. Ellipse template
5. Flexible curve

Objectives that students should strive to obtain:

1. Accuracy - should convey the correct information
2. Speed - for productivity
3. Legibility - (clear and legible for communication)
4. Neatness
5. Use only one side of the drawing paper.

1.2 Paper sizes, lettering and line types

1.2.1 Paper Sizes

In this course, we will adopt the ISO A standard drawing sheet sizes and inside borders. The ISO A0 size is defined as having an area of one square meter (1 m^2). The sides are in proportions of 1:$\sqrt{2}$. Each smaller sheet size is exactly half the area of the previous size, for instance,

- an A0 sheet cut in half gives two A1 sheets
- an A1 sheet in half you get two A2 sheets

Figure 1.1 shows ISO A paper size series.
Table 1.1 shows dimensions of ISO A series drawing sheet sizes, while figure 1.2 clarifies the terms used in table 1.1. The most commonly used smallest format is A4.

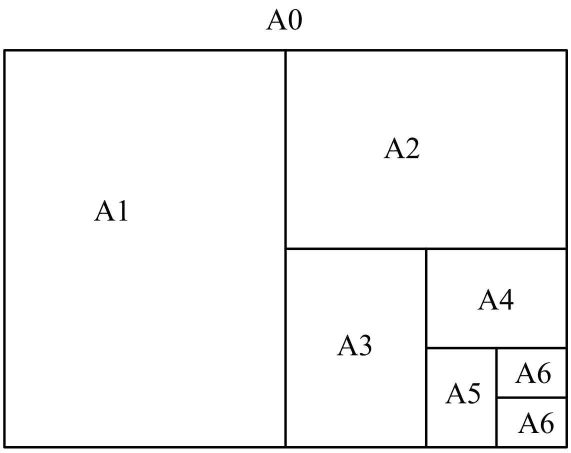


Figure 1.1: ISO A Drawing paper sizes

Table 1.1: Dimensions of ISO A drawing sheet sizes

Series designation	Trimmed size (mm)		Inside border (mm)	
	Y	X	V	U
A0	841	1189	821	1159
A1	594	841	574	811
A2	420	594	400	564
A3	297	420	267	390
A4	210	297	190	267

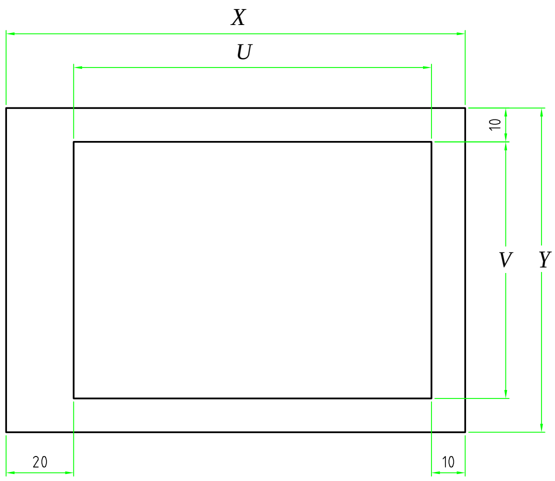


Figure 1.2: Drawing borders

1.2.2 Drawing layout

The Inside border encloses the working area, including the title block and other tables. The border shall be 20 mm wide on the binding edge and 10 mm wide on the other three sides, with resulting working area sizes as shown in Table 1.1. The border on the binding edge allows for binding or hole punching for filing purposes. The drawing layouts can be in two formats:

- portrait, the longer edge is vertical

- landscape, the longer edge is horizontal

1.2.3 Title Block

A title block is a system of labeling and cross-referencing drawings so that the may be stored and when required, identified and located easily and efficiently. Title blocks are used to record all the important information necessary for the working drawings. It contains general as well as specific information. The basic requirements for a title block located at the **bottom right hand** corner of a drawing are:

- Title of the drawing
- Drafters name and number
- Name of firm or organization
- Scale
- Date
- Dimensions (units of measurements) used
- Drawing number or projection symbol

Figure 1.3 shows a sample title block

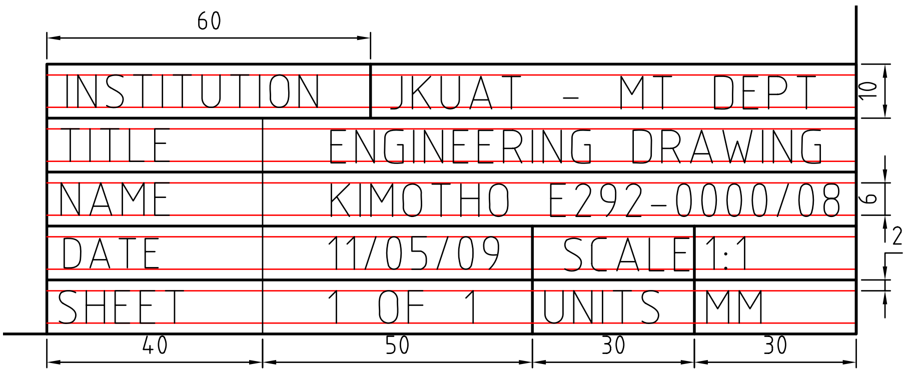


Figure 1.3: Sample title block

1.2.4 Lettering

Lettering is used to give dimensions and other pertinent information of what is being drawn. ANSI recommends that **Single Stroke Gothic style** be the accepted lettering standard due to the following reasons:

- Most plain lettering style

- Written rapidly
- Highly legible

Single stroke lettering has all the strokes of uniform thickness, and each stroke is produced by one movement of the pencil. Figure 1.4 shows sample lettering using Gothic style. Guidelines for

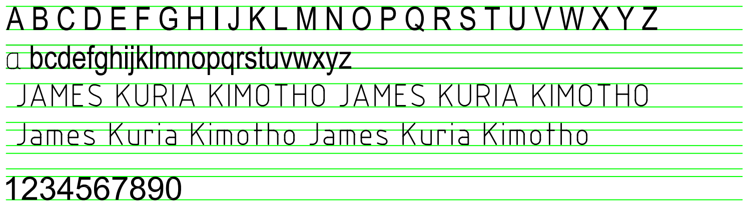


Figure 1.4: Lettering using Gothic style

lettering in technical drawing:

- Use H or HB pencils when lettering
- Pencils should be sharpened to a conical point
- Good lettering requires the use of guidelines drawn using construction lines (4H pencil)
- Characters should have the simplest form possible
- Letter spacing - use uniform area between letters and not uniform spacing
- Word and sentence spacing - should be equivalent to the letter height
- Letter height
  - 6 mm for upper case letters
  - 4 mm for lower case letters
- For dimensions and notes, a character height of 3 mm should be used.
- Spacing between lines of letters should be at least $\frac{2}{3}$ the letter height
- Lettering guides can be used (AMES lettering guide)
- fraction : $\frac{4}{5}$ not 4/5

1.2.5 Line Types

Thin line lines that are dark, and drawn with 2H pencil include: centerlines, extension lines, dimension lines, leader lines, section lines, hidden lines.

Thick lines that are dark and drawn with a HB pencil include; outlines, visible lines.

Very thick lines that are dark and drawn with a B pencil include: cutting plane lines, viewing plane lines.

Thin Light lines drawn with a 4H pencil include: Guidelines used for lettering, construction lines

Dark features drawn with a HB pencil include: arrowheads, lettering

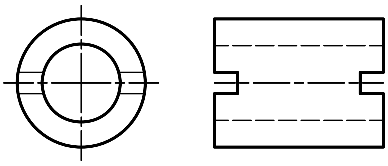
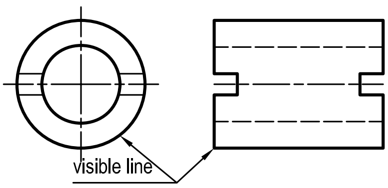
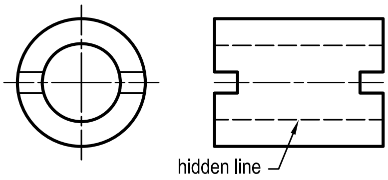
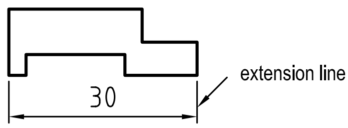
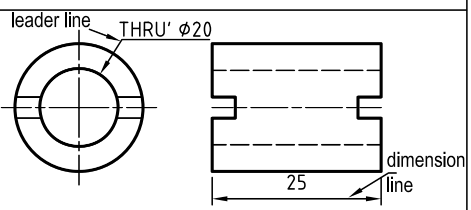
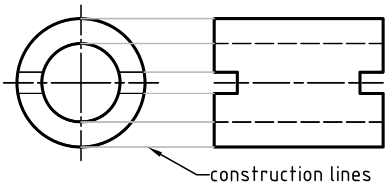
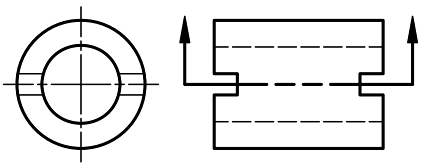
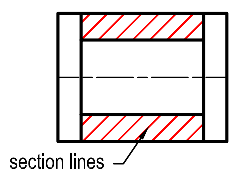
Name	convention	Description and Application	Example
CENTER LINES		Thin dark lines made up of long and short dashes alternately spaced. Used to indicate symmetry about an axis and location of centres - **2H pencil**	
VISIBLE LINES		Thick dark continuous line Used to indicate visible edges of an object - **HB pencil**	
HIDDEN LINES		Thin dark lines made up of short evenly spaced dashes Used to indicate conceled edges of an object - **2H pencil**	
EXTENSION LINES		Thin dark continuous lines used to indicate extent of dimensions- **2H pencil**	
LEADER LINES DIMENSION LINES		used to indicate a part, dimension or other reference used to indicate distance measured - **2H pencil**	
CONSTRUCTION LINES		Thin light continuous lines. Should not be visible at arms length Used when constructing a drawing. - **4H pencil**	
CUTTING PLANE LINES		used to indicate where an imaginary cutting took place - **B pencil**	
SECTION LINES		Thin dark continuous lines Used to indicate the surface in the section view imagined to have been cut along the cutting plane line - **2H pencil**	

Figure 1.5: Types of lines

Chapter 2

Orthographic Projection

2.1 Introduction

A view of an object is known technically as a projection. Orthographic projection is a system of drawing views of an object using perpendicular projectors from the object to the projection plane. The object is positioned in such a way that the principal face is parallel to the projection plane. The projected view describes the exact shape of the object as seen in a specified direction. There are three planes for an orthographic projection:

1. Frontal plane - plane on which the front view is projected.
2. Horizontal plane - plane on which the top or bottom view is projected.
3. profile plane - plane on which the end view is projected.

Once the views are projected onto the respective planes, the planes are opened out so that they lie on the same plane. This produces a number of separate two-dimensional inter-related views which represent faces that are mutually at right angles to each other. Several views of an object can therefore be shown simultaneously on a single drawing paper.

Figure 2.1 shows how views of an object are obtained by using projectors. If the planes of projection are parallel to the principal faces of the object, they form a glass box. Note that the object has three principal dimensions: *width, height* and *depth*. These are fixed terms used for dimensions in these directions regardless of the shape of the object. Since it is required to show the views of a solid or 3D object on flat sheet of paper, it is necessary to unfold the planes so that they all lie in the same plane. Since the glass box has six sides, we can have six views of the object as shown in figure 2.2.

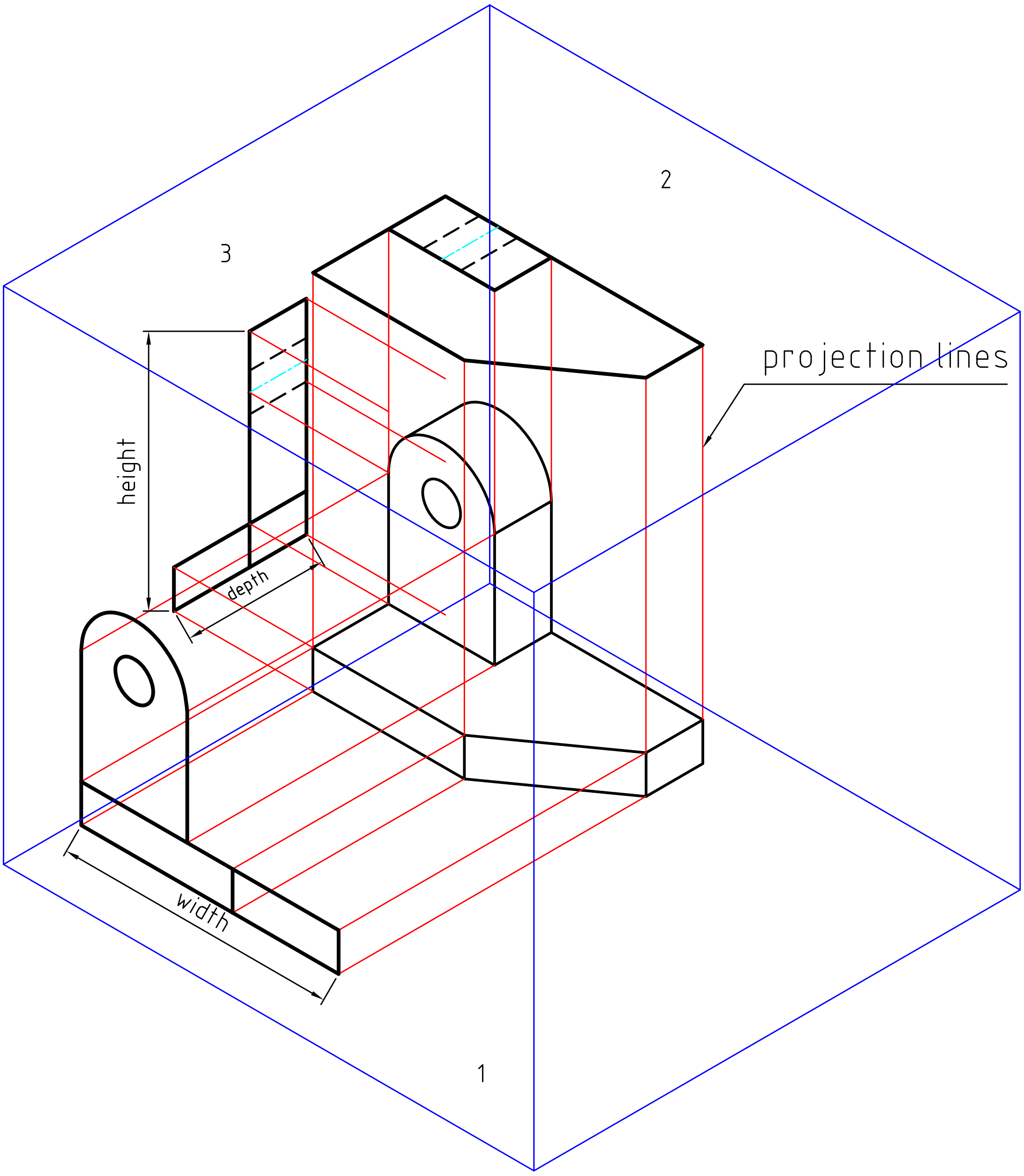


Figure 2.1: Projection of views on a glass box.

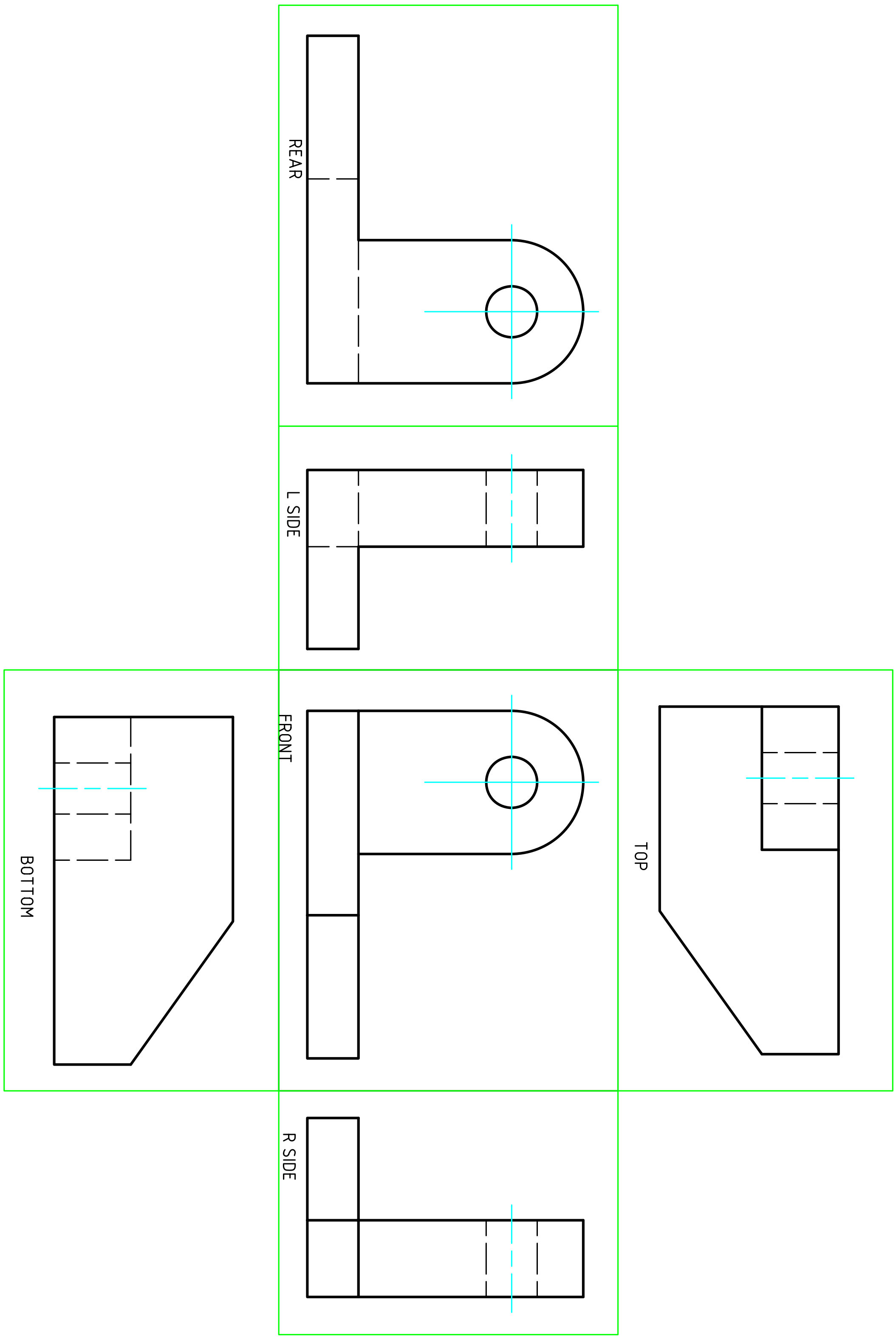


Figure 2.2: Unfolded planes.

2.2 Visualizing the Views

The mental process of reading a drawing in order to obtain the views is known as visualizing the views. Figure 2.3 shows the process of visualization.

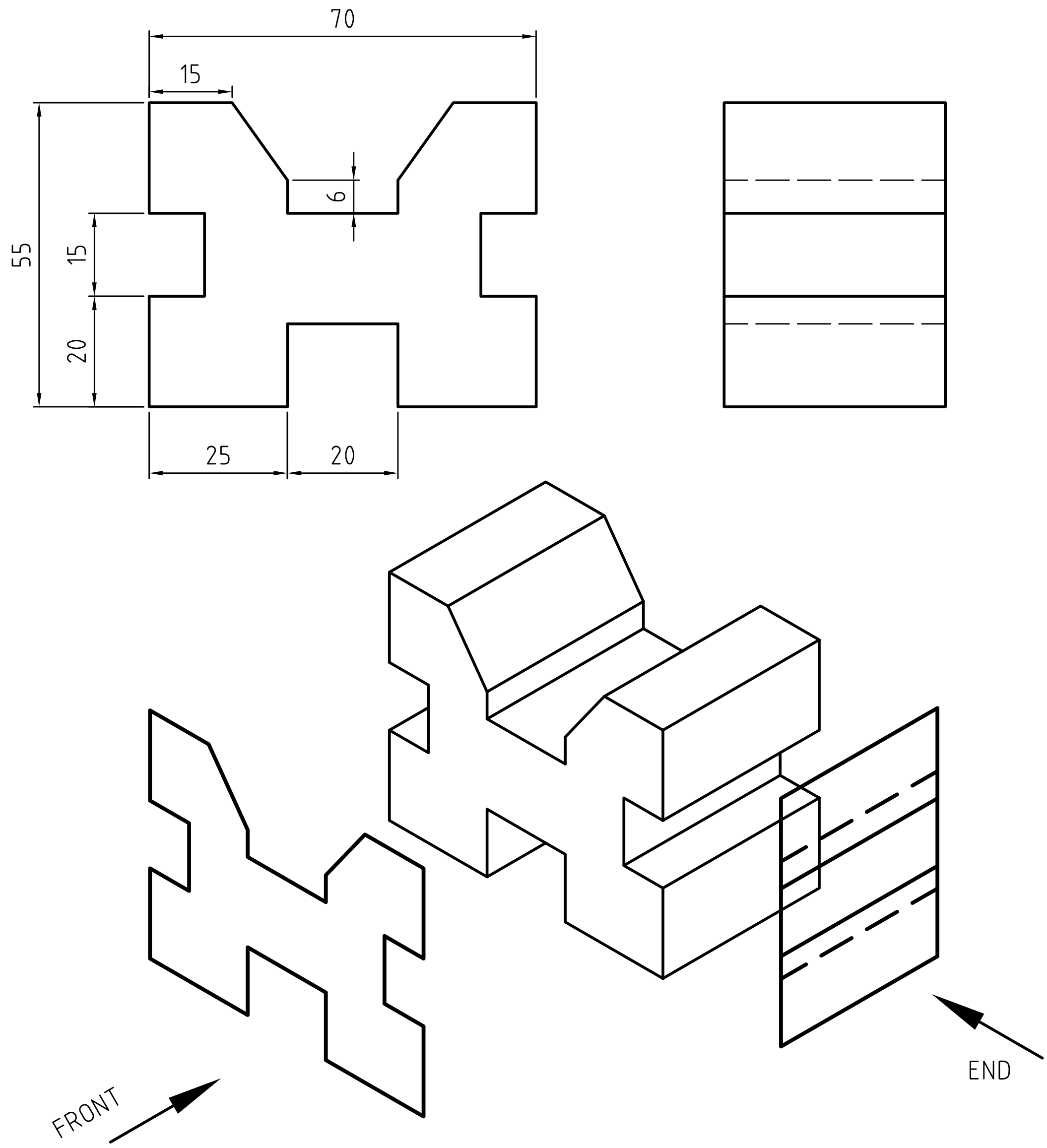


Figure 2.3: Visualization

2.3 Types of Orthographic Projections

Orthographic projection uses two main principle planes of projection; the frontal plane and the vertical plane. These planes intersect to produce four quadrants or angles as shown in figure 2.4. The object to be drawn is imagine to be placed in one of these quadrants and orthographic views of it are projected onto these planes. In practice, only the first and third angles are used since views in the second and fourth quadrants may overlap.

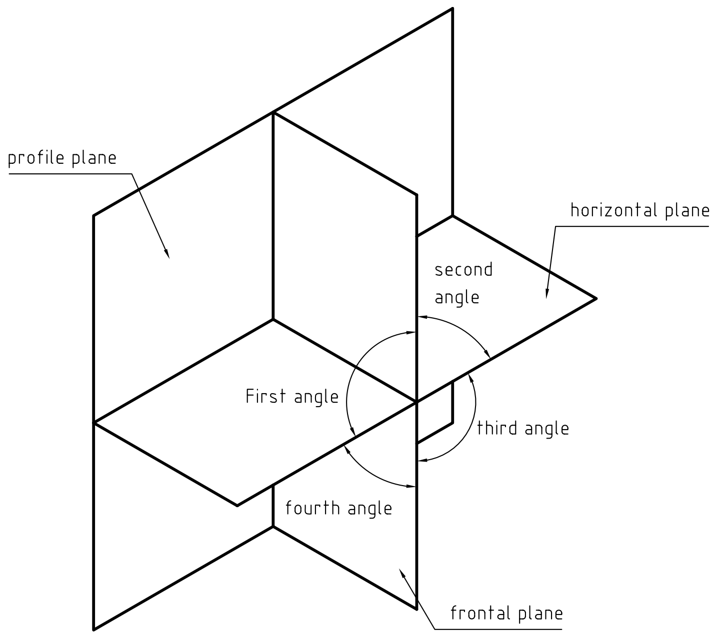


Figure 2.4: Principal planes of projection

2.3.1 First Angle Orthographic Projection

Figure 2.5 shows an object positioned in the First quadrant. Views of the have been drawn on the plane using projectors. The view on the frontal plane is called the **elevation**, that on the horizontal plane **the plan** and that on the profile plane **the end view, end elevation or side elevation**. The observer always looks through the object and to the planes of projection. To obtain the views, the horizontal and profile planes are opened out (or rabatted) about the line of intersection with the profile plane.

