

CHAPTER FOUR: TECHNICAL DRAWING

Unit of learning code: ENG/LG/MC/CC/04/5/A

Related Unit of Competency in Occupational Standard; Prepare and interpret technical drawings

Introduction to the unit of learning

Unit Description

This unit covers the competencies required to prepare and interpret technical drawings. It involves competencies to select, applying and maintaining drawing equipment and materials, producing plane geometry drawings, producing solid geometry drawings, producing orthographic and pictorial drawings and applying CAD packages

Summary of Learning Outcomes

1. Apply and maintain drawing equipment and materials
2. Produce plane geometry drawings
3. Produce solid geometry drawings
4. Produce orthographic and pictorial drawings
5. Apply CAD packages

4.1 Apply and Maintain Drawing Equipment and Materials

Introduction to the learning outcome

This learning outcome is intended to equip the trainee to be competent in identifying, and gathering drawing and drawing materials according to task requirements. It also covers content on maintenance of drawings and drawing materials.

Performance standard

- i. **Drawings** are identified and gathered according to task requirements
- ii. Drawing materials are identified and gathered according to task requirements
- iii. Drawings are used and maintained as per manufacturer's instructions
- iv. Drawing materials are used as per workplace procedures
- v. Waste materials are disposed in accordance with workplace procedures and **environmental**
- vi. **Personal Protective** is used according to occupational safety and health regulations

Identification and care of drawing equipment and materials

Basic Drawing Tools

A drafts person needs some basic tools to draw. These should include the following:

- i. A range of pencils
- ii. Ruler
- iii. Set squares
- iv. Rubber
- v. Compasses
- vi. Dividers
- vii. Drawing board
- viii. T-square
- ix. Clips or tape
- x. Emery board or fine sandpaper

Pencils: You will need a selection of pencils. A hard lead pencil (6H) can be used for light lines, a softer pencil (2H) for the outlines and an even softer pencil (HB) for printing. (More than one pencil of each grade will save you from frequent re-sharpening.)

Ruler: It is advisable to have a transparent ruler.

Set squares: You will need at least two set squares: a 60 ° and a 45 ° set square. It will be also useful to have an adjustable set square, which will enable you to set the angle on the set square to anywhere between 0 ° and 90 °. If you have an adjustable set square you can manage without the other two.

Rubber: Choose a good quality rubber, one that does not smudge.

Compasses: You will need at least two compasses: a small spring bow compass for small circles and one for larger circles.

Dividers: A pair of dividers is essential.

Drawing board and T-square: Drawing boards for size A2 paper can be bought with a fitted horizontal square which slides up and down on rollers. A less expensive board is one that is used with a separate T-square which slides up and down on the side of the drawing board and has to be held in place when used.

Clips or tape: The best tape to use to hold paper on the drawing board is masking tape but metal drawing board clips are easier to use.

Emery board or fine sandpaper: This is used to ensure that the lead in the pencils is kept sharp.

Instruments for Drawing Straight Lines

- T- Square
- Set- squares

Instruments for Drawing Curved Lines

- Compass
- French curve

Instruments for Measuring Distance

- Divider
- Scales

Instruments for Measuring Angles

- Protractors
- Set-squares
- Special Tool
- Mini drafter

There are other instruments that will help you to draw quickly and accurately.

These include the following:

- a) French curves (for drawing non-circular curves accurately).
- b) Large spring bow compasses.
- c) Trammel (for drawing circles with very large diameters).
- d) Scales (rulers with special markings for drawing items bigger or smaller than they are in real life)

Using the Equipment

First fix the paper to your board, using clips or tape.

Then sharpen your pencils, either to a point using a pencil sharpener, or to a chisel shape using the emery board and use this shape for drawing lines, drawing from the ends of each line to meet in the middle.

Use the emery board to sharpen your compass leads to a chisel point too. Finally, draw a frame on your paper if required.

Precautions for Neatness in Drawing Work

1. The hands should be kept clean at all times during work.
2. All the drawing instruments should be kept clean by wiping with a cloth/towel.
3. Special emphasis is to be given to sliding instruments on the drawing sheet, such as T- square and set squares. These instruments must be cleaned properly every time.
4. Pencil should always be kept sharp and used properly. It should be sharpened away from the drawing sheet and other instruments.
5. Dirt and graphite particles from the pencil will make the drawing dirty. Hence, every care should

- be taken to remove them from the drawing sheet.
6. Direct contact of hand with the drawing sheet should be avoided.
 7. Rubbing or erasing should be done properly with soft eraser.

Identification and care of drawing materials

Drawing materials

These are consumable items used for technical drawing. They are consumable because they cannot be reused after being used.

The following are the necessary drawing materials.

1. Drawing paper

These are white papers on which drawing is done. The mostly used sizes are A2 to A4

2. Erasers

Erasers are rubber materials used to clean errors made. A good eraser should be able to clean errors without tearing the paper.

3. Handkerchief

It is a small clothing material used for cleaning and dusting.

4. Emery clothes/glass paper

They are materials used to maintain the sharpness of pencils at all times

5. Adhesives

It is commonly called callotape. It is used to fix drawing paper on the drawing board.

6. Drawing pencils

The drawing pencil is used for preparing the drawing on the drawing paper.

Pencils

Pencils are the main drawing instruments used to draw the lines, circles, arcs, polygons, etc. with respect to the scale provided. Some of the pencils are hard and some of the pencils are smooth.

The hard pencils are used to draw the construction lines and the smooth pencils are used to draw the main lines.

4. H Grades:

H leads give cleaner lines and are also smudge resistant, making them perfect for outlining, technical drawings, painting with watercolors after the sketch and light sketches.

The only flip side is that as you move up the scale, the harder the leads will get and they tend to be scratchy. So make sure you practice and experiment before you begin on your actual art project.

2. HB:

The HB grade lies in the middle of the spectrum. HB is dark enough to be read clearly with minimal smudging and is therefore used mostly for writing.

3. B Grade:

B grades smudge easily, are smooth to write and draw with. But they are easily erasable. As you go higher up the scale with these pencils, artists can take advantage of the brush- like expressions that can result while using this grade of pencils. Animators in particular love using 10B on the animator paper as it writes so smoothly – like butter, creating quick, heavy lines without friction.

4. F Grade:

The F grade also lies in the middle of the spectrum. The letter ‘F’ stands for ‘fine’. The lead with ‘F’ grade contains a limited amount of graphite and more amount of clay. It has a hard lead but gives a lighter shade when used.

Depending on the smooth and hard quality or the hardness, pencils are classified into 18 grades and they are as follows.

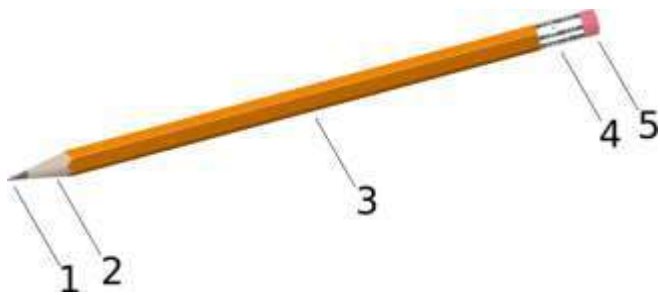
Grade of Pencil	Hardness of Pencil
9H	Hardest
6H, 5H, 4H	Extremely Hard
3H	Very hard
2H	Hard
H	Moderately hard
F	Firm
HB	Medium hard
B	Moderately soft and black
2B	Soft and black
3B	Very soft and black
4B, 5B, 6B	Very soft and very black
7B	Softest

Table 7: Grades of pencils

Out of the above 18 grades of pencils, the following grades are used in engineering drawings.

Grade of Pencil	Used to Draw
3H	Construction lines
2H	Dimension lines, center lines, sectional lines, hidden lines
H	Object lines, lettering
HB	Dimensioning, boundary lines

Table 8: Continuation of grades of pencils



1. Solid pigment core (typically graphite, commonly called pencil lead).
2. Wood.
3. Painted body.
4. Ferrule.
5. Eraser.

Care in handling and maintaining drawing instruments and materials

Drawing board

1. Do not use drawing board for any other purpose than for drawing
2. The surface of the drawing board must be in good condition. Do not using sharp object to cut on it.
3. Always clean the drawing board before use.
4. Cover drawing board surface with paper or cardboard after use

Tee square

1. Tee square should not be used as a walking stick.
2. The blade must be straight at angle 90° to the stock.

3. Always clean the tee square before using it.

Set of drawing instruments

1. Do not place heavy load on them to prevent breakage.
2. Do not use sharp objects to cut on their edges.
3. Store them in a safe place

Drawing pencil

1. Drawing pencil should be kept in a pencil packet after use.
2. Pencil points must be pointed

Other instruments

All other instruments should be stored in a safe place to prevent damage

<http://schoolportalng.com/drawing-instruments-and-materials/>

Title Block

The title block should lie within the drawing space at the bottom right hand corner of the sheet. The title block can have a maximum length of 170 mm providing the following information.

1. Title of the drawing
2. Drawing number
3. Scale
4. Symbol denoting the method of projection
5. Name of the firm
6. Initials of staff who have designed, checked and approved
7. Date when the drawing was finished
8. Name of the person who checked the drawing
9. Remarks

Lettering

Lettering used in engineering drawing is referred to as a *Single Stroke, Commercial Gothic Hints on Lettering*

- To save time, use a guide lining device
- The recommended height of lettering is 3-mm
- During initial learning period, make a point of concentrating on hand control
- Endeavor to make your hand do what you want it to do and not otherwise. Remember your fingers are not used to such movements, so they have to be trained until hand control becomes effortless
- Do not guess at the construction of letters and numerals. Use the sample letter
- Make letters and numerals as wide as they are high with individual letters of a word almost touching

- Spacing between words is a matter of judgment and tends to improve with practice
- Lines of lettering should be spaced the same distance apart
- Do not attempt to erase guide lines after lettering has been completed

Printing

Most notes on drawings are done in upper case (capital letters) although this is not always so. Two alphabets and numbers are shown below.

Most draftspersons develop great skills in printing by hand. If you need to print, try both standard and italic and develop a style that suits you.

Standard print



A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

a b c d e f g h I j k l m n o p q r s t u v w x y z

1 2 3 4 5 6 7 8 9 0

Lines

In Engineering Drawing, we make use of different lines and line styles to convey the desired message. These lines differ in (i) thickness and (ii) style

Type of Line and Designation	Applications	Recommended line thickness [mm]	
		PAPER SIZE	
		A3/A2	A1/A0
 continuous thick line	. Object line	0.5	0.7
 continuous thin line	1. Dimensioning line 2. Projection or extension lines <i>used to project points from one view to another)</i> 3. Hatching 4. Outlines of adjacent parts 5. Outline of revolved views or revolved sections	0.5	0.35


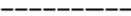
	6. Leaders for notes 7. Imaginary outlines		
 continuous wavy line	1. Break line of part views and part sections when break lines are not center lines	5	0.35
 short thin dashes	4. Non-visible outline (hidden) 3 – 4-mm strokes, 1 – 2-mm spaces	5	0.35

Table 9: Types of lines in drawings

Learning Activities

Learning activity 1: Apply and maintain drawing equipment and materials

Make a sketch of an A 1 size drawing sheet, showing in it, the border lines, margin lines, folding marks, zones and the title block. Give the untrimmed and trimmed sizes of this sheet.

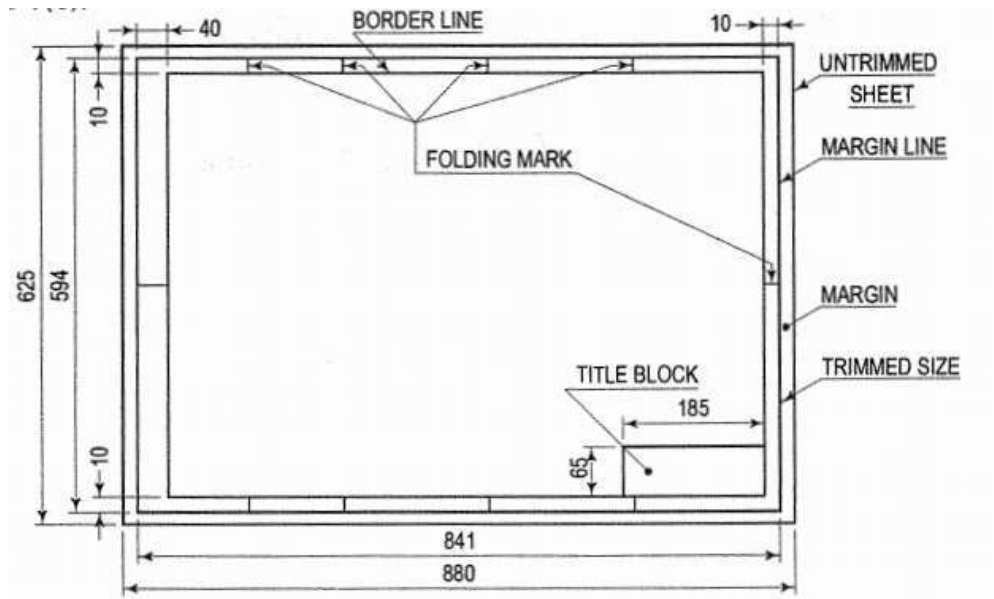


Figure 51: Drawing paper layout

Learning activity 2: Apply and maintain drawing equipment and materials

In an A3 size sheet, Copy the drawings below as per layout shown. [All dimensions are in mm.]

- i. Draw the border lines as per the standards learnt.
- ii. Draw the title block as per the standards learnt.

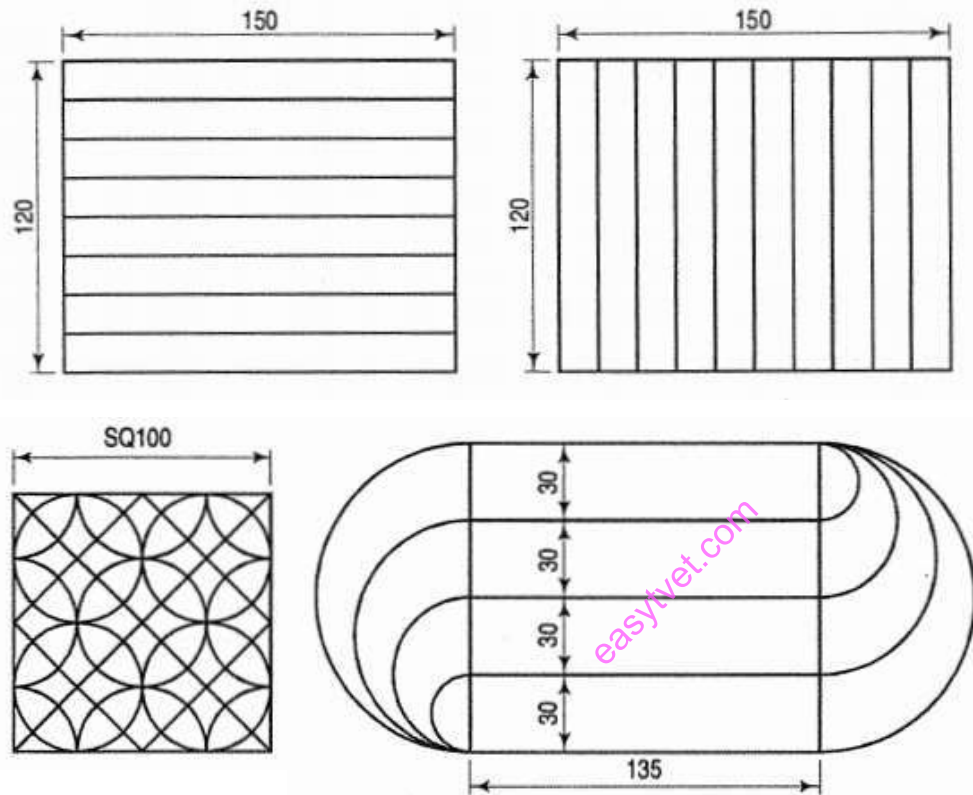


Figure 52: Patterns

Learning activity 3: Apply and maintain drawing equipment and materials

Write freehand the following, using single stroke vertical (CAPITAL and lower-case) letters:

1. Alphabets (Upper-case & Lower-case) and Numerals 0 to 9 (h = 5 and 7 mm)
2. PRACTICE MAKES A PERSON PERFECT (h = 3.5 and 5)
3. BE A LEADER NOT A FOLLOWER (h = 5)
4. LETTERING SHOULD BE DONE FREEHAND WITH SPEED (h = 5)

Self-assessment

1. What is a technical drawing?
 - A. A sketch
 - B. A detailed drawing with measurements
 - C. A brainstorming sketch

- D. A drawing with labels
2. Once a drawing is determined to be complete, the title block is used to document the change from:
 - A. A draft to a finished drawing
 - B. A finished to a working drawing
 - C. An assembly to a finished drawing
 - D. A working drawing to a draft
 3. Which of the following types of lines is used on construction line?
 - A. Thick line
 - B. Thin line
 - C. Dash line
 - D. Wavy line
 4. What is the size of an A3 drawing sheet?
 - A. 1189 x 841mm
 - B. 594 x 420mm
 - C. 420mm x 297mm
 - D. 297 x 210mm
 5. The primary unit of measurement for engineering drawings and design in the mechanical industries is the:
 - A. Millimeter
 - B. Centimeter
 - C. Meter
 - D. Kilometer
 6. With regard to lettering, the shapes of letters are not described as part of drawing standards.
 - A. True
 - B. False
 7. Scale is stated as a ratio of the number of drawing units to the number of actual units.
 - A. True
 - B. False
 8. Why the drawing is called the language of Engineers?
 9. What is the Necessity of Dimension a Drawing?

Tools, Equipment, Supplies and Materials

1. Drawing tools
2. Drawing set
3. Drawing papers
4. Erasers
5. Series of pencils
6. Drawing board

References

1. Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing : Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.
2. Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.
3. Narayana, K. L., Kannaiah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.
4. Reddy, K. V. 2010. Textbook of Engineering Drawing . B.S. Publ., Hyderabad.
5. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,

easytvvet.com

4.2. Produce Plane Geometry Drawings

Introduction to the learning outcome

This learning outcome is intended to equip the trainee to acquire the competence of producing plane geometry drawings.

Performance Standard

- i. Different types of lines used in drawing and their meanings are identified according to standard drawing conventions
- ii. Different types of *geometric forms* are constructed according to standard conventions
- iii. Different types of angles are constructed according to principles of trigonometry
- iv. Different types of angles are measured using appropriate measuring tools
- v. Angles are bisected according to standard conventions
- vi. Freehand sketching of different types of geometric forms, tools, , diagrams is conducted

Information sheet

Construction of geometric forms and *geometrical constructions*

1. Dividing a straight line into equal parts

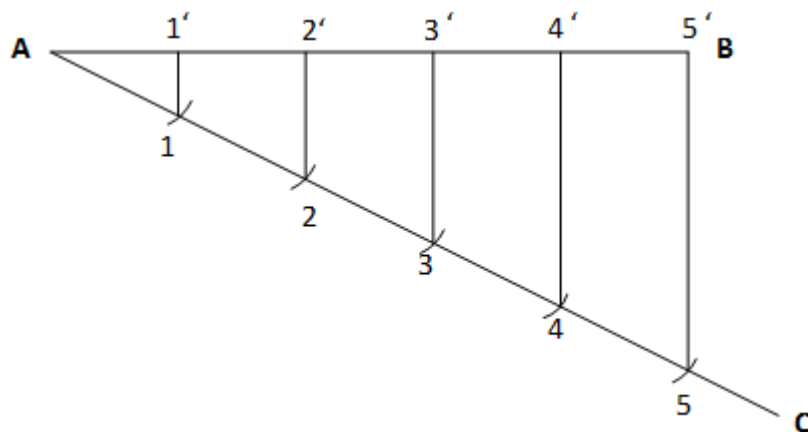


Figure 53: A line divided into equal parts

- i. Draw AC at any angle θ to AB.
- ii. Construct the required number of equal parts of convenient length on AC like 1, 2, and 3.

- iii. Join the last point 5 to B
 - iv. Through 4, 3, 2, 1 draw lines parallel to 5B to intersect AB at 4', 3', 2' and 1'.
2. Dividing a line in ratios

Take the line to be divided in the ratio 1:3:4

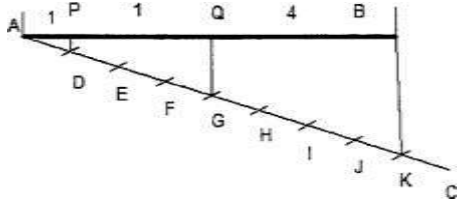


Figure 54: Line divided in ratio

- i. Add the ratios $1+3+4 = 8$ and divide the line into 8 equal divisions.
- ii. Obtain P and Q to divide the line AB in the ratio 1:3:4.

Construction of different types of triangles

Triangles

This is a plane figure bounded by three straight sides.

Types of triangles

- i. Scalene triangle is a triangle with three unequal sides and three unequal angles.
- ii. Isosceles triangle is a triangle with two sides, and hence two angles, equal.
- iii. Equilateral triangle is a triangle with all the sides, and hence all the angles, equal.
- iv. Right-angled triangle is a triangle containing one right angle. The side opposite the right angle is called the 'hypotenuse'.
- v. Obtuse-angled triangle

Acute-angled triangle

Construct the different triangles given:

- i. One of the sides
- ii. Perimeter and altitude
- iii. Base angles and perimeter
- iv. Base, altitude and vertical angle
- v. Perimeter and the ratio of the sides
- vi. Perimeter, altitude and vertical angle
- vii. Similar triangle with different perimeter

Constructions of triangles

1. When all the three sides are given

To construct a ΔABC in which $AB = 4$ cm; $BC = 6$ cm and $AC = 5$ cm.

- i. Draw $AB = 4$ cm.
- ii. With A as centre and radius 5 cm, draw an arc.
- iii. With B as centre and radius 6 cm, draw an arc.
- iv. The two arcs cut each other at point C.
- v. Join AC and BC to complete the triangle ABC.

Example:

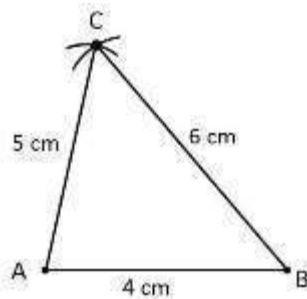


Figure 55: Triangle

When Two Sides and an Angle are Given

To construct a ΔABC in which $QP = 4$ cm; $QR = 6.5$ cm and included angle $Q = 60^\circ$

- Draw $QR = 6.5$ cm
- Construct $\angle XQR = 60^\circ$
- With Q as center and radius 4 cm, draw an arc to cut QX at P
- Join QP
- Thus, ΔPQR is the required triangle

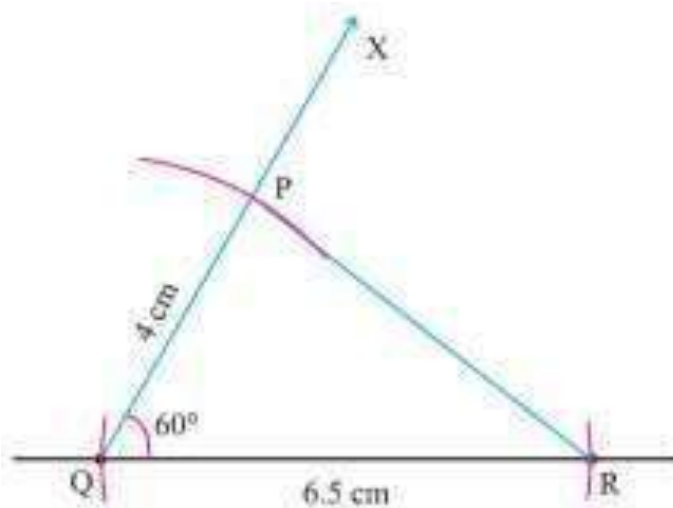


Figure 56: Construction Triangle

When two angles and their included side is given

To construct a $\triangle ABC$ in which $\angle B = 60^\circ$; $\angle C = 45^\circ$ and their included side $BC = 3\text{cm}$

- Draw $BC = 3\text{cm}$
- Construct $\angle BCQ = 45^\circ$
- Construct $\angle PBC = 60^\circ$
- The lines BP and CQ at point A
- Thus, $\triangle ABC$ is the required triangle

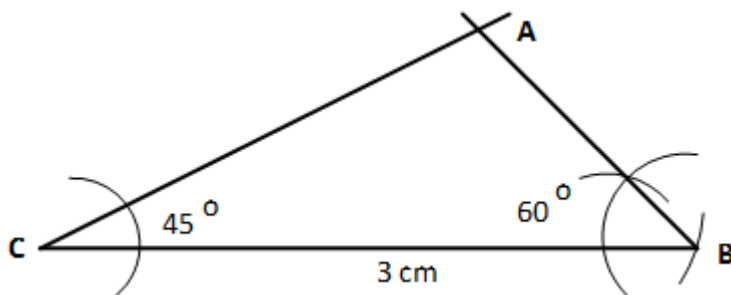


Figure 57: Construction of triangle

Quadrilaterals

This is a plane figure bounded by four straight sides.

Types of quadrilaterals

- Square is a quadrilateral with all four sides of equal length and one of its angles (and hence the other three) a right angle.
- Rectangle is a quadrilateral with its opposite sides of equal length and one of its angles (and hence the other three) a right angle.
- Parallelogram is a quadrilateral with opposite sides equal and therefore parallel.
- Rhombus is a quadrilateral with all four sides equal.
- Trapezium is a quadrilateral with one pair of opposite sides parallel.
- Trapezoid is a quadrilateral with all four sides and angles unequal.

Steps to Construct a Rectangle:

Step 1: Draw a side of given length (say) $QR = 4.8\text{ cm}$

Step 2: Draw side QP (say) of given length perpendicular to QR at Q .

Step 3: Draw side RS (say) of length equal to PQ and perpendicular to QR at R .

Step 4: Draw side PS .

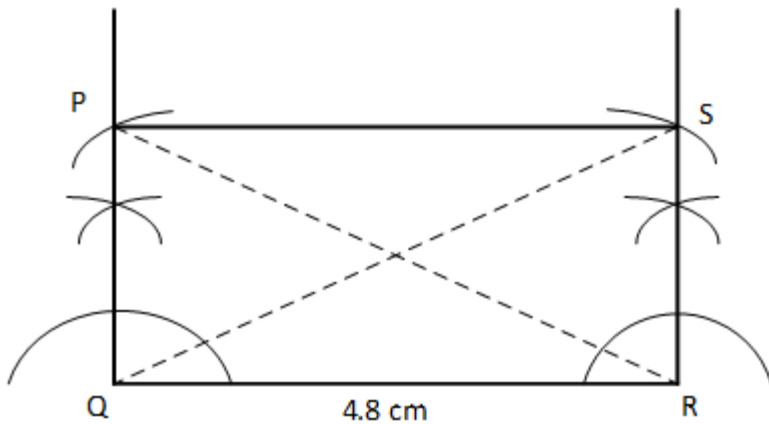


Figure 58: Construct a Rectangle

Steps to Construct a Kite:

Step 1: Draw diagonal (say) AY and its perpendicular bisector.

Step 2: Draw sides say AL and AZ of given length.

Step 3: Draw sides LY and YZ.

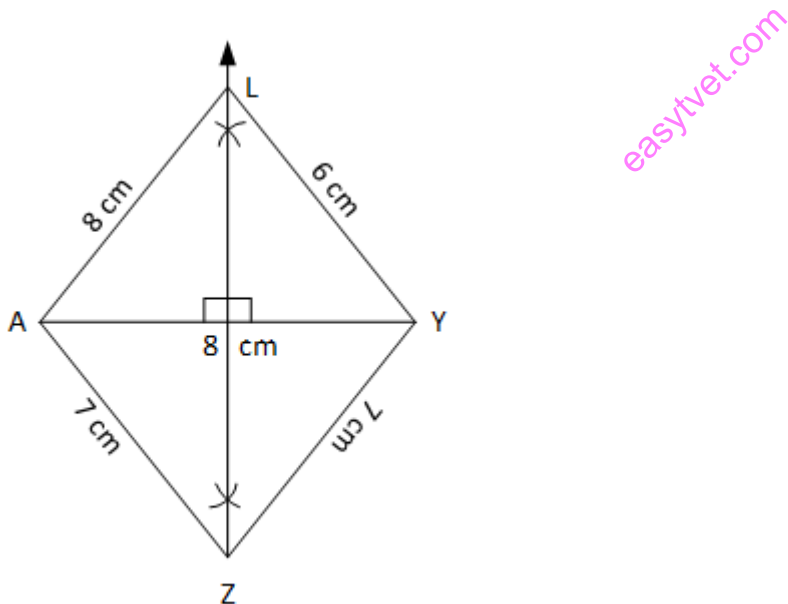


Figure 59: A Kite

Construction of a Square

a) **Construct a square whose one side is given.**

Construct a square ABCD, given that $AB = 3$ cm.

Step 1: Draw line segment $AB = 3$ cm.

Step 2: Construct $\angle ABX = 90^\circ$.

Step 3: Draw an arc with B as the center and radius 5 cm, cutting ray BX at C.

Step 4: Draw an arc with C as the center and radius 5 cm.

Step 5: Draw another arc with A as the center and radius 5 cm, cutting the previous arc at D.

Step 6: Join points D, A and D, C. ABCD is the required square.

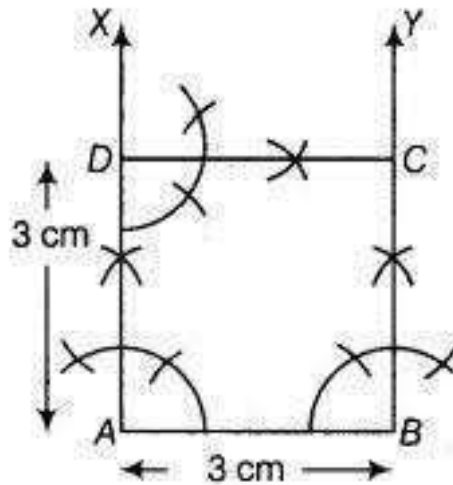


Figure 60: Square given one side

b) Construct a square whose one diagonal is given.

Construct a square ABCD, given that $AC = 5$ cm.

Step 1: Draw diagonal $AC = 5$ cm.

Step 2: Draw the perpendicular bisector of AC, meeting AC at O.

Step 3: Set the compass for a length equal to OA or OC.

Step 4: Draw arcs on the perpendicular bisector with O as the center, without changing the compass setting, cutting the perpendicular bisector at points B and D.

Step 5: Join points A, B; points A, D; points B, C and points C, D. ABCD is the required square.

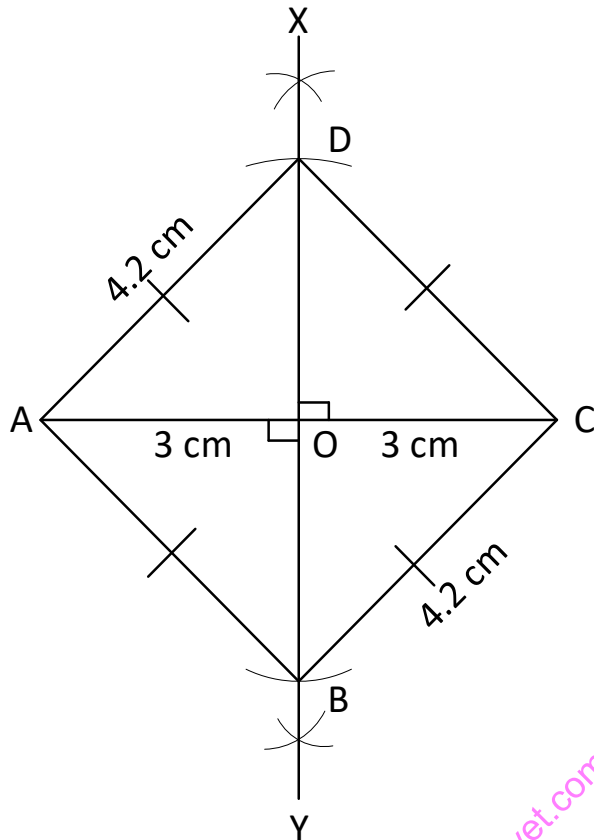


Figure 61: Construct a square whose one diagonal

Construction of Parallelogram

Construction of a parallelogram when both the diagonals and the angle between them are given.

Construct a parallelogram ABCD in which diagonal AC = 8 cm, diagonal BC = 9.2 cm and the angle between them is 50° .

In a parallelogram, diagonals bisect each other:

$$AO = \frac{1}{2} AC = \frac{1}{2} \times 8 = 4 \text{ cm}$$

$$BO = \frac{1}{2} BD = \frac{1}{2} \times 9.2 = 4.6$$

cm

Step 1: Draw line segment AC = 8 cm

Step 2: Draw the perpendicular bisector of AC.

Step 3: Construct. $\angle DAOX = 50^\circ$. Extend XO to Y.

Step 4: With O as the centre and radius equal to 4.6 cm, draw an arc cutting OX at D, and OY at B.

Step 5: Join points A, B, points B, C, points C, D and points A, D. ABCD is the required parallelogram.

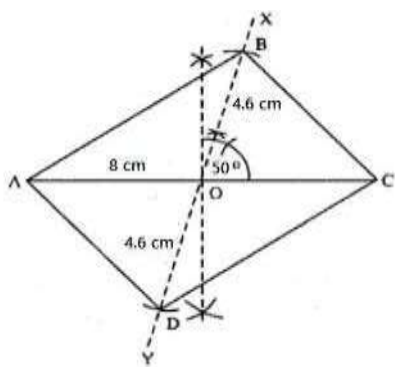


Figure 62: Parallelogram

a) Construct a rhombus given one side and one angle

Construct a rhombus ABCD in which AB = 6 cm and Angle A = 60° Steps of construction:

Step 1: Draw line segment AB = 6 cm.

Step 2: Construct Angle BAX = 60°.

Step 3: With A as the center and radius equal to 6 cm, draw an arc on ray AX.

Step 4: Mark the point of intersection as D.

Step 5: With D as the center and radius equal to 6 cm, draw an arc.

Step 6: With B as the center and the same radius, draw another arc such that it intersects the previous arc at C.

Step 7: Join points C, D and points C, B.

ABCD is the required rhombus.

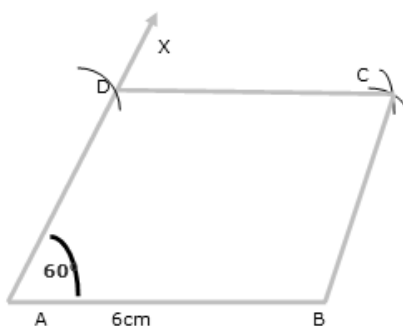


Figure 63: Rhombus

Construction a rhombus given one side and one diagonal:

Construct a rhombus ABCD in which AB = 5.4 cm and AC = 7.4 cm

Step 1: Draw line segment AB = 5.4 cm.

Step 2: With B as the center and radius equal to 5.4 cm, draw an arc.

Step 3: With A as the center and radius equal to 7.4 cm, draw another arc such that it intersects the

previous arc at C.

Step 4: Join points B, C and points A, C.

Step 5: With A as the center and radius equal to 5.4 cm, draw an arc.

Step 6: With C as the center and the same radius, draw another arc such that it intersects the previous arc at D.

Step 7: Join points D, A and points D, C.

ABCD is the required rhombus.

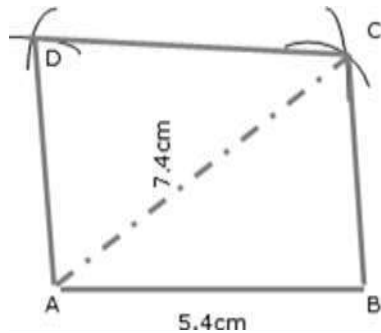


Figure 64: Rhombus

CIRCLES

Definition

A circle is a plane figure bounded by a curved line called the circumference, which is always equidistant from the center.

PROPERTIES OF A CIRCLE

- i. A diameter is a straight line drawn through the center meeting the circumference at both ends.
- ii. A radius is a straight line drawn from the center to the circumference.
- iii. An arc is part of the circumference.
- iv. A chord is any straight line drawn across the circle meeting the circumference at both ends.
- v. A tangent is a straight line which touches the circumference. It is always at right angles to the radius.
- vi. A segment is part of a circle bounded by an arc and a chord.
- vii. A sector is a part of a circle bounded by two radii and an arc.
- viii. A quadrant is part of a circle bounded by two radii at right angles and an arc.
- ix. Concentric circles are circles of the same center but different radii

Eccentric circles are circles of different centers

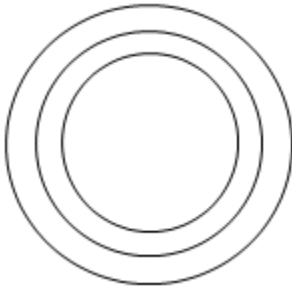


Figure 65: Concentric circles

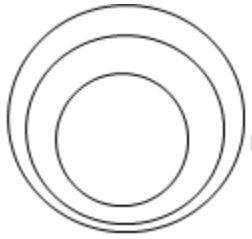


Figure 66: Eccentric circles

POLYGONS

Definitions

A polygon is a plane figure bounded by more than four straight sides. Polygons are frequently referred to have particular names. Some of these are listed below

Polygons

1. A pentagon is a plane figure bounded by five sides
2. A hexagon is a plane figure bounded by six sides
3. A heptagon is a plane figure bounded by seven sides
4. An octagon is a plane figure bounded by eight sides
5. A nonagon is a plane figure bounded by nine sides
6. A decagon is a plane figure bounded by ten sides.
7. A regular polygon is one that has all its sides equal and therefore all its exterior angles equal and all its interior angles equal.

The diameter of that circle is called the diameter of the polygon.

The diagonal of a polygon is the distance from one corner to the corner furthest away from it.

To construct a regular octagon given the diagonal, i.e. within a given circle Steps

1. Draw the circle and insert a diameter AE.
2. Construct another diagonal CG, perpendicular to the first diagonal.

3. Bisect the four quadrants thus produced to cut the circle in B, D, F, and H. ABCDEFGH is the required octagon.

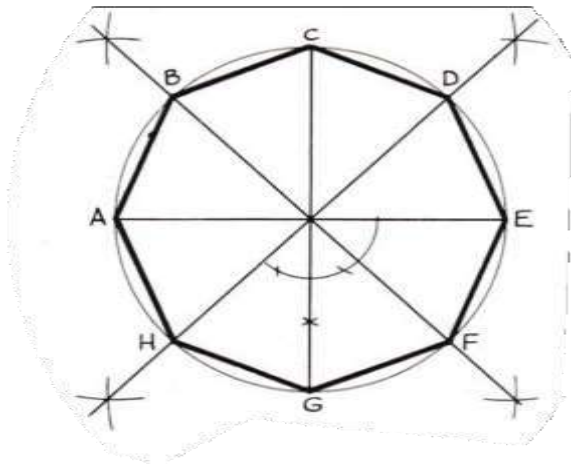


Figure 68: Regular octagon

To construct a rectangular octagon; given the diameter, i.e, within a given square.

1. Construct a square PQSR, length of side equal to the diameter.
2. Draw the diagonals SQ and PR to intersect in T.
3. With centres P, Q, R, and S draw four arcs, radius $PT (=QT = RT = ST)$ to cut the square in A, B, C, D, E, F, G and H.

ABCDEFGH is the required octagon.

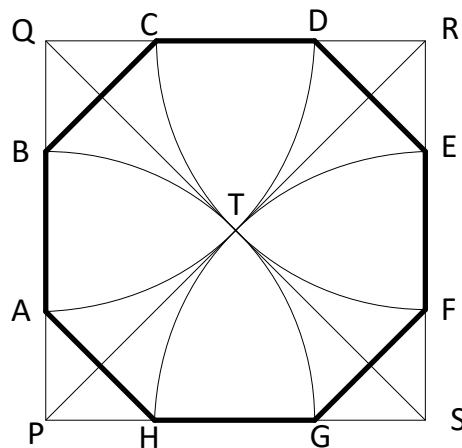


Figure 69: Rectangular octagon

To construct any given polygon; given the length of a side.

There are three fairly simple way of constructing a regular polygon. Two methods require a simple calculation and the third requires very careful construction if it is to be exact. All three methods are shown. The constructions work for any polygon, and a heptagon (seven sides) has been chosen to illustrate them

Method 1

1. Draw a line AB equal in length to one of the sides and produce AB to P.
2. Calculate the exterior angle of the polygon by dividing $360^{\circ}/7 = 51\ 3^{\circ}/7$.
3. Draw the exterior angle PBC so that $BC = AB$.
4. Bisect AB and BC to intersect in O.
5. Draw a circle, centre O and Radius OA ($=OB = OC$).
6. Step off the sides of the figure from C to D, D to E, etc. ABCDEFG is required heptagon.

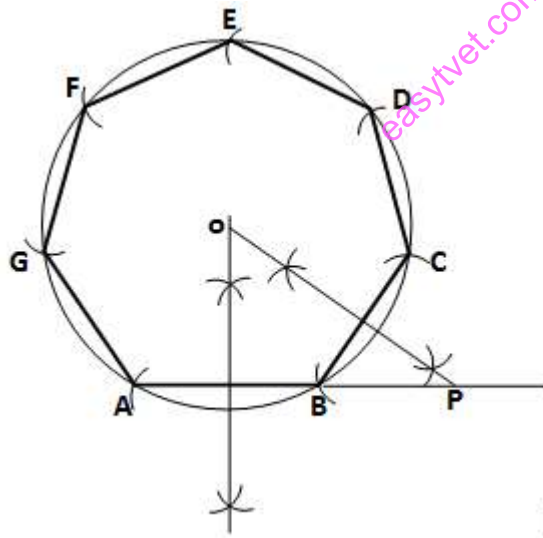


Figure 70: Construction of polygon given the length of a side

Method 2

1. Draw a line AB equal in length to one of the sides
2. From a, erect a semi-circle, radius AB to meet BA produced in P.
3. Divide the semi-circle into the same number of equal parts as the proposed polygon has sides. This may be done by trial and error or by calculation ($180^{\circ}/7 = 25\ 5^{\circ}/7$ for each arc).

4. Draw a line from A to point 2 (For all polygons). This forms a second side to the polygon.
5. Bisect AB and A2 to intersect in O.
6. With center O draw a circle, radius OB ($=OA = O2$).
7. Step off the sides of the figure from B to C, C to D etc. ABCDEFG is the required heptagon.

Method 3

1. Draw a line GA equal in length to one of the sides
2. Bisect GA
3. From A construct an angle of 45° to intersect the bisector at point 4.
4. From G construct an angle of 60° to intersect the bisector at point 6.
5. Bisect between points 4 and 6 to get point 5. Point 4 is the center of the circle containing a square. Point 5 is the center of a circle containing a pentagon. Point 6 is the center of a circle containing a hexagon. By marking off points at similar distance the centers of circles containing any regular polygon can be obtained.
6. Mark off point 7 so that $6 \text{ to } 7 = 5 \text{ to } 6$ and $=4 \text{ to } 5$.
7. With center at point 7 draw a circle, radius 7 to A ($=7 \text{ to } G$).
8. Step off the sides of the figure from A to B, B to C, etc. ABCDEFG is the required heptagon

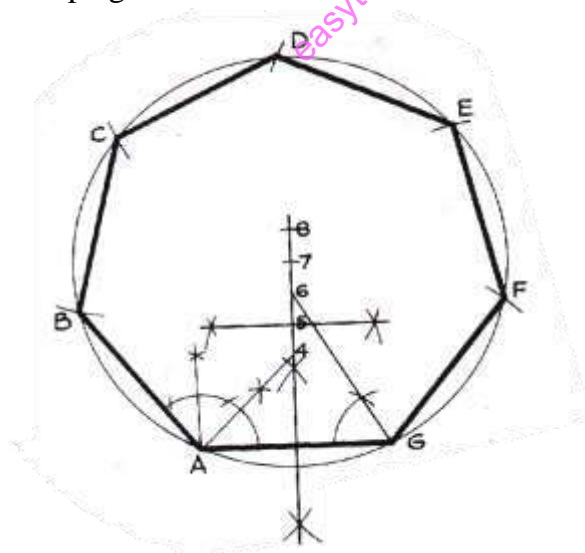


Figure 71: To construction Polygon by 45-60 degrees

To construct a regular polygon given a diagonal i.e. within a given circle

1. Draw the given circle and insert a diameter AM.
2. Divide the diameter into the same number of divisions as the polygon has sides.

3. With center M draw an arc, radius MA. With center A draw another arc of the same radius to intersect the first arc in N.
4. Draw N2 and produce to intersect the circle in B (for any polygon).
5. AB is the first side of the polygon. Step out the other sides BC, CD, etc.
6. ABCDE is the required polygon.
7. draw the given circumference AB
8. Bisect AB in C.
9. With center C, and radius CA, Draw a semi –circle.
10. With center B and radius BC, draw an arc to cut the semi-circle in D.
11. From D draw perpendicular to AB, to cut AB in E.
12. With center E and radius ED draw an arc to cut AB in F. AF is the required diameter. The rest of this chapter shows the construction for finding circles drawn to satisfy certain gain conditions.

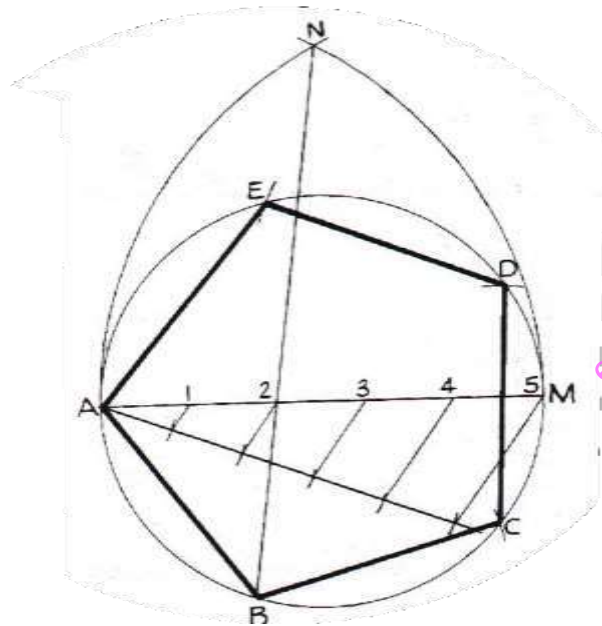


Figure 72: To construct a regular polygon given a diagonal

Tangency

A tangent to a circle is a straight line that touches the circle at one point.

Construct the different conditions of tangency

1. Common tangent to two equal circles
2. Common interior tangent to two equal circles
3. Common tangent between two unequal circles
4. Common internal tangent between two unequal circles

Construct the following conditions Inscribed, Circumscribed and Escribed

i. Inscribed Circle

Bisect any two of the interior angles to intersect in O. (If the third angle is bisected it should also pass through O.)

O is the center of the inscribed circle. This center is called the in center.

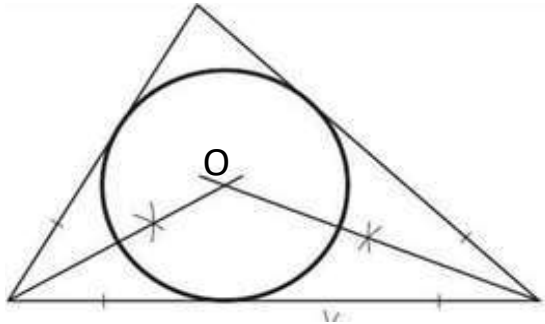


Figure 73: Inscribed Circle

ii. Circumscribed Circle

Perpendicularly bisect any two sides to intersect in O. (If the third side is bisected it should also pass through O). O is the centre of the circumscribed circle. This centre is called the circumcenter.

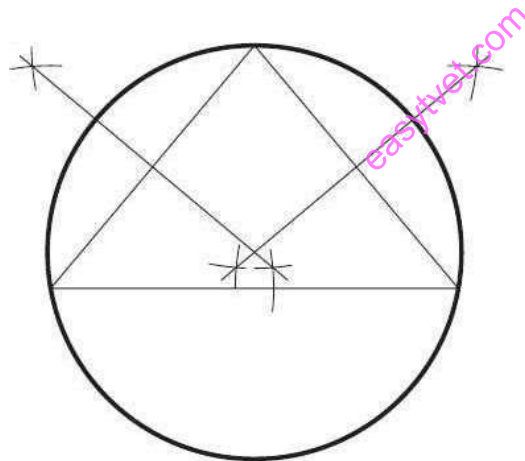


Figure 74: Circumscribed Circle

iii. Escribed Circle

An escribed circle is a circle that touches a side and the two adjacent sides produced. Thus, the first step is to produce the adjacent sides.

Bisect the exterior angles thus formed to intersect in O. O is the centre of the escribed circle

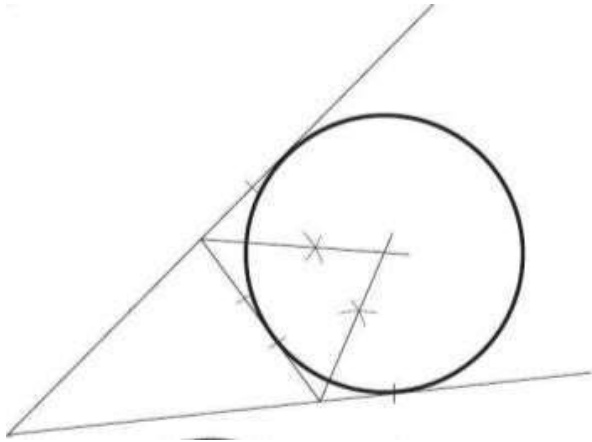


Figure 75: Escribed Circle

Construction of different angles

Construction of an angle using compass and ruler

To draw an angle equal to a given angle

In this section, we will learn how to construct angles of 60° , 30° , 90° , 45° and 120° with the using a ruler and compasses only.

Construction of some standard angles

Construction of an angle of 60°

In order to construct an angle of 60° with the help of ruler and compasses only, we follow the following steps:

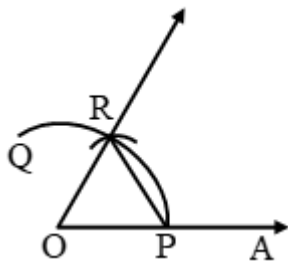


Figure 76: angle of 60°

Steps of Construction

Step 1: Draw a ray OA.

Step 2: With centre O and any radius draw an arc PQ with the help of compasses, cutting the ray OA

at P.

Step 3: With centre P and the same radius draw an arc cutting the arc PQ at R.

Step 4: Join OR and produce it to obtain ray OB.

The angle $\angle AOB$ so obtained is the angle of measure 60° .

Justification: In above figure, join PR.

In $\triangle OPR$, we have

$OP = OR = PR$

$\Rightarrow \triangle OPR$ is an equilateral triangle.

$\Rightarrow \angle POR = 60^\circ$

$\Rightarrow \angle AOB = 60^\circ$ [$\because \angle POR = \angle AOB$]

(ii) **Construction of an Angle of 30°**

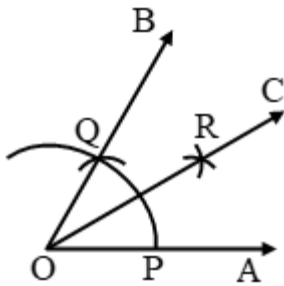


Figure 77: Angle of 30°

easytvet.com

Steps of Construction:

Step 1: Draw $\angle AOB = 60^\circ$ by using the steps mentioned above.

Step 2: With centre O and any convenient radius draw an arc cutting OA and OB at P and Q respectively.

Step 3: With centre P and radius more than $\frac{1}{2}(PQ)$, draw an arc in the interior of $\angle AOB$.

Step 4: With centre Q and the same radius, as in step III, draw another arc intersecting the arc in step III at R.

Step 5: Join OR and produce it to any point C.

Step 6: The angle $\angle AOC$ is the angle of measure 30° .

(iii) Construction of An Angle of 90°

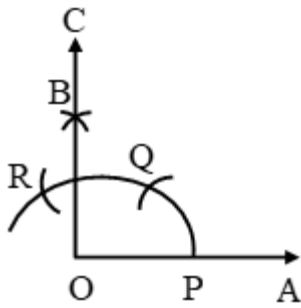


Figure 78: An Angle of 90°

Steps of Construction:

Step 1: Draw a ray OA.

Step 2: With O as centre and any convenient radius, draw an arc, cutting OA at P.

Step 3: With P as centre and the same radius, an arc cutting the arc drawn in step 2 at Q.

Step 4: With Q as centre and the same radius as in steps 2 and 3, draw an arc, cutting the arc drawn in step 2 at R.

Step 5: With R as centre and the same radius, draw an arc.

Step 6: With R as centre and the same radius, draw an arc, cutting the arc drawn in step V at B.

Step 7: Draw OB and produce it to C. $\angle AOC$ is the angle of measure 90° .

(iv) Construction of An Angle of 45°

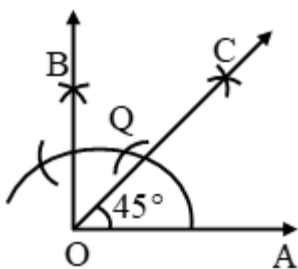


Figure 79: An Angle of 45°

Steps of Construction:

Step 1: Draw $\angle AOB = 90^{\circ}$ by following the steps given above.

Step 2: Draw OC, the bisector of $\angle AOB$.

The angle $\angle AOC$ so obtained is the required angle of measure 45° .

(v) Construction of An Angle of 120°

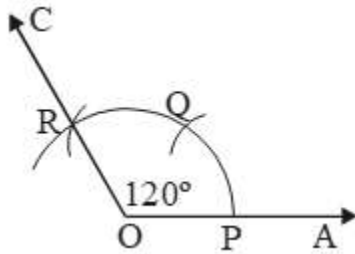


Figure 80: An Angle of 120°

Steps of Construction:

- Step 1:** Draw a ray OA.
- Step 2:** With O as centre and any convenient radius, draw an arc cutting OA at P.
- Step 3:** With P as centre and the same radius draw an arc, cutting the first arc at Q.
- Step 4:** With Q as centre and the same radius, draw an arc, cutting the arc drawn in step II at R.
- Step 5:** Join OR and produce it to any point C. $\angle AOC$ so obtained is the angle of measure 120°

<https://www.aplustopper.com/construction-of-angles-using-compass-ruler/>

Measurement of different angles

Different types of angles

Angle:

Two rays with a common end point form an angle. OA, OB is rays & O is end point.

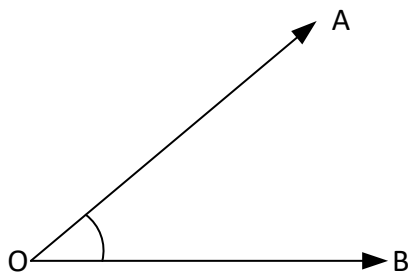


Figure 81: Rays & end point of an angle

Types of Angles

In geometry, angles can be classified according to the size (or magnitude) of the angle.

1. **Right angle:** An angle, whose measure is 90° , is called a right angle. Two lines that meet at a right angle are said to be perpendicular.

2. **Acute angle:** An angle, whose measure is less than 90° , is called an acute angle.
3. **Obtuse angle:** An angle, whose measure is greater than 90° and less than 180° , is called an obtuse angle.
4. **Straight angle:** An angle whose measure is 180° is called a straight angle.
5. **Reflex angle:** An angle, whose measure is more than 180° but less than 360° , is called a reflex angle.
6. **Complete angle:** An angle whose measure is 360° is called a complete angle.
7. **Zero angles:** An angle whose measure is 0° is called a zero angle.

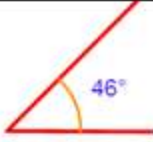

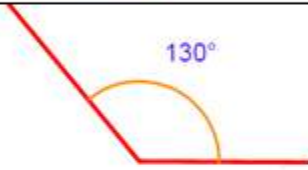
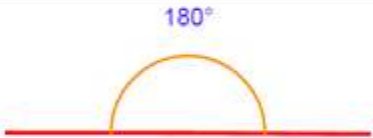
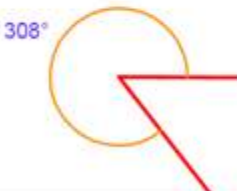
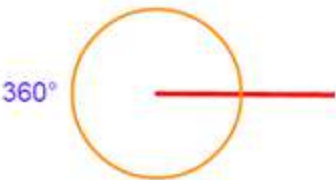
Type of Angle	Description	Example
Acute Angle	An angle that is less than 90°	
Right Angle	An angle that is exactly 90°	
Obtuse Angle	An angle that is greater than 90° and less than 180°	
Straight Angle	An angle that is exactly 180°	
Reflex Angle	An angle that is greater than 180° and less than 360°	
Full Angle	An angle that is exactly 360°	

Table 10: types of angles

Measure of an angle:
 The amount of turning from OA to OB is called the measure of $\angle AOB$, written as $m \angle AOB$. An angle is measured in degrees denoted by $^{\circ}$.