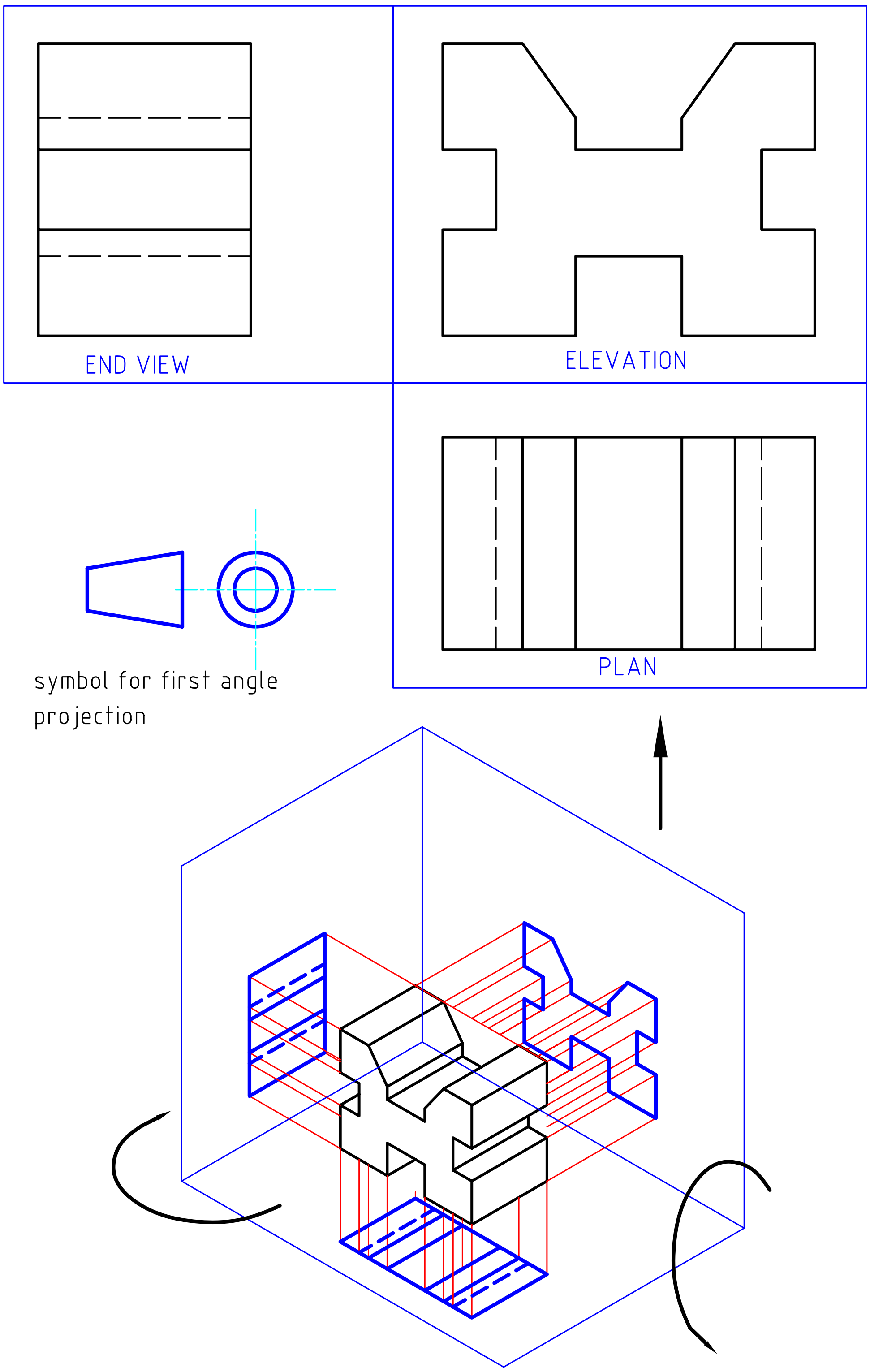


Figure 2.5: First angle orthographic projection

2.3.2 Third Angle Orthographic Projection

This is done by positioning the object in the third quadrant and projecting the views onto the planes as shown in figure 2.6. Since the planes now come between the observer and the object, they are imagined to be transparent and the object is viewed through them. The views are the same in both systems and the only ultimate difference between the two systems is the arrangement of the views.

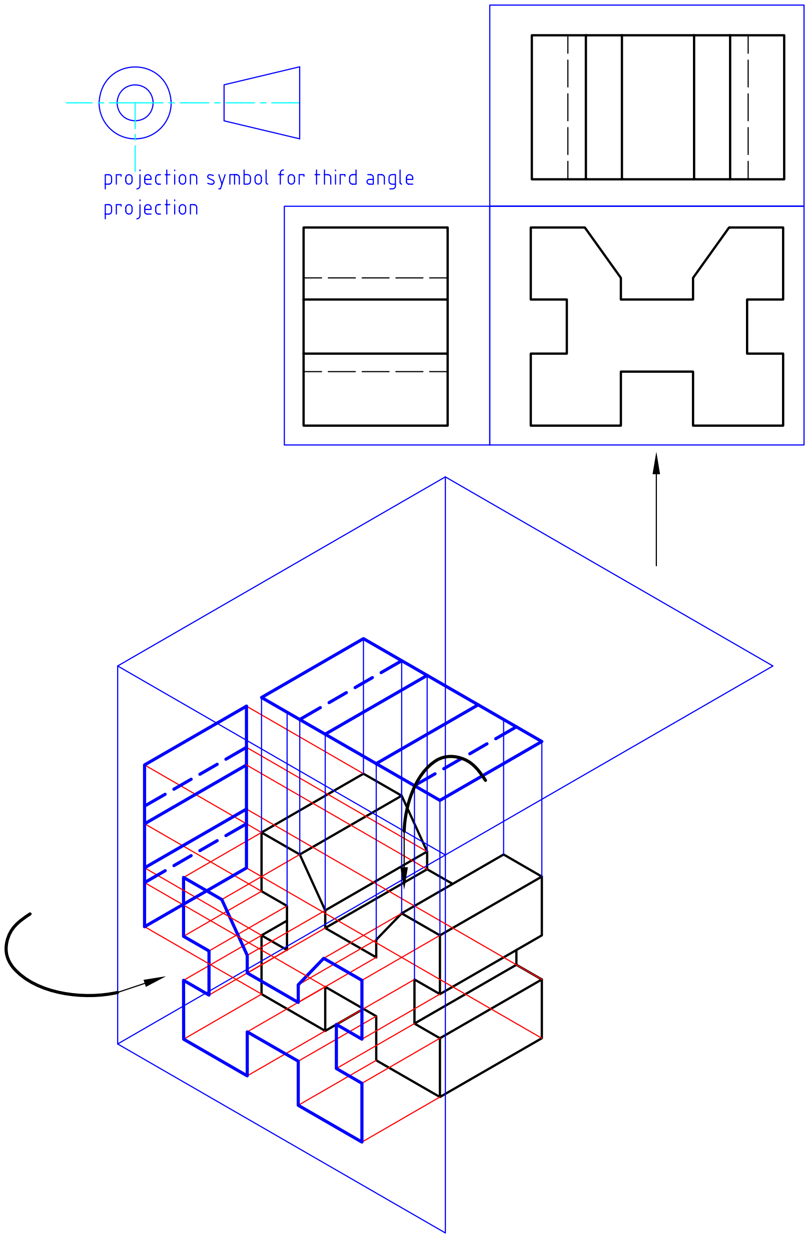
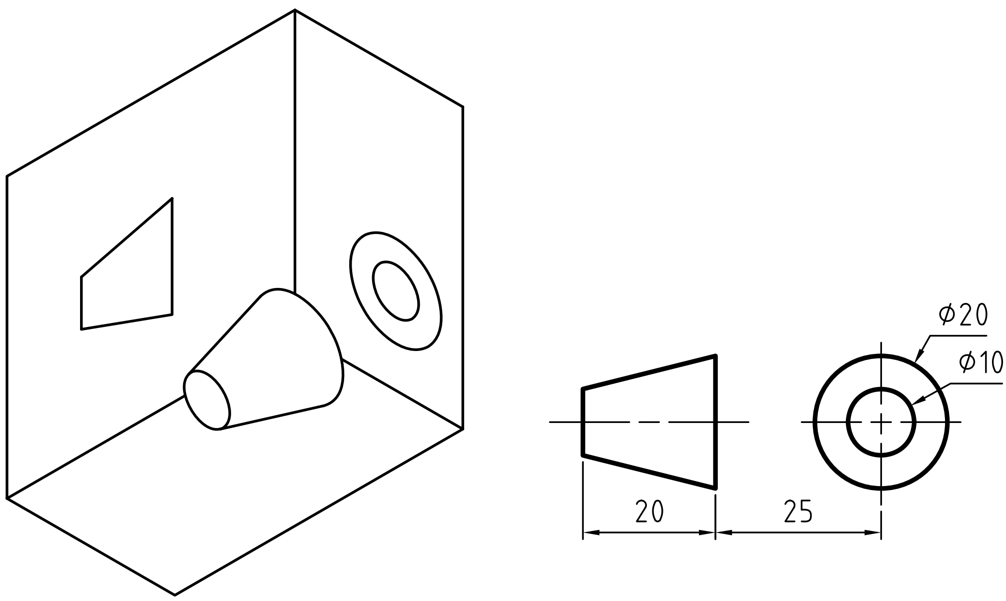


Figure 2.6: Third angle orthographic projection

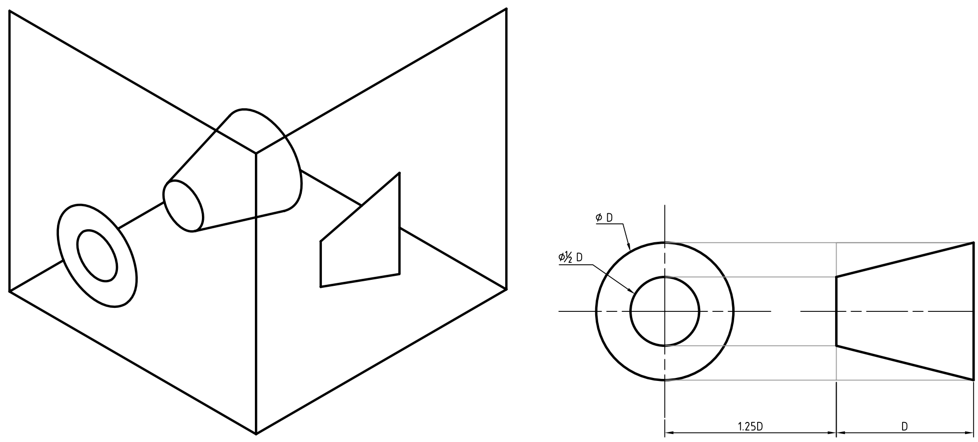
2.3.3 Projection Symbols

Since two systems of projection, 1^{st} and 3^{rd} angle are approved internationally, it is necessary to indicate on the drawing which system has been used. This is done by a symbol consisting of the an elevation and end view of a frustum of a cone. This symbols are shown in figures 2.5 and 2.6.



(a) Projection of symbol (b) Drawing proportions

Figure 2.7: First angle projection symbol



(a) Projection of symbol (b) Drawing proportions

Figure 2.8: Third angle projection symbol

2.3.4 Comparison between First and Third Angle Projections

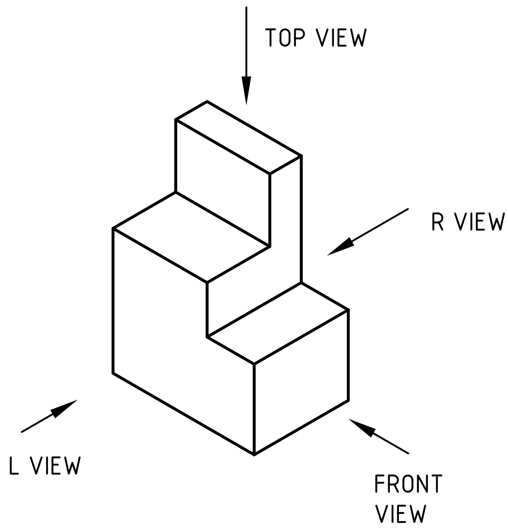


Figure 2.9: Block to be projected

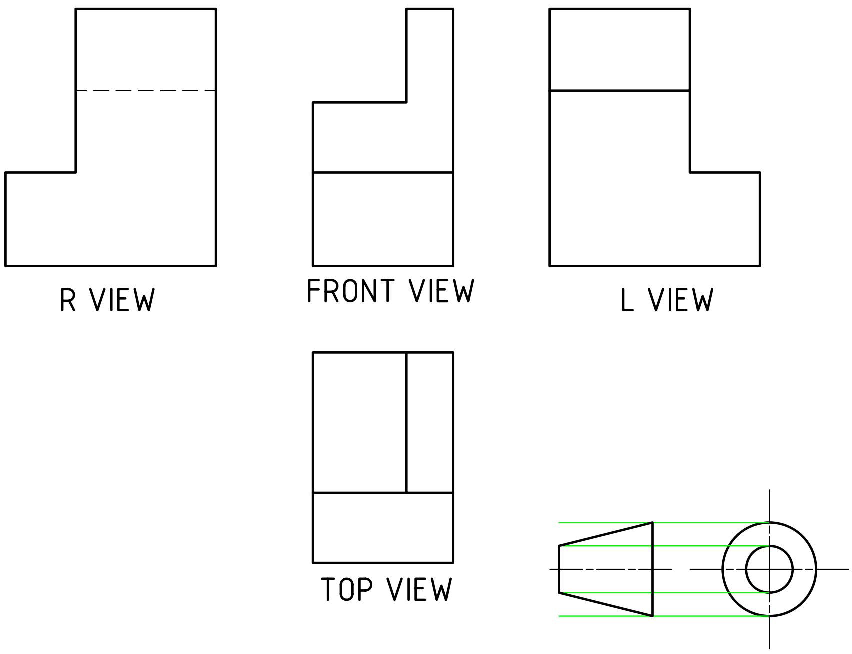


Figure 2.10: First angle projection

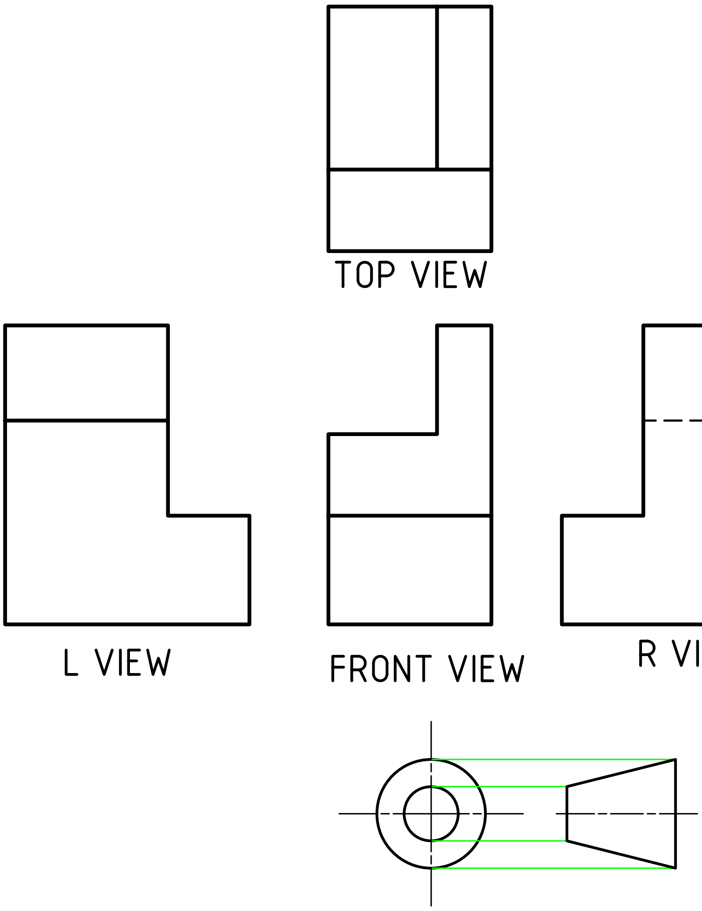


Figure 2.11: Third angle Projection

2.3.5 Two View Mechanical Drawing

It may not be necessary to show all the six views to completely describe an object. Two views are sometimes enough to completely describe an object. This convention is particularly applied to symmetrical objects with less features. If a view does not shows any additional features to the first two views, it should be excluded. If only two views are necessary and the top view and right side view are equally descriptive, the combination chosen is that which spaces best on the paper.

View selection guidelines

- The ”principle views” should be chosen to show the most detail of the object and with the least number of hidden lines.
- The most descriptive view should be selected as the front view
- Build up all the views together by projecting measurements from one view to another.
- Always allow enough space between the views on a drawing to accommodate dimensions and notes without crowding. $C \geq 15$ mm.

Figure 2.12 shows orthographic views of a object that requires only two views to completely define

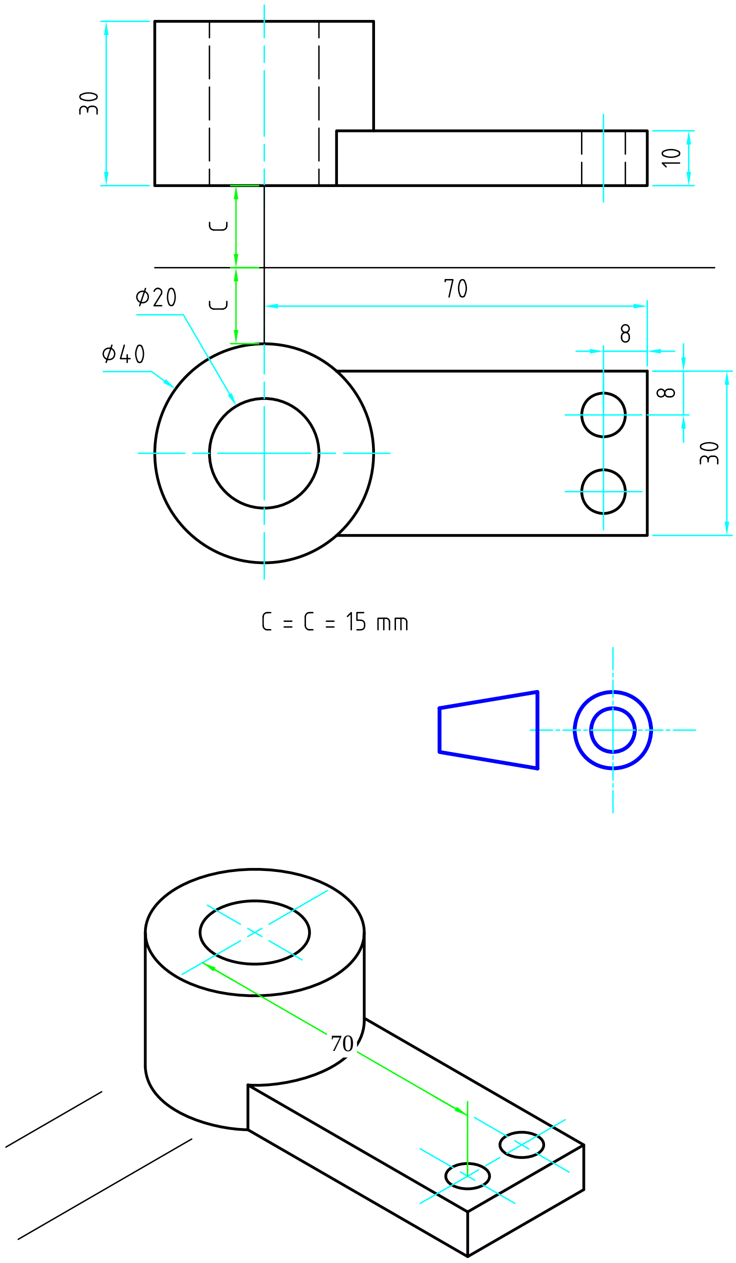


Figure 2.12: 2- view orthographic drawing of a support arm

the object.

2.3.6 Three View Mechanical Drawing

Most components require at least three views (a front view, top view and an end view) to completely describe them.

2.4 Dimensioning

An engineering drawing must be properly dimensioned in order to convey the designer's intent to the end user. Dimensions provide the information needed to specify the *size* and *location* of every feature on the object. A properly dimensioned drawing helps ensure that the part produced in the manufacturing phase matches the part you asked for. There are a few simple guidelines to be followed when dimensioning a drawing and these guidelines cover the majority of cases you will encounter. Before we can begin to go over the rules for dimensioning, we must learn a little bit about the anatomy of a dimension. Figure 2.15 shows a dimensioned view of an object.

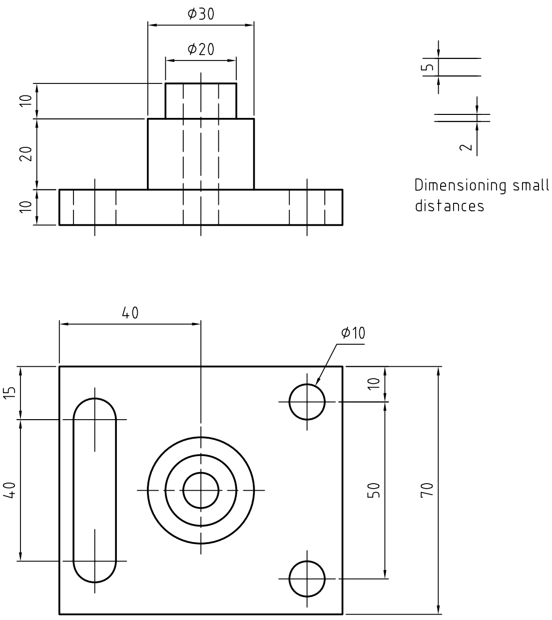


Figure 2.15: The anatomy of a dimension 2.15

2.4.1 Guidelines for Dimensioning

- Dimensions should be placed outside the outline of the view wherever possible. This is achieved by drawing projection or extension lines from points or lines on the view and placing a dimension line between them. There should be a small gap between the outline and the start of the extension line and the extension line should continue a short distance beyond the dimension line. The dimension line has arrow heads about 3 mm long at each end and should touch the extension line or other limiting line.

- The dimension line which is nearest to the outline should be about 10 mm from it if possible and succeeding dimensions should be well spaced for clarity.

- The dimension should be applied in the view that provides the best description of the feature being dimensioned. For example, holes should be dimensioned in a view where they appear round. A slot should be dimensioned in a view where the contour of the slot is visible. Apply dimensions in a view where the feature appears true size.

- Place larger dimensions towards the outside so that extension lines don't cross dimension lines.
- Do not over-dimension. Each feature should be dimensioned once and only once.
- Use the diameter dimension to specify the size of holes and cylinders. Precede the dimension with the diameter symbol, ϕ.
- Use the radius to dimension an arc. The radius dimension is preceded by the symbol, R. A leader line is commonly used for diameters and radii. The leader line should be a radial line directed through the center of the arc or circle
- Concentric circles should be dimensioned in a longitudinal view (figure 2.15).
- Use the times symbol, $\times$, to indicate repeated dimensions or features.
- Dimensions should be arranged such that they can be read from the bottom of the drawing or from the right hand end of the drawing.

2.5 Drawing scales

Most drawings are made to full size, but if the size of an object makes it impossible to draw to full size, it can be drawn in proportion, that is to a uniform scale. The ratio of reduction or enlargement often depends upon the relative sizes of the object and of the sheet of paper upon which the drawing is to be made. Scales can be classified into 5:

- metric scale - the primary unit of measurement for engineering drawings is millimeter (mm)
- engineers scale - the engineers scale is graduated in units of one inch divided into 10, 20, 30, 40, 50, and 60 parts.
- decimal scale - on the full scale, one inch is divided into fiftieths of an inch, or 0.02.
- mechanical engineers scale - mechanical engineers scales are divided into units representing inches to full size, half size, quarter size or eighth size.
- architects scale - is primarily intended for drawing buildings, piping systems, and other large structures which must be drawn to a reduced scale to fit on a sheet of paper.

The scale used must be stated on the drawing as a ratio for example 1:2 which means half full size and each division on a metric scale equals 2 mm with the calibration numbering at 20-unit intervals. Drawings can also be drawn in an enlarged form for example 2:1 which means the drawing has been drawn twice the full size. Scale multipliers and divisors of 2, 5 and 10 are recommended for most commonly used scales eg.

- 1:1 full size

- 1:2 half full size
- 1:5 one-fifth full size
- 1:10 one-tenth full size
- 2:1 twice full size
- 5:1 five times full size
- 10:1 10 times full size.

2.6 Hidden detail Format

Hidden lines are used to conceal edges that are not visible from a given viewing point. A hidden lines consists of medium lines with short evenly spaced dashes. Hidden lines should join visible lines except where the hidden line forms a continuation of the visible line. In this case, a gap should be left. Hidden detail lines should intersect to form L and T corners as shown:

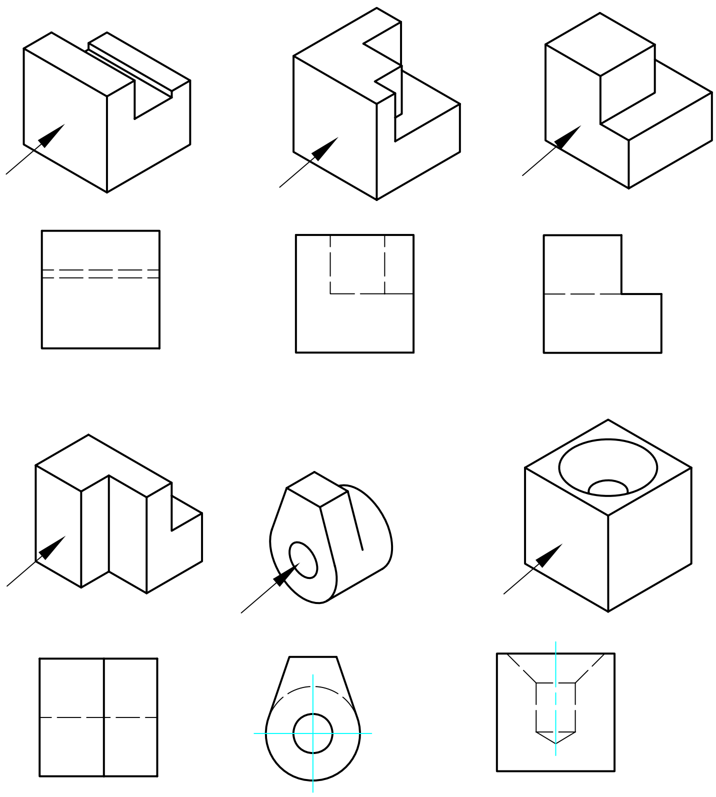


Figure 2.16: Hidden line practices

Chapter 3

Three Dimensional Views

3.1 Introduction

Three dimensional drawing (pictorial drawing) show several faces of an object simultaneously, approximately as they appear to the observer. Pictorial drawings show only the appearances of parts but does not completely describe complex or detailed forms. Pictorial drawings enable a person without technical training to visualize the design represented. It also enables the designer to visualize the successive stages of the design and to develop it in a satisfactory manner. There are three principal types of pictorial drawings:

1. Isometric
2. Oblique
3. Perspective

3.2 Isometric Projection

Isometric means equal measure. An isometric projection is produced by placing the object so that its principle edges or axis make equal angles with the plane of projection. In this position, the edges of a cube would be projected equally and would make equal angles with each other (120^o). Figure 3.2 shows the projected view. In this case, the edges of the cube are inclined to the plane

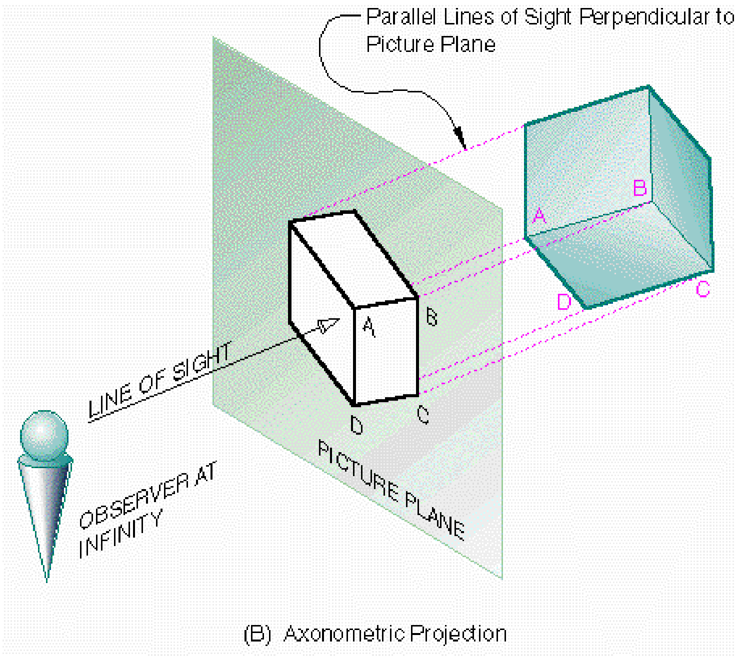


Figure 3.1: isometric projection

of projection and are therefore foreshortened. Therefore to obtain the full size view, an isometric

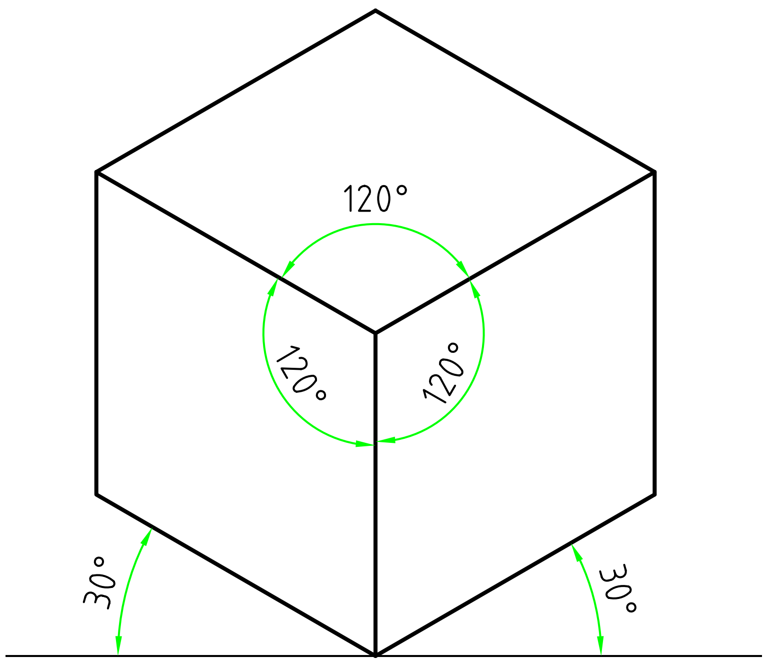


Figure 3.2: isometric projection

scale is used. When the view is prepared with an ordinary scale, it is an isometric drawing, when prepared with an isometric scale, it is an isometric projection. Isometric drawings are much easier to execute and are satisfactory for all practical applications.

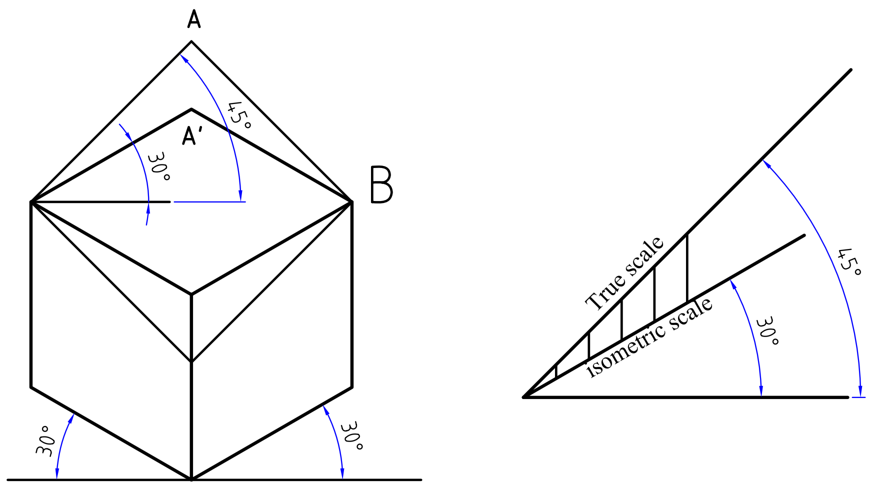


Figure 3.3: Isometric Scale

$$\frac{\text{Isometric length}}{\text{True length}} = \frac{\cos 45^o}{\cos 30^o} = 0.8165$$

3.2.1 Objects composed of entirely isometric lines

These objects are easily drawn as all dimensions in the orthographic views may be drawn directly onto the isometric view. Hidden detail is omitted unless it is essential to show the shape of the object. Figure 3.4 shows the procedures in drawing an isometric view.

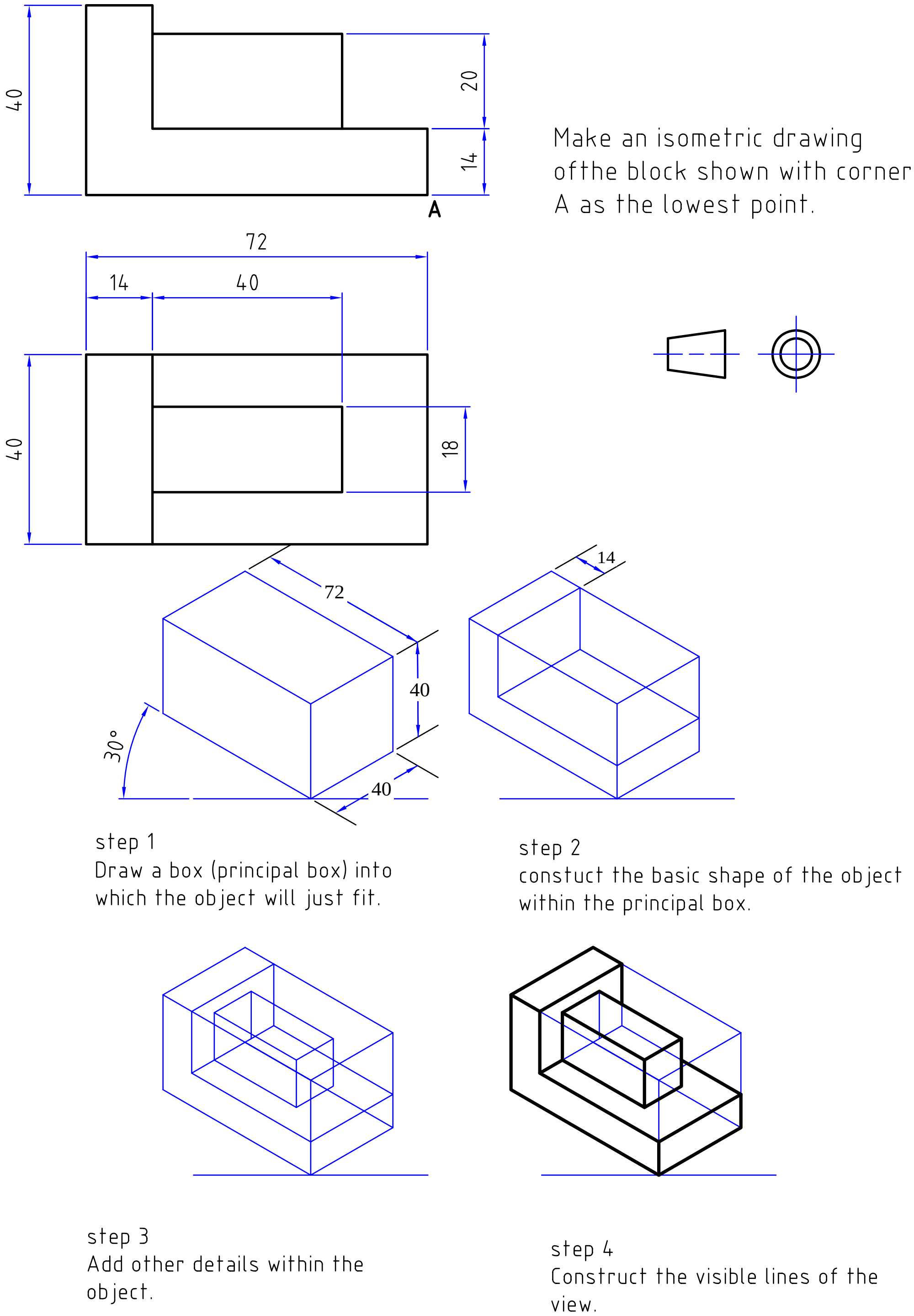


Figure 3.4: Isometric drawing

3.2.2 Objects with non-isometric lines

Lines on an object which are located by angles are non-isometric lines. Angles cannot be laid off directly on an isometric drawing as they do not appear in their true sizes. Lines positioned by angles are drawn by fixing their ends using isometric lines as shown in figure 3.5.

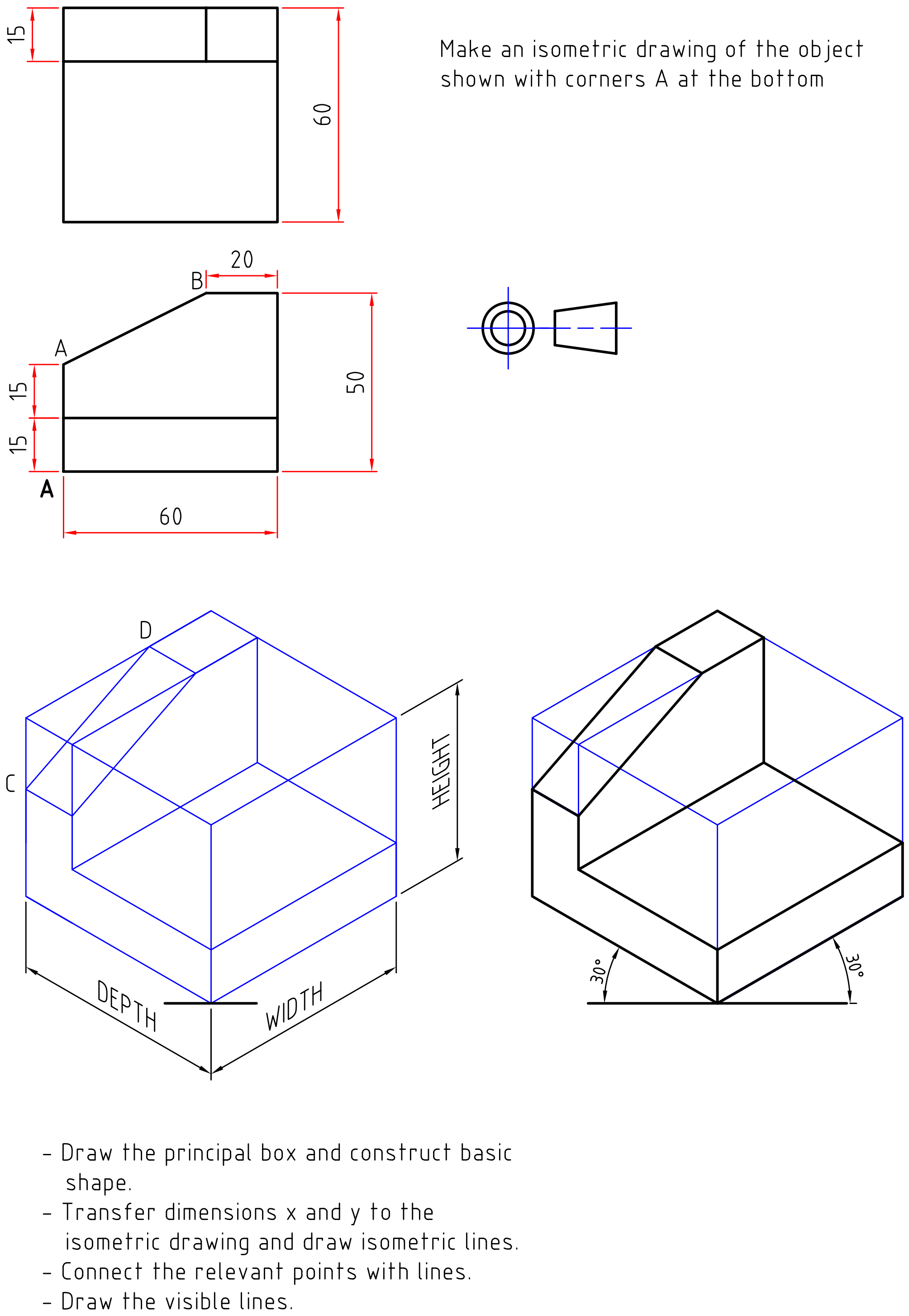


Figure 3.5: Isometric drawing

3.2.3 Circles in isometric projection

Any circle on an isometric drawing will appear as an ellipse which may be drawn in several ways:

1. circle construction by circumscribing square method

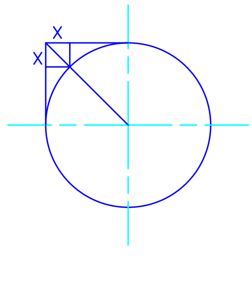


Figure 3.6: Isometric drawing

2. approximate circle construction; the ellipse occurs so frequently on isometric drawings that an approximate method using circular arcs is often used to draw it. This is done by drawing an isometric square with sides equal to the diameter of the circle. The long diagonal is drawn and either B or D is joined to the midpoints of opposite sides. Where these lines cross the long diagonal are two arc centers. The other centers are corners B and D on the short diagonal. When drawing a cylinder, the centers of the other end are obtained by drawing isometric lines thru' centers B, D, X and Y and marking off the length L of the cylinder to obtain centers B', D', X' and Y'. The same method may be used to draw holes if both ends are visible.

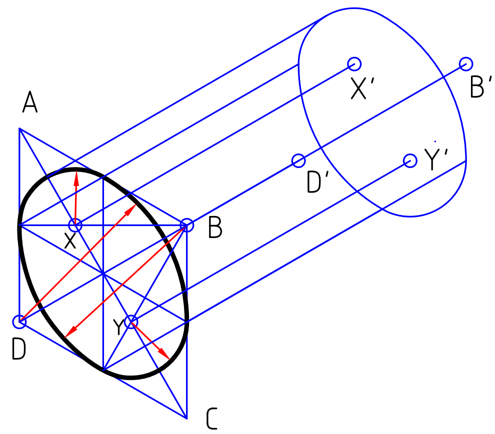


Figure 3.7: Isometric circle drawing by circular arc approximation

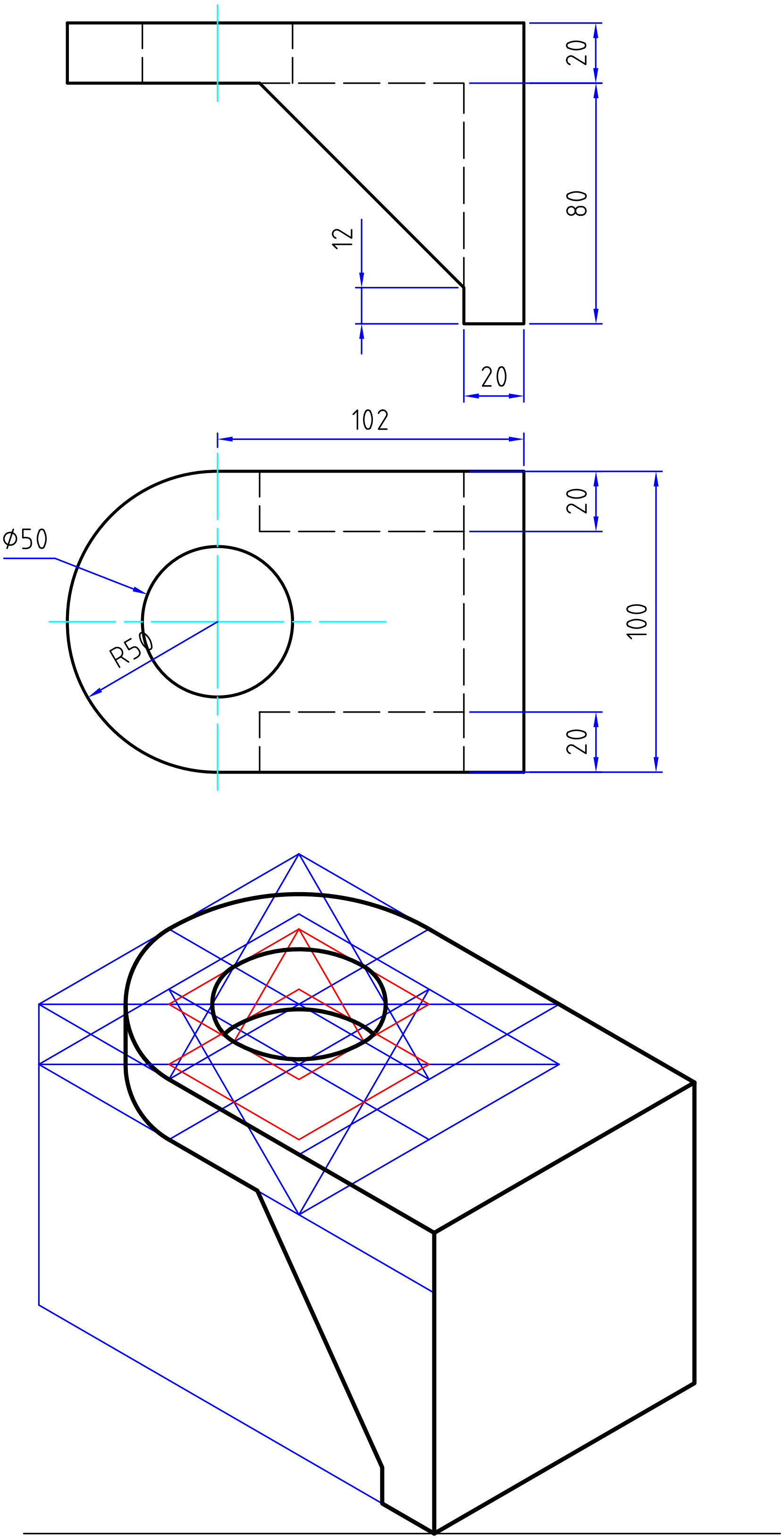


Figure 3.8: Isometric drawing

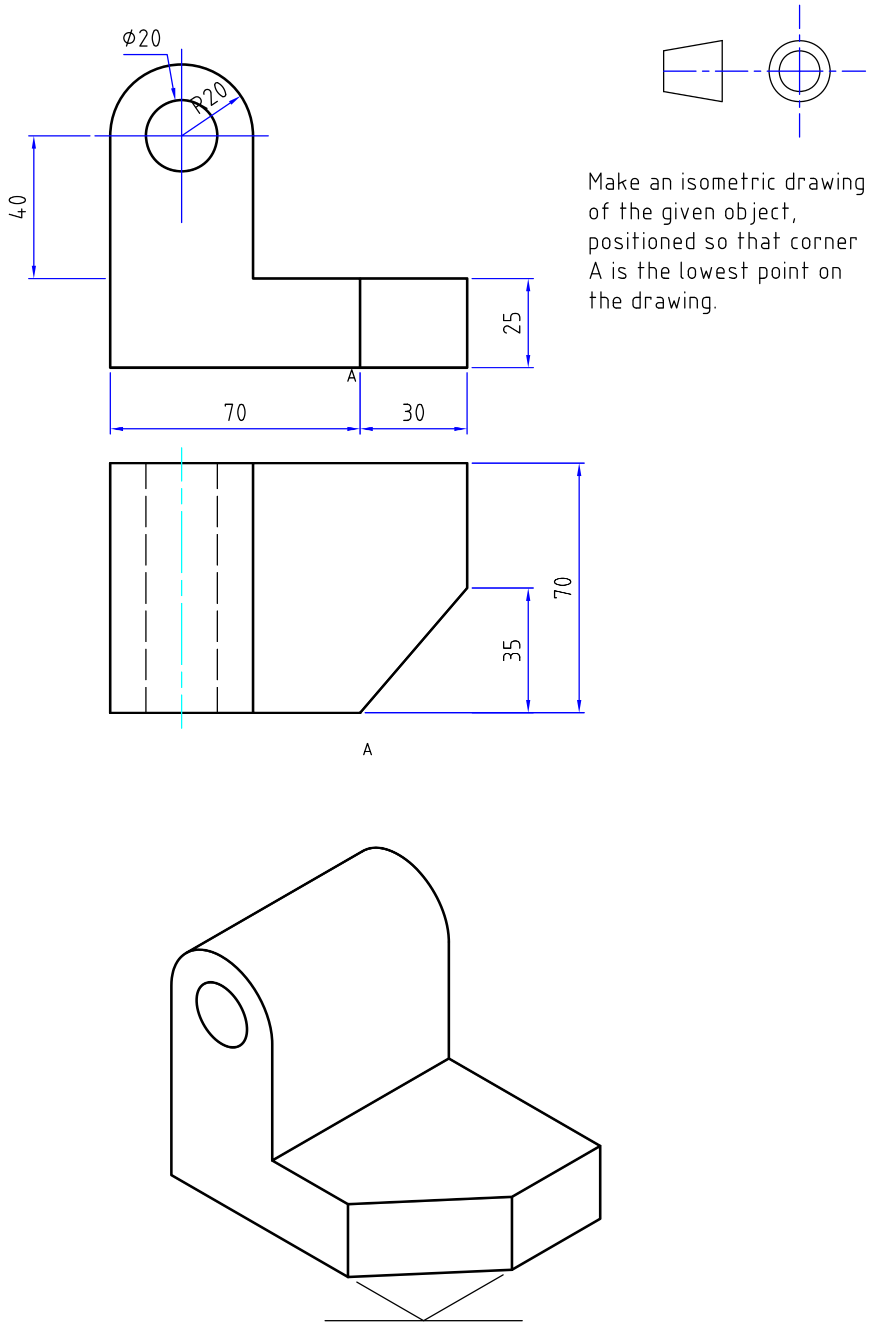


Figure 3.9: Isometric drawing

3.3 Oblique Projection

Oblique projection is a method of producing a pictorial view of an object. In oblique, the projectors are parallel to each other but oblique to the projection plane as opposed to isometric projection where the projectors are parallel and normal to the projection plane. The principal face is kept parallel to the projection plane.

In oblique drawing, surfaces that are parallel to the principal face appear as true shapes while lines which are perpendicular to the principal surfaces are drawn at a receding angle, 30^o, 45^o or 60^o. The receding angle to be used depends on the shape of the object and location of its significant

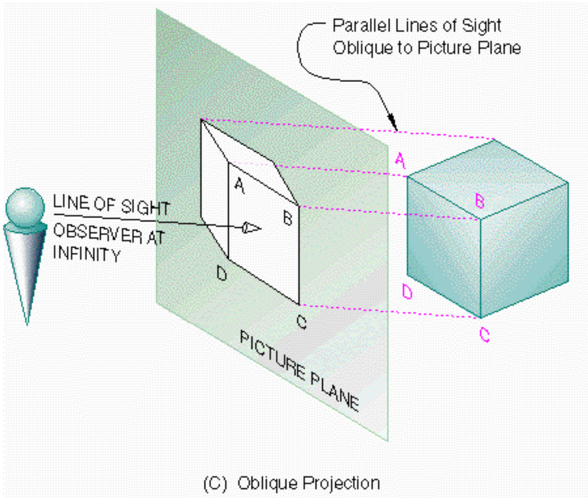


Figure 3.10: oblique projection

features. A larger angle is used to show features on the top plane of an object while a smaller angle is used to show features on the side plane of an object.

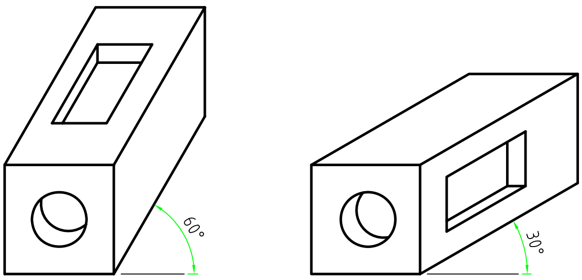


Figure 3.11: Angle of receding line

When the receding lines are drawn with their true lengths, the object appears distorted. The degree of distortion may be decreased by decreasing the the length of receding lines. Scales of $\frac{1}{2}$ and $\frac{3}{4}$ full size are commonly used. When the receding lines are true lengths (drawn to full scale), the oblique drawing is called a **cavalier projection**.

When the receding lines are drawn to $\frac{1}{2}$, the drawing is commonly known as a **cabinet projection**. The term is attributed to the early use of this type of oblique drawing in the furniture industries.

The face of an object containing circles and arcs should be placed parallel to the plane of projection if possible. Circular features which are not parallel to the front plane appear elliptical. The longest dimension of the object should be placed parallel to the plane of projection if possible.