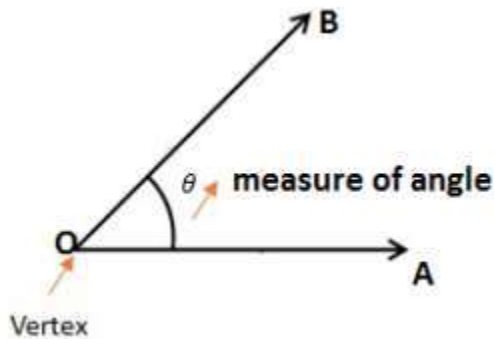


Figure 82: Measure of an angle

An angle of 360° :

If a ray OA starting from its original position OA, rotates about O, in the anticlockwise direction and after making a complete revolution it comes back to its original position, we say that it has rotated through 360 degrees, written as 360° .

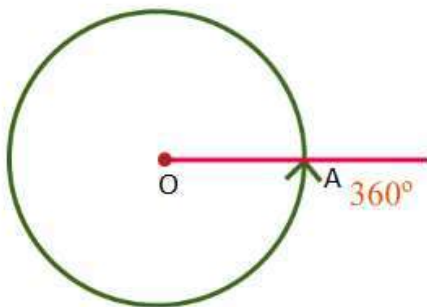


Figure 83: Angle of 360°

<https://www.aplustopper.com/different-types-of-angles/>

A PROTRACTOR

Protractor: The Protractor is a circular or semi-circular tool for measuring angles. The units of measurement used are degrees. Some protractors are simple half-discs. More advanced protractors

usually have one or two swinging arms, which can be used to help measuring angles.

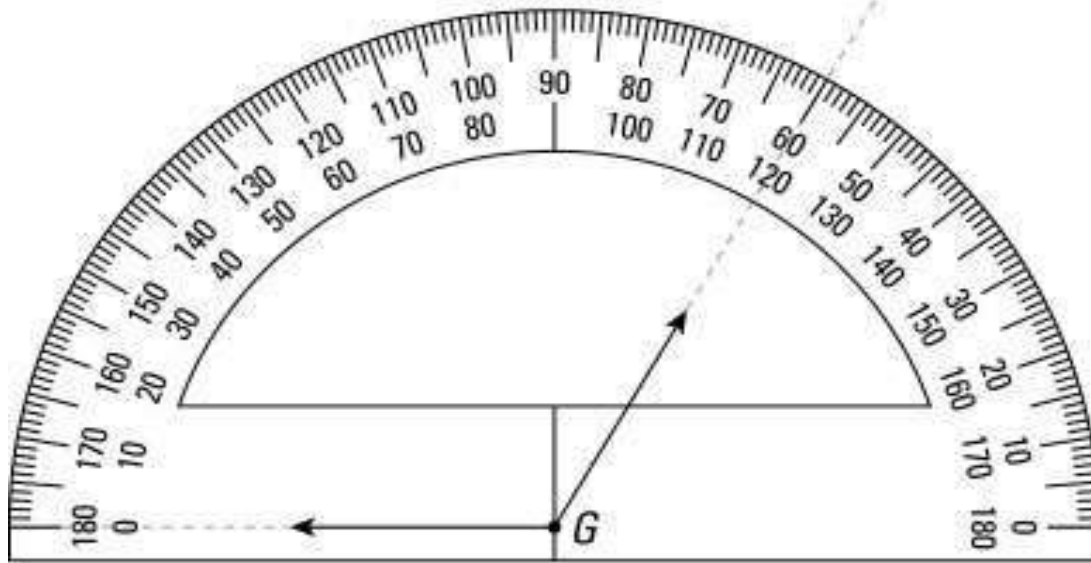


Figure 84: The handy-dandy protractor.

How to use a protractor

1. Place the notch or center point of your protractor at the point where the sides of the angle meet (the vertex).
2. Place the protractor so that one of the lines of the angle you want to measure reads zero (that's actually 0°).
3. Read the number off the protractor where the second side of the angle meets the protractor.

Bisection of different angles and lines

1. Bisect a given angle

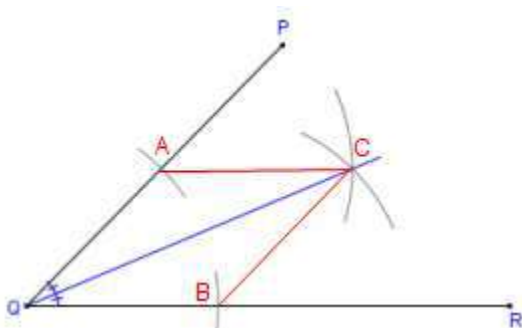


Figure 85: Bisection of an angle

- i. Draw line QP and QR making the given angle.

- ii. With centre Q and any convenient radius R draw an arc intersecting the sides at A and B.
- iii. With centres A and B and radius larger than half the chord length AC, draw arcs intersecting at C.
- iv. Join QC, $\angle PQC = \angle RQC$

Bisecting a Line

Draw a line segment AB of the desired length by using a graduated ruler.

1. With A as centre and radius more than half of AB, draw arcs, one on each side of AB.
2. With B as centre and the same radius as in step 2, draw arcs cutting the arcs drawn in step 2 at C and E respectively.
3. Draw the line segment with C and E as end-points. Suppose it meets AB at D. Then bisects the line segment AB.

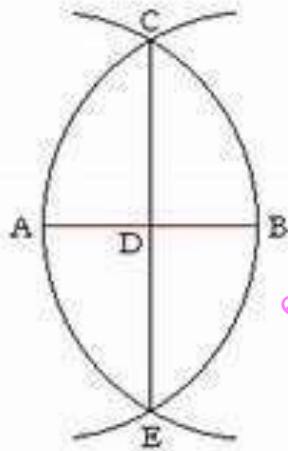


Figure 86: Bisection of line

Standard drawing conventions

In the construction industry all drawings are carried out to a British Standard referred to as BS 1192.

Dimensioning

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.

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. Never repeat a dimension.
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 millimeters, 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 center lines should be done by a long dash and not a short dash.
9. Circles are usually dimensioned using the measurement of their diameter.
10. There are dimension lines and projection lines. Projection lines are thin lines, which begin 1mm from the drawing and extend beyond the last dimension line by 2mm. They define the area being dimensioned and never touch the actual object. Dimension lines are also thin lines with arrows placed at each end that touch the projection line.
11. Each dimension line starts 10mm from the object and is then 10mm apart. The smaller dimensions are placed closer to the object. Longest dimension lines are furthest away from a view (for example, total height).
12. Each Dimension Line has an arrowhead that can be open or closed. Arrowheads touch (but do not cross) projection lines.
13. Dimension numbers can be written vertically or horizontally. The selection of vertical or horizontal writing must be consistent throughout the drawing.

Dimensions should be shown as follows:

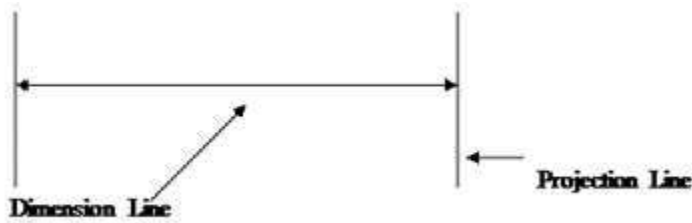


Figure 87: Dimension line and projection line

The conventions relating to dimensions are as follows:

- State dimensions once only.
- Place in the most appropriate view.
- Keep related dimensions on the same view.
- Select the functional dimensions.
- Avoid redundant dimensions.

Give metric dimensions to the least number of significant figures, for example;

2.5	not	2.50
3	not	3.0

Dimensions less than 1 are expressed with a zero preceding the decimal point; 0.5 not 5

Letters and Numbers

All drawings require some form of lettering and numbers. The principles to remember are:

They should be legible and clear – especially numbers, as they often have to be read on their own.

They should be of a suitable size and not less than 3mm tall. Title blocks and relative information are usually larger.

They should be correctly spaced and positioned. Notes and captions should be placed so that they can be read in the same direction as in the title block. In other words it should not be necessary to turn a drawing on its side to read the information.

Notes should be grouped together and not spread over the drawing.

Underlining is not recommended.

Borders and Title Blocks

One of the most important features of any drawing is the border and title block. The border (or margin) is a line which follows the outer edge of the drawing and is usually 10 or 20mm inside it. This margin is very important because everything inside it forms part of any contract. The 'Title Block' is locked within the boarder and contains information such as:

- i. Project title
- ii. The subject
- iii. The date of the original drawing.
- iv. Dates of any revisions.
- v. Job Number.
- vi. Drawing Number.
- vii. Scale.
- viii. The name of the person who drew up the drawing.
- ix. Name of architects, consultant engineers or surveyors.

Title Blocks are usually located along the bottom or sides of drawings as shown below:

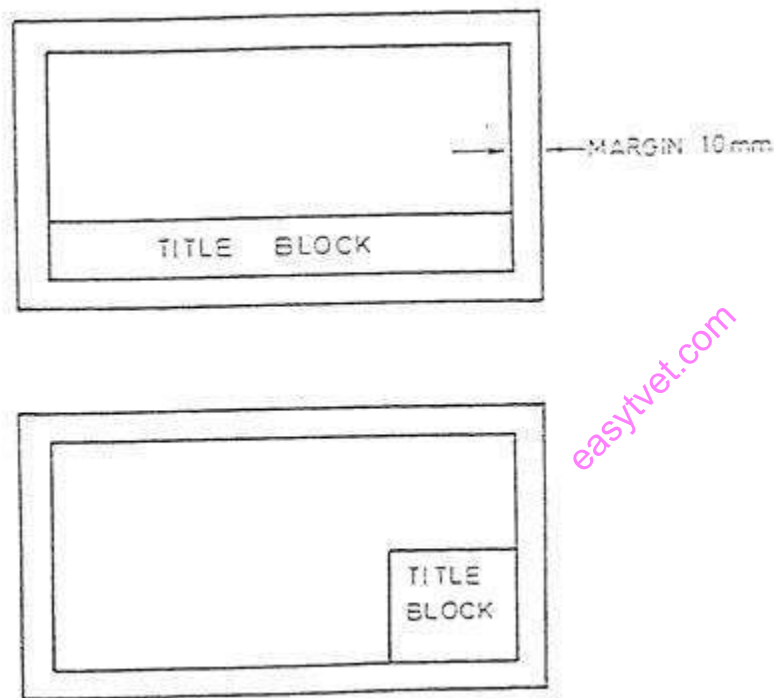


Figure 88: Title block styles

Scales

A scale can be used to increase the detail of a small object or to accurately represent a large object on a smaller piece of paper. The majority of scaled work done in the construction industry is to reduce objects to a smaller more suitable size that will fit on a sheet of paper. The list below shows the scales used in BS 1192:

Block Plans 1:2500. These show the outlines of buildings and may also indicate roads, railway lines or rivers.

Site Plans: Between 1:500 and 1:2500 .Although often drawn at the same scale as the block plan site plans only give details relevant to the actual project. These details could relate to landscaping arrangements or show underground drainage pipe-work.

General Location Drawings 1:200 or 1:100. These drawings can show pipe runs within the building and the location of radiators and sanitary fixtures.

When details of boiler houses or plant rooms are given the scale may increase to 1:50. This enables greater detail to be shown. Where particular detail is necessary the scale could be as high as 1:20 or 1:10. This could be in the case of a bracket or support for a piece of equipment.

LOCI

A locus (Plural loci) is the path traced out by a point which moves under given definite conditions or rules. You may not have been aware of it, but you have met loci many times before. One of the most common loci is that of a point which moves so that its distance from another fixed point remains constant: this produces a circle. Another locus that you know is that of a point which moves so that its distance from a line remains constant: this produces parallel lines.

The problems of loci can take several different forms. One important practical application in building is in the setting out of curves such as parabolic, hyperbolic and circular curves. Another important application of loci in engineering is finding the path traced out by points on mechanisms. This may be simply to see if there is sufficient clearance around a mechanism.

ELLIPSE

Definition

An ellipse is the locus of a point which moves so that distance from a fixed point (called the focus) bears a constant ratio, always less than 1, to its perpendicular distance from a straight line called the directrix). An ellipse has two foci and two and two directrices. Figure 3 shows how to draw an ellipse given the relative positions of and the directrix, and the eccentricity. In this case the focus and the directrix are 20mm apart and the eccentricity is $\frac{4}{3}$

The first point to plot is the one that lies between the focus and the directrix. This is done by dividing DF in the same ratio as the eccentricity $\frac{4}{3}$. The other end of the ellipse, point is found by working out the simple algebraic sum shown on

The condition for the locus is that it is always $\frac{3}{4}$ as far from the focus as it is from the directrix. It is therefore $\frac{3}{4}$ as far from the directrix as it is from the focus. Thus. If the point is 30mm from F, it is $40\frac{3}{4}$ mm from the directrix; if the point is 20mm from F, it is $\frac{3}{4} \times 20$ mm from the directrix; if the

point is 30mm from F, it is $\frac{3}{4} \times 30\text{mm}$ from the directrix. The intersections of radii drawn from F and line drawn parallel to the directrix, their distance from the directrix being proportional to the radii, give the outline of the ellipse. These points are joined together with a neat freehand curve.

General method of construction of an ellipse

To construct an ellipse when the distance of the focus from the directrix is equal to 50 mm and eccentricity is $\frac{2}{3}$

- i. Draw any vertical line AB as directrix.
 - ii. At any point C on it, draw the axis perpendicular to the AB (directrix).
 - iii. Mark a focus F on the axis such that $CF = 50 \text{ mm}$.
 - iv. Divide CF into 5 equal divisions (sum of numerator and denominator of the eccentricity)
 - v. Mark the vertex V on the third division-point from C.
Thus, eccentricity, $e = VF/VC = \frac{2}{3}$
 - vi. A scale may now be constructed on the axis (as explained below), which will directly give the distances in the required ratio
 - vii. At V, draw a perpendicular VE equal to VF. Draw a line joining C and E.
thus, in triangle CVE, $VE/VC = VF/VC = \frac{2}{3}$
 - viii. Mark any point 1 on the axis and through it, draw a perpendicular to meet CE-produced at 1'.
 - ix. With centre F and radius equal to 1-1', draw arcs to intersect the perpendicular through 1 at points P₁ and P'₁. These are the points on the ellipse, because the distance of P₁ from AB is equal to C1,
 - x. $P_1F = 1 - 1'$
- and

$$\frac{1 - 1'}{C1} = \frac{VF}{VC} = \frac{2}{3}$$

Similarly, mark points 2, 3 etc. on the axis and obtain points P₂ and P'₂, P₃ and P'₃ etc. (x)

Exercise

Draw the ellipse through these points. It is a closed curve having two foci and two directrices.

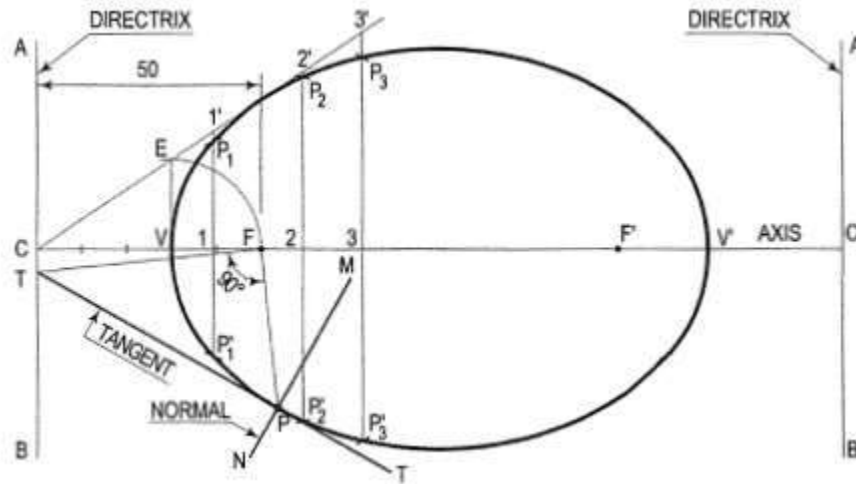


Figure 89: General method of construction of an ellipse

To construct an ellipse, given the major and minor axes.

The ellipse is drawn by, first determining a number of points through which it is known to pass and then, drawing a smooth curve through them, either freehand or with a french curve. Larger the number of points, more accurate the curve will be.

Concentric circles method

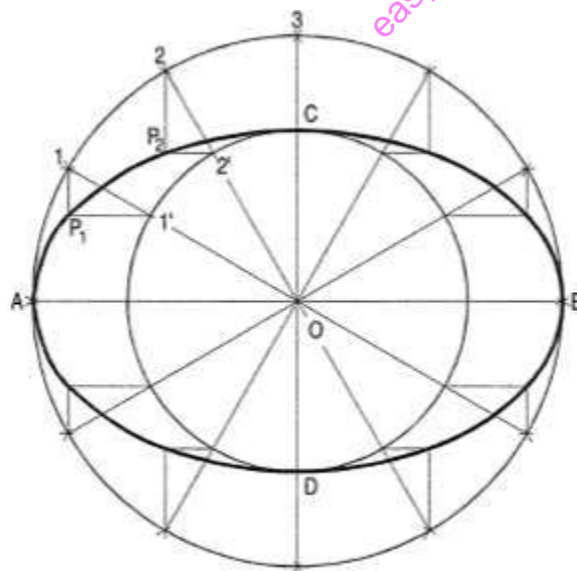


Figure 90: Concentric circle method

Concentric circle method

- i. Draw the major axis AB and the minor axis CD intersecting each other at O.

- ii. With centre O and diameters AB and CD respectively, draw two circles.
- iii. Divide the major-axis-circle into a number of equal divisions, say 12 and mark points 1, 2 etc. as shown.
- iv. Draw lines joining these points with the centre O and cutting the minor-axis-circle at points 1', 2' etc. (v) Through point 1 on the major-axis-circle, draw a line parallel to CD, the minor axis.
- v. Through point 1' on the minor-axis-circle, draw a line parallel to AB, the major axis. The point P₁, where these two lines intersect is on the required ellipse.
- vi. Repeat the construction through all the points. Draw the ellipse through A, P₁, P₂ etc.

Oblong method

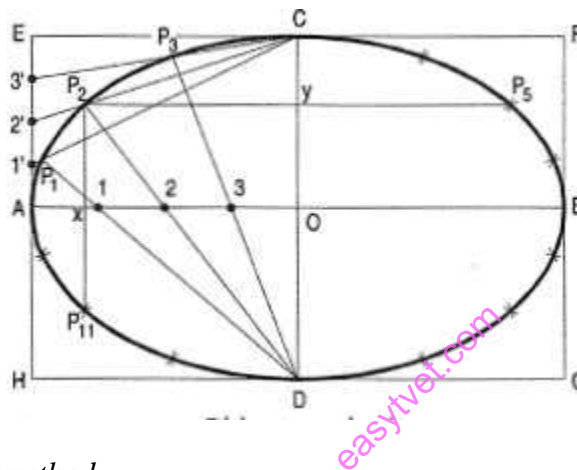


Figure 91: Oblong method

- (i) Draw the two axes AB and CD intersecting each other at O.
- (ii) Construct the oblong EFGH having its sides equal to the two axes.
- (iii) Divide the semi-major-axis AO into a number of equal parts, say 4, and AE into the same number of equal parts, numbering them from A as shown.
- (iv) Draw lines joining 1', 2' and 3' with C.
- (v) From D, draw lines through 1, 2 and 3 intersecting C₁, C₂ and C₃ at points P₁, P₂ and P₃ respectively.
- (vi) Draw the curve through A, P₁ C. It will be one quarter of the ellipse.
- (vii) Complete the curve by the same construction in each of the three remaining quadrants.

As the curve is symmetrical about the two axes, points in the remaining quadrants may be located by drawing perpendiculars and horizontals from P₁, P₂ etc. and making each of them of equal length on both the sides of the two axes. For example, P₂x = x P₁₁ and P₂y = yP₅.

Trammel method

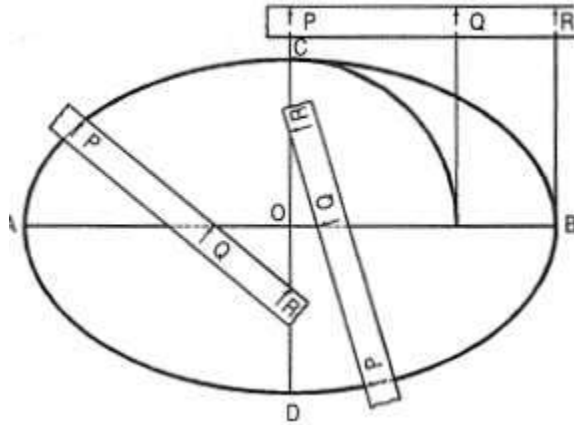
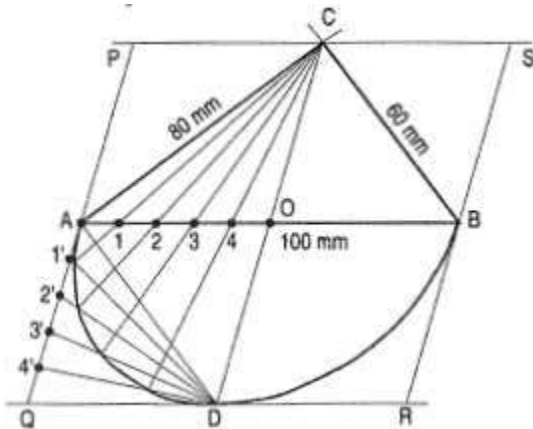


Figure 92: Trammel method

- i. Draw the two axes AB and CD intersecting each other at O. Along the edge of a strip of paper which may be used as a trammel, mark PQ equal to half the minor axis and PR equal to half the major axis.
- ii. Place the trammel so that R is on the minor axis CD and Q on the major axis AB. Then P will be on the required ellipse. By moving the trammel to new positions, always keeping R on CD and Q on AB, obtain other points. Draw the ellipse through these points.

Learning activity

1. ABC is a triangle such that AB = 100 mm, AC = 80 mm and BC = 60 mm. Draw an ellipse passing through points A, B and C. (figure below)



- i. Draw horizontal line AB = 100 mm. Take A as centre draw an arc of 80 mm. Similarly B as centre and the radius equal to 60 mm, draw the arc such that it intersects previously drawn arc at the point C. Join ABC to complete triangle.
- ii. Mark the mid point of AB such that OA = OB = 50 mm. Join OC and extend CO such that CO = OD.

- iii. Draw parallel lines from C and D to the line AB. Similarly draw parallel lines from A and B to the line CD and complete the rhombus (PQRS).
- iv. Divide AO into convenient number of equal parts $A1 = 12 = 23 = 34 = 40$ and AQ to same number of equal parts $A1' = 1' 2' = 2' 3' = 3' 4' = 4' Q$. Join A, 1', 2', 3', 4' with D. Join C1 and extend it to intersect line 01'. Similarly join C2, C3, C4 and extend it to intersect 02', 03', 04' respective. Draw smooth curve passing through all intersection.
- v. Complete the ellipse by above method for the remaining part.

PARABOLA

Use of parabolic curves is made in arches, bridges, sound reflectors, light reflectors etc. Mathematically a parabola can be described by an equation $y^2 = 4ax$ or $x^2 = 4ay$.

General method of construction of a parabola

To construct a parabola when the distance of the Focus from the directrix is 50 mm.

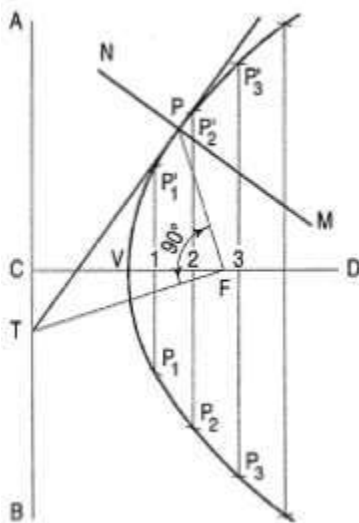


Figure 93: Parabola

Directrix and focus

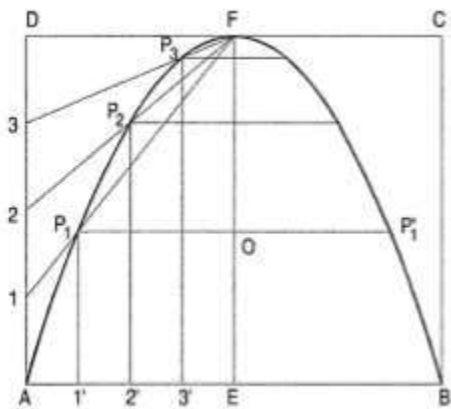
- i. Draw the directrix AB and the axis CD.
- ii. Mark focus F on CD, 50 mm from C.
- iii. Bisect CF in V the vertex (because eccentricity = 1).
- iv. Mark a number of points 1, 2, 3 etc. on the axis and through them, draw perpendiculars to it.
- v. With centre F and radius equal to C1, draw arcs cutting the perpendicular through 1 at P_1 and P'_1 .
Similarly, locate points P_2 and P'_2 , P_3 and P'_3 etc. on both the sides of the axis.

- vi. Draw a smooth curve through these points. This curve is the required parabola. It is an open curve.

Rectangle method

To construct a parabola given the base and the axis.

- (i) Draw the base AB.
- (ii) At its mid-point E, draw the axis ff at right angles to AB.
- (iii) Construct a rectangle ABCD, making side BC equal to ff.
- (iv) Divide AE and AD into the same number of equal parts and name them as shown (starting from A).
- (v) Draw lines joining F with points 1, 2 and 3. Through 1', 2' and 3', draw perpendiculars to AB intersecting F1, F2 and F3 at points P1, P2 and P3 respectively.
- (vi) Draw a curve through A, P1, P2 etc. It will be a half parabola. Repeat the same construction in the other half of the rectangle to complete the parabola. Or, locate the points by drawing lines through the points P1, P2 etc. parallel to the base and making each of them of equal length c on both the sides of ff, e.g. P1O = OP'1. AB and EF are called the base and the axis respectively of the parabola.



Rectangular method

Tangent method

- (i) Draw the base AB and the axis ff. (These are taken different from those in method I.)
- (ii) Produce ff to O so that EF = FO.
- (iii) Join O with A and B. Divide lines OA and OB into the same number of equal parts, say 8.
 - (iv) Mark the division-points as shown in the figure.
- (iv) Draw lines joining 1 with 1', 2 with 2' etc. Draw a curve starting from A and tangent to lines 1-1', 2-2' etc. This curve is the required parabola.

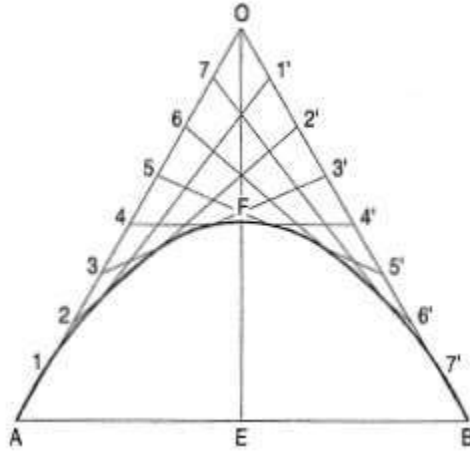


Figure 94: Tangent method of constructing parabola

HYPERBOLA

Definition

A hyperbola is the locus of a point which moves so that its distance from a fixed point (called the focus) bears a constant ratio, always greater than 1, to its perpendicular distance from a straight line (called the directrix).

Figure 45 shows how to draw a hyperbola given the relative positions of the focus and the directrix and the eccentricity ($3/2$). The first point to plot is the one that lies between the focus and the directrix.

This is done by dividing the distance between them in the same ratio as the eccentricity, $3:2$.

The condition for the locus is that it is always $2/3$ as far from the directrix as it is from the focus. Thus, if the point is 15mm from the focus, it is $2/3 \times 15\text{mm}$ from the directrix; if it is 20mm from the focus, it is $2/3 \times 20\text{mm}$ from the directrix. This is continued for as many points as may be required.

Use of hyperbolic curves is made in cooling towers, water channels etc.

Rectangular hyperbola

It is a curve traced out by a point moving in such a way that the product of its distances from two fixed lines at right angles to each other is a constant. The fixed lines are called asymptotes.

This curve graphically represents the Boyle's Law, viz. $P \times V = a$, P = pressure, V = volume and a is constant. It is also useful in design of water channels.

General method of construction of a hyperbola

Mathematically, we can describe a hyperbola by $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$

(figure 44): Construct a hyperbola, from the directrix is 65 mm and eccentricity is f

- i. Draw the directrix AB and the axis CD.
- ii. Mark the focus F on CD and 65 mm from C.
- iii. Divide CF into 5 equal divisions and mark V the vertex, on the second division from C.

$$\text{Thus, eccentricity} = \frac{VF}{VC} = \frac{3}{2}$$

To construct the scale for the ratio draw a line VE perpendicular to CD such that VE = VF. Join C with E.

$$\text{Thus, in triangle CVE, } \frac{VE}{VC} = \frac{VF}{VC} = \frac{3}{2}$$

- i. Mark any point 1 on the axis and through it, draw a perpendicular to meet CE-produced at 1

- ii. With centre F and radius equal to 1-1', draw arcs intersecting the perpendicular through 1 at P₁ and P'₁.
- iii. Similarly, mark a number of points 2, 3 etc. and obtain points P₂ and P'₂, P₃ and P'₃ etc.
- iv. Draw the hyperbola through these points.

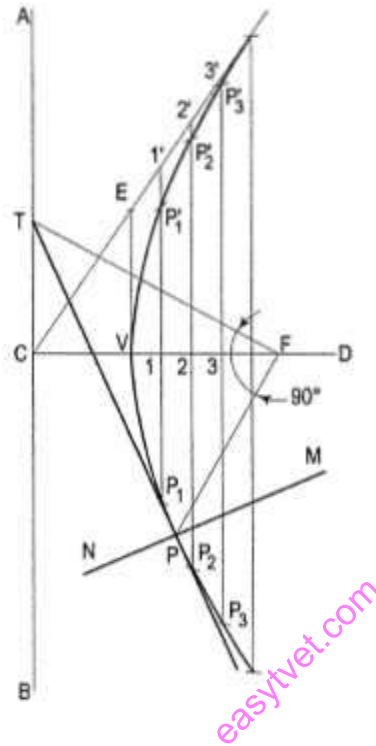
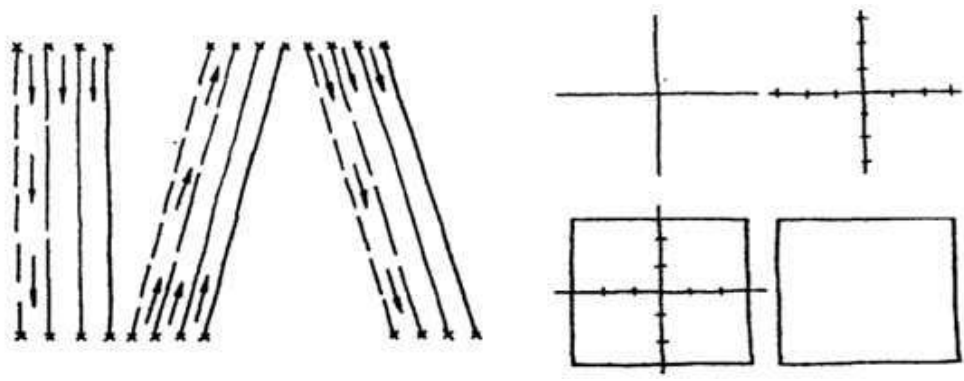


Figure 95

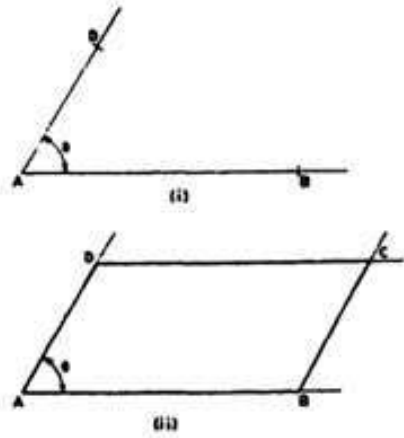
Freehand Sketching

Freehand sketching is one of the effective methods to communicate ideas irrespective of the branch of study. The basic principles of drawing used in freehand sketching are similar to those used in drawings made with instruments.

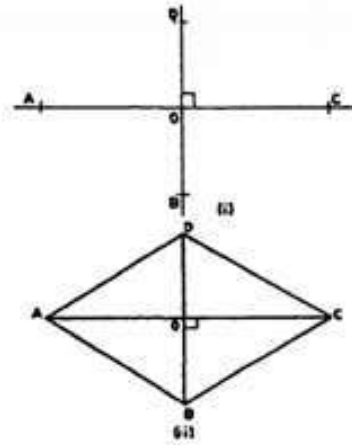


Sketching a Square

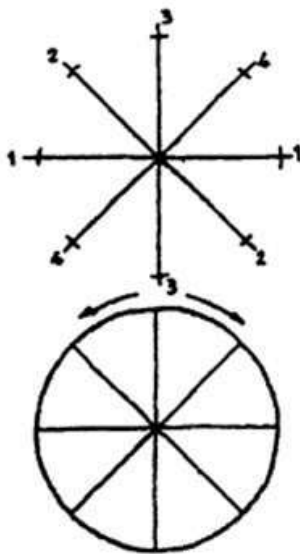
Sketching Straight Lines



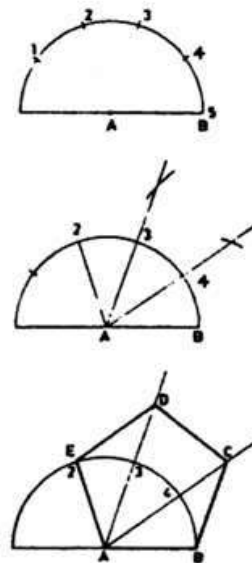
Sketching a Rhombus



Sketching a Parallelogram

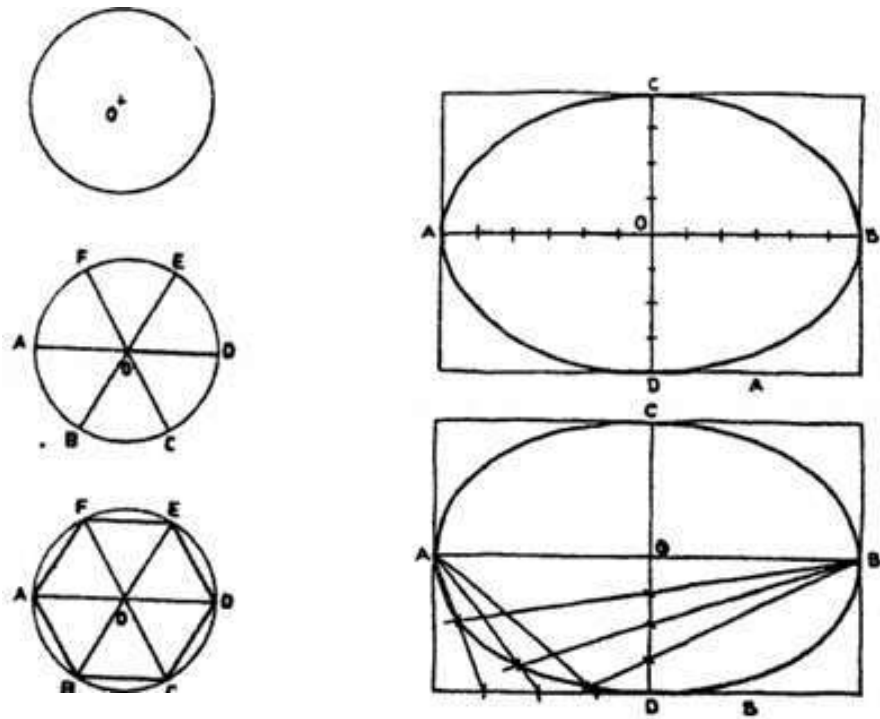


Sketching a Pentagon



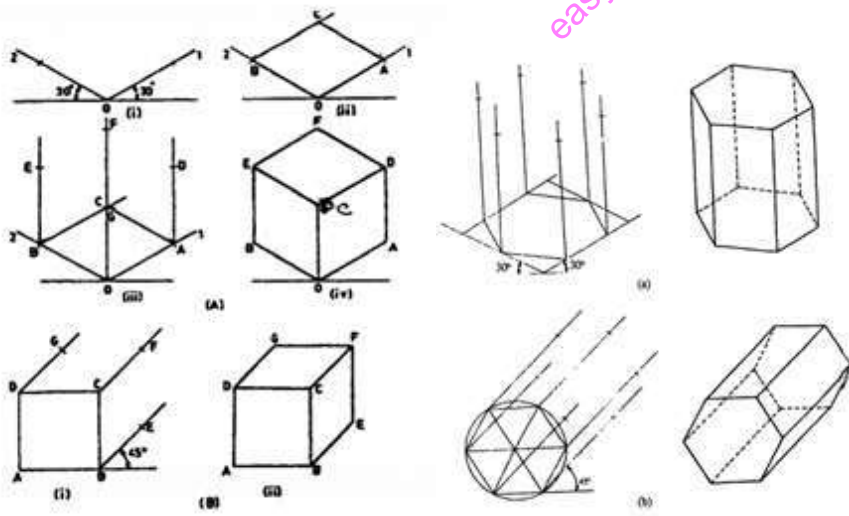
Sketching a Circle

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Sketching an Ellipse

Sketching a Hexagon



Sketching a Hexagonal Prism

Sketching a Cube

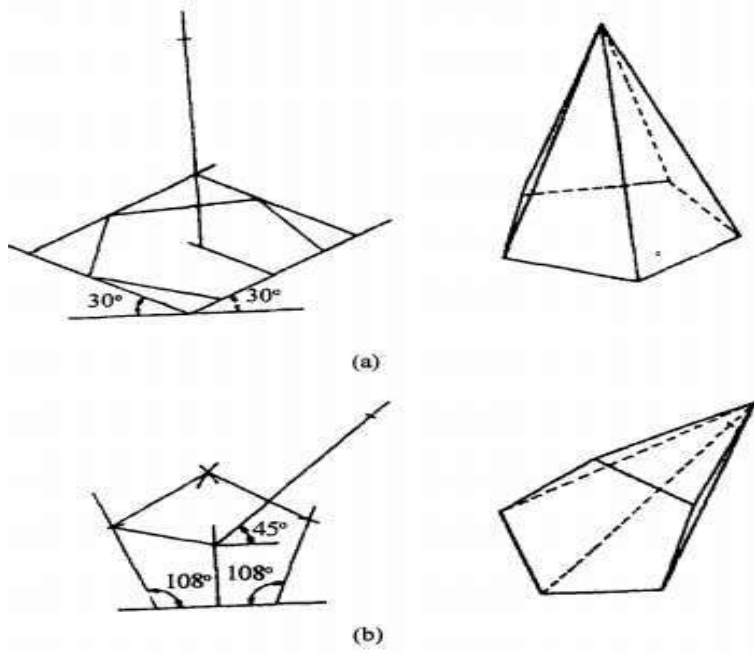
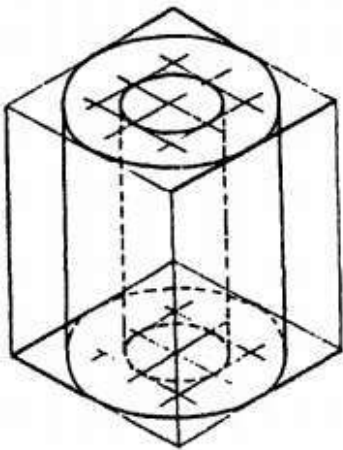
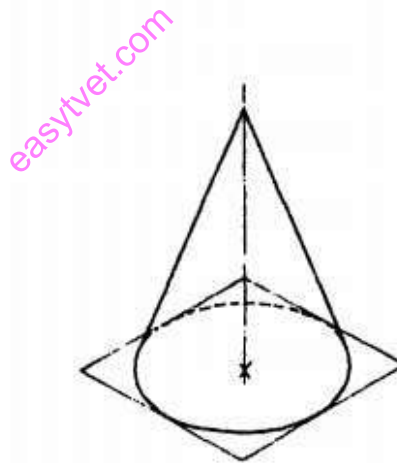


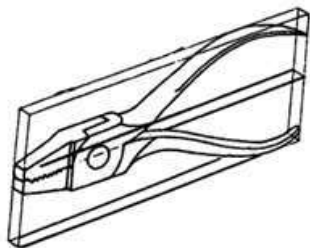
Figure 96: Sketching a Pentagonal Pyramid



Sketching a Cone



Sketching a Hollow Cylinder



Sketching a Ball Peen Hammer



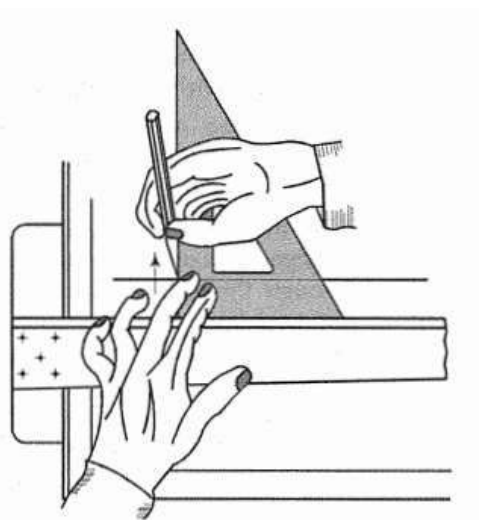
Sketching a Cutting Plier

Learning activities

Learning activity 1: Produce plane geometry

To draw a fine perpendicular to a given horizontal line from a given point within it.

- i. Place the T-square a little below the given line
- ii. Arrange any one set-square with one of the edges containing the right angle touching the working edge of the T-square, and the other edge passing through the given point.
- iii. Hold the T-square and the set-square in this position firmly with the left hand.
- iv. With the right hand, draw the required line through the given point in the upward direction as shown by the arrow. The pencil point should always be in contact with the edge of the set-square. A perpendicular from any given point outside the line can also be drawn in the same manner. Vertical parallel lines may be drawn by sliding the set-square along the edge of the T-square to the required positions.



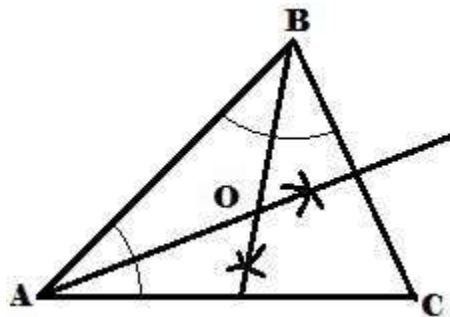
Learning activity 2: Produce plane geometry

To inscribe a regular polygon of any number of sides, say 5, in a given circle

- i. With centre O, draw the given circle.
- ii. Draw a diameter AB and divide it into five equal parts (same number of parts as the number of sides) and number them as shown.
- iii. With centres A and B and radius AB, draw arcs intersecting each other at P.
- iv. Draw a line P2 and produce it to meet the circle at C. Then AC is the length of the side of the pentagon.
- v. Starting from C, step-off on the circle, divisions CD, DE etc., equal to AC.
- vi. Draw lines CO, DE etc., thus completing the pentagon.

Self-assessment

1. How many sides have a regular nonagon?
 - A. 12
 - B. 11
 - C. 10
 - D. 9
2. When the construction is completed, the figure drawn describes _____ circle.



- A. a circumscribed
 - B. a concentric
 - C. an eccentric
 - D. an escribed
 - E. an inscribed
3. Draw a parabola by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 1:1.
 4. Draw a hyperbola by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 2:3.
 5. Draw an ellipse by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 3:2.

6. A ground is in the shape of a rectangle 120 m X 60m. Inscribe an elliptical lawn in it to a suitable scale by concentric circle method.
7. Divide a line of 40 mm in ratio 1:3:4

Tools, Equipment, Supplies and Materials

1. Drawing tools
2. Drawing set
3. Drawing papers
4. Erasers
5. Series of pencils
6. Drawing board

References

1. Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing: Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.
2. Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.
3. Narayana, K. L., Kannaiah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.
4. Reddy, K. V. 2010. Textbook of Engineering Drawing. B.S. Publ., Hyderabad.
5. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College
6. <https://www.aplustopper.com/construction-of-angles-using-compass-ruler/>

4.3 Produce Solid Geometry Drawings

Introduction to the Learning Outcome

This learning outcome is intended to equip the trainee with competence on how to produce solid geometry drawings. Knowledge on how to develop and interpret patterns is learnt and exercised in this learning outcome

Performance Standard

- i. Drawings of patterns are interpreted according to standard conventions
- ii. Patterns are developed in accordance with standard conventions
- iii. Interpretation of sketches and drawings of patterns e.g. cylinders, prisms and pyramids

Information sheet

Concept of developing surfaces

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.

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 following are the methods of development.

i. Parallel-line Development

It is used for developing prisms and single curved surfaces like cylinders in which all the edges / generators of lateral surfaces are parallel to each other.

ii. Radial-line Development

It is employed for pyramids and single curved surfaces like cones in which the apex is taken as center and the slant edge or generator (which are the true lengths) as radius for its development.

Orthographic views

Development of surfaces of pyramids

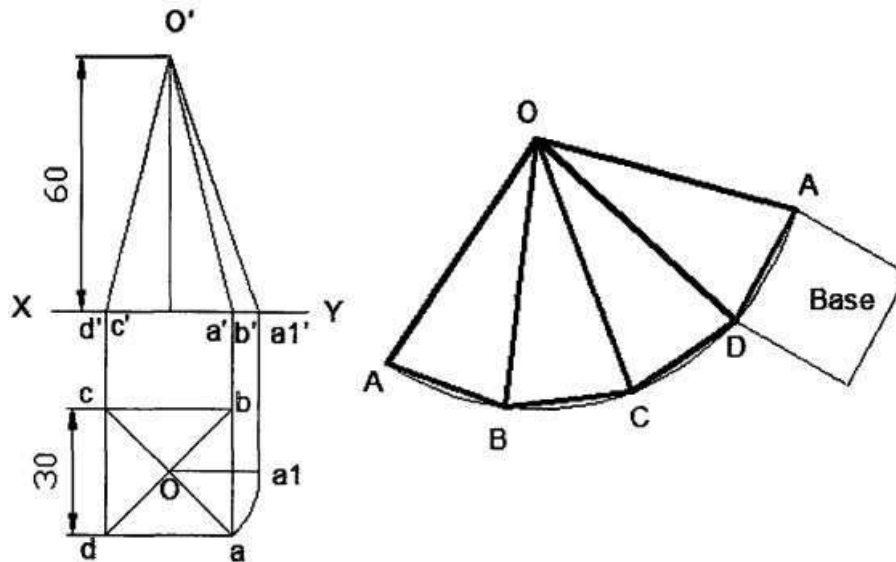


Figure 97: Development of surfaces of pyramids

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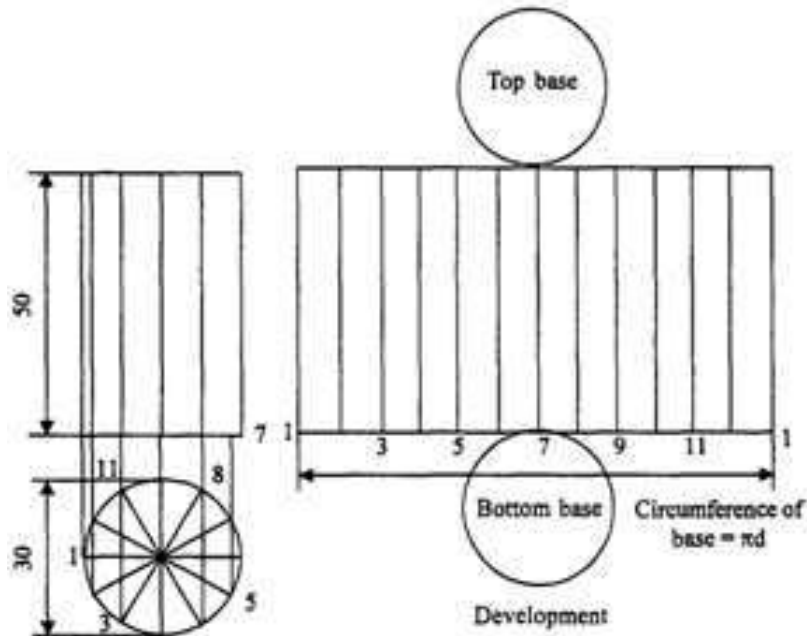


Figure 98: Development of cylinder surfaces

Development of surfaces of cones

The development of the lateral surface of a cone is a sector of a circle. The radius and length of the arc are equal to the slant height and circumference of the base of the cone respectively. The included angle of the sector is given by $(r / s) \times 360^\circ$, where r is the radius of the base of the cone and s is the true length.

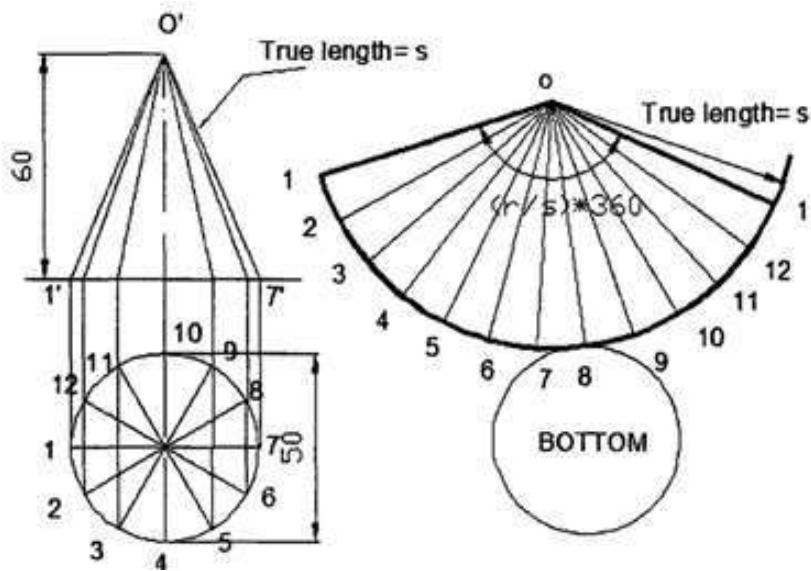


Figure 99: Development and interpenetrations of solids

Development and interpenetrations of solids

Intersection of regular solids

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 necessitates the preparation of the development of the joints objects. Orthographic drawings of lines and curves of intersection of surfaces must be prepared first for the accurate development of objects.

Intersection of cylinder and cylinder

Case I: Cylinders of Same size

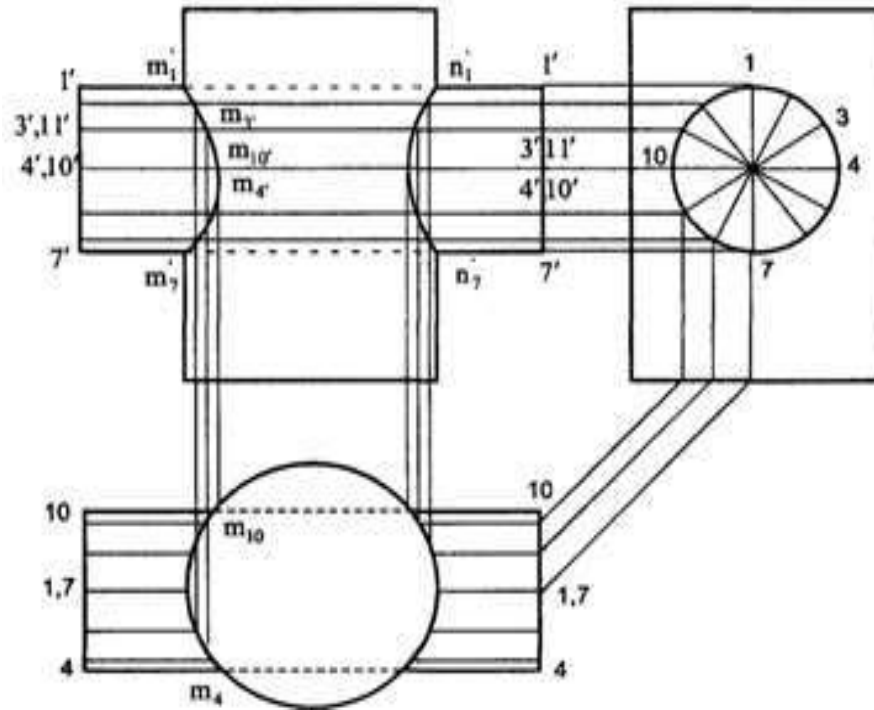
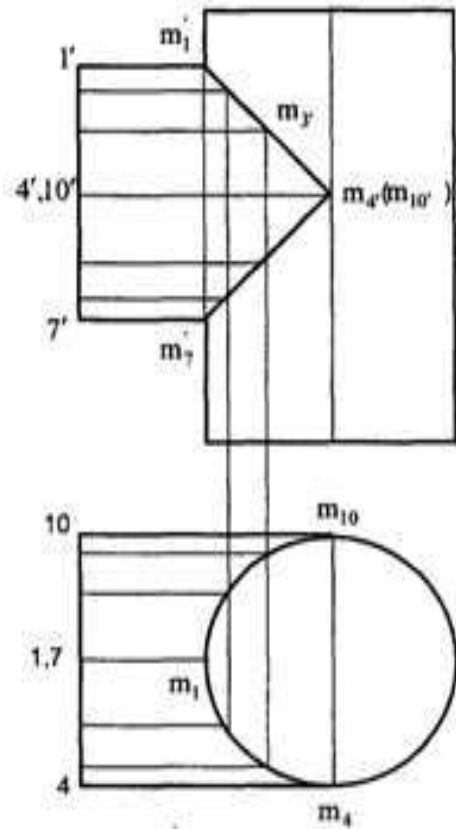


Figure 100: Cylinders of Same size

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Case II: Cylinders of Same size



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Figure 101: Cylinders of Same size

Intersection of prism and prism

When a prism penetrates another prism, plane surface of one prism intersects the plane surfaces of another prism and hence the lines of intersection will be straight lines. In these cases, lines on the surface of one of the solids need not necessarily be drawn as it is done with cylinders. Instead, the points of intersections of the edges with the surface are located by mere inspection. These points are projected in the other view and the lines of intersection obtained.

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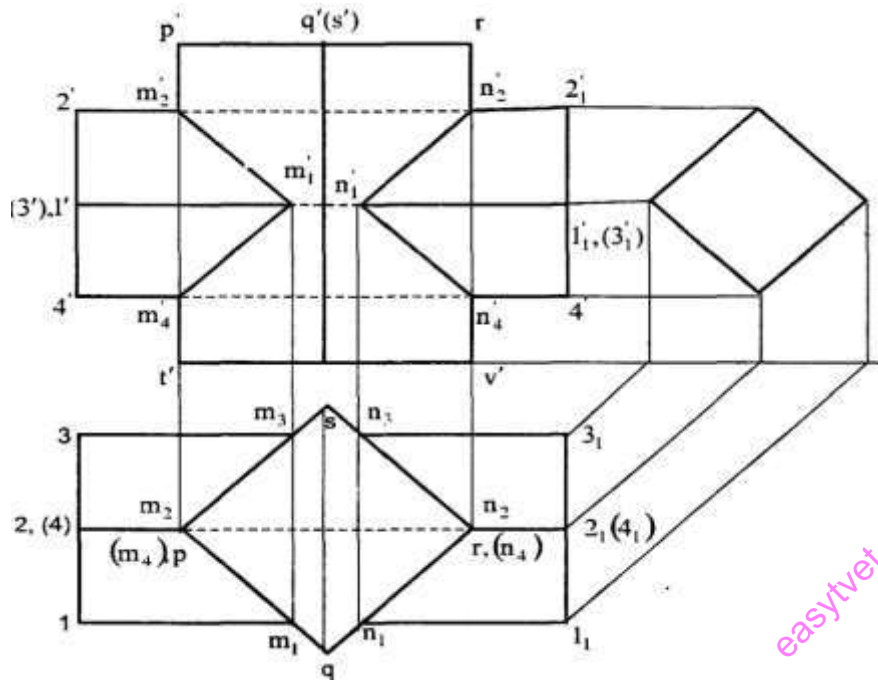


Figure 102: Intersection of prism and prism

Learning activities

Learning activity 1: Produce solid geometry drawings

Develop the lateral surface of the truncated cylinder

- i. Divide the circle in the top view into twelve equal parts. Project the division points to the front view and draw the generators. Mark points a', b' and b₁, c' and c₁ etc. in which the generators are cut.