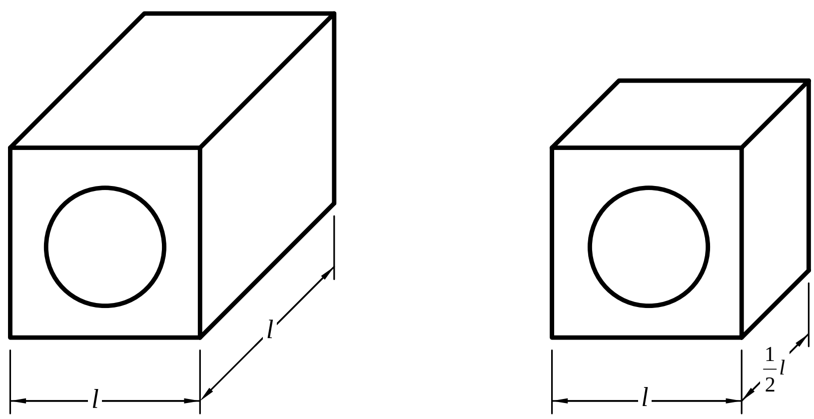


Figure 3.12: Cavalier Versus Cabinet projection

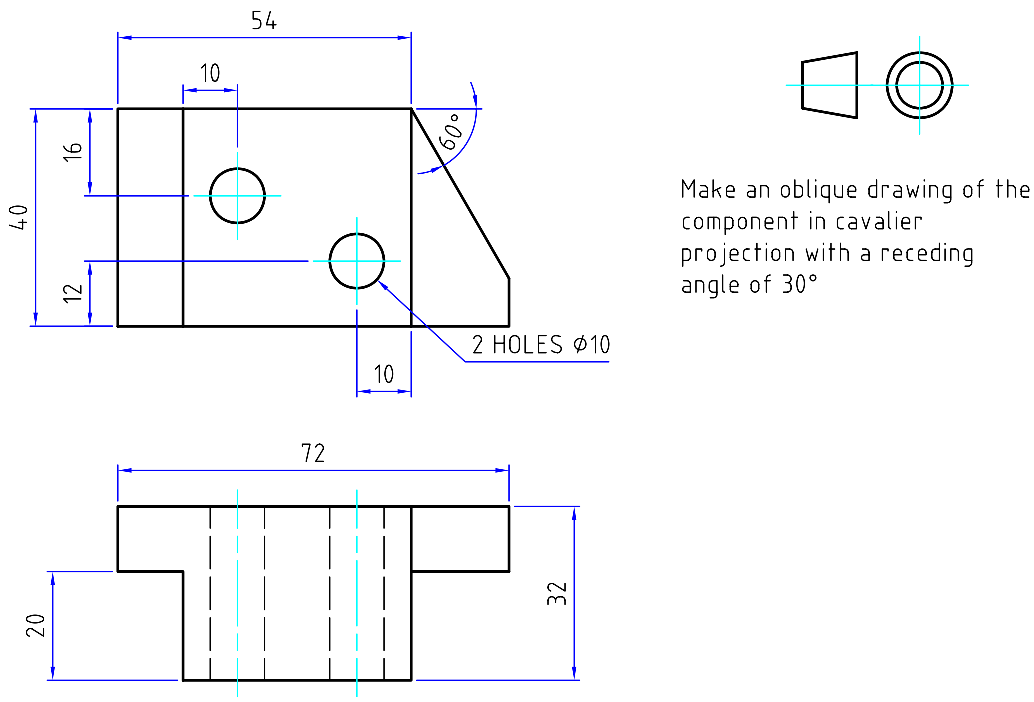


Figure 3.13: Oblique example

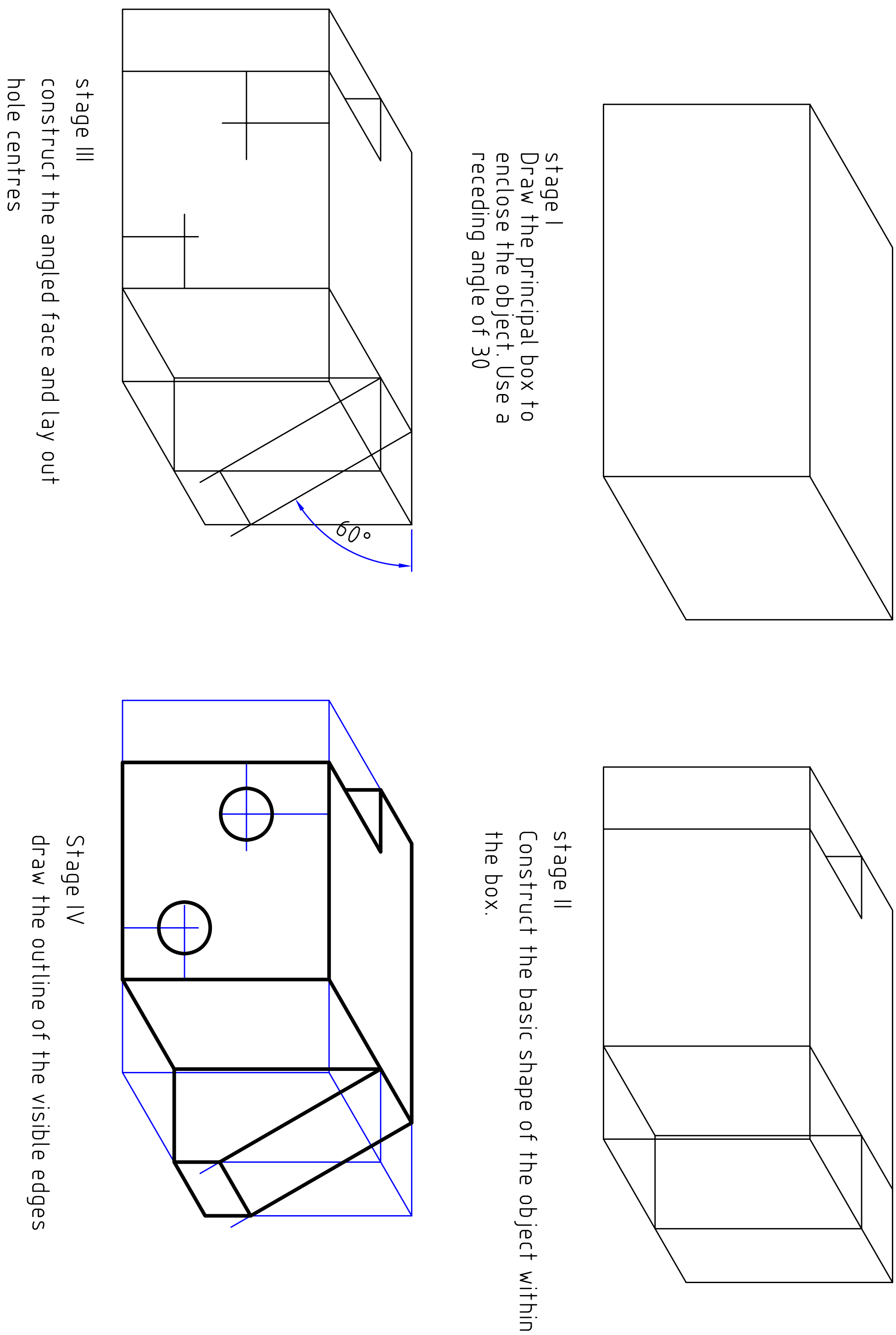


Figure 3.14: Procedures for oblique drawing

3.4 Perspective Projection

Perspective projection (central projection) is a form of pictorial representation of objects that closely approximates the view obtained by the human eye more than the other types of pictorial drawings. Perspective is of major importance to the architect, industrial engineer and civil engineer.

Perspective drawing involves four main elements

1. the observers eye
2. the object being viewed
3. the plane of projection
4. the projectors from the observers eye to all points on the object

The plane of projection is placed between the observer and the object and collective piercing points in the plane of projection of all the projectors produces the perspective.

Perspective drawings are normally classified according to the number of vanishing points required which in turn depends upon the position of the object with respect to the projection plane or picture plane.

- If the object is placed with one face parallel to the projection plane, only one vanishing point is required and the result is **one point perspective** or **parallel perspective**
- If the object is situated at an angle to the projection plane, but with the vertical edges parallel to the projection plane, two vanishing points are required and the result is a **two point perspective** or **angular perspective**. This is the most common type of perspective drawing.
- If the object is situated so that no system of parallel edges is parallel to the projection plane, three vanishing points are necessary and the result is a **three point perspective**

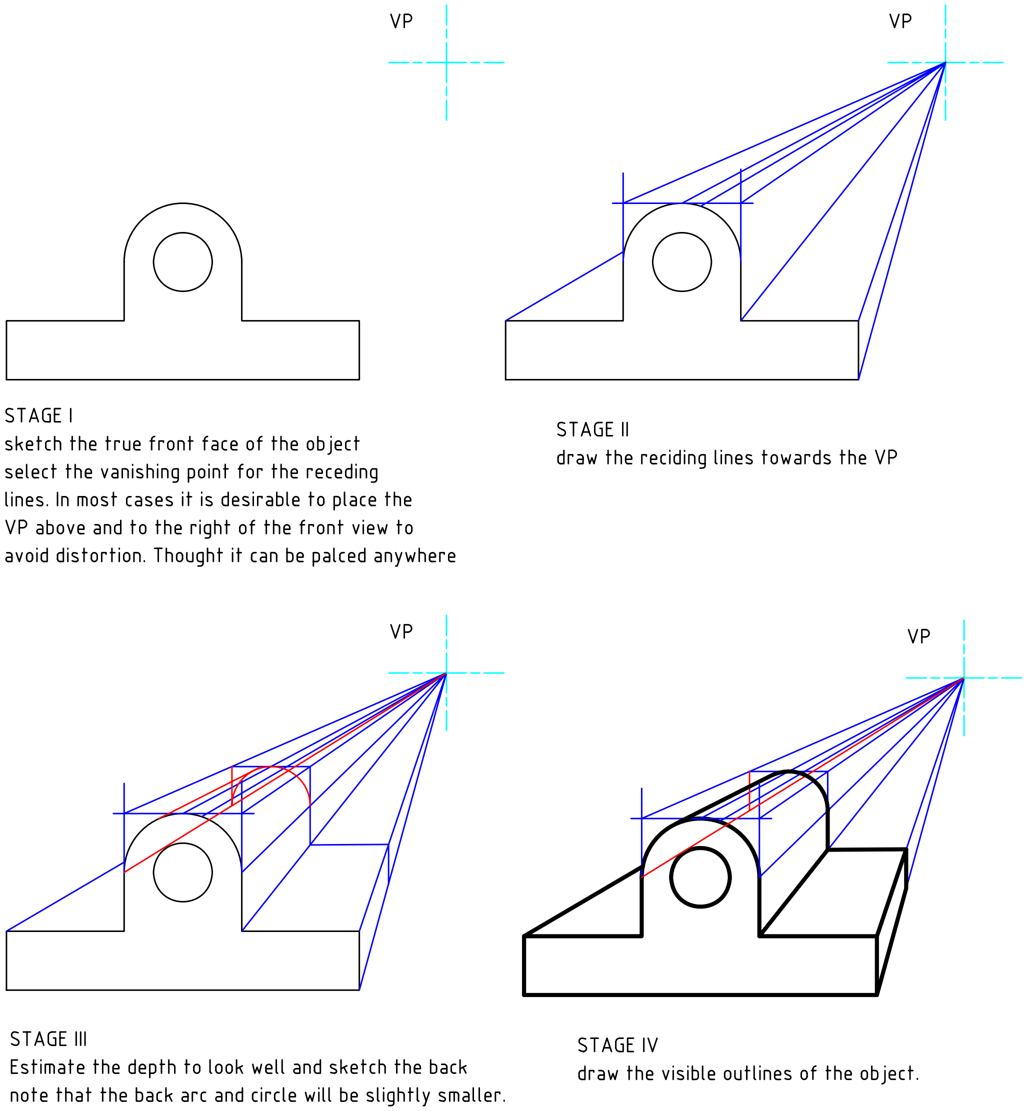


Figure 3.15: Procedures for one-point perspective drawing

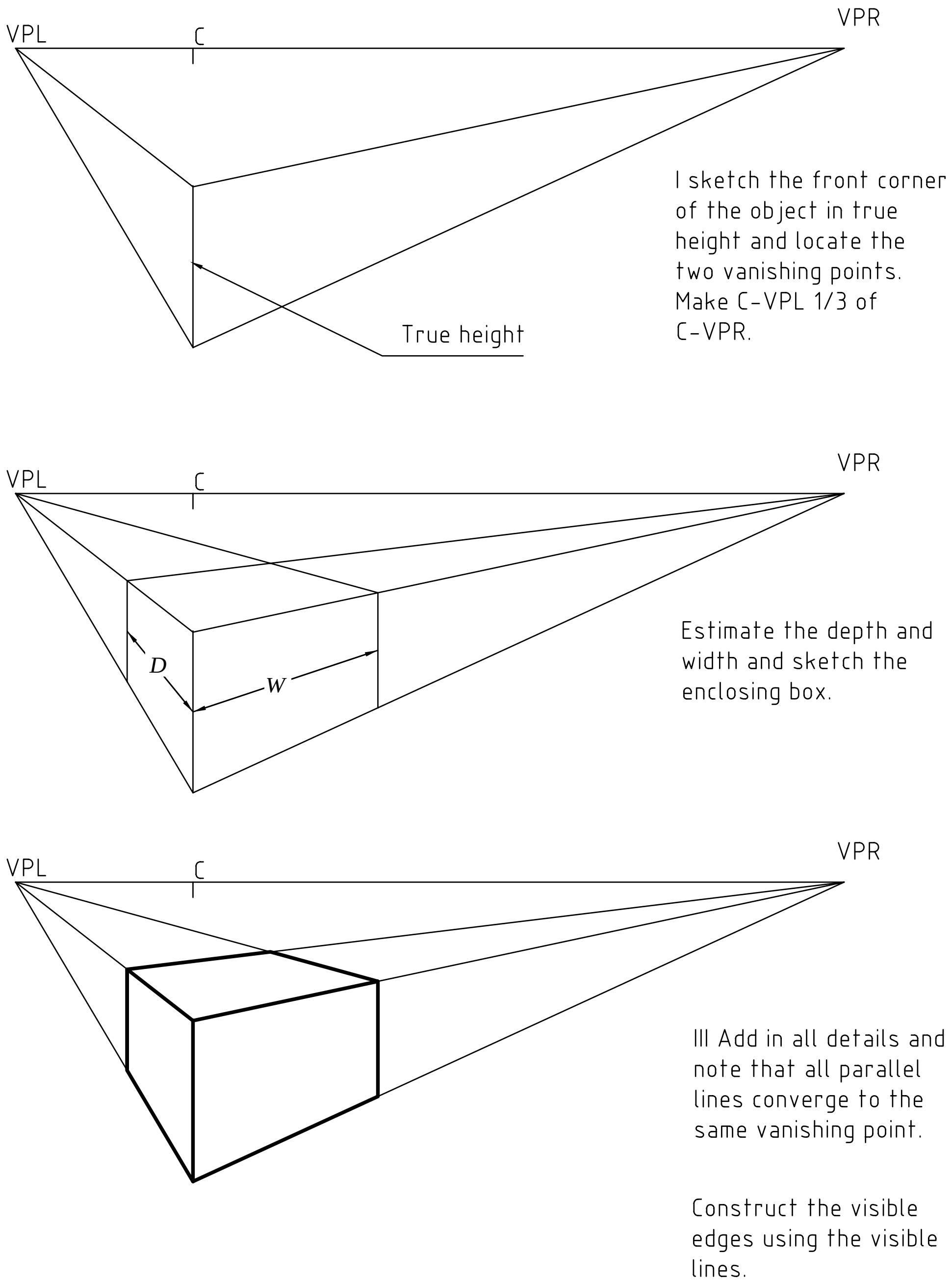


Figure 3.16: Procedures for two-point perspective drawing

Chapter 4

Loci

4.1 Introduction

The locus of a point is the path traced by that point when moving under given conditions. Many curves can be classified as loci; ellipse, parabola, hyperbola, hypocycloid, cycloid,trochoid,involute, etc. The study of loci is especially important in machine design where it is often necessary to determine the space requirements for a linkage or the envelope of a mechanism for the provision of effective guards.

4.2 Involute

An **involute** is the path traced by a point on a string as it unwinds from a line, a polygon, or a circle. The involute of a circle is the most important of these curves as it finds applications in the construction of involute gear teeth. The involute may be generated by points on a straight line which is rolled on a fixed circle. This can be done as follows:

- set off equal distances 0-1, 1-2, 2-3 ... along the circumference of the circle.
- draw a tangent at each division point
- set off along each tangent, the length of the corresponding circular arc.
- draw the required curve through the points set off on the several tangents A, B, C, D, ...

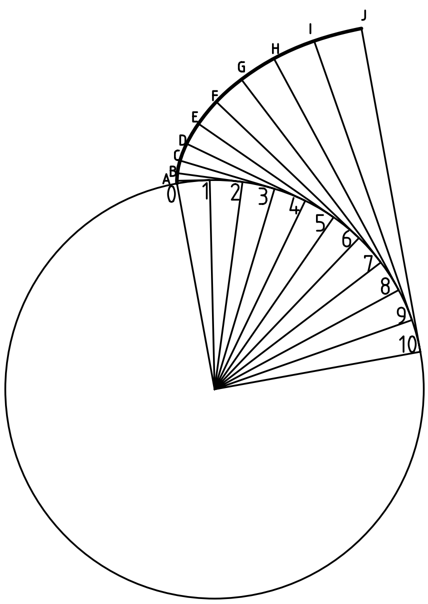


Figure 4.1: involute curve

4.3 Cycloids

A **cycloid** is the locus of points generated by a fixed point on the circumference of a circle as the circle rolls along a straight line. This curve can be obtained as follows:

- Given the generating circle and the straight line AB tangent to it, make the distances CA and CB equal to half the circumference of the circle.
- Divide these distances and each semicircle into 6 equal parts and number them consecutively as shown.
- Suppose the circle rolls to the left, point 1 on the circumference move to point 1' on the line, the center will be at D and the generating point 6 will be at the same distance from line AB as point 5 is when the circle is i the home position.
- To find point p draw a line through point 5 parallel to line AB and intersect it with an arc drawn from center D with radius equal to that of the circle.

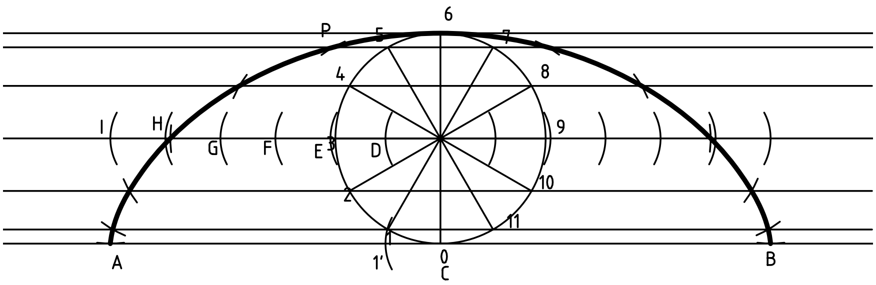


Figure 4.2: cycloidal curve

4.4 Trochoids

A trochoid is the locus of a point P at distance b from the center of a circle (of radius r) as the circle rolls along a straight line, where $b \neq r$

Ass 2(a)

Plot the locus of a point p shown in figure 4.3 as the circle rolls along line AB for one complete revolution of the circle. Figure 4.4 shows the locus in ass 2(a).

Trochoidal curves find application in the construction of the fillet gear tooth profiles.

4.5 Parabola

A parabola is the curve traced by a set of points in a plane, that are equidistant from a point (focus) and a line (directrix). The parabola can be developed in various ways:

i. Given the focus and directrix AB, draw a line perpendicular to AB to cut AB at C. Divide this line into a number of equal parts. Draw lines parallel to AB through the

The intersection of like-numbered lines are points on the parabola. A perpendicular bisector of a line OP tangent to the parabola and intersecting the axis, intersects the axis at the focus.

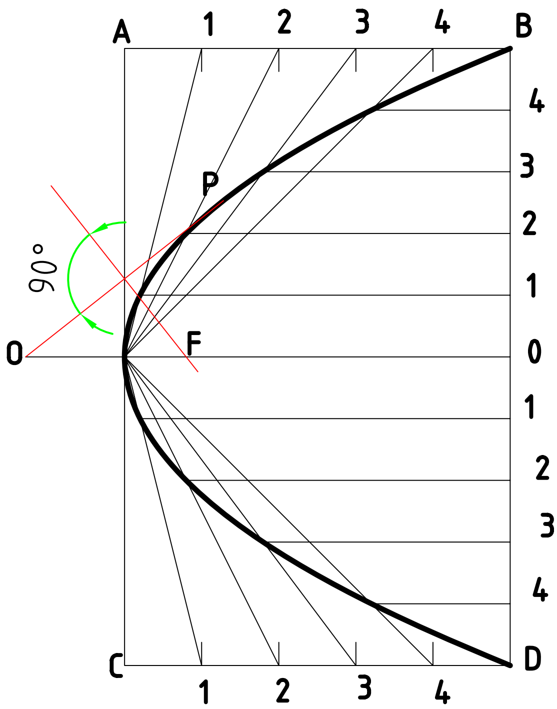


Figure 4.6: parabola construction given rectangle

Practical Applications:

- The parabola is used for reflecting surfaces for light and sound
- Curves of cables for suspension bridges
- to show bending moment at any point on a uniformly loaded beam
- To obtain the displacement diagram for uniformly accelerating motion.

4.6 Ellipse

An ellipse is the curve generated by a point moving so that the sum of its distances from two points (the foci) is constant and equal to the major axis. Ellipse construction:

1. Given the major and minor axis, draw concentric circles with the major and minor diameters. Divide the circles into a number of equal sectors. Draw horizontal lines from the division points on the minor circle to intersect a vertical line from a corresponding division point on the major circle. The point of intersection is a point on the ellipse. To find the foci F1 and F2, strike arcs with radius equal to half the major axis and with centers at the ends of the minor axis.

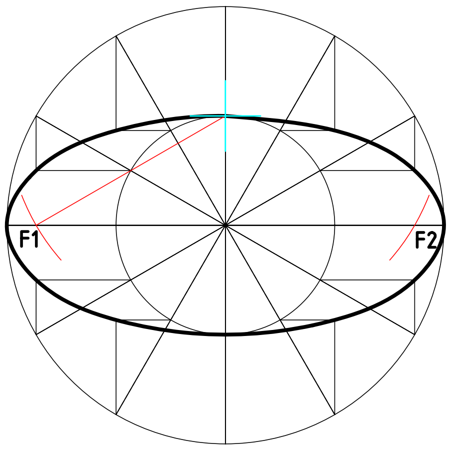


Figure 4.7: ellipse construction given the major and minor diameters

2. Given major and minor axis, or the conjugate diameters AB and CD, draw a rectangle or parallelogram with sides parallel to the axes respectively. Divide AO and AJ into the same number of equal parts and draw lines through these points. The intersection of like-numbered lines will be points on the ellipse.

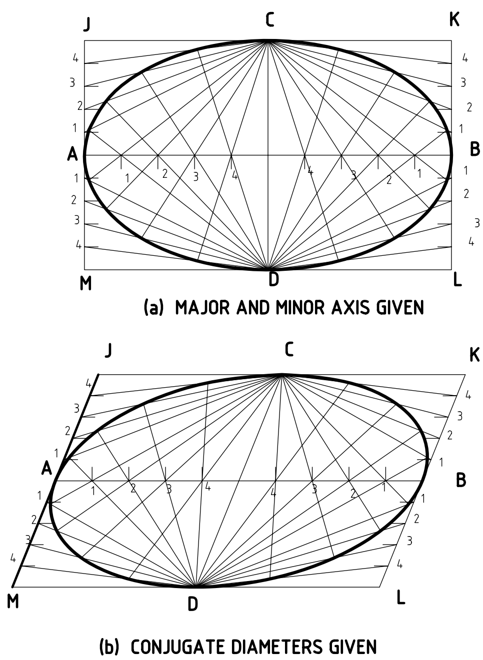


Figure 4.8: ellipse construction given major or minor diameters

4.7 Locus of a point on a mechanism

Mechanism are used for power transmission in machines. It is sometimes necessary to plot the locus of a point on a mechanism for construction of suitable guards or for motion analysis The usual method of drawing the locus of a point on a mechanism is to construct the outline or or skeleton drawings of the mechanism in a number of positions, plotting the point in each position and then drawing a smooth curve (the locus) through the points obtained.

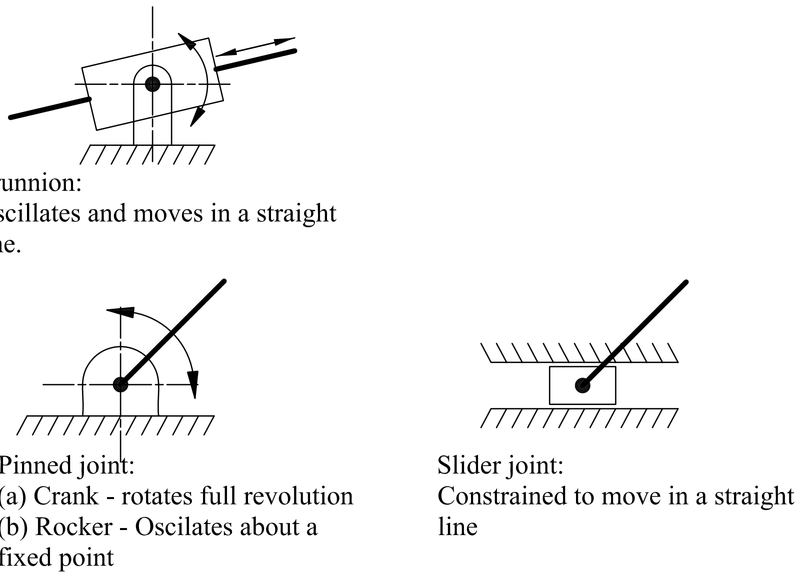


Figure 4.9: Common joints in mechanisms

Example 1

Figure 4.10 shows a slider crank mechanism. Plot the locus of point C for one complete revolution of the crank OA.

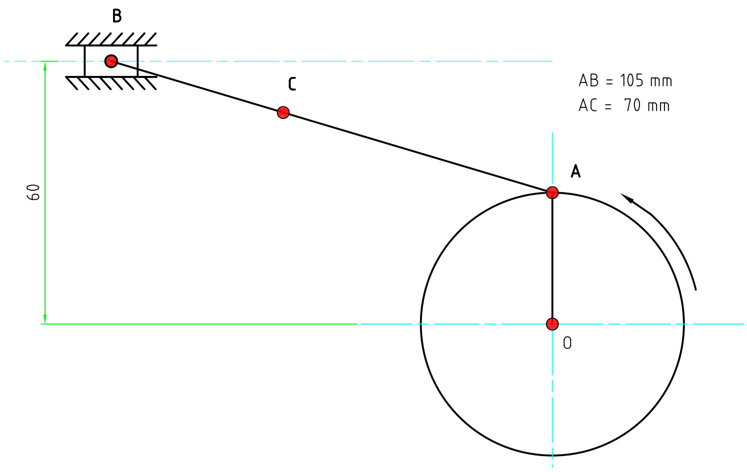


Figure 4.10: Slider crank mechanism

Chapter 5

Cam profiles

5.1 Introduction

Cams are used to convert the input motion (usually rotary motion) to reciprocating motion by causing the follower to rise and fall in a predetermined manner. As the cam turns, in a circular motion, the cam follower traces out the surface of the cam, transmitting its motion into the required mechanism. Figure 5.1 shows a simple cam and follower used in a combustion engine.

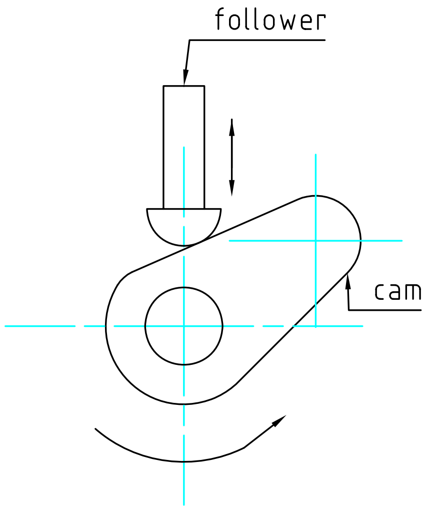


Figure 5.1: Cam and follower

Typical example of their usage include:

- Textile machinery
- Internal combustion engine
- Control systems and devices
- Food processing machines
- Toys

In all cam systems it is important that the follower is always in contact and following the motion of the cam. This is achieved in a number of ways including the following.

- Gravity
- Using a mechanical constraint system i.e groove
- Using a spring force
- Using a pneumatic or hydraulic force

The problem of the designer is to construct the cam profile necessary to obtain the desired motion of the follower.

5.2 Displacement diagrams

Since the motion of the follower is of primary importance, its rate of speed and its various positions should be carefully planned in a displacement diagram before the cam profile is constructed.

A displacement diagram is a curve showing the displacement of the follower as ordinates erected on a baseline that represents one revolution of the cam. The follower displacement should be drawn to scale but any convenient length can be used to represent 360^o of the cam rotation.

Types of follower motion:

- **Uniform velocity**; equal displacements of the follower during equal periods of time (equal change of cam angular displacement)

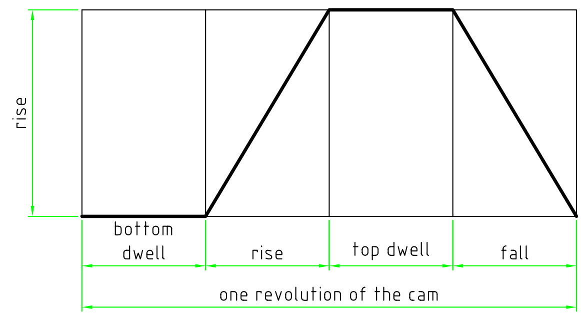


Figure 5.2: Uniform velocity displacement diagram

  The main disadvantage of this type of motion is that it produces abrupt changes of movement in the follower at the beginning and end of both rise and fall.

- **Simple harmonic motion**; the displacement diagram is a sine curve. This motion provides the smoothest change of motion in the follower.

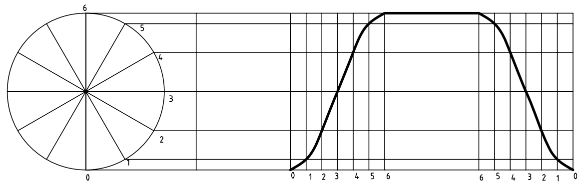


Figure 5.3: Uniform velocity displacement diagram

- **Uniform acceleration and retardation**; this displacement diagram is parabolic. It gives a uniform rate of accelaration from the start to the midpoint and a similar uniform rate of retardation from the midpoint to the end of the movement.

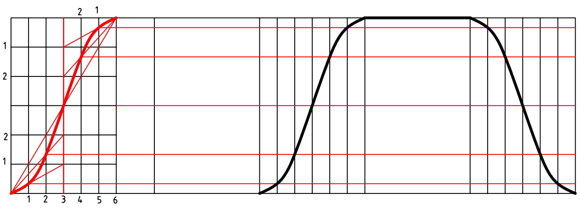


Figure 5.4: Uniform velocity displacement diagram

Cams are made in a variety of forms,including:

- A rotating disk or plate with the radial required profile;
- A reciprocating wedge of the required shape.
- A cylindrical barrel cam (drum) with a follower groove cut in the diameter
- A cylinder with the required profile cut in the end (end cam);

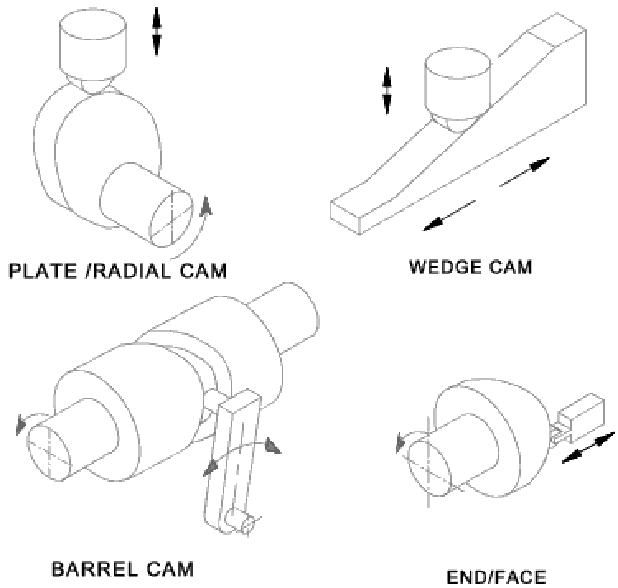


Figure 5.5: Types of cams

Cam followers can either be reciprocating or pivoting. There are various ways of transferring the motion from the cam to the follower which include:

- knife edge
- flat face
- roller
- curved shoe or spherical.

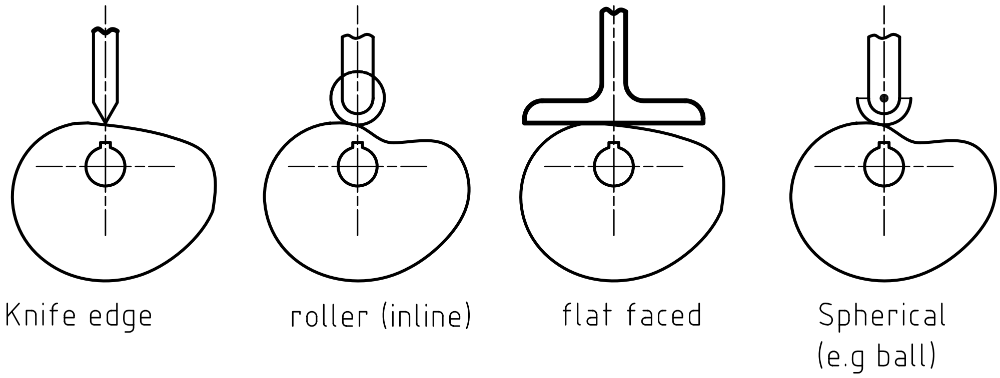


Figure 5.6: Cam follower types

The cam follower can be either offset or in line with the cam center of rotation as shown in figure 5.7.

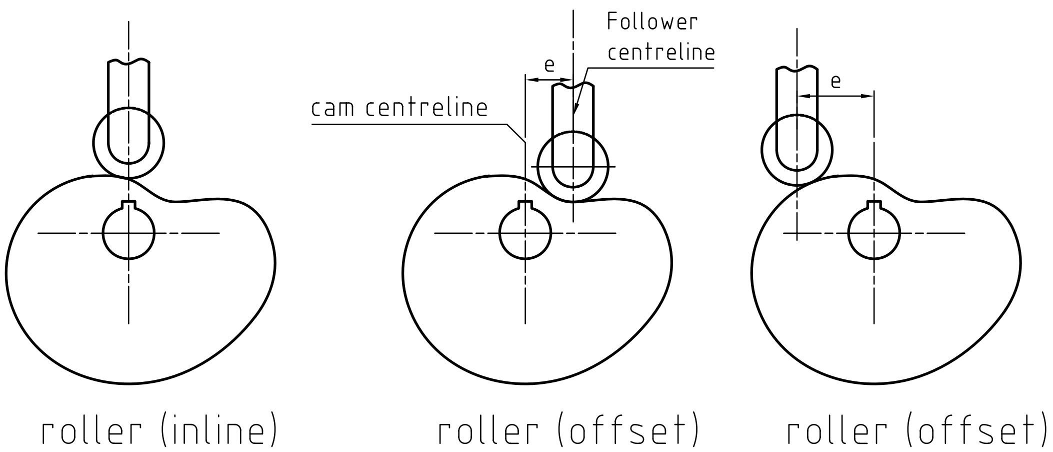


Figure 5.7: Cam follower types

5.3 Drawing a cam profile to a given data

The first stage in creation of a cam system is to create the displacement diagram.

- Draw the two centerlines of the cam to locate its center of rotation.
- Draw the maximum and minimum diameter circles about the cam center. Divide these radially into sectors to correspond with the displacement divisions.
- Strike arcs to cut the appropriate radial division
- Draw a smooth curve through the intersection points
- For roller ended followers, the baseline of the displacement diagram is set in line with the center line of the roller and the cam curve is drawn tangential to the series of plotted roller circles.

Exercise

1. Draw a cam profile given the following data:
    - In-line knife edge follower
    - 50 mm minimum diameter
    - 70 mm rise and fall with Uniform velocity
    - $0^o - 90^o$ bottom dwell, $90^o - 180^o$ rise, $180^o - 270^o$ top dwell, $270^o - 360^o$ fall
    - clockwise rotation
2. Draw a cam profile given the data below:
    - In-line roller follower $\phi 12$ mm
    - 50 mm minimum diameter
    - 60 mm rise and fall with simple harmonic motion
    - $0^o - 90^o$ bottom dwell, $90^o - 180^o$ rise, $180^o - 270^o$ top dwell, $270^o - 360^o$ fall
    - clockwise rotation
3. Draw the cam profile which imparts the following vertical motion to a flat follower acting along the vertical centerline of the cam:
    - $0^o - 90^o$ rise 28 mm with uniform acceleration
    - $90^o - 180^o$ rise 21 mm with uniform retardation
    - $180^o - 210^o$ dwell
    - $210^o - 360^o$ fall 49 mm with simple harmonic motion
    - least distance from follower to cam center 50 mm
    - cam shaft diameter 20 mm
    - Clockwise rotation of the cam

Chapter 6

Gear Teeth Profiles

6.1 Introduction

Gears are machine components used to transmit motion or power from one machine part to another. They are the most common power transmitting components due to the following reasons:

- They provide a positive drive
- They provide a constant transmission ratio
- Compactness
- Ease of production
- Allow interchangeability

Gears may be classified according to the position of the shafts they connect:

1. Parallel axis shafts - spur gears, helical gears, herringbone gears
2. intersecting shafts - bevel gears, hypoid gears, worm and wheel.

6.1.1 Spur Gears

Spur gears have their teeth cut parallel to the axis of the gear. If two cylinders are positioned as shown in figure 6.1 and some pressure applied between them so as to maintain contact, then any rotating motion in one cylinder will be transmitted to the other by friction. However, a slight loading applied to the driven cylinder will cause it to slip. To overcome this slipping, matching teeth are cut in both cylinders transforming them into a pair of meshing gear wheels.

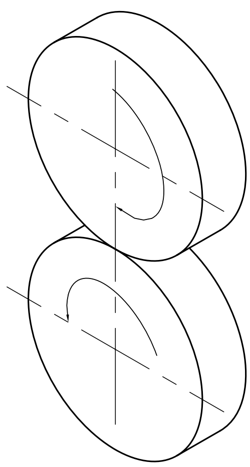


Figure 6.1: Gear teeth nomenclature

Involute Gear Terminology

The most common tooth form for the gear tooth flank is the involute, and when it is made in this form, the gears are known as involute gears.

- **Pitch Circle** is an imaginary circle corresponding to the circumference of the friction cylinders from which the gear is derived. Its diameter is designated as D. Given the module, m and the number of teeth on a gear wheel, N, the pitch diameter is obtained by the relation:

$$D = m \times N \tag{6.1}$$

- **Base circle** the imaginary circle from which the involute profile is developed.

- **Circular pitch, p** is the distance measured along the pitch circle from a point on one tooth to a corresponding point on the adjacent tooth. It includes one tooth and one space.

$$p = \pi \frac{D}{N} \tag{6.2}$$

  where N is the number of teeth on the gear

- **Module, m** is the pitch diameter in mm divided by the number of teeth on the gear wheel.

$$m = \frac{D}{N} \tag{6.3}$$

- **Diametral pitch, P** is the ratio of the number of teeth divided by the pitch diameter in inches

$$P = \frac{N}{D} \tag{6.4}$$

- **Chordal thickness, t** is the thickness of a tooth measured along a chord of the pitch circle

$$t = Dsin\left(\frac{90^o}{N}\right) \tag{6.5}$$

- **Addendum, a** is the radial distance from the pitch circle to the tip of the tooth.

- **Dedendum, b** is the radial distance from the pitch circle to the root of the gear tooth.

$$b = a + c \tag{6.6}$$

- **Pressure angle** ϕ is the angle that determines the direction of pressure between contacting gear teeth. It also determines the size of the base circle.

- **Clearance, c** is the radial distance between the tip of a tooth and the root of a mating tooth space.

- **Center Distance, C** The distance between the centers of two mating gears.

$$C = \frac{D_g + D_p}{2} \tag{6.7}$$

  The subscripts g and p refer to the gear and pinion respectively.

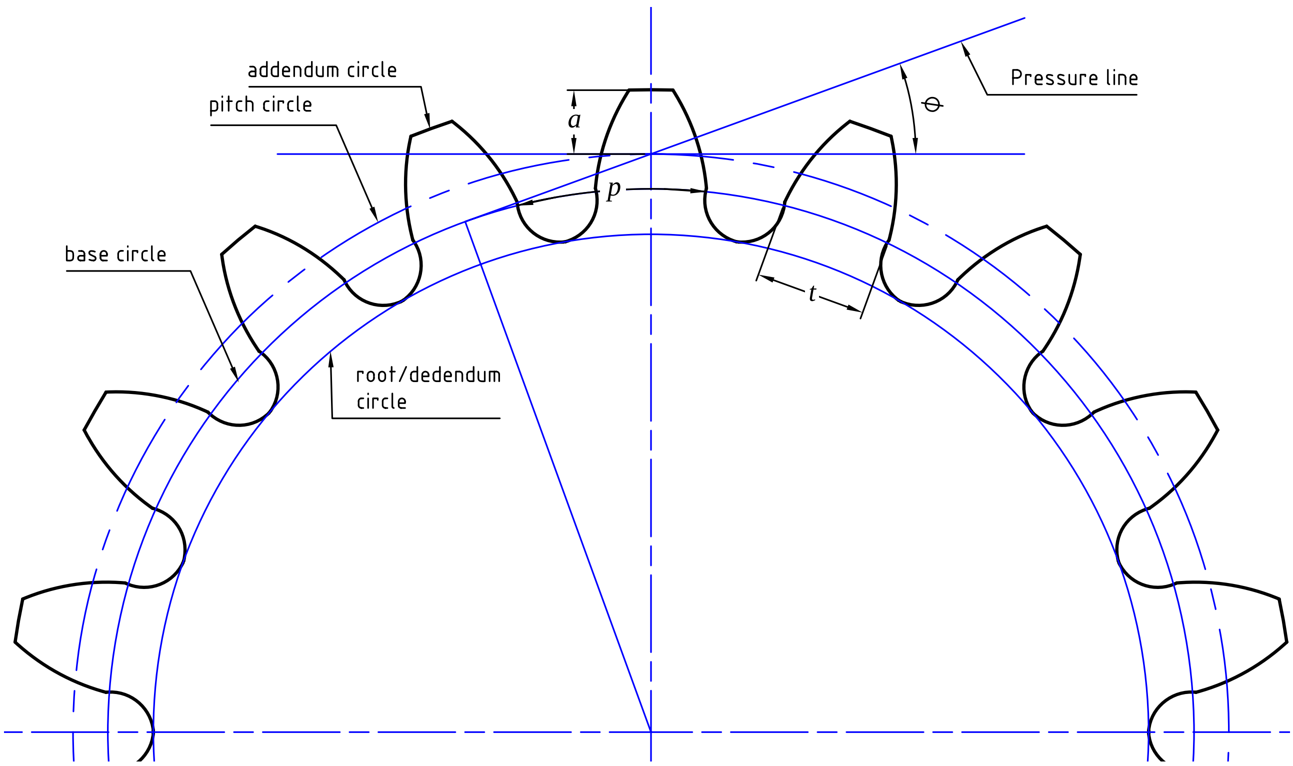


Figure 6.2: Gear teeth nomenclature

Metric gear specification usually give the number of teeth, the module and the pressure angle. Imperial gear specification usually give the number of teeth, the diametral pitch and the pressure angle.

The pitch circle is always drawn in thin long chain line because it is a center line. It is common practice to show two teeth of one wheel meshing with three teeth of the other wheel, the remainder of both wheels being left in blank outline only. Other relevant data should be given in tabular form.

6.1.2 To Draw an Involute Gear Tooth

1. Draw the vertical center line of the gears (This passes through the centers of both gears)
2. Draw the horizontal line through the pitch point (a distance $\frac{D}{2}$ from the center of the gear)
3. Draw the line of action (pressure line) through the pitch point at an angle ϕ to the horizontal
4. Draw the base circle tangential to the pressure line. Draw the pitch circle. Calculate the addendum, dedendum and draw the addendum circle and the root circle
5. Set out and draw the involute on the base circle.
6. Copy this involute profile on to a tracing paper including a section of the base circle to aid in correct aligning of the tracing. Set the tracing with the gear profile passing through the pitch point and running from the base circle to the addendum circle.

7. From the pitch point step off along the pitch circle, the chordal thickness of the tooth. Turn the tracing over and draw the other half of the tooth profile. Join the profile from the base circle to the root circle using radial lines and include a fillet of radius $0.1p$ to round off the corner between the tooth flank and the dedendum circle. Line in the Tip of the tooth along the addendum circle and the root of the tooth space along the dedendum circle to complete the tooth.
8. Step off the chordal thickness and draw three more teeth.
9. Repeat the procedure to the mating gear and draw at least two more teeth. Figure 6.3 shows the completed gear teeth.

Given data	Derived data
N = 18 teeth m = 10 mm c = 0.25m ϕ = 20°	pitch diameter = 180mm outer diameter = 200 mm root diamterer = 155 mm chordal thickness = 15.69 mm

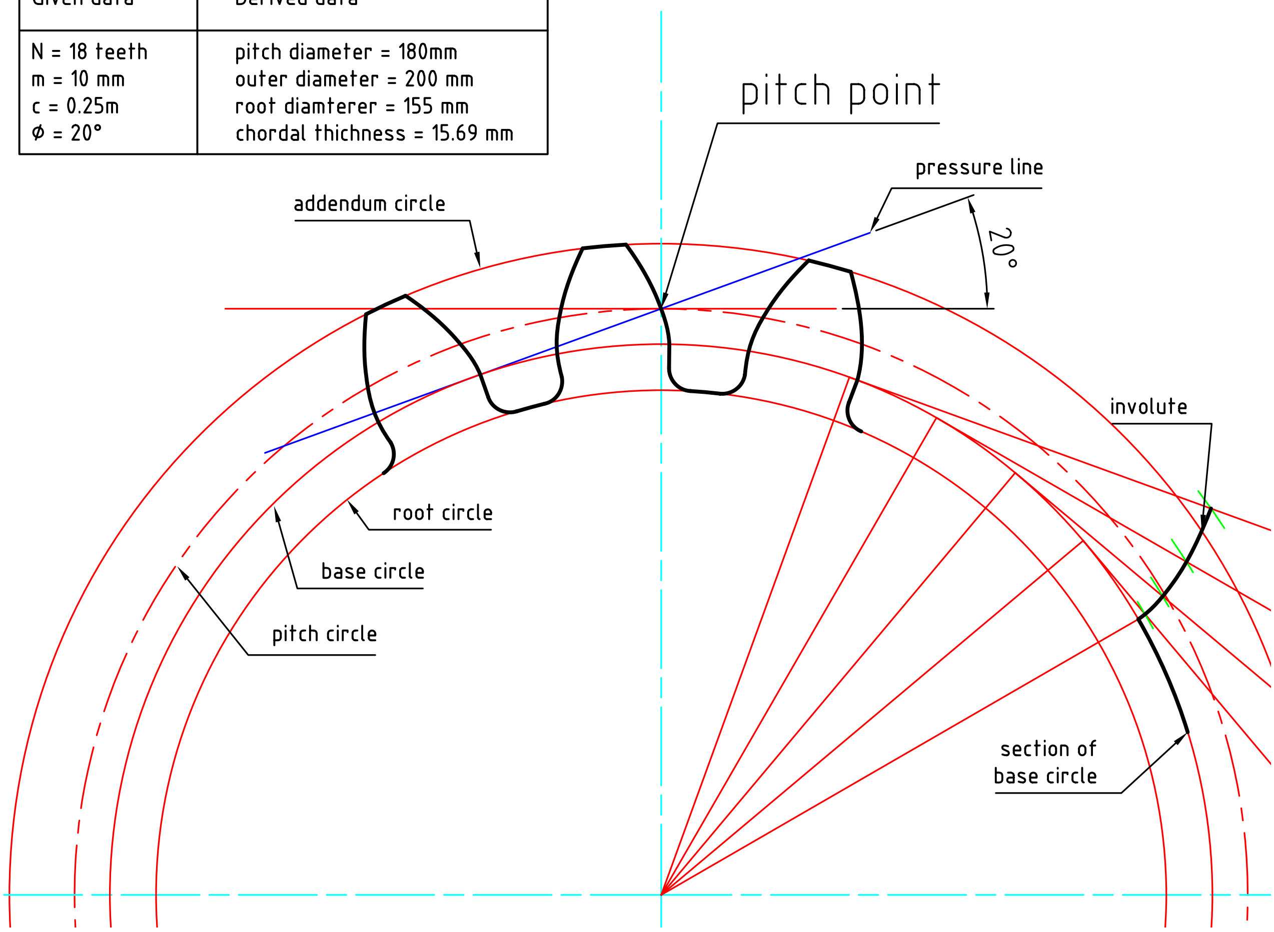


Figure 6.3: Gear teeth drawing

6.1.3 Fillet Construction

1. Calculate the fillet radius (0.1p).
2. Draw radial lines connecting the involute profile at the base. With center at the point of intersection of the radial line and the root circle and with the fillet radius (r), strike arcs A and B. With centers at A and B, and radius r, strike arcs to obtain the center of the fillet arc.

3. Draw the fillet arc using a visible line, Figure 6.4.

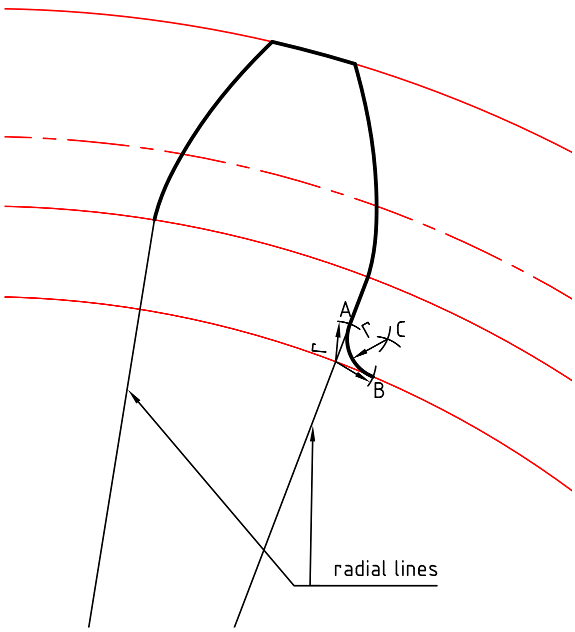


Figure 6.4: Construction of the fillet arc

6.1.4 To draw the teeth of a standard gear by approximate arc method

1. Lay off the pitch circle, the root circle and the addendum circle
2. Starting with the pitch point, divide the pitch circle into distances equal to the circular thickness of the tooth
3. Draw the pressure line through the pitch point
4. Draw the base circle, tangential to the pressure line.
5. With the compass set to a radius equal to the distance from the pitch point to the end of the pressure line on the base circle (radius of curvature), strike arcs through the division points on the pitch circle, with the center on the base circle.
6. Darken the arcs for the tops of the teeth and bottom of the spaces and add tooth fillets to complete the gear teeth as shown in figure 6.5.