- ii. Draw the development of the lateral surface of the whole cylinder along with the generators. The length of the line 1-1 is equal to $\pi \times D$ (circumference of the circle). This length can also be marked approximately by stepping off with a bow divider, twelve divisions, each equal to the chord-length ab . (The length thus obtained is about 1 % shorter than the exact length; but this is permitted in drawing work.)
- iii. Draw horizontal lines through points a' , b' and $b'1$ etc. to cut the corresponding generators in points A , B and $B1$ etc. Draw a smooth curve through the points thus obtained. The figure 1-A-A-1 is the required development.

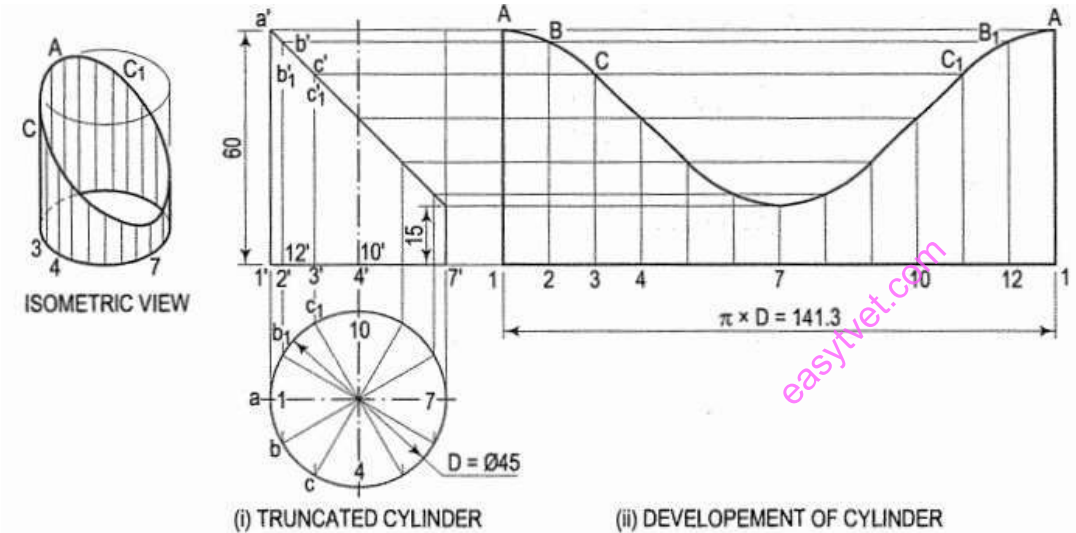


Figure 103: Lateral surface of the truncated cylinder

Learning activity 2: Produce solid geometry drawings

Draw the development of the of the truncated cone

Assuming the cone to be whole, let us draw its development.

- i. Draw the base-circle in the top view and divide it into twelve equal parts.
- ii. With any point O as centre and radius equal to o'1' or o'7', draw an arc of the circle. The length of this arc should be equal to the circumference of the base circle. This can be determined in two ways.
- iii. Calculate the subtended angle Θ by the formula,

$$\Theta = 3600 \times \frac{\text{radius of the base circle}}{\text{slant height}}$$

Cut-off the arc so that it subtends the angle Θ at the centre and divide it into twelve equal parts.

- iv. Step-off with a bow-divider, twelve equal divisions on the arc, each equal to one of the divisions of the base-circle. (This will give an approximate length of the circumference. Note that the base-circle should not be divided into less than twelve equal parts.)
- v. Join the division-points with O, thus completing the development of the whole cone with twelve generators shown
- vi. The truncated portion of the cone may be deducted from this development by marking the positions of points at which generators are cut and then drawing a curve through them. For example, generators o'2' and o'12' in the front view are cut at points b' and b'1 which coincide with each other. The true length of o' b' may be obtained by drawing a line through b', parallel to the base and cutting o'7' at b". Then o'b" is the true length of o'b'.
- vii. Mark points B and B₁ on generators O2 and O-12 respectively, such that OB = OB₁ = o' b". Locate all points in the same way and draw a smooth curve through them. The figure enclosed this curve and the arc is the development of the truncated cone.

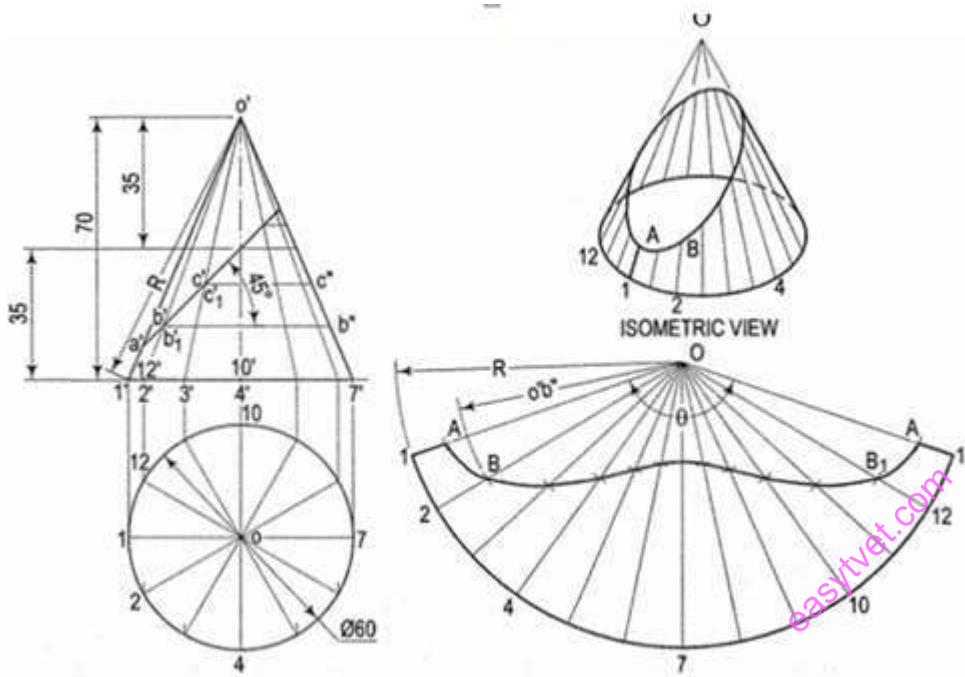
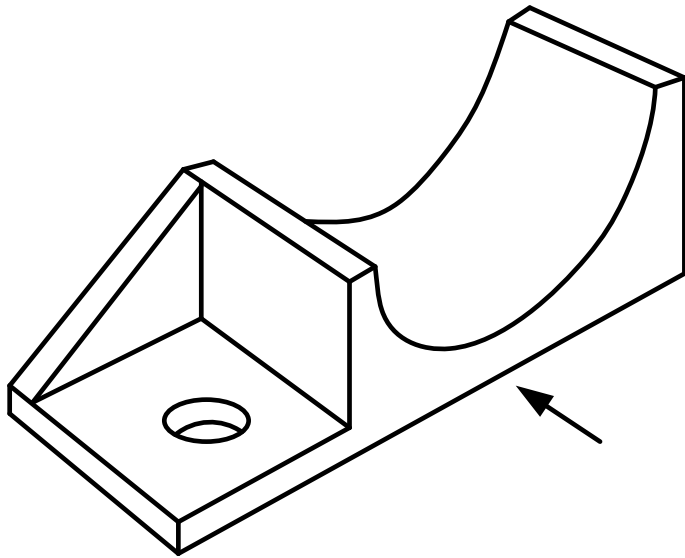


Figure 104: Truncated cone and surface development

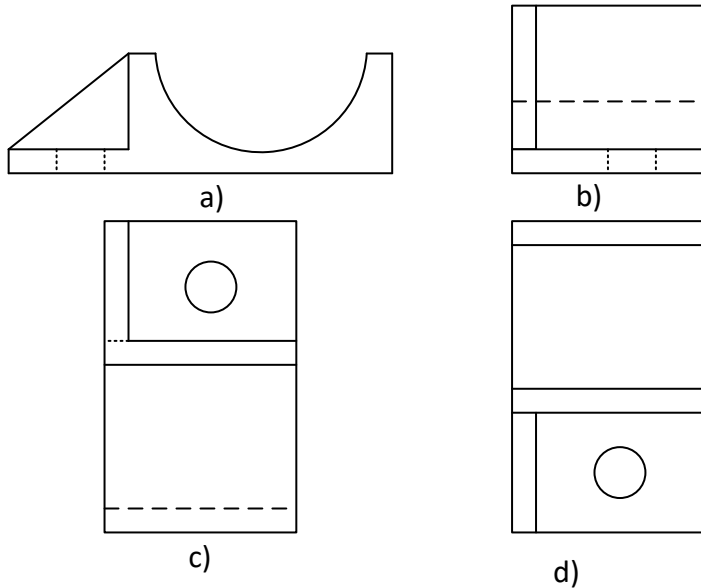
Self-assessment

1. The bounding box method for setting up an isometric drawing helps the drafter _____.

- A. confines the isometric drawing to its maximum size
 - B. figure what lines are to be illustrated vertical and horizontal
 - C. position the isometric drawing in paper space
 - D. none of the above
2. This type of section is limited by a break line:
- A. Removed section
 - B. Revolved section
 - C. Broken-out section
 - D. Half section
3. In the section view, the areas that would have been in actual contact with the cutting plane are shown with:
- A. A cutting plane line
 - B. Section lining
 - C. Visible lines
 - D. Lines and arrows
4. What is the difference between regular and irregular polygons?
5. If an isometric drawing is made use of isometric scale then the drawings are called
- A. Isometric projection
 - B. Isometric view
 - C. Isometric perception
 - D. Orthographic view
6. Identify the front view of the pictorial drawing below.



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Tools, Equipment, Supplies and Materials

- i. Drawing tools
- ii. Drawing set
- iii. Drawing papers
- iv. Erasers
- v. Series of pencils
- vi. Drawing board

References

1. Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing: Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.

2. Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.
3. Narayana, K. L., Kannaiah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.
4. Reddy, K. V. 2010. Textbook of Engineering Drawing. B.S. Publ., Hyderabad.
5. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,

4.4 Produce Orthographic and Pictorial Drawings

Introduction to the learning outcome

This learning outcome is intended to equip the trainee with competence on how to produce orthographic and pictorial drawings.

Performance Standard

- i. Symbols and abbreviations are identified and their meaning interpreted according to standard drawing conventions
- ii. First and third angle orthographic drawings are interpreted and produced in accordance with the standard conventions
- iii. Orthographic elevations are dimensioned in accordance with standard conventions
- iv. Isometric drawings are interpreted and produced in accordance with standard conventions
- v. Assembly drawing is produced and interpreted in line with the operating standards

Information sheet

Definitions

Projections

The technique of representing an object in a drawn form is referred to as projection. Projection can be divided into pictorial (3- dimensional) projection and orthographic (2- dimensional) projection. Pictorial projection is further divided into isometric,

oblique and perspective projections; while the orthographic projection is divided into 1st angle and 3rd angle projection is referred to as projection. Projection can be divided into pictorial (3- dimensional) projection and orthographic (2- dimensional) projection. Pictorial projection is further divided into isometric, oblique and perspective projections; while the orthographic projection is divided into 1st angle and 3rd angle projection.

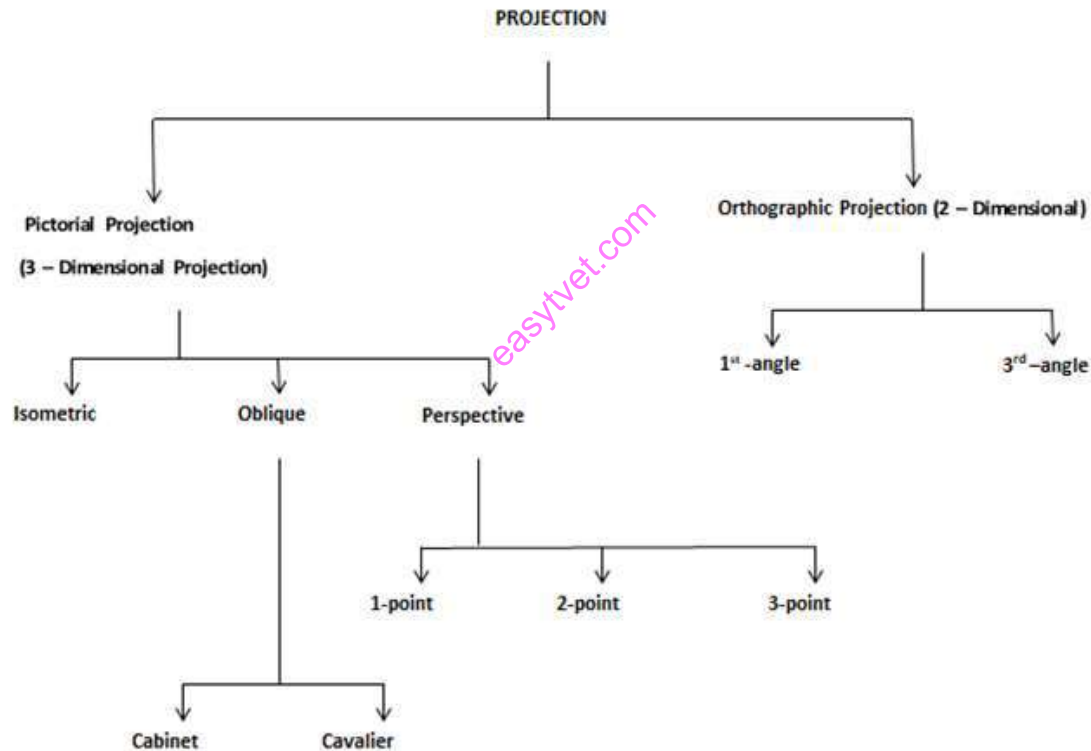


Figure 105: Types of projections

Orthographic Drawing

'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. It is in two dimensions (2D). It uses multiple views of the object, from points of view rotated about the object's center through increments of 90° . The views are positioned relative to each other according to either of two schemes: *first- Angle* or *third-Angle* projection. In each, the appearances of views may be thought of as being *projected* onto planes that form a transparent "box" around the object.

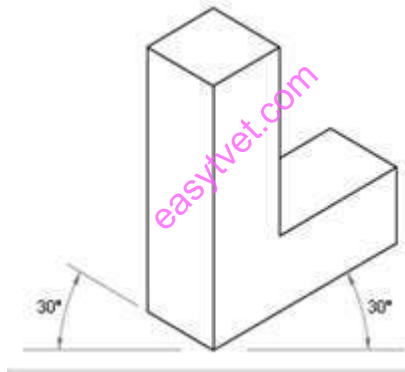


Figure 106: Isometric drawing

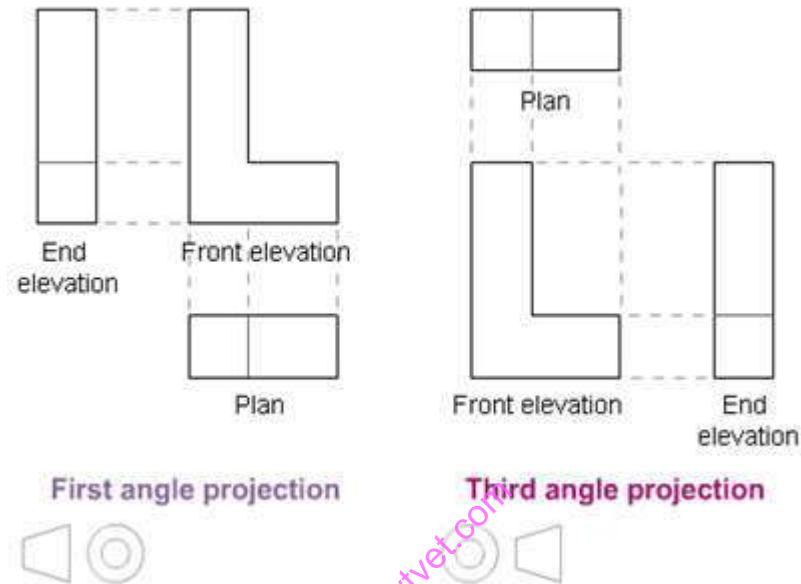
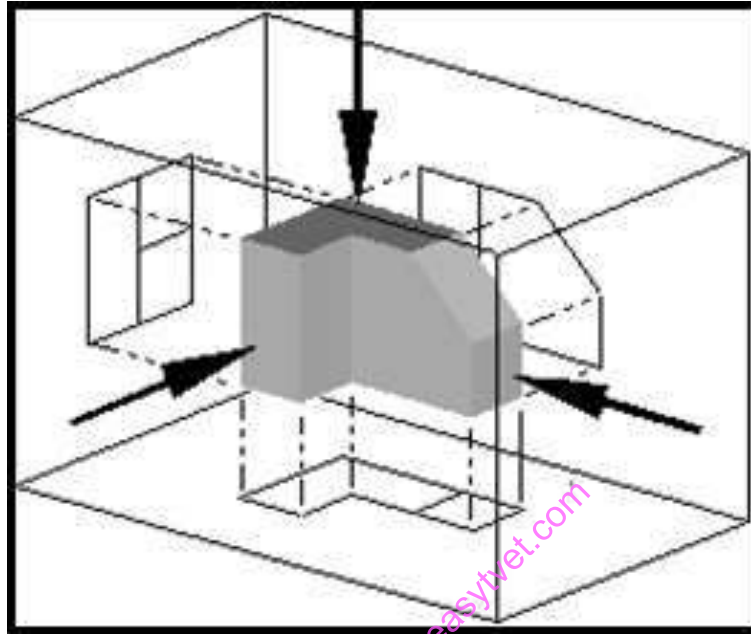


Figure 107: Illustrating the difference between 1st. and 3rd. angles projection

The Differences between 1st & 3rd Angle Projection

First-Angle Projection

In **first-angle projection**, each view of the object is projected in the direction (sense) of sight of the object, onto the interior walls of the box



A two-dimensional representation of the object is then created by "unfolding" the box, to view all of the *interior* walls

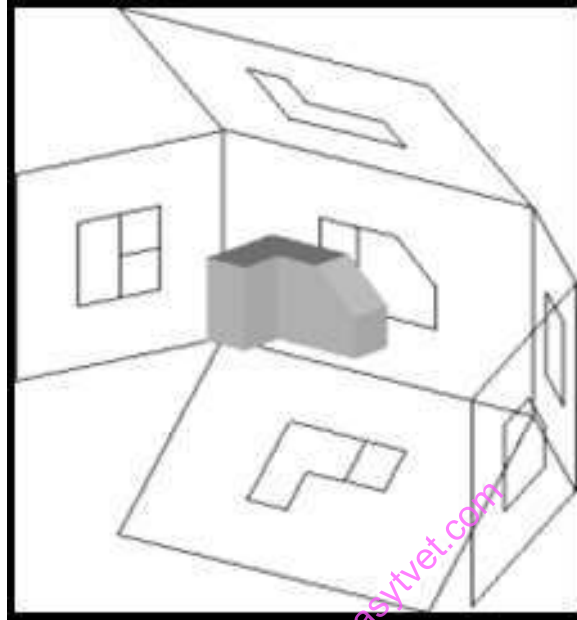


Figure 108: unfolding

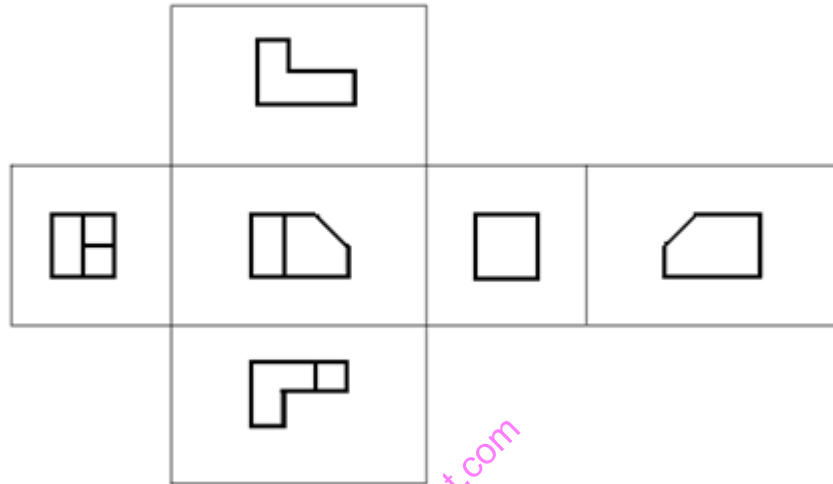


Figure 109: unfolded views

Third-Angle Projection

In **third-angle projection**, each view of the object is projected opposite to the direction (sense) of sight, onto the (transparent) exterior walls of the box in the figure below.

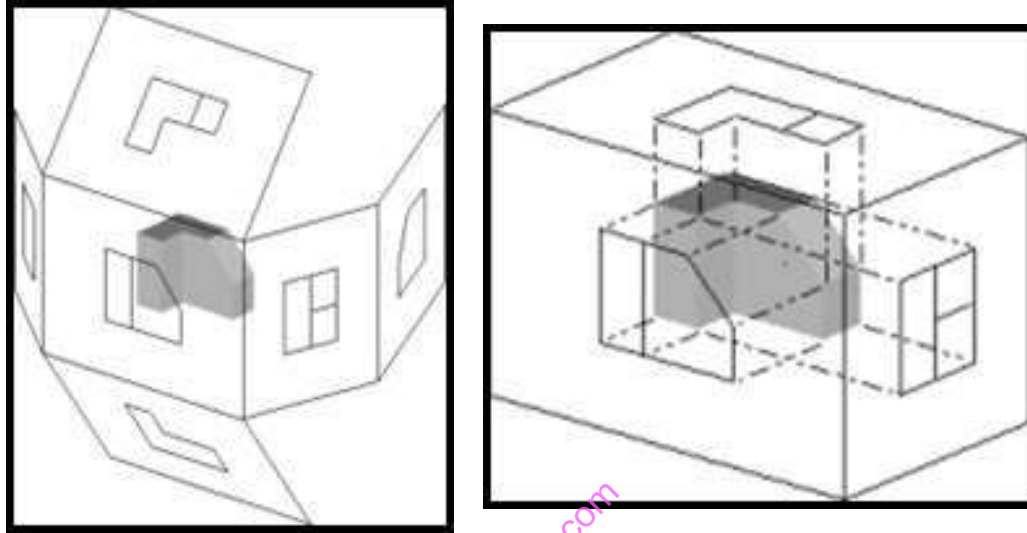


Figure 110: unfolding

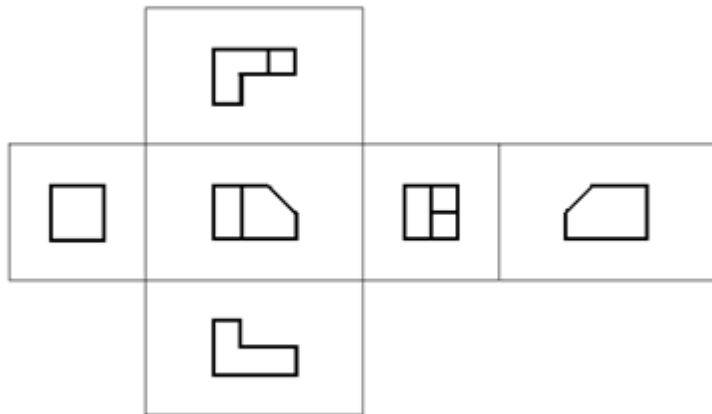
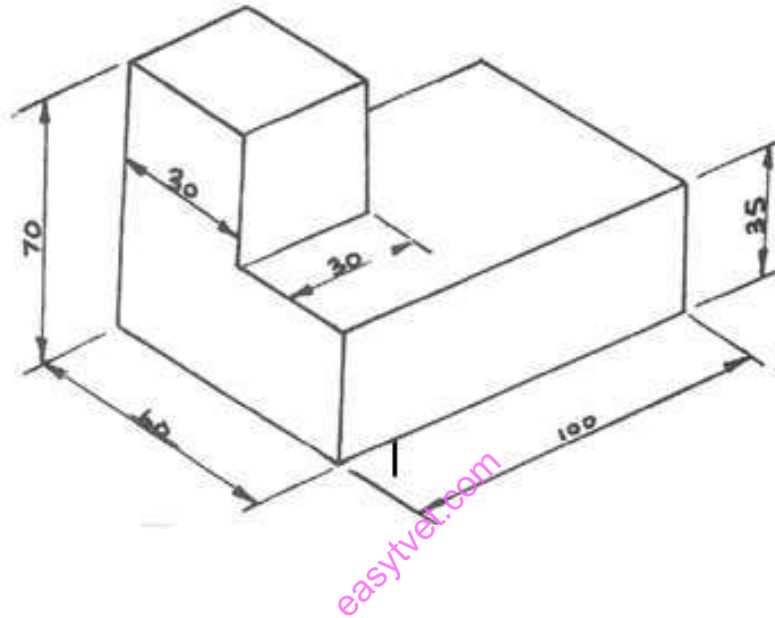


Figure 111: unfolding views

A two-dimensional representation of the object is then created by unfolding the box, to view all of the *exterior* walls. Before starting drawing the views of the component shown in Figure below, it is necessary to decide the best Angle to project on the component; good decision will make the reading of the details of the views much easier afterwards.



SECTIONING

To produce a sectional view, a cutting plane is imagined cutting through the part, as shown in fig. (a). Picture the two halves of the object pulled apart, exposing the interior construction, as shown in fig. (b). In this case, we will look toward the left half of the object in the section view. This sectional view replaces the right-side view.

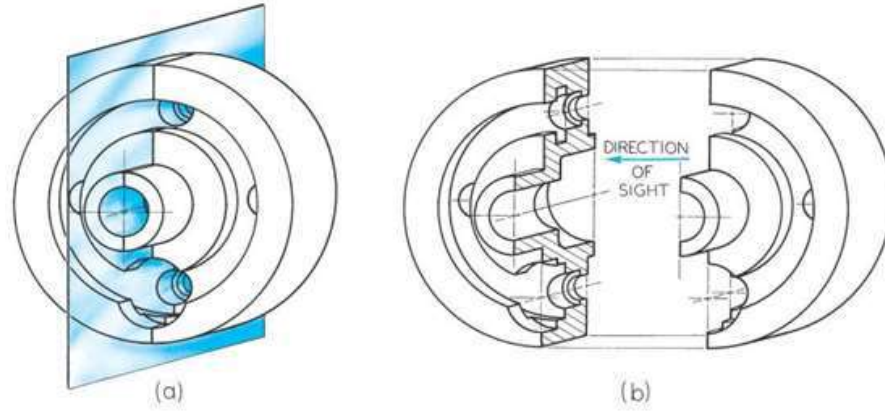


Figure 112: Cutting plane

Full Sections

The section produced by cutting through the entire object is called a full Section, as shown in fig. (c) below.

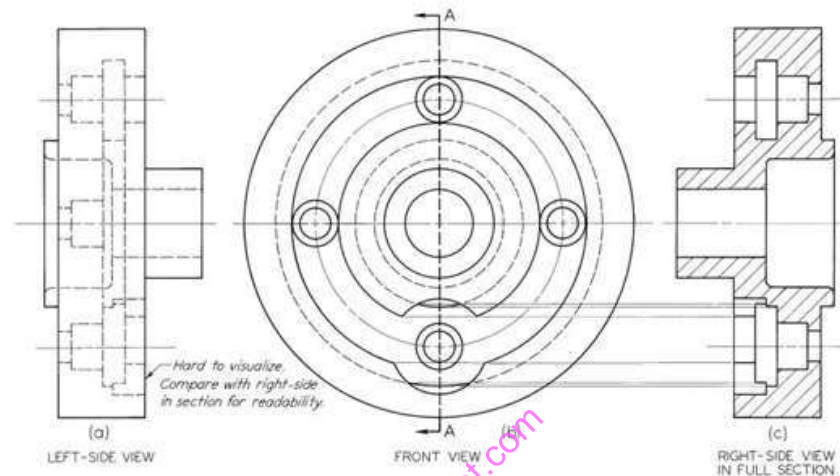


Figure 113: Full Sections

The Cutting Plane

The cutting-plane line is shown as a special pattern. The arrows at the ends of the cutting plane line indicate the direction of sight for the section view. We can think the cutting-plane line as showing the edge view of the cutting plane.

When a cutting-plane line coincides with a centerline, the cutting-plane line takes precedence.

Cutting-Plane Line Patterns

Figures below show two line patterns used to show the cutting-plane line. Arrowheads indicate the direction in which the cut object is viewed.

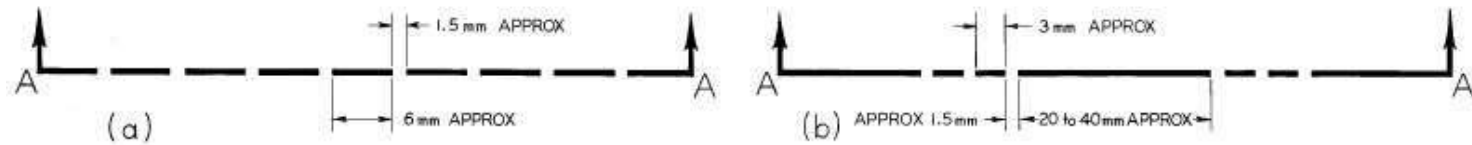


Figure 114: Cutting-Plane Line Patterns

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Interpreting Cutting Planes and Sections

Sectional views often replace standard views. As figures shown, the cutting plane is a frontal plane and appears as a line in the top view. The arrows at the ends of cutting-plane line point in the direction of sight for front section. The result is called a front section, or front view in section, since it replaces the front view in the drawing.

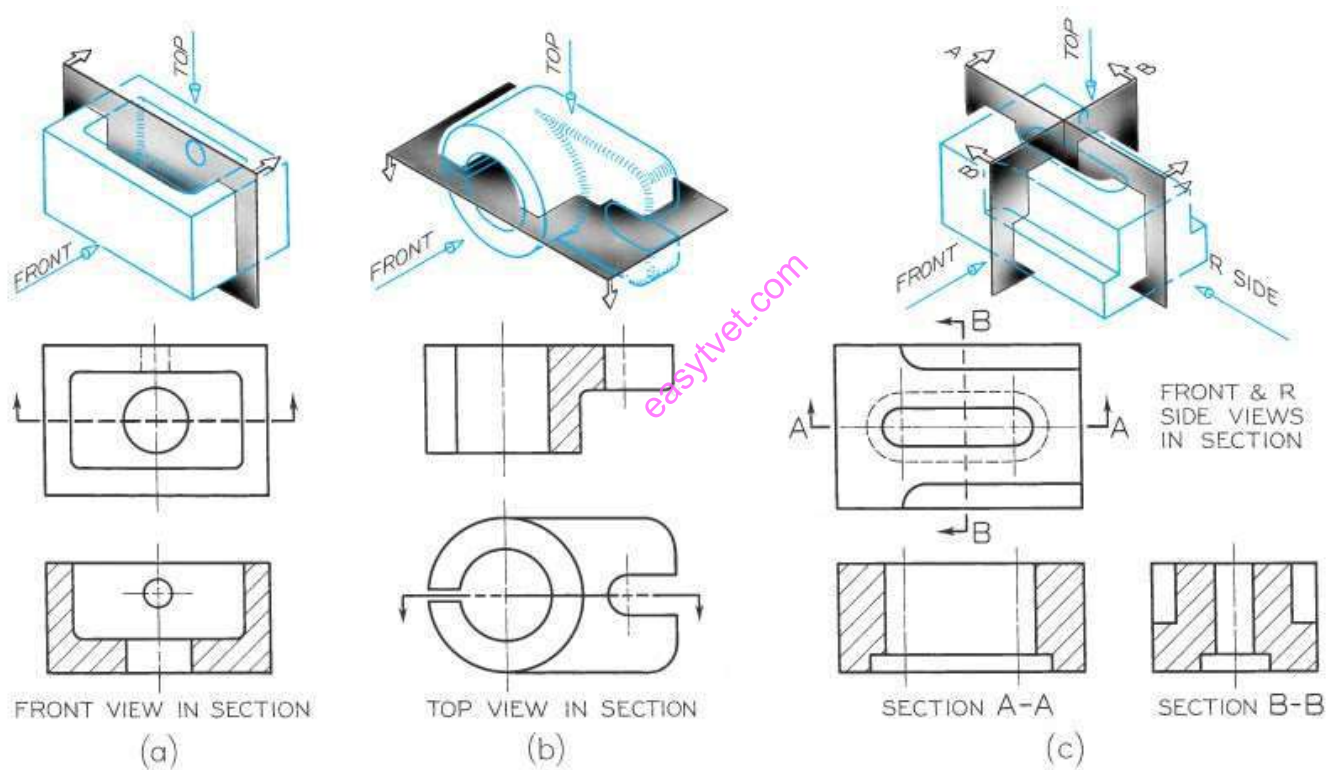
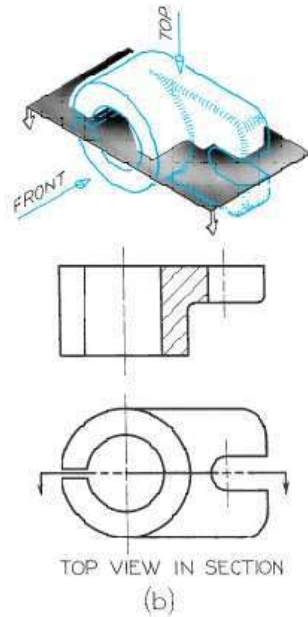


Figure 115: Cutting Planes and Sections

As shown in figures, the cutting plane is a horizontal plane, appearing as a line in the front view. The arrows point toward the lower half in the same direction of sight as for a top view. This result is top view in section.



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Figure 116: sectional views

Figures below show two cutting planes - one a frontal plane, the other a profile plane - and both appear on edge in the top view. Each section is completely independent of the other and drawn as if the other were not present.

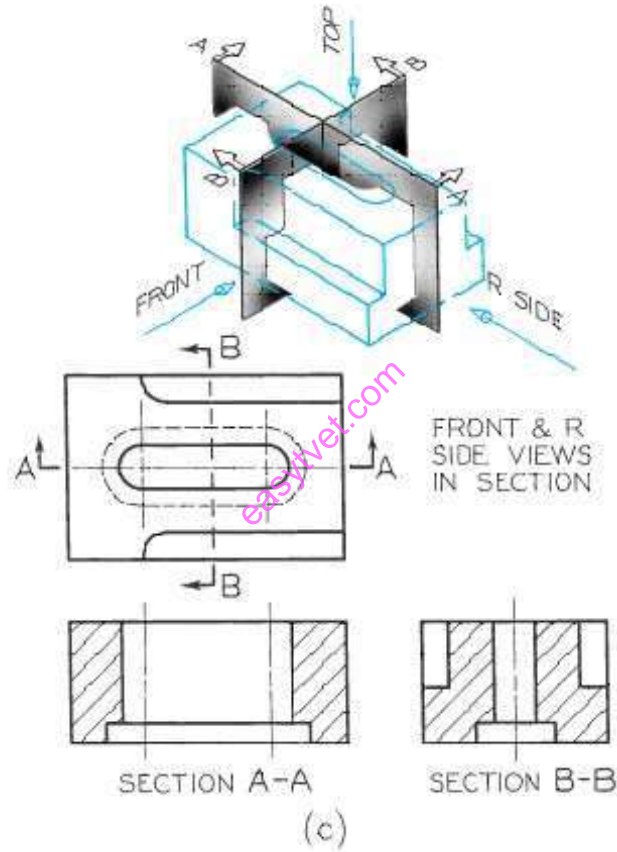
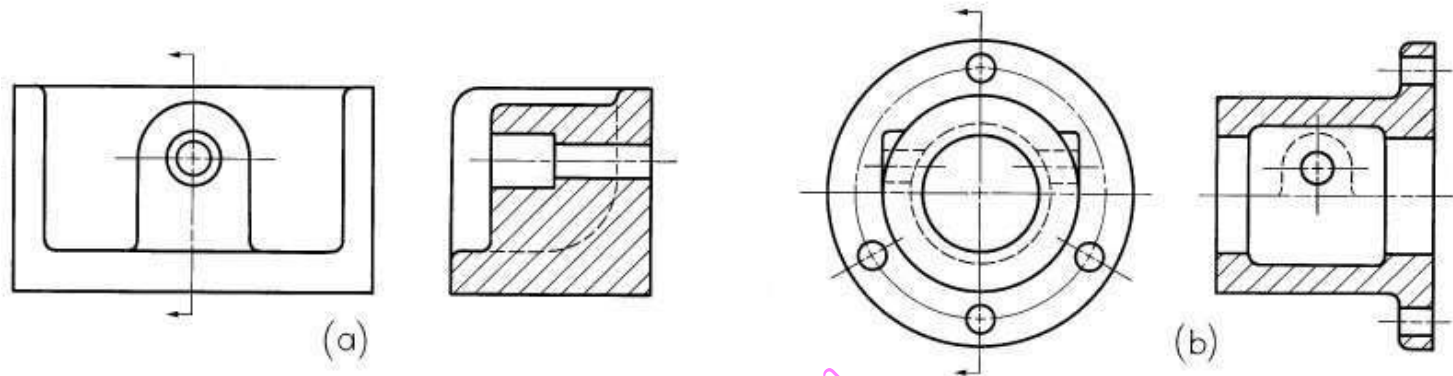


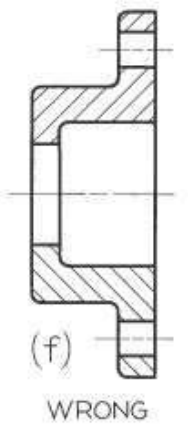
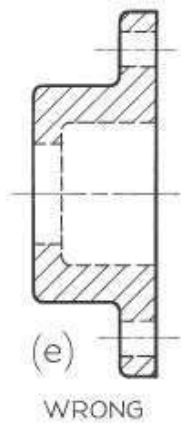
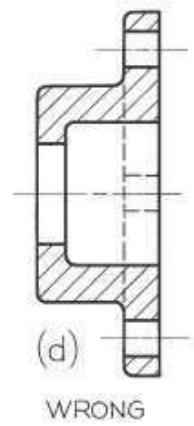
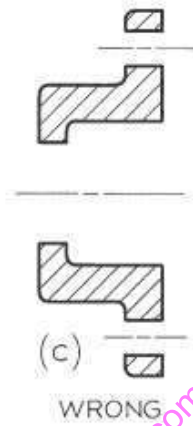
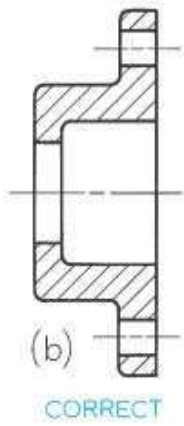
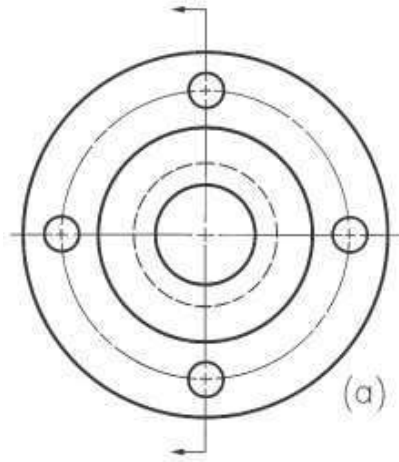
Figure 117:Sectional views

Keep the following things in mind when drawing sectional views. Visible edges and contours behind the cutting plane should be as shown in figure (a) below. Hidden lines should be omitted in section views unless they are necessary, as in figure (b).



A section-lined area is always completely bounded by a visible outline never by a hidden line. The cross hatching in all hatched areas must be parallel in a sectional view of a single object, along or in assembly.

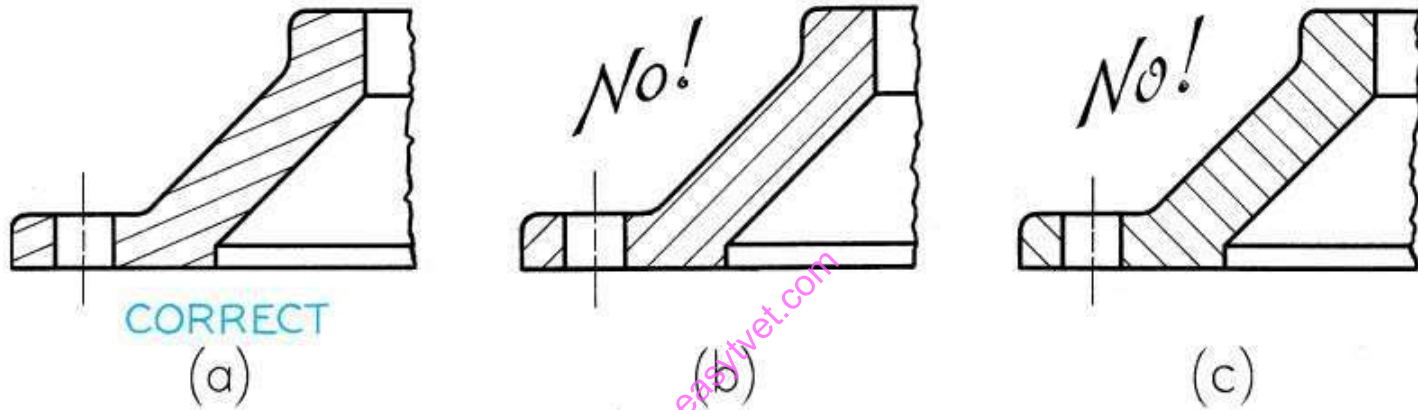
Find the errors in section views



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Cross-Hatching

Cross-hatching patterns, shown in Fig. 7.6 are used to present general material types. Make hatching lines at 45 degrees with horizontal, unless they look better at a different angle.

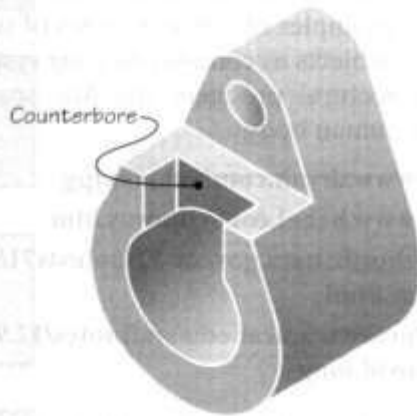


In figures above, cross-hatching at 45 degrees with horizontal would be nearly parallel or nearly perpendicular to a prominent feature. In this case, the hatching appears better drawn at 30 degrees, 60 degrees, or some other angle.

Step by Step Visualizing of a full section

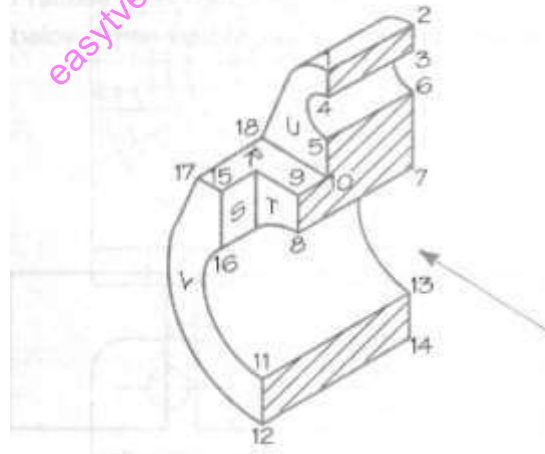
STEP 1: CHOOSE A CUTTING PLANE

The illustration below shows two views of a collar to be sectioned. It has a drilled and counterbored hole. To produce a clear section showing both the counterbored hole and the smaller hole near the top of the object, choose the cutting plane to pass through the vertical center line in the front view and imagine the right half of the object removed.

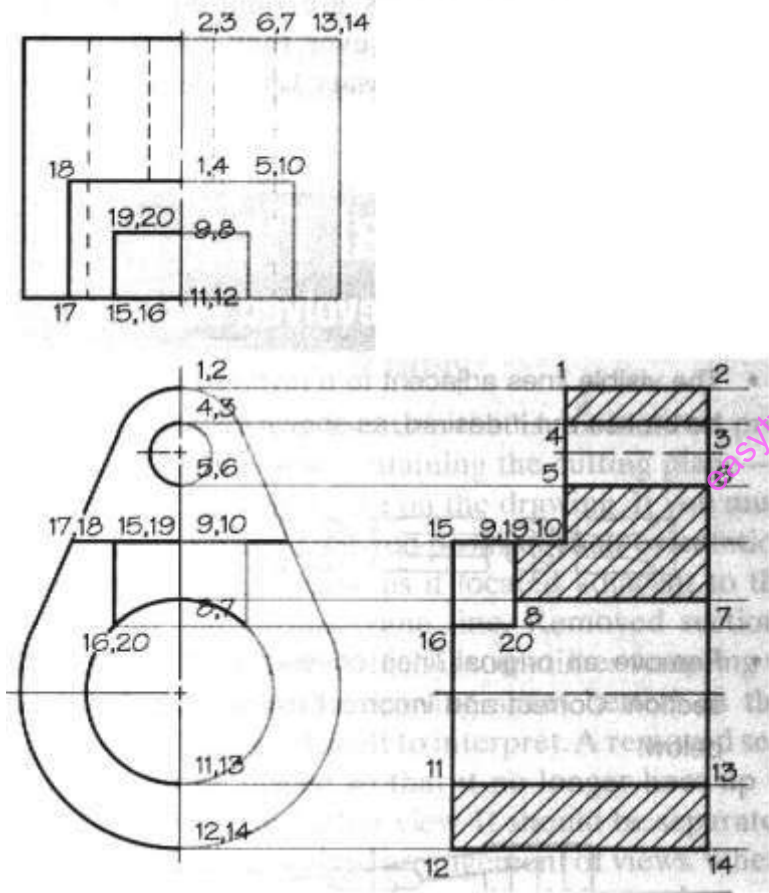


STEP 2: IDENTIFY THE SURFACES

Below is a pictorial drawing of the remaining half. The first step in projecting the section view is making sure that you interpret the object correctly. Identifying the surfaces on the object can help. Surfaces R, S, T, U and V have been labeled on the given views and the pictorial view. Which surface is R in the front view? Which surface is U in the top view? Are they normal, inclined, or oblique surfaces. Can you identify the counterbore in each view?



STEP 3: DRAWING THE SECTION VIEW



STEP 4: PROJECTING THE VISIBLE LINES

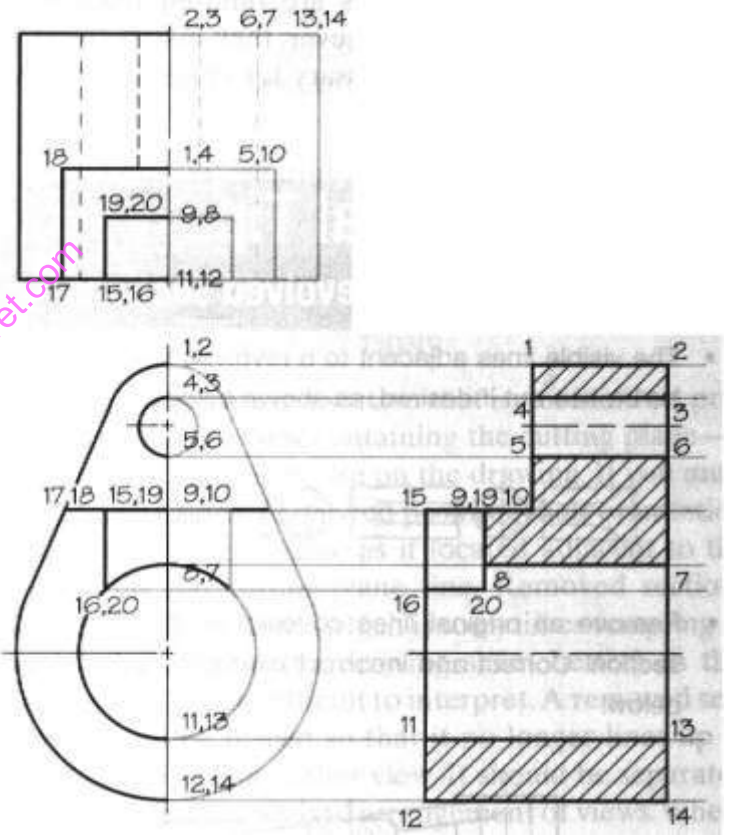


Figure 118: Drawing the sectional view

Half Sections

Symmetrical objects can be sectioned using a cutting plane passing halfway through an object, resulting in a half section. A half section exposes the interior of one half of the object and still shows the exterior of the other half. Half sections are very useful in undimensioned assembly drawing since they show both internal and external construction on the same view.

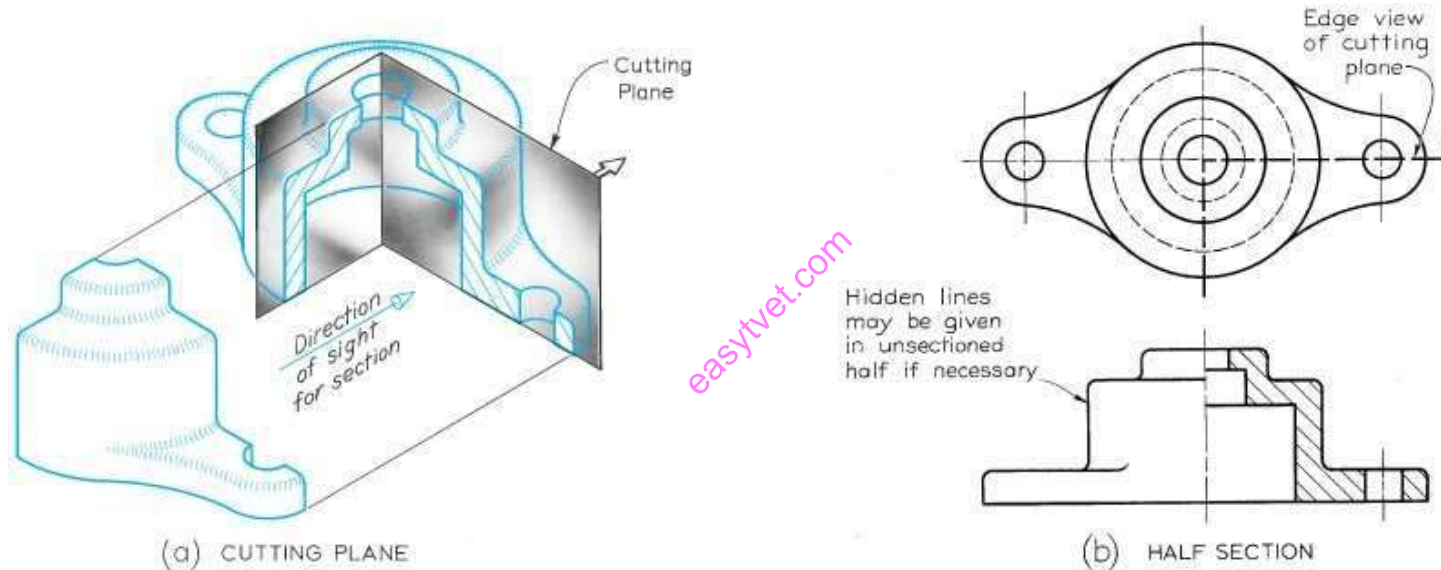


Figure 119:Half Sections

In general, hidden lines are omitted from both halves of a half section. However, they may be used in the unsectioned half if necessary for dimensioning.

Broken-out Sections

Often, only a partial section of a view is needed to expose interior shapes. Such a section, limited by a break line, is called a broken-out section. In the first figure, a full of half section is not necessary. A broken-out section is sufficient to explain the construction.

In the second figure, a half section would have caused the removal of half the keyway. The keyway is preserved by breaking out around it. In this case, the section is limited partly by a break line and partly by a centerline (i.e., break-around keyway).

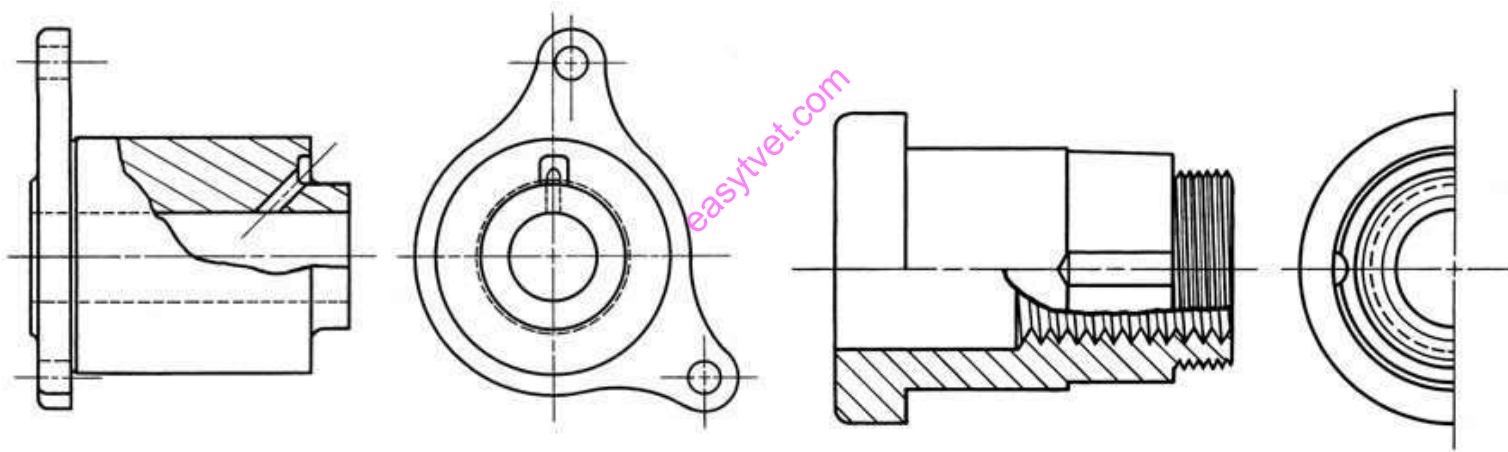


Figure 120: Broken-out Sections

Revolved Sections

The shape of the cross-section of a bar, arm, spoke, or other elongated object may be shown by means of a revolved section.

Revolved sections are made by assuming a plane perpendicular to the centerline or axis of the bar or other object, and then revolving the plane through 90 degrees about a centerline at right angles to the axis.

The figure below depicts the process of creating a revolved section.