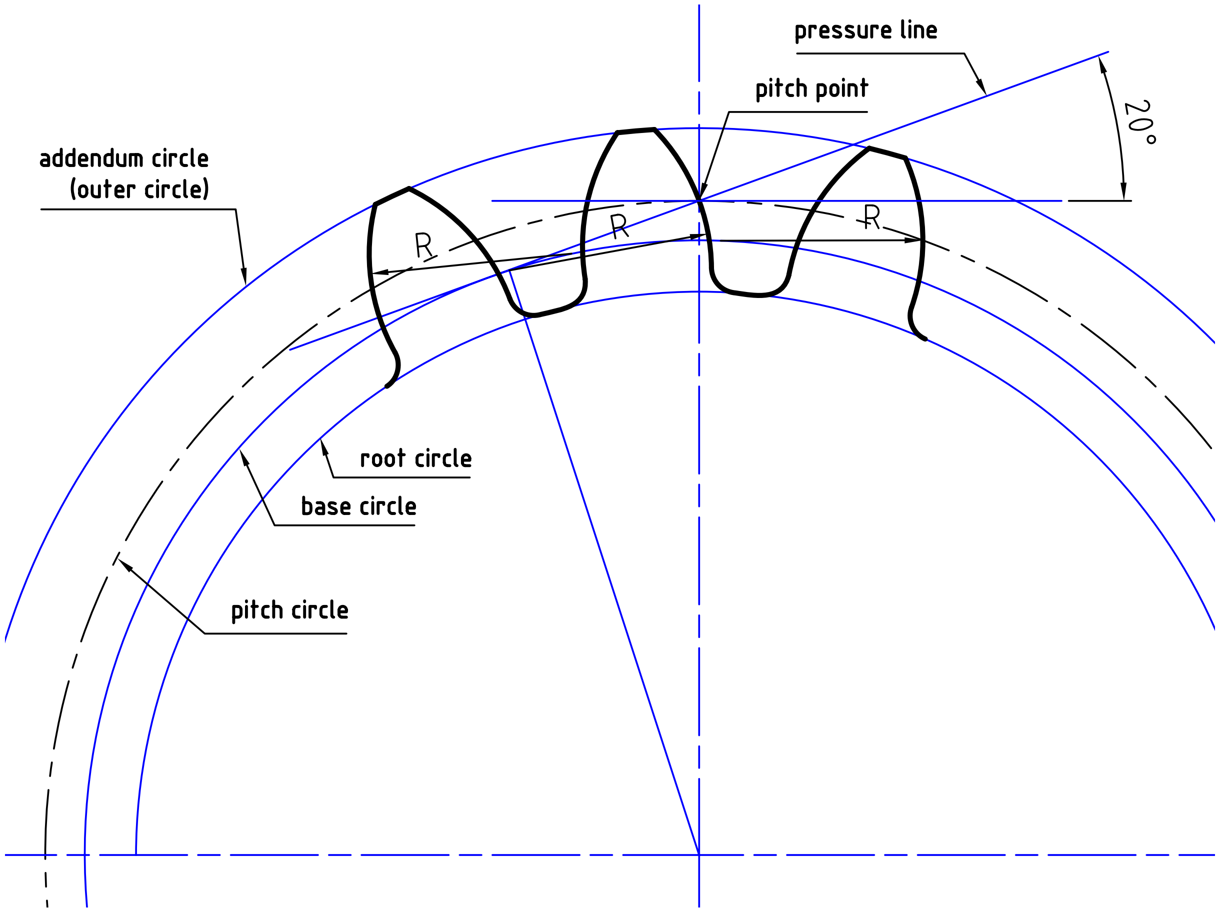


Figure 6.5: Gear teeth drawing by approximate arc method

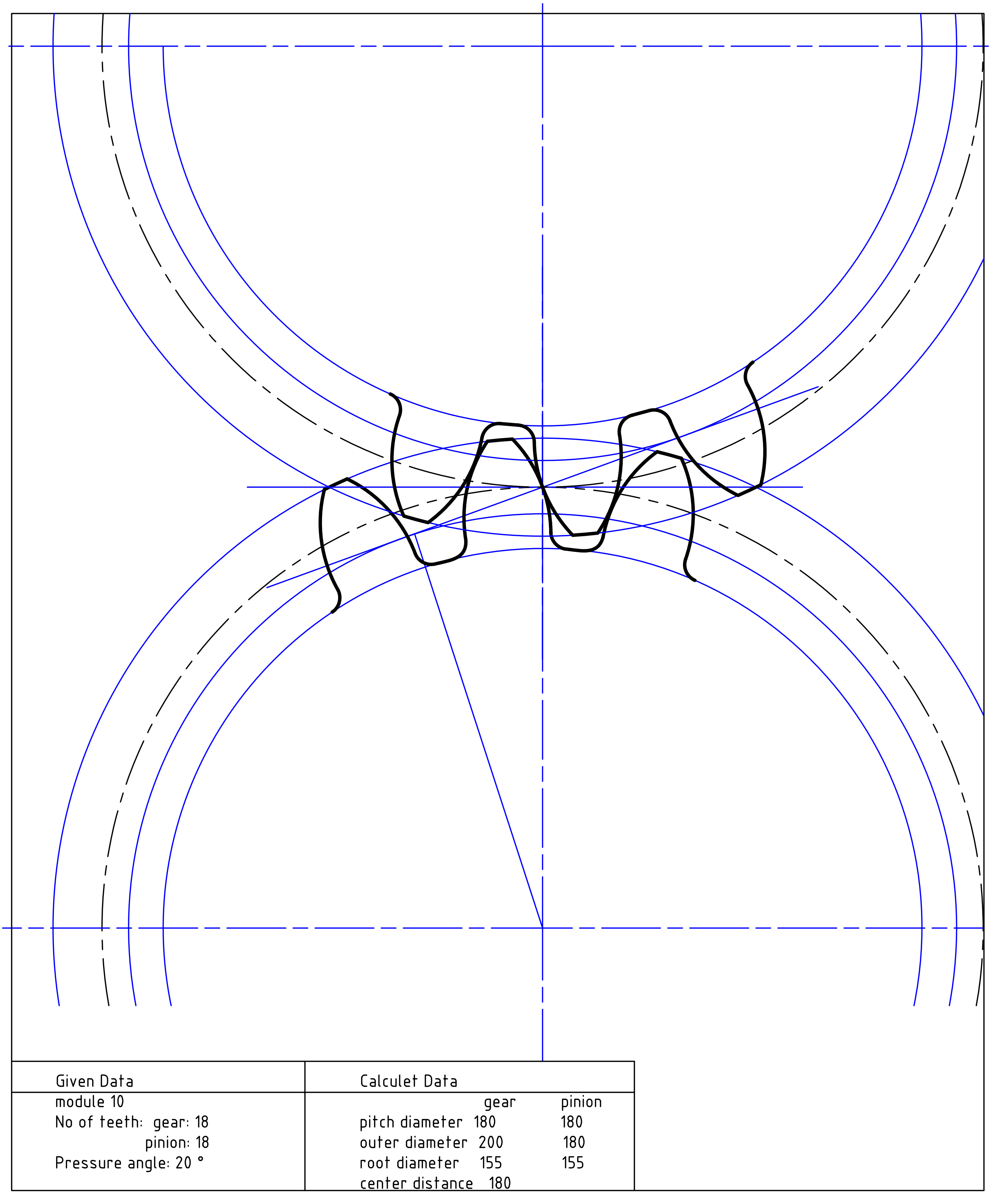


Figure 6.6: Meshing pair of gears

Chapter 7

Screw Threads

7.1 Introduction

A screw thread is a helical groove which is cut, rolled, or sometimes cast on a cylinder or cylindrical hole. The threads are parallel to each other with those on the cylinder (screw) being external, and those in the hole (nut) being internal. Tapered threads are formed on a cone or in a conical hole. The form of the groove varies with different threads depending on the use. Threads may be right- or left-handed and single or multi-start. Screw threads have three main applications:

- Assembly or fastening parts together.
- To adjust the position of parts.
- Power transmission purposes.

7.1.1 Screw Thread Terms

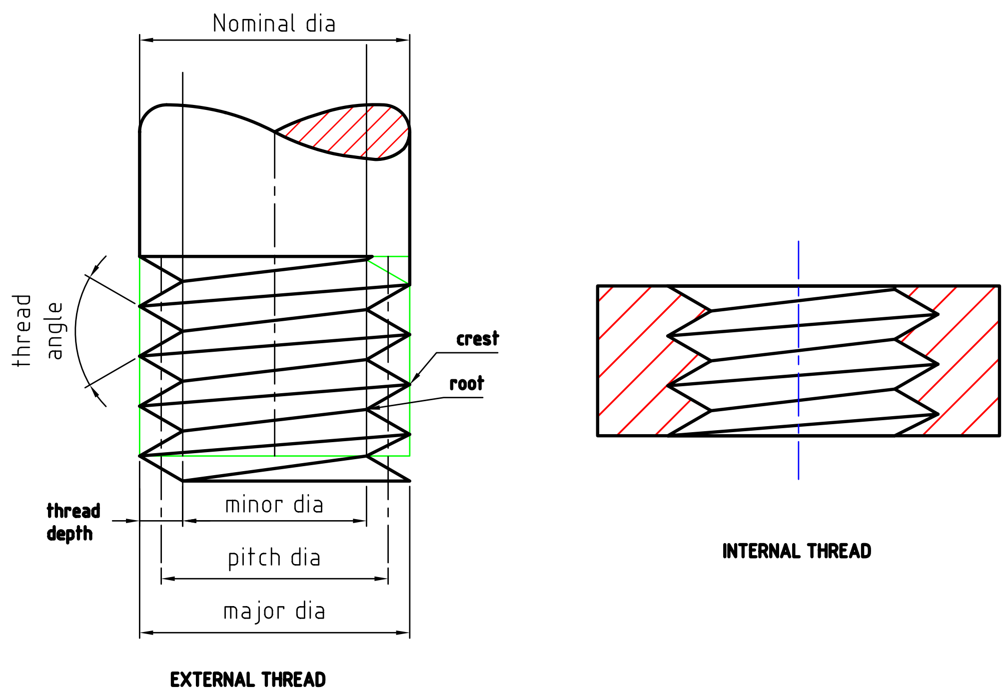


Figure 7.1: Screw thread terminology

Figure 7.1 shows the primary terms useful in defining screw threads. These terms are:

- **External thread (screw)**; A thread on the external surface of a cylinder.
- **Internal thread (nut)**; A thread on the internal surface of a cylinder.
- **Major Diameter**; The largest diameter of a screw thread.

- **Minor Diameter**; The smallest diameter of a screw thread.
- **Pitch diameter**; The diameter of an imaginary cylinder, the surface of which cuts the thread forms where the width of the thread and groove are equal.
- **Crest**; The edge or surface that joins the sides of adjacent thread forms and is farthest from the cylinder axis
- **Root**; The edge or surface that joins the sides of adjacent thread forms and coincides with the cylinder from which the thread projects.
- **Flanks**; The straight sides which connect the crest and the root.
- **Pitch**; The distance between corresponding points on adjacent thread forms measured parallel to the axis
- **Lead**; The distance a threaded part moves axially with respect to a fixed mating part, in one complete revolution.
- **Form**; The profile (cross-section) of the thread.

7.1.2 Thread Forms

"Thread Form" describes the shape of the thread if one cut a thread form in half along its axis and then looked at the thread configurations. Different thread forms have different uses:

i. **Metric Thread** The ISO metric screw threads are the worlds most commonly used type of general purpose screw threads. The design principles of this thread form are defined in the standards ISO 68-1.

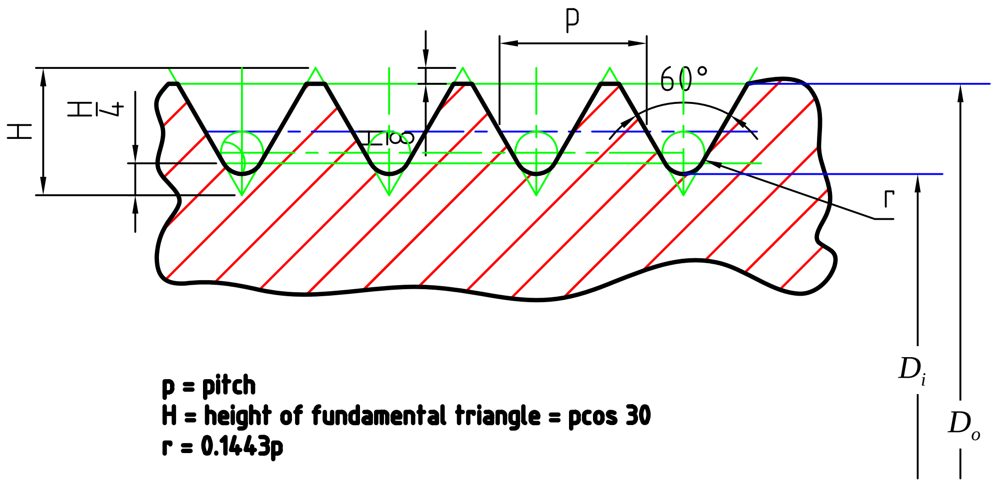


Figure 7.2: External ISO metric thread terms

Designation

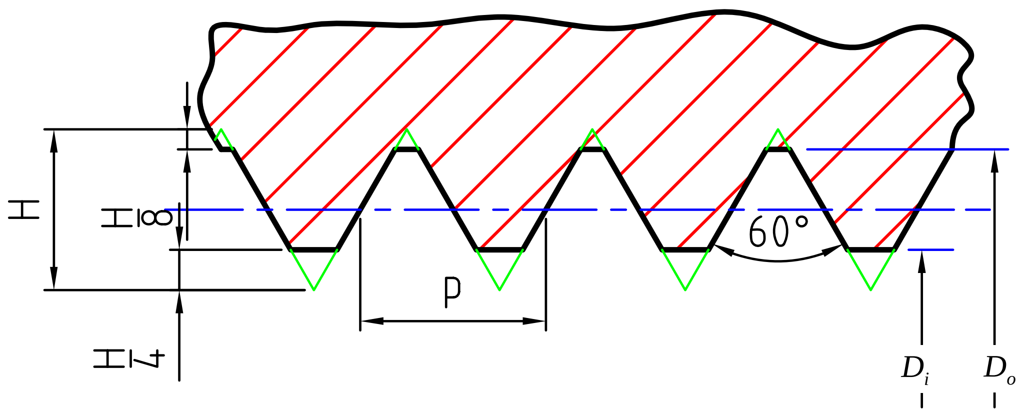


Figure 7.3: Internal ISO metric thread

A metric ISO screw thread is designated by the letter M followed by the value of the nominal diameter D and the pitch, p, both expressed in mm and separated by a times sign e.g. $M8 \times 1.5$, signifies that the thread has a nominal diameter of 8 mm and a pitch of 1.5 mm. Applications include assembly and adjustment purposes. Other types of threads for general purpose applications include:

- Unified thread standard (UTS)- commonly used in the USA and Canada.
- British Standard Whitworth - British standard fine threads and British standard cycle

ii. **Square thread** This type of thread has its flanks normal to the axis thus making it the most ideal for power transmission purposes. However, the right angle flanks cause machining difficulties when the thread is cut on the lathe.

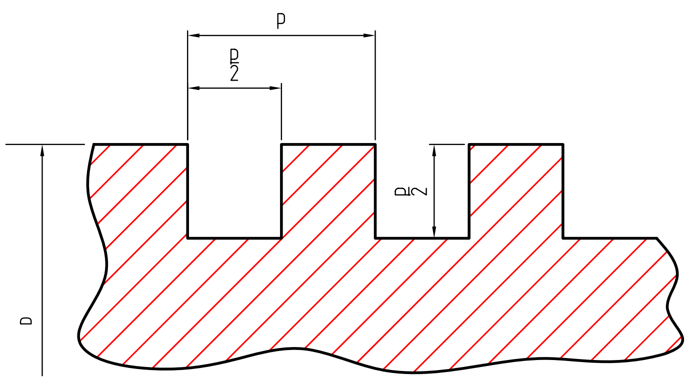


Figure 7.4: Square thread

iii. **ACME thread** This type is an adaptation of the square thread, with the flanks having a thread angle of 29^o. It is also used for power transmission applications where the nut has to be disengaged from the screw.

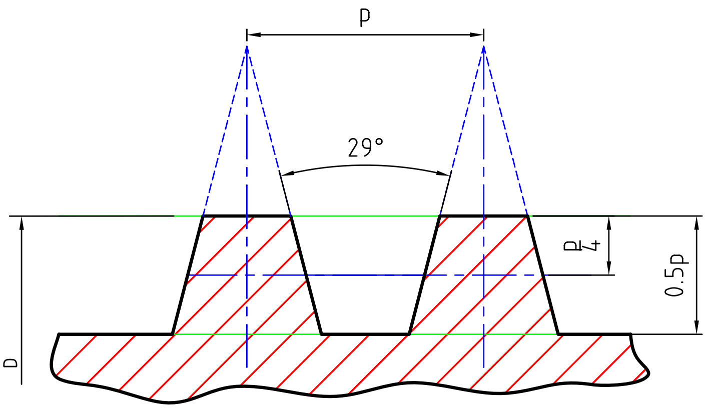


Figure 7.5: ACME thread

iv. **Buttress thread** The front face against which the load is applied is inclined at 7^o to the vertical. The thread is used to transmit power in one direction only, indicated by the arrow on the diagram.

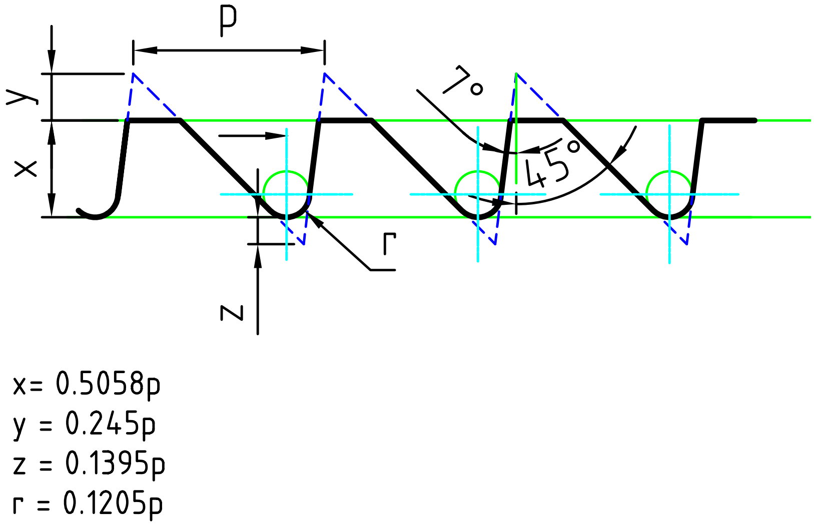


Figure 7.6: Buttress thread

7.1.3 Conventional Representation of Screw Threads

Since projection of screw threads is tedious and takes considerable time, threads are shown conventionally on engineering drawings.

On the longitudinal view of an external thread, the major diameter is shown by a pair of thick lines and the minor diameter by a pair of thin lines. The end of a thread is shown by a thick line. The end of the full thread is drawn as a thick line. The thread run out (incompletely formed threads) are represented by thin lines at 30^o to the major diameter. On the circular view, the major diameter appears as a complete thick circle and the minor diameter as a thin circle with a gap as shown in figure 7.7. For internal threads in section the minor diameter drilling is drawn

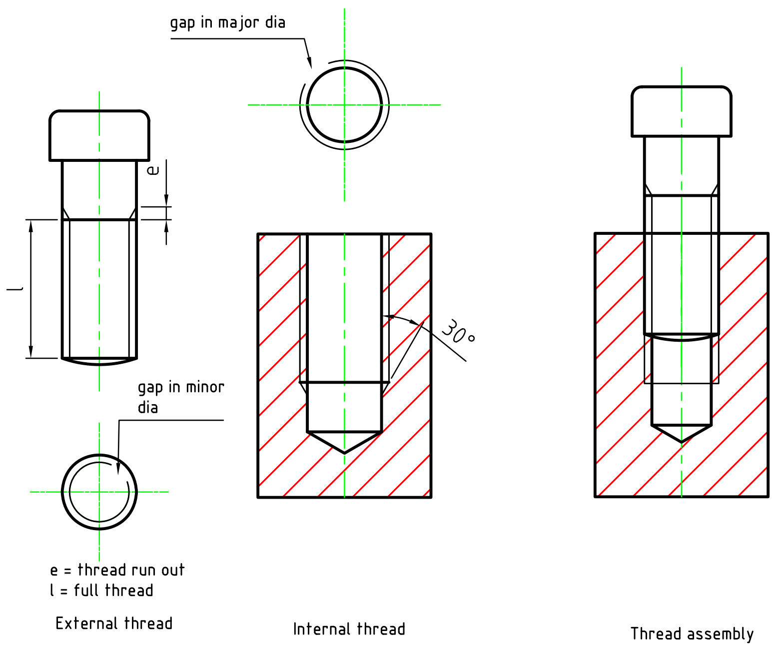


Figure 7.7: Conventional representation of crew threads

in thick lines. The major diameter and thread run outs are shown by thin lines. The hatching crosses the major diameter and terminates on the minor diameter. If an internal thread is shown in hidden detail, all lines are thin short dashes.

7.2 Threaded Fasteners

Most engineering products are composed of separate parts held together by some means of fastening. Threaded have advantage over permanent methods (riveting and welding) in that they are easily disassembled. Threaded fasteners have descriptive names with five types being the most common;

1. **Bolt**; A bolt, has an integral head on one end and a thread on the other end and is passed through clearance holes in two parts and draws them together by means of a nut screwed on the threaded end. It comes in a variety of head forms, the most common being the hexagonal head and the square head. On the sectional view, the nut and bolt are not sectioned even though the section plane passes through them. If the details being joined are of a soft material, a plain washer may be placed under the nut and sometimes under the bolt head as well to prevent damage when the nut is tightened.

2. **Stud**; A stud is a rod threaded on each end. The fastener passes through a clearance hole in one part and screws into a tapped hole in the other. A nut then draws the parts together. The stud is used when through bolts are not suitable for parts that must be removed frequently such as a cylinder head. They are also used in situations where there is insufficient space on one side of the assembly for bolt heads or nuts

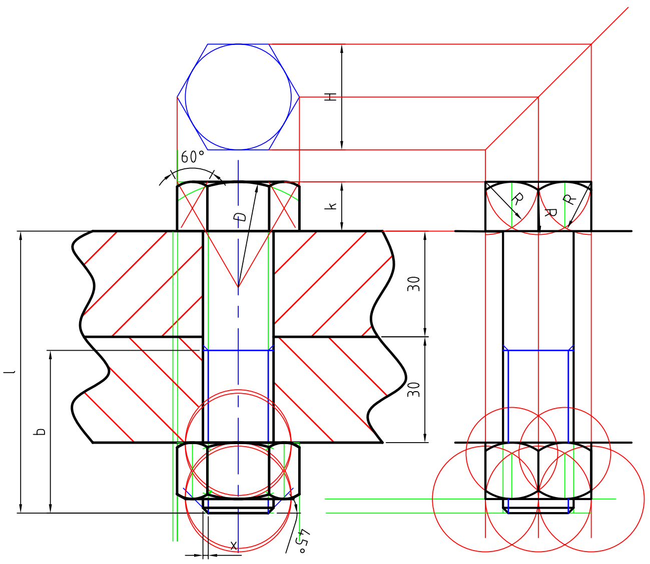


Figure 7.8: Hexagonal bolt and nut assembly

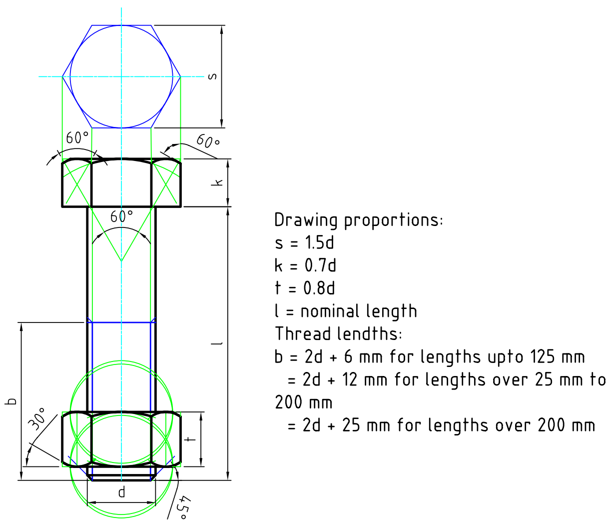


Figure 7.9: Front and side view of a hexagonal bolt and nut assembly

3. **Cap screw** A cap screw passes through a clearance hole in one piece and screws into a tapped hole in the other. The head, which is an integral part of the screw draws the parts together as the screw enters the tapped hole. A hexagonal head cap screw is similar to a bolt except that it generally has a greater length of thread.

4. **Machine Screw** Is a small fastener used with a nut to function in the same way as a bolt or without a nut to function as cap screw. machine screws are used in a limited number of diameter sizes. These come in ten standardized head shapes which except for the hexagonal head, are available in slotted form or with cross recesses. The size of the recess varies with the size of the screw. The hexagonal machine screw is not made with a cross recess but may be optionally slotted.

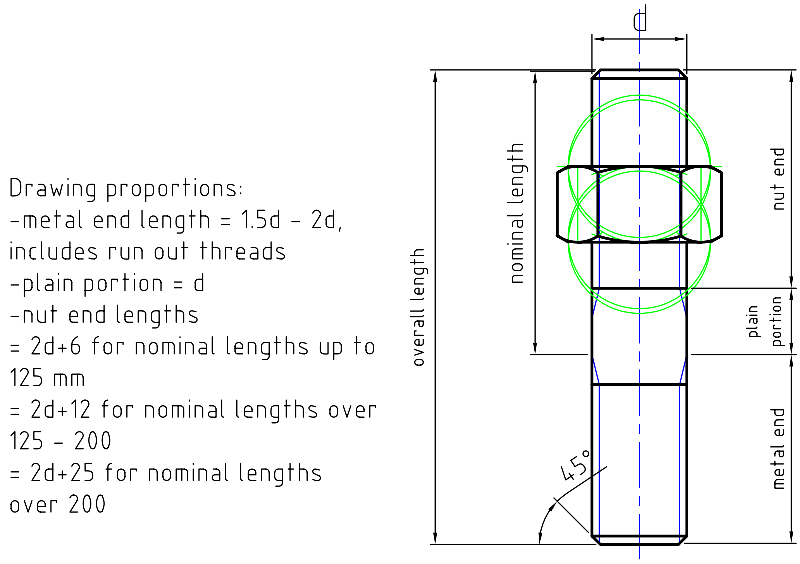


Figure 7.10: Stud and nut assembly

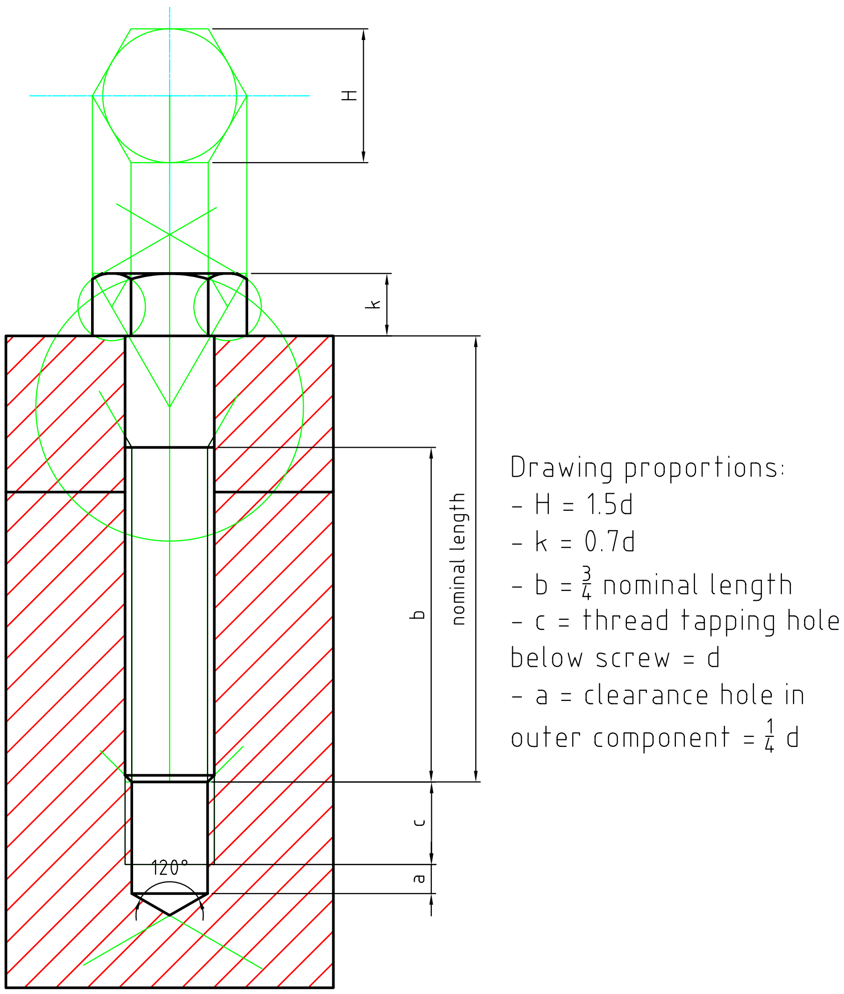


Figure 7.11: Sectional view of a cap screw assembly

5. **Set screw** A set screw screws into a tapped hole in an outer part, often a hub and bears with its point against an inner part, usually a shaft. Set screws hold two parts in relative

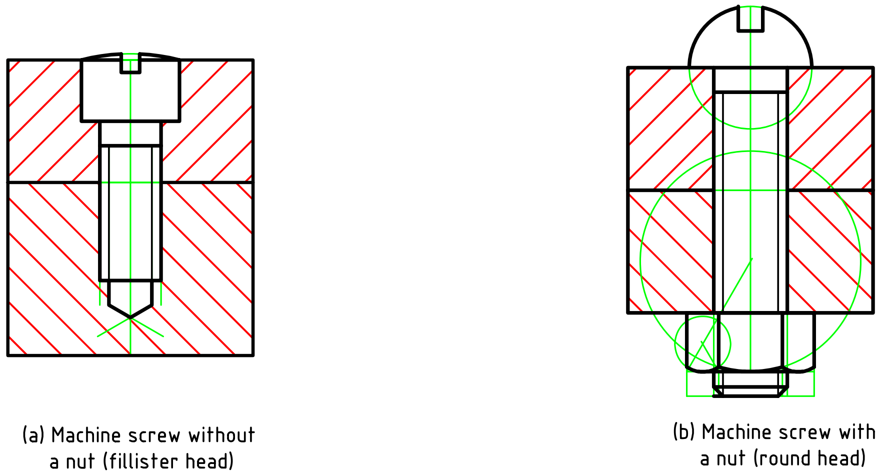


Figure 7.12: Sectional views of machine screw assembly

position by having the end set against the inner part.

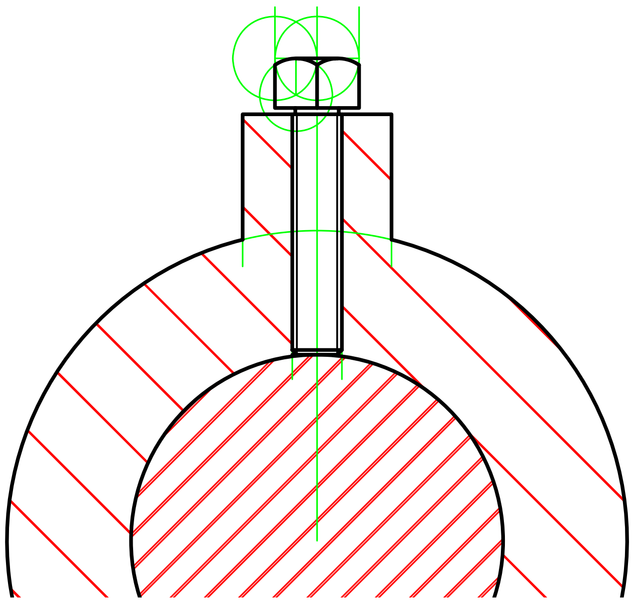


Figure 7.13: Sectional view of a set screw assembly

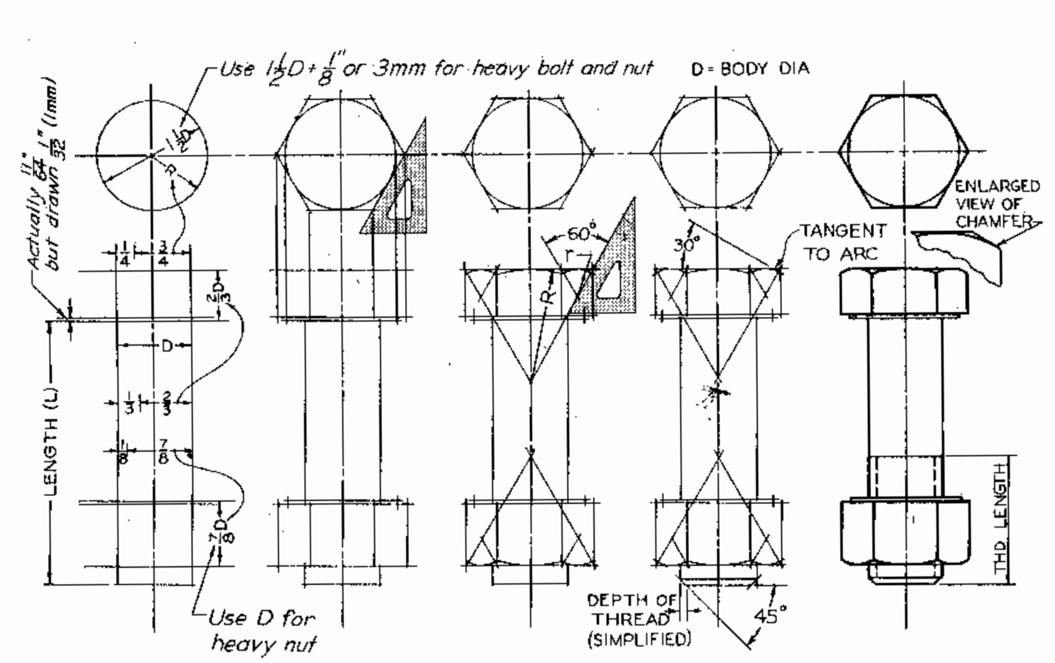


Figure 7.14: Steps in drawing a hexagon-head bolt and hexagon nut

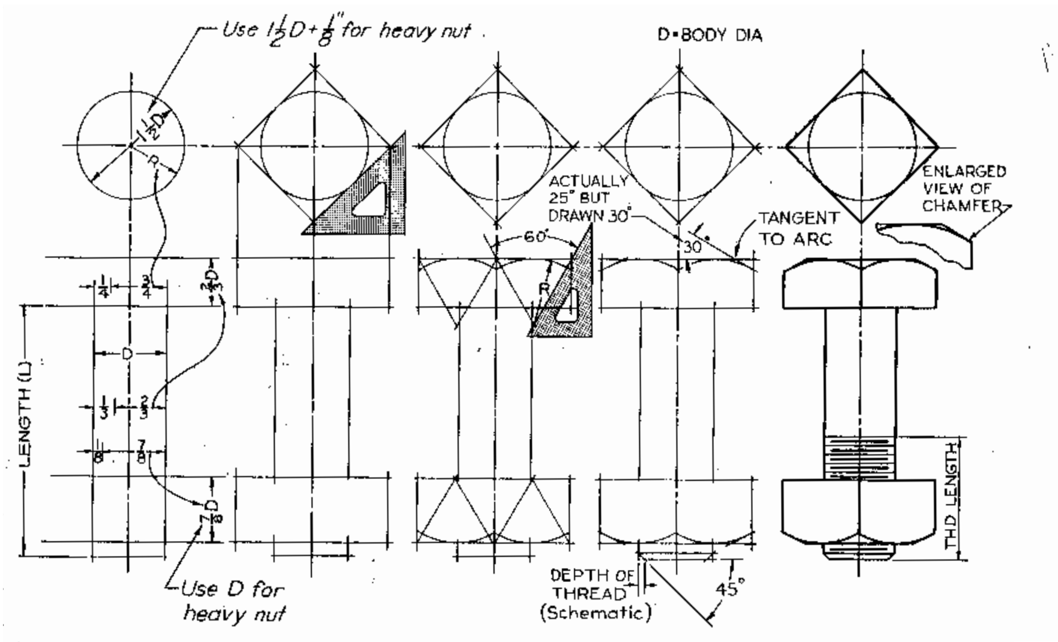


Figure 7.15: Steps in drawing a square-head bolt and square nut

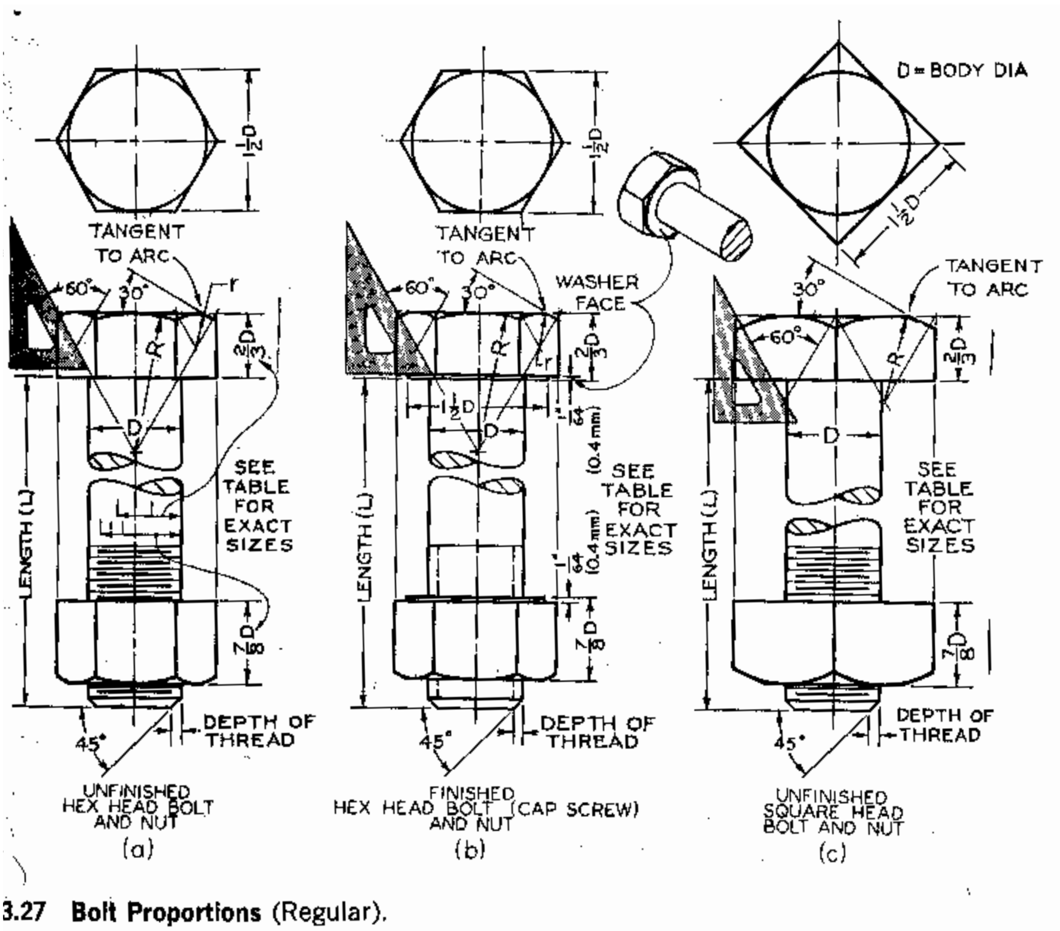


Figure 7.16: Bolt proportions

Chapter 8

Design Phases and Free-Hand Sketching

8.1 Aspects of Design

To design is to formulate a plan for the satisfaction a human need. The design process provides a structure in which the various phases of design occur in a logical and efficient sequence in order to arrive at the most successful outcome.

Phases of deign:

1. Recognition of need
2. Definition of problem - creation of the design requirements or design specifications (inputs, outputs, size, space, etc.)
3. Conceptual design - initial ideas
4. Concept development - Synthesis or feasibility analysis
5. Detailed design - Analysis and optimization
6. Evaluation - prototype manufacture and testing
7. Presentation - manufacture

A **prototype** is an original type, form, or instance of something serving as a typical example, basis, or standard for other things of the same category.

In many fields, there is great uncertainty as to whether a new design will actually do what is desired. New designs often have unexpected problems. A prototype is often used as part of the product design process to allow engineers and designers the ability to explore design alternatives, test theories and confirm performance prior to starting production of a new product. Engineers use their experience to tailor the prototype according to the specific unknowns still present in the intended design. For example, some prototypes are used to confirm and verify consumer interest in a proposed design where as other prototypes will attempt to verify the performance or suitability of a specific design approach.

In general, an iterative series of prototypes will be designed, constructed and tested as the final design emerges and is prepared for production. With rare exceptions, multiple iterations of prototypes are used to progressively refine the design. A common strategy is to design, test, evaluate and then modify the design based on analysis of the prototype.

In many products it is common to assign the prototype iterations Greek letters. For example, a first iteration prototype may be called an "Alpha" prototype. Often this iteration is not expected to perform as intended and some amount of failures or issues are anticipated. Subsequent prototyping iterations (Beta, Gamma, etc.) will be expected to resolve issues and perform closer to the final production intent.

In many product development organizations, prototyping specialists are employed - individuals with specialized skills and training in general fabrication techniques that can help bridge between theoretical designs and the fabrication of prototypes.

8.2 Introduction

A free hand drawing or sketching is a drawing created without the use of drawing instruments. Free hand sketching allows allows a designer or drafter to convey ideas quickly and easily. It also helps in the conceptualization phase of the design process:

- How we picture objects in our minds.
- How we visualize spatial relationships

Sketching materials:

i. Soft pencil such as HB or B

ii. Paper

iii. Cross-section paper (with uniform squares) - helpful for sketching to scale.

iv. For isometric sketching, a specially ruled isometric paper may be used.

v. Good quality eraser

8.3 Types of sketches

The form of any technical sketch should conform to one of the three standard types of drawings:

1. Multi-view
2. Pictorial
    - axonometric (isometric)
    - oblique
    - perspective
3. diagrammatic

8.3.1 Scale/ Proportion

Sketches are usually not made to scale but should be made in their correct proportions as accurately as possible. proportion is the relationship between the size of one part to another and to the object as a whole. In some cases, a cross-section paper may be used to assist in sketching to correct proportions. The size of a sketch is normally optional, depending upon the complexity of the object and the size of paper available. Small objects are often sketched oversize so as to show the necessary details clearly.

8.3.2 Sketching Tips

- Hold pencil loosely so that it has a free and easy movement.
- Rotate pencil to maintain a sharp point
- Practice using different pressure to produce desired line types.
- Draw in a direction comfortable to you.
- Reorient paper to your convenience
- Do NOT use a straight edge to draw lines!
- Mark end points of the lines to be sketched and draw between them
- Draw long lines as a series of short light ones and then darken them to obtain the finished lines.
- Begin by drawing bounding boxes with construction lines
- Make construction lines much lighter and thinner than finished lines
- Identify the major features
- Leave construction lines on the sketch
- Use grid paper when available.
- Include written notes and dimensions to aid in interpretation.

8.3.3 Multi view sketching

- A drawing for use in production should contain only those views needed for a clear and complete shape description of the object. These minimum required views are referred to as the **necessary views**.
- In selecting views, choose those views that show best, the essential contours or shapes and give preference to those with least number of hidden details.
- Very thin extrude parts may be shown using one view and a note added to indicate the thickness

of the part.
- Cylindrical objects can be shown using two views, a circular and a rectangular view.
- Always try to maintain the natural orientation of the object.
- Keep views aligned

Chapter 9

Conventional Representation of Features

9.1 Introduction

Drawing of most engineering components is tedious and consumes a lot of time. The primary object of the use of conventions is to save the draughtsman time and in some cases to save on space. A set of representations have been developed and standardized to show commonly used engineering components. The following conventions are selected from BS 8888 and ISO 2203.

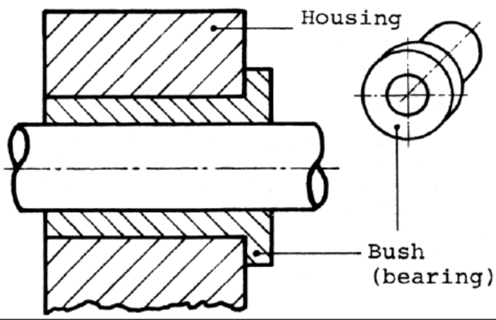
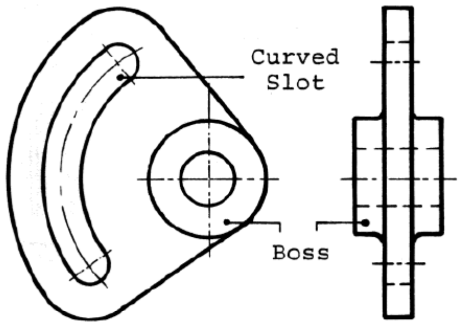
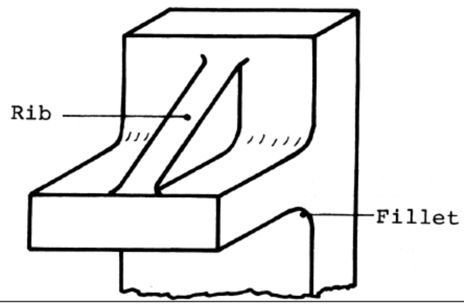
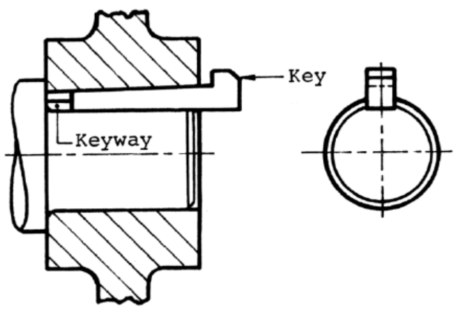
<table>
<tr><td colspan="2">General:</td></tr>
<tr><td>Housing:
A component into which a 'male' mating part fits, sits or is 'housed'.</td><td rowspan="2">
</td></tr>
<tr><td>Bush/bearing:
A removable sleeve or liner. Known also as a simple or plane bearing.</td></tr>
<tr><td>Boss:
A cylindrical projection on surface of component.</td><td rowspan="2">
</td></tr>
<tr><td>Curved slot:
Elongated hole, whose centerline lies on an arc. Used usually on components requiring adjustment.</td></tr>
<tr><td>Rib:
A reinforcement, positioned to stiffen surfaces.</td><td rowspan="2">
</td></tr>
<tr><td>Fillet:
A radius or rounded portion suppressing a sharp internal corner.</td></tr>
<tr><td>Key:
A small block or wedge inserted between a shaft and a mating part (a hub). Used to prevent relative rotation of the two parts.</td><td rowspan="2">
</td></tr>
<tr><td>Key way:
A parallel sided slot or groove cut into a bore or a shaft, to 'house' a mating key.</td></tr>
</table>

Figure 9.1:

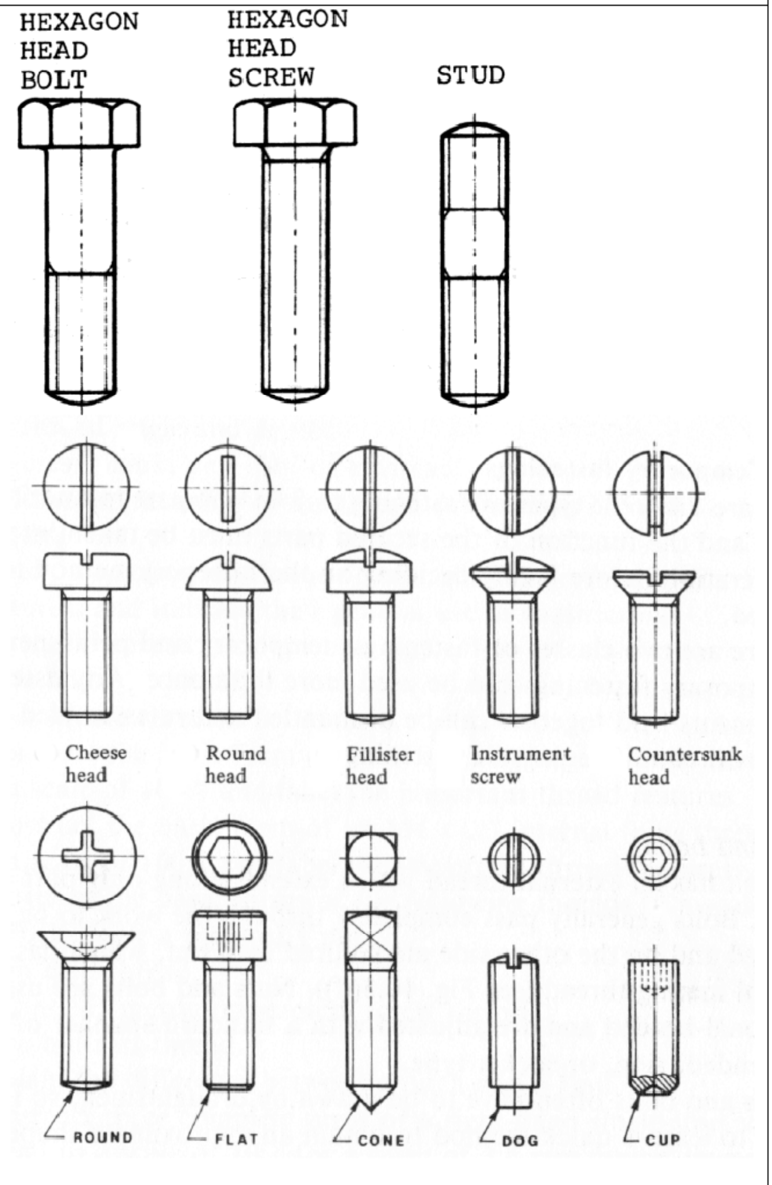
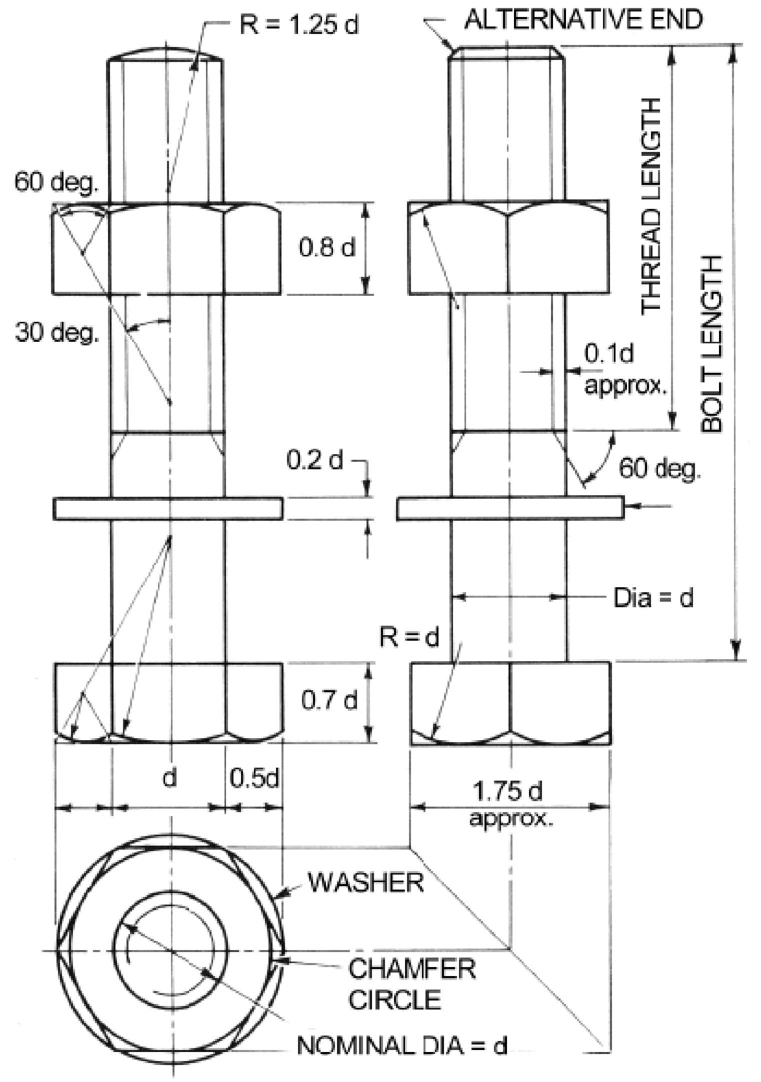
Fasteners:	
Bolts, screws & studs: Threaded fasteners. Bolts have a shank partially threaded, whereas screws are threaded along the entire length. For guidance on dimensioning, see next page. The last three examples here are called set screws and are used to position or lock components.	

Figure 9.2:

This diagram gives approximate dimensioning methods for drawing hexagon headed metric bolts, nuts and plane washers.