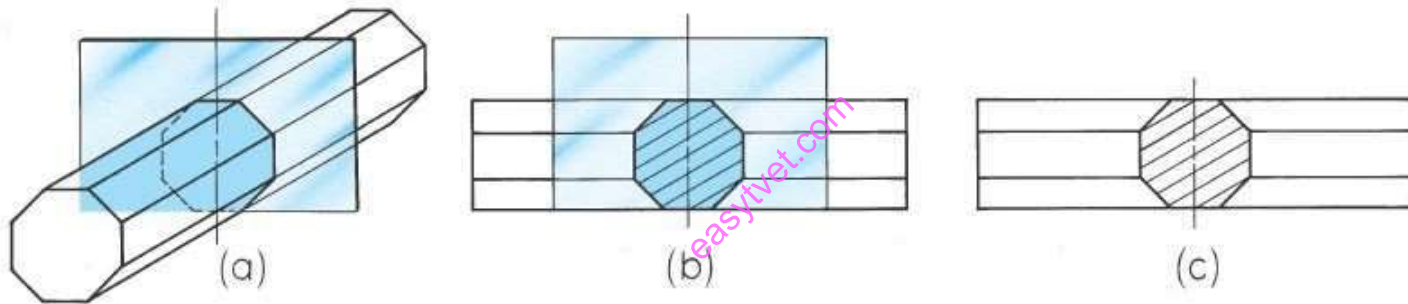
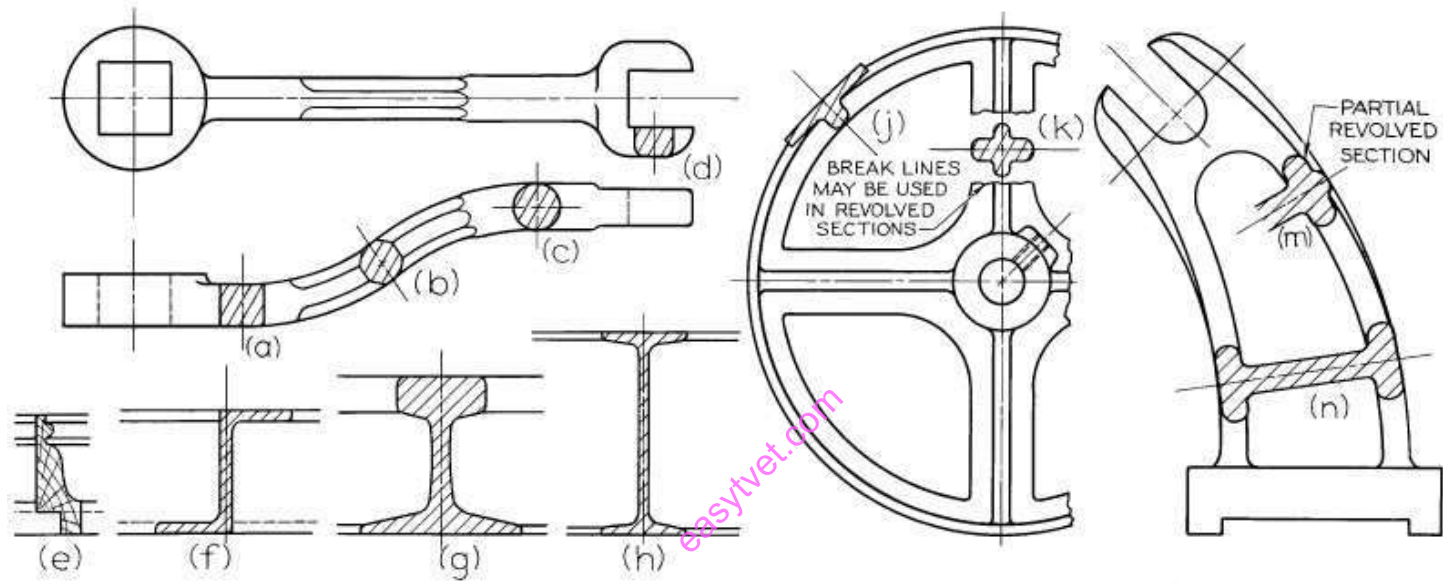


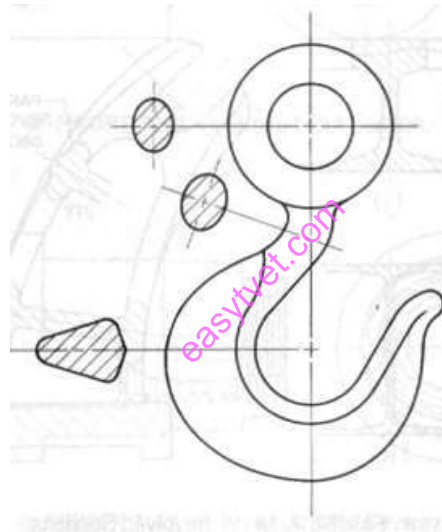
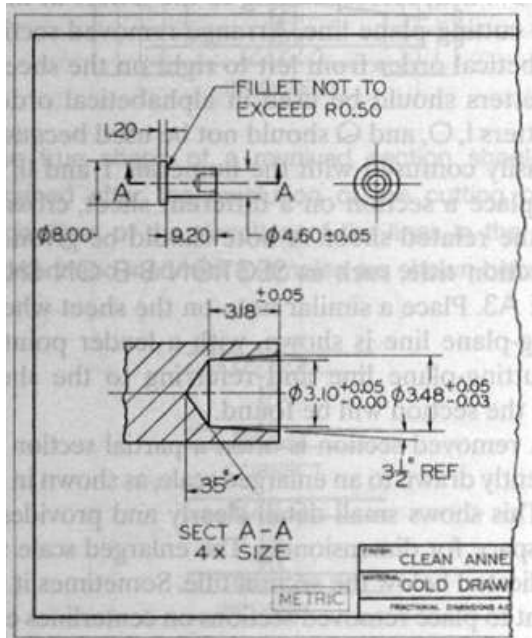
Figure 121: Revolved Sections

A number of examples of revolved sections are shown below.



Removed Sections

A removed section is a section that is not direct projection from the view containing the cutting plane – it is located somewhere else in the drawing.



Removed sections

Figure 122: Removed Sections

Offset Sections

In sectioning irregular objects, we may show features that do not lie in a straight line by offsetting, or bending the cutting plane. Such a section is called an offset section.

In figure (a) the cutting plane is offset in several places to include the hole at the left end, one of the parallel slots, the rectangular recess, and one of the holes at the right end.

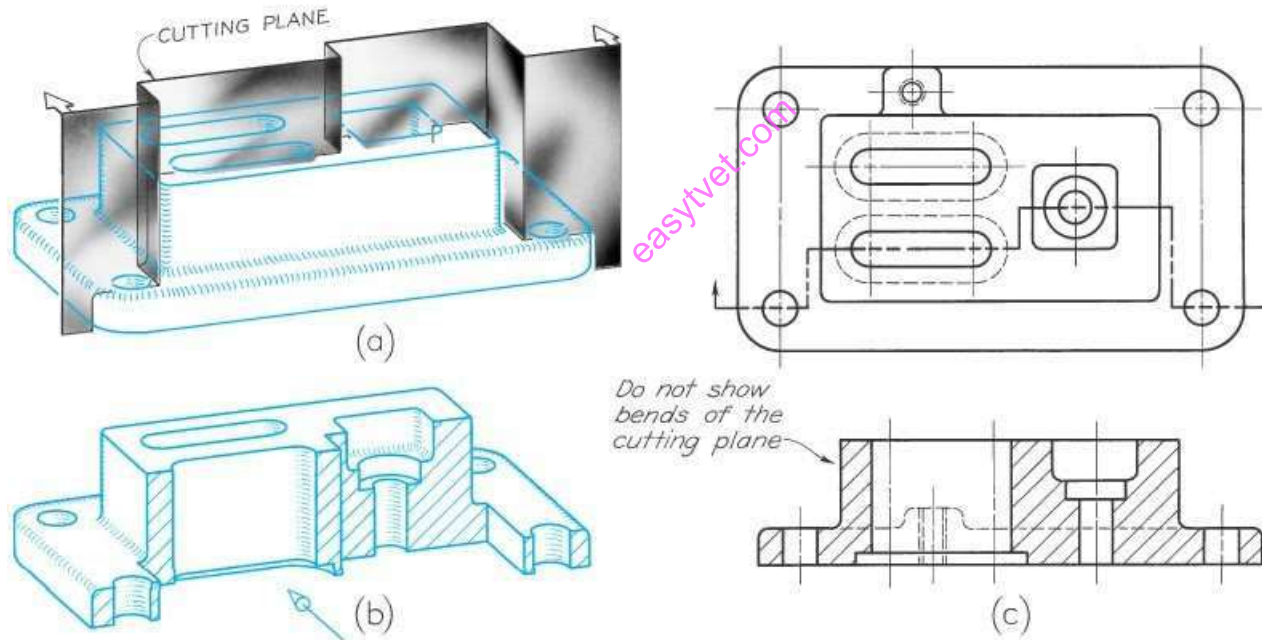


Figure 123: Offset Sections

The front portion of the object is then imagined to be removed, as shown in fig. (b). The path of the cutting plane is shown by the cutting-plane line in the top view of fig. (c), and the resulting offset section is shown in the front view. The offsets or bends in the cutting plane are all 90 degrees. Figure (c) also illustrates how hidden lines in a section eliminate the need for an additional view. If the hidden lines were not shown, an extra view would be needed to show the small boss on the back.

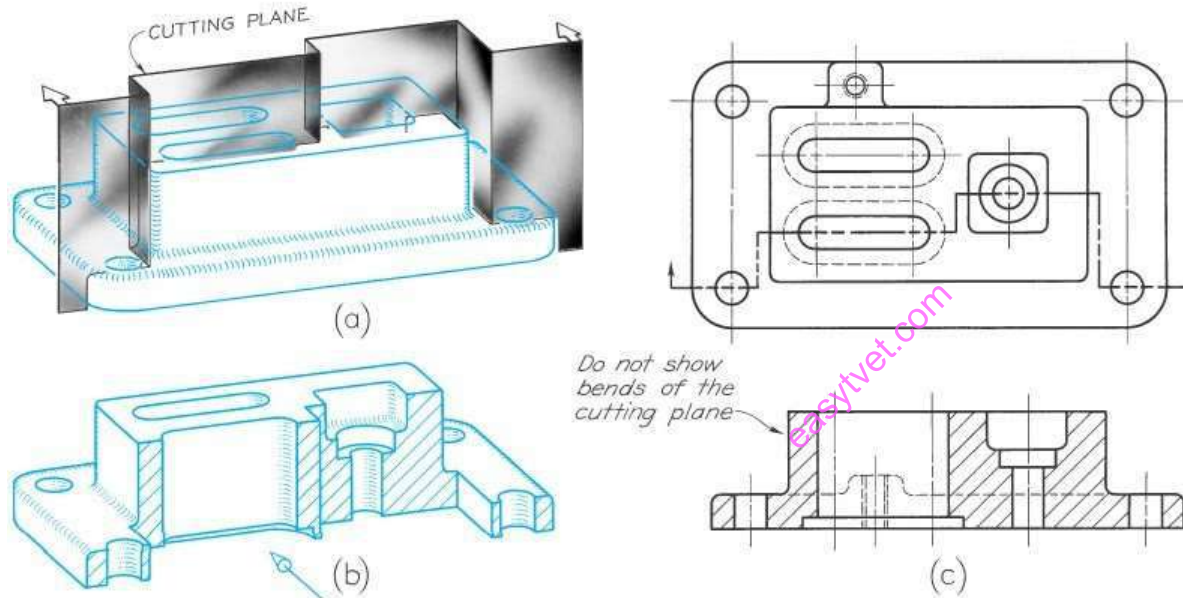
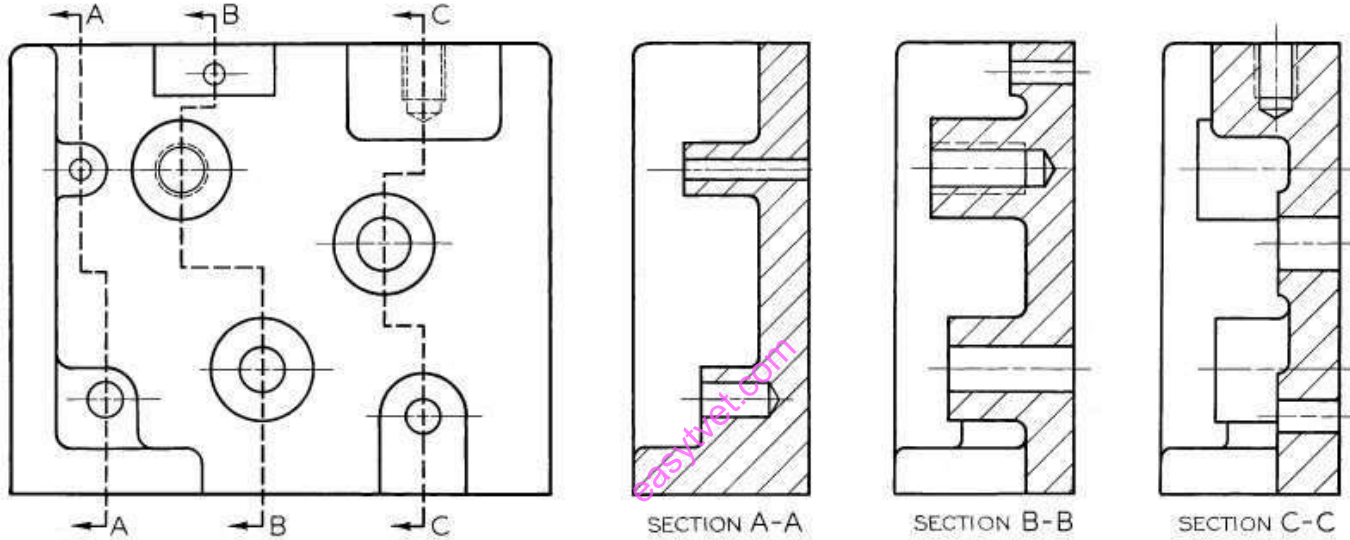


Figure below shows an example of multiple offset sections. Notice that the visible background shapes without hidden lines, appear in each sectional view.

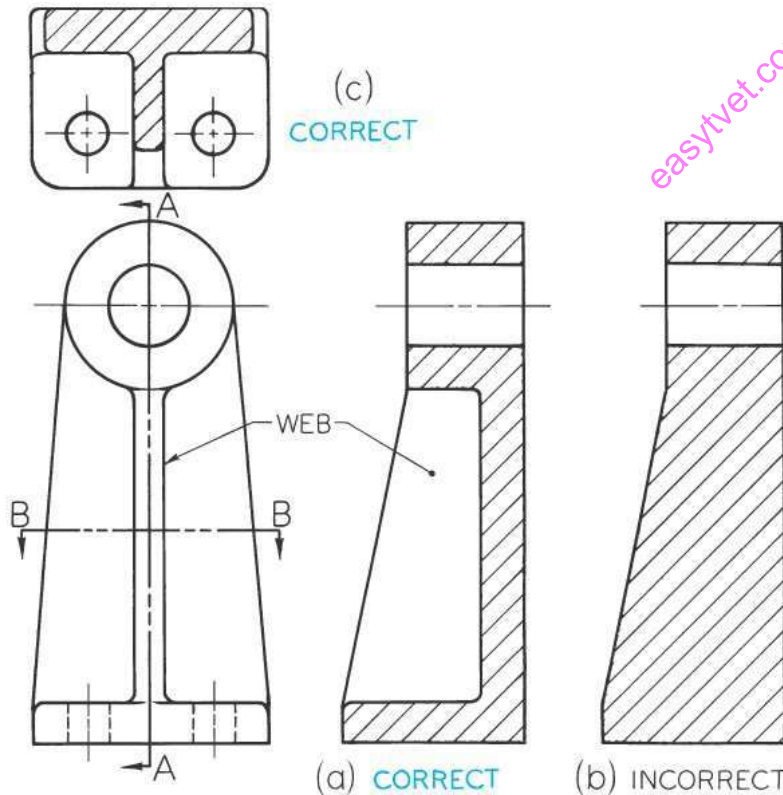


Ribs in Sections

To avoid a false impression of thickness and solidity, ribs, webs, gear teeth, and other similar flat features are not sectioned, even though the cutting plane passes along the center plane of the feature.

For example, in figure at right the cutting plane A-A passes through the long dimension of the vertical web, or rib, but as figure a shows, the web is not section lined. Such thin features should not be section lined, even though the cutting plane passes through them.

Figure b shows an incorrect drawing.



Aligned Sections

To include in a section certain angled features, the cutting plane may be bent to pass through those features. The plane and features are then imagined to revolve into the original plane.

For example, in figure below the cutting plane bends to pass through the angled arm and then is aligned to a vertical position, where it is projected to the sectional view.

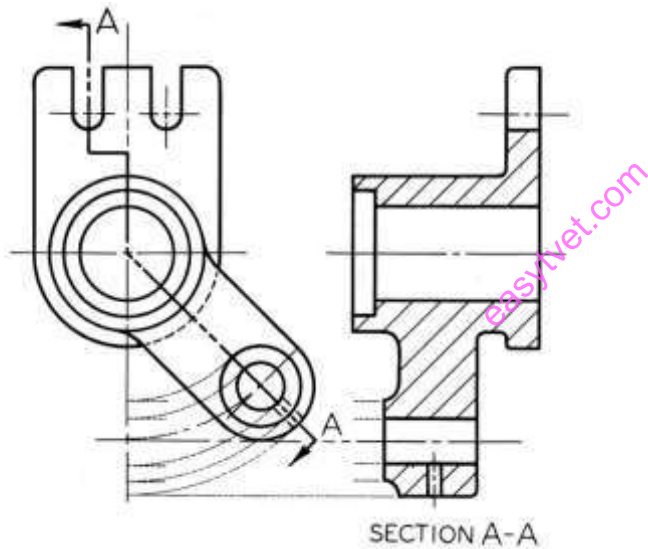
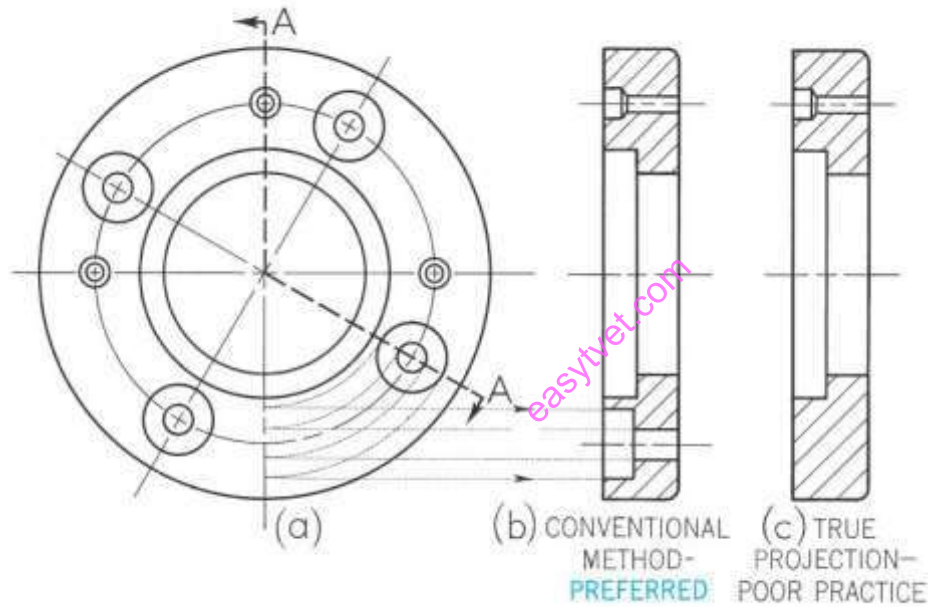
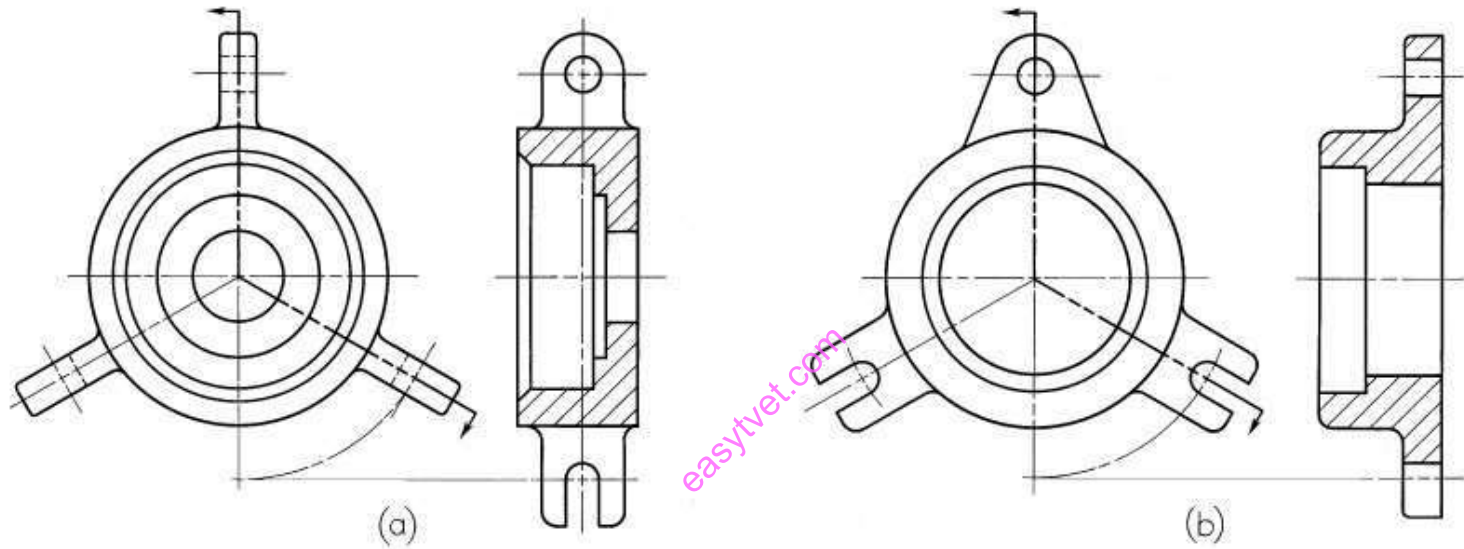


Figure 124: Aligned Sections

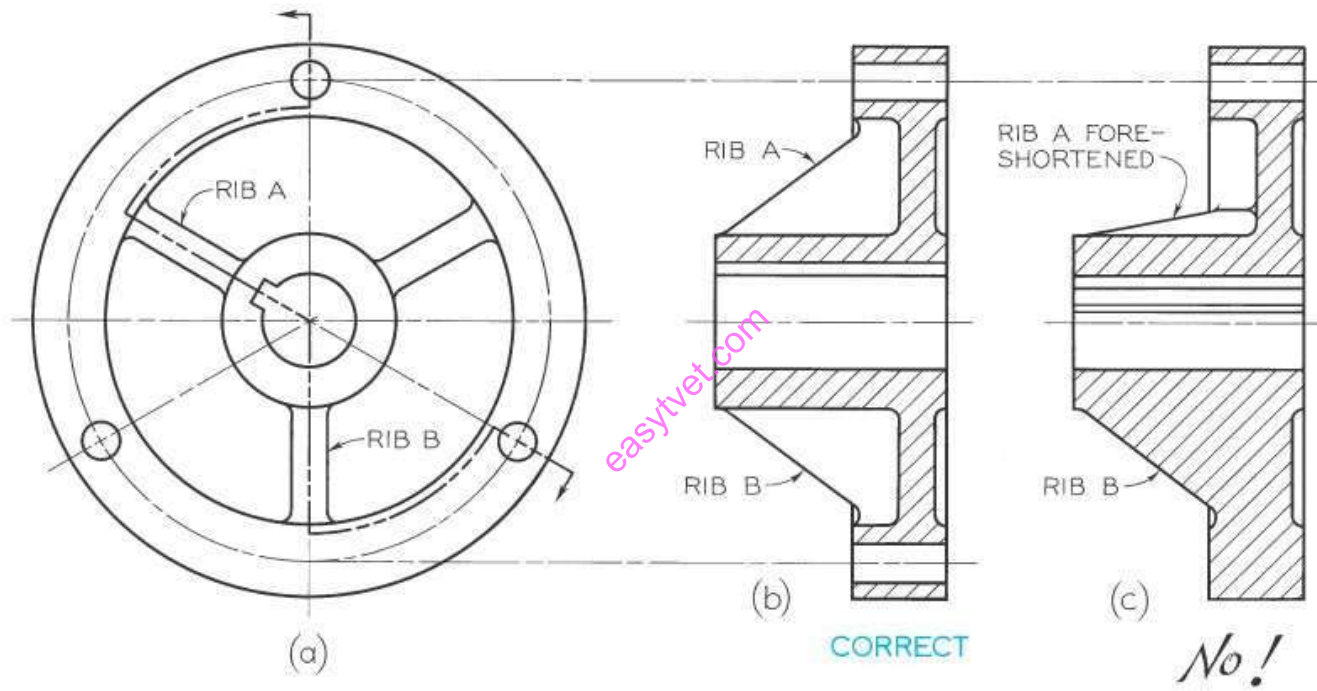
In the figure below, the cutting plane is bent so that both a drilled and a counterbored hole will be included in the sectional view. The correct sectional view, shown in fig. (b), is clearer and more complete than a full section, shown in fig. (c). The angle of revolution should always be less than 90 degree.



In figure (a) the projecting lugs are not sectioned for the same reason that ribs are not sectioned. In figure (b) the projecting lugs are located so that the cutting plane passes through them crosswise; therefore, they are sectioned.



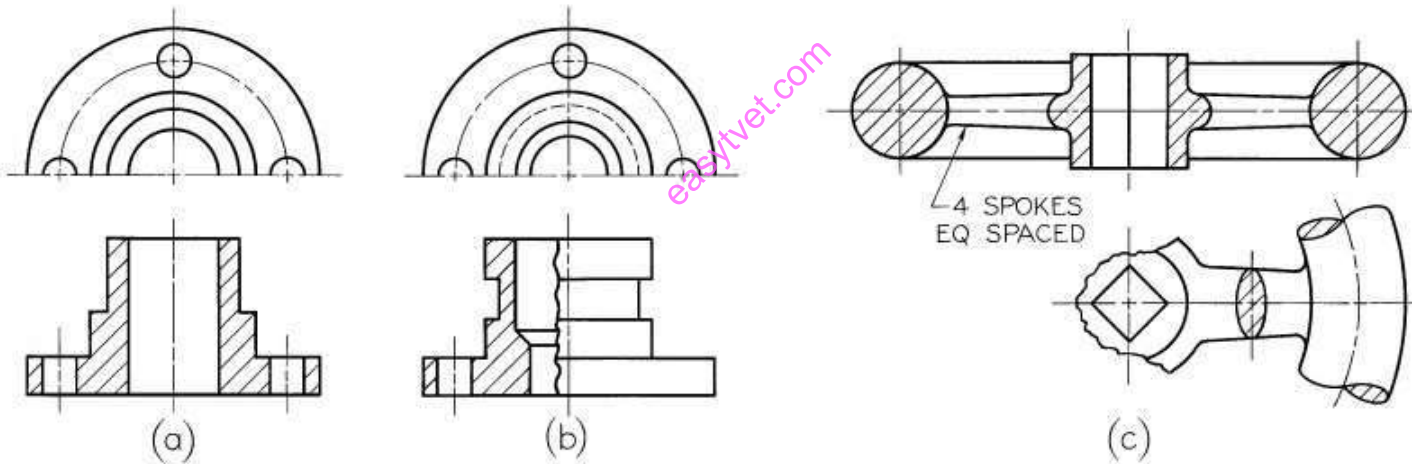
Another example involving rib sections and aligned sectioning is shown below.



Partial Views

If space is limited on the paper or to save drafting time, partial views may be used in connection with sectioning. Figures (a) and (b) only show half views of the top view. In each case the back half of the object in the circular view is shown to expose the back portion of the object for viewing in section.

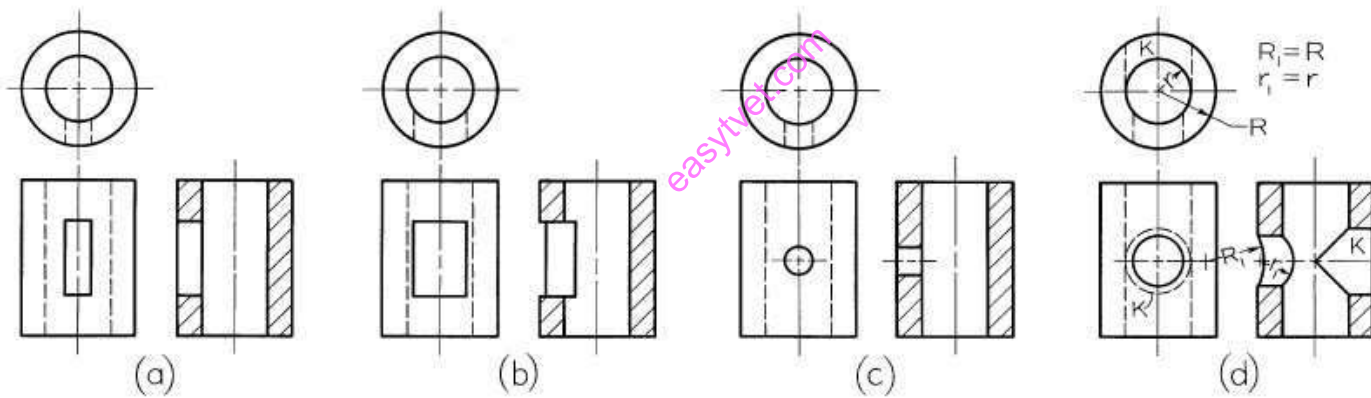
Another method of drawing a partial view is to break out much of the circular view, retaining only those features that are needed for minimum representation, as shown in figure (c).



Intersections in Sectioning

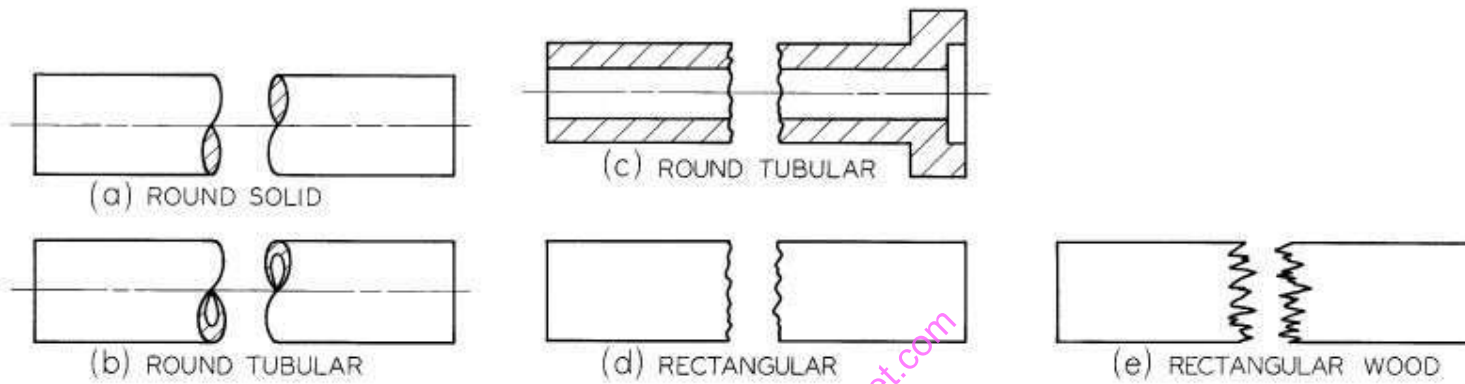
Where an intersection is small or unimportant in a section, it is standard practice to disregard the true projection of the figure of intersection, as shown in a and c. Larger figures of intersection may be projected, as shown in fig. (b), or approximated by circular arcs, as shown for the smaller hole in fig. (d).

Note that the larger hole K is the same diameter as the vertical hole. In such cases the curves of intersection, or ellipses, appear as straight lines, as shown.

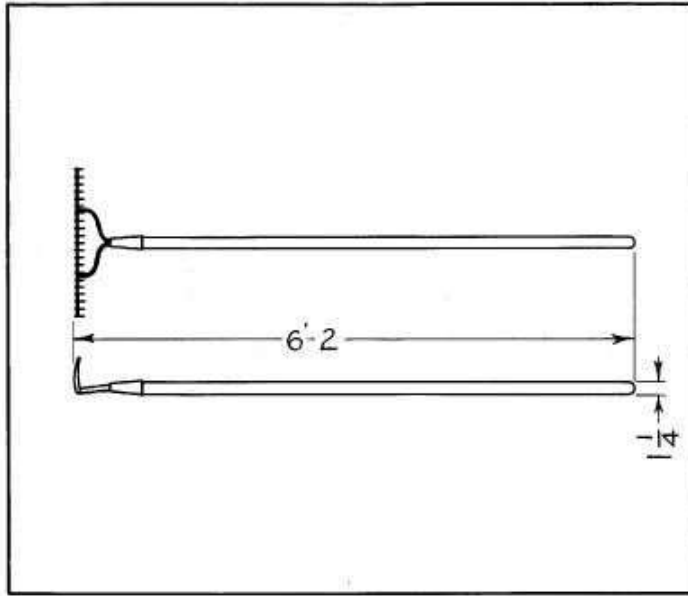


Conventional Breaks

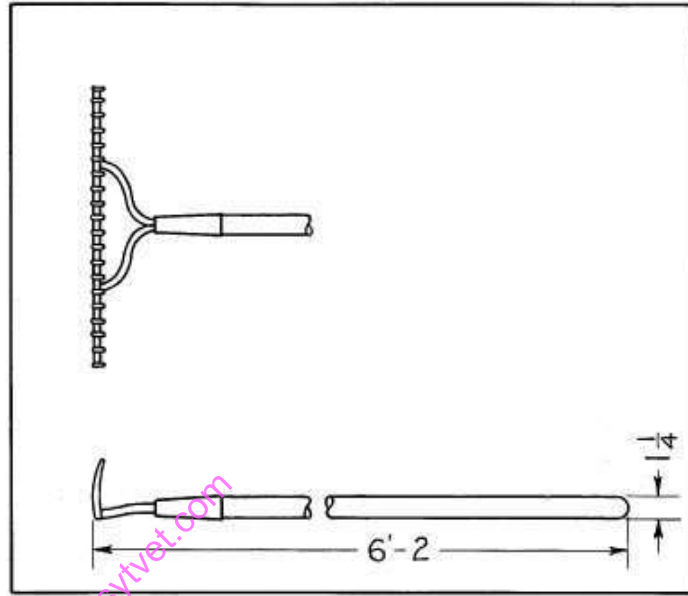
To shorten a view of an elongated object, whether in section or not, conventional breaks are recommended, as shown below.



Another example of conventional breaks is shown below.



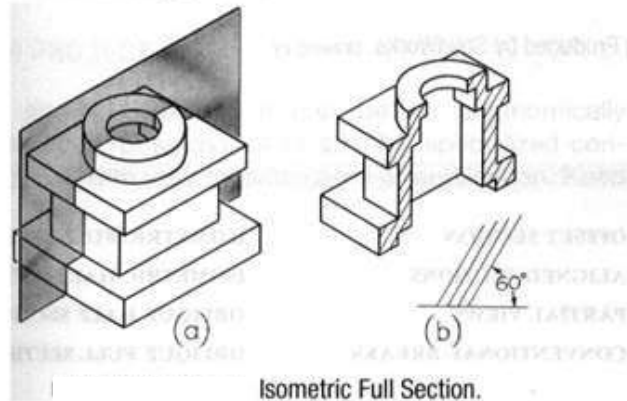
(a)



(b)

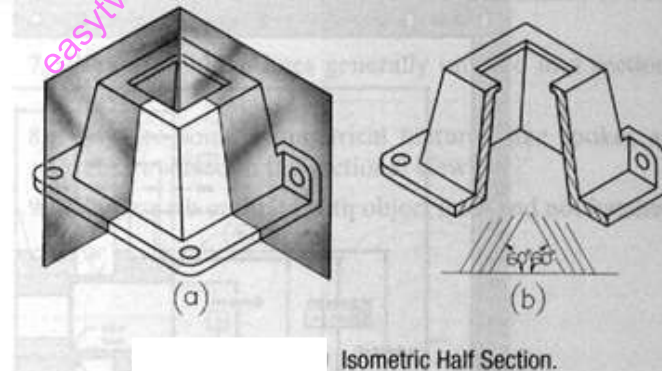
Isometric Sectioning

You can create pictorial sectional views by showing the cut object in an isometric or oblique view and hatching the cut surfaces. An *isometric full section* is shown in Figure 7.32. It is usually best to draw the cut surface first and then to draw the portion of the object that lies behind the cutting plane.

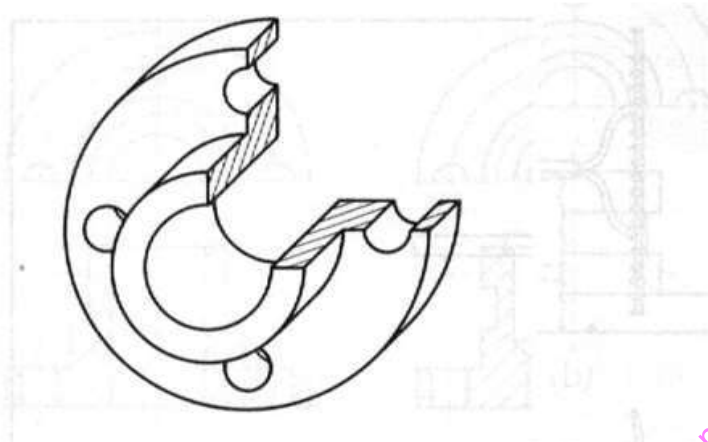


An *isometric half section* is shown in Figure 7.33. To sketch isometric half-sections, it is usually easiest to first sketch the entire object and then the cut surfaces. Since only a quarter of the object is removed in a half section, the resulting pictorial sketch is more useful than a full section to show both the exterior and interior shapes. Isometric broken-out sections are also sometimes used.

Hatching in an isometric sketch is similar to that in a multiview sketch. Showing it at an angle of 60 degrees with horizontal is recommended, but the direction should be changed if this would be parallel to major visible lines.

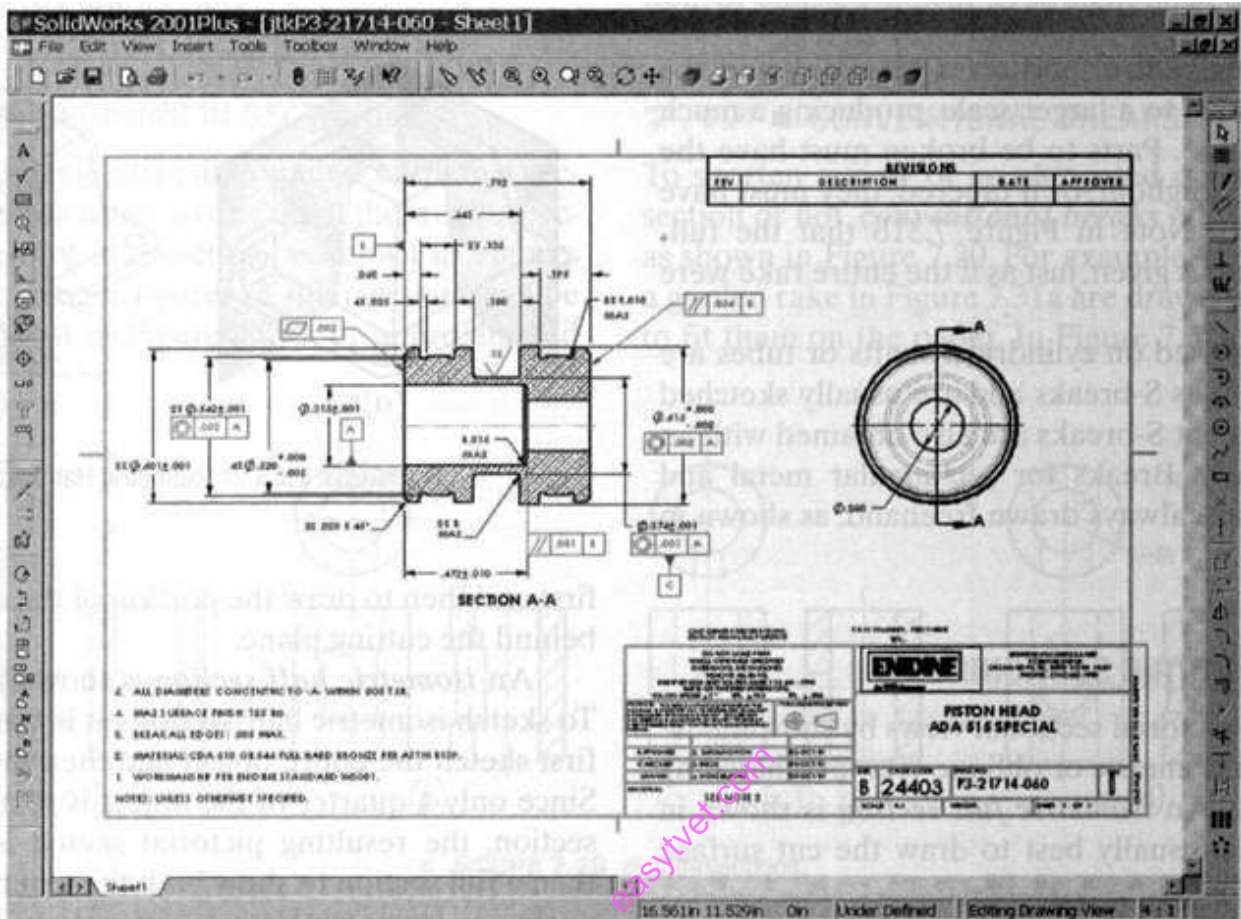


Oblique Sections



Oblique Half Section.

You can also show pictorial sections in oblique view, especially to show interior shapes. An **oblique half section** is shown in Figure **Oblique full sections** are seldom used because they do not show enough of the exterior shapes. In general, oblique sections are similar to isometric sections.



Dimensioned Detail Drawing Produced by SolidWorks. Drawing by Enidine. Courtesy of SolidWorks Corporation.

Assembly drawings

Introduction

A drawing which displays the parts of a machine or a machine unit assembled in their relative working positions is known as assembly drawing.

The assembly drawing would be such that it should satisfy:

- (i) Manufacturing requirements
- (ii) Operational requirements
- (iii) Maintenance requirements.

Designed assembly

This assembly drawing is prepared at the design-stage on a larger scale.

Layout assembly

This is an assembly drawing showing how the parts are assembled with their basic proportions (dimensions).

Installation assembly

This is prepared for the installation or erection of a machine. This is also sometimes known as an outline assembly.

Working drawing assembly

A complete set of working drawings of a machine comprises of detailed drawings, giving all necessary information for the production of individual parts and assembly drawing showing the location of each part. The assembly drawing should be ready before the detailed drawings are accepted as finished and the blue-prints are made.

General assembly

It comprises of the detailed drawings of the individual parts, sub-assembly and the assembly drawings of the machine

Norms to be observed in preparing assembly drawings

- (i) Selection of views: The main or important view which is usually in section should show all the individual parts and their relative locations. Additional views are shown only when they add necessary information.
- (ii) Sectioning: The parts should be sectioned according to the requirements (i.e. half-section or partial section) to show important assembly details. Code of the BIS (SP:46-1988) for general engineering drawings must be observed
- (iii) Dotted lines: The dotted lines should be omitted from the assembly drawing when a proper section is taken. If the view of a part is drawn by the half-section, then in un section portion of the view, the dotted lines may be drawn to clarify details of the part.
- (iv) Dimensions: The overall dimensions and centre-to centre distances showing the relationship of parts to the machine as a whole, are sometimes shown.
- (v) Detailed dimensions are given on working assembly drawings when the detailed drawings are not prepared.

Bill of Materials

Bill of materials: Each part of the machine is identified on assembly drawing by the leader line and number, which are used in the detail drawing and in the bill of material. The height of the number may be

approximately 5 mm and encircled by 9 mm diameter. Leader lines are drawn radially touching the respective parts.

The bill of materials also shows the following:

- a) Number of parts
- b) Material of parts required for one unit
- c) Shop processes
- d) Name of the company
- e) Standard norm for standard components
- f) Designed by, drawn by and checked by
- g) Scale
- (i) Any special remark.

The table containing above information must be prepared as shown in the illustrative problems.

Suggested approach

1. Preparing an assembly form exploded view is easy task as clue to the position and sequence is available
2. For preparing from orthographic view of the individual components some skill is needed

The suggested approach is

1. Functional Matching or Mapping
2. Geometrical mapping
3. Dimensional mapping

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Sequences of preparing the assembly drawing

- (i) Study functional requirements of each component and their inter relationship. • Learn the actual working of a machine.
- (ii) Study carefully the views of each component in the detail drawing and decide the relative location of each part for the proper functioning of the machine.
- (iii) Decide the mating dimensions between two components which are required to be assembled.
- (iv) Prepare free-hand sketch of the main view or an important view (generally front-elevation). Add additional views, if necessary.
- (v) Select a suitable scale for the entire assembly drawing.
- (vi) Lay out the views of the assembly drawing so that it become easier to understand.
- (vii) Prepare the bill of materials.
- (viii) Label each component by the leader-line and number it.

- (ix) Show overall dimensions.
- (x) Draw the section-lines according to the convention

(xi) Show required fits and tolerances between the two mating components.

Classification of Drawings

Machine drawing

It is pertaining to machine parts or components. It is presented through a number of orthographic views, so that the size and shape of the component is fully understood. Part drawings and assembly drawings belong to this classification. An example of a machine drawing is given in the figure below.

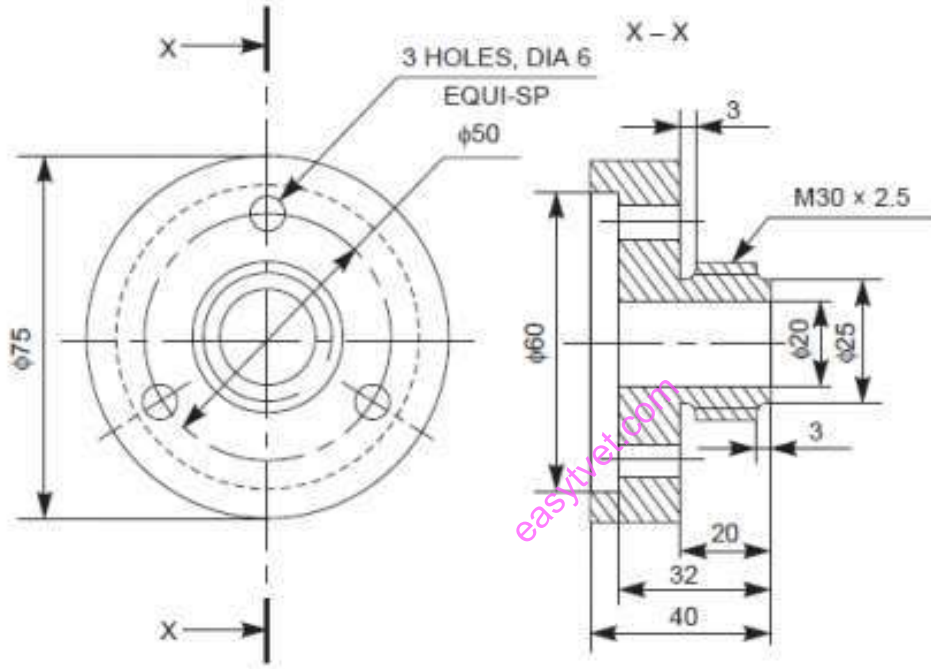


Figure 125: Machine drawing.

Production drawing

A production drawing, also referred to as working drawing, should furnish all the dimensions, limits and special finishing processes such as heat treatment, honing, lapping, surface finish, etc., to guide the craftsman on the shop floor in producing the component. The title should also mention the material used for the product, number of parts required for the assembled unit, etc. Since a craftsman will ordinarily make one component at a time, it is advisable to prepare the production drawing of each component on a separate sheet. However, in some cases the drawings of related components may be given on the same sheet. Figure below represents an example of a production drawing.

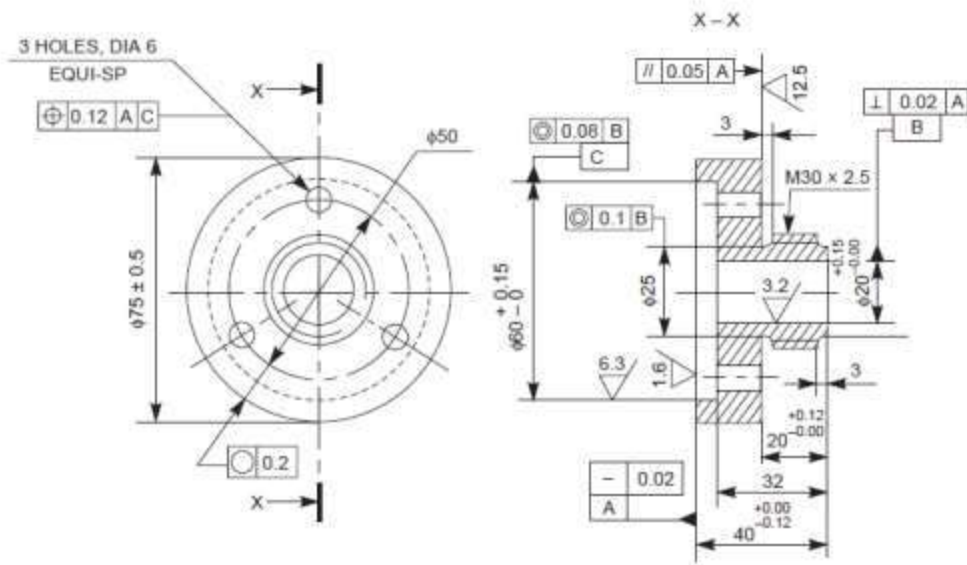


Figure 126: Production drawing.

Assembly drawing

A drawing that shows the various parts of a machine in their correct working locations is an assembly drawing as shown in the figure below. There are several types of such drawings.

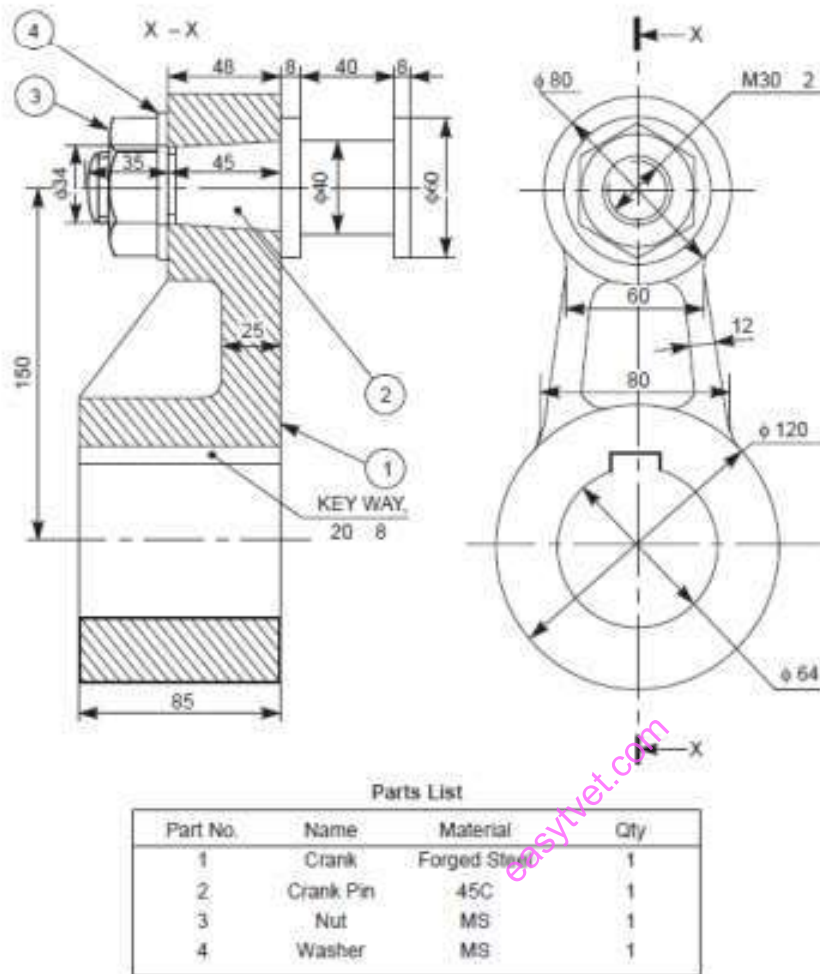


Figure 127: Assembly drawing.

Design Assembly Drawing When a machine is designed, an assembly drawing or a design layout is first drawn to clearly visualise the performance, shape and clearances of various parts comprising the machine.

Detailed Assembly Drawing

It is usually made for simple machines, comprising of a relatively smaller number of simple parts. All the dimensions and information necessary for the construction of such parts and for the assembly of the parts are given directly on the assembly drawing. Separate views of specific parts in enlargements, showing the fitting of parts together, may also be drawn in addition to the regular assembly drawing.

Sub- Assembly Drawing

Many assemblies such as an automobile, lathe, etc., are assembled with many pre-assembled components as well as individual parts. These pre-assembled units are known as sub-assemblies. A sub-assembly drawing is an

assembly drawing of a group of related parts, that form a part in a more complicated machine. Examples of such drawings are: lathe tail-stock, diesel engine fuel pump, carburettor, etc.

Installation Assembly Drawing

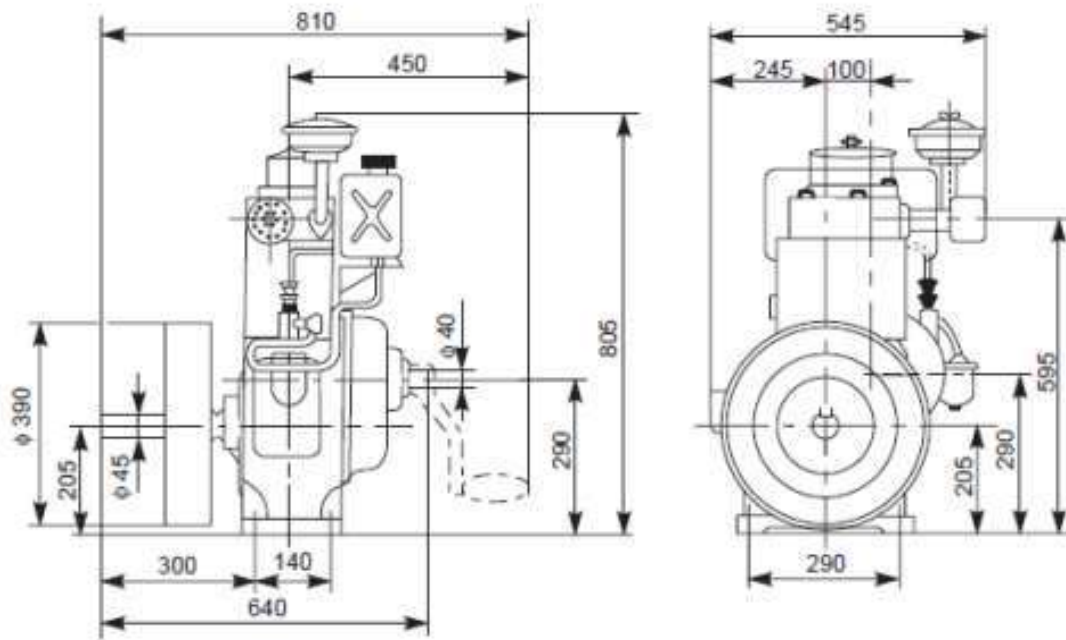
On this drawing, the location and dimensions of few important parts and overall dimensions of the assembled unit are indicated. This drawing provides useful information for assembling the machine, as this drawing reveals all parts of a machine in their correct working position.

Assembly Drawings for catalogues

Special assembly drawings are prepared for company catalogues. These drawings show only the pertinent details and dimensions that would interest the potential buyer. Fig. 1.4 shows a typical catalogue drawing, showing the overall and principal dimensions. Assembly Drawings for instruction manuals These drawings in the form of assembly drawings, are to be used when a machine, shipped away in assembled condition, is knocked down in order to check all the parts before reassembly and installation elsewhere. These drawings have each component numbered on the job. Figure below shows a typical example of such a drawing.

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Assembly Drawings for instruction manuals



These drawings in the form of assembly drawings, are to be used when a machine, shipped away in assembled condition, is knocked down in order to check all the parts before reassembly and installation elsewhere. These drawings have each component numbered on the job. Figure below shows a typical example of such a drawing.

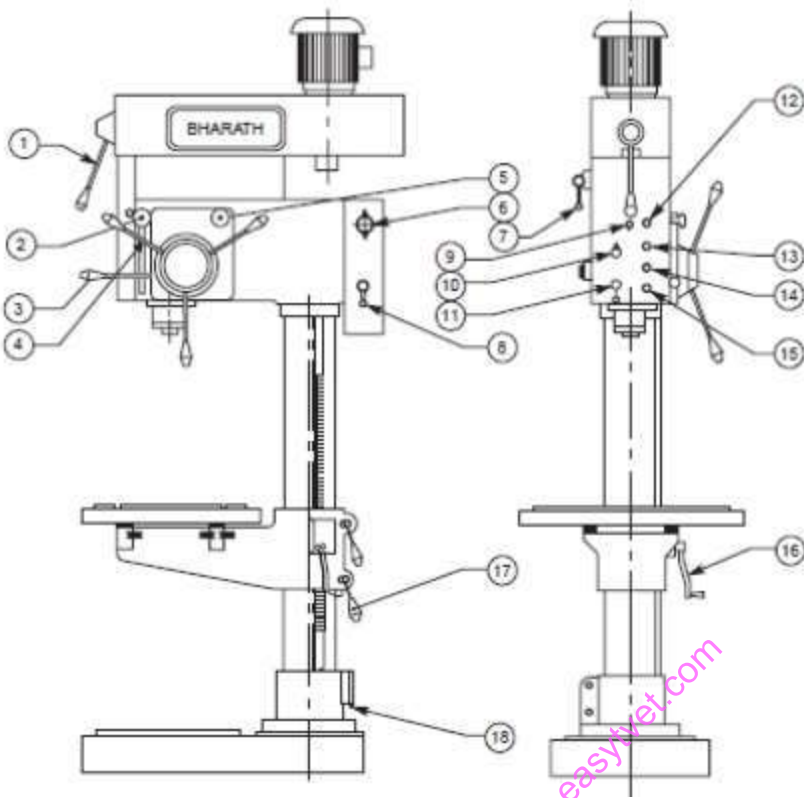


Figure 128: Assembly drawing for instruction manuals

Speed change lever (1)

Selector switch (10)

Depth adjusting knob (2)

Forward switch (11)

Mech. Feed engagement lever (3)

Pilot lamp (12)

Hand free lever (4)

Feed disengagement push button (13)

Feed change knob (5)

Start push button (14)

Switch for tapping(6)

Emergency stop (15)

Gear shifting lever (7)

Elevating handle (16)

Main switch(8)

Clamping handle(17)

Lamp switch(9)

Supply inlet (18)

Exploded Assembly Drawing

In some cases, exploded pictorial views are supplied to meet instruction manual requirements. These drawings generally find a place in the parts list section of a company instruction manual. Figure shows drawings of this type which may be easily understood even by those with less experience in the reading of drawings; because in these exploded views, the parts are positioned in the sequence of assembly, but separated from each other.

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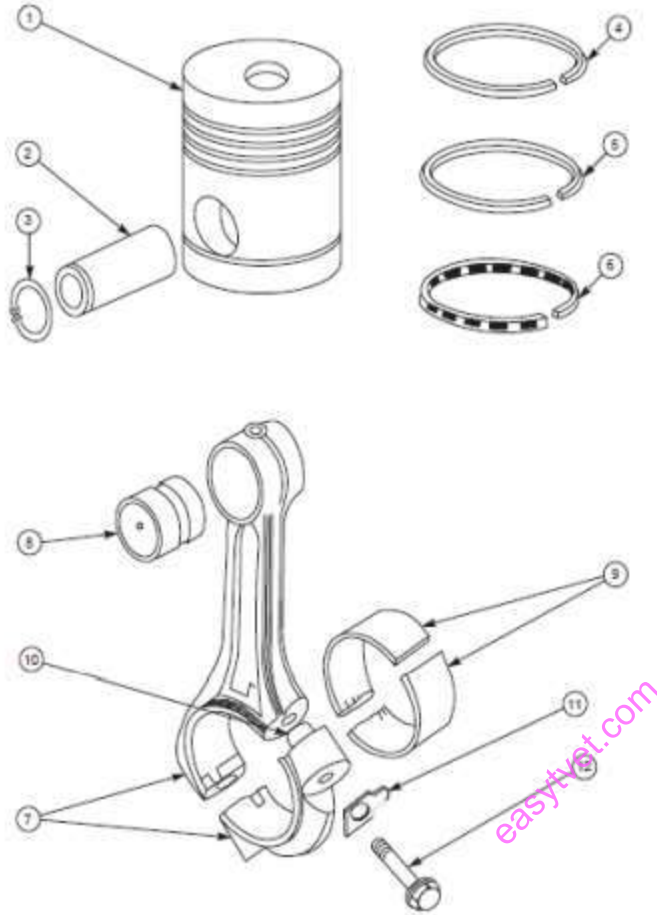


Figure 129: Exploded assembly drawing.

Schematic Assembly Drawing It is very difficult to understand the operating principles of complicated machinery, merely from the assembly drawings. Schematic representation of the unit facilitates easy understanding of its operating principle. It is a simplified illustration of the machine or of a system, replacing all the elements, by their respective conventional representations. The figure below shows the schematic representation of a gearing diagram.

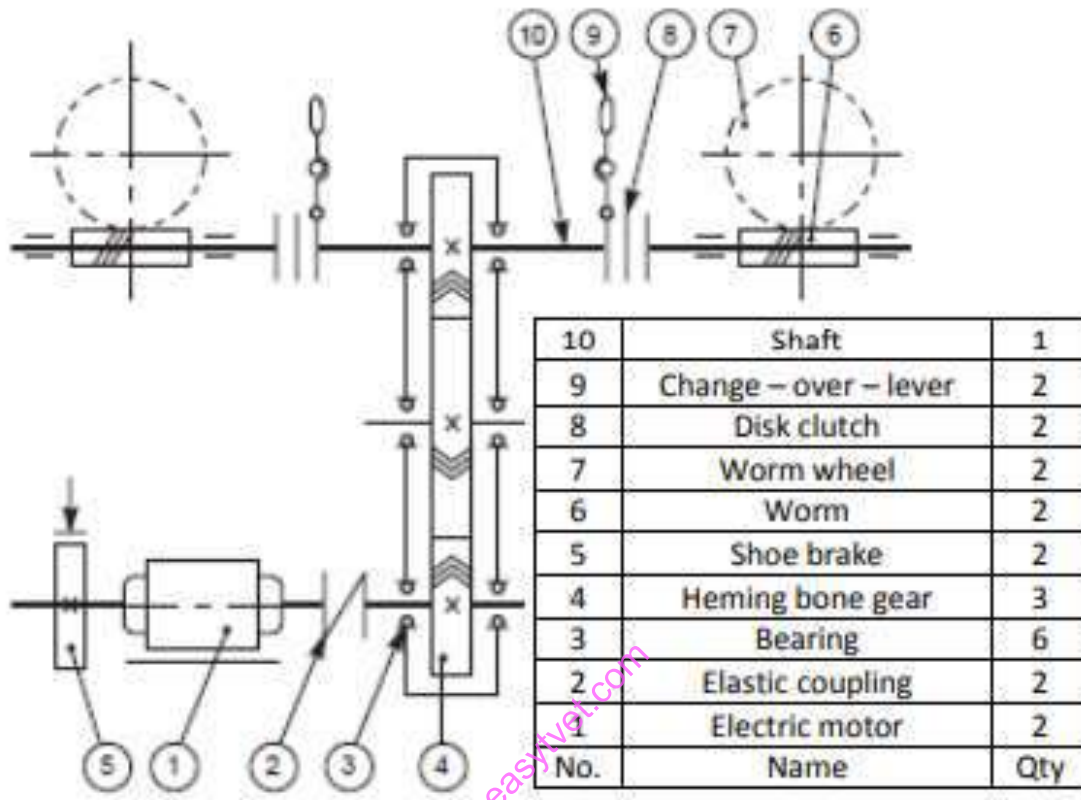


Figure 130: Schematic assembly drawing

Machine Shop Drawing

Rough castings and forgings are sent to the machine shop for finishing operation. Since the machinist is not interested in the dimensions and information of the previous stages, a machine shop shown in figure below. Schematic assembly drawing.

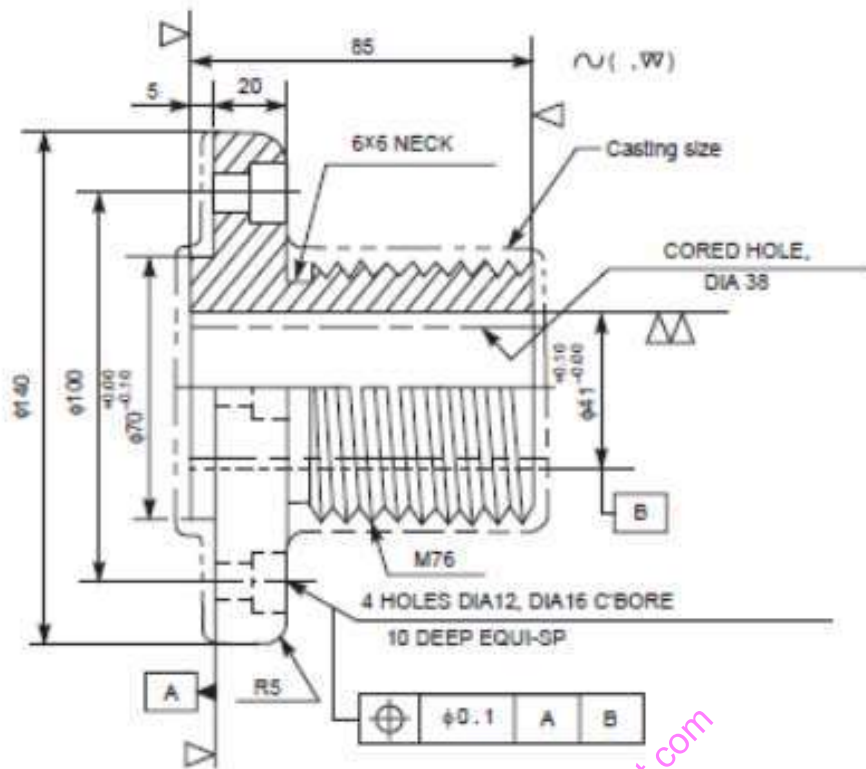


Figure 131: Machine Shop drawing.

Representation of external thread (Stud bolt)

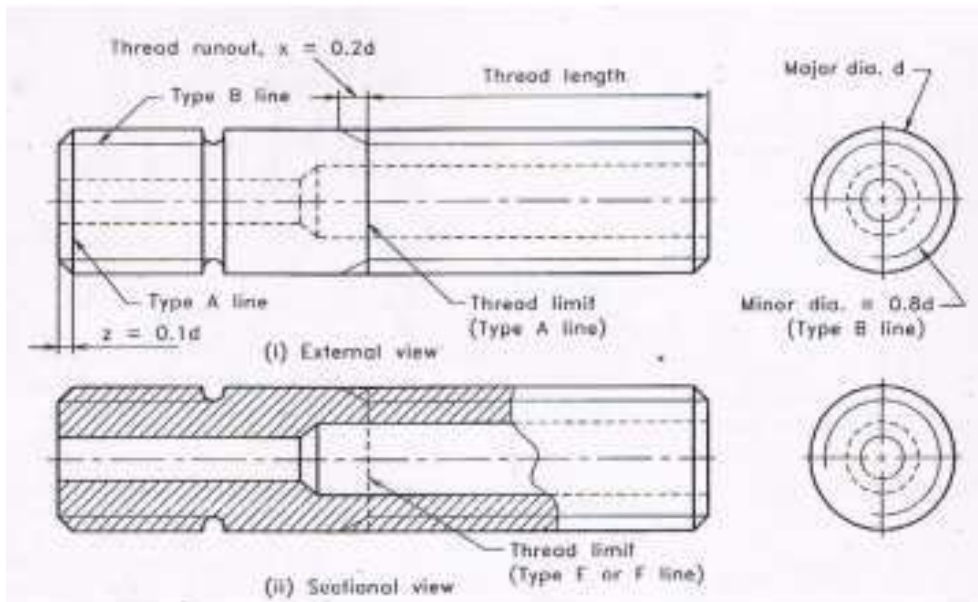


Figure 132: Representation of external thread.

Representation of internal thread

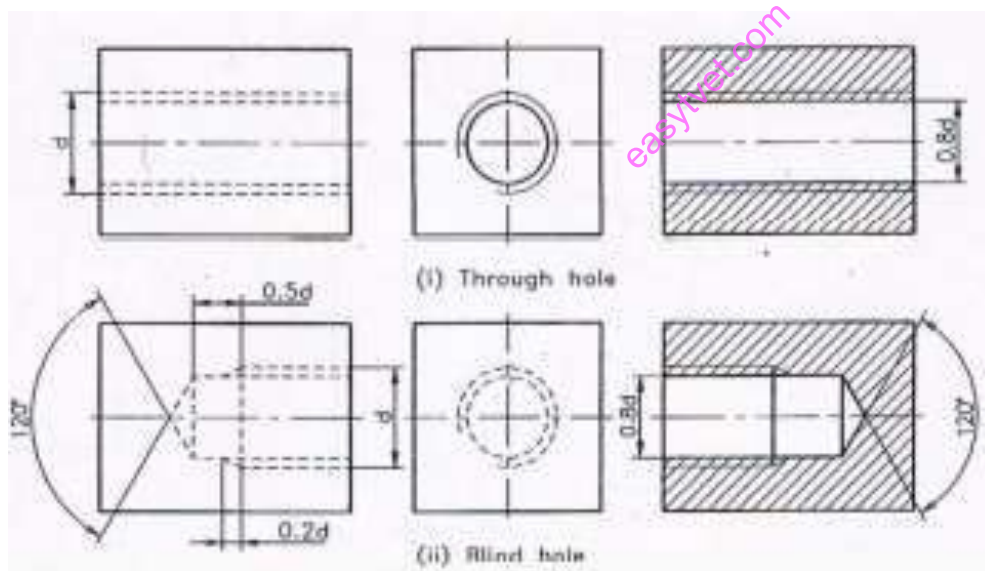


Figure 133:Representation of internal thread

Terminology of bolt and nut

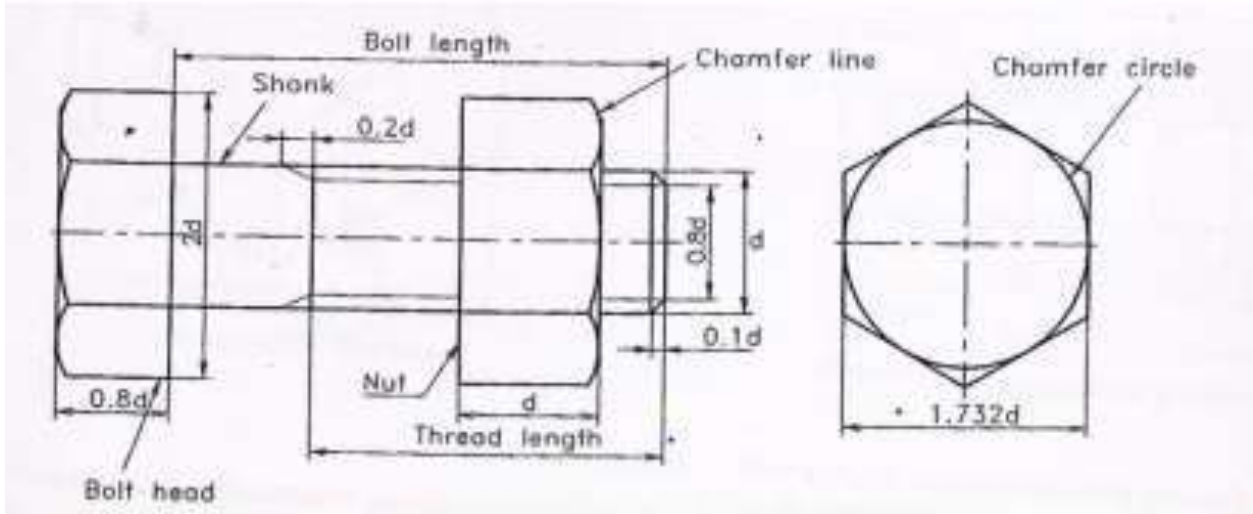


Figure 134: Terminology of bolt and nut

Figure: Terminology of bolt and nut.

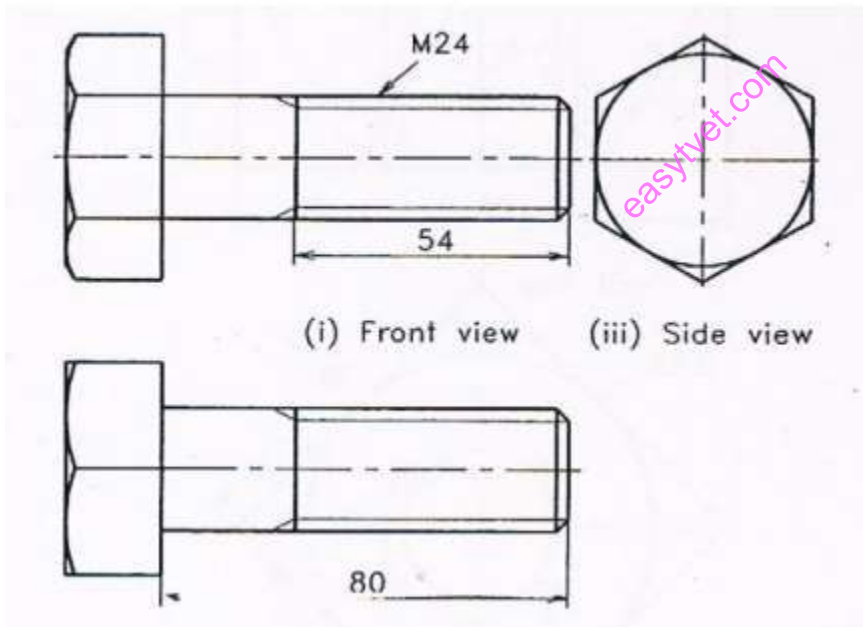


Figure 135: Hexagonal headed bolt

Pictorial Drawing

Isometric Drawing

It is a pictorial orthographic projection of an object in which a transparent cube containing the object is tilted until one of the solid diagonals of the cube becomes perpendicular to the vertical plane and the three axes are equally inclined to this vertical plane.

Types of isometric drawing

- Cavalier
- Cabinet

Lines in Isometric Projection

The following are the relations between the lines in isometric projection

- The lines that are parallel on the object are parallel in the isometric projection.
- Vertical lines on the object appear vertical in the isometric projection.
- Horizontal lines on the object are drawn at an angle of 30° with the horizontal in the isometric projection.
- A line parallel to an isometric axis is called an isometric line and it is foreshortened to 82%.
- A line which is not parallel to any isometric axis is called non-isometric line and the extent of foreshortening of non-isometric lines are different if their inclinations with the vertical planes are different.

Isometric drawing methods

- Box construction
- Four center method

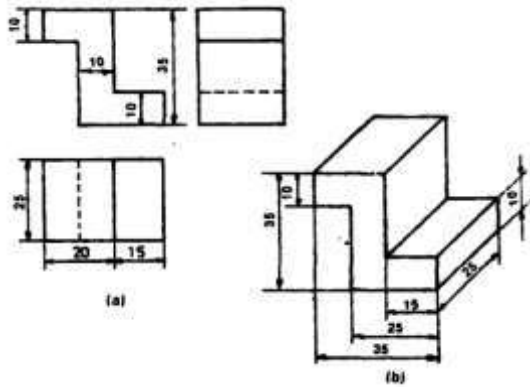
Oblique Drawing

Characteristics of an oblique drawing

In oblique projection, the front face of the object appears in its true size and shape, as it is placed parallel to the picture plane. The receding lines representing the other two faces are usually drawn at 30° , 45° or 60° to the horizontal, 45° being the most common practice.

Oblique projections are classified as cavalier, cabinet.

Draw an oblique box



Isometric and Oblique Circles

Construction of Isometric circles using the method of points

- i. Enclose the circle in a square 1-2-3-4 and draw diagonals. Also draw lines YA horizontally and XA vertically.
- ii. To draw the isometric view of the square 1-2-3-4
- iii. Mark the mid points of the sides of the square as B, D, F and H.
- iv. Locate the points X and Y on lines 1-4 and 1-2 respectively.
- v. Through the point X, draw AX parallel to line 1-2 to get point A on the diagonal 1-3. The point A can be obtained also by drawing YA through the point Y and parallel to the line 1-4.
- vi. Similarly obtain other points C, E and G
- vii. Draw a smooth curve passing through all the points to obtain the required isometric view of the horizontal circular plane.
- viii. Similarly obtain isometric view of the vertical circular plane

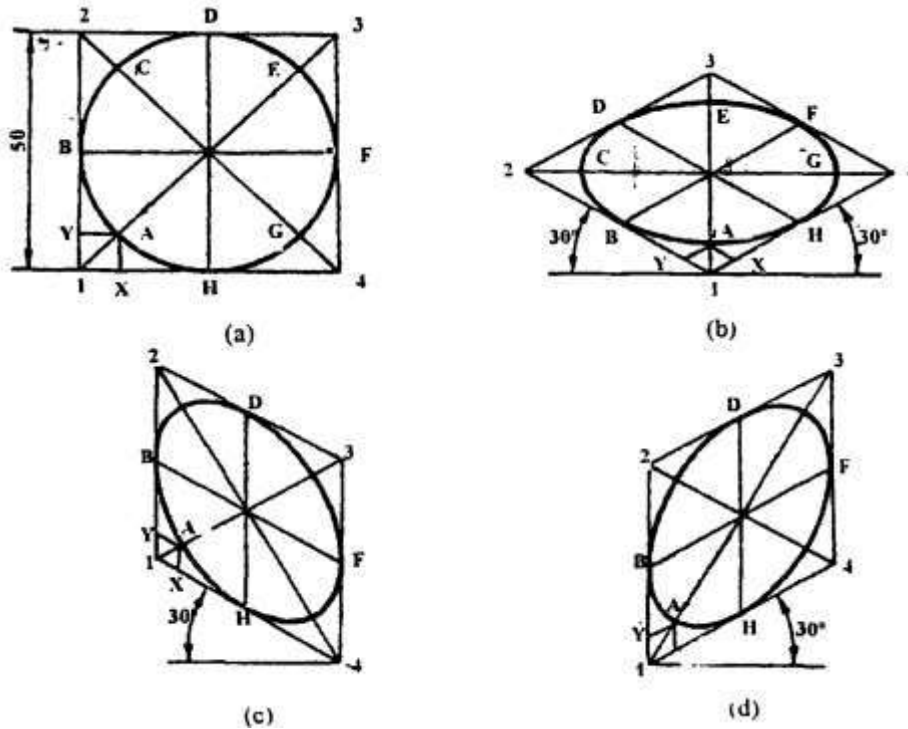


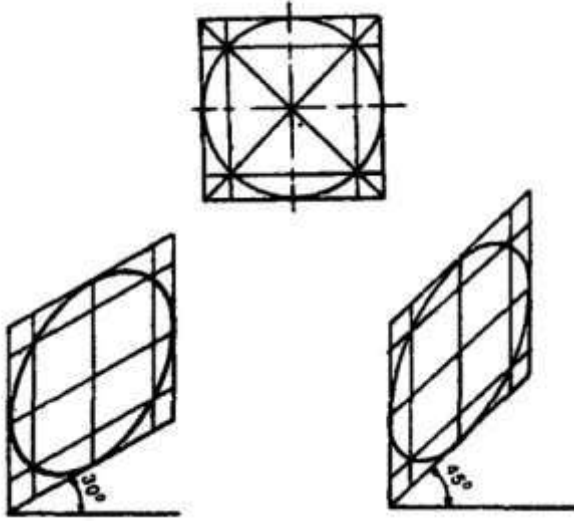
Figure 136: Angles, Circles and Curves in Oblique Projection

As already mentioned, angles, circles and irregular curves on the surfaces, parallel to the picture plane, appear in true size and shape. However, when they are located on receding faces, the construction methods, similar to isometric drawing may be followed.

For example, the method of representing a circle on an oblique face may be carried out by offset method and the four center method cannot be used. In case of cabinet oblique, the method and the result is the same as that of isometric drawing, since the angle of the receding axis can be the same as that of isometric axis.

Shows circles of same size in both isometric and oblique projections using 45° for the receding axis for oblique projections.

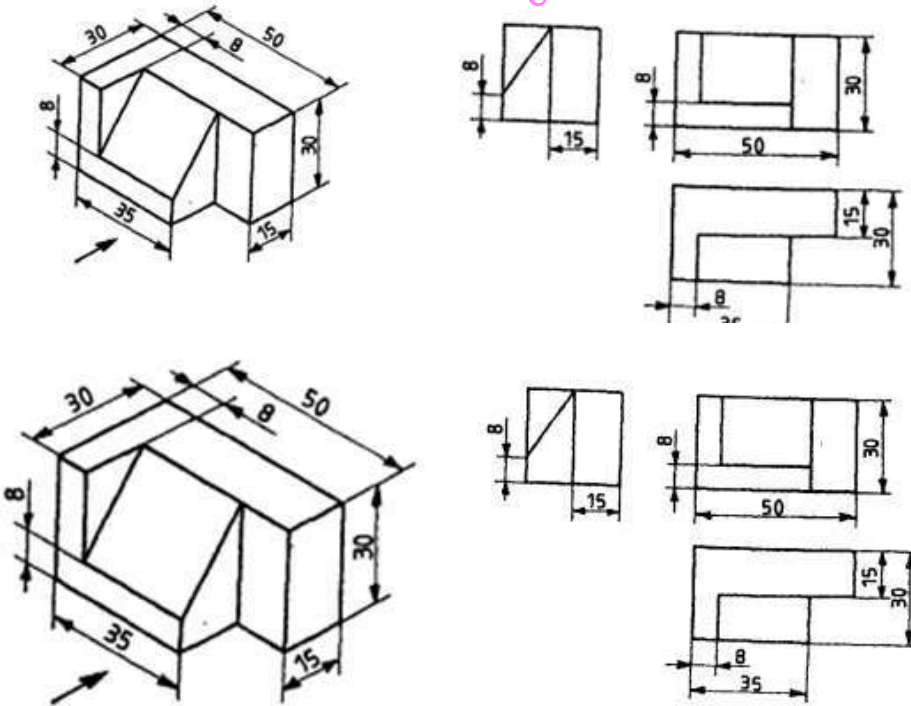
Curved features of all sorts on the receding faces or inclined surfaces may be plotted either by the off-set or co-ordinate methods as shown in the figure below.



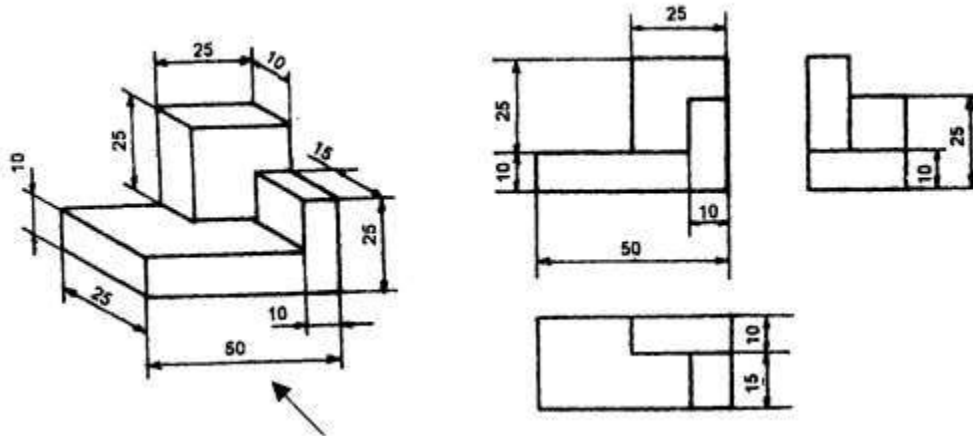
Learning activities

LEARNING ACTIVITY 1: Produce orthographic and pictorial drawings

i. The following figures are in isometric view. Draw the orthographic views in first angle.



ii. The following figures are in oblique view. Draw the orthographic views in first angle.



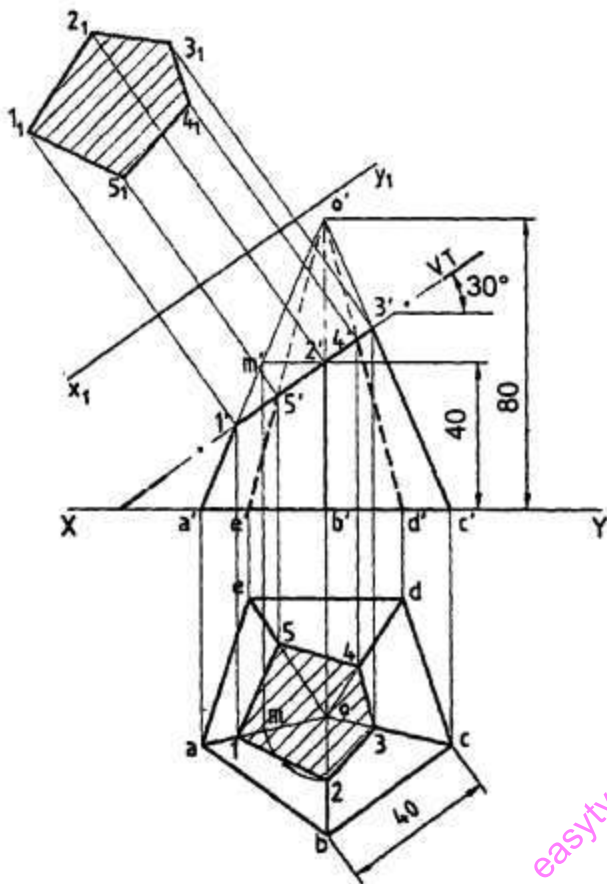
Learning activity 2: Produce orthographic and pictorial drawings

A pentagonal pyramid of base side 40 mm and axis length 80mm is resting on HP on its base with one of its base side parallel to VP. It is cut by a plane inclined at 30° to HP and perpendicular to VP and is bisecting the axis. Draw its front view, sectional top view, and the true shape of section.

Draw the projection of the pyramid in the given position. The top view is drawn and the front view is projected.

To draw the cutting plane, front view and sectional top view

1. Draw the VT of the cutting plane inclined at 30° to XY line and passing through the midpoint of J the axis.
2. As a result of cutting, new comers 1', 2', 3', 4' and 5' are obtained on slant edges a '0', b '0', c '0', d'o' and e '0' respectively.
3. Show the remaining portion in front view by drawing dark lines.
4. Project the new points to get 1,2,3,4 and 5 in the top view on the respective slant edges.
5. Note that 2' is extended horizontally to meet the extreme slant edge a '0 ' at m', it is projected to meet ao in top view at m. Considering 0 as centre, om as radius, draw an arc to get 2 on bo



6. Join these points and show the sectional top view by drawing hatching lines.

To draw true shape of section.

I. Draw the new reference. Line $x_1 y_1$ parallel to VT of the cutting plane.

1.2.3.2 Projectors from $1', 2'$ etc. are drawn perpendicular to $x_1 y_1$ line.

1.2.3.3 The distance of point 1 in top view from XY line is measured and marked from $x_1 y_1$ in the projector passing through $1'$ to get $1'_1$. This is repeated to get $2'_1, 3'_1$ etc.

I. Join these points and draw hatching lines to show the true shape of section.

Learning activity 3

Assemble the following parts and Draw full sectional view of the assembly for the following:

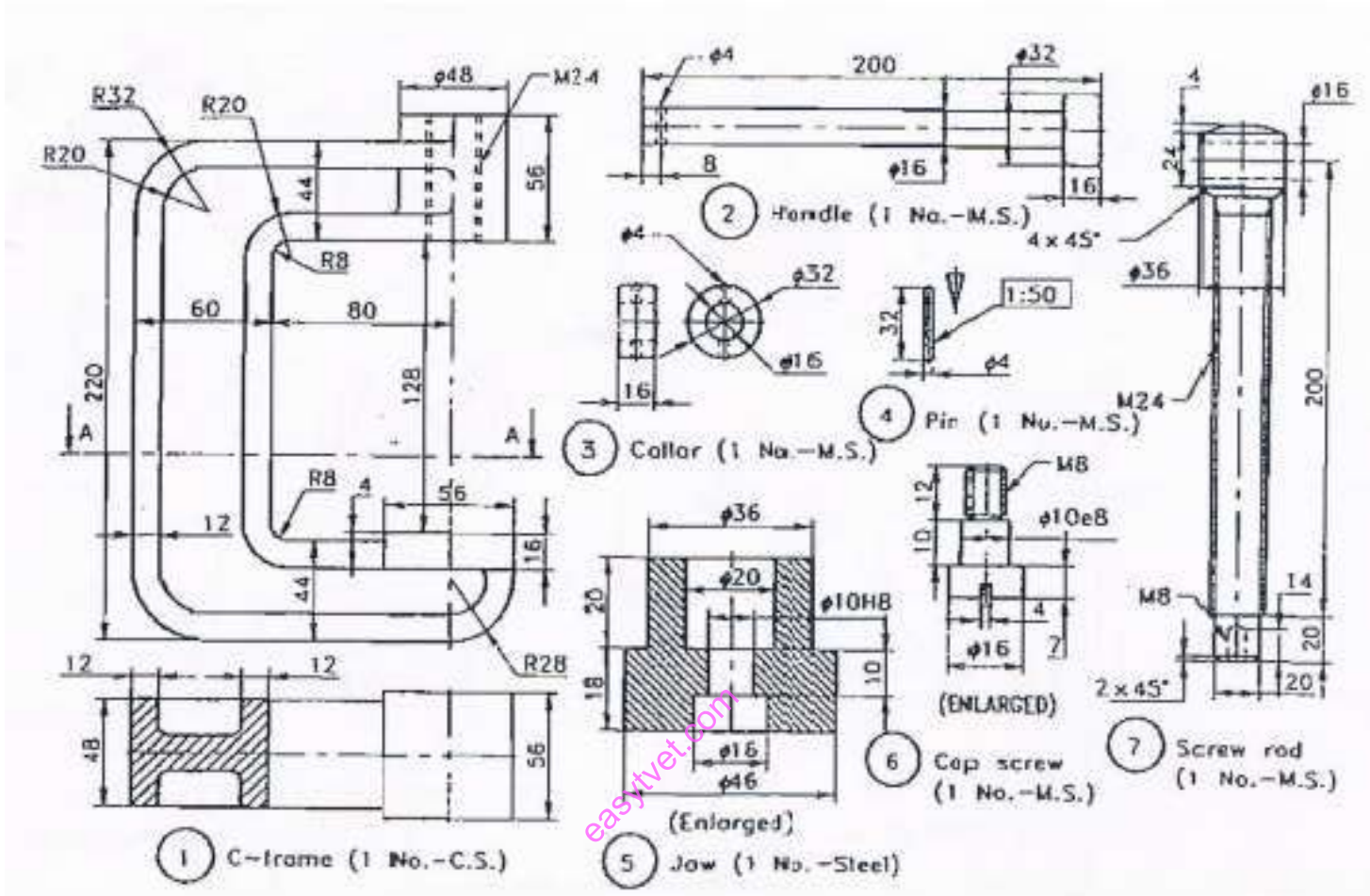


Figure: C-clamp parts.

The assembled clamp

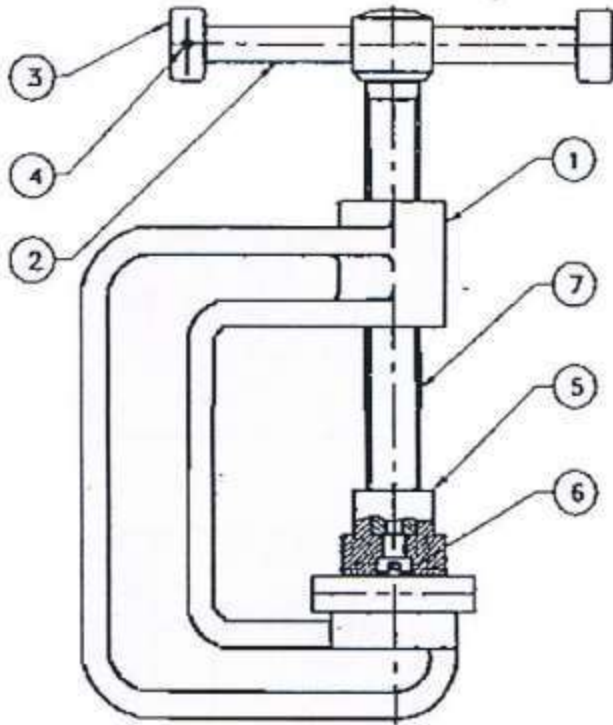


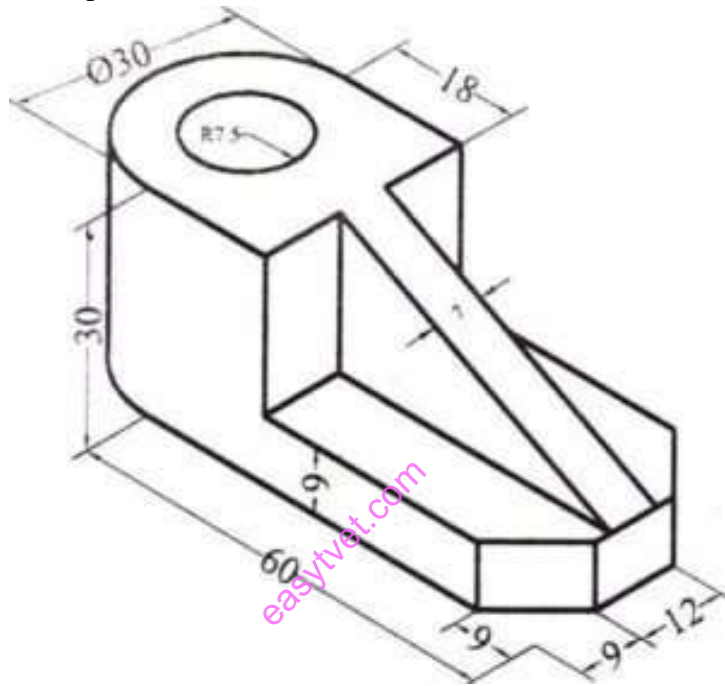
Figure: C-clamp assembly.

7	Screw rode	M.S.		1
6	Cap screw	M.S.		1
5	Jaw	Steel		1
4	Pin	M.S.		1
3	Collar	M.S.		1
2	Handle	M.S.		1
1	C-frame	C.S.		1
No.	Name of part	Material	Notes	Q

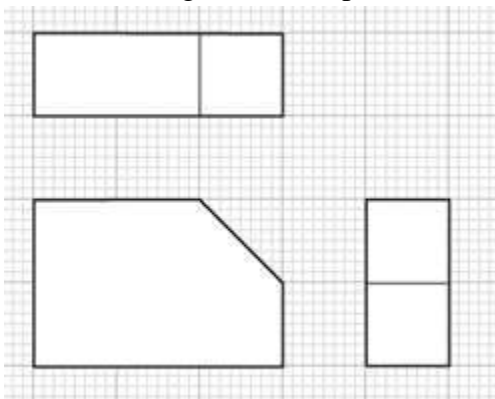
Self-assessment

1. What are the types of orthographic projections?
2. Isometric drawings are often used by _____ to help illustrate complex designs.
 - A. mechanical engineers
 - B. piping drafters
 - C. aerospace engineers
 - D. all of the above

3. When the receding lines are true length, and the projectors are at 45 degrees to the plane of projection, the oblique drawing is called this:
- A. Cabinet projection
 - B. Cavalier projection
 - C. Axonometric projection
 - D. Isometric projection
4. This drawing is an example of:



- A. An orthographic drawing
 - B. An isometric drawing
 - C. A perspective drawing
 - D. An oblique drawing
5. This drawing is an example of:

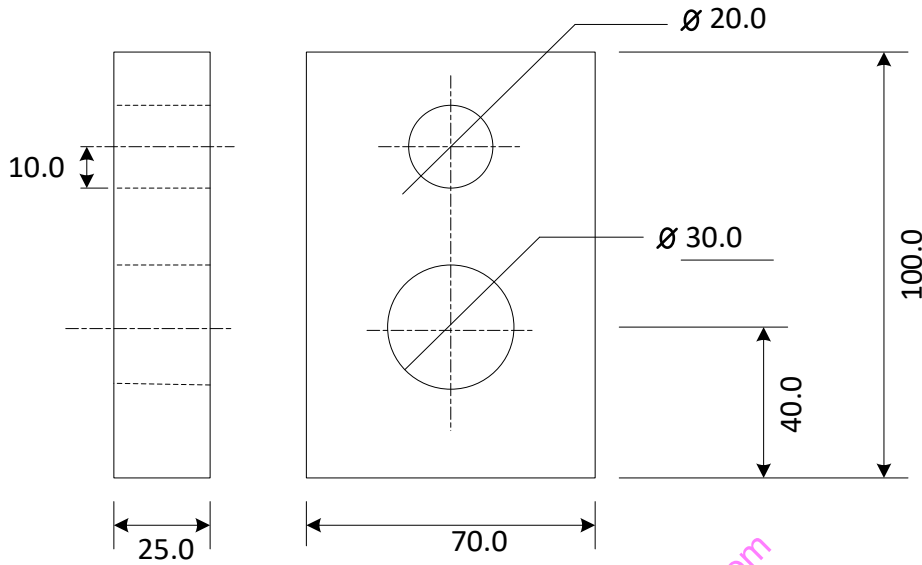


- A. An orthographic drawing
- B. An isometric drawing

- C. A perspective drawing
 - D. An oblique drawing
6. This type of projection is when projectors are parallel to each other, but is at an angle other than 90 degrees to the plane of projection:
 - A. Oblique projection
 - B. Perpendicular projection
 - C. Aesthetic projection
 - D. Angular projection
 7. Name the views in an Orthographic Drawings
 8. The top, front, and bottom views align in this manner:
 - A. Horizontally
 - B. Vertically
 - C. According to the planar views
 - D. Parallel to the frontal plane
 9. If a plane is parallel to the plane of projection, it appears:
 - A. True size
 - B. As a line or edge
 - C. Foreshortened
 - D. As an oblique surface
 10. Three systems are used to arrange orthographic views: first, second, and third angle projection.
 - A. True
 - B. False
 11. This line pattern is composed of three dashes, one long dash on each end with a short dash in the middle:
 - A. Object
 - B. Hidden
 - C. Center
 - D. Phantom
 12. This is the plane upon which the top view is projected:
 - A. Horizontal
 - B. Frontal
 - C. Profile
 - D. Base
 13. An advantage of this type of view is that each view shows the object all the way through as if it were transparent:
 - A. Planar
 - B. Horizontal
 - C. Auxiliary
 - D. Orthographic
 14. This type of surface is tipped to all principal planes of projection and does not appear true size in any standard view:

- A. Foreshortened
- B. Parallel
- C. Orthographic
- D. Oblique

15. From the following figure, which is the repetitive dimension?



- A. 30
- B. 70
- C. 10
- D. 20

Tools, Equipment, Supplies and Materials

1. Drawing tools
2. Drawing set
3. Drawing papers
4. Erasers
5. Series of pencils
6. Drawing board

References

1. Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing: Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.
2. Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.
3. Narayana, K. L., Kanniah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.
4. Reddy, K. V. 2010. Textbook of Engineering Drawing . B.S. Publ., Hyderabad.

5. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical

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4.6 Apply Cad Packages

Introduction to the learning outcome

This learning outcome is intended to equip the trainee with competence on how to apply CAD packages.

In this learning outcome AutoCAD has been selected to be the dominant CAD software to be learnt.

Performance Standard

- i. CAD packages are selected according to task requirements
- ii. CAD packages are applied in production of electrical drawings

Information sheet

Identification of CAD packages

Computer-Aided Design (CAD) Software

Computer-Aided Design (CAD) is the use of an application to help create or optimize a design. Therefore, CAD software allows engineers, architects, designers, and others to create precision drawings or technical illustrations in 2D or 3D. This category of software can increase productivity, improve quality, and maximize organization by creating a documentation database for manufacturing.

CAD software has a host of applications, including the design of manufacturing parts, electronic circuit boards, prototypes for 3D printers, and buildings. Typically, this software uses either traditional vector-based graphics or raster graphics which show how finished objects would actually look.

CAD software can also facilitate the flow from the design process to the manufacturing process. This software can simulate the movement of a part through the manufacturing process in three dimensions. As this software becomes ever better at simulating the manufacturing process, specialized software for designing the manufacturing process and controlling machine tools called Computer-Aided Manufacturing (CAM) has become integrated with CAD as a single platform.

Computer-Aided Design (CAD) Features & Capabilities

AutoCAD

DEFINITION OF TERMS

Basics

This section reviews the basic AutoCAD controls.

Viewing

Pan and zoom in a drawing, and control the order of overlapping objects.

Geometry

Create basic geometric objects such as lines, circles, and hatched areas.

Precision

Ensure the precision required for your models.

Layers

Organize your drawing by assigning objects to layers.

Properties

You can assign properties such as color and linetype to individual objects, or as default properties assigned to layers.

Modifying

Perform editing operations such as erase, move, and trim on the objects in a drawing.

Blocks

Insert symbols and details into your drawings from commercial online sources or from your own designs.

Layouts

Display one or more scaled views of your design on a standard-size drawing sheet called a layout.

Notes and Labels

Create notes, labels, bubbles, and callouts. Save and restore style settings by name

Dimensions

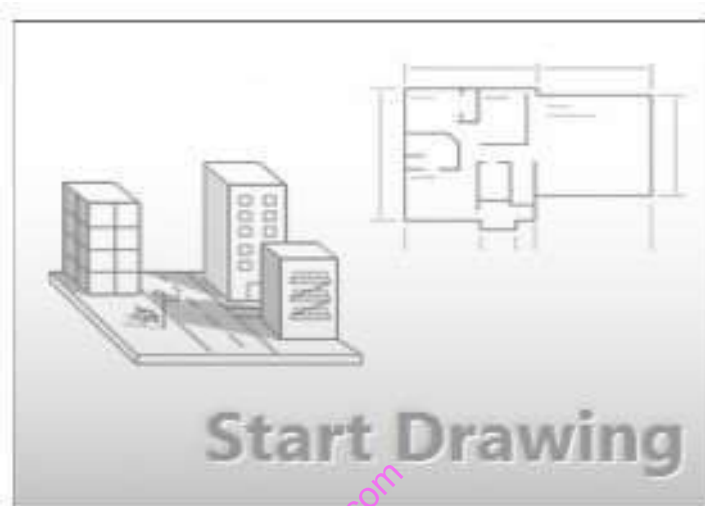
Create several types of dimensions and save dimension settings by name.

Printing

Output a drawing layout to a printer, a plotter, or a file. Save and restore the printer settings for each layout.

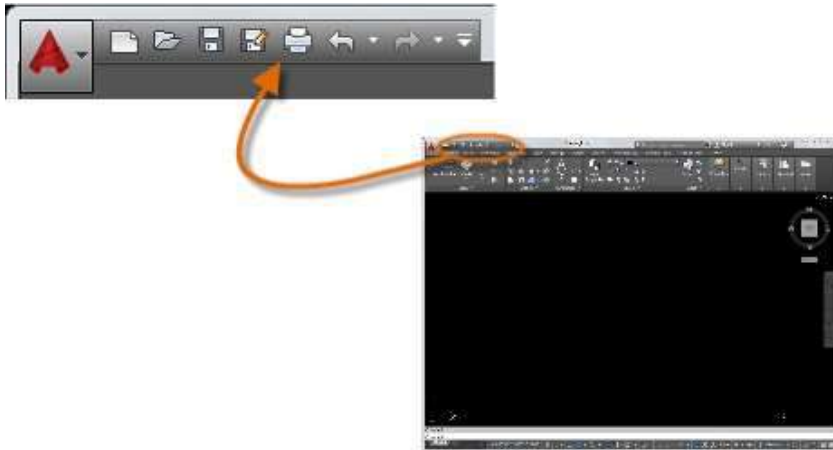
Basics

Review the basic AutoCAD controls. After you launch AutoCAD, click the Start Drawing button to begin a new drawing.



AutoCAD includes a standard tabbed ribbon across the top of the drawing area. You can access nearly all the commands presented in this guide from the **Home** tab. In addition, the Quick Access toolbar shown below includes familiar commands

such as New, Open, Save, Print, Undo, and so on.



The Command Window

At the heart of AutoCAD is the Command window, which is normally docked at the bottom of the application window. The Command window displays prompts, options, and messages.

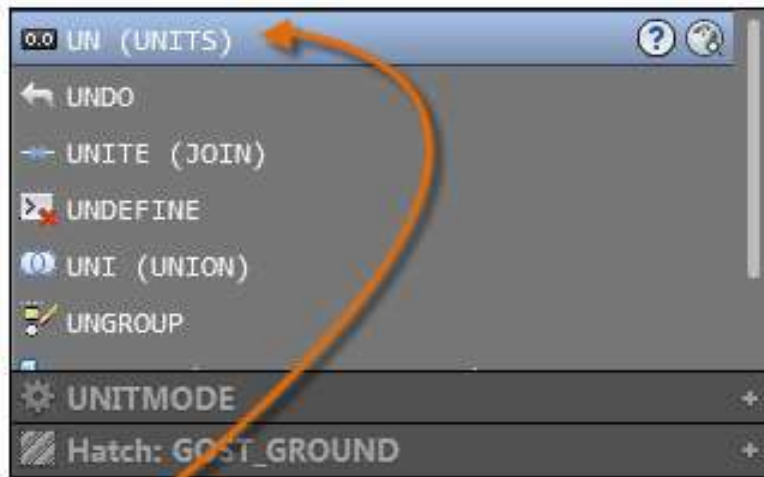


You can enter commands directly in the Command window instead of using the ribbon, toolbars, and menus.

Many long- time AutoCAD users prefer this method.

Notice that as you start to type a command, an autocomplete menu appears.

When several options are available, such as in the example below, make your choice by clicking the correct option or using the arrow keys and then pressing Enter or the Spacebar to confirm your selection.



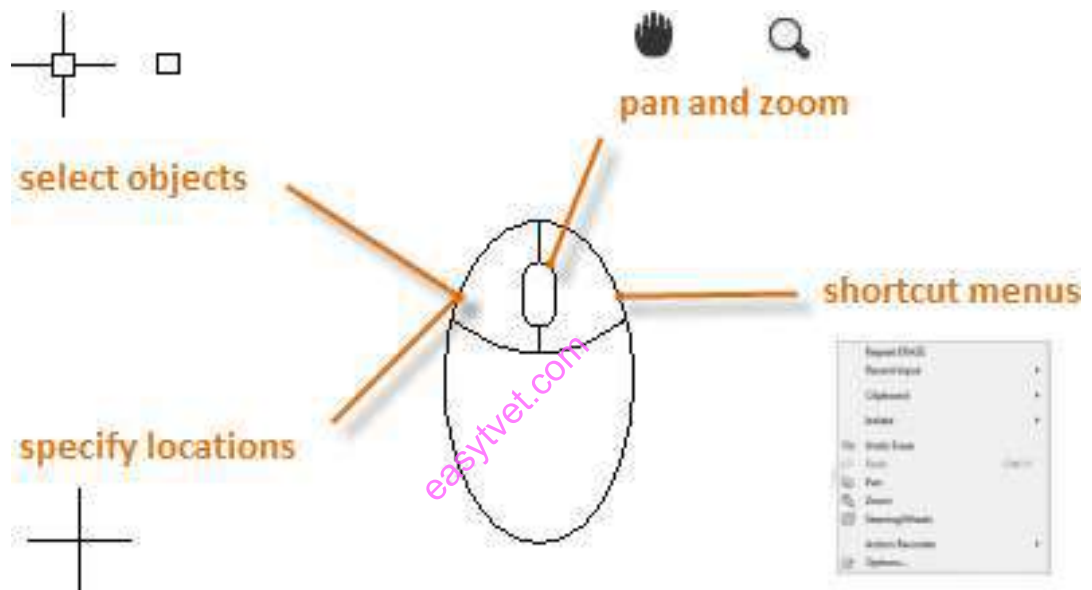
The Mouse

Most people use a mouse as their pointing device, but other devices have equivalent controls.

Here's a Tip:

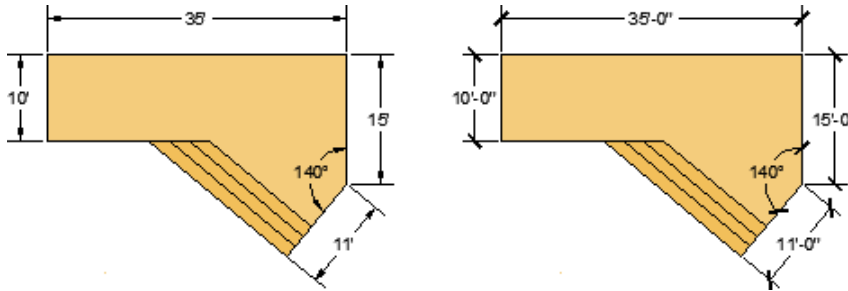
When looking for a command or option, try right-clicking.

Depending on where your cursor is located, different menus will display relevant commands and options.



New Drawings

You can easily conform to industry or company standards by specifying settings for text, dimensions, linetypes, and several other features. For example, this backyard deck design displays two different dimension styles.



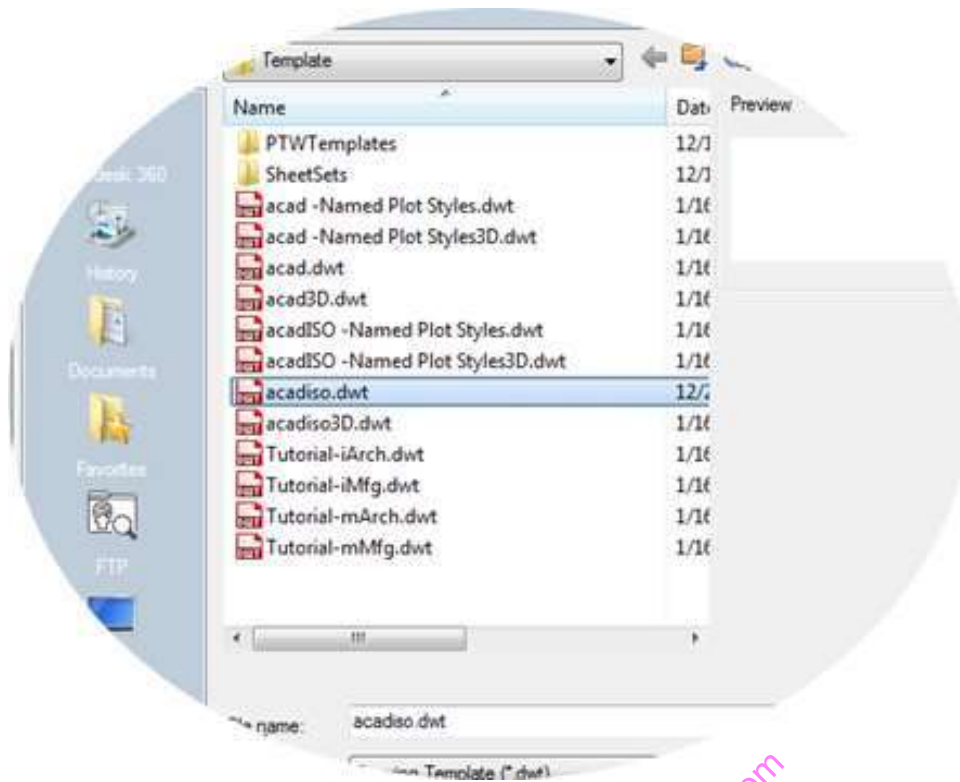
All these settings can be saved in a *drawing template* file. Click New to choose from several drawing



Template files:

For imperial drawings that assume your units are inches, use *acad.dwt* or *acadlt.dwt*.

For metric units that assume your units are millimeters, use *acadiso.dwt* or *acadltiso.dwt*.



The “Tutorial” template files in the list are examples of the architectural or mechanical design templates using both imperial (i) and metric (m) measurements.

You might want to experiment with them.

Most companies use drawing template files that conform to company standards, and they will often use different drawing template files depending on the project or client.

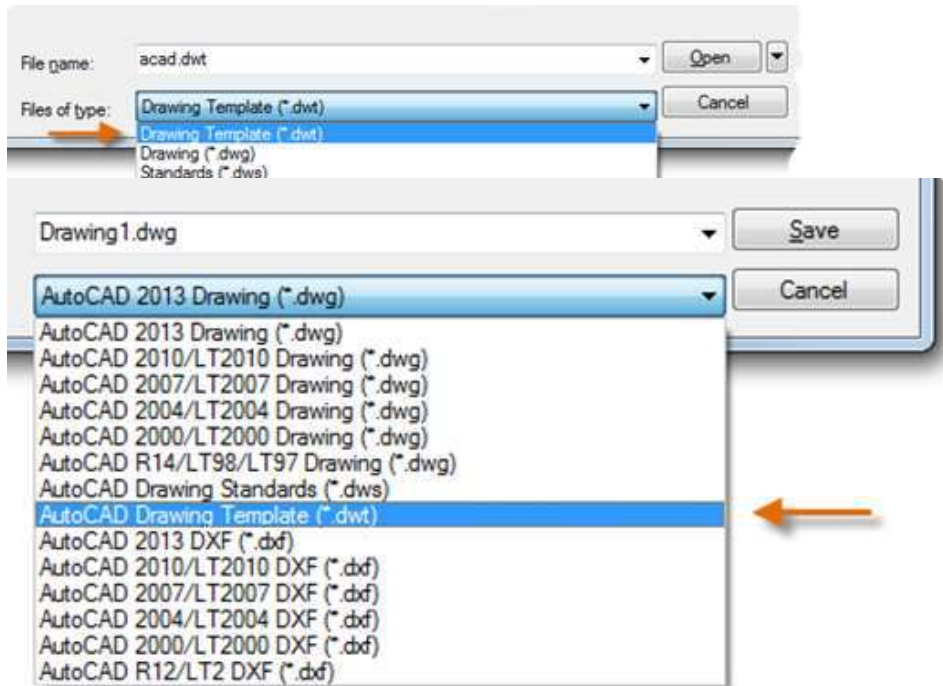
Create Your Own Drawing Template File

You can save any drawing (.*dwg*) file as a drawing template (.*dwt*) file. You can also open any existing drawing template

If you work independently, you can develop your drawing template files to suit your working preferences, adding settings for additional features as you become familiar with them.

To modify an existing drawing template file, click Open, specify Drawing Template (*.*dwt*) in the Select File dialog box, and choose the template file. Important:

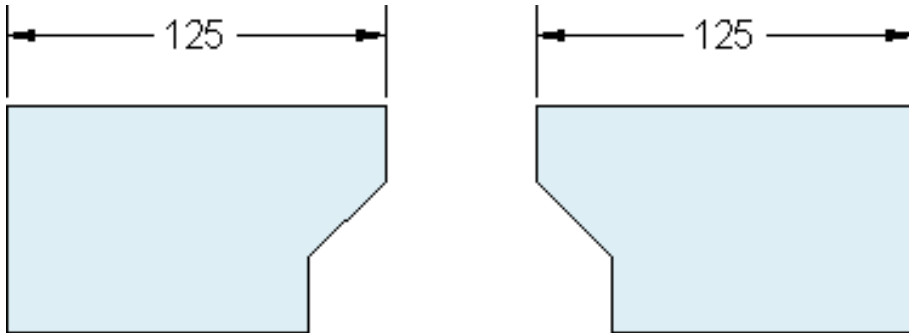
If your company has already established a set of drawing template files, check with your CAD manager before modifying any of them.



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Units

When you first start a drawing, you need to decide what the length of one unit represents an inch, a foot, a centimeter, a kilometer, or some other unit of length. For example, the objects below could represent two buildings that are each 125 feet long, or they could represent a section from a mechanical part that is measured in millimeters.



Unit Display Settings

After you decide what unit of length that you want to use, the **UNITS** command lets you control several unit display settings including the following:

Format (or Type): For example, a decimal length of 6.5 can be set to display as a fractional length of 6-1/2 instead.

Precision: For example, a decimal length of 6.5 can be set to display as 6.50, 6.500, or 6.5000.

If you plan to work in feet and inches, use the **UNITS** command to set the unit type to Architectural, and then when you create objects, specify their lengths in inches. If you plan to use metric units, leave the unit type set to Decimal. Changing the unit format and precision does not affect the internal precision of your drawing, it affects only how lengths, angles, and coordinates are displayed in the user interface

Here's a Tip:

If you need to change the **UNITS** settings, make sure that you save the drawing as a drawing template file (.dwt). Otherwise, you will need to change the **UNITS**

Model Scale

Always create your models at full size (1:1 scale). The term *model* refers to the geometry of your design. A *drawing* includes the model geometry along with the views, notes, dimensions, callouts, tables, and the title block displayed in the *layout*.

You can specify the scaling that is necessary to print a drawing on a standard-sized sheet later, when you create the layout.

Recommendations

To open **Help** for information about the command in progress, press F1.

To **repeat** the previous command, press Enter or the Spacebar.

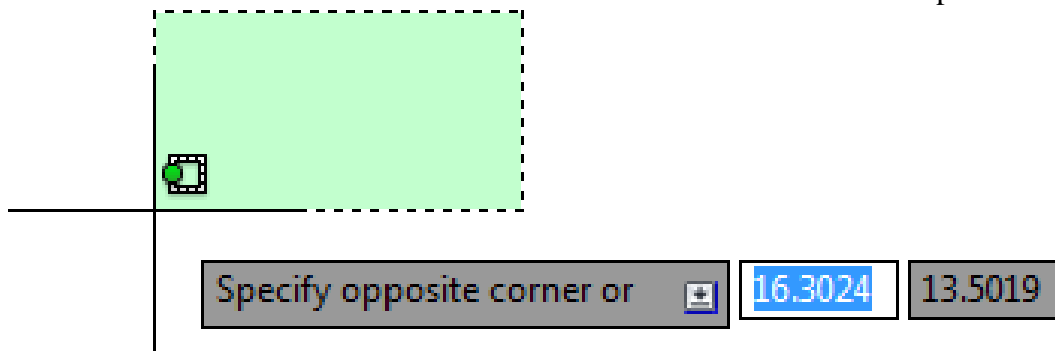
To see various **options**, select an object and right-click or right-click a user interface element.

To **cancel** a command in progress or if you ever feel stuck, press Esc.

For example GUIDE TO AUTOCAD BASICS: PRINTING e, if you click in the drawing area before entering a command, you will see something like the following:

Here's a Tip:

Press Esc to cancel this preselection operation.



Viewing

Zoom in on a drawing to better control the order of overlapping objects. The easiest way to change your view is by using the mouse wheel.

Zoom in or out by rolling the wheel.

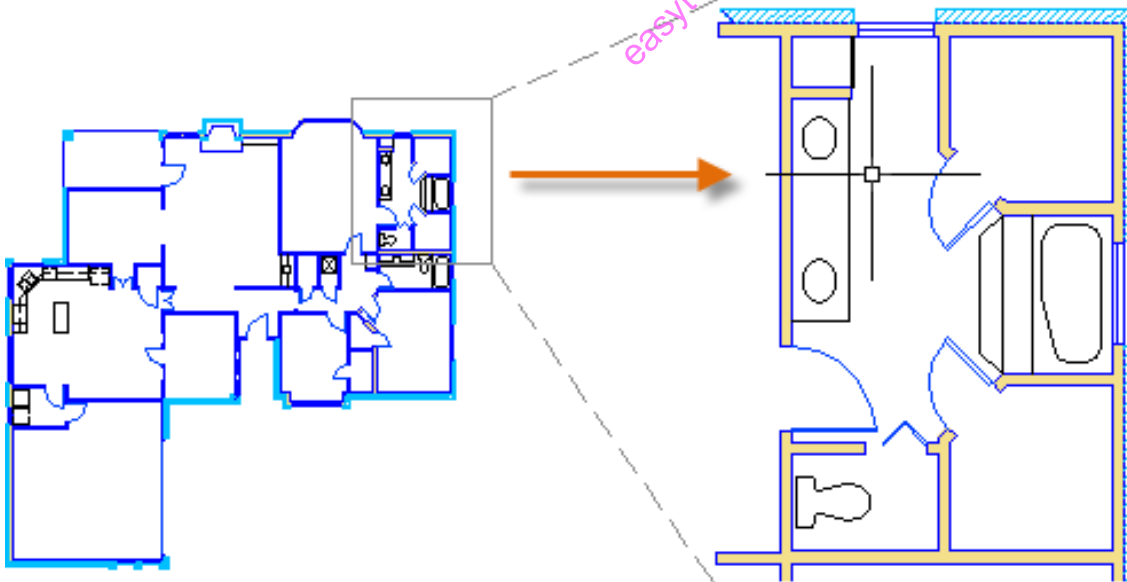
Pan a view in any direction by holding the wheel down while moving your mouse.

Zoom in on a specific area for greater detail holding your mouse over the area and clicking the wheel twice.

Here's a Tip:

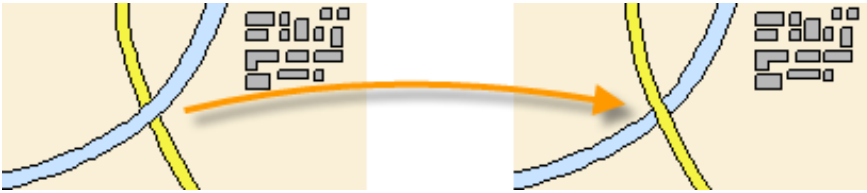
When you zoom in or out, the location of the cursor is important. Think of your cursor as a magnifying glass. For example, if you position the cursor in the upper-right area of the floor plan as shown below, zooming in magnifies the dressing room without shifting the view.

NOTE: If you cannot zoom or pan any more, type **REGEN** in the Command window and press Enter. This command regenerates the drawing display and resets the extents available for panning and z



Overlapping Objects

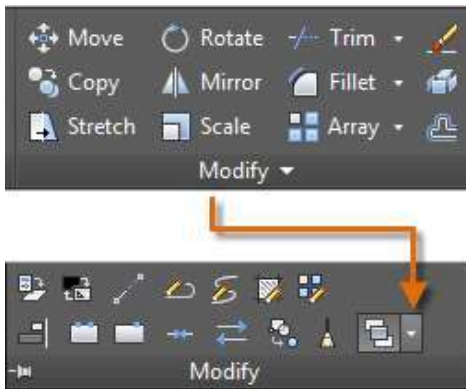
If you create objects that overlap, you might need to change which objects are displayed on top or in front of the others. For example, if you want the yellow highway to cross the blue river rather than the other way around,



use the **DRAWORDER** command to reorder the objects.

You can access several draw order options from the Modify panel on the ribbon. Click to expand the Modify panel, and then click the down-arrow as shown below.

The draw order options that are listed include sending all hatches to the back, all text to the front, and so on.



Geometry

Create basic geometric objects such as lines, circles, and hatched areas.

You can create many different types of geometric objects in AutoCAD, but you only need to know a few of them for most 2D drawings.

NOTE: If you want to simplify the display while creating geometric objects, press *F12* to turn off dynamic input.

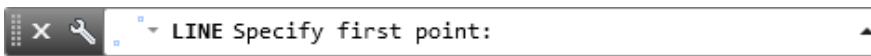
Lines

The line is the most basic and common object in AutoCAD drawings. To draw a line, click the Line tool.



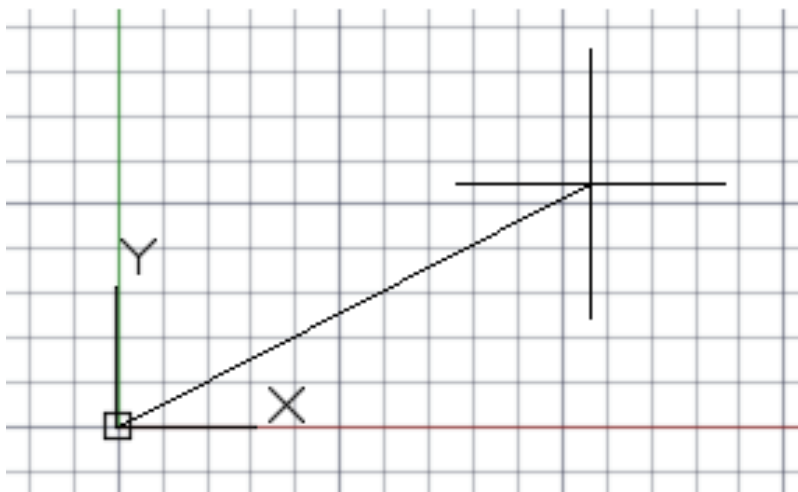
Alternatively, you can type **LINE** or just **L** in the Command window, and then press Enter or the Spacebar.

Notice the prompt in the Command window for a point location.



To specify the starting point for this line, you would type in the coordinates 0,0. It is a good idea to locate one corner of your model at 0,0, which is called the origin point. To locate additional points, you could specify additional X,Y coordinate

locations in the drawing area, however more efficient methods for specifying points are available, and will be presented in the Precision topic.

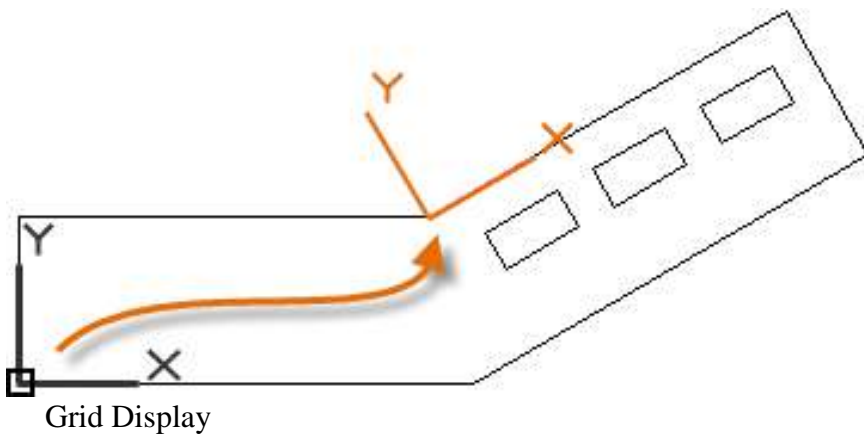


After you specify the next point, the LINE command automatically repeats itself, and it keeps prompting you for additional points.

Press Enter or the Spacebar to end the sequence.

The User Coordinate System

The user coordinate system (UCS) icon indicates the direction of the positive X and Y axis for any coordinates that you enter, and it also defines the horizontal and vertical directions in a drawing. In some 2D drawings, it can be convenient to click, drag, and rotate the UCS to change the origin point, and the horizontal and vertical directions.



Some people like working with grid lines as a reference, while others prefer working in a blank area. To turn off the grid display, press F7. Even with the grid turned off, you can force your cursor to snap to grid increments by pressing F9.

Lines as Construction Aids

Lines can serve as reference and construction geometry such as:

Property line setbacks

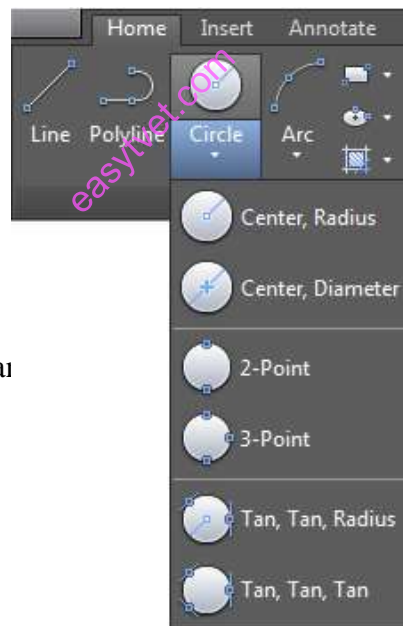
The mirror line of a symmetrical mechanical part

Clearance lines to avoid interferences

Traversal path lines

Circles

The default option of the **CIRCLE** command

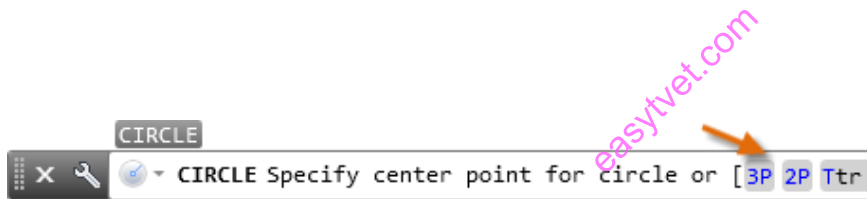


ter point and a radius.

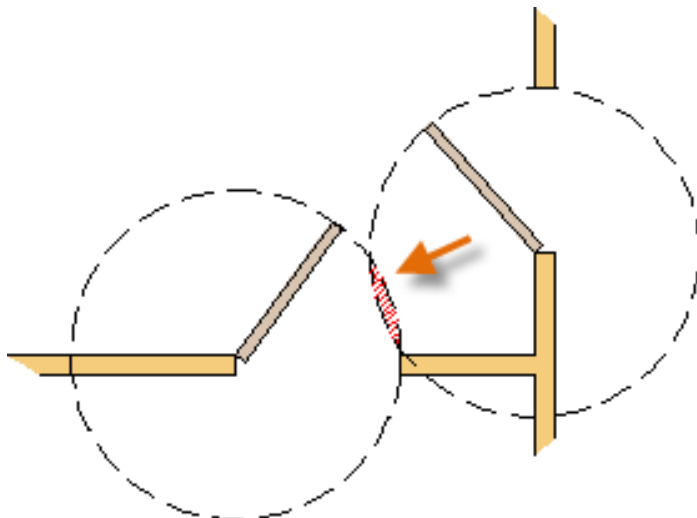


The other circle options are available from the drop-down:

Alternatively, you can also enter **CIRCLE** or just **C** in the Command window and click to choose an option. If you do, you can specify a center point, or you can click one of the highlighted command options as shown below.



Circles can be useful as reference geometry. For example, you can see that the two doors in the illustration can interfere with each other.



Polylines and Rectangles

A polyline is a connected sequence of line or arc segments that is created as a single object.



Use the **PLINE** command to create open or closed polylines for:

Geometry that requires fixed-width segments

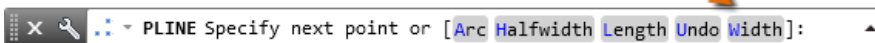
Continuous paths for which you need to know the total length

Contour lines for topographic maps and isobaric data

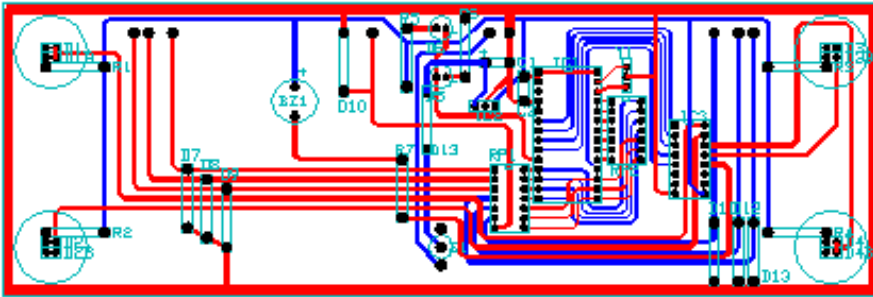
Wiring diagrams and traces on printed circuit boards

Process and piping diagrams

Polylines can have a constant width or they can have different starting and ending widths. After you specify the first point of the polyline, you can use the Width option to specify the width of all subsequently created segments. You can change the width value at any time, even as you create new segments.



Here is an example of a printed



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Polylines and Rectangles

Polylines can have different starting and ending widths for each segment as shown here:



A fast way to create closed rectangular polylines is to use the **RECTANG** command (enter **REC** in the Command window).

Simply click two diagonal points for the rectangle as illustrated. If you use this method, turn on grid snap (F9) for precision.



Hatches and Fills

In AutoCAD, a hatch is a single, compound object that covers a specified area with a pattern of lines, dots, shapes, a solid fill color, or a gradient fill.



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When you start the **HATCH** command, the ribbon temporarily displays the Hatch Creation tab. On this



tab, you can choose from over 70 industry-standard imperial and ISO hatch patterns along with many specialized options.

The simplest procedure is to choose a hatch pattern and scale from the ribbon, and click within any area that is completely enclosed by objects. You must specify the scale factor for the hatch in order to control its size and spacing.

After you create a hatch, you can move the bounding objects to adjust the hatch area, or you can delete one or more of the bounding objects to create partially bounded hatches:

Here's a Tip:

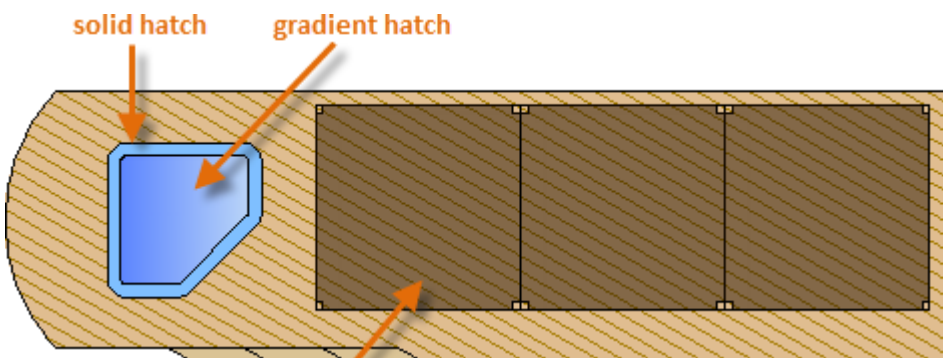
If you set a solid or gradient fill hatch pattern, also consider setting a transparency level on the Hatch Creation tab for interesting overlap effects.

Hatches and Fills (continued)

Here are some examples of how you can use solid-fill hatches:

Here's a Tip:

If you need to align the pattern in a hatch, which might be the case with the decking boards above, use the Set Origin option to specify an alignment point.



Precision

Ensure the precision required for your models.

There are several precision features available, including:

Polar tracking: Snap to the closest preset angle and specify a distance along that angle.

Locking angles: Lock to a single, specified angle and specify a distance along that angle.

Object snaps: Snap to precise locations on existing objects, such as an endpoint of a polyline, the midpoint of a line, or the center point of a circle.

Grid snaps: Snap to increments on a rectangular grid

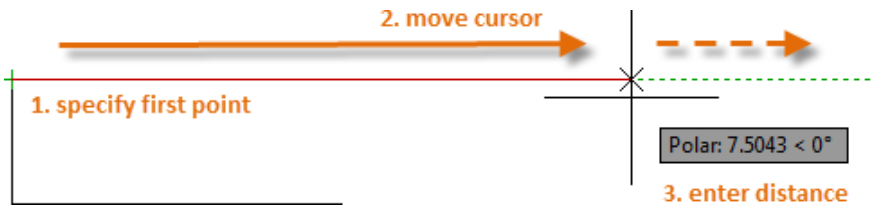
Coordinate entry: Specify a location by its Cartesian or polar coordinates, either absolute or relative.

The three most commonly used features are polar tracking, locking angles, and object snaps.

Polar Tracking

When you need to specify a point, such as when you create a line, you can use polar tracking to guide the movement of your cursor in certain directions.

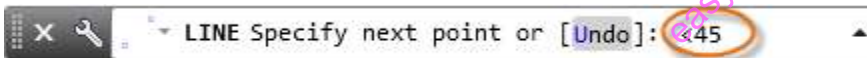
For example, after you specify the first point of the line below, move your cursor to the right, and then enter a distance in the Command window to specify a precise horizontal length for the line.



By default, polar tracking is turned on and guides your cursor in a horizontal or vertical direction (0 or 90 degrees).

Locking Angles

If you need to draw a line at a specified angle, you can lock the angle for the next point. For example, if the second point of a line needs to be created at a 45 degree angle, you would enter '<45' in the Command window.

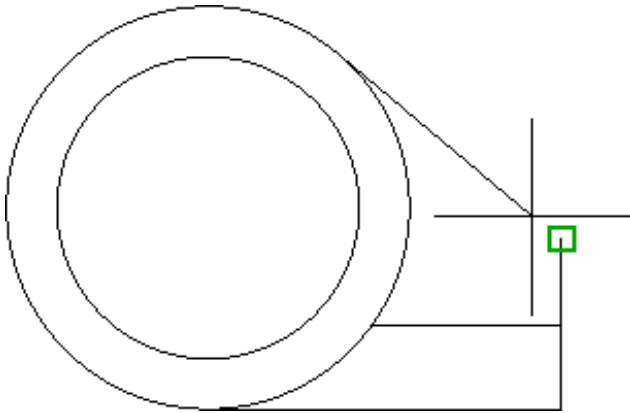


After you move your cursor in the desired direction along the 45-degree angle, you can enter the length of the line.

Object Snaps

By far, the most important way for you to specify precise locations on objects is to use object snaps. In the following illustration, several different kinds of object snaps are represented by markers.

Object snaps become available during a command whenever AutoCAD prompts you to specify a point. For example, if you start a new line and move your cursor near the endpoint of an existing line, the cursor will automatically snap to it.



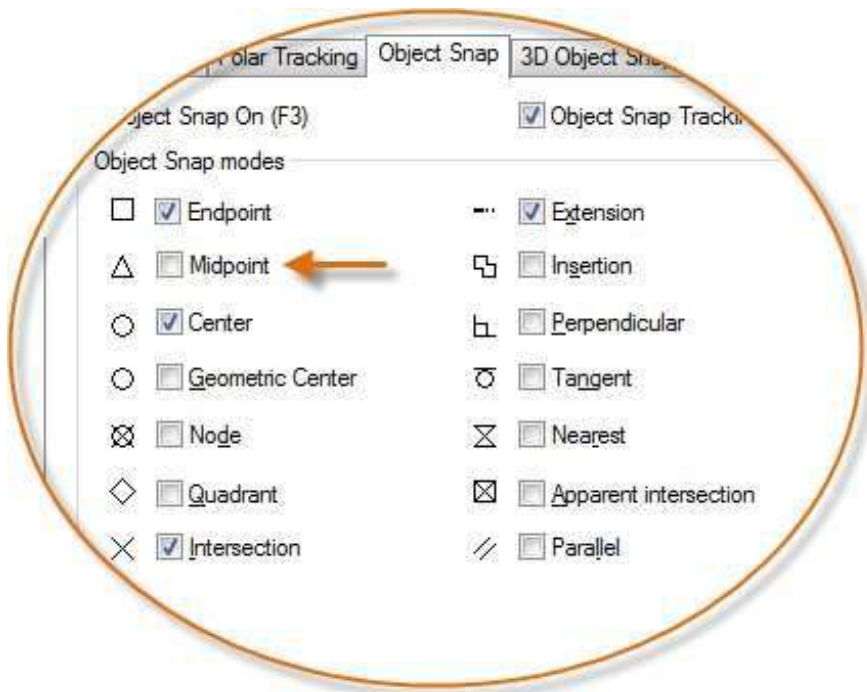
Set Default Object Snaps

Enter the **OSNAP** command to set the default object snaps, which are also called “running” object snaps. For example, you might find it useful to turn on the Midpoint object snap by default.

Recommendations

At any prompt for a point, you can specify a single object snap that overrides all other object snap settings. Hold down Shift, right-click in the drawing area, and choose an object snap from the Object Snap menu. Then move the cursor to select a location on an object.

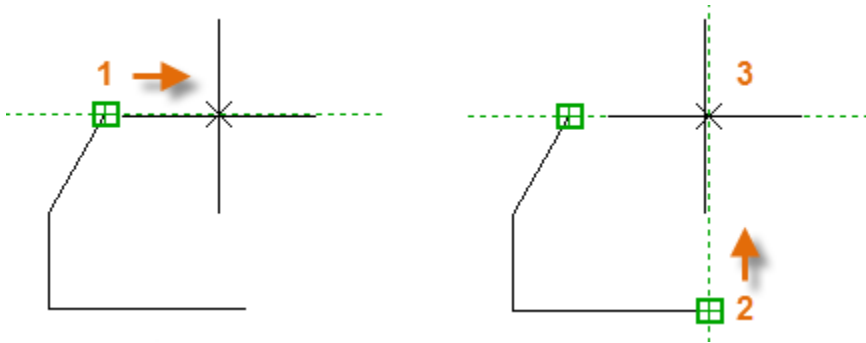
Make sure that you zoom in close enough to avoid mistakes. In a densely populated model, snapping to the wrong object will result in an error that can propagate throughout your model.



Object Snap Tracking

During a command, you can align points both horizontally and vertically from object snap locations. In the following illustration, you first hover over endpoint 1 and then hover over endpoint

2. When you move your cursor near location 3, the cursor locks into the horizontal and vertical location shown.



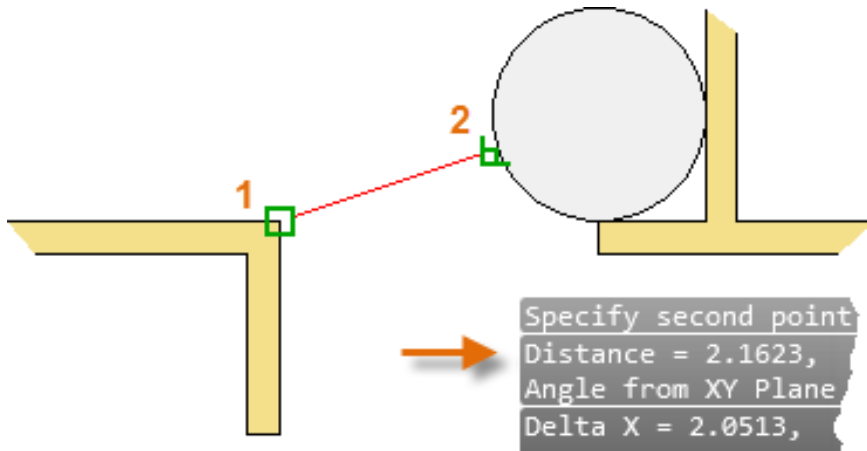
You can now finish creating the line, circle, or other object that you were creating from that location.

Verify Your Work

Recheck your geometry to catch mistakes early. Enter the **DIST** command (or just **DI**) to measure the distance between any two points in your model.

For example, you might need to find the clearance between two points shown, which might represent the corner of a wall and a small table, or perhaps a 2D section of a plastic part and a wire.

After you enter **DIST**, click the endpoint on the corner (1). Next, hold down Shift as you right-click, and then choose Perpendicular from the object snap menu. Finally, click the circle (2).



Handy Function Key Reference

All keyboard function keys have assignments in AutoCAD. The ones that are most commonly turned on and off are indicated with a key.

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Key	Feature	Description
	Help	Displays Help for the active tooltip, command palette, or dialog box.
F2	Expanded History	Displays expanded command history in the Command Window.
F3	Object Snap	Turns object snap on and off.
F4	3D Object Snap	Turns on additional object snaps for 3D elements.
F5	Isoplane	Cycles through 2-1/2D isoplane settings.
F6	Dynamic UCS	Turns on UCS alignment with planar surfaces.
F7	Grid Display	Turns the grid display on and off.
	Ortho	Locks cursor movement to horizontal or vertical.
F9	Grid Snap	Restricts cursor movement to specified grid intervals.
	Polar Tracking	Aides cursor movement to specified angles.
F11	Object Snap Tracking	Tracks the cursor horizontally or vertically from object snap locations.

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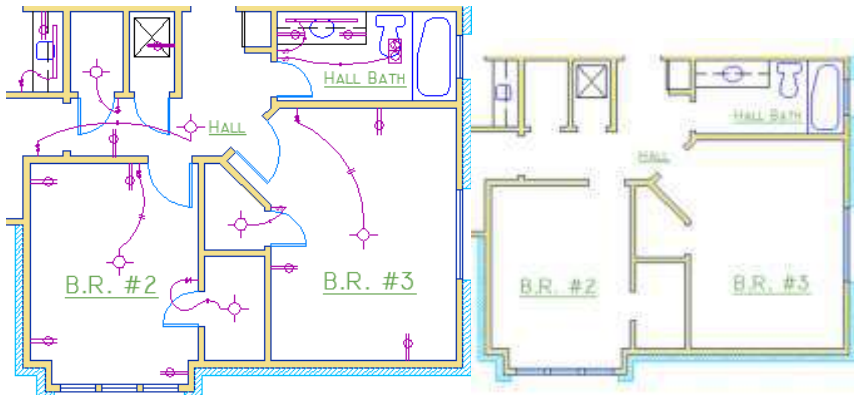
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Layers

Organize your drawing by assigning objects to layers.

When a drawing becomes visually complex, you can hide objects that you currently do not need to see.

In the drawing below, the doors and electrical wiring were temporarily hidden by hiding their layers.



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Layers

You gain this level of control by organizing the objects in your drawing on layers that are associated with a specific function or purpose. It might be helpful to think of layers as clear plastic sheets:

With layers, you can:

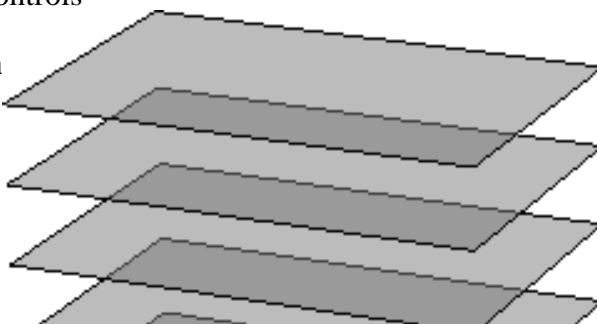
Associate objects by their function or location

Display or hide all objects related to a single operation

Enforce linetype, color, and other property standards for each layer

Layer Controls

To see h
You can



Cabinets the Layer Properties Manager.
click the Layer Properties tool

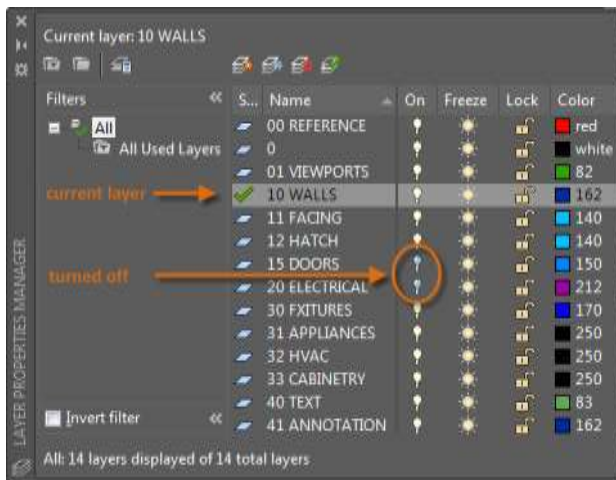
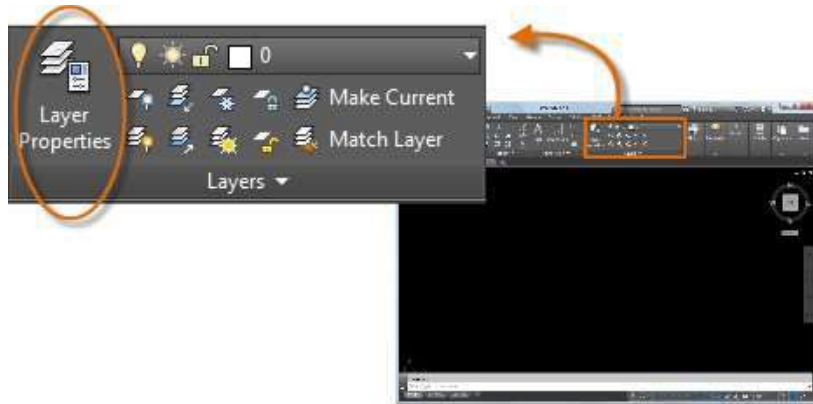
Fixtures

Electrical

Doors

on the ribbon.

Here's what the Layer Properties Manager displays for this drawing.



As indicated, layer 10 WALLS is the *current layer*. All new objects are automatically placed on that layer. In the list of layers, the green check next to layer 10 WALLS indicates that it is the current layer.

In the column labeled On, notice that the light bulb icons for two layers are dark. This indicates that these layers were turned off to hide the doors and electrical wiring in the floor plan.

Notice that each layer name starts with a two-digit number. This convention makes it easy to control the order of the layers because their order does not depend on the alphabet.

Here's a Tip:

For complex drawings, you might want to consider a more elaborate layer naming standard. For example, layer names could begin with 3 digits followed by a naming code that accommodates multiple floors in a

building, project numbers, sets of survey and property data, and so on.

Practical Recommendations

Layer 0 is the default layer that exists in all drawings and has some esoteric properties. Instead of using this layer, it's best to create your own layers with meaningful names.

Any drawing that contains at least one dimension object automatically includes a reserved layer named Defpoints.

Create a layer for behind-the-scenes construction geometry, reference geometry, and notes that you usually do not need to see or print.

Create a layer for layout viewports. Information about layout viewports is covered in the Layouts topic.

Create a layer for all hatches and fills. This lets you to turn them all on or off in one action.

Layer Settings

The following are the most commonly used layer settings in the Layer Properties Manager. Click the icon to turn the setting on and off.

Turn off Layers: This will help reduce the visual complexity of your drawing while you work

Freeze Layers: Freeze layers that you do not need to access for a while. Freezing layers is similar to turning them off, but improves performance in very large drawings.

Lock Layers: Locking layers prevents accidental changes to the objects on those layers.

Controls in the Layer Properties Manager

To create a new layer, click the button shown and enter the name of the new layer. To make a different layer the current one, click the layer and then click the indicated button.



Quick Access to Layer Settings

The Layer Properties Manager takes up a lot of space, and you may not always need to access all the options. For quick access to the most common layer controls, use the controls on the ribbon. When no objects are selected, the Layers panel on the Home tab displays the name of the current layer as shown here.

Occasionally, check to make sure that the objects you create will be on the correct layer. It's easy to forget to do this, but it's also easy to set. Click the drop-down arrow to display a list of layers, and then click a layer on the list to make it the current layer. You can also click on any layer setting icon in the list to



change its setting.

Maintain Your Standards

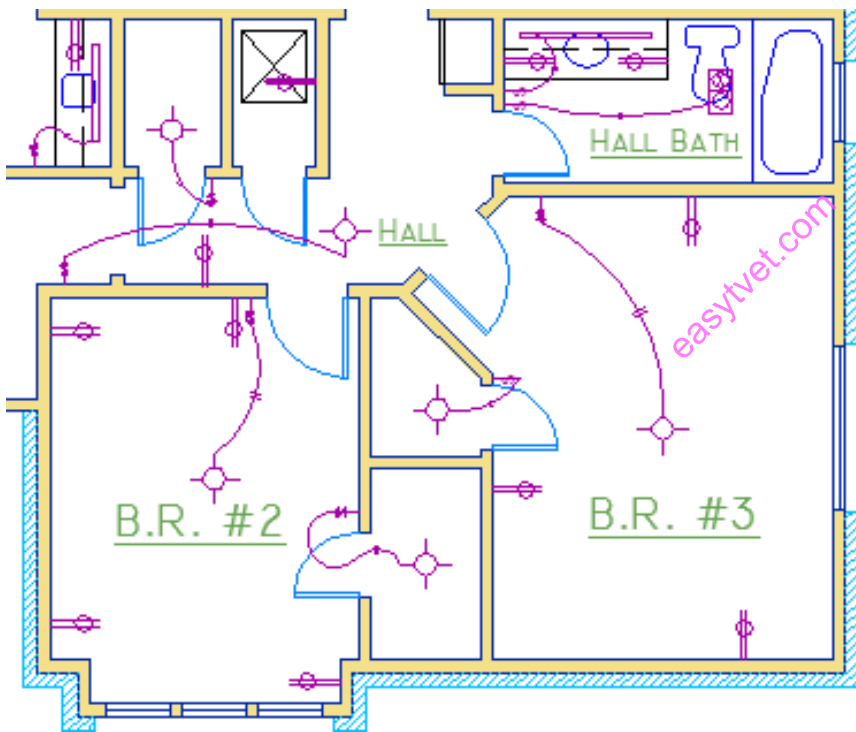
It's important to either establish or conform to a company-wide layer standard. With a layer standard, drawing organization will be more logical, consistent, compatible, and maintainable over time and across departments. Layer standards are essential for team projects.

If you create a standard set of layers and save them in a drawing template file, those layers will be available when you start a new drawing, and you can start working immediately. Additional information about drawing template files is presented in the Basics topic.

Properties

You can assign properties such as color and linetype to individual objects, or as default properties assigned to layers.

In the following drawing, the walls, exterior stone facing, doors, fixtures, cabinetry, HVAC, electrical, and text were created using different colors to help differentiate them.



The Properties Palette

The Properties palette is an essential tool. You can open it with the **PROPERTIES** command (enter **PR** in the Command window), you can press **Ctrl + 1**, or you can click the tiny arrow in the Properties panel on the Home tab whichever you prefer.

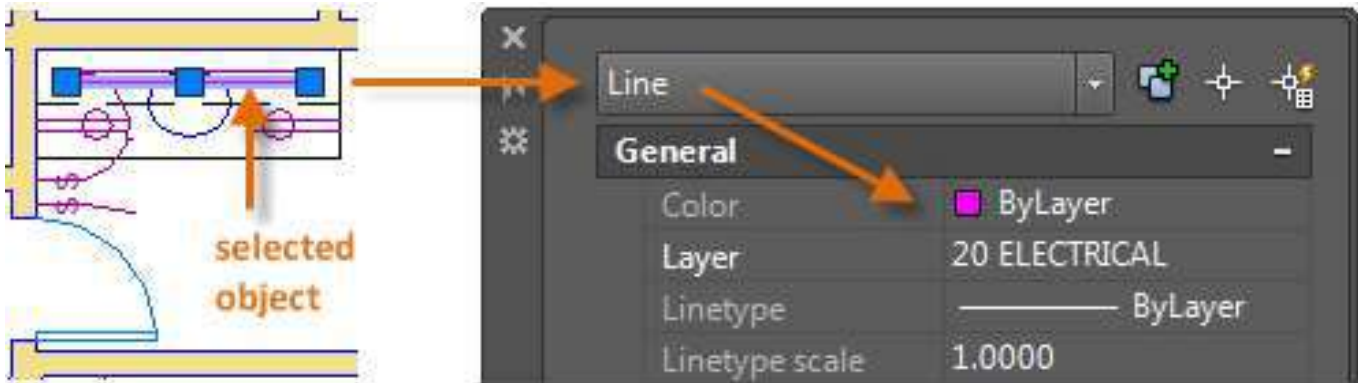


The Properties palette displays a list of all the important property settings. You can click any of the available fields to change the current settings. In the following example, if no objects are selected, the current color will be changed from ByLayer to Red and the UCS icon will be turned off.



Verify and Change Object Properties

You can use the Properties palette to verify and change property settings for selected objects. If you click an object in your drawing to select it, here is what you might see in the Properties palette.



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NOTE: To clear the current selection, press Esc.

Notice that the current properties for the selected object are displayed in the palette. You can change any of these properties by clicking and changing the setting.

A property that is set to “ByLayer” inherits its setting from the layer. In the previous example, the objects that were created on the 20 ELECTRICAL layer are purple because that is the default color of the objects on that layer.

If you select several objects, only their common properties are listed in the Properties palette. If you change one of these properties, all the selected objects will change in one operation. Selecting objects is covered in more detail in the Modifying topic

Quick Access to Property Settings

The Properties palette can take up a lot of space. For quick access to the most common properties, use the Properties panel. As you can see in this example, the listed properties will all be determined by the current layer.



The Properties panel works the same way as the Properties palette. When you select an object, the current property settings are replaced by the properties assigned to the selected object, and you can use this panel to easily change the properties of one or more selected objects.



Match the Properties of Objects

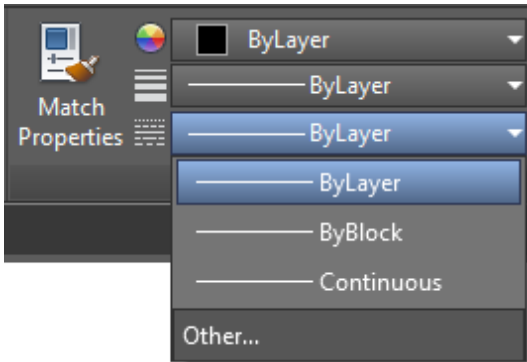
For a fast way to copy the properties of a selected object to other objects, use the Match Properties tool, or enter **MATCHPROP** or **MA** in the Command window.

Select the source object, and then select all of the objects that you want to modify.

Linetypes

Dashed and other non-continuous linetypes are assigned from the Properties panel. You must first load a linetype before you can assign it.

In the Linetype drop-down list, click Other.



This action displays the Linetype Manager dialog box. Perform the following steps in order:

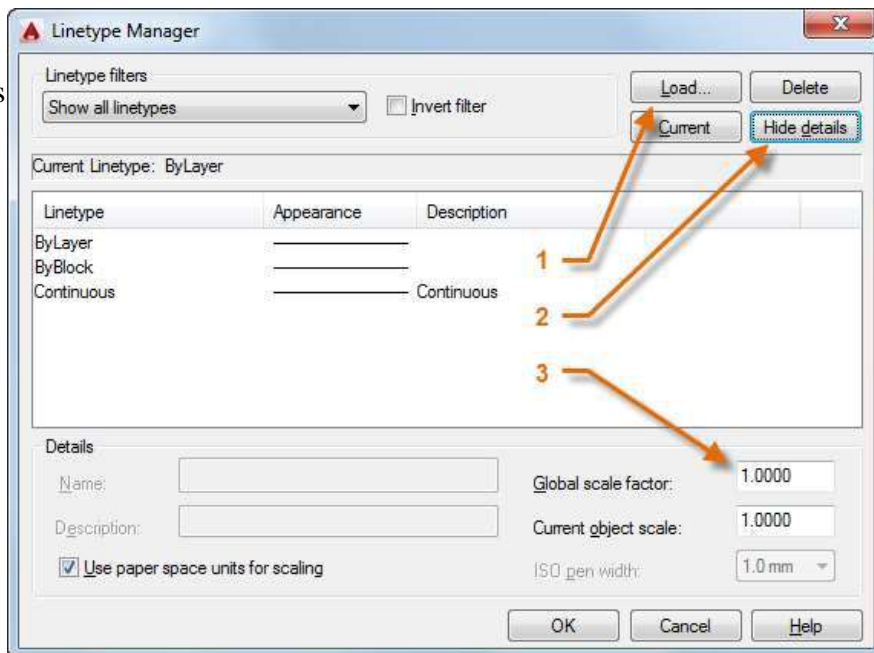
Click Load. Choose one or more linetypes that you want to use. Notice that dashed (non-continuous) linetypes come in several preset sizes.

Click Show/Hide details to display additional settings.

Specify a different “global scale factor” for all linetypes—the larger the value, the longer the dashes and spaces. Click OK.

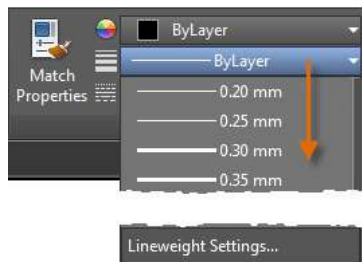
Once you’ve loaded the linetypes that you plan to use, you can select any object and specify a linetype from the Properties panel or the Properties palette. Alternatively, you can specify a default linetype for any layer in the Layer

Properties



Lineweights

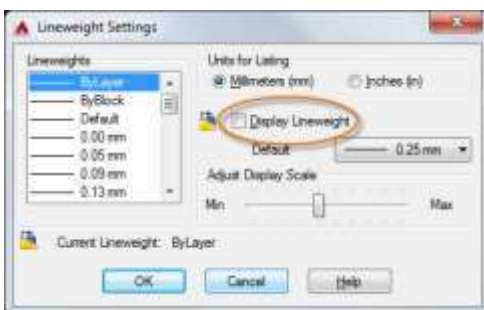
The Lineweight property provides a way to display different thicknesses for selected objects. The thickness of the lines remains constant regardless of the scale of the view. In a layout, lineweights are always displayed and printed in real-world units. Lineweights can also be assigned from the Properties panel.



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You can leave the lineweight set to ByLayer, or you can specify a value that overrides the layer's lineweight. In some cases, the lineweight previews look the same because they are displayed in approximated pixel widths on a monitor. However, they will print at the correct thickness.

To control the display of lineweights, click the Lineweight Settings button at the bottom of the lineweight list. In the Lineweight Settings dialog box, you can choose whether you want to display or hide lineweights.



Regardless of the display setting, lineweights will always be printed at the correct scale.

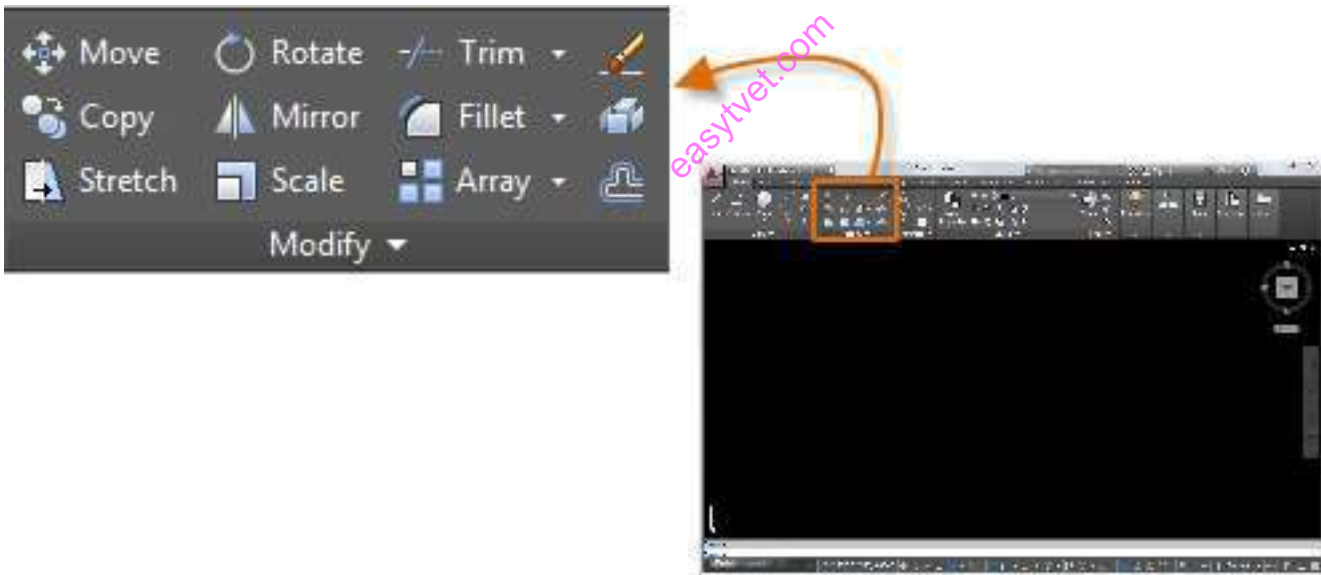
Here's a Tip:

It's usually best to leave lineweights turned off while you work. Heavy lineweights can obscure nearby objects when you use object snaps. You might want to turn

Modifying

Perform editing operations such as erase, move, and trim on the objects in a drawing.

The most common modifying tools are located on the Modify panel of the Home tab. Take a minute to look through them.

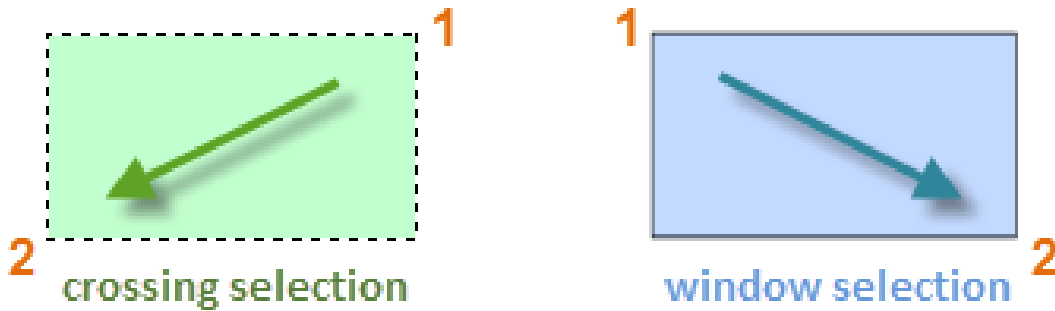


Erase

To erase an object, use the **ERASE** command. You can enter **E** in the Command window, or click the Erase tool. When you see the cursor change to a square pickbox, click each object that you want to erase, and then press Enter or the Spacebar.

Select Multiple Objects

Sometimes you may need to select a large number of objects. Instead of selecting each object individually, you can select the objects in an area by clicking an empty location (1), moving your cursor right or left, and then clicking a second time (2).



With a *crossing selection*, any objects within or touching the green area are selected.

With a *window selection*, only the objects completely contained within the blue area are selected.

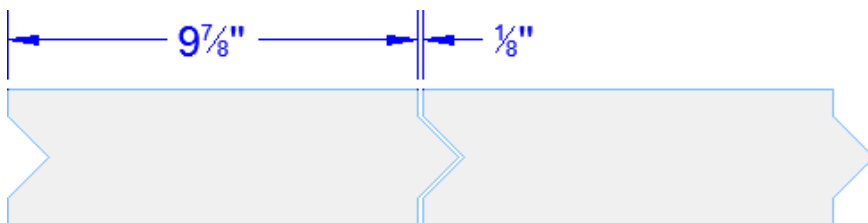
The result is called the *selection set*, which is the set of objects that will be processed by a command.

Here's a Tip:

You can easily remove objects from the selection set. For example, if you select 42 objects, and two of them should not have been

selected, hold down Shift and then select the two that you want to remove. Then, press Enter or the Spacebar, or right click to end the selection process.

Move and Copy

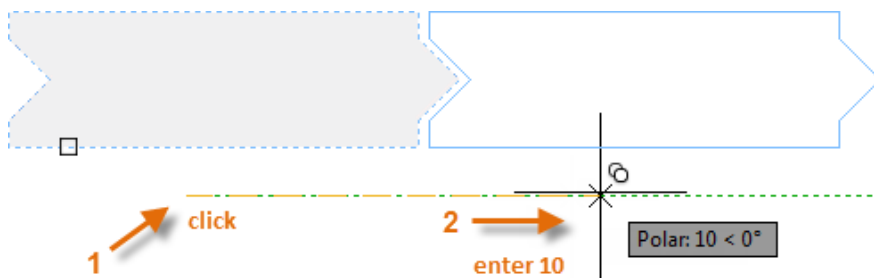


Here's how you would use the **COPY** command to lay out a row of decorative tiles. Starting with a polyline that represents its shape, you need to make copies that are $\frac{1}{8}$ " apart.

Click the Copy tool or enter **CP** in the Command window to start the command. From here, you can choose between two methods, depending on which is more convenient. You will use these two methods frequently.

The Distance Method

The second tile needs to be a total of $9\text{-}7/8'' + 1/8'' = 10''$ to the right of the original tile. Start by selecting the tile, pressing Enter or the Spacebar to end your selection, and clicking anywhere in the drawing area (1). This point does not have to be located on the tile.

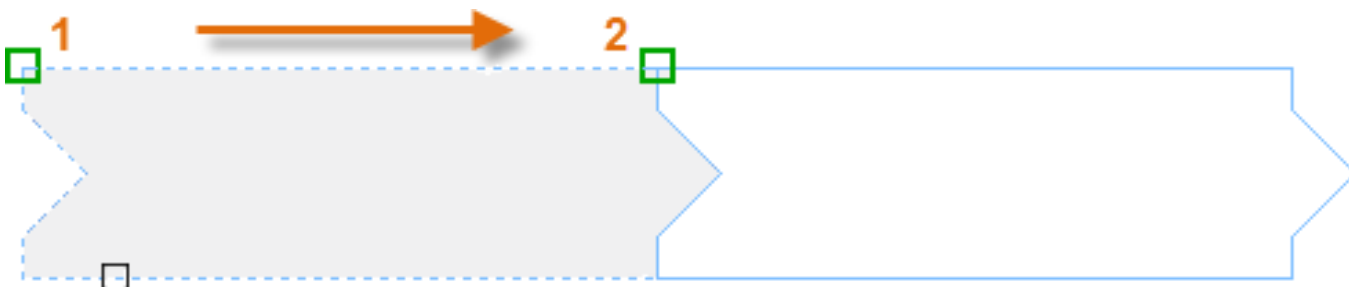


Next, move your cursor to the right, relying on the polar tracking angle to keep the direction horizontal, and then enter 10 for the distance. Press Enter or the Spacebar a second time to end the command.

Move and Copy (continued)

The Two Points Method

Another method, one that you will often use when you don't want to add numbers together, requires two steps. Enter the **COPY** command and select the tile as before, but this time click the two endpoints as shown. These two points also define a distance and direction.



Next, to add the 1/8" space between the tiles, click the Move tool or enter **M** in the Command window. The **MOVE** command is similar to the **COPY** command. Select the newly copied tile, and press Enter or the Spacebar. As before, click anywhere in the drawing area and move your cursor to the right. Enter 1/8 or .125 for the distance.

Here's a Tip:

The two points that define the distance and direction don't need to be located on the object that you want to copy. You can use two points specified anywhere in your

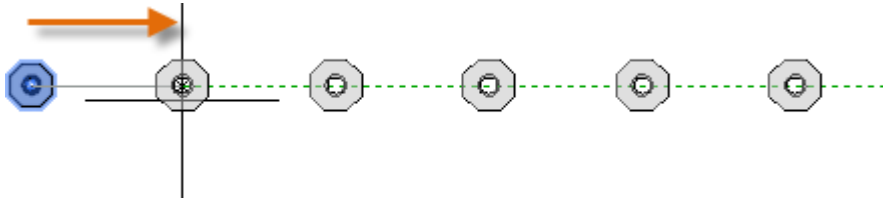
Create Multiple Copies

You can use the two-point method as a repeating sequence. Let's say that you want to make more copies of the circle at the same horizontal distance. Enter the **COPY** command and select the circle as shown.

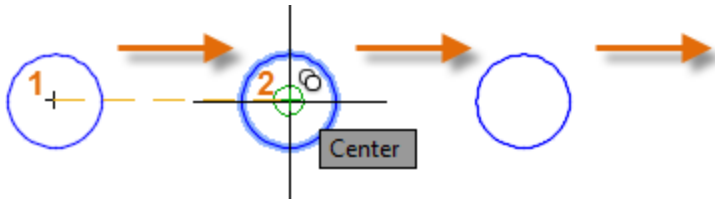


Then, using the Center object snap, click the center of circle 1, followed by the center of circle 2, and so on.

For larger numbers of copies, try experimenting with the Array option of the **COPY** command. For example, here's a linear arrangement of deep foundation piles. From a base point, you specify number of copies and the center-to-center distance.

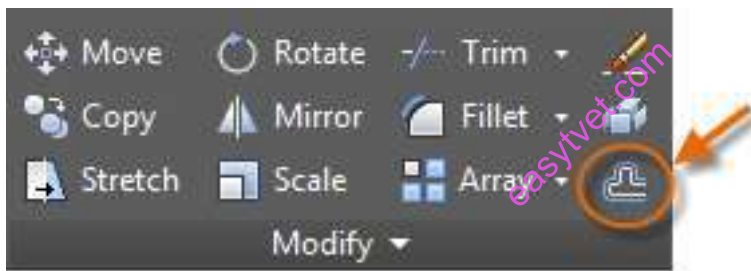


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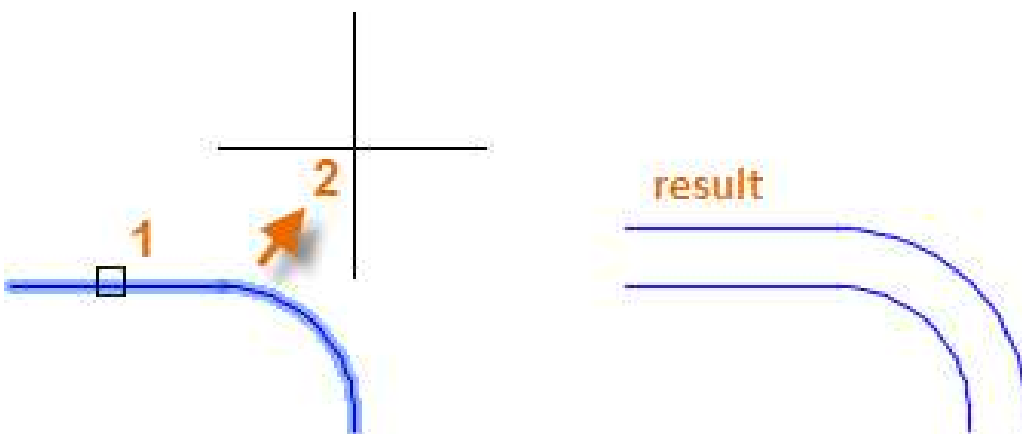


Offset

Most models include a lot of parallel lines and curves. Creating them is easy and efficient with the **OFFSET** command. Click the **OFFSET** tool or enter **O** in the Command window



Select the object (1), specify the offset distance, and click to indicate on which side of the original that you want the result (2). Here is an example of offsetting a polyline.

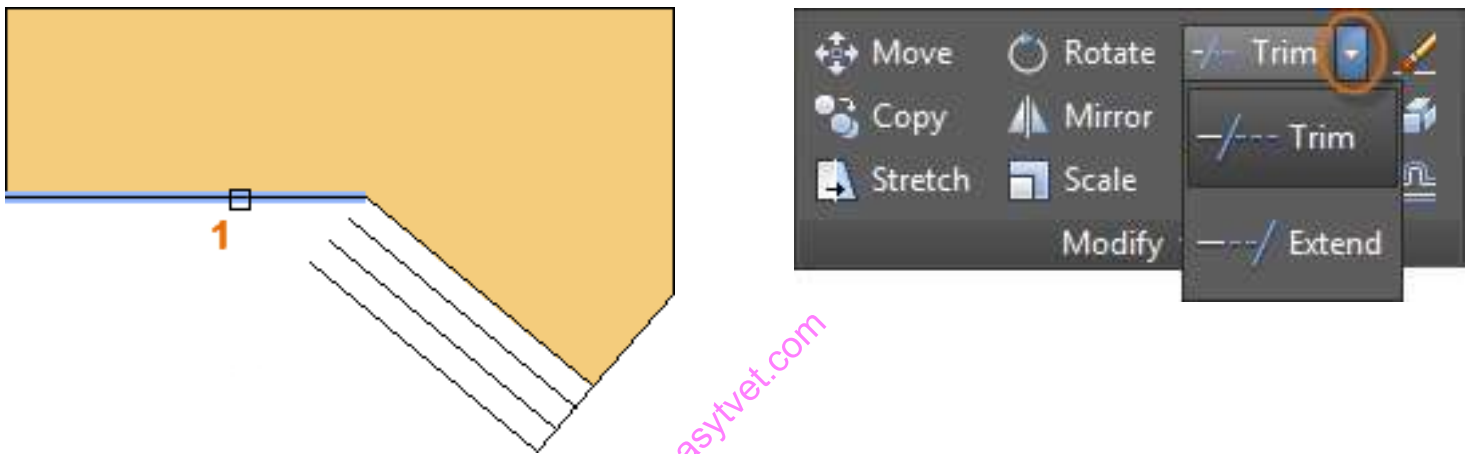


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Trim and Extend

A popular technique is to use the **OFFSET** command in combination with the **TRIM** and **EXTEND** commands. In the Command window, you can enter **TR** for **TRIM** or **EX** for **EXTEND**. Trimming and extending are some of the most commonly used operations.

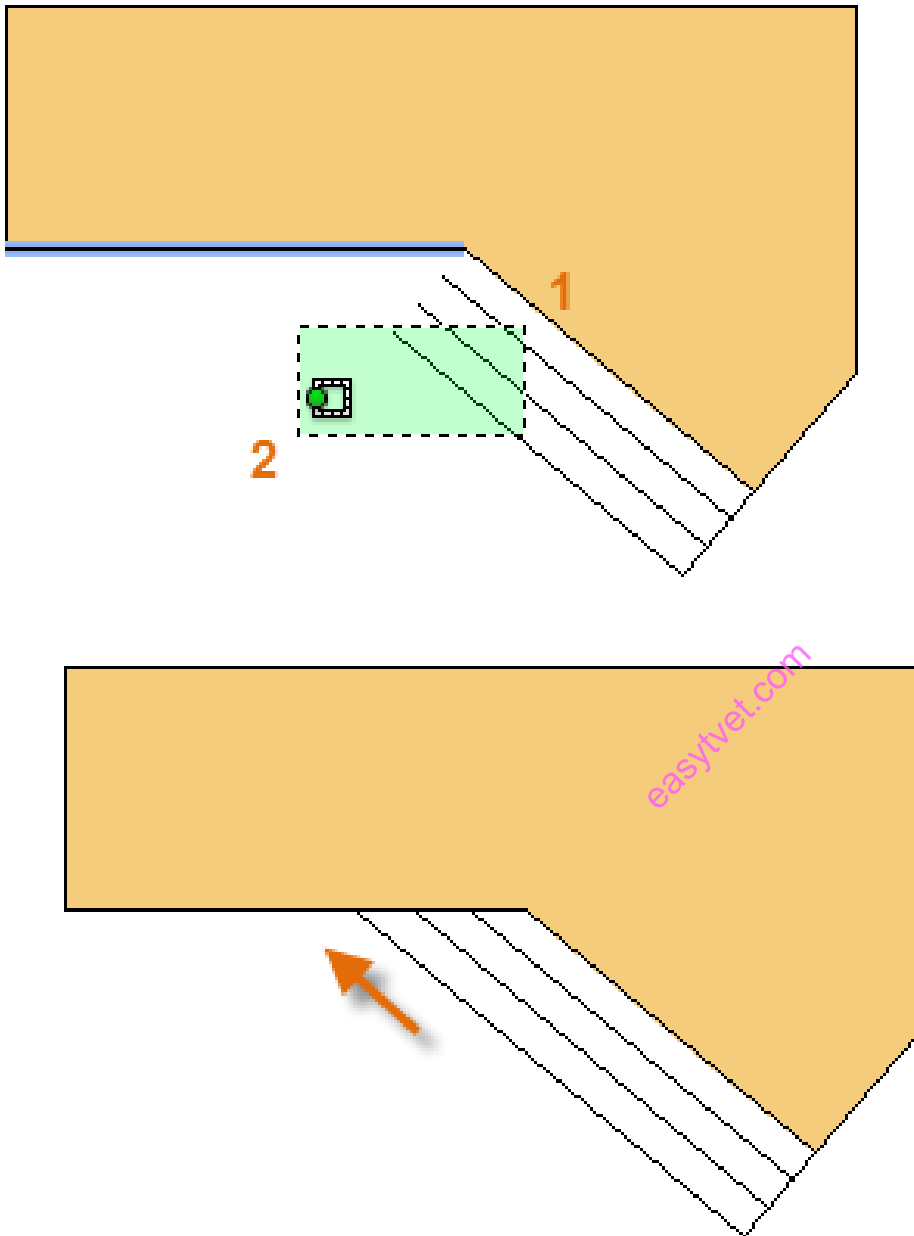
In the following illustration, you want to extend the lines that represent the steps for this deck. Enter the **EXTEND** command, select the boundary, and then press Enter or the Spacebar.



Pressing Enter or the Spacebar indicates that you've finished selecting the boundaries, and that you're now ready to select the objects to be extended. Here's a Tip:

A faster method is to press Enter or the Spacebar right away instead of selecting any boundary objects. The result is that all objects are available as possible boundaries

Next, select the objects to be extended (near the ends to be extended), and then press Enter or the Spacebar to end the command.

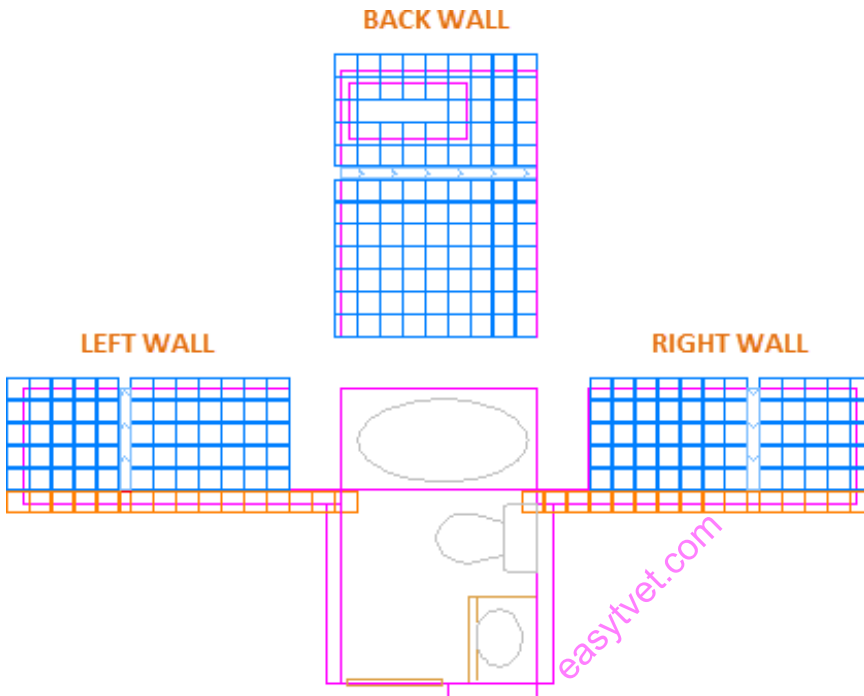


As you can see, the selected lines are extended to the boundary.

The **TRIM** command follows the same steps, except that when you select the objects to trim, you select the portions to trim away.

Mirror

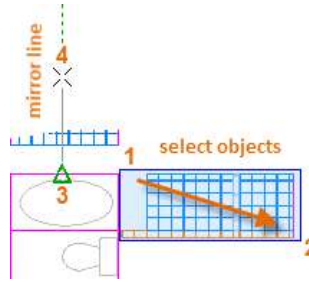
The following illustration comes from a tile project. The walls in this residential bathroom are flattened out to be able to lay out the tile pattern and estimate the number of tiles needed.



You can save a lot of work by taking advantage of the symmetry between the left and right walls. All you need to do is create the tiles on one wall and then mirror the wall across the center of the room. In the example below, begin the **MIRROR** command (or enter

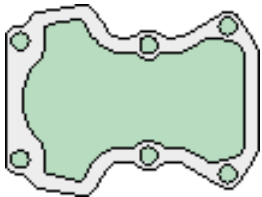
MI in the Command window), use window selection (1 and

2) to select the geometry on the right wall, press Enter or the Spacebar, and then specify a mirror line (3 and 4) corresponding to the centerline of the bathroom.

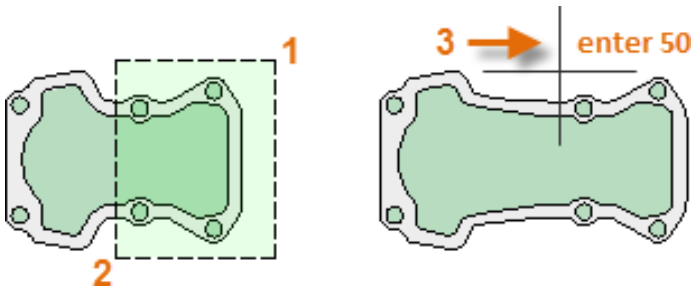


Finally, Stretch

You can stretch most geometric objects. This lets you lengthen and shorten parts of your model. For example, this model might be a gasket or the design for a public park.



Use the **STRETCH** command (or enter **S** in the Command window) and select the objects with a crossing selection as shown below (1 and 2). The crossing selection is mandatory— only the geometry that is crossed by the crossing selection is stretched. Then click anywhere in the drawing area (3), move the cursor to the right, and enter 50 as the distance. This distance might represent millimeters or feet.

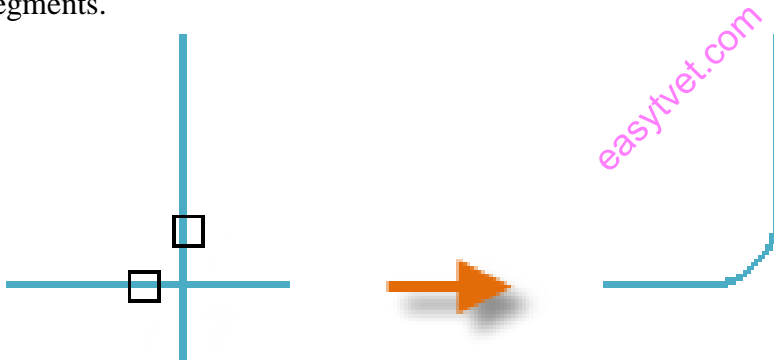


To shorten the model by a specified amount, you'd move your cursor to the left instead.

Fillet

The **FILLET** command (enter **F** in the Command window) creates a rounded corner by creating an arc that is tangent to two selected objects. Notice that the fillet is created relative to where you select the objects.

You can create a fillet between most types of geometric objects, including lines, arcs, and polyline segments.



Here's a Tip:

If you specify 0 (zero) as the radius of the fillet (imagine a circle shrinking to a radius of 0), the result trims or extends the selected objects to a sharp corner.

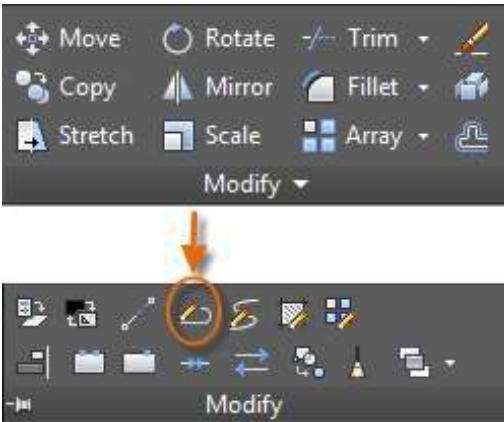
Explode

The **EXPLODE** command (enter **X** in the Command window) disassociates a compound object into its component parts. You can explode objects such as polylines, hatches, and blocks (symbols).

After you explode a compound object, you can modify each resulting individual object.

Edit Polylines

You can choose from several useful options when you want to modify a polyline. The **PEDIT** command (enter **PE** in the Command window) is located on the drop-down list of the Modify panel.



With this command, you can:

Join two polylines into a single polyline if they share a common endpoint

Convert lines and arcs into a polyline—simply enter **PEDIT** and select the line or arc

Change the width of a polyline

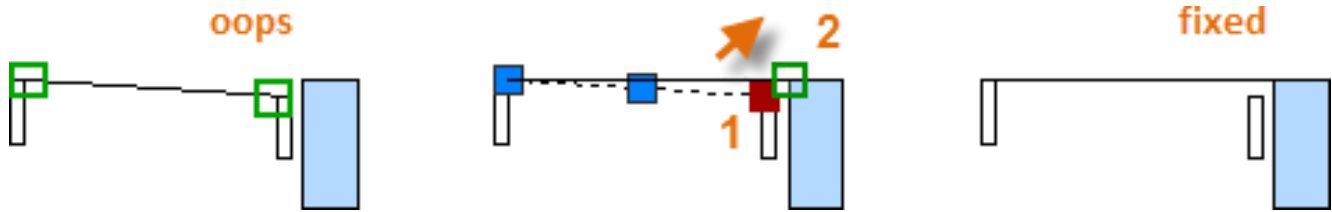
Here's a Tip:

In some cases, the easiest method to modify a polyline is to explode it, make the modifications, and then turn the objects back into a polyline using the Join option of the **PEDIT** command.

Grips

Grips are displayed when you select an object without starting a command. Grips are often handy for light editing. For example, the line below accidentally snapped to the wrong endpoint. You can

_____ select the misaligned line, click on a grip and then click to specify the correct location.

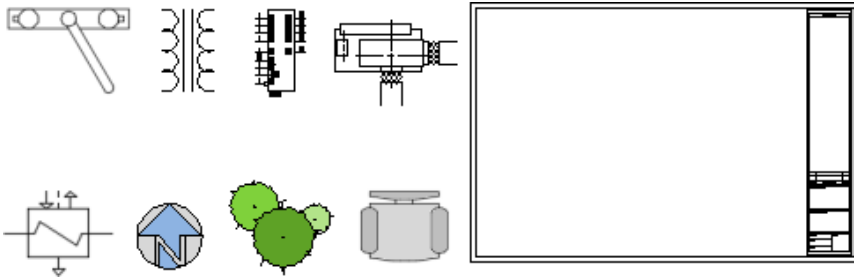


By default, when you click a grip, you automatically start in ****STRETCH**** mode as indicated in the Command window. If you want to explore other ways of editing

Blocks

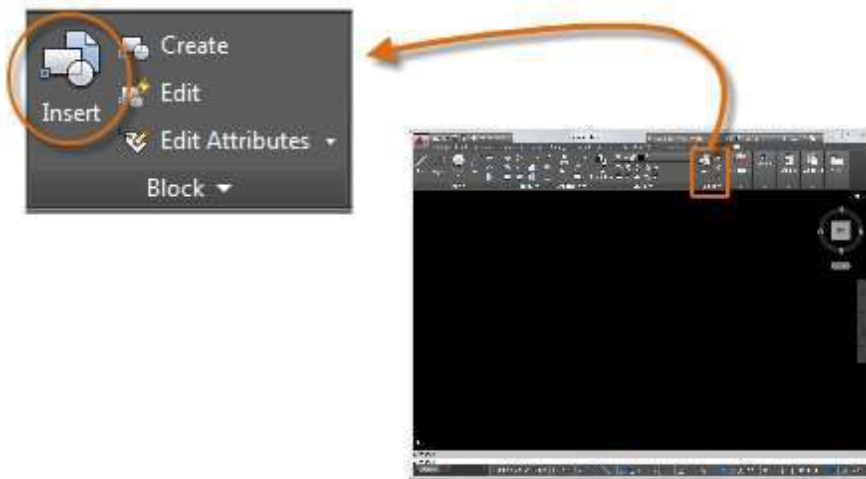
Insert symbols and details into your drawings from commercial online sources or from your own designs.

In AutoCAD, a *block* is a collection of objects that are combined into a single named object. The following are some sample blocks at various scales.



Some of these blocks are realistic representations of objects, some are symbols, and one of them is an architectural title block for a D-size drawing.

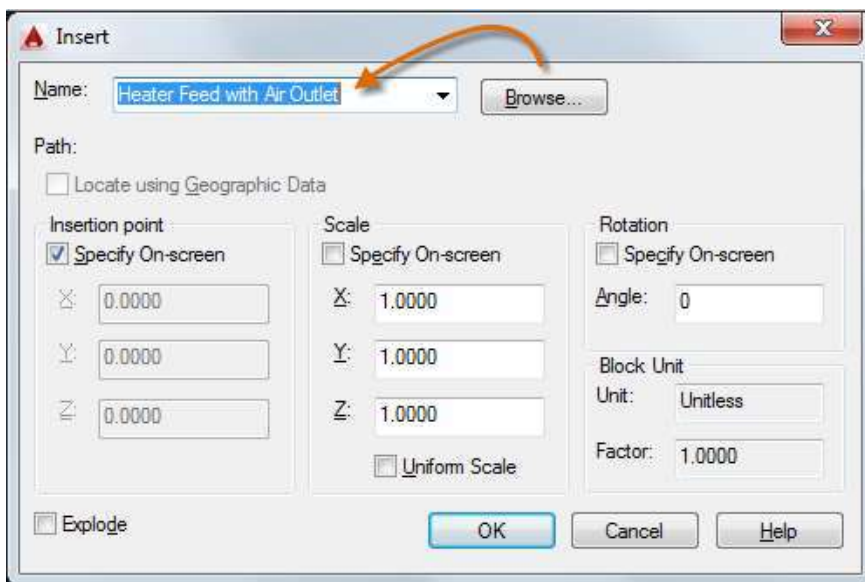
Insert a Block



Typically, each of these blocks is an individual drawing file, perhaps saved in a folder with similar drawing files. When you need to insert one into your current drawing file, use the **INSERT** command (or enter **I** in the Command window).

Insert a Block

The first time you insert the drawing as a block, you must click Browse to locate the drawing file. Make sure you organize your blocks into easy-to-find folders.

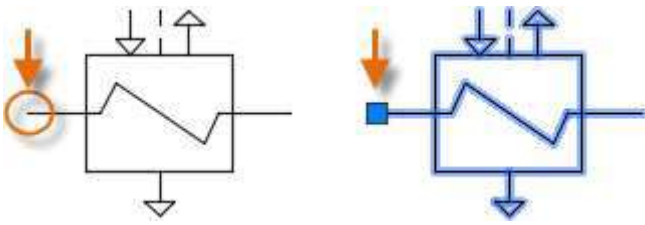


Once inserted, the *block definition* is stored in your current drawing. From then on, you can choose it from the Name drop-down list without needing to click the Browse button.

Here's a Tip:

The default settings in the Insert dialog box are usually acceptable. After you choose the block name, click OK, and then specify its location in your drawing. You can rotate it later, if necessary.

Notice that when you insert a block, it is attached to your cursor at the point indicated. This location is called the insertion point. By default, the insertion point is the origin point (0,0) of the original drawing.



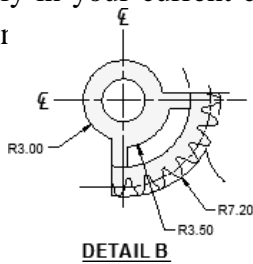
After inserting the block, you can select it and a grip appears. You can easily move and rotate this block using this grip.

In the following example, a drawing file is inserted into the current drawing to provide a standard detail view.

***NOTE:** Inserting a drawing file as a block provides a static reference to the specified drawing. For a reference that automatically updates, you can attach the drawing with the External References palette (**XREF** command) instead.*

Create a Block Definition

Instead of creating a drawing file to be inserted as a block, you might want to create a block definition directly in your current drawing. Use this method if you do not plan to insert the block into any other drawing the **BLOCK** command to create the block definition.





For example, this is how you could create a module for a cubicle design.

Create the objects for the block.

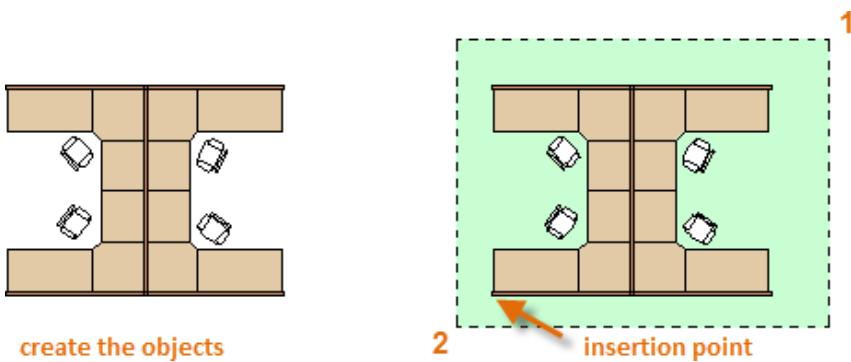
Start the **BLOCK** command.

Enter a name for the block, in this case Quad-Cube.

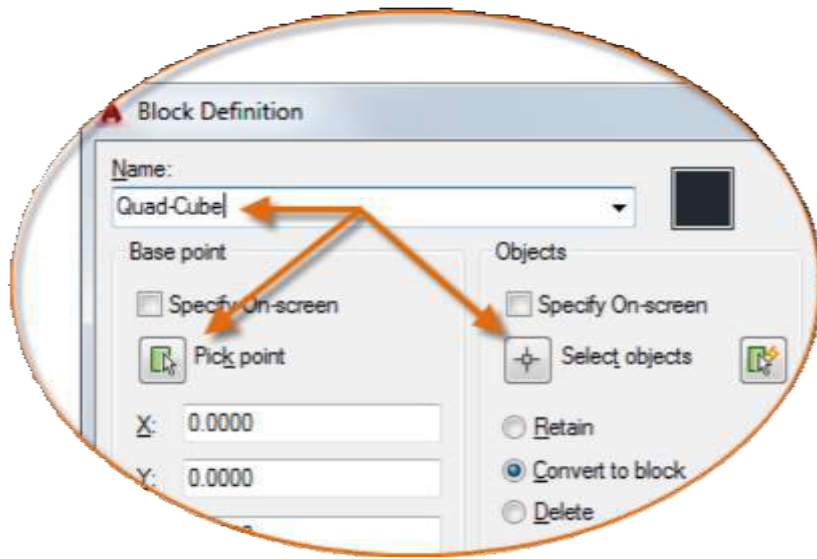
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Select the objects that you created for the block (click 1 and 2).

Specify the block insertion point.

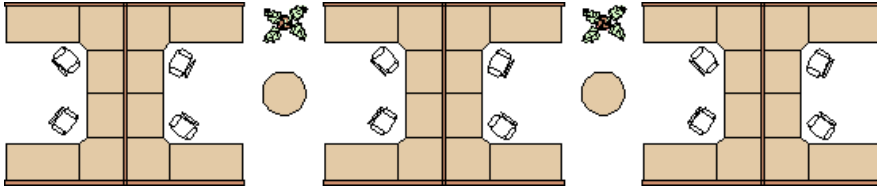


You can enter the information for steps 3, 4, and 5 into the Block Definition dialog box in any order.

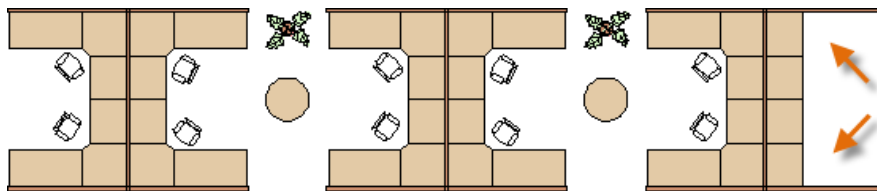


Create a Block Definition (continued)

After creating the block definition, you can insert, copy, and rotate the block as needed.



Using the **EXPLODE** command, you can explode a block into its component objects if you need to make changes. In the illustration below, the cubicle on the right was exploded and modified.



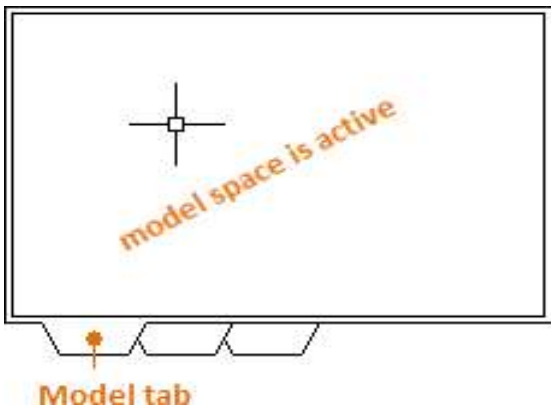
In this example, you would probably create a new block definition from the objects in the exploded block.

Layouts

Display one or more scaled views of your design on a standard- size drawing sheet called a layout.

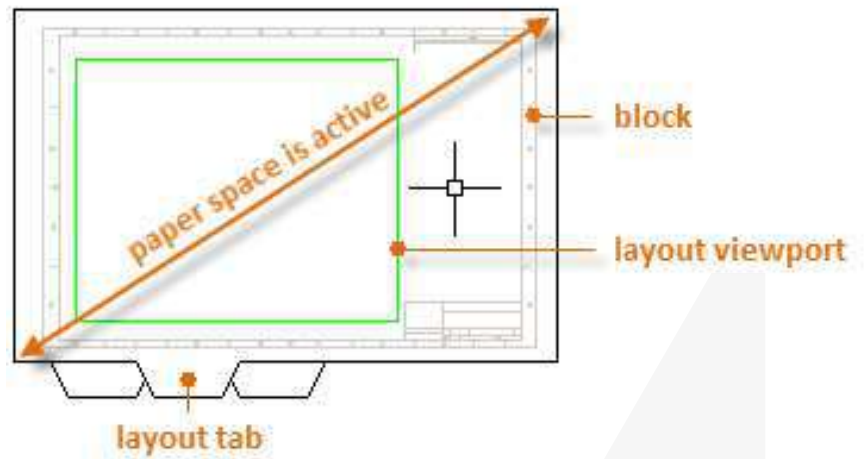
After you finish creating a model at full size, you can switch to a *paper space layout* to create scaled views of the model, and to add notes, labels, and dimensions. You can also specify different linetypes and line widths for display in paper space.

Model Space and Paper Space



Originally, this was the only space available in AutoCAD. All notes, labels, dimensions, and the drawing border and title block were also created and scaled in the model space.

After *paper space* was introduced, you could click a layout tab to access a space designed specifically for layouts and scaling. In the following illustration, paper space is active. There are currently only two objects in paper space: a drawing border block, and a single *layout viewport*, which displays a view of model space.



Four Methods for Scaling

There are four different methods in AutoCAD that are used to scale views, notes, labels, and dimensions. Each method has its advantages depending on how the drawing will be used.

Here's a brief summary of each of the methods:

The Original Method: You create geometry, annotate, and print from model space.

Dimensions, notes, and labels must all be scaled in reverse. You set the dimension scale to the inverse of the plot scale. With this method, scaling requires a little math. For example, a common scale used in architecture is $1/4'' = 1'-0''$ which is 1:48 scale. If a note is to be printed $1/4''$ high, then it must be created 48 times as large, or $12''$ high in model space. The same scale factor also applies to dimensions, and an ARCH D drawing border at that scale is 144 feet long. When the drawing is printed as a D-size sheet, everything scales down to the correct size.

The Layout Method: You create geometry and annotate in model space, and print from the layout. Set the dimension scale to 0 and the dimensions will scale automatically.

The Annotative Method: You create geometry in model space, create *annotative* dimensions, notes, and labels (using a special annotative style) in model space from the layout, and you print from the layout. Annotative objects display only in layout viewports that share

***NOTE:** Many AutoCAD drawings were created with this method, and many companies still use it. Once everything is set up, the method works well for 2D drawings with single views and inserted details.*

the same scale. The dimension scale is automatically set to 0 and all annotative objects scale automatically.

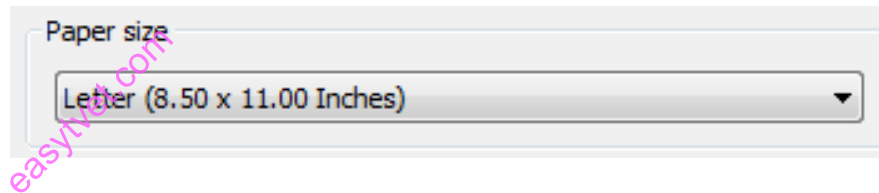
The Trans-Spatial Method: You create geometry in model space, create annotations in paper space on a layout with dimension scale set to 1, and you print from the layout. This is arguably the easiest, most direct method, and it is the method of choice for this guide.

Talk to other AutoCAD users in your discipline about these four methods and why they chose the method that they use.

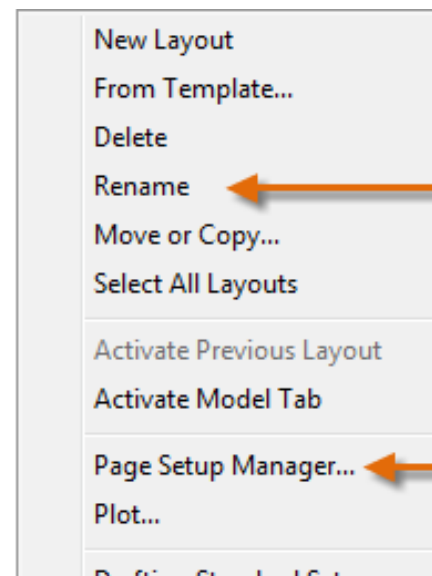
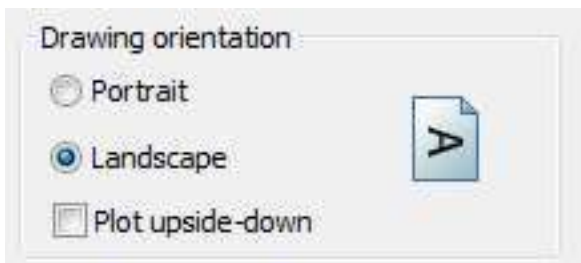
Specifying the Paper Size of a Layout

The first thing you should do when you access a layout tab (1) is right-click the tab (2) and rename it (3) to something more specific than Layout 1. For a D-size layout, ARCH D or ANSI D might be good choices.

Next, open the Page Setup Manager (4) to change the paper size displayed in the layout tab.

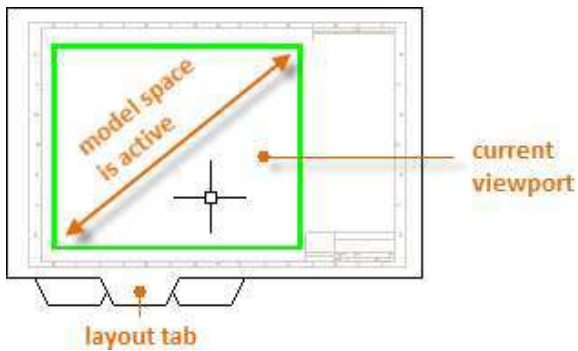


***NOTE:** You might be wondering why there are two entries in the list for every sheet size. This is because some printers and plotters do not recognize the drawing orientation setting.*

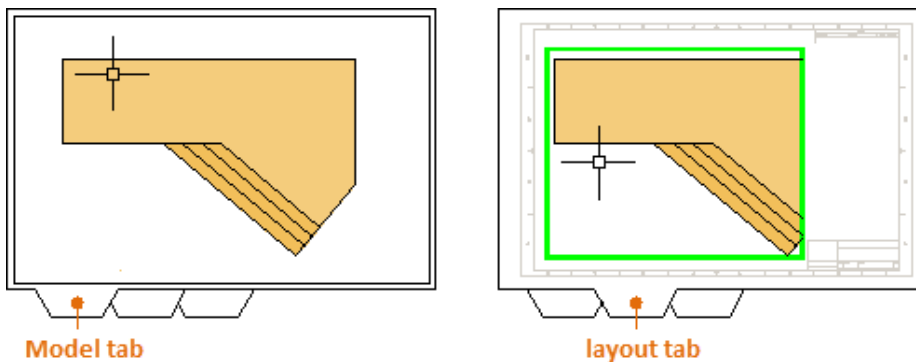


Layout Viewports

A layout viewport is an object that is created in paper space to display a scaled view of model space. You can think of it as a closed-circuit TV monitor that displays part of model space. In the illustration, model space is active and accessible from within the current layout viewport



In a layout, when model space is active, you can pan and zoom, and anything else that you could do on the Model tab. For example, let's say that you created a backyard deck design in model space, and now you want to lay out and print your design from a layout tab.



The view in the layout viewport is not yet set to the correct scale.

Important:

You can switch between paper space and model space by double-clicking inside or outside the layout viewport.

NOTE: You can use the **MVIEW** (make view) command to create additional layout viewports in paper space. With several layout viewports, you can display several views of model space at the same or at different scales.

Here are the steps to follow if you use the trans-spatial method of annotating your drawing:

Click the layout tab. If you started the drawing with your own custom drawing template file, several tasks might already have been completed: the layout might already be set to

D-size, and the title block might already have been inserted in the layout.

By default, paper space is active, so double-click within the layout viewport to make the model space active. Notice that the edge of the layout viewport becomes thicker as a result of switching to model space.

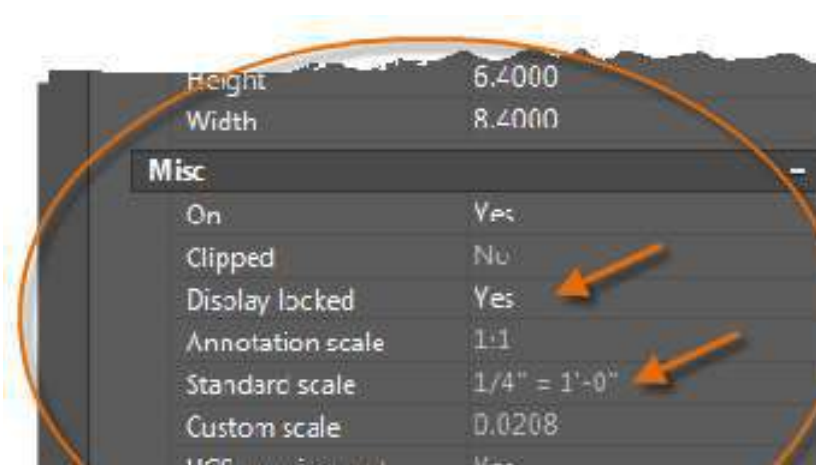
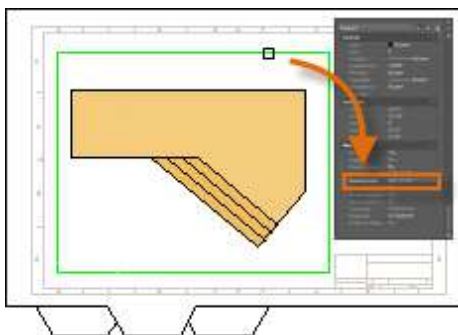
Zoom out and center the model space view by panning. Note that the displayed view will not yet be set to the correct scale.

Double-click outside the layout viewport to make paper space active again.

Open the Properties palette and then click to select the edge of the layout viewport.

In the Properties palette, specify a standard scale of 1/4" =

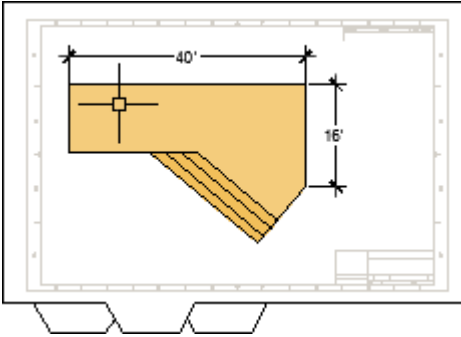
1'-0" from the drop-down list. This action scales your view of model space precisely to the D-size drawing. You should also set the Display Locked property from No to Yes, which will prevent any unintentional display changes to the view.



(continued)

Move the layout viewport as needed, and adjust its edges using grips.

Create notes, labels, and dimensions directly in paper space. They will automatically appear at the correct size.



Turn off the layer on which you created the layout viewport object. This hides the edges of the layout viewport as shown below.

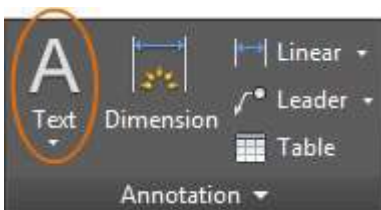
Print the drawing to paper or as a DWF or PDF file.

NOTE: After you have finished dimensioning, you can use the *EXPORTLAYOUT* command to merge everything in model and paper space into the model space of a separate drawing file. This operation creates a drawing file that conforms to the original method of creating the model and all annotations in model space.

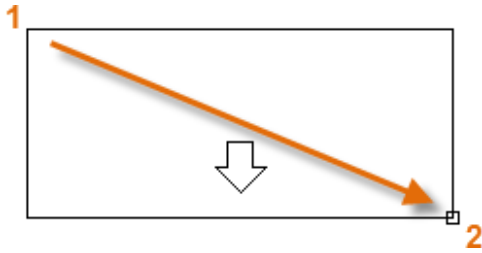
Notes and Labels

Create notes, labels, bubbles, and callouts. Save and restore style settings by name.

You can create general notes using the **MTEXT** command (or enter **MT** in the Command window), which stands for *multiline text*. The multiline text tool is available on the Annotation panel.



After you start the **MTEXT** command, you are prompted to create a “text box” with two diagonal clicks.



Create a Text Style

As with several other annotation features, multiline text provides a lot of settings. You can save these settings as a *text style*

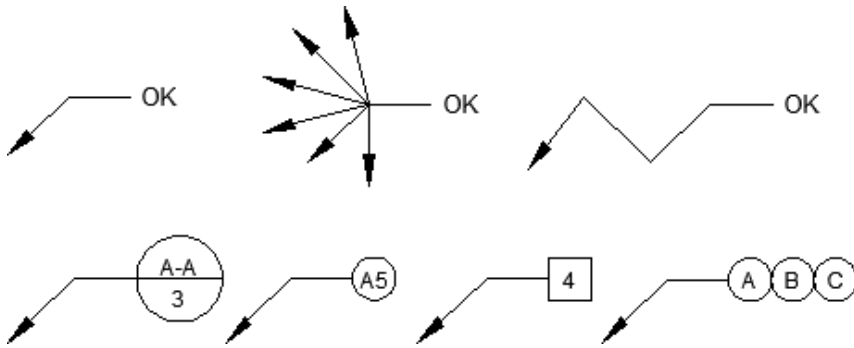
using the **STYLE** command, and then you can access the text styles you’ve saved by clicking the drop-down arrow on the Annotation panel. The current text style is displayed at the top of the drop-down list.

To create a new text style, click the Text Style control as shown.

Multileaders

Multileader objects are used to create text with leader lines such as general labels, reference labels, bubbles, and callouts.

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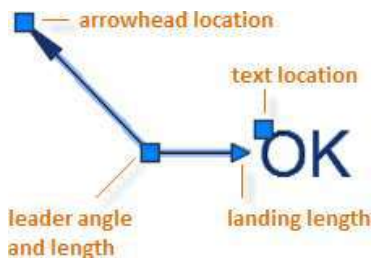
Create a Multilayer

To create a multilayer, use the **MLEADER** command. Click the Multilayer tool in the Annotation panel or enter **MLD** in the Command window. Follow the prompts and options in the Command window. Feel free to experiment.

After you create a multilayer, select it and then modify it by clicking and moving its grips.

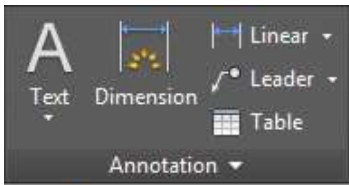
Grip menus appear when you hover over arrowhead and leader grips. From these menus, you can add leader segments or additional leaders.

You can edit the text in a multilayer by double-clicking it.



Create a Multileader Style

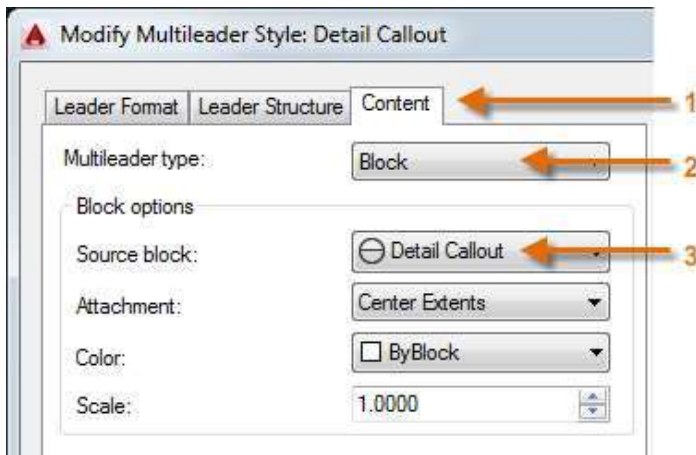
You can create your own multileader styles from the drop-down list in the expanded Annotation panel, or by entering **MLEADERSTYLE** in the Command window.



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For example, to create a “detail callout” style, start the **MLEADERSTYLE** command. In the Multileader Styles Manager, click New and choose a descriptive name for the new multileader style. Click the Content

tab, choose Block, and then Detail Callout as shown.

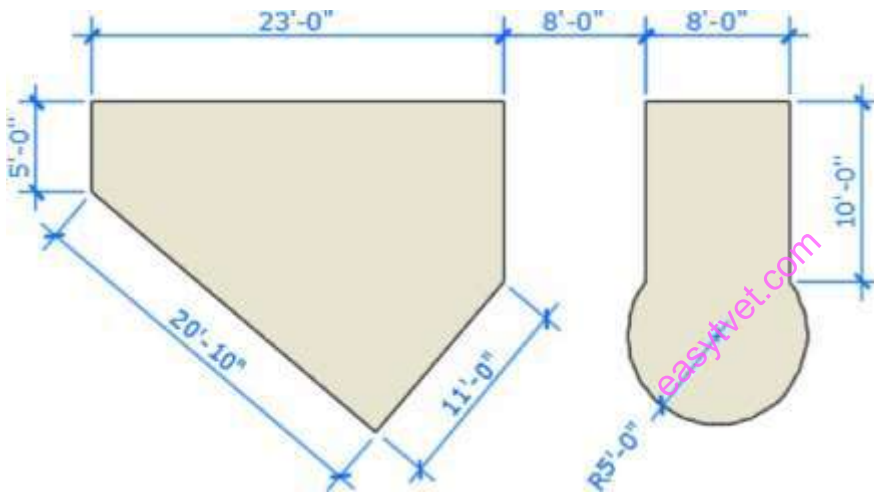


NOTE: As with text styles, once you create one or more multileader styles, save them in your drawing template files.

Dimensions

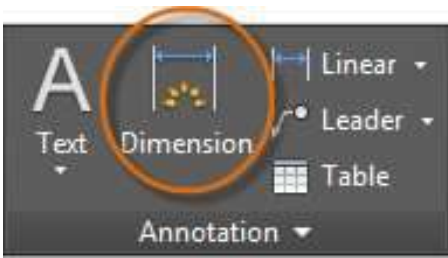
Create several types of dimensions and save dimension settings by name.

Here is an example of several types of dimensions using an architectural dimension style with imperial units.

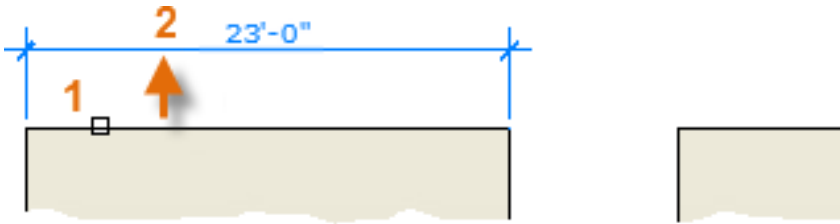


Linear Dimensions

You can create horizontal, vertical, aligned, and radial dimensions with the **DIM** command. The type of dimension depends on the object that you select and the direction that you drag the dimension line.

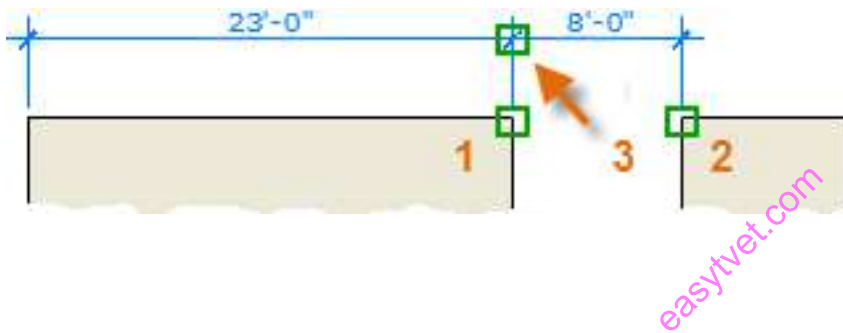


The following illustration demonstrates one method for using the **DIM** command. Once you start the command, press Enter or the Spacebar, select the line (1), and then click the location of the dimension line (2).



Linear Dimensions (continued)

For the 8'-0" dimension below, you use another method. You start the DIM command, click two endpoints (1 and 2) and then the location of the dimension line (3). To line up the dimension lines point 3 was snapped to the endpoint of the previously created dimension line.



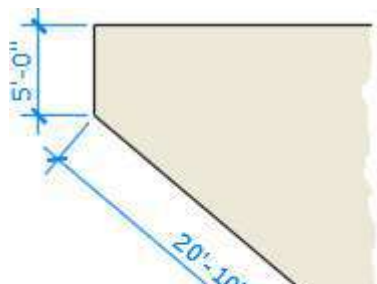
Use the **DIM** command to create dimensions that are parallel to an object by dragging the dimension line at an angle rather than horizontally or vertically.

Here's a Tip:

If points 1 and 2 are not on the same horizontal line, press Shift to force the dimension line to be horizontal. In addition, if the building or part being dimensioned is at an angle, enter **DIMROTATED** for that case.

Another Tip:

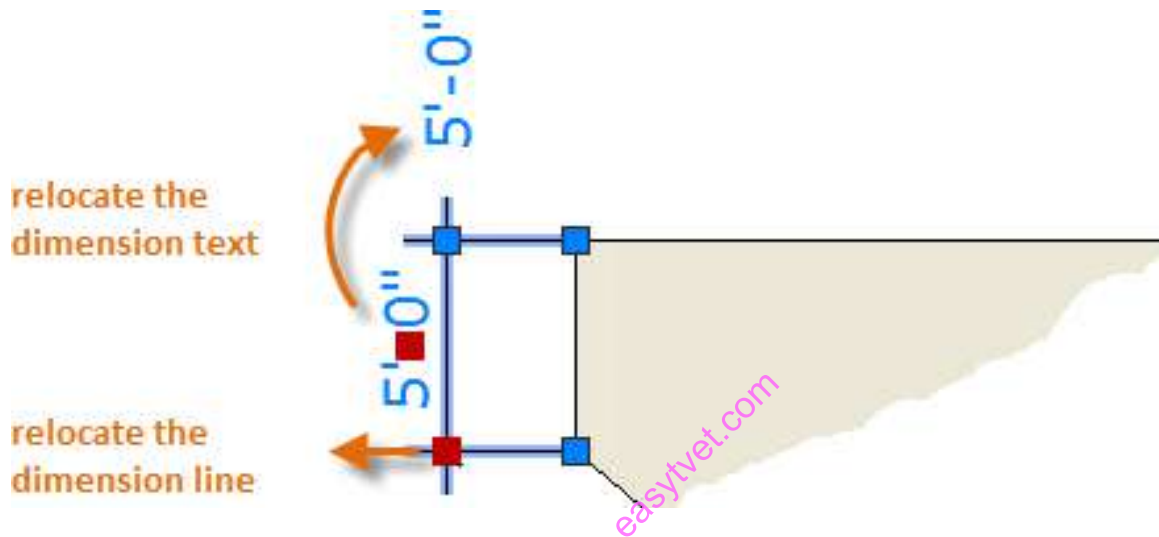
Because it is easy to accidentally snap to the wrong feature or part of a dimension object, be sure to zoom in closely enough to avoid mistakes.



Modify Dimensions

For simple adjustments to dimensions, nothing is faster than using grips.

In this example, you select the dimension to display its grips. Next, click the grip on the dimension text and drag it to a new location, or click one of the grips at the end of the dimension line and drag the dimension line.



Here's a Tip:

If the changes are more complicated than this, it might be faster simply to delete and then recreate the dimension.

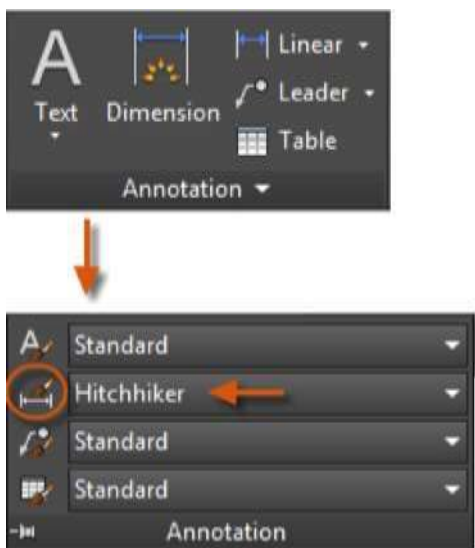
Dimension Styles

Dimension styles help establish and enforce drafting standards. There are many dimension variables that can be set with the **DIMSTYLE** command to control virtually every nuance of the appearance and behavior of dimensions. All these settings are stored in each dimension style.

The default dimension style is named either Standard (imperial) or ISO-25 (metric). It is assigned to all dimensions until another style is set as the current dimension style.

The current dimension style name, Hitchhiker in this case, is displayed in the drop-down list of the Annotation panel.

To open the Dimension Style Manager, click the indicated button. You can create dimension styles that match nearly any standard, but you will need to invest time into specifying them completely. For this reason, you should save any dimension styles that you create in one or more drawing template files.



Printing

Output a drawing layout to a printer, a plotter, or a file. Save and restore the printer settings for each layout.

Originally, people *printed* text from printers and *plotted* drawings from plotters. Now, you can perform both with either device, so this guide will use the terms 'print' and 'plot' interchangeably.

The command to output a drawing is **PLOT** and you can access it from the Quick Access toolbar.



To display all of the options in the Plot dialog box, click the More Options button.



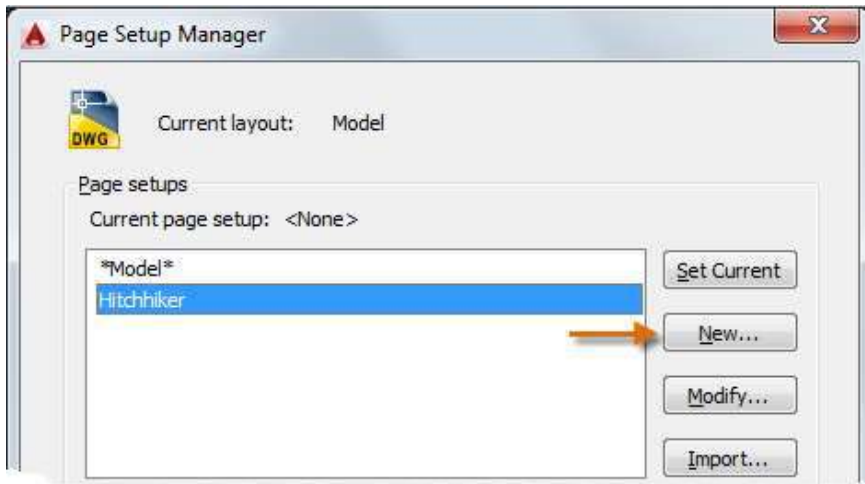
As you can see, there are many settings and options available.

For the sake of convenience, you can save and restore collections of these settings by name. These are called *page setups*. With page setups you can store the

Create a Page Setup

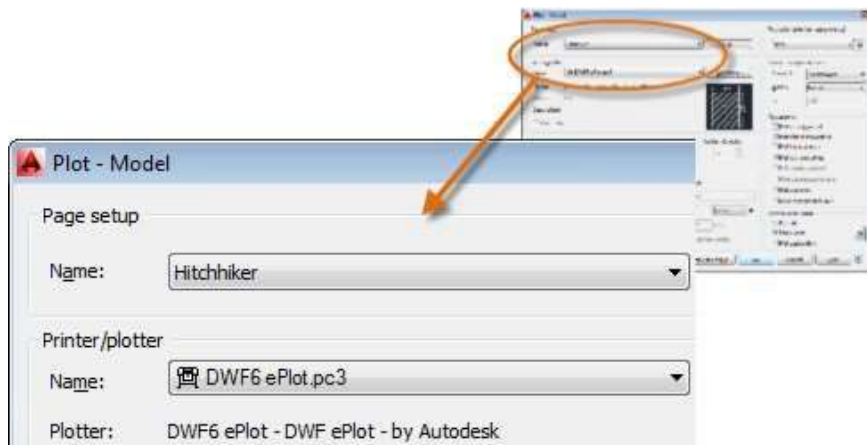
To open the Page Setup Manager, right-click on the Model tab or a layout tab and choose Page Setup Manager. The command is **PAGESETUP**.

Each layout tab in your drawing can have an associated page setup. This is convenient when you use more than one output device or format, or if you have several layouts with different sheet sizes in the same drawing.



To create a new page setup, click New and enter the name of the new page setup. The Page Setup dialog box that displays next looks like the Plot dialog box. Choose all the options and settings that you wish to save.

When you are ready to plot, simply specify the name of the page setup in the Plot dialog box, and all your plot settings will be restored. In the following illustration, the Plot dialog box is set to use the Hitchhiker page setup, which will output a DWF (Design Web Format) file rather than print to a plotter.



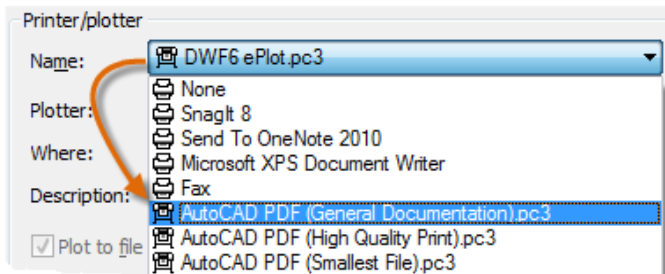
Here's a Tip:

You can

Output to a PDF File

The following example shows you how to create a page setup for creating PDF files.

From the Printer/plotter drop-down list, choose *AutoCAD PDF (General Documentation).pc3*:



Next, choose the size and scale options that you want to use:

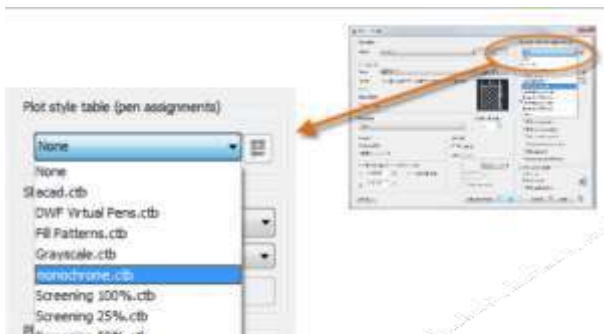
Paper Size: The orientation (portrait or landscape) is built into the choices in the drop-down list.

Plot Area: You can clip the area to be plotted with these options, but typically everything will be plotted.

Plot Offset: This setting changes based on your printer, plotter, or other output. Try centering the plot or adjusting the origin, but remember that printers and plotters have a built-in margin around the edges.

Plot Scale: Choose your plot scale from the drop-down list. A scale such as 1/4" = 1'-0" is meant for printing to scale from the Model tab. On a layout tab, you normally print at a 1:1 scale.

The plot style table provides information about processing colors. Colors that look good on your monitor might not be suitable for a PDF file or for printing. For example, you might want to create a drawing in color, but create monochrome output. Here is how you specify monochrome output:



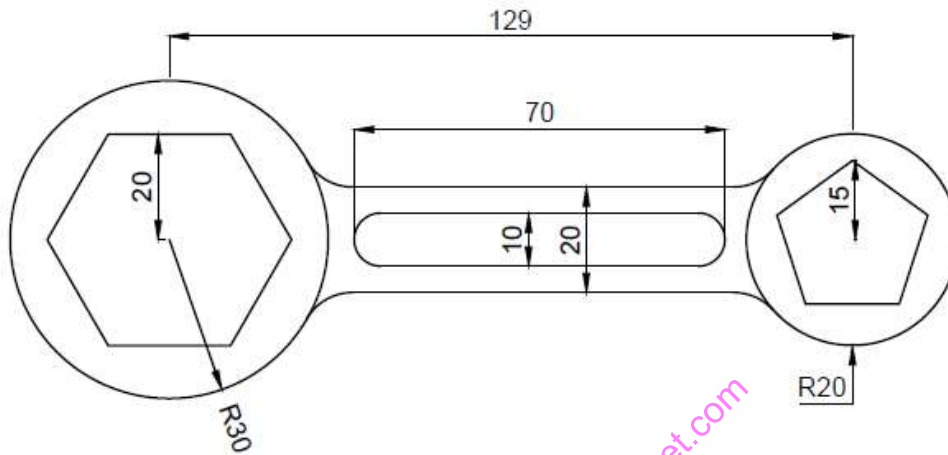
Learning activities

Learning activity 1: Apply CAD packages

The following figure is an orthographic view of a lever crank. Redraw the view using AutoCAD.

SET-UP INSTRUCTIONS: Using the UNITS command:

- i. Set UNITS to Decimal.
- ii. Set the accuracy to 2 decimal places.
- iii. Accept the defaults for the remaining prompts.



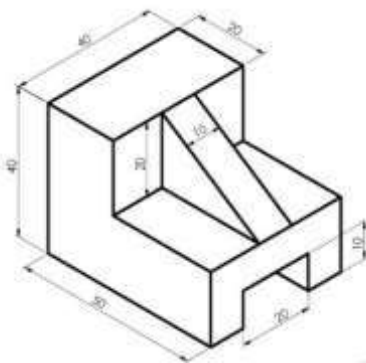
Learning activity 2: Apply cad packages

The following figure is an ISOMETRIC view. Redraw the view using AutoCAD.

SET-UP INSTRUCTIONS:

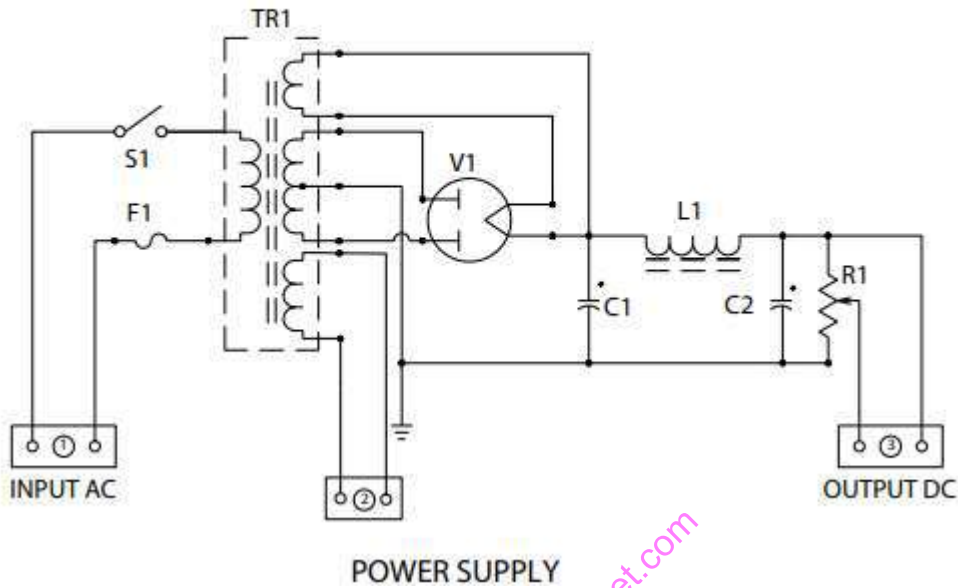
Using the UNITS command:

- i. Set UNITS to Decimal.
- ii. Set the accuracy to 2 decimal places.
- iii. Accept the defaults for the remaining prompts.



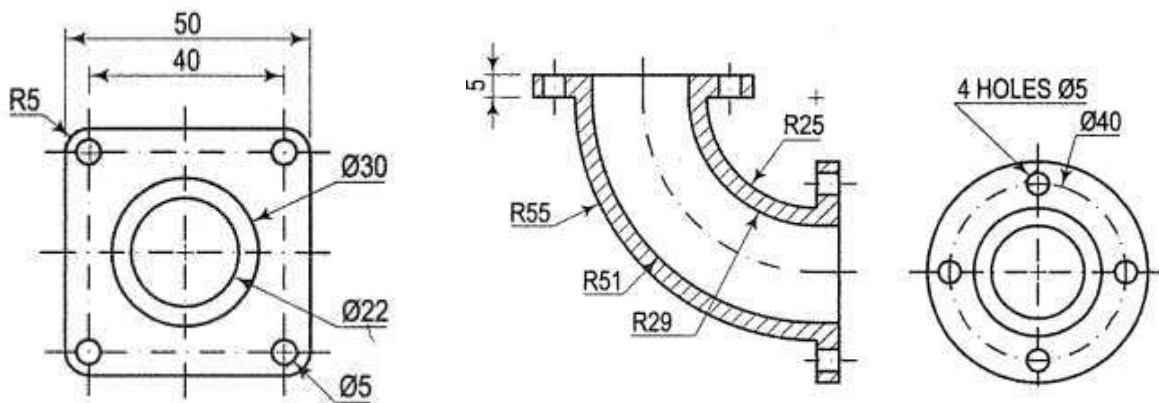
Learning activity 3: Apply cad packages

Draw this circuit, using the techniques you have learned using AutoCAD.



Learning activity 4: Apply cad packages

Draw the figure below using line, circle, rectangle, fillet, rectangular array, polar array, dimension, hatch, layer, hidden line, and center line etc., commands.



Self-assessment

1. When creating your own blocks, it is important to avoid drawing any portion of the block in the _____ layer.
 - A. 0
 - B. center line
 - C. hatch
 - D. hidden line
2. An AutoCAD term that refers to a pre-drawn object which is stored in a drawing file and can be inserted into any other drawing file as needed is a _____.
 - A. Block
 - B. Brick
 - C. Balloon
 - D. none of the above
3. Before starting an isometric drawing in AutoCAD the drafter needs to _____.
 - A. set the grid to isometric
 - B. set the current layer to Defpoints
 - C. turn Object Snap off
 - D. turn Ortho off
4. When lettering a CAD drawing, for clarity you should limit the number of fonts to:
 - A. One
 - B. Two
 - C. Three
 - D. Any number
5. The same general concepts and drafting standards apply to CAD as to drawings created by hand.
 - A. True
 - B. False
6. The main difference between a CAD drawing and a freehand sketch is in the appearance of lines.
 - A. True
 - B. False
7. In a CAD system, you can draw an ellipse by specifying these:
 - A. The bounding lines
 - B. The midpoint and end points
 - C. The center and major and minor axes
 - D. The center and radius

8. When creating an isometric drawing in AutoCAD the drafter can utilize the Dynamic Input and Polar Coordinate system to place both vertical and horizontal lines. A line created from one point 3 inches at 180 degrees would be a _____ line.
- A. horizontal
 - B. vertical
 - C. inclined
 - D. none of the above
9. AutoCAD refers to isometric ellipses as _____.
- A. Ellipses
 - B. Isoellipses
 - C. Isocircles
 - D. circles
10. Drafters should use a _____ in a section view of a mechanical part that includes the cylindrical view of a threaded hole.
- A. Center line
 - B. Hatch line
 - C. Poly line
 - D. Dimension line
11. When filling an area with a hatch pattern in AutoCAD the drafter needs to be able to _____.
- A. See the entire bounding area to hatch
 - B. set Ortho on
 - C. turn ISO grid off
 - D. set the layer to Defpoints
12. The default position of the UCS icon is positioned at _____ on the AutoCAD grid.
- A. 0,0,0
 - B. 10,10,10
 - C. 20,20,20
 - D. None of the above
13. A cylinder can be created by drawing a rectangular shape then the _____ tool.
- A. Revolve
 - B. Sweep
 - C. Extrude
 - D. none of the above
14. The MASSPROP shortcut will provide the following information.
- A. mass
 - B. volume
 - C. bounding box

- D. all of the above
15. The 3-D commands on the Modeling toolbar include _____.
- A. box
 - B. sphere
 - C. extrude
 - D. all of the above
16. CAD programs which incorporate parametric modeling utilize a system in which the dimensions control the _____.
- A. size and shape of the model features
 - B. perspective of the model
 - C. shading used to render the model
 - D. all of the above
17. In order to create one solid model from two or more separate solid shapes the drafter will need to position them and then _____.
- A. use Union to join them
 - B. use the Join command
 - C. use the Add Parts tool
 - D. none of the above
18. The Conceptual Visual Style tool is located on the _____ toolbar.
- A. Visual Styles
 - B. Modify
 - C. 3-D Modeling
 - D. All of the above
19. Drawings created with commercial software are typically saved as:
- A. Rapid prototypes
 - B. Electronic files
 - C. Draft drawings
 - D. Change orders
20. Newer versions of AutoCAD utilize the _____ to make block library management very easy.
- A. File / find
 - B. Design Center
 - C. File / search
 - D. None of the above
21. Inserting blocks into a drawing file usually requires exacting placement. The drafter should insure that _____ is turned on.
- A. O Snaps
 - B. Ortho
 - C. Grid

- D. Dynamic Input
22. The command which identifies the points on drawing entities that are visible on screen is and this option allows the user to pick-up the points very accurately with respect to drawing displayed.
- A. OSNAP
 - B. TABSURF
 - C. SNAP
 - D. GRID
23. The commands Erase, Copy, Mirror, Trim, Extend, Break etc belongs to which tool bar?
- A. Layer tool bar
 - B. Style tool bar
 - C. Modify tool bar
 - D. Draw tool bar
24. The commands Donut, Block, Spline, Polygon, and Arc etc belong to which tool bar?
- A. Layer tool bar
 - B. Style tool bar
 - C. Modify tool bar
 - D. Draw tool bar
25. The command which works on two lines or a single poly line to create a beveled edge is
- A. Chamfer
 - B. Fillet
 - C. Stretch
 - D. Extend
26. The command which is used to create a round corner between two lines is
- A. Chamfer
 - B. Fillet
 - C. Stretch
 - D. Extend
27. The command 'Oops' is used to
- A. create one or more copies of selected objects at another location
 - B. creates mirror image of selected objects about specified line
 - C. retrieves all objects erased by the last erase
 - D. deletes the selected entities
28. The command 'pedit' is used for
- A. erases a portion of line, arc, circle or a 2D poly line between two selected points
 - B. reverses the effects of a series of previously used commands
 - C. breaking a poly line into individual segments
 - D. editing of poly line properties
29. The command 'break' is used for
- a) erases a portion of line, arc, circle or a 2D poly line between two selected points
 - b) reverses the effects of a series of previously used commands
 - c) breaking a poly line into individual segments
 - d) editing of poly line properties

30. The command 'U' is used for
- erases a portion of line, arc, circle or a 2D poly line between two selected points
 - reverses the effects of a series of previously used commands
 - breaking a poly line into individual segments
 - editing of poly line properties
31. The command 'Explode' is used for
- erases a portion of line, arc, circle or a 2D poly line between two selected points
 - reverses the effects of a series of previously used commands
 - breaking a poly line into individual segments
 - editing of poly line properties
32. The command which is used to set a new coordinate system by shifting the working XY plane to be desired location is?
- 3DFACE
 - VPOINT
 - UCS
 - ELEV
33. The command which is used for making planar unmeshed surfaces that have three or four sides is
- 3DFACE
 - VPOINT
 - UCS
 - ELEV
34. The command which is used to set the viewpoint in 3D space for viewing the 3D models is
- 3DFACE
 - VPOINT
 - UCS
 - ELEV
35. The command which is used to set elevation and thickness properties for 2D wireframe objects such as line, point, circle, polygon, arc is
- 3DFACE
 - VPOINT
 - UCS
 - ELEV

Tools, Equipment, Supplies and Materials

- Drawing tools
- Drawing set
- Drawing papers
- Erasers
- Series of pencils
- Drawing board

References

1. *Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing : Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.*
2. *Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.*
3. *Narayana, K. L., Kanniah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.*
4. *Reddy, K. V. 2010. Textbook of Engineering Drawing . B.S. Publ., Hyderabad.*
5. *Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,*
6. *Learn about AutoCAD manual. An Introduction to AutoCAD for Beginners*

4.7 MODEL ANSWERS

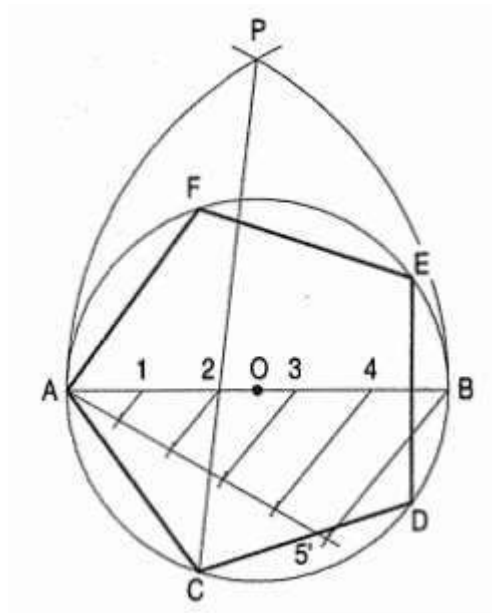
Apply and Maintain Drawing Equipment and Materials

1. B
2. A
3. B
4. C
5. A
6. B
7. Why the drawing is called the language of Engineers?
Engineering drawing teaches us to imagine and read the drawing, which is important in industrial or construction engineers to execute the construction with the help of a drawing and execute according to the drawing. Without drawing we can't construct in construction work
8. What is the Necessity of Dimension a Drawing?

Learning activity 2: Produce plane geometry

To inscribe a regular polygon of any number of sides, say 5, in a given circle

- vii. With centre O , draw the given circle.
- viii. Draw a diameter AB and divide it into five equal parts (same number of parts as the number of sides) and number them as shown.
- ix. With centres A and B and radius AB , draw arcs intersecting each other at P .
- x. Draw a line AP and produce it to meet the circle at C . Then AC is the length of the side of the pentagon.
- xi. Starting from C , step-off on the circle, divisions CD , DE etc., equal to AC .
- xii. Draw lines CO , DO etc., thus completing the pentagon.



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Produce Plane Geometry Drawings

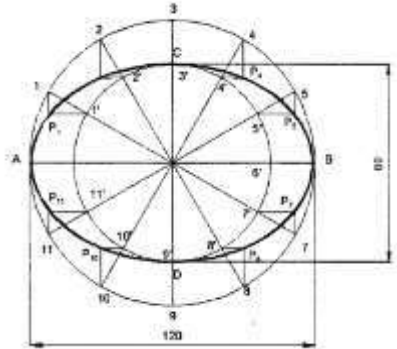
1. D 9

2. D

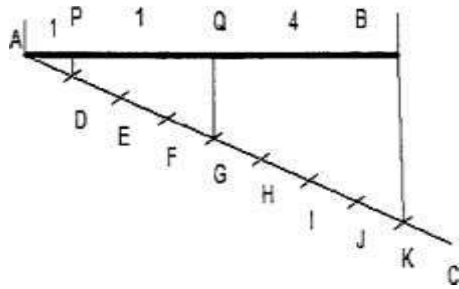
an

inscribed

3. Ellipse

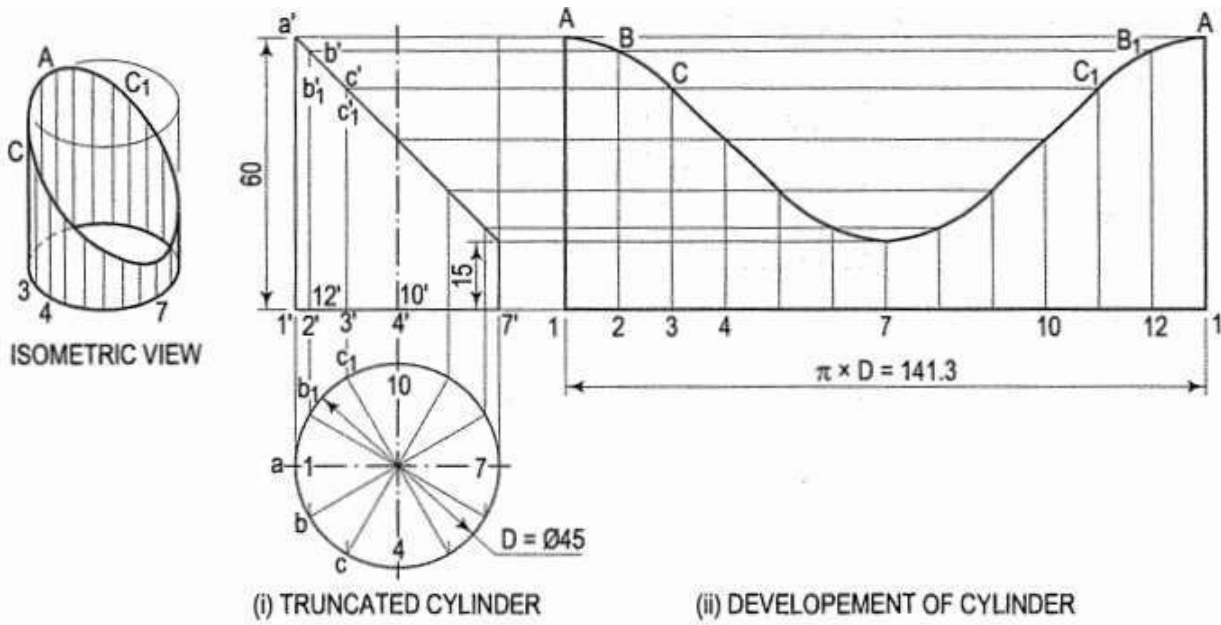


4.

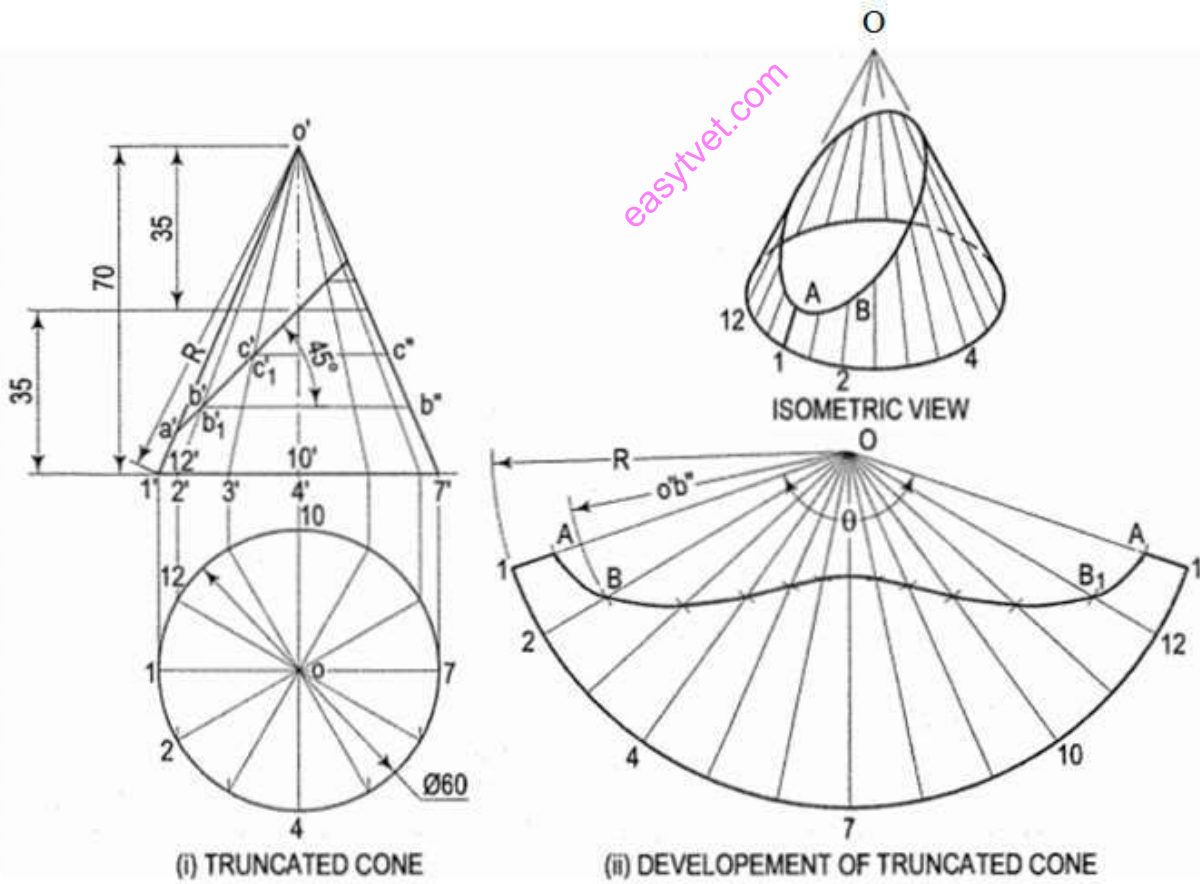


Add the ratios $1+3+4 = 8$ and divide the line into 8 equal divisions.
Obtain P and Q to divide the line AB in the ratio 1:3:4.

Learning activity 1: Produce solid geometry drawings
Develop the lateral surface of the truncated cylinder



Learning activity 2: Produce solid geometry drawings
Draw the development of the of the truncated cone



Produce Solid Geometry Drawings

1. A
2. C
3. B

4. What is the difference between regular and irregular polygons?

Regular polygon – A regular polygon is a plane figure in which all the sides and angles are equal.

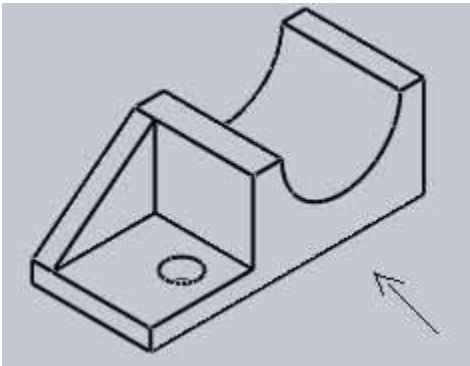
Irregular polygon – An irregular polygon is a plane figure in which all the sides and angles are not equal.

5. If an isometric drawing is made use of isometric scale then the drawings are called

Answer: A

Explanation: To avoid confusion, the view drawn with the true scale is called isometric drawing or isometric view, while that drawn with the use of isometric scale is called isometric projection.

6. Identify the front view of the below isometric view.



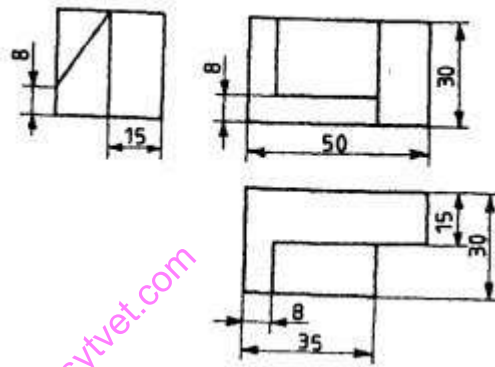
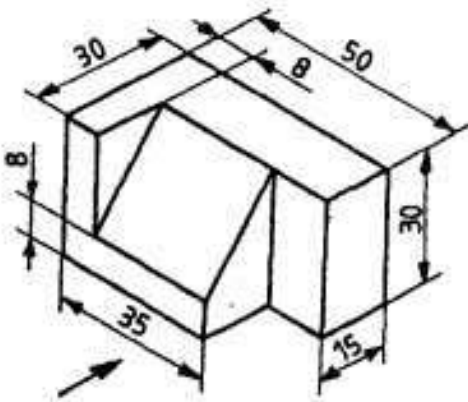
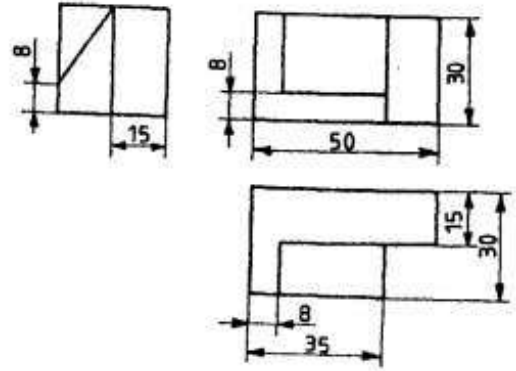
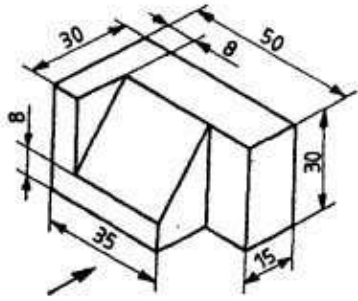
easyvet.com

Answer: a

Explanation: Here the isometric view of some example picture is given. Arrow in question represents the line of sight in case of front view from that we can get other view. Front view is asked which can be watched along the arrow.

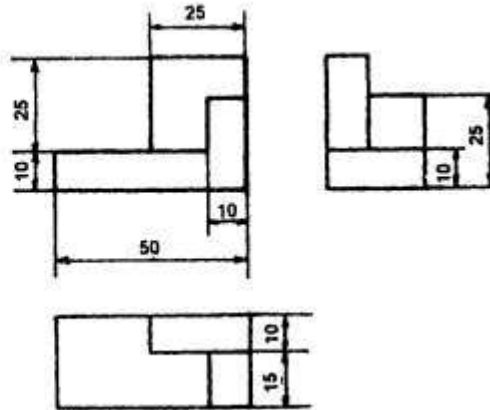
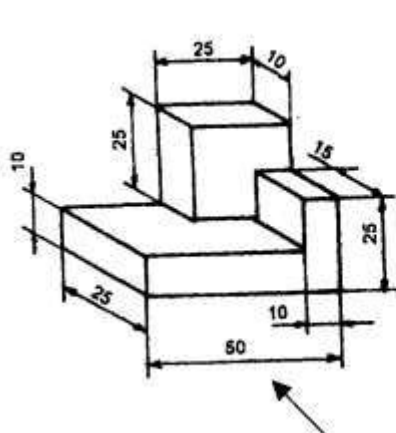
LEARNING ACTIVITY 1: Produce orthographic and pictorial drawings

- i. The following figures are in isometric view. Draw the orthographic views in first angle.



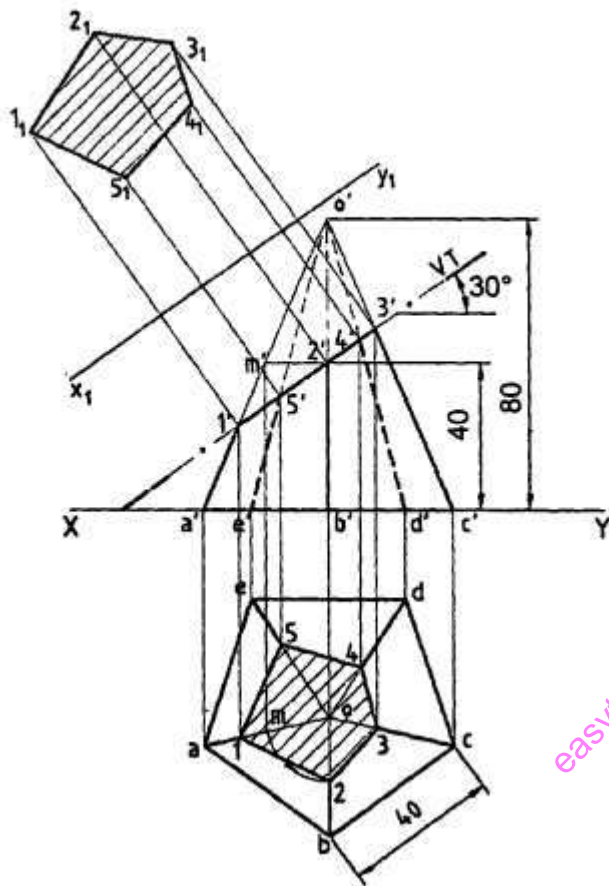
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ii. The following figures are in oblique view. Draw the orthographic views in first angle.



Learning activity 2: Produce orthographic and pictorial drawings

A pentagonal pyramid of base side 40 mm and axis length 80mm is resting on HP on its base with one of its base side parallel to VP. It is cut by a plane inclined at 30° to HP and perpendicular to VP and is bisecting the axis. Draw its front view, sectional top view, and the true shape of section.



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Produce Orthographic and Pictorial Drawings

1. D
2. B
3. B
4. A
5. A
6. B
7. A
8. B
9. C
10. A
11. D
12. D

13. C

Explanation: From the front view it is clear that the circle has diameter 20 mm. Hence its radius will be 10mm. The dimension 10mm in the side view is just a repetition of this information. Repetitive dimensions are redundant and they need to be avoided.

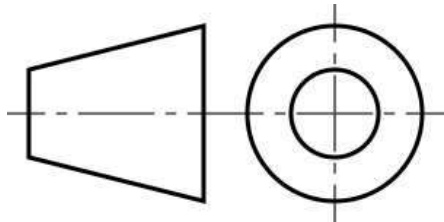
14. Views in an Orthographic Drawings

Front view

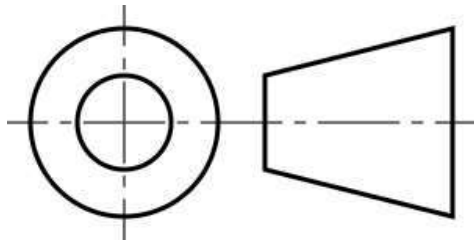
Side view

Plan

15. First angle projection:-In this projection the object is assumed to be situated in first quadrant, i.e. in front of V.P and above HP the projections obtained on these planes is called first angle projection. The symbol for the first angle projection is



Third angle projection: – In this Projection the object is assumed to be situated in the third quadrant that is below HP and behind VP .The front view comes below the XY line and the top view above it. The symbol for the third angle projection is



First angle and third angle symbol in machine drawing

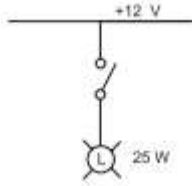
Produce Electrical Drawings

1. Definitions;
 - i. Schematic diagram

Schematic diagram: a diagram that uses lines to represent the wires and symbols to represent components. It is used to show how the circuit functions.

ii. Line diagram

Line diagram: a one-line diagram or single-line diagram is a simplified notation for representing an electrical system. The one-line diagram is similar to a block diagram except that electrical elements such as switches, circuit breakers, transformers, and capacitors are shown by standardized schematic symbols.



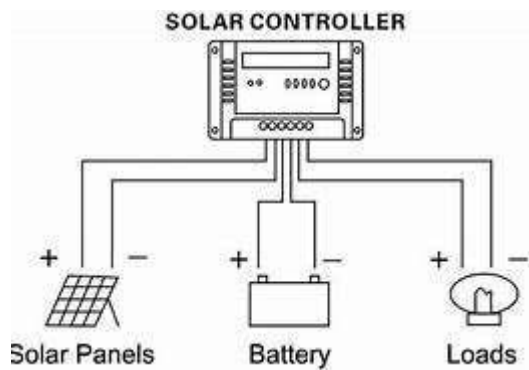
iii. Wiring diagram

A diagram which shows the connections of an installation or its component devices or parts. It may cover internal or external connections, or both, and contains such detail as is needed to make or trace connections that are involved.

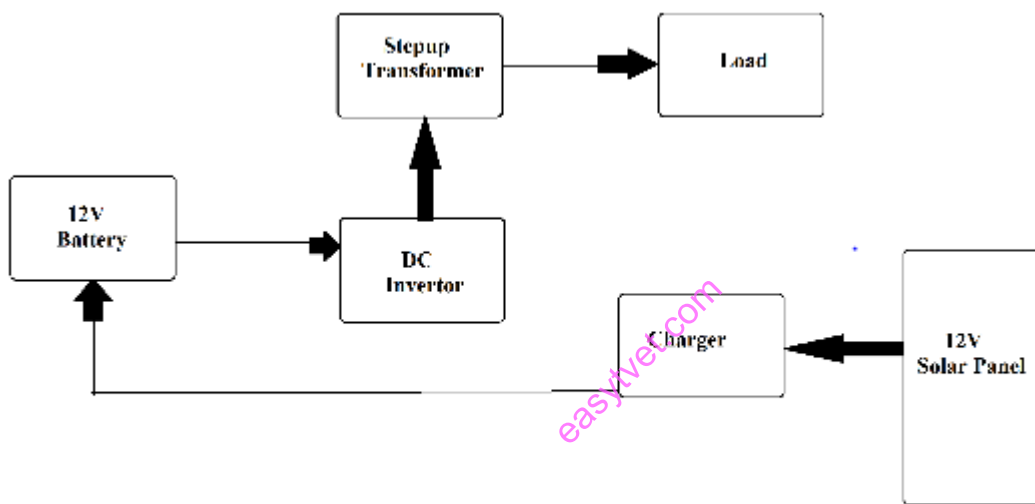
2. Indicate the meaning of the following symbols

Symbol	Meaning
	1 gang switched socket-outlet
	Battery
	Inverter
	Switch, general symbol
	Filament lamp
	Semi-Conductor Diode - general symbol

3. A pictorial diagram to show the connection of the solar panel, the battery, and the load to a charge controller.



4. Block diagram of a solar system.



Apply Cad Packages

1. A
2. A
3. A
4. B
5. A
6. A
7. C
8. B
9. C
10. A

11. A

12. A

13. A

14. D

15. D

16. A

17. A

18. A

19. B

20. B

21. A

22. Answer: a

Explanation: The command which identifies the points on drawing entities that are visible on screen is OSNAP. This option allows the user to pick-up the points very accurately with respect to drawing displayed.

23. Answer: c

Explanation: The commands Erase, Copy, Mirror, Trim, Extend, Break, Join, Scale, Array etc belongs to 'Modify tool bar'. The commands Donut, Block, Spline, Hatch, Rectangle, Ellipse, Polygon, and Arc etc belong to 'Draw tool bar'.

24. Answer: d

Explanation: The commands Erase, Copy, Mirror, Trim, Extend, Break, Join, Scale, Array etc belongs to 'Modify tool bar'. The commands Donut, Block, Spline, Hatch, Rectangle, Ellipse, Polygon, and Arc etc belong to 'Draw tool bar'.

25. Answer: a

Explanation: Chamfer works on two lines or a single poly line to create a beveled edge. Fillet is used to create a round corner between two lines. Stretch command can either lengthen entities or shorten them and thus their shapes.

26. Answer: b

Explanation: Fillet is used to create a round corner between two lines. Chamfer works on two lines or a single poly line to create a beveled edge. Stretch command can either lengthen entities or shorten them and thus their shapes.

27. Answer: c

Explanation: The command 'Oops' is used to retrieves all objects erased by the last erase. Mirror is used to creates mirror image of selected objects about specified line. Command copy creates one or more copies of selected objects at another location. The command 'pedit' is used for

28. Answer: d

Explanation: The command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands. Command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points.

29. Answer: a

Explanation: The command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points. Command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands.

30. Answer: b

Explanation: The command 'U' is used for reverses the effects of a series of previously used commands. Command 'pedit' is used for editing of poly line properties. Command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points.

31. Answer: c

Explanation: The command 'Explode' is used for breaking a poly line into individual segments. Command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands.

32. Answer: c

Explanation: UCS is used to set a new coordinate system by shifting the working XY plane to be desired location. 3DFACE is used for making planar unmeshed surfaces that have three or four sides. VPOINT is used to set the viewpoint in 3D space for viewing the 3D models.

33. Answer: a

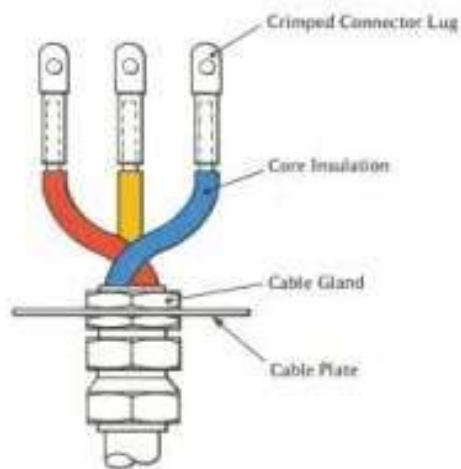
Explanation: 3DFACE is used for making planar unmeshed surfaces that have three or four sides. VPOINT is used to set the viewpoint in 3D space for viewing the 3D models. UCS is used to set a new coordinate system by shifting the working XY plane to be desired location.

34. Answer: b

Explanation: VPOINT is used to set the viewpoint in 3D space for viewing the 3D models. 3DFACE is used for making planar unmeshed surfaces that have three or four sides. UCS is used to set a new coordinate system by shifting the working XY plane to be desired location.

35. Answer: d

Explanation: ELEV is used to set elevation and thickness properties for 2D wireframe objects such as line, point, circle, polygon and arc. 3DFACE is used for making planar unmeshed surfaces that have three or four sides.



Cable termination

The methods used to terminate the cables vary according to;

- Type of cable,
- Type of connector and application.

- Outdoor or indoor use
- Voltage
- Current
- Overhead, or underground
- Type of Connector on the equipment where the cable will be connected.

The common type of terminations

- Crimp connection,
- Soldered connection,
- Compression termination, and wire-wrapping connection,
- Direct connection,
- Loop or eye connection.

Electrical power cable joints

The cable joints are used to connect low, medium or high voltage cables. The type of cable joint sizes, shapes and configurations vary according to the voltage, structure, insulation and the number of cores of the cable to be jointed.

The joints provide electrical insulation as well as mechanical protection and strength. The electrical connection is made in various ways and can crimping, or use of mechanical connectors, soldering, etc.

Voltage- The joints are designed for low, medium or high voltages and it is important to match the capacity of the joint to voltage in the cable. Low power cable joint will fail if subjected to high current.

Structure- The cable joints are made according to how the cables are to be connected. The simple joints such as the straight through connectors are used to connect two power cables at one point while the other more advanced branch connectors may be used to accommodate a cable branching off the main line or several cables coming into one joint to form one main cable.

Cores- The cable joints are required to have the same number of cores to those of the cables to be jointed.

Insulation- There are different cable insulations depending on the application of the cable and the cable joint must be compatible with the cable insulation. There are a variety of insulation procedures, and can be either heat or cold shrinkable insulation, molded type of insulation, or use of tape.

Types of electrical power cable joints

There are about four commonly used types of joints; these differ in mechanical arrangement and where they are used. However, some manufacturers may provide custom designs to suit unique customer requirements.

Straight through joints- This is the mostly used type of a joint and is used to extend pieces of electrical cables.

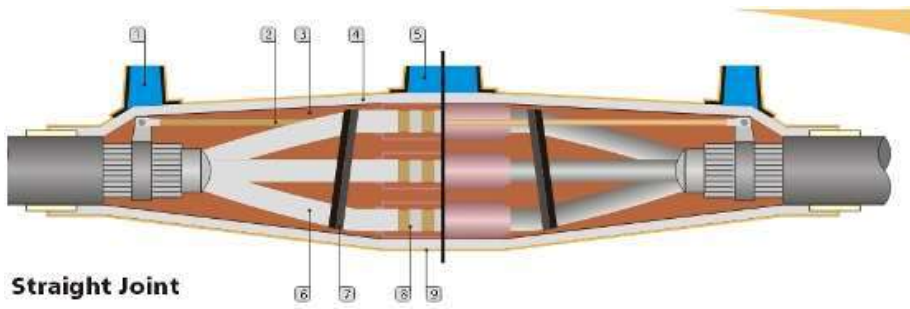


Figure 137: Cable joint:

1. Riser
2. Earth continuity connection
3. C.J compound
4. Plastinet
5. Pouring gate
6. Core Insulation
7. PVC (NA) Tape
8. Ferrule
9. BOPP Tape two layers each half overlapped over plastinet

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Branch which can be a T or Y joint- This is used to join low voltage, polymeric, non-shielded cables of between 1 and 5 cores. The branch jointing provides a reliable electrical connection, electrical insulation and mechanical protection. The connectors are either the compression or the mechanical type. The branch joints can be used for indoor, outdoor, submerged and underground cable jointing.



T or Y joint

Pot End Joints- The pot end joints are used at the live voltage cable ends. In a typical cable, each of the cores is sealed separately using a heat shrink cable end caps. A screen bandage is then applied to provide for earth fault protection and the combination is then covered with a thick wall of heat shrink cable cap. The pot ends

joints are suitable for temporary and permanent cable abandonment to provide safe termination of live power cables for indoor, outdoor as well as underground cables

Follow the link below to watch tutorials on cable terminations-

<https://www.youtube.com/watch?v=PgD2D2VnNg0>

- **Importance of termination**

- Provides electrical continuity in the circuit
- Provides mechanical support and physical protection to the cables
- Ensures safety of the circuit, the user and maintenance technician

Types of cable terminations

Soldering- Flame soldering units can be used to automate the process. In a flame soldering application, the object is placed over a tiny flame, heated for a specified time and a precise amount of solder is applied. Some applications require the terminal to be soldered after it is crimped onto the end of the wire. This method is mainly used in electronics

Insulation Displacement Connections- Insulation displacement connectors (IDC) are probably the fastest way to terminate wires. The process can quickly and efficiently terminate the hundreds of wires in large patch panels. There is no need to strip the wires when using IDC. IDC tools are inexpensive and virtually error-proof. There are no chemicals to deal with and no insulation slugs to clean up. IDC applications are usually reserved for small, stranded wire up to 22 AWG.

Crimping- Crimping is the most commonly used method of wire termination, and is most efficient for high-volume wire termination. The terminations are fast, clean and mechanically strong. For low volume or fieldwork, loose terminals are applied with a plethora of handheld and benchtop crimping devices.

Ultrasonic Welding- Ultrasonic welding is used in various bonding applications, such as joining such dissimilar metals as copper, aluminum, nickel and brass. Ultrasonic welding is widely used in wire harness manufacturing, where welding multiple wires is required. The resulting molecular bonds are strong and can provide lower resistance than soldering or crimping. Ultrasonic welding can also bond wire to terminals. The advantage is the lower resistance. The disadvantage is that this process takes longer than crimping

Cable lug- A device attached to a conductor to permit connection to a terminal. It has provisions for attachment of wires or similar electrical conductors in order to establish an electrical connection and could require the use of tools for attachment of wire. A terminal may be attached to a wire by a number of methods including screw-on, press-on or crimp-on

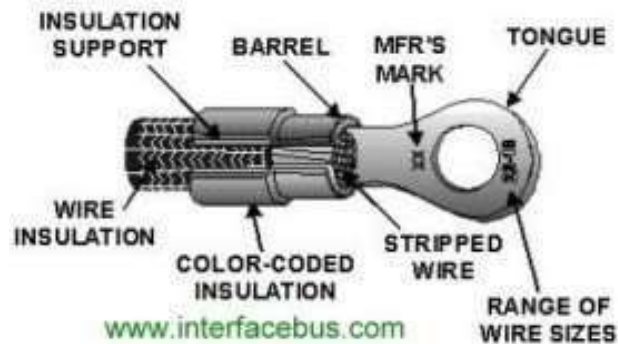


Figure 138: terminal lug (from www.Interfacebus.com):

- **Cable labeling**

Letters, numbers, and wording on wiring labels tell you important information, such as the wire material, the size of the wire, and the type of insulation used on the conducting wires. Labels are found on both individual insulated wires and on insulated cable containing bundles of wires. Cables carry labels indicating the cable type or construction as well as the number of wires inside the cable.

A ground wire is indicated by "G," "w/G," or "with Ground." The wire material is indicated by "CU" for copper and "AL" for aluminum.

Example

- **14-2G:** Cable contains two insulated wires plus a ground wire; the wires are 14-gauge.
- **14-3G:** Cable contains three insulated wires plus a ground wire; the wires are 14-gauge.
- **12-2 w/G:** Cable contains two insulated wires plus a ground wire; the wires are 12-gauge.
- **12-3 w/G:** Cable contains three insulated wires plus a ground wire; the wires are 12-gauge.
- **600 V:** Cable is rated for a maximum of 600 volts; this is standard for residential NM cable.
- **TYPE NM-B:** Non-metallic type-B cable; this is the current standard for residential installations. "NM-B" cable is more heat-resistant than older "NM" cable.

Underground Feeder Cable

Most NM cable is used in "dry," or interior, locations, where the cable is protected inside wall, ceiling, and floor cavities. Underground feeder (UF) cable is a special type of non-metallic cable that is suitable for "wet" locations, or for unprotected locations like direct burial in the ground. UF cable is usually gray (not white, yellow, orange, or black, like standard NM cable); it is labeled "UF-B" and may include "Sunlight Resistant" or similar wording. UF cable uses the same symbols as standard NM cable to indicate the number and gauge of wires.

Labels on Individual Wires

Individual insulated wires are used in home wiring when an installation calls for conduit—a rigid or flexible protective pipe or tubing through which the wires are run. The important labeling on individual wires relates to the wire insulation—the plastic coating that covers the metal conducting wire. The most common types of wire used in home wiring include:

THHN, THWN, THW and XHHN where;

- **T:** Thermoplastic insulation, a fire-resistant material
- **H:** Heat-resistant; able to withstand temperatures up to 167 F.
- **HH:** Highly heat-resistant; able to withstand temperatures up to 194 F.
- **W:** "Wet," or approved for damp and wet locations; this wire is also suitable for dry locations
- **X:** Insulation made of a synthetic polymer that is flame-retardant
- **N:** Nylon-coated for resistance to oil and gasoline

Labels on Low-Voltage and Thermostat Wires

Low-voltage wiring used around the home includes small non-metallic cable used for thermostats and other control devices and paired insulated wire used for landscape lighting systems. Wire for landscape lights usually is black and has labeling stamped into the wire insulation. Labels typically include:

- **Wire size:** Indicated by a number (such as 12, for 12-gauge) or a number followed by "AWG," for American Wire Gauge.
- **Number of wires:** Usually indicated by the number 2; landscape wiring typically has two insulated wires stuck together (similar to a lamp cord) and contains no ground wire.
- **Properties:** Wording indicating sunlight-resistance or suitability for underground installation.

Thermostat cable is similar to NM cable but contains four or more small insulated wires and no ground wire. The cable may or may not be labeled. Each wire has its own colour to help you connect to the appropriate terminal at the thermostat and the equipment it controls. Although colour coding is not universal, the lettering on the thermostat terminals is relatively standard:

C: Common wire; allows for continuous power flow from the R wire; not all thermostats use this terminal

- **R:** 24-volt power supply from the furnace transformer
- **Rc:** Calls for heat or cooling; there may be more than one Rc terminal
- **G:** Fan
- **W:** Heat
- **Y:** Air conditioner

Technicians in their line of work may also find it necessary to label cables especially in industrial installation, cabinets and automated systems for easy troubleshooting and safety.

- **Tools used for cable termination**

- Needle nose crimping pliers-They are applicable as small lug crimpers



Figure 11

Needle nose pliers

- Crimping tool- It is used for fixing a connector to the end of a cable

RJ-11 (6-Pin) and RJ-45 (8-Pin) Crimping Tool



- Snips- They are used to cut small cables and conductors, and to trim insulation.



Figure 12

- Wire stripper hole for 22- to 24-gauge wire- They are used to strip insulation from conductors. The adjusting screw should be used to prevent the cutting tips doing damage to the conductor. They may also

be used to remove the sheath from single core PVC / PVC cable, 1.5mm² and 2.5mm², while leaving the insulation intact



Figure 13

➤ Automatic wire stripper- The automatic wire stripper is designed to remove insulation from a range of conductor sizes.



Figure 14

➤ Hack saw- It is used to cut the larger size cables, cut mini trunking and cut out openings in surface boxes for cable entry.



➤ Electrician's knife- Electrician's penknife is mainly used to remove the sheath from the various types of cables and flexible cords.

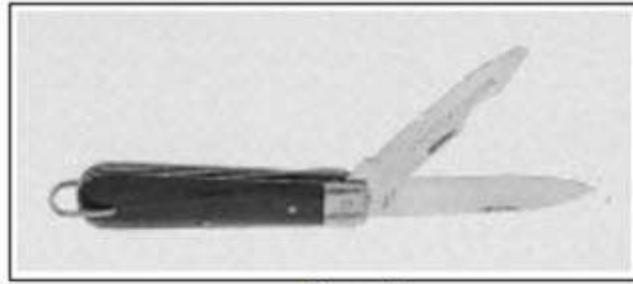


Figure 17

➤ Phase tester -It is a very useful tool when checking if a circuit is “live” or not. This ensures safety of the electrician



Figure 22

1.2.6.1 Learning activities

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Practical activities

Field/Visit to an electrical Installation Sites

Visit Objective/Aim	Indicators	Special Instruction
To establish how to perform termination on electrical installation	Types of terminations Cable labelling Cable lugging Tools used in termination	<ul style="list-style-type: none"> • Observe keenly • Take notes • Ask questions

Industrial attachment

Visit Objective/Aim	Indicators	Special Instruction
To experience how to terminate electrical cables	<ul style="list-style-type: none"> • Demonstrate various methods of cable termination • Demonstrate methods of cable jointing • Use of various cable termination tools 	<ul style="list-style-type: none"> • Participate actively • Take notes • Ask questions

A case study

Carefully read the case study in the excerpt below and answer that follow

You are employed by ABC Company limited. The company which deals with electrical installation and consultancy. The company is required to install electrical power in a wheat grinding plant. The plant is powered by 3 phase 415V power to run grinding the machine. The company has assigned you responsibility to supervise installation process. Installation is complete and now you are required to terminate cables.

1. Explain how you would get 240V power from the 415V for lighting and socket outlets
2. Discuss various termination methods you will apply in the system
3. Give some considerations in selecting cable joints
4. Explain importance of termination in electrical installation
5. Names various tools and how they are applied in cable termination.

1.2.6.2 Tools, Equipment, Supplies and Materials

- Functional workshop
- Tools equipment used in electrical installation e.g.
 - ✓ Pliers
 - ✓ Cable strippers
 - ✓ Crimping tools
 - ✓ Materials e.g.
 - ✓ Cables
 - ✓ Trunking
 - ✓ Conduits
 - ✓ Enclosures

Supplies and consumables e.g.

- ✓ Cable ties
- ✓ Silicon glue

- ✓ Connectors
- ✓ Switches
- ✓ circuit breakers

Computer

Stationery

Classroom and classroom resources

1.2.6.3 Self-Assessment

1. What are the factors you will consider before selecting the method of termination suitable for various parts of the installation?
2. Give various types of the terminations you will apply for the installation
3. Explain importance of termination
4. What are the factors you will consider when selecting types of cable joints to apply during installation?
5. Give various types of cable joints
6. Explain importance of cable labeling in electrical installation
7. Explain some tools used for performing various types of terminations

1.2.6.4 References

1. Technical Description, electrical installations by World Skills
2. Measurements on electrical installations Metrel measuring and regulating manufacturer
3. Electrical wiring components
4. Measurement and instrumentation principles third edition by Alan S Moris

CHAPTER FOUR: TECHNICAL DRAWING

Unit of learning code: ENG/LG/MC/CC/04/5/A

Related Unit of Competency in Occupational Standard; Prepare and interpret technical drawings

Introduction to the unit of learning

Unit Description