(Manufacturers data sheets may give more accurate measurements.)



Circlip:

Internal & external.

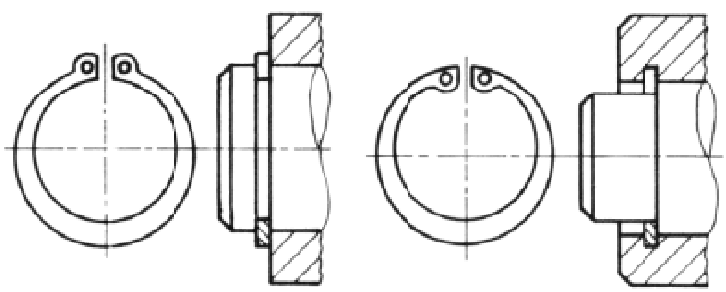


Figure 9.3:

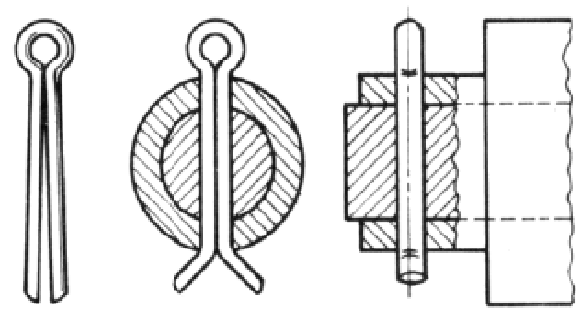
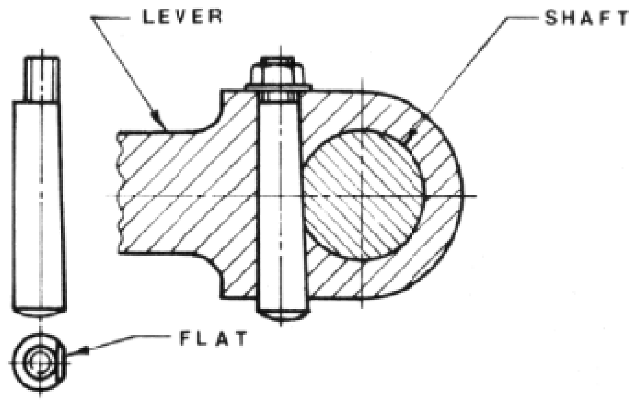
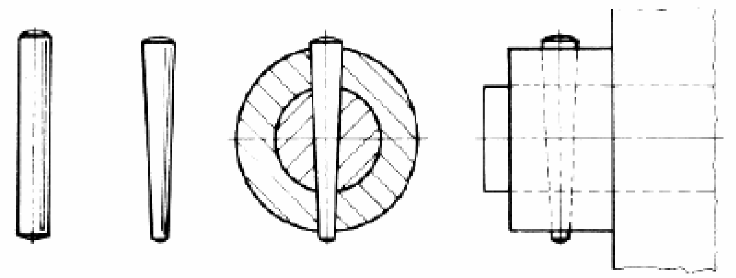
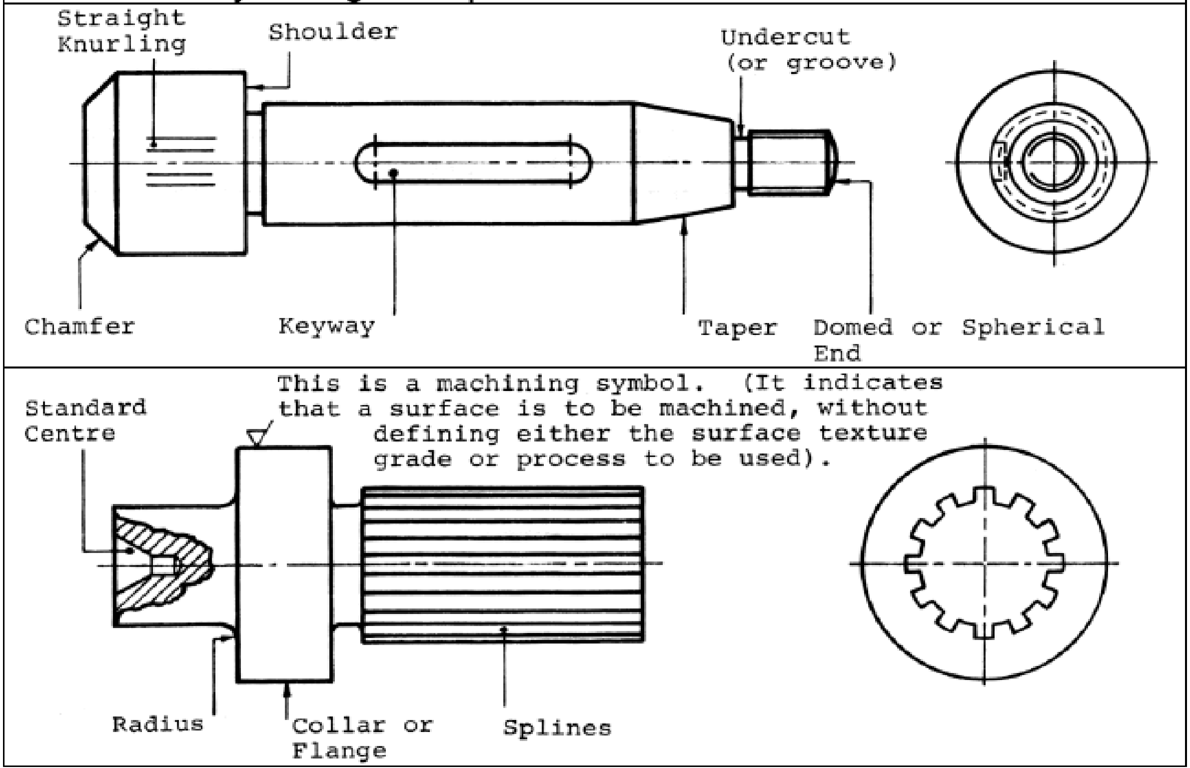
Pins:	
Split Cotter Pin: Used to lock components, prevent fasteners from coming 'un-fastened'. e.g. lock-nuts on suspension systems.	
Cotter Pin: Used to retain components, usually where loads are transmitted.	
Dowel Pin & Taper Pin: Provides location, alignment.	

Figure 9.4:

Features usually relating to components turned on a lathe:



Holes:

Drilled:
Loose tolerance, for pilot holes or clearance holes for fasteners.

Reamed:
Accurate finishing process after drilling or boring.

Counterbore:
Usually used to recess the head of a square shouldered fastener.

Countersunk:
Usually used to recess the head of a countersink screw.

Spotface:
Used to clean up and level the surrounding area, usually for a fastener or something such as a hydraulic fitting using a seal.

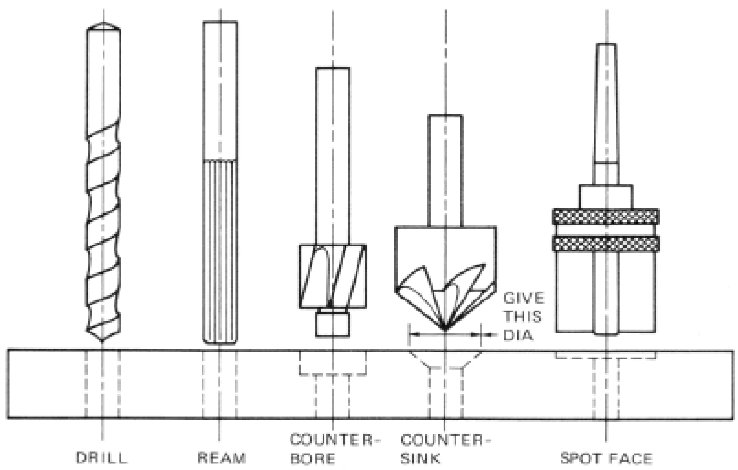


Figure 9.5:

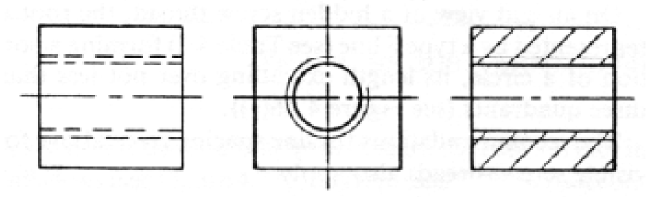
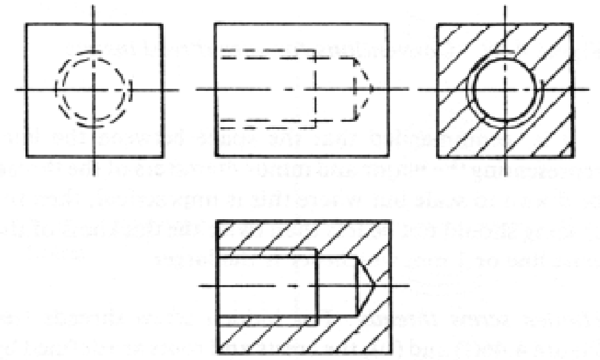
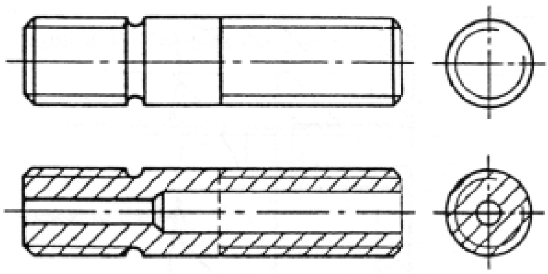
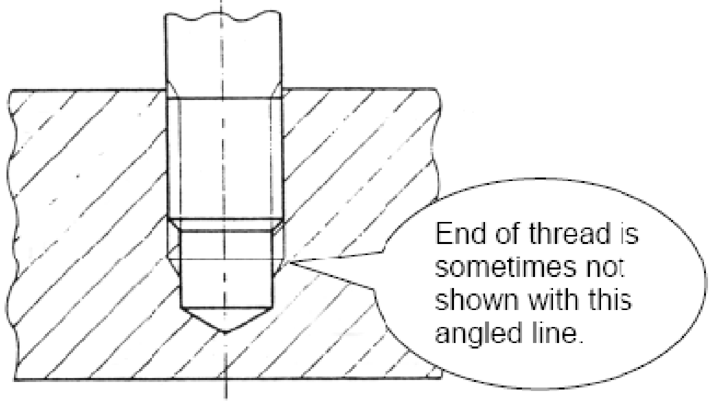
Screw threads:	
Female thread, through: Usually drilled and tapped.	
Female thread, blind: Usually drilled and tapped.	
Male thread: Usually cut with a die, turned or rolled. Note use of undercut or groove and appearance of thread in sectioned view.	
Male & Female: e.g. a fastener in a tapped hole. Note here that the tapped hole is sectioned, the fastener is not.	

Figure 9.6:

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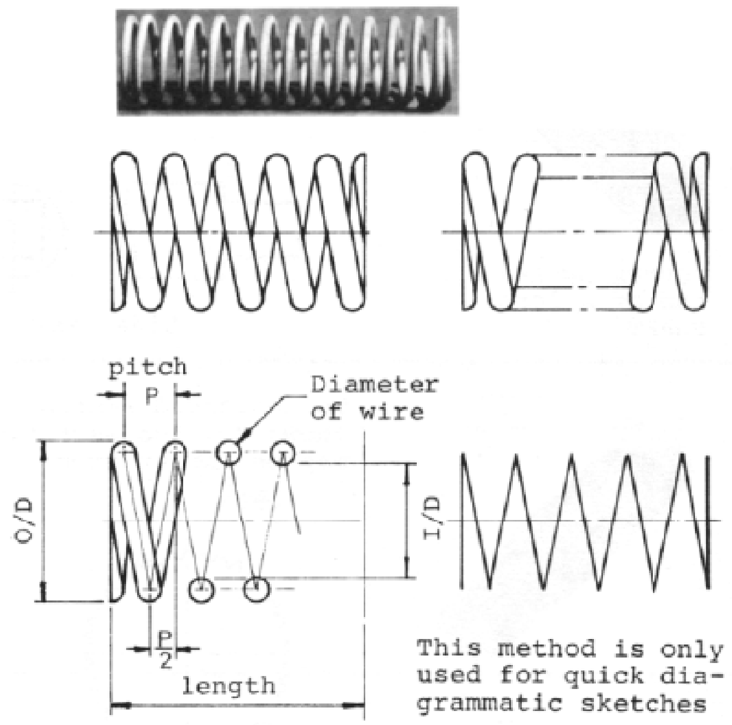
<tr><td>Compression:</td><td>
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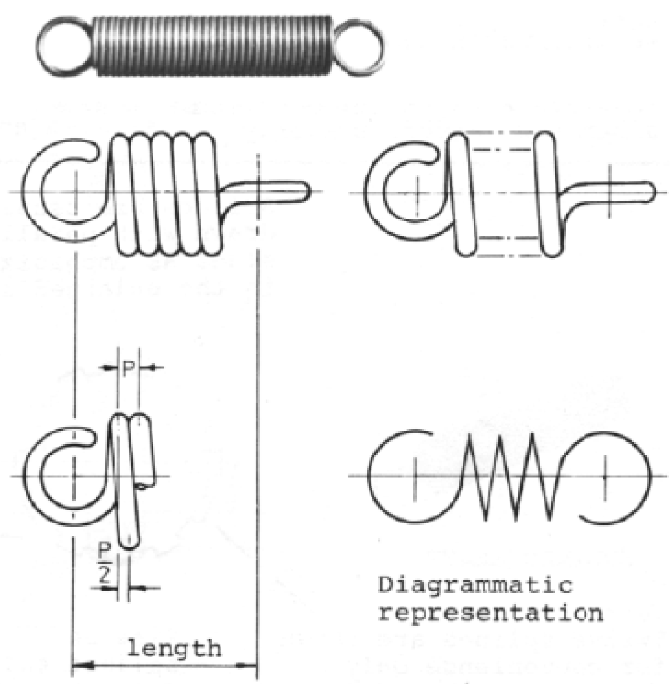
<tr><td>Tension:</td><td>
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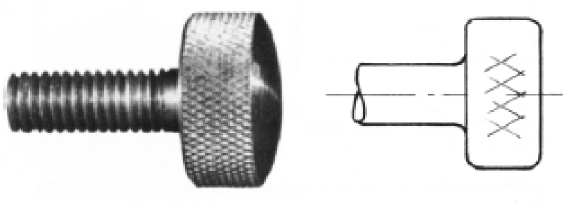
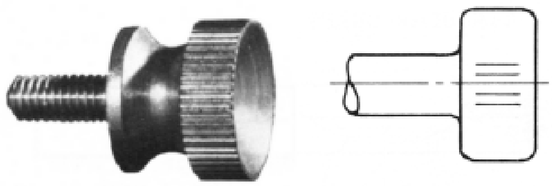
Figure 9.7:

Knurling:	
Diamond.	
Straight.	

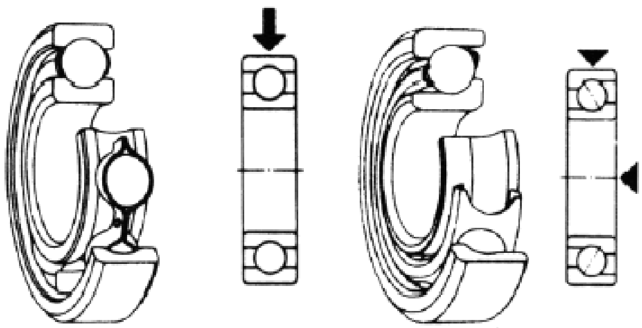
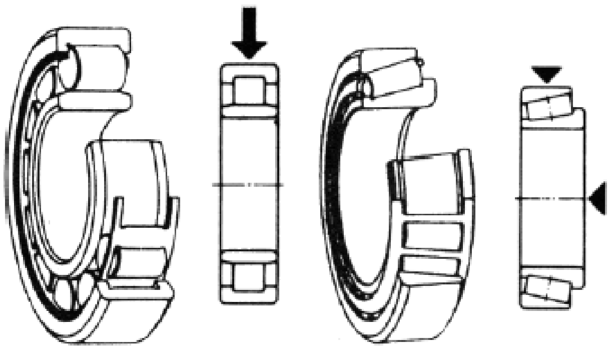
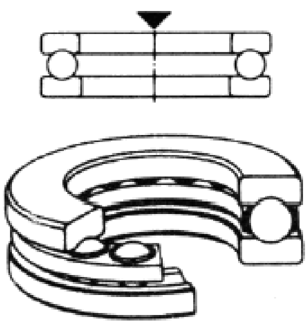
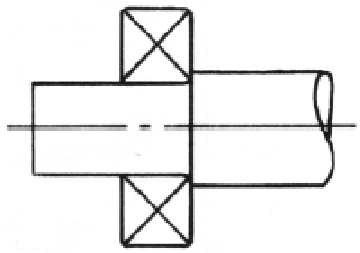
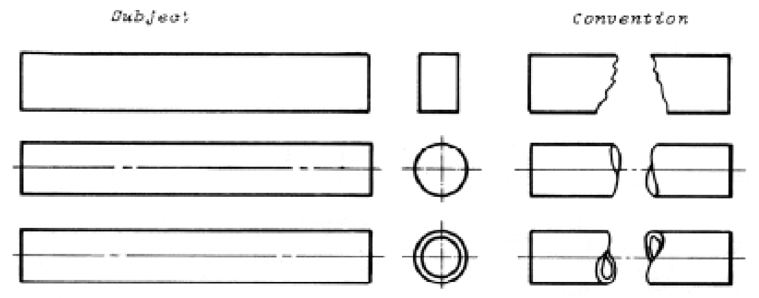
Bearings:	
Some examples of rolling element barings. Arrows indicate directions of load bearing. Deep groove (near). Angular contact (far).	
Roller (near). Taper roller (far).	
Thrust (near). Standard drawing representation of a bearing.	 

Figure 9.8:

Long components:	
Rectangular bar: Round bar: Round tube:	

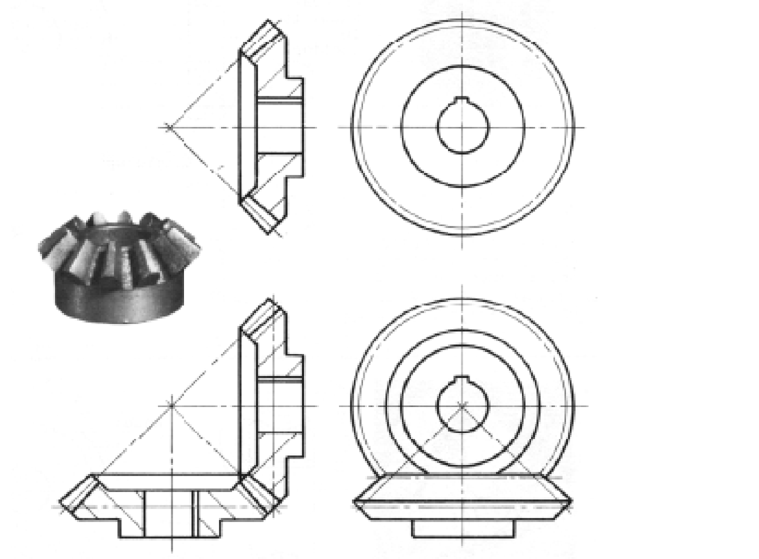
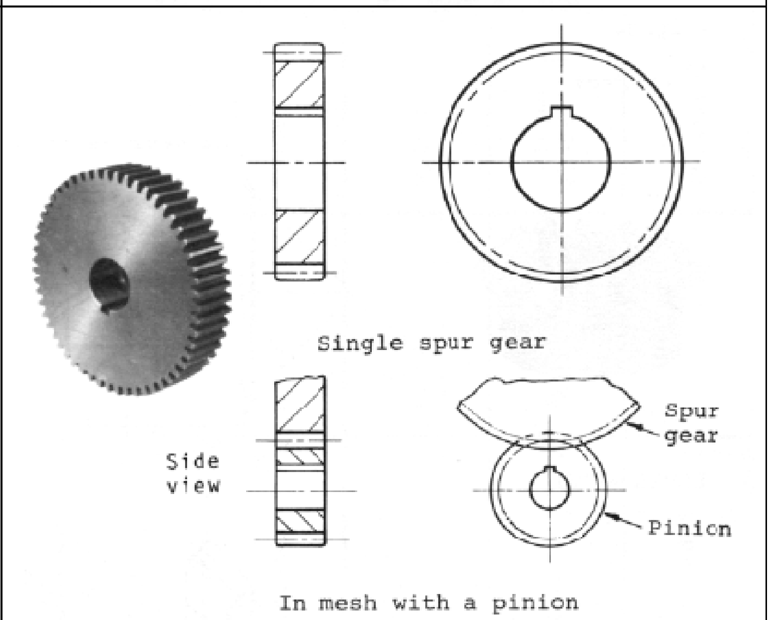
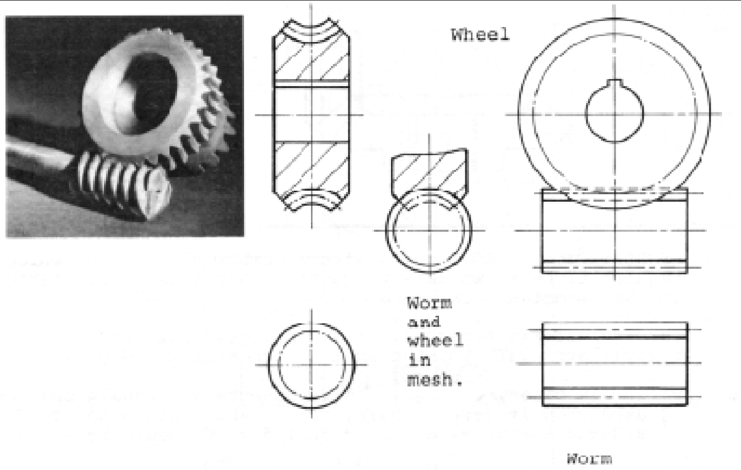
Gears:	
Bevel:	
Spur:	

Figure 9.9:

Worm & wheel:	

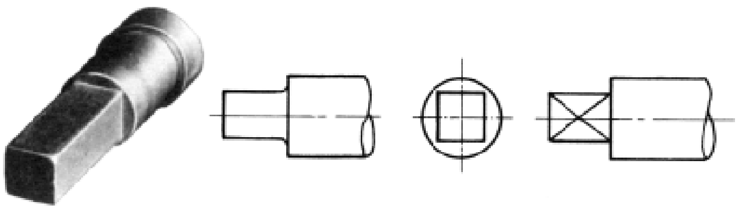
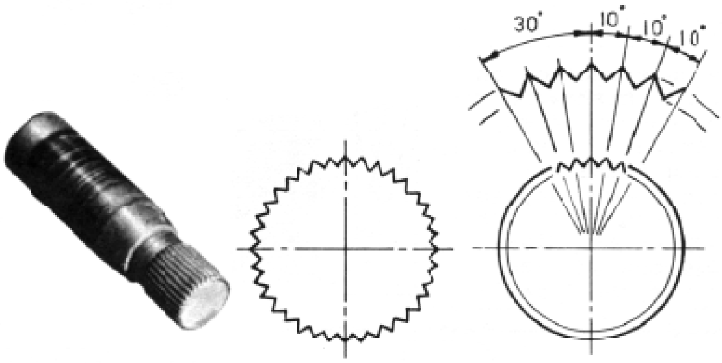
Shaft ends:	
Square: Frequently used for hand driven adjustments with removable handles, such as those found on machine tools, etc.	
Serrations: Often used for push fit components such as plastic fans or pulleys, or levers such as motorcycle gear shifters.	

Figure 9.10:

Splines:
Usually used for transmitting rotational torque and allowing an axial 'sliding' movement.

Examples can be found on automotive drive shafts.

The figures opposite show splined shafts and housings in sectioned and non-sectioned views.

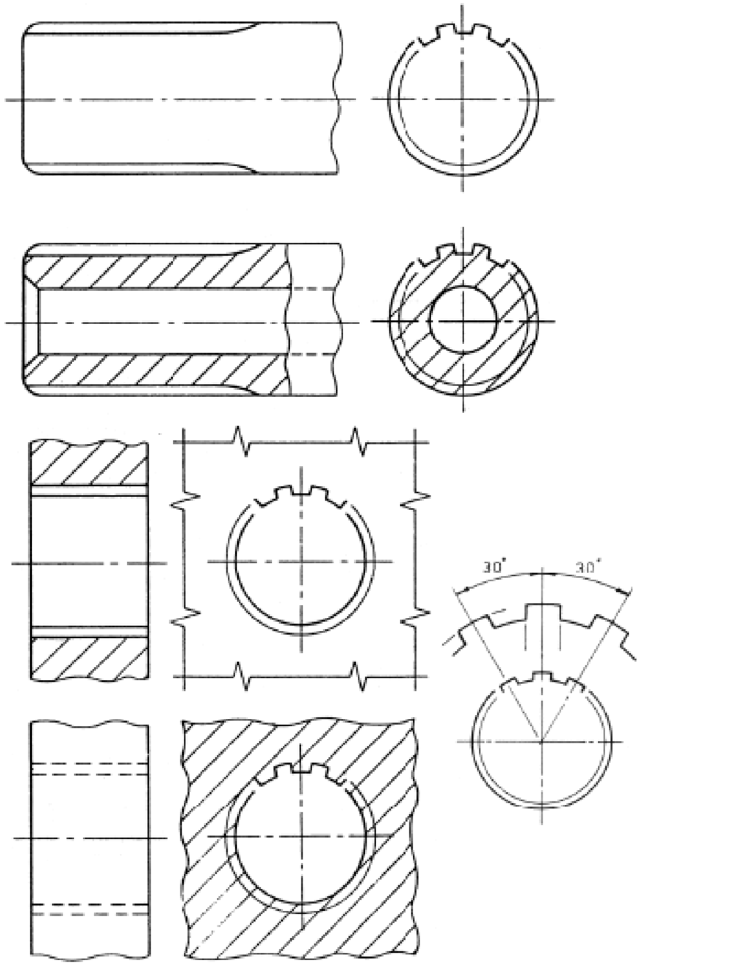


Figure 9.11: