Engineering Drawing

Lecture # 01

Introduction

Syllabus

1. Importance of engineering drawing; Drawing techniques
2. Manual drawing instruments and their uses – Drawing board; Mini-drafter; Set squares; Drawing instrument box; Scales; Protractor; French curves; Drawing papers; Drawing pencils; Eraser; Drawing pins/clips; Sand paper block; Duster.
3. Conventions - ISO and BIS; Layout of drawing sheets; Border lines; Title block; Folding of drawing sheets; Lines, lettering and dimensioning.
4. Scales – Plane, diagonal and vernier
5. Curves used in engineering practice:
6. Orthographic projection – Theory of projection

7. **Projection of points**
8. **Projection of straight lines**
9. **Projection of planes**
10. **Projection of solids**
11. **Auxiliary projections**
12. **Sections of solids**
13. **Development of surfaces**
14. **Intersections of solids**
15. **Isometric projections**

Books/references

1. Dhananjay A Jolhe, Engineering drawing, TMH, 2008
2. M.B. Shah and B.C. Rana, Engineering Drawing, Pearsonson, 2009.
3. N D Bhatt and V M Panchal, Engineering Drawing, 43rd edition, Charator Publishing House, 2001
4. T E French, C J Vierck and R J Foster, Graphic Science and Design, 4th edition, McGraw Hill, 1984
5. W J Luzadder and J M Duff, Fundamentals of Engineering Drawing, 11th edition, Prentice-Hall of India, 1995.
6. K Venugpoal, Engineering Drawing and Graphics, 3nd edition, New Age International, 1998.

Note to the students

1. **Practical assignments are to be completed in the Drawing Hall during the respective practice period itself.**
2. **No make-up class for the completion of the incomplete assignments.**
3. **Only one make-up class for a missed class, that too only under medical ground. Students having attendance (lecture + tutorial) less than 75%, or for both lecture and tutorial independently will be debarred from appearing in the end semester examination.**
4. **No entry to the lecture hall 5 minutes after the start of the class.**

ENGINEERING DRAWING

Graphical means of expression of technical details without the barrier of a language.

Universal language for Engineers

What will you learn from this course?

How to communicate technical information.

- **Visualization – the ability to mentally understand visual information.**
- **Graphics theory – geometry and projection techniques used for preparation of drawings.**
- **Standards – set of rules for preparation of technical drawings. Conventions – commonly accepted practices in technical drawings.**
- **Tools – devices used to create technical drawings and models.**
- **Applications – the various uses for technical drawings.**

Graphic language: **mode of communication through <u>SKETCHES</u>**

Drawing: **graphical representation of an <u>OBJECT</u>**

<u>Engineering Drawing</u>

Drawing of an object contains all the necessary information, required for the construction/fabrication of the object, like

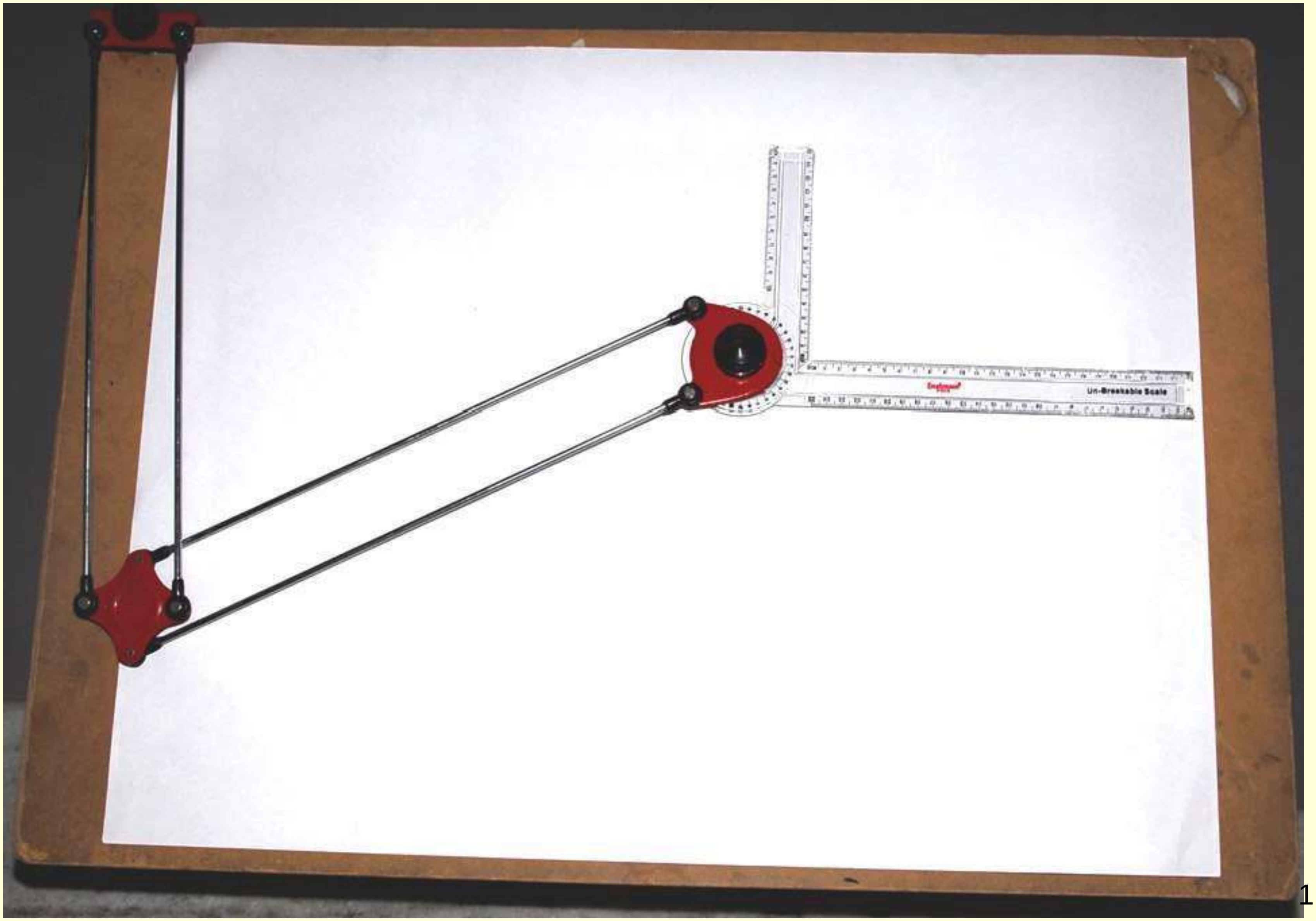
- **actual shape,**
- **accurate sizes,**
- **manufacturing methods,**
- **materials to be used etc.,**

List of tools required for the drawing practice session

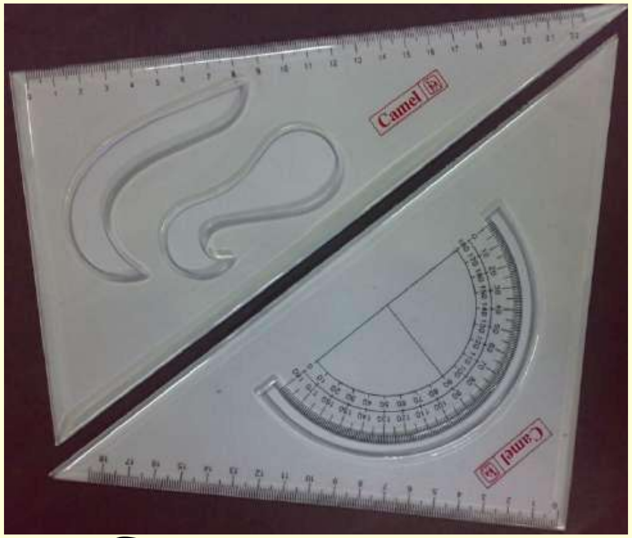
Sl. No.	Item	Quantity
1	Mini-drafter (or T-Square)	1
2	Engineering Drawing Box	1
3	French curves	1 set
4	Set-square	1 set
5	Protractor	1
6	Drawing Clip	1 set
7	Lead pencil/clutch pencil	2-3
8	Lead (HB, H & 2H)	1 each set
9	Eraser	1
10	Sand paper/cello tape	1
11	Blade / pencil sharpener	1
12	Drawing Sheet	1 per session

- **Students without Engineering Drawing Box will not be allowed to attend the practical session.**
- **School Instrument box is not allowed.**

Mini-drafter

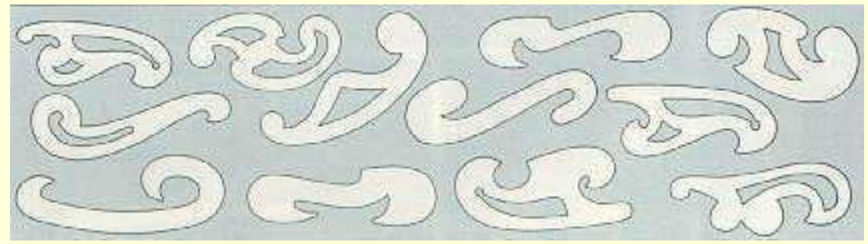


Mini-drafter fixed on a drawing table

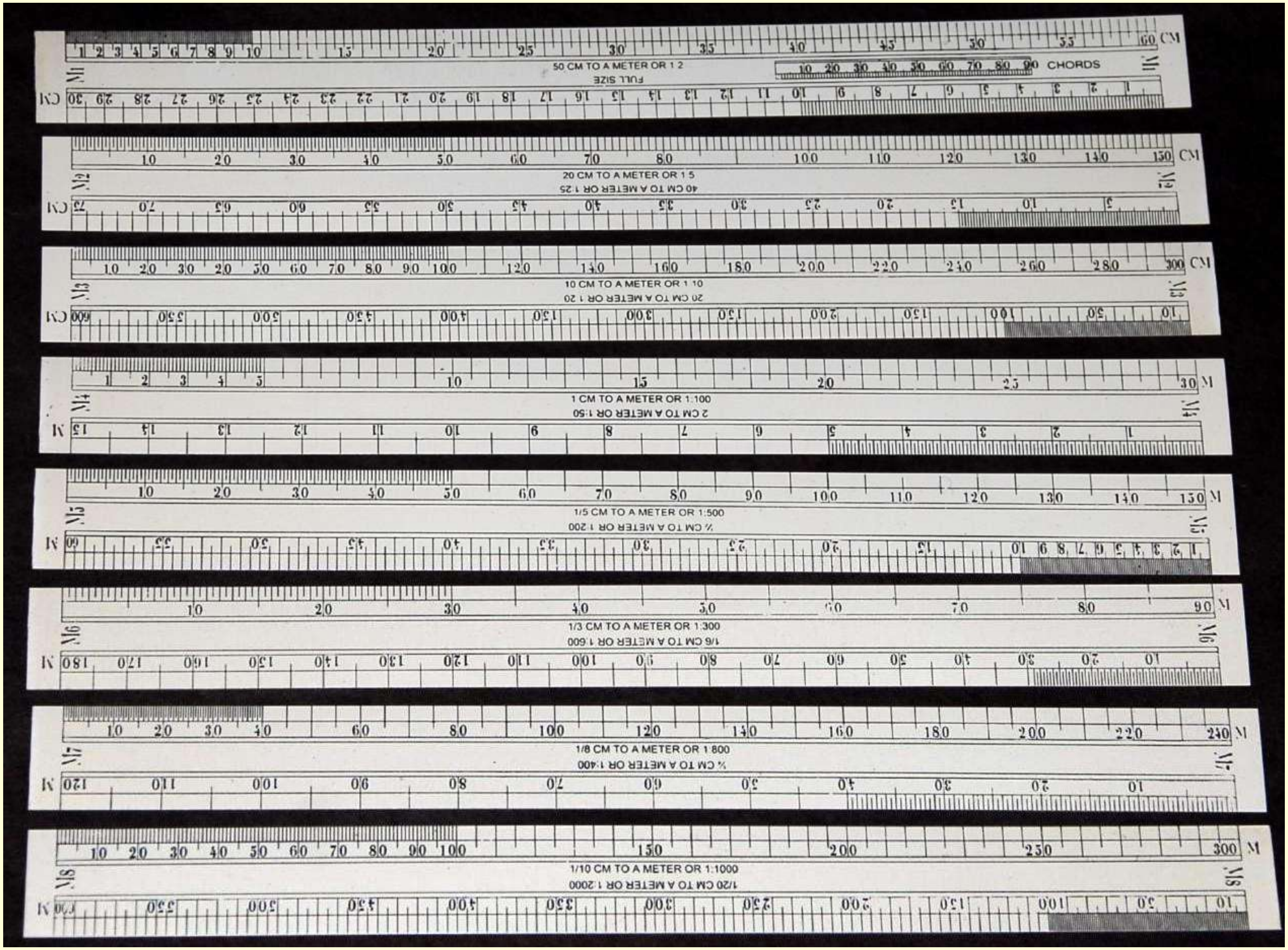


Set-square

Drawing Clips



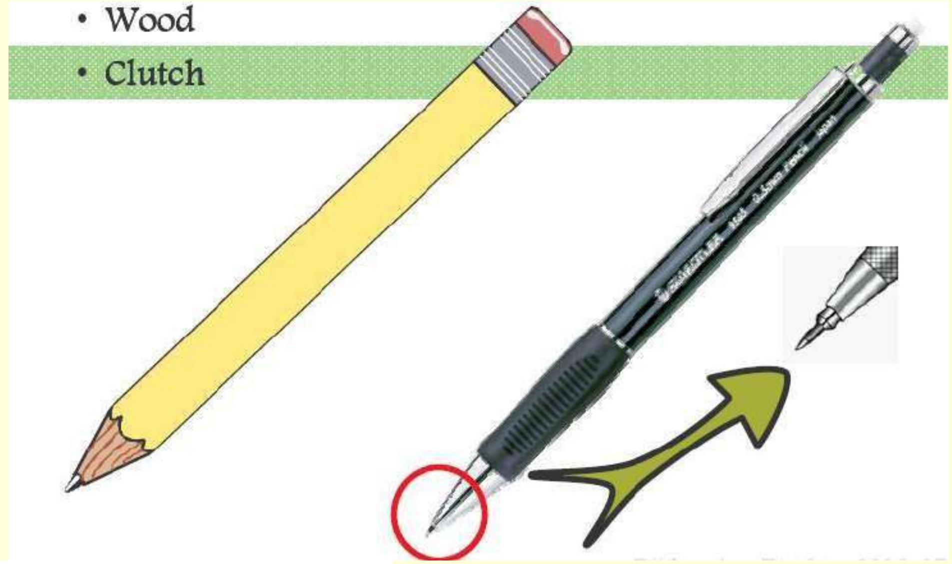
French Curves


50 CM TO A METER OR 1:2
CHORDS
20 CM TO A METER OR 1:5
10 CM TO A METER OR 1:10
1 CM TO A METER OR 1:100
1/5 CM TO A METER OR 1:500
1/3 CM TO A METER OR 1:300
1/8 CM TO A METER OR 1:800
1/10 CM TO A METER OR 1:1000

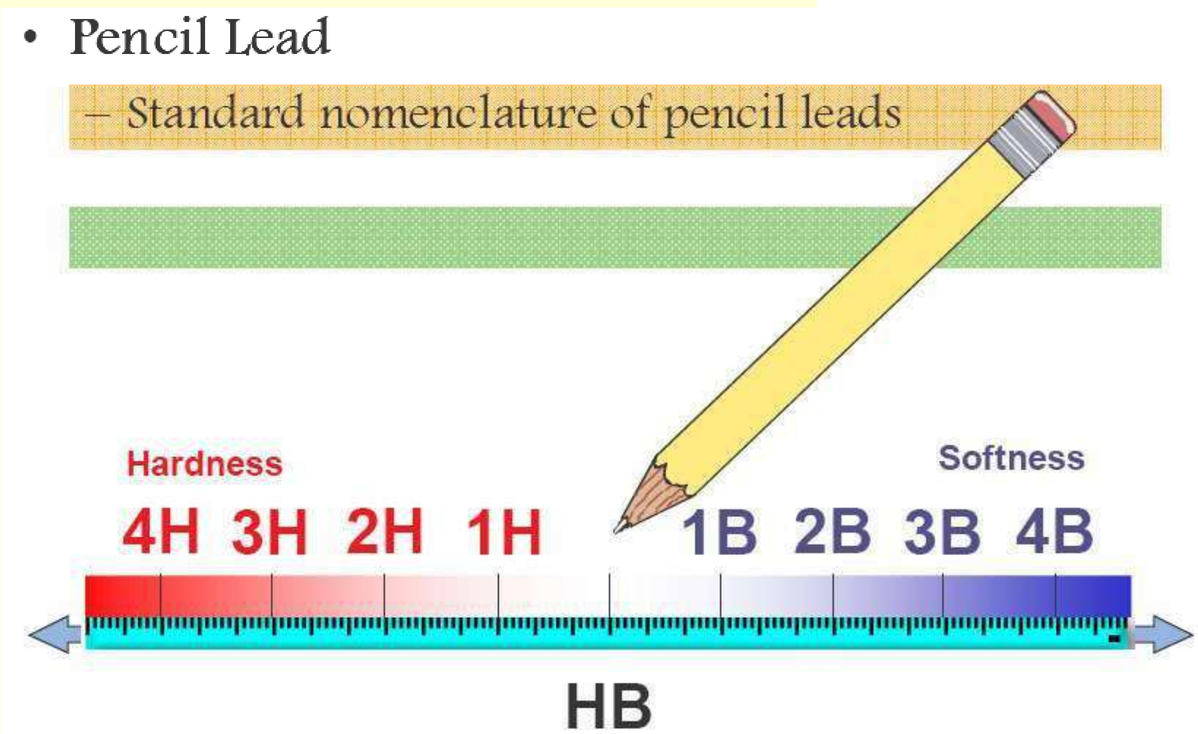
[Scale set]

Engineering Drawing Box

Pencils



• Wood
• Clutch



• Pencil Lead
– Standard nomenclature of pencil leads
Hardness
Softness
4H 3H 2H 1H
1B 2B 3B 4B
HB

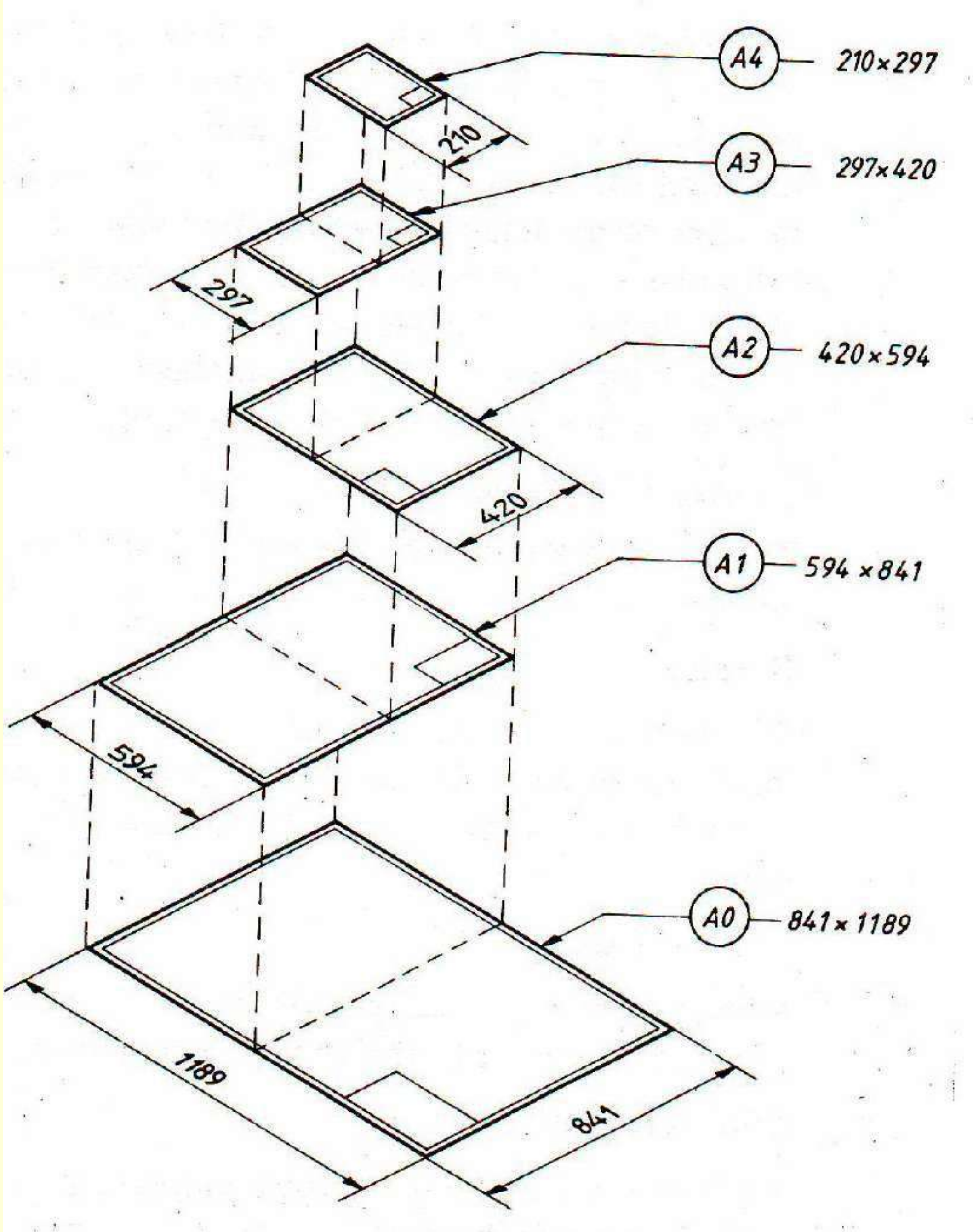
Dimensions of Engineer's Drawing Boards

Designation	Length x Width (mm)	Recommended for use with sheet sizes
D0	1500 x 1000	A0
D1	1000 x 700	A1
D2	700 x 500	A2
D3	500 x 500	A3

D0 and D1 for drawing offices, for students use – D2

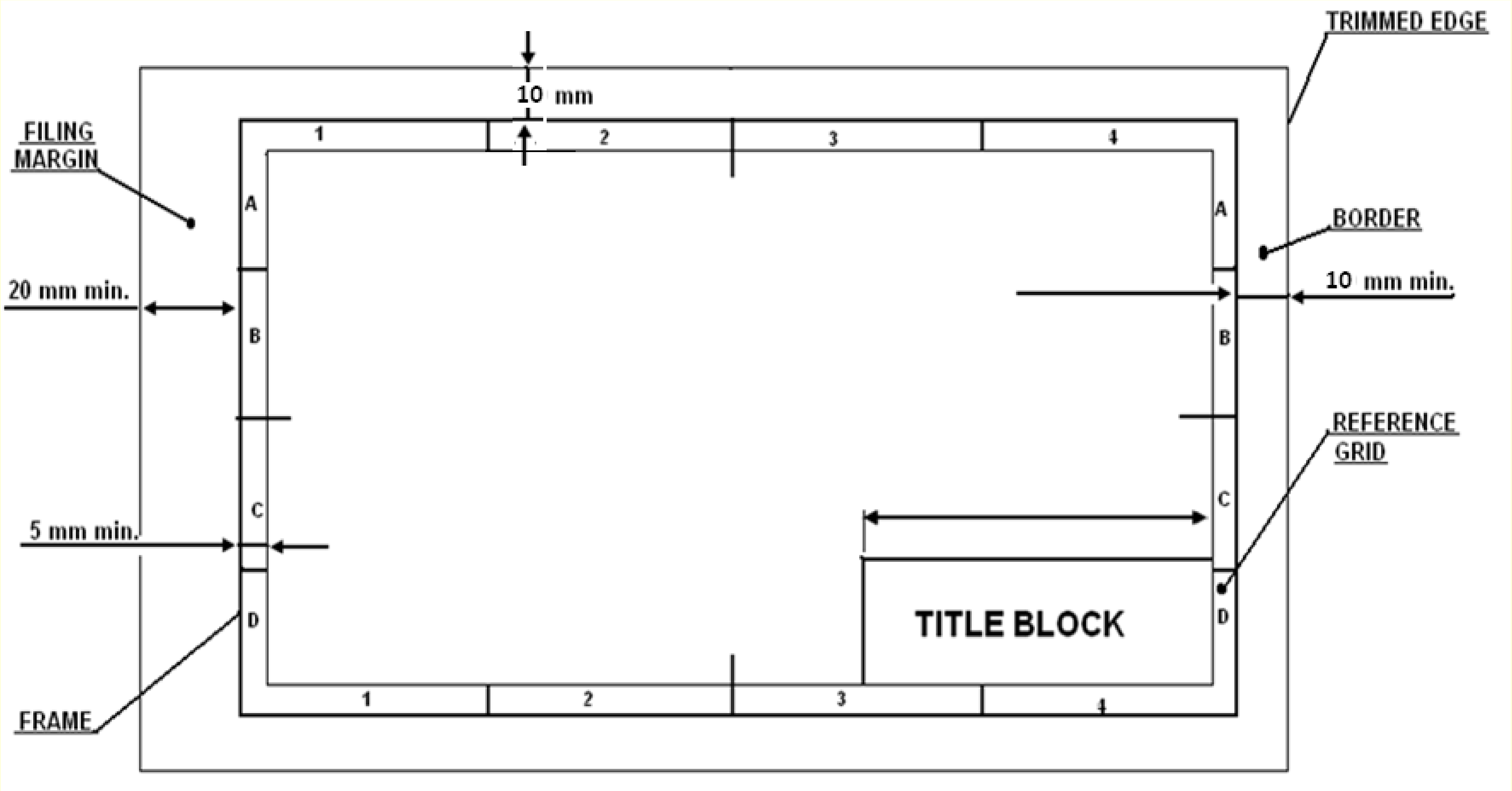
Standard sizes of drawing sheets as per BIS

Designation	Size (mm)
A0	841 x 1189
A1	594 x 841
A2	420 x 594
A3	297 x 420
A4	210 x 297



Drawing Sheet Sizes

Drawing sheet Layout



TITLE BOX PRACTICE

LINES AND LETTERING*

LINES

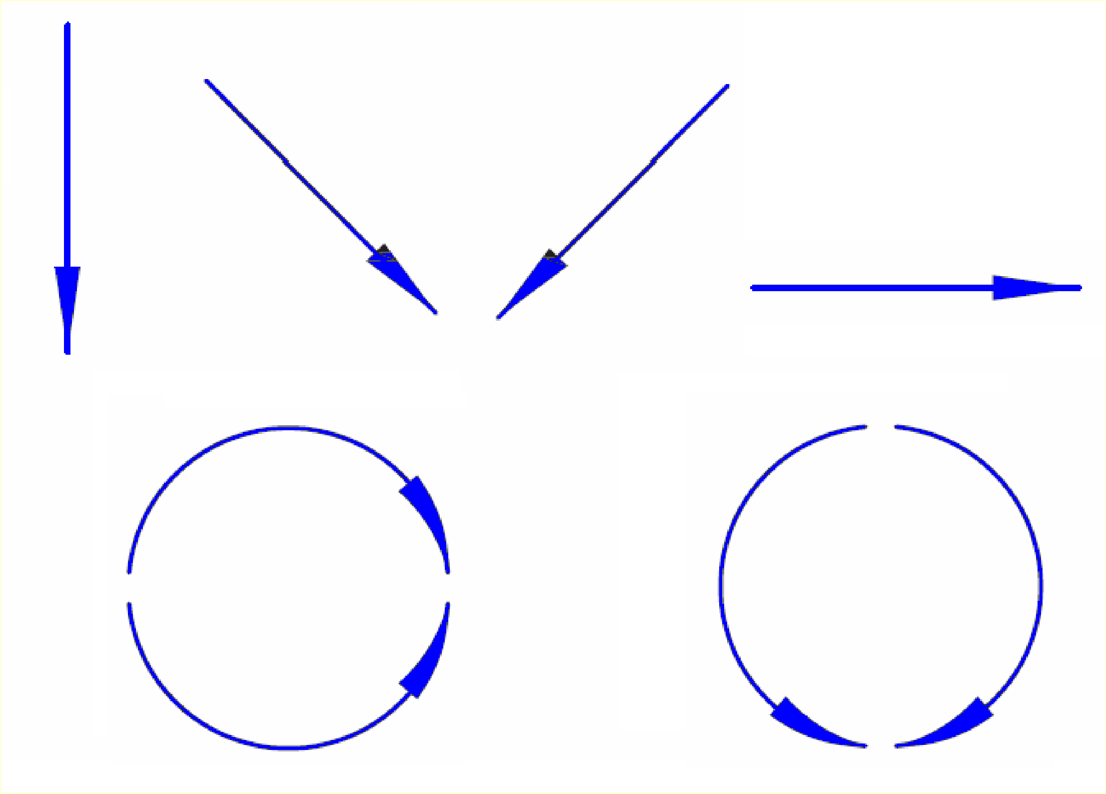
Lines are the basic feature of a drawing. A line may be straight, curved, continuous, segmented, thin, thick, etc., each having its own specific sense.

Line strokes refer to the directions of drawing straight and curved lines

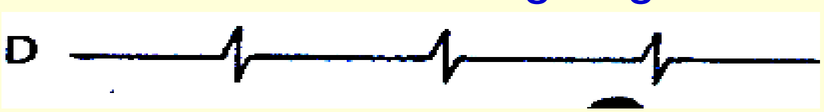
*standard given in BIS : SP-46, 2003

Line Strokes

Vertical and inclined lines are drawn from top to bottom, horizontal lines are drawn from left to right. Curved lines are drawn from left to right or top to bottom.



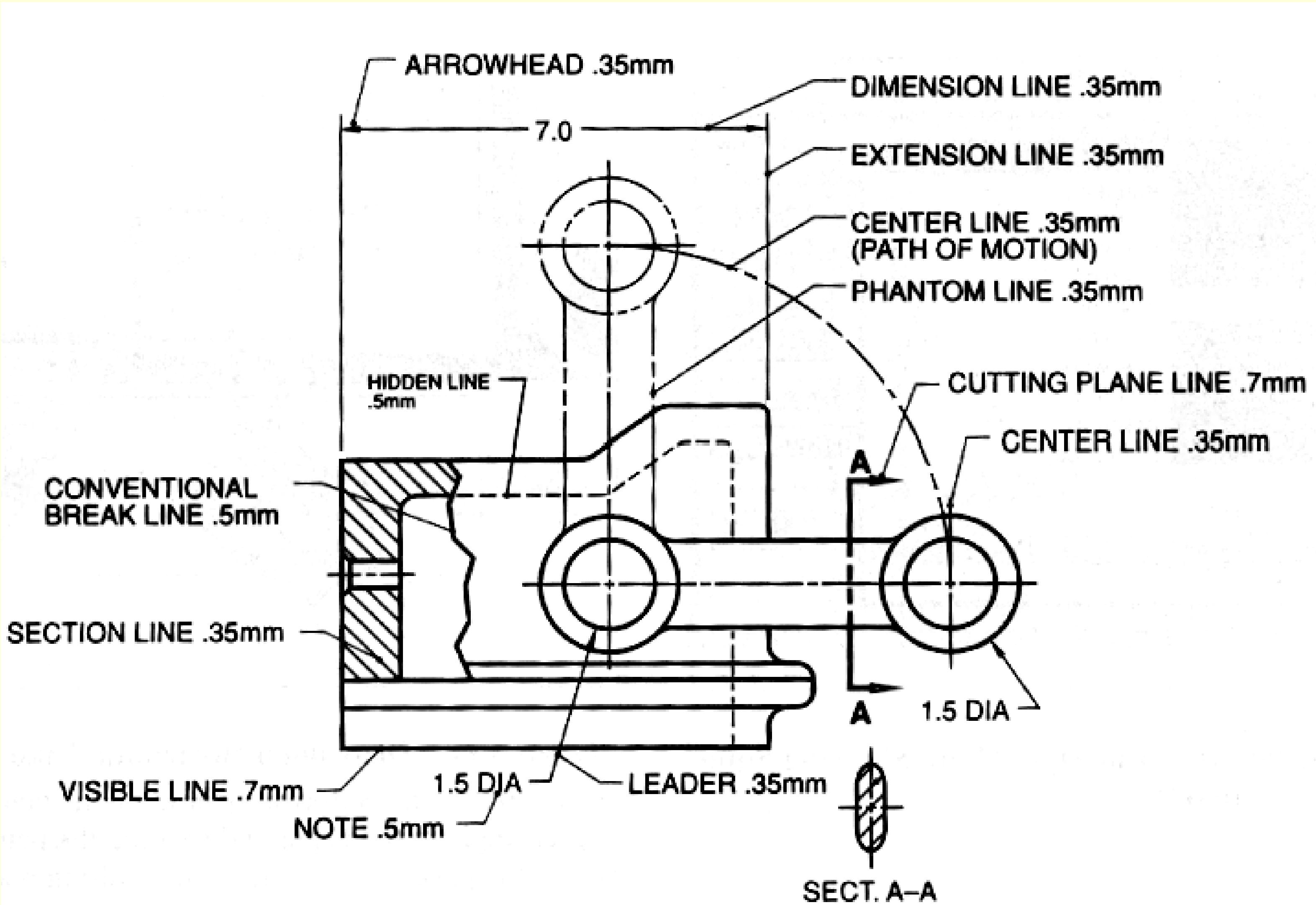
Line types

Illustration	Application
Thick	**Outlines, visible edges, surface boundaries of objects, margin lines**
Continuous thin	**Dimension lines, extension lines, section lines leader or pointer lines, construction lines, boarder lines**
Continuous thin wavy	**Short break lines or irregular boundary lines – drawn freehand**
Continuous thin with zig-zag 	**Long break lines**
Short dashes, gap 1, length 3 mm	**Invisible or interior surfaces**

Line types

Illustration	Application
Short dashes	**Center lines, locus lines** **Alternate long and short dashes in a proportion of 6:1,**
Long chain thick at end and	**Cutting plane lines**
Continuous thick border line	**Border**

Uses of different types of lines in a given drawing



Units of Measurement

- International systems of units (SI) – which is based on the meter.
- Millimeter (mm) - The common SI unit of measure on engineering drawing.
- Individual identification of linear units is not required if all dimensions on a drawing are in the same unit (mm).
- The drawing shall however contain a note: ALL DIMENSIONS ARE IN MM. (Bottom left corner outside the title box)

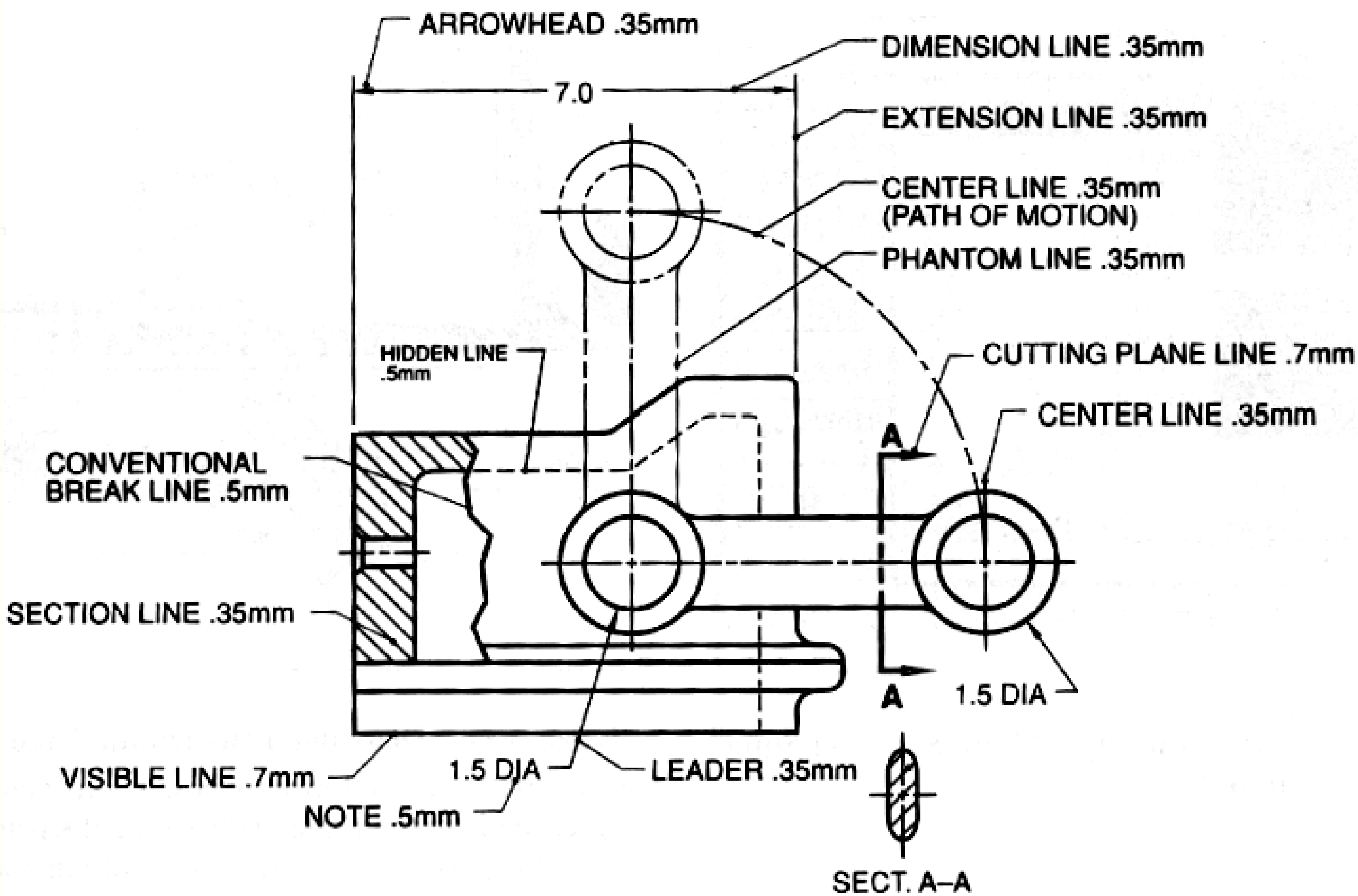
Dimensioning

- Indicating on a drawing, the size of the object and other details essential for its construction and function, using lines, numerals, symbols, notes, etc.

- Dimensions indicated on a drawing should be those that are essential for the production, inspection and functioning of the object.

- Dimensions indicated should not be mistaken as those that are required to make the drawing of an object.

An example



ARROWHEAD .35mm
7.0
DIMENSION LINE .35mm
EXTENSION LINE .35mm
CENTER LINE .35mm
(PATH OF MOTION)
PHANTOM LINE .35mm
HIDDEN LINE
.5mm
CUTTING PLANE LINE .7mm
CENTER LINE .35mm
CONVENTIONAL
BREAK LINE .5mm
A
SECTION LINE .35mm
A
1.5 DIA
VISIBLE LINE .7mm
1.5 DIA
LEADER .35mm
NOTE .5mm
SECT. A–A

- **Extension line** – a thin, solid line perpendicular to a dimension line, indicating which feature is associated with the dimension.

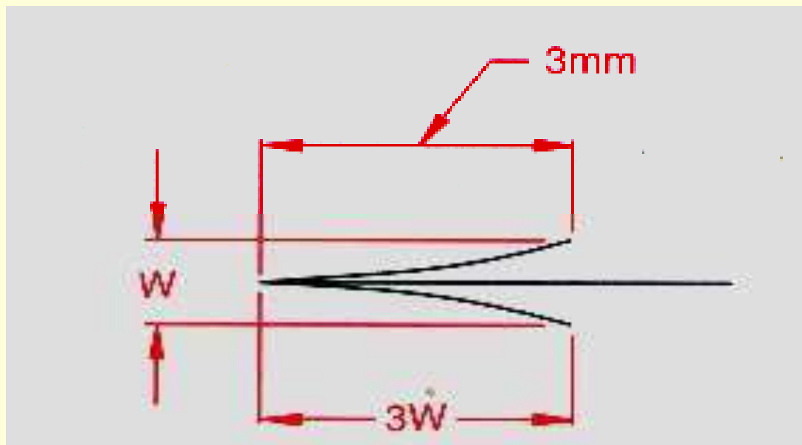
- **Visible gap** – there should be a visible gap of **1.5 mm** between the feature's corners and the end of the extension line.

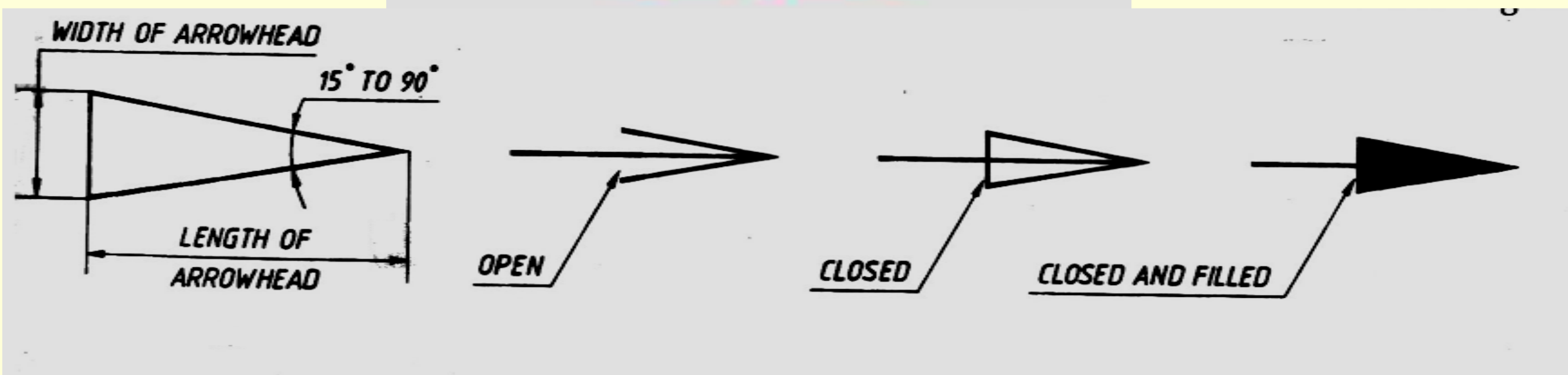
Leader line

- A thin, solid line used to indicate the feature with which a dimension, note, or symbol is associated.
- Generally a straight line drawn at an angle that is neither horizontal nor vertical.
- Terminated with an arrow touching the part or detail.
- On the end opposite the arrow, the leader line will have a short, horizontal shoulder. Text is extended from this shoulder such that the text height is centered with the shoulder line

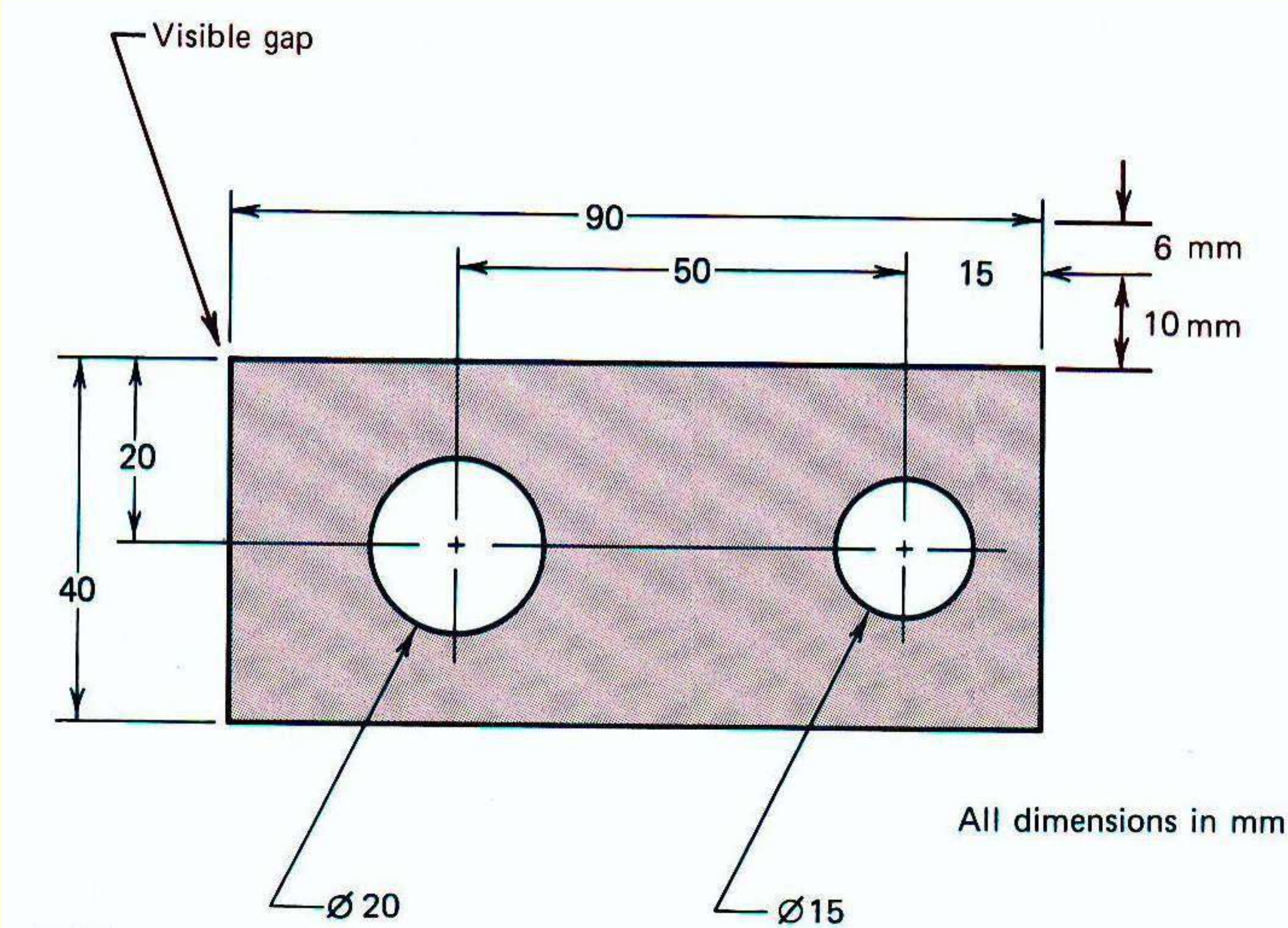
Arrows

3 mm wide and should be 1/3rd as wide as they are long - symbols placed at the end of dimension lines to show the limits of the dimension. Arrows are uniform in size and style, regardless of the size of the drawing.

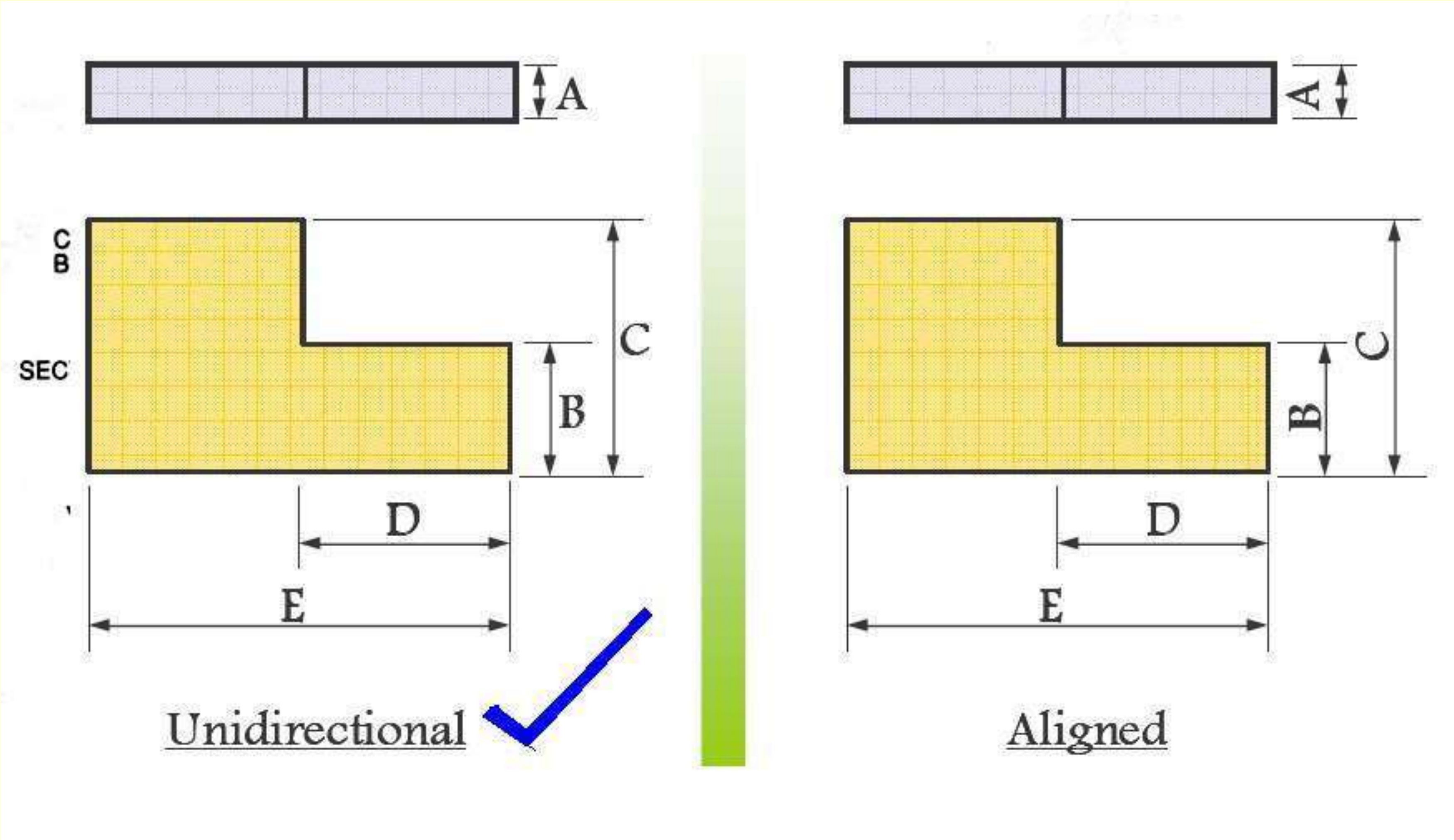




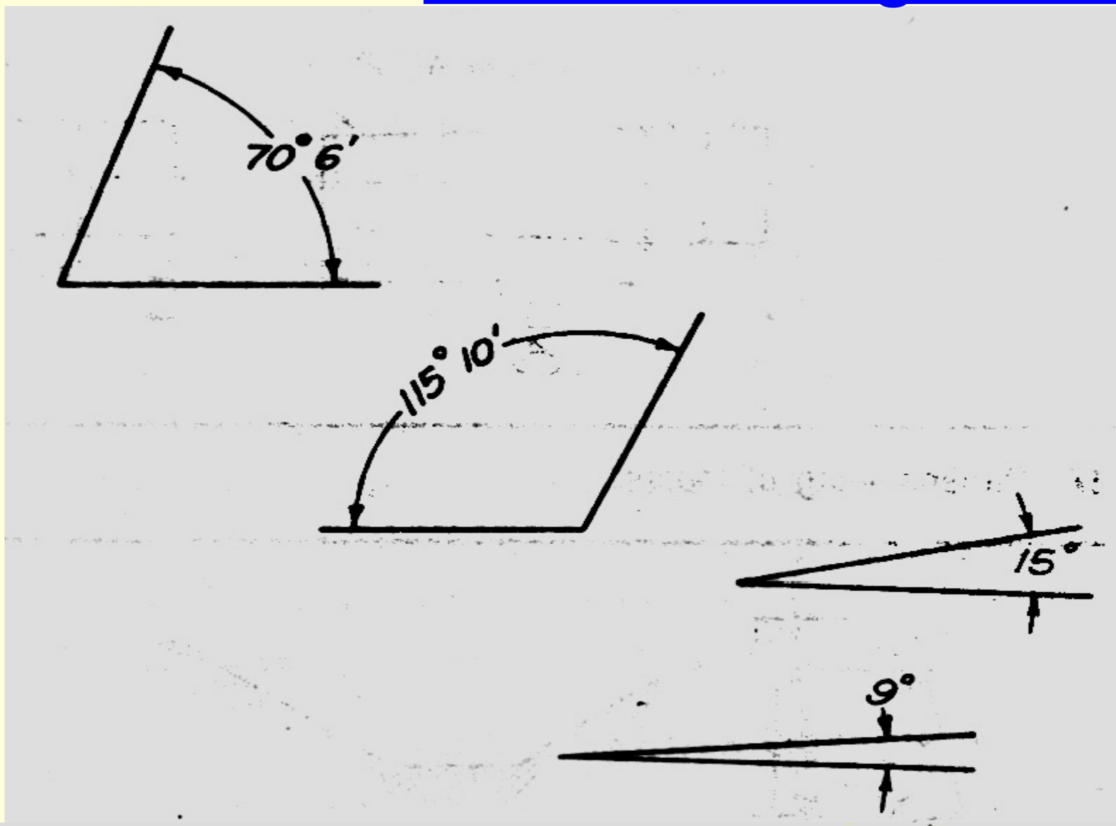
Spacing of Dimensions

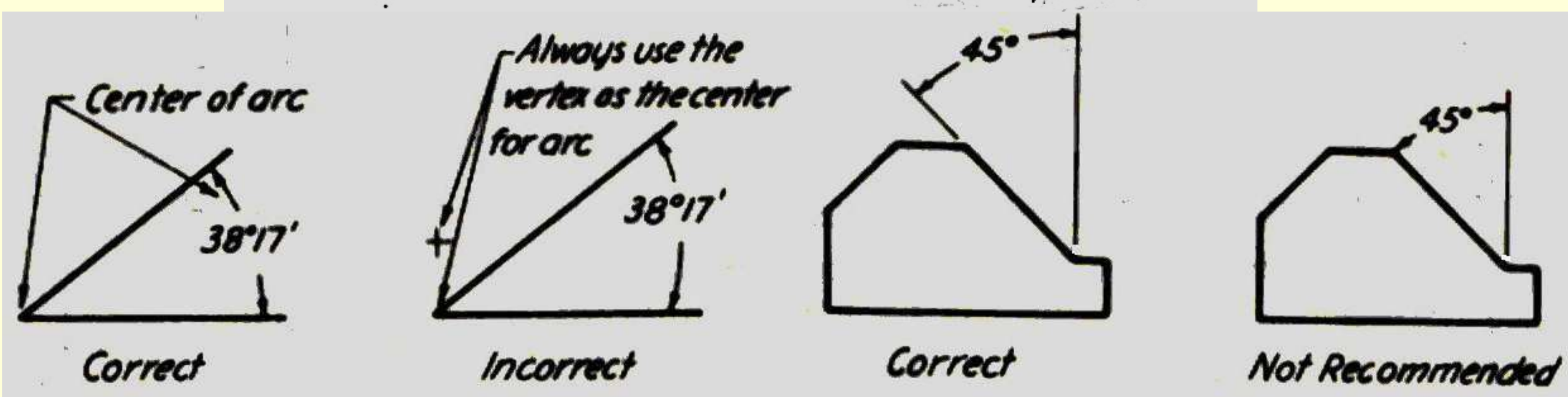


Placing of Dimensions



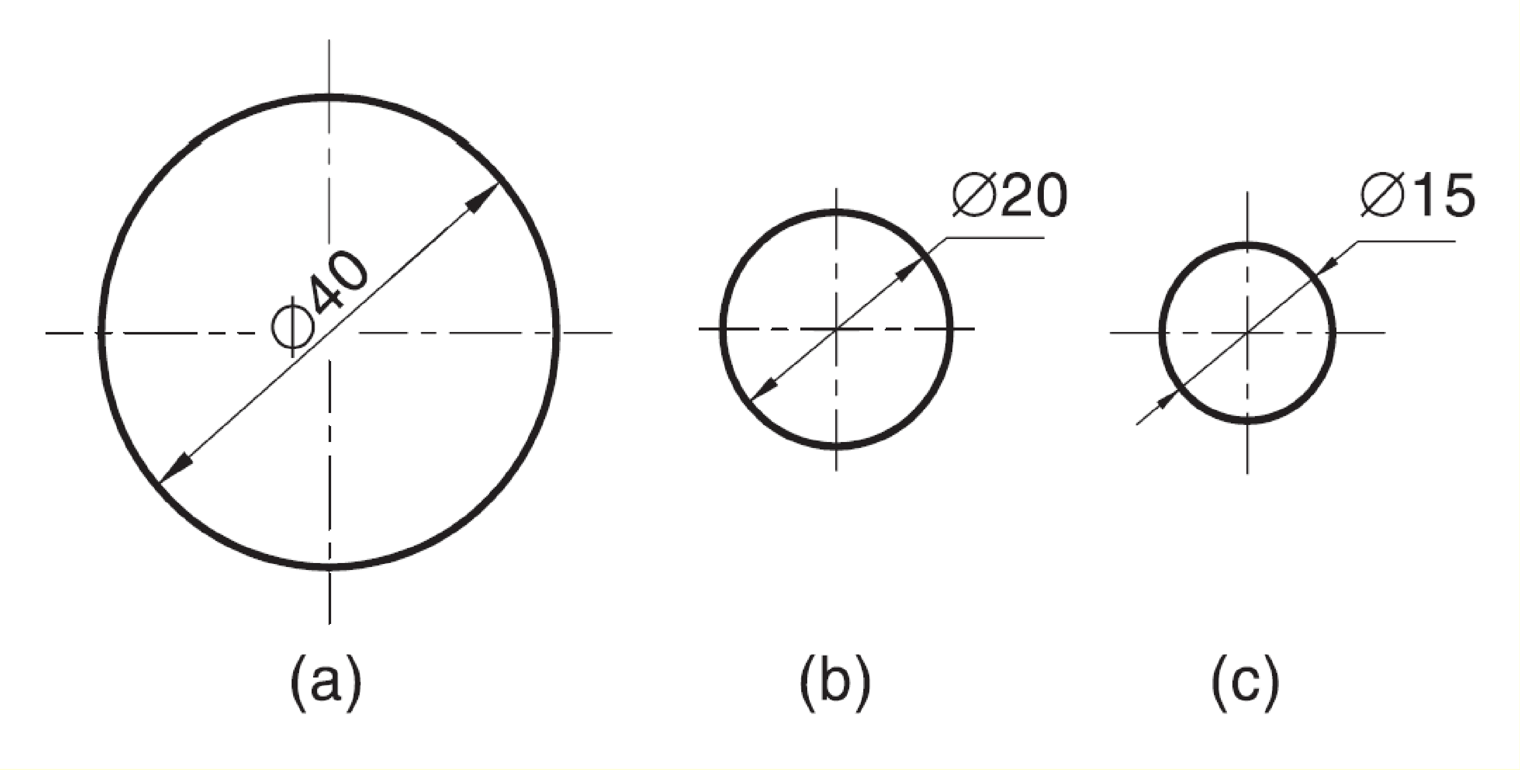
Dimensioning of angles





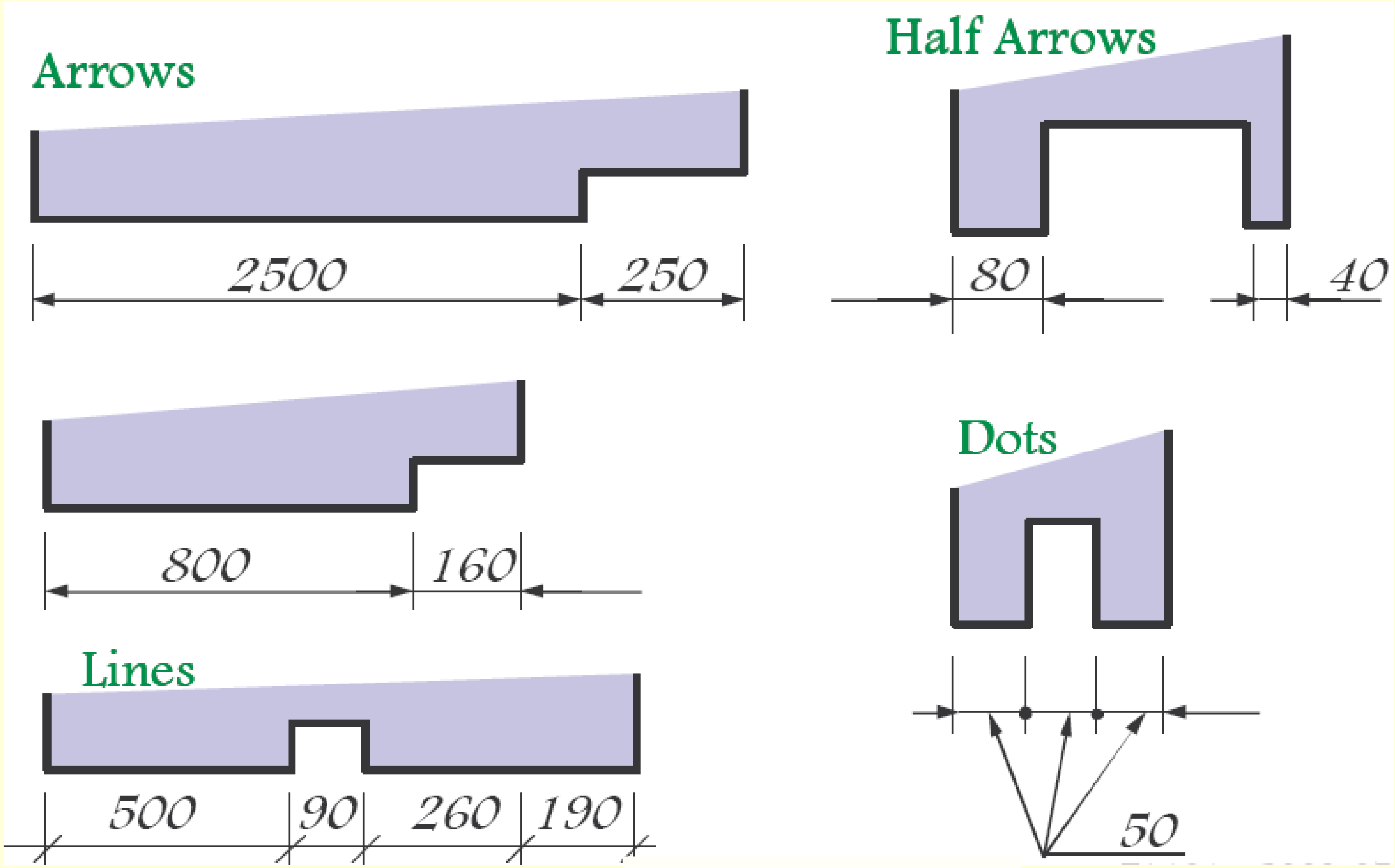
Dimensioning of Circular Features

A circle should be dimensioned by giving its diameter instead of radius. The dimension indicating a diameter should always be preceded by the symbol ø,



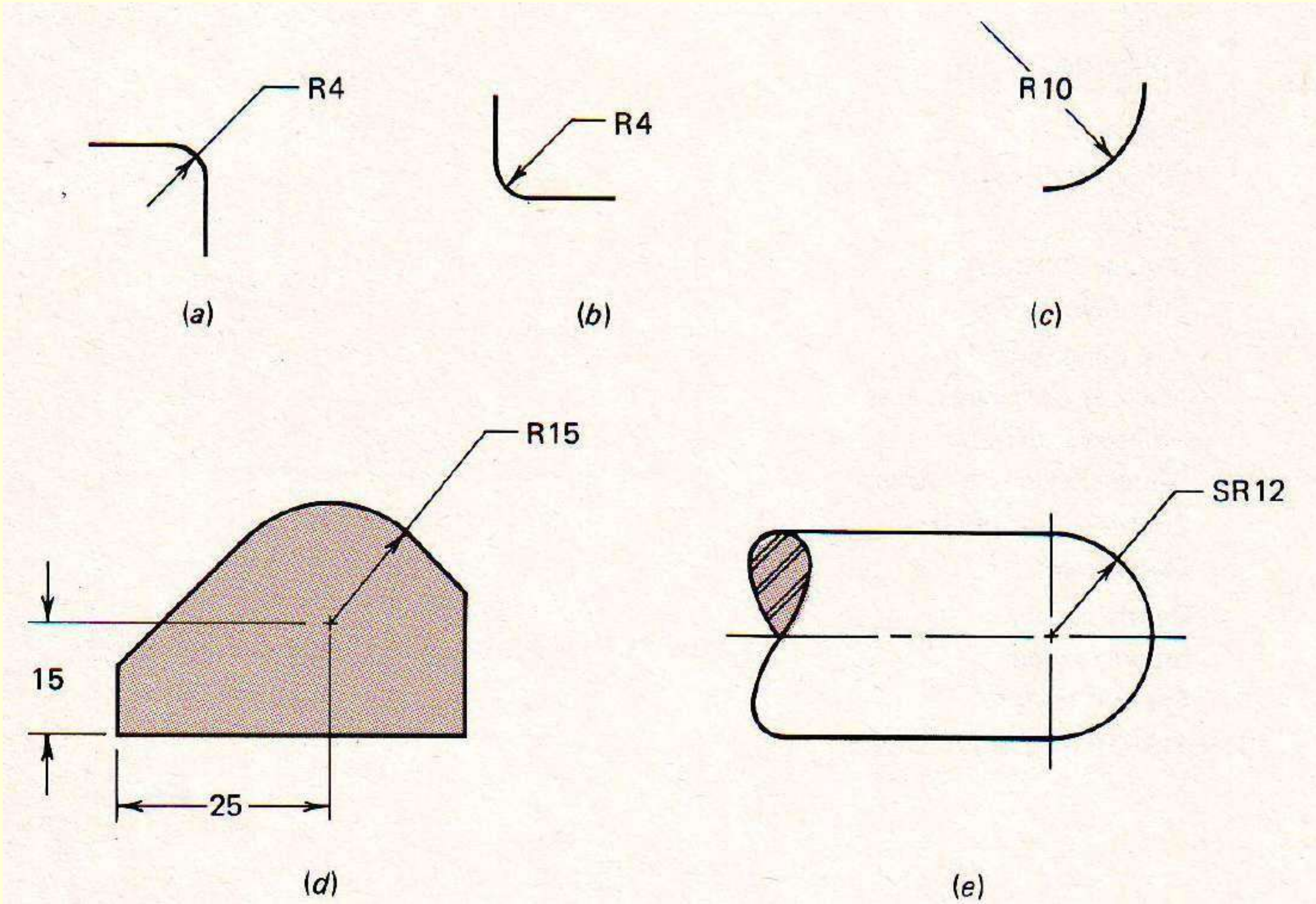
Dimensioning a Length

Depends on Available Space



Dimensioning Radii

Arcs of Circle Precede with 'R' to distinguish from length



RULES OF DIMENSIONING

1. Between any two extension lines, there must be one and only one dimension line bearing one dimension.
2. As far as possible, all the dimensions should be placed outside the views. Inside dimensions are preferred only if they are clearer and more easily readable.
3. All the dimensions on a drawing must be shown using either Aligned System or Unidirectional System. In no case should, the two systems be mixed on the same drawing.
4. The same unit of length should be used for all the dimensions on a drawing. The unit should not be written after each dimension, but a note mentioning the unit should be placed below the drawing.
5. Dimension lines should not cross each other. Dimension lines should also not cross any other lines of the object.
6. All dimensions must be given.
7. Each dimension should be given only once. No dimension should be redundant.

8. **Do not use an outline or a centre line as a dimension line. A centre line may be extended to serve as an extension line.**

9. **Avoid dimensioning hidden lines.**

10. **For dimensions in series, adopt any one of the following ways.**

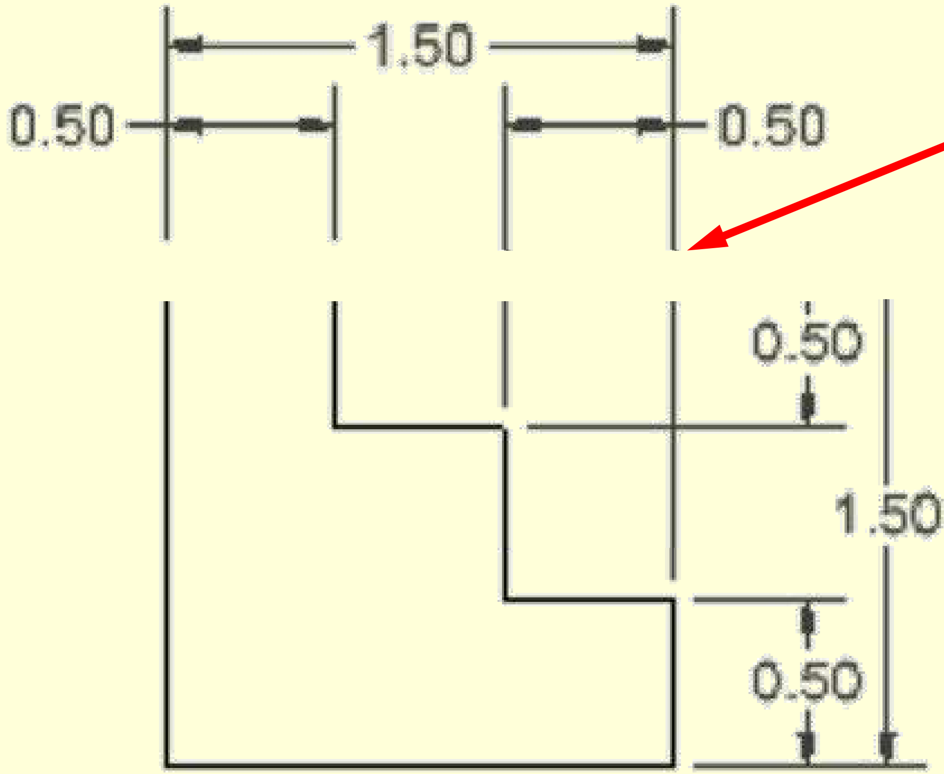
    i. **Chain dimensioning (Continuous dimensioning) All the dimensions are aligned in such a way that an arrowhead of one dimension touches tip-to-tip the arrowhead of the adjacent dimension. The overall dimension is placed outside the other smaller dimensions.**

    ii. **Parallel dimensioning (Progressive dimensioning) All the dimensions are shown from a common reference line. Obviously, all these dimensions share a common extension line. This method is adopted when dimensions have to be established from a particular datum surface**

    iii. **Combined dimensioning When both the methods, i.e., chain dimensioning and parallel dimensioning are used on the same drawing, the method of dimensioning is called combined dimensioning.**

Dimensioning Guidelines

Avoid crossing extension lines



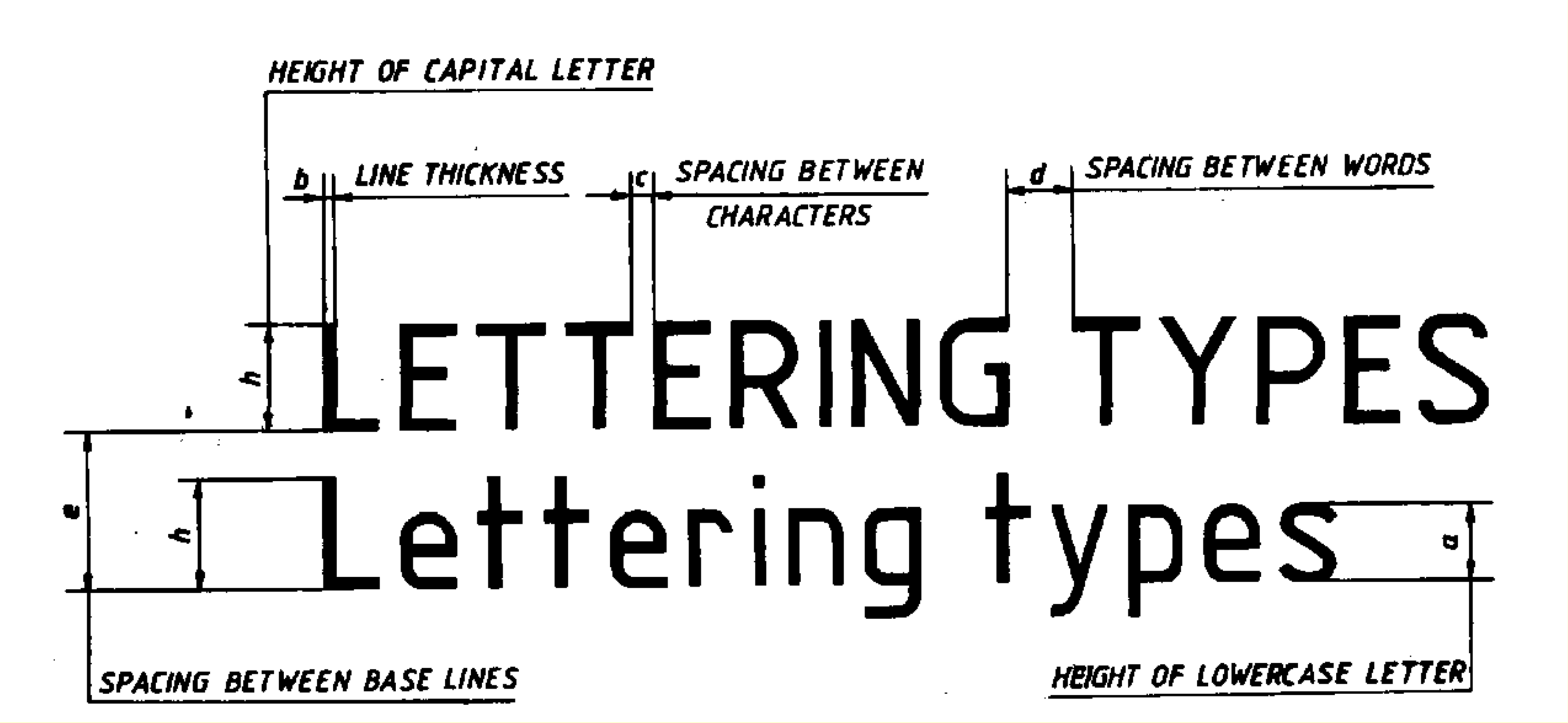
Multiple extension line crossings may be confused for the outside corner of the part.

•**Single stroke refers to the thickness obtained in one stroke of a pencil or ink pen .**

•**It does not mean that the pencil or pen should not be lifted while completing a particular letter.**

Lettering types

- **Lettering A – Height of the capital letter is divided into 14 equal parts**
- **Lettering B – Height of the capital letter is divided into 10 equal parts**



Specifications of A -Type Lettering

Specifications	Value	Size (mm)						
Capital letter height	**h**	**2.5**	**3.5**	**5**	**7**	**10**	**14**	**20**
Lowercase letter height	**a = (5/7)h**	**-**	**2.5**	**3.5**	**5**	**7**	**10**	**14**
Thickness of lines	**b = (1/14)h**	**0.18**	**0.25**	**0.35**	**0.5**	**0.7**	**1**	**1.4**
Spacing between characters	**c = (1/7)h**	**0.35**	**0.5**	**0.7**	**1**	**1.4**	**2**	**2.8**
Min. spacing b/n words	d = (3/7)h	1.05	1.5	2.1	3	4.2	6	8.4
Min. spacing b/n baselines	**e = (10/7)h**	**3.5**	**5**	**7**	**10**	**14**	**20**	**28**

Ratio of height to width varies, but in most cases is 6:5

THANK YOU

Engineering Drawing

Lecture 2

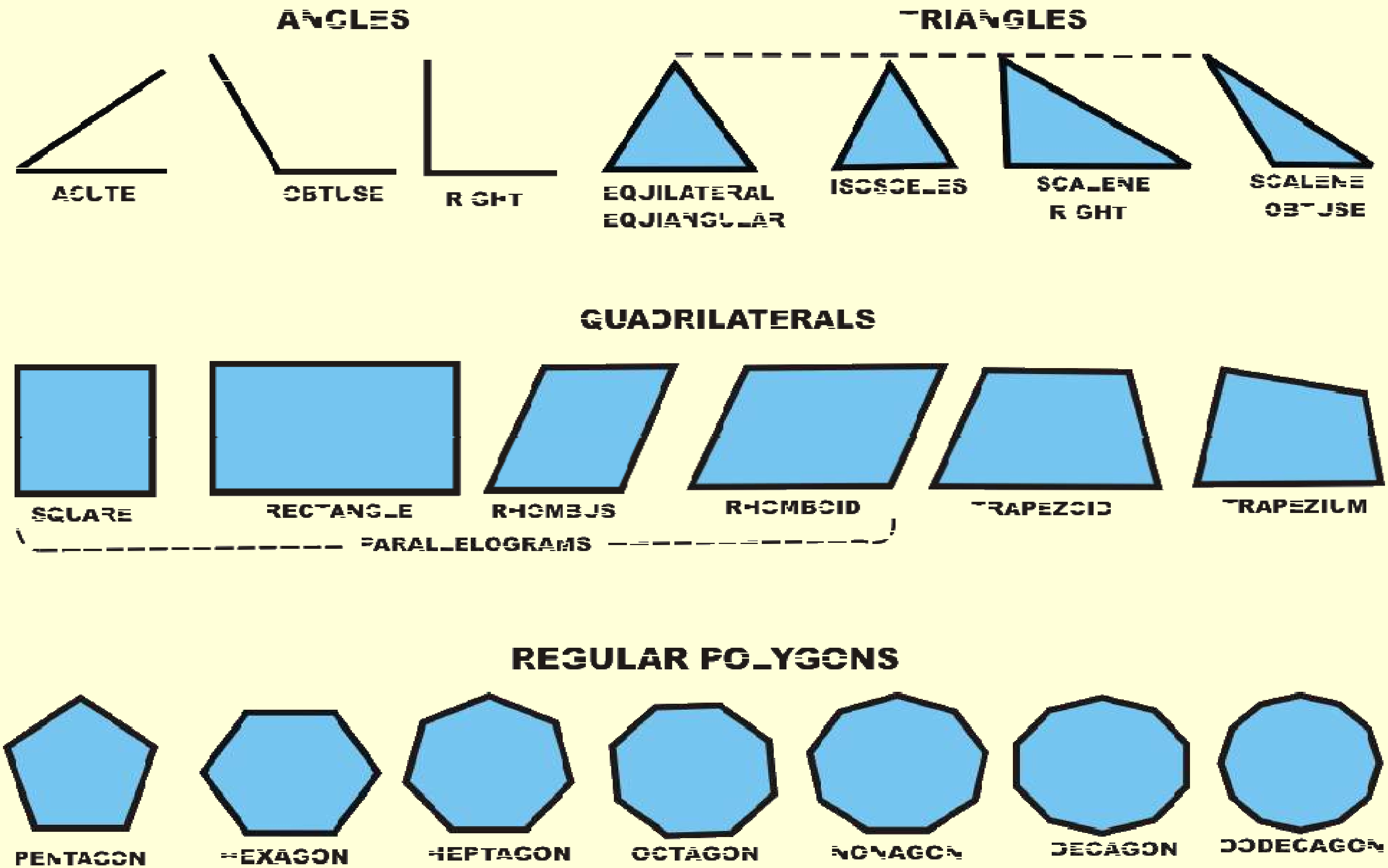
Geometric Constructions

Geometric Construction

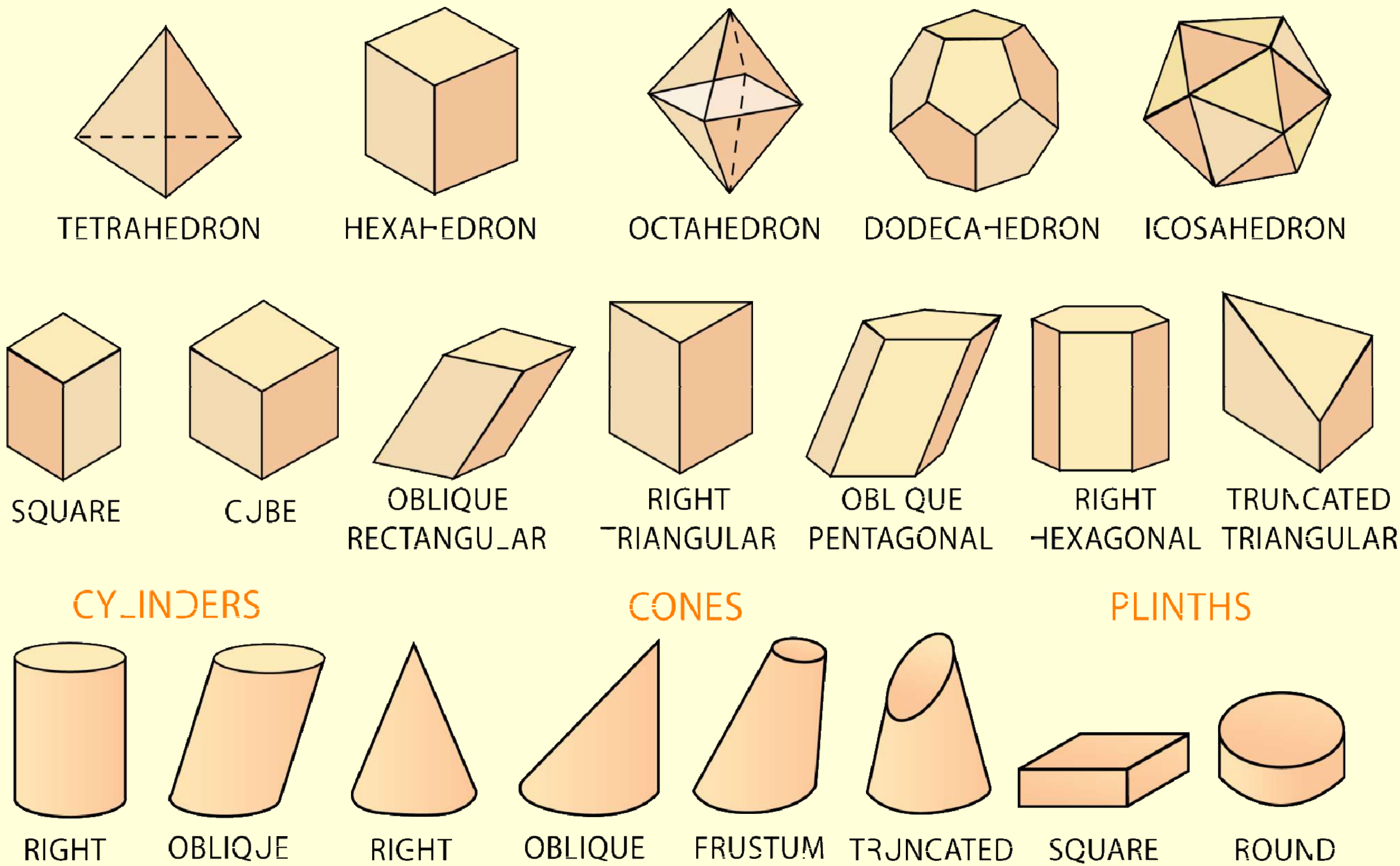
- **Construction of primitive geometric forms (points, lines and planes etc.) that serve as the building blocks for more complicated geometric shapes.**

- **Defining the position of the object in space**

Lines and Planes

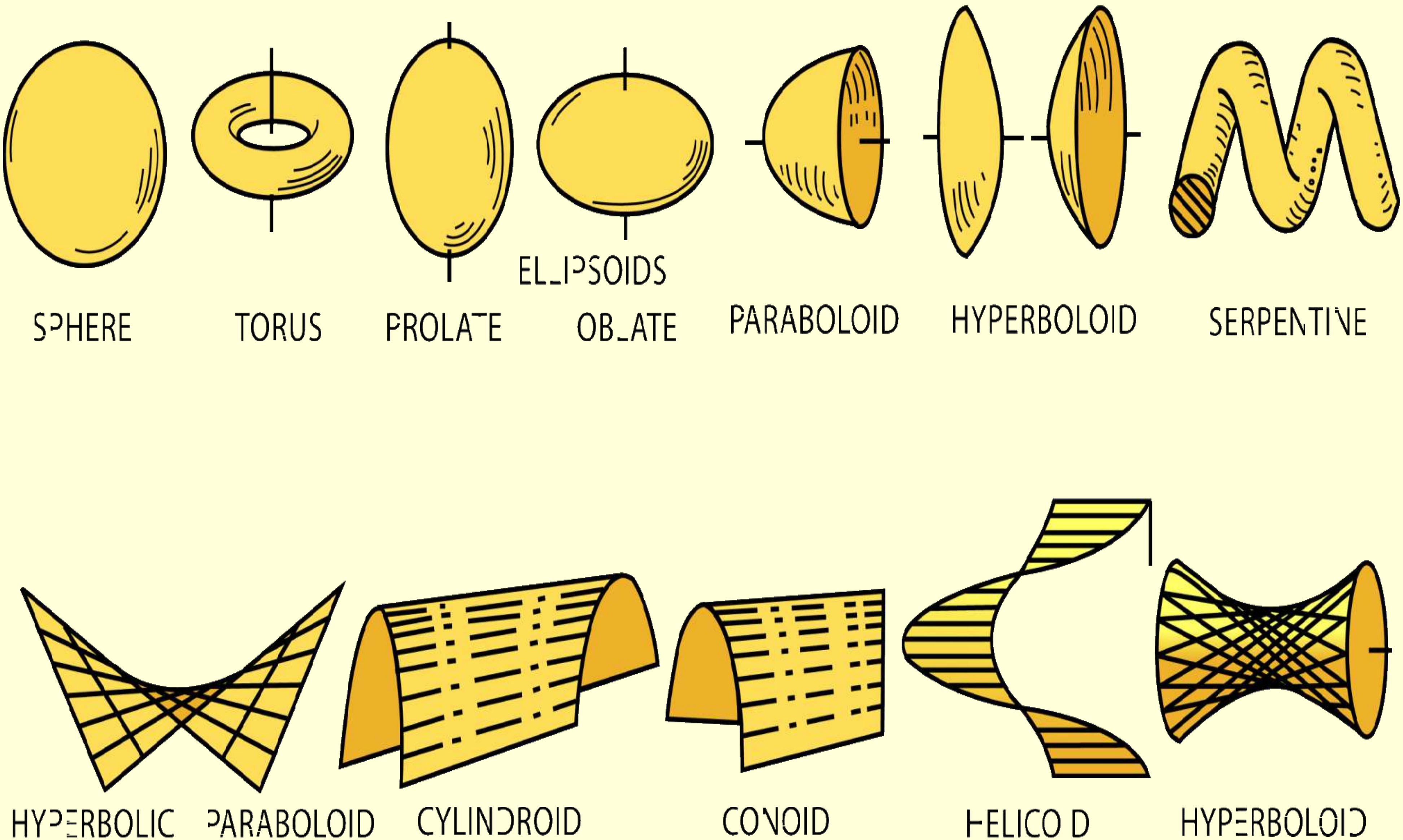


Solids



TETRAHEDRON
HEXAHEDRON
OCTAHEDRON
DODECAHEDRON
ICOSAHEDRON
SQUARE
CUBE
OBLIQUE RECTANGULAR
RIGHT TRIANGULAR
OBLIQUE PENTAGONAL
RIGHT HEXAGONAL
TRUNCATED TRIANGULAR
CYLINDERS
CONES
PLINTHS
RIGHT
OBLIQUE
RIGHT
OBLIQUE
FRUSTUM
TRUNCATED
SQUARE
ROUND

Curved surfaces



Primitive geometric forms

- Point
- Line
- Plane
- Solid
- …….etc

The basic 2-D geometric primitives, from which other more complex geometric forms are derived.

- **Points,**
- **Lines,**
- **Circles, and**
- **Arcs.**

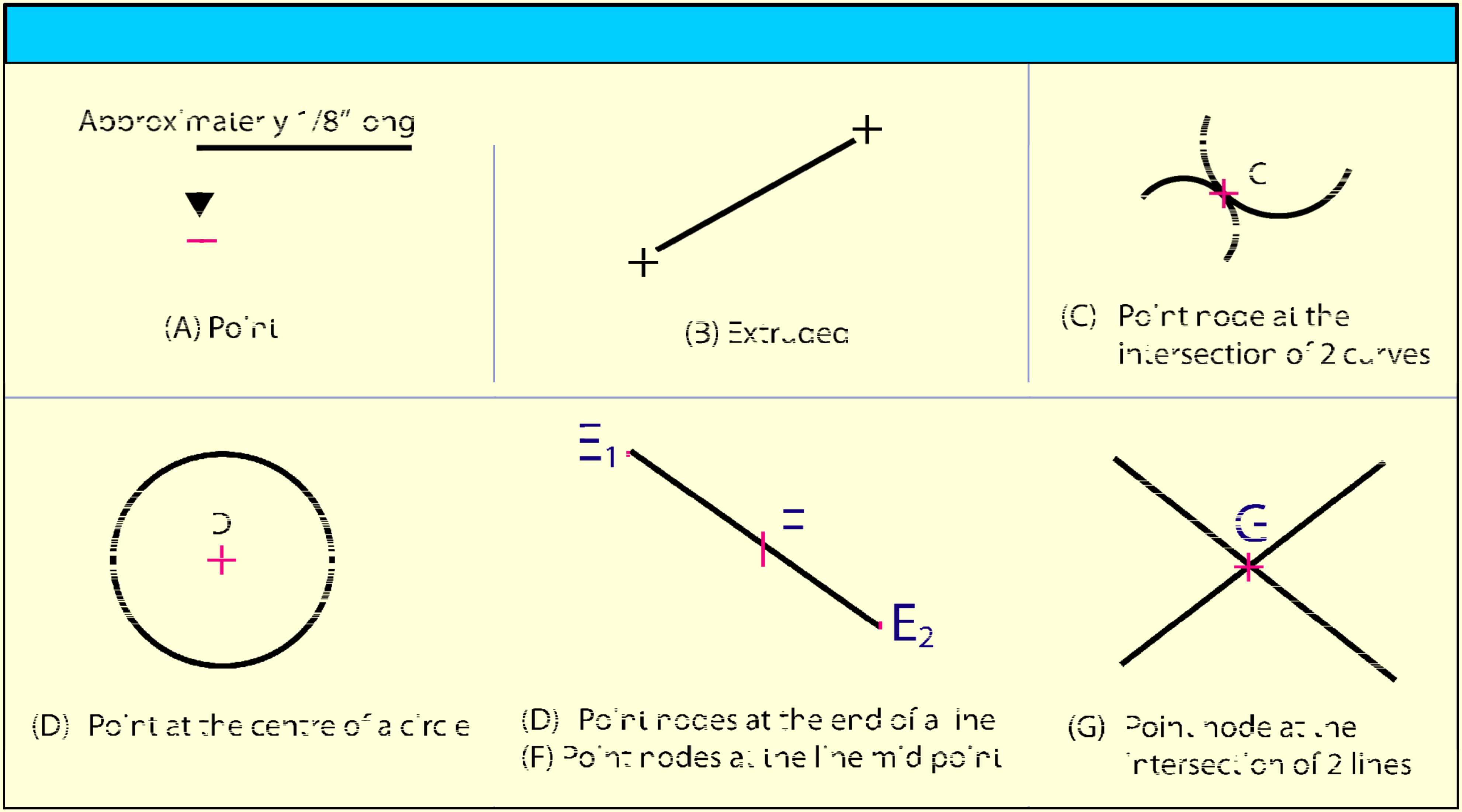
Point

- A theoretical location that has neither width, height, nor depth.

- Describes exact location in space.

- A point is represented in technical drawing as a *small cross* made of dashes that are approximately *3 mm long*.

A point is used to mark the locations of centers and loci, the intersection ends, middle of entities.

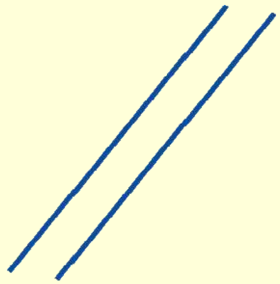


Line

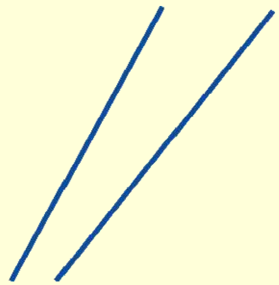
- A geometric primitive that has length and direction, but no thickness.
- It may be straight, curved or a combination of these.
-

  conditions, such as parallel, intersecting, and tangent.
- Lines – specific length and non-specific length.
- Ray – Straight line that extends to infinity from a specified point.

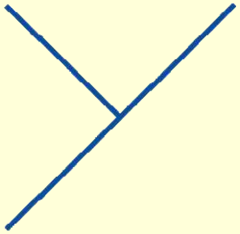
Relationship of one line to another line or arc



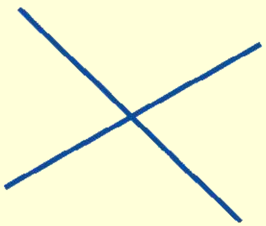
Parallel Line Condition



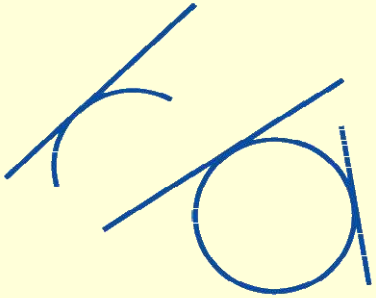
Nonparallel Line Condition



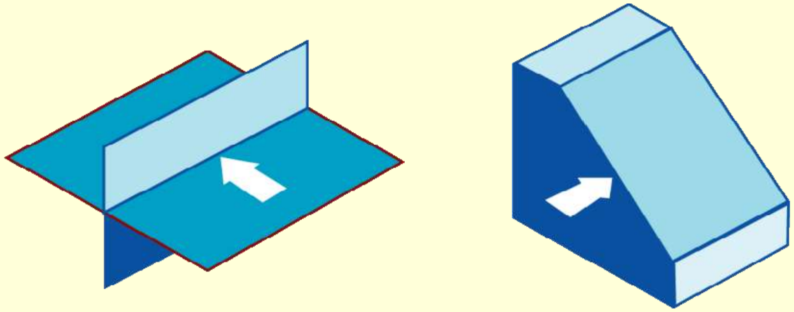
Perpendicular Line Condition



Intersecting Lines

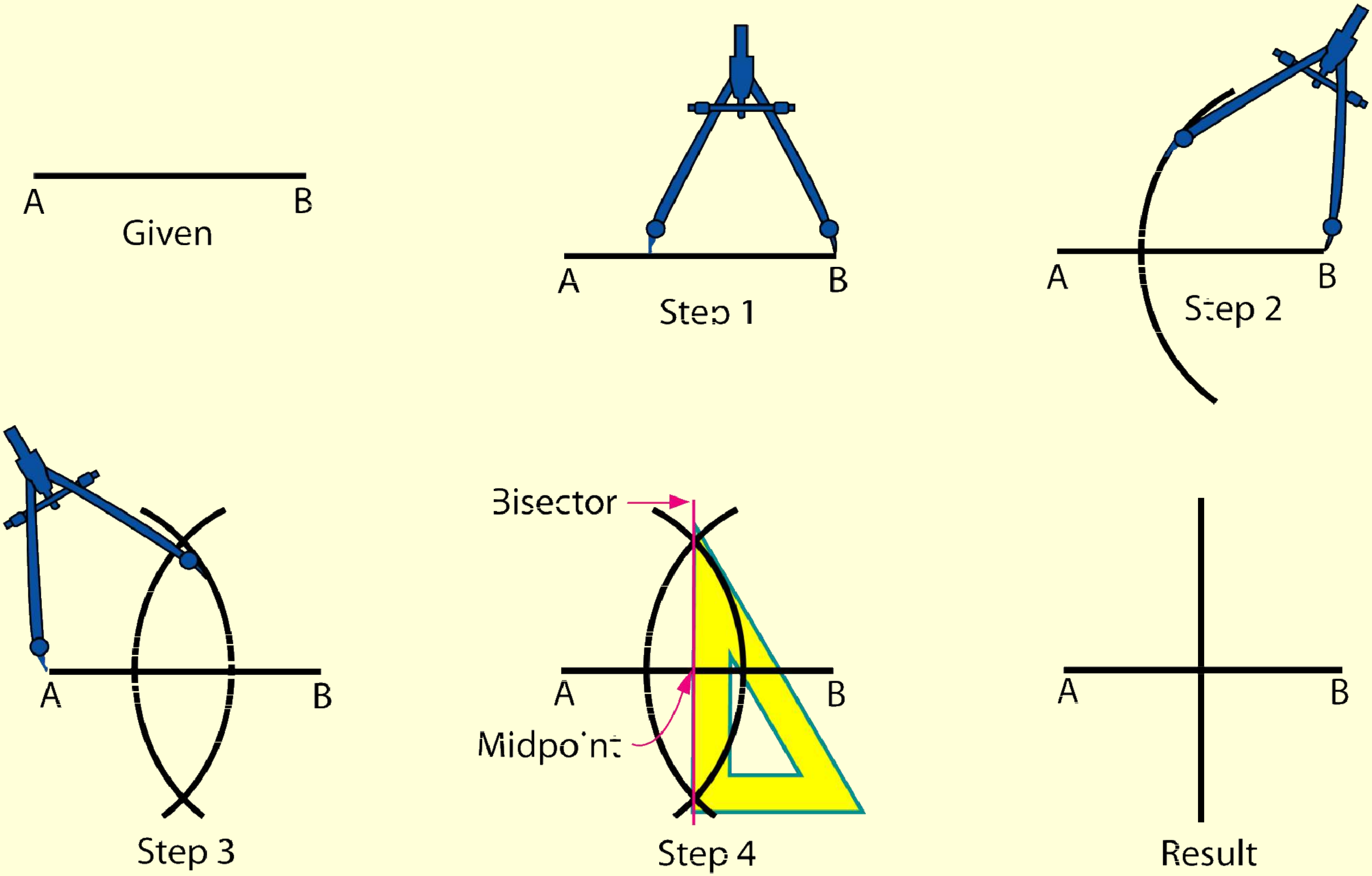


Tangent Condition

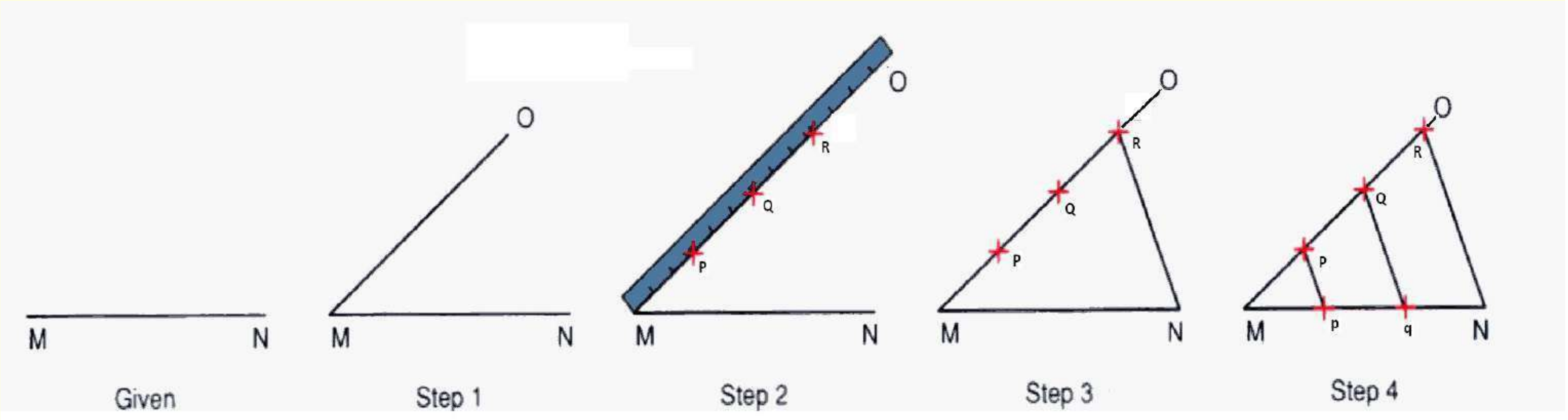


Line at the Intersection of Two Planes (Edge)

Bisecting a line

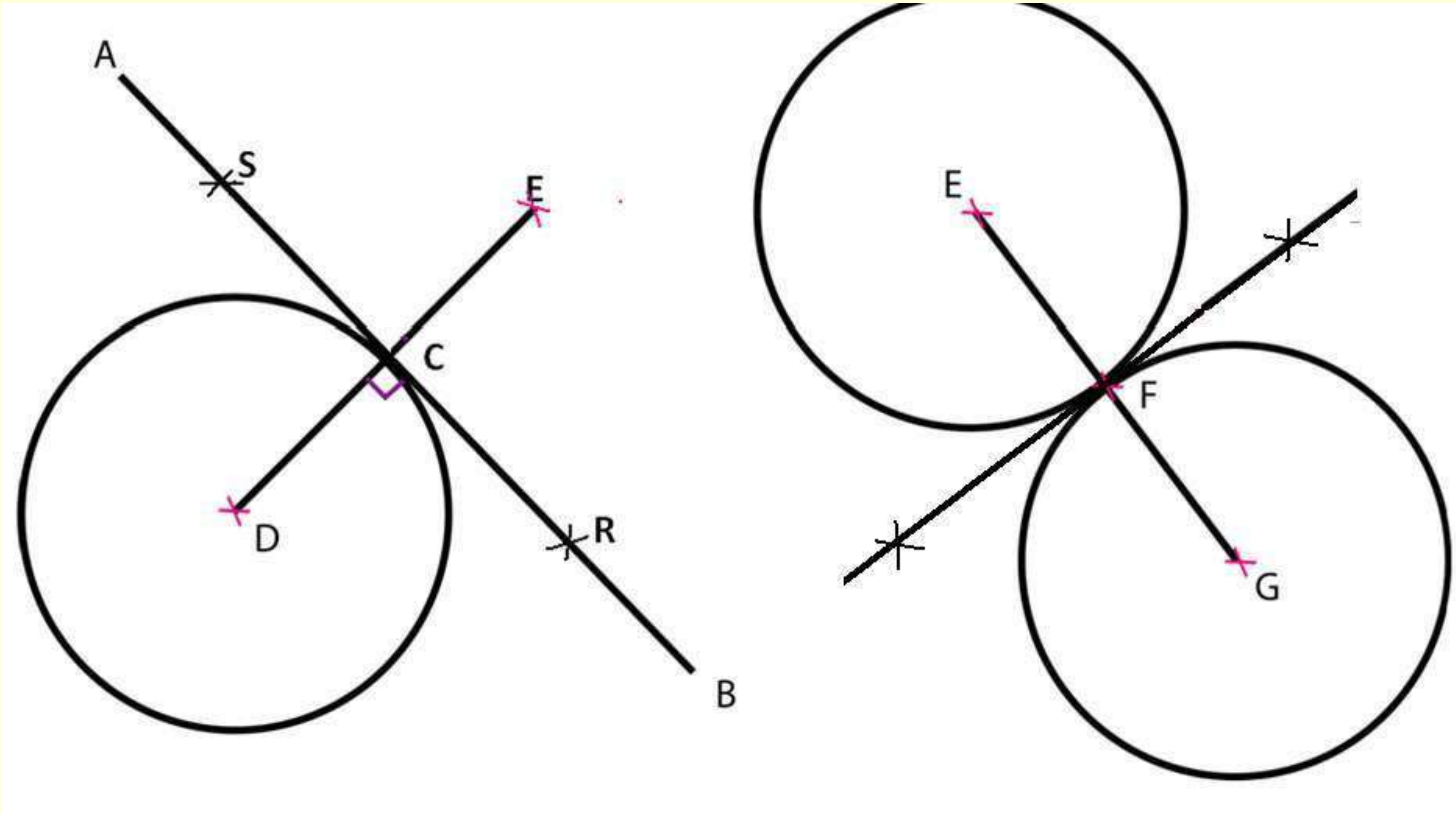


Dividing a line into equal parts

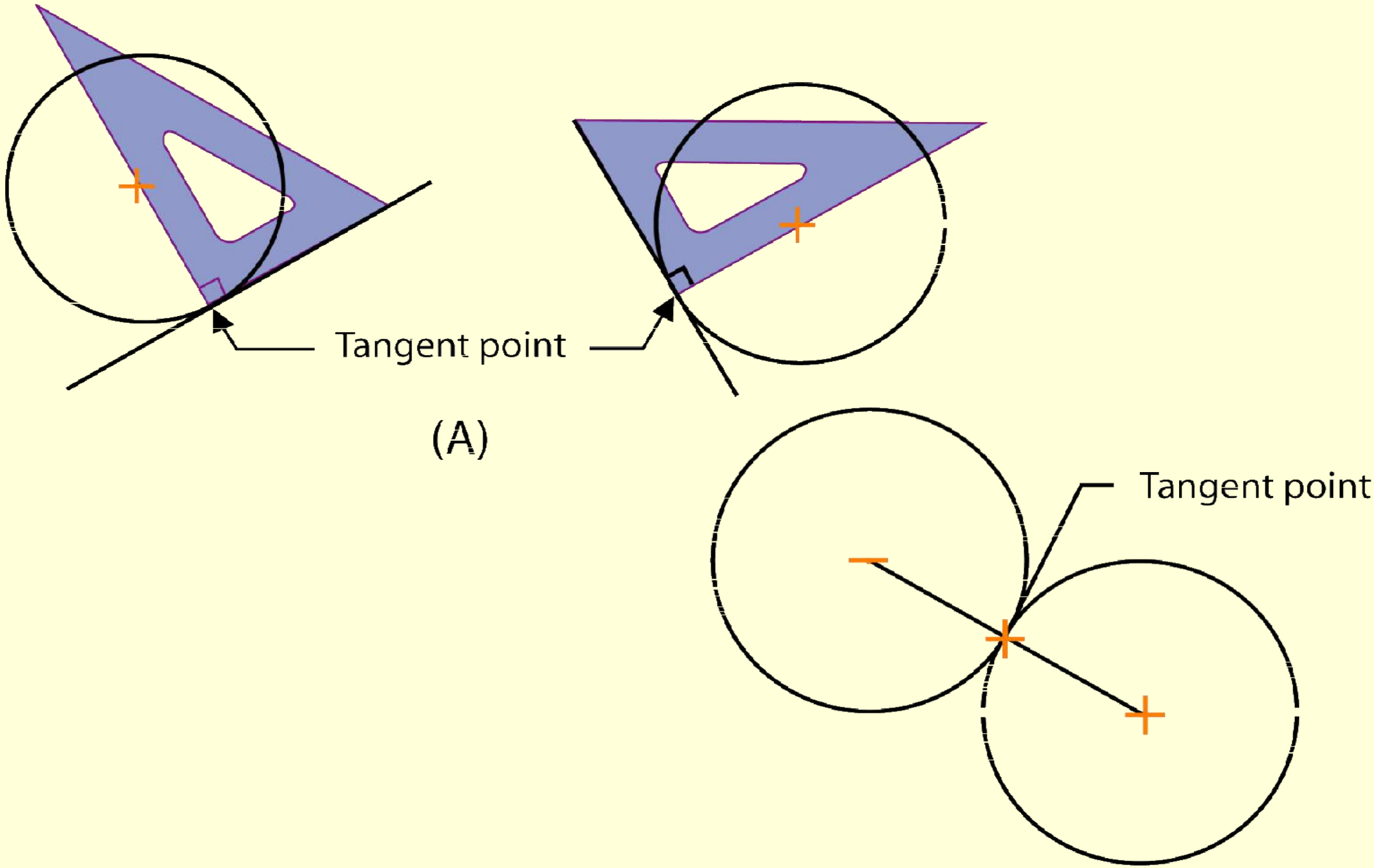


- Draw a line MO at any convenient angle (preferably an acute angle) from point M.
- From M and along MO, cut off with a divider equal divisions (say three) of any convenient length.
- Draw a line joining RN.
- Draw lines parallel to RN through the remaining points on line MO. The intersection of these lines with line MN will divide the line into (three) equal parts.

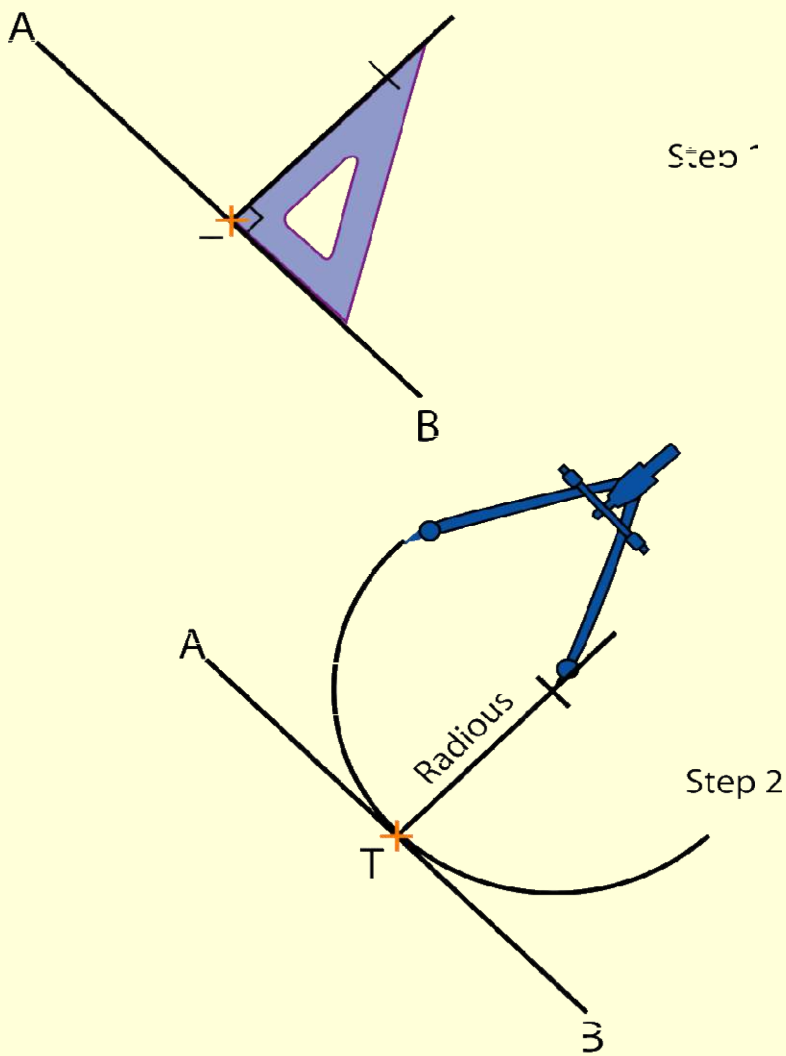
Planar tangent condition exists when two geometric forms meet at a single point and do not intersect.



Locating tangent points on circle and arcs



Drawing an arc tangent to a given point on the line

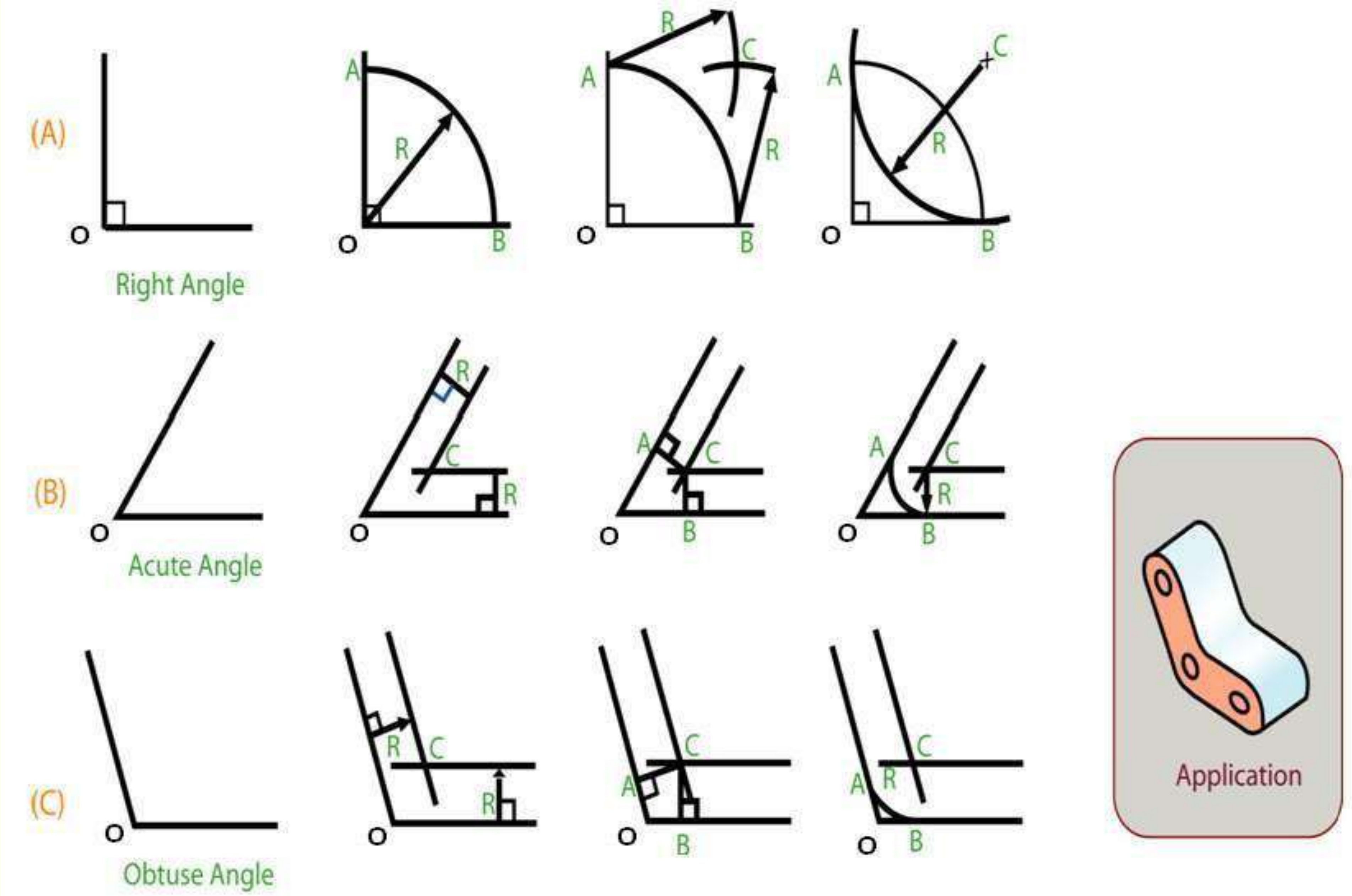


Steps

- **Given line AB and tangent point T. Construct a line perpendicular to line AB and through point T.**

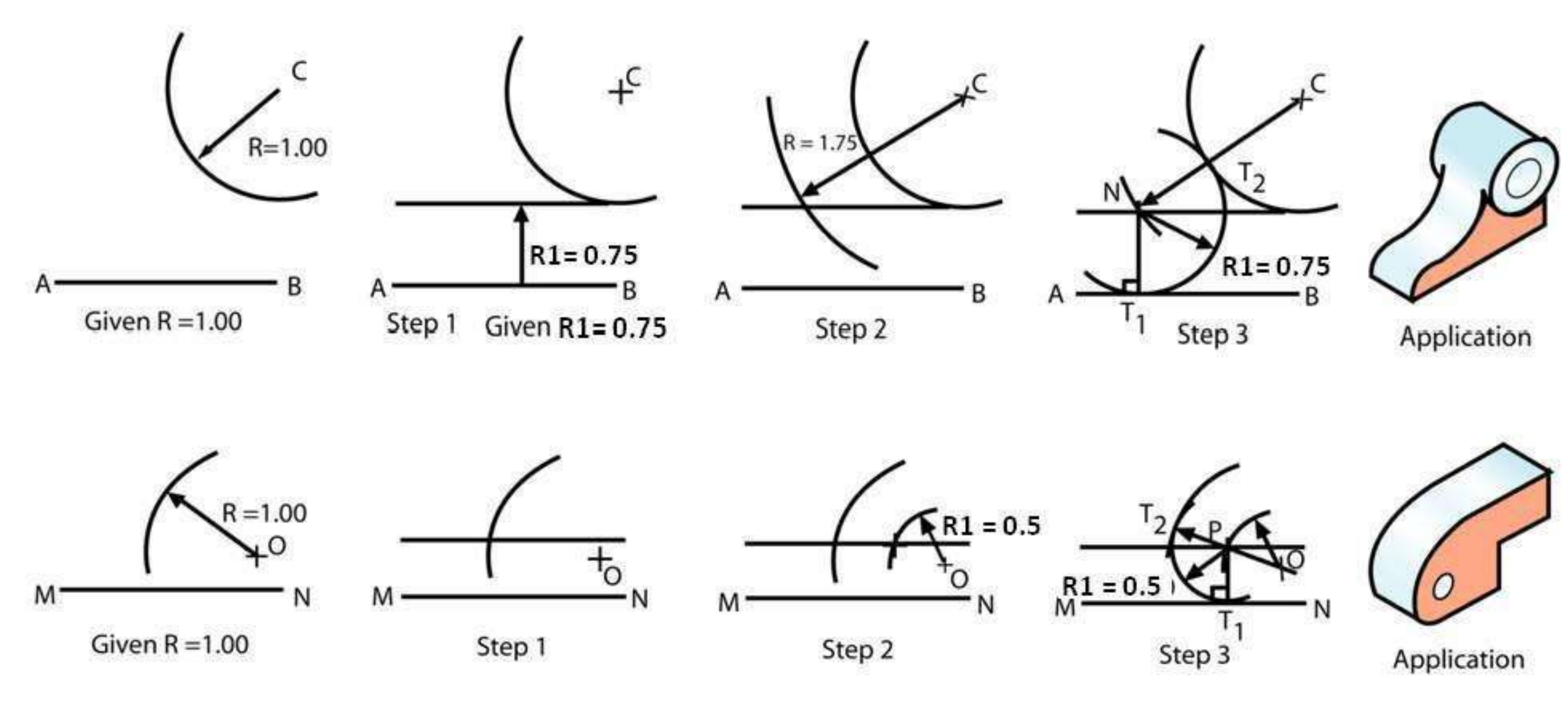
- **Locate the center of the arc by making the radius on the perpendicular line. Put the point of the compass at the center of the arc, set the compass for the radius of the arc, and draw the arc which will be tangent to the line through the point T.**

Drawing an arc, tangent to two lines

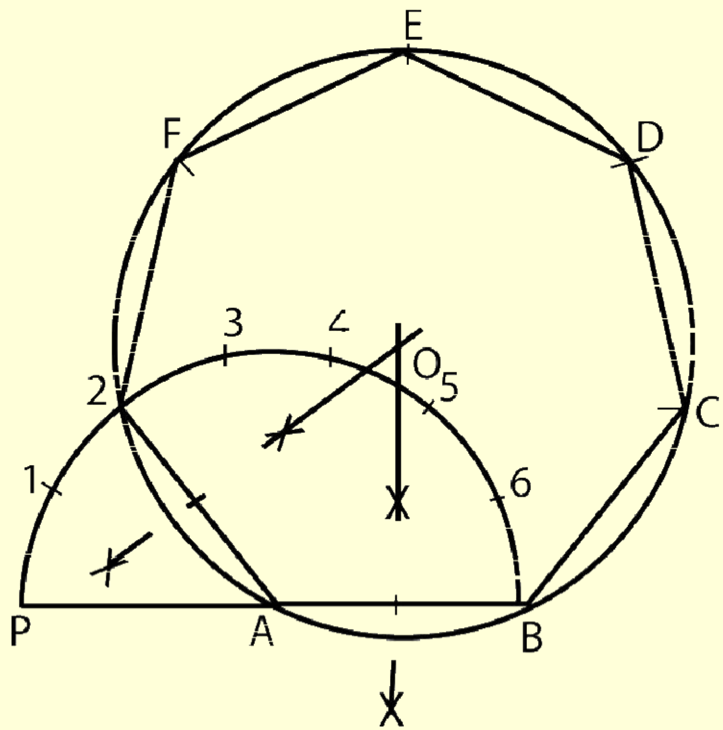


Drawing an arc, tangent to a line and an arc

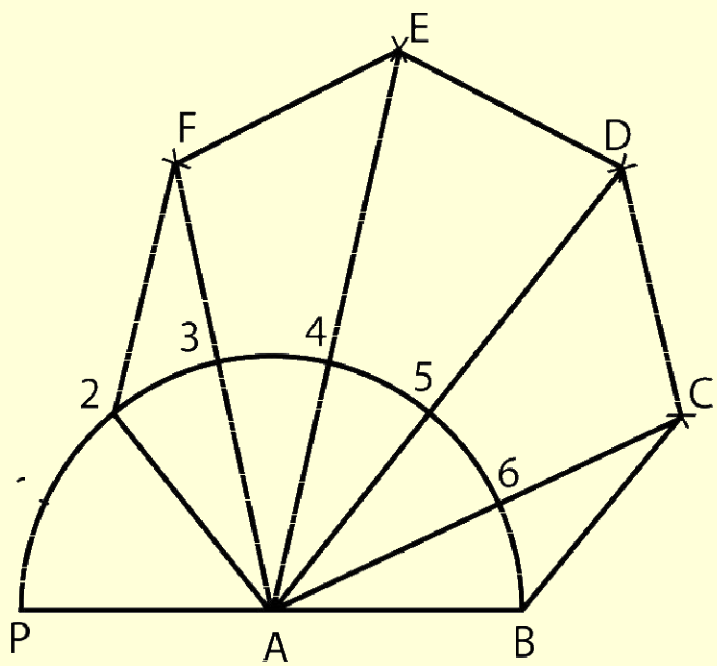
(a) that do not intersect (b) that intersect



Construction of Regular Polygon of given length AB



(A)



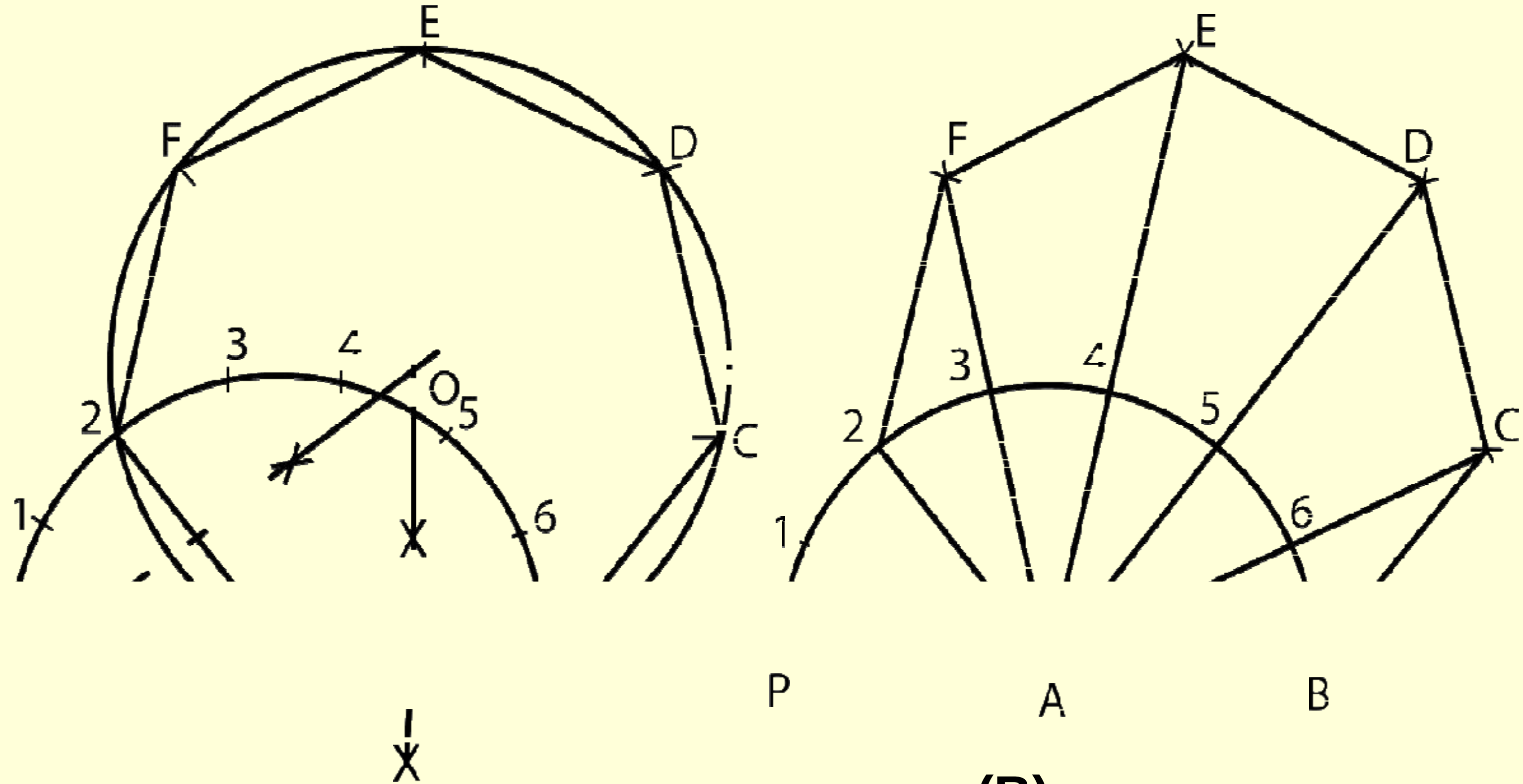
(B)

Draw a line of length AB. With A as centre and radius AB, draw a semicircle.

With the divider, divide the semicircle into the number of sides of the polygon.

Draw a line joining A with the second division-point 2.

Construction of Regular Polygon of given length AB……



(A) (B)

The perpendicular bisectors of A2 and AB meet at O. Draw a circle with centre O and radius OA. With length A2, mark points F, E, D & C on the circumferences starting from 2 (*Inscribe circle method*)

With centre B and radius AB draw an arc cutting the line A6 produced at C. Repeat this for other points D, E & F (*Arc method*)

General method of drawing any polygon

Draw AB = given length of polygon

At B, Draw BP perpendicular & = AB

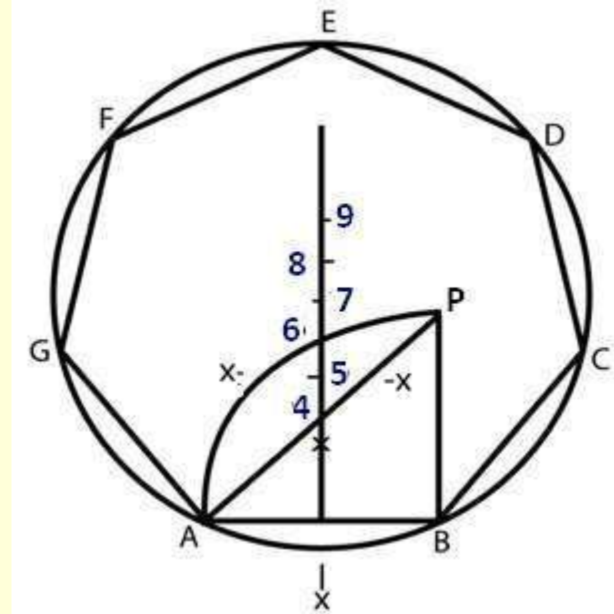
Draw Straight line AP

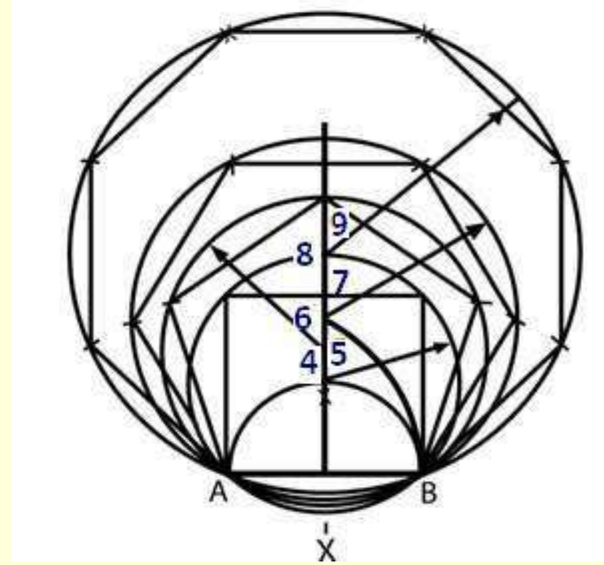
With center B and radius AB, draw arc AP.

The perpendicular bisector of AB meets st. line AP and arc AP in 4 and 6 respectively.

Draw circles with centers as 4, 5,&6 and radii as 4B, 5B, & 6B and inscribe a square, pentagon, & hexagon in the respective circles.

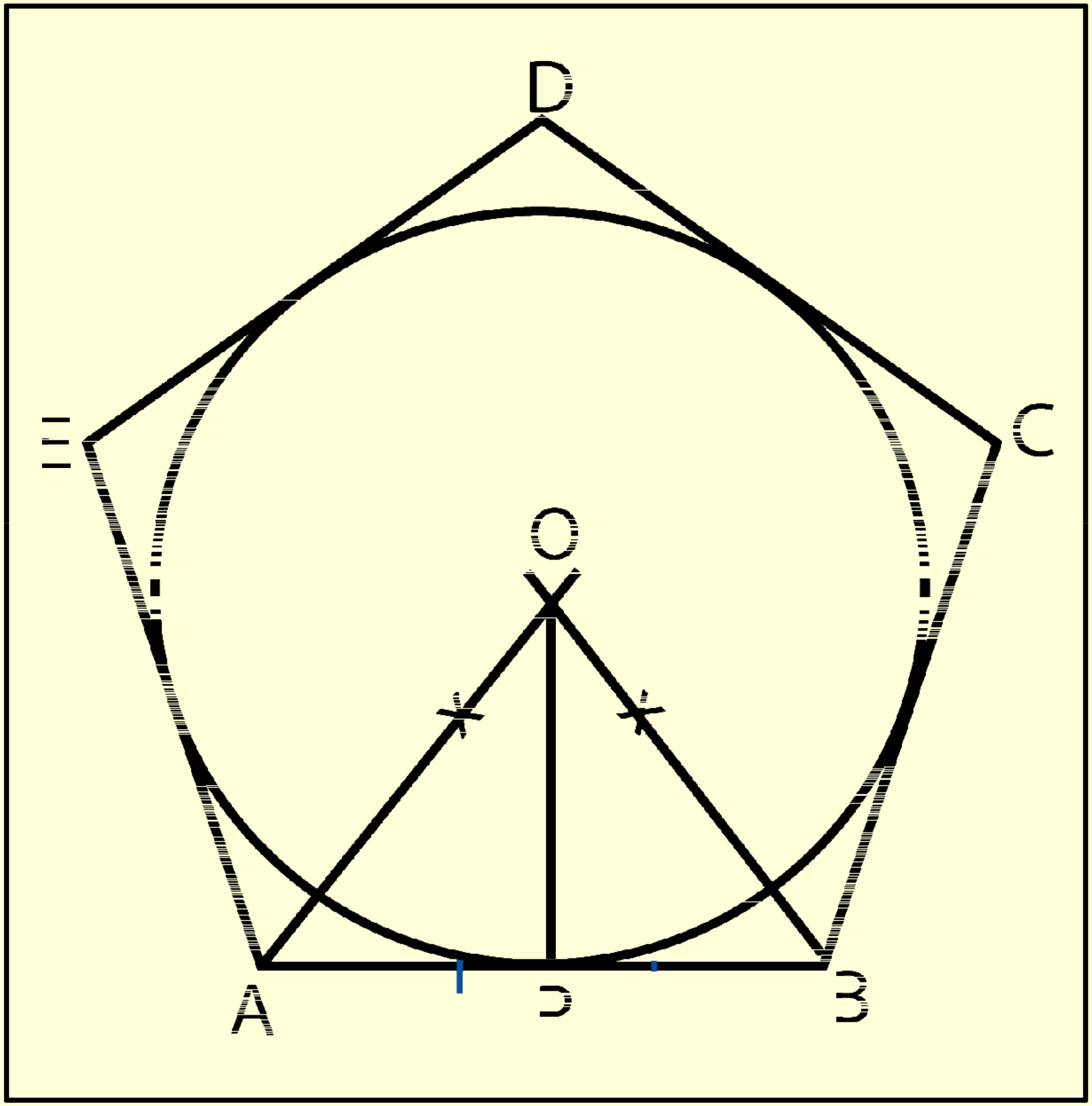
Mark point 7, 8, etc with 6-7,7-8,etc. = 4-5 to get the centers of circles of heptagon and octagon, etc.





Inscribe a circle inside a regular polygon

- Bisect any two adjacent internal angles of the polygon.
- From the intersection of these lines, draw a perpendicular to any one side of the polygon (say OP).
- With OP as radius, draw the circle with O as center.



Inscribe a regular polygon of any number of sides (say n = 5), in a circle

Draw the circle with diameter AB.

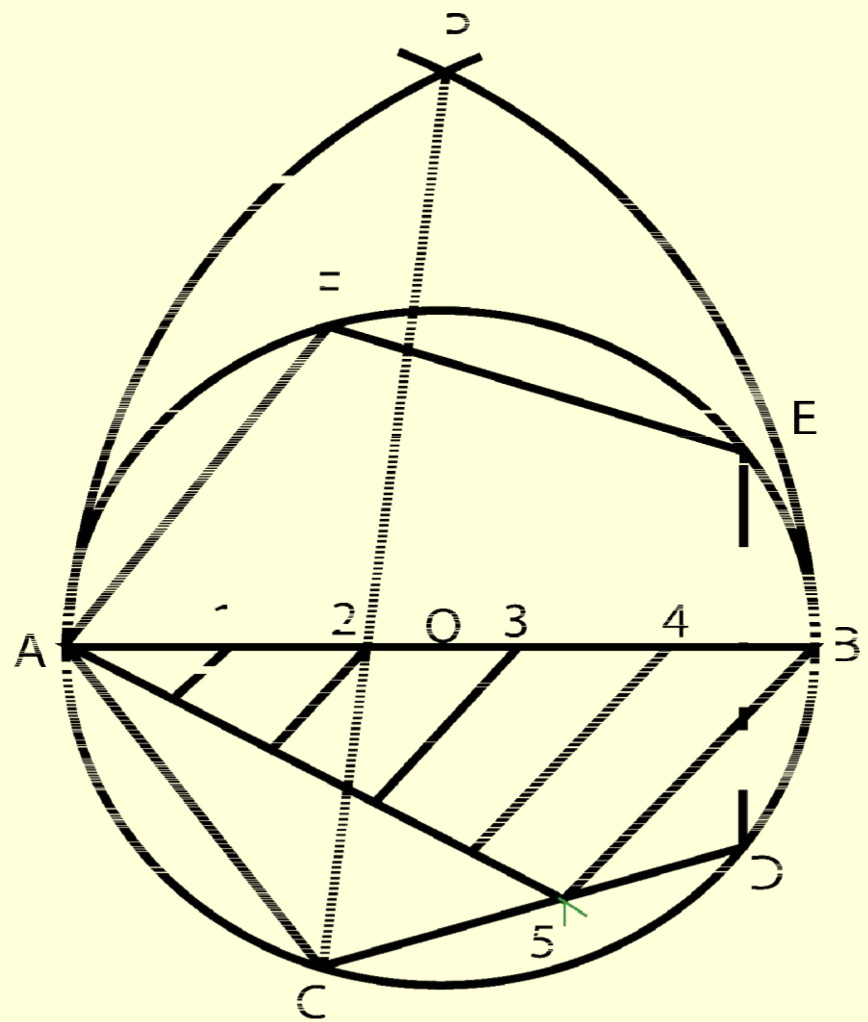
Divide AB in to “n” equal parts

Number them.

With center A & B and radius AB, draw arcs to intersect at P.

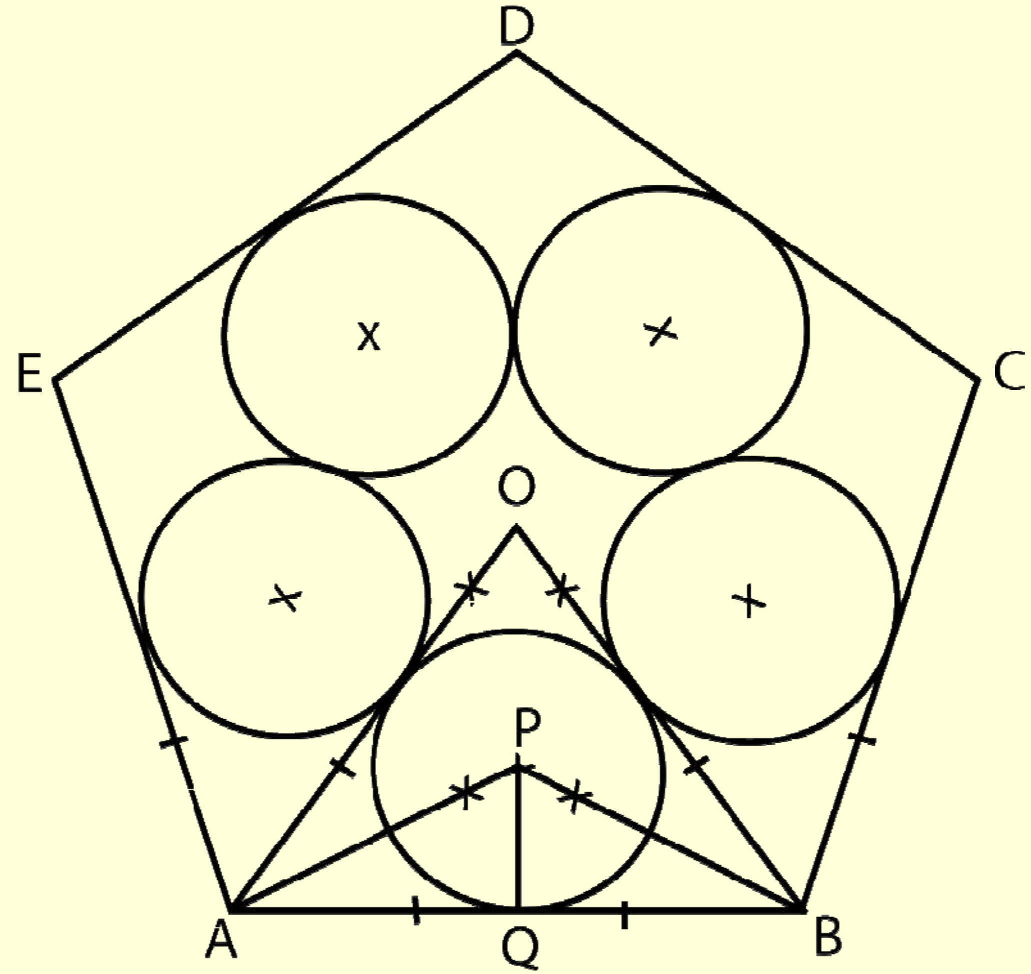
Draw line P2 and produce it to meet the circle at C.

AC is the length of the side of the polygon.



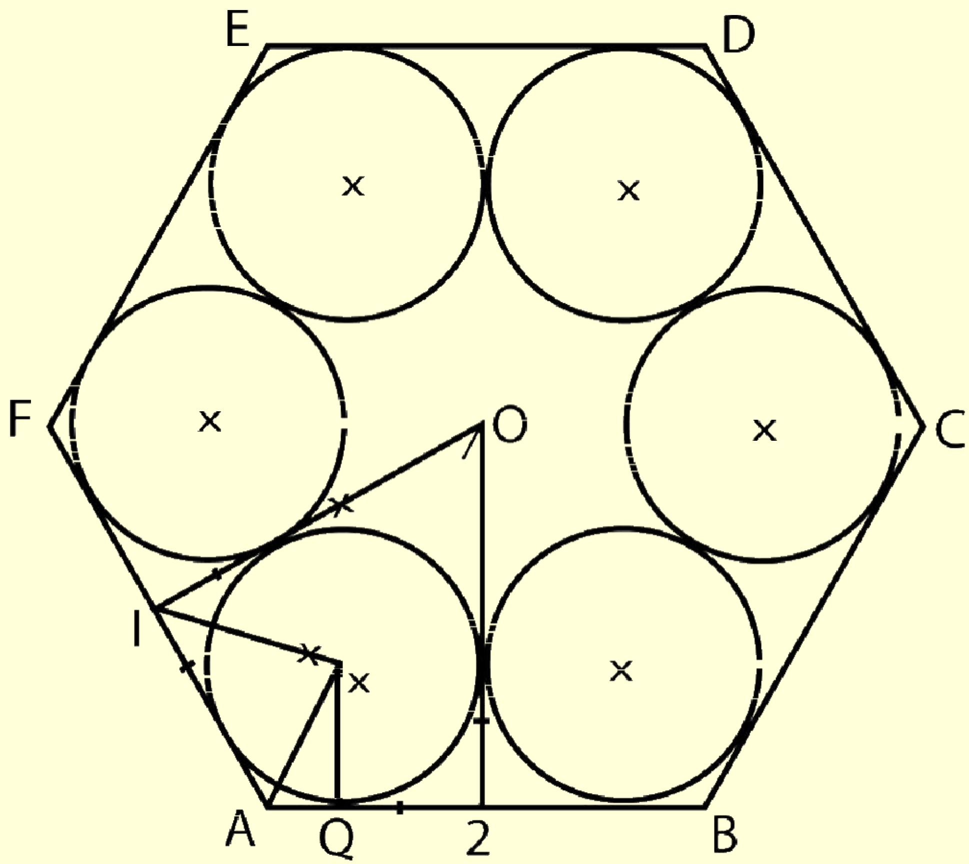
Inside a regular polygon, draw the same number of equal circles as the side of the polygon, each circle touching one side of the polygon and two of the other circles.

- **Draw bisectors of all the angles of the polygon, meeting at O, thus dividing the polygon into the same number of triangles.**
- **In each triangle inscribe a circle.**



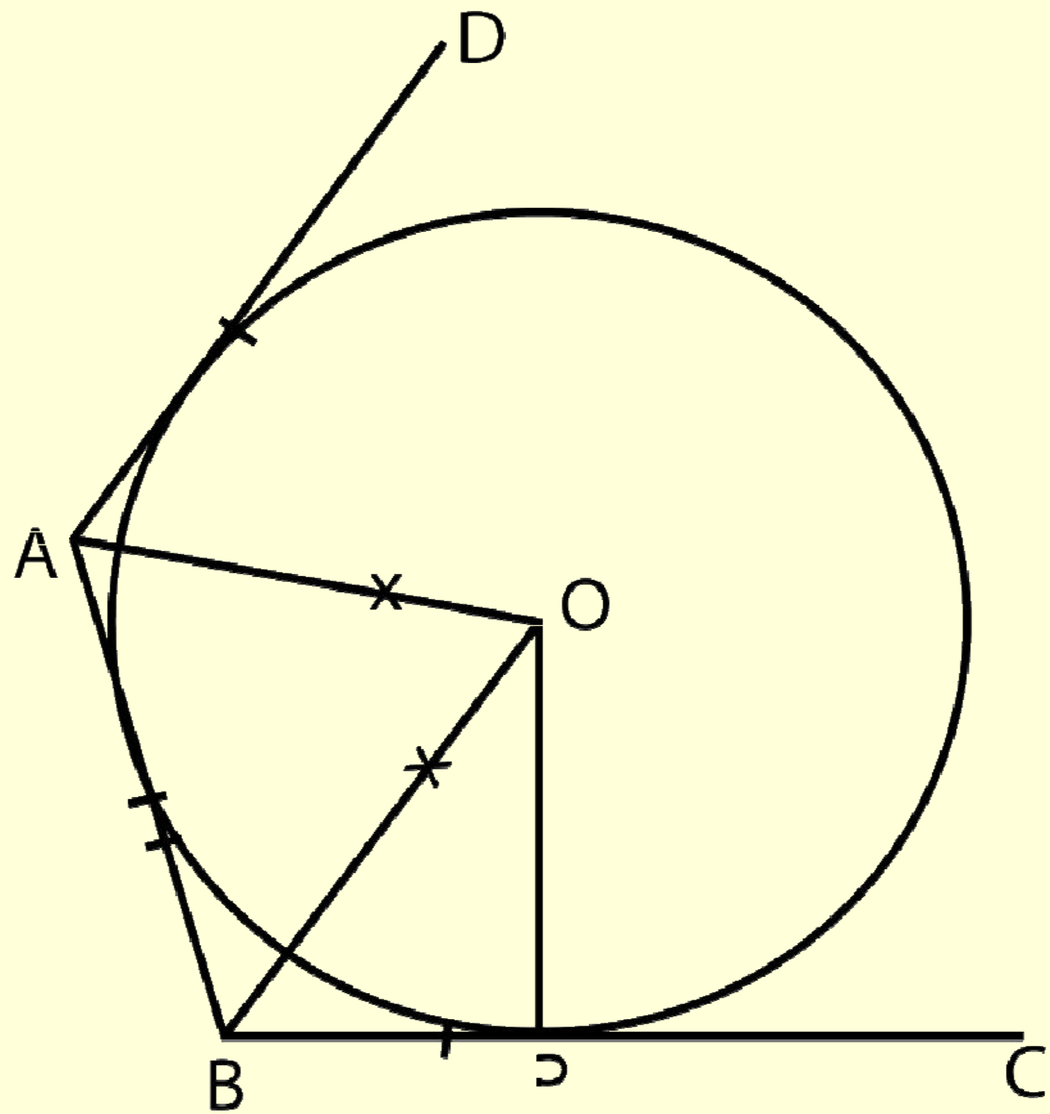
Inside a regular polygon, draw the same number of equal circles as the side of the polygon, each circle touching two adjacent sides of the polygon and two of the other circles.

- **Draw the perpendicular bisectors of the sides of the polygon to obtain same number of quadrilaterals as the number of sides of the polygon.**
- **Inscribe a circle inside each quadrilateral.**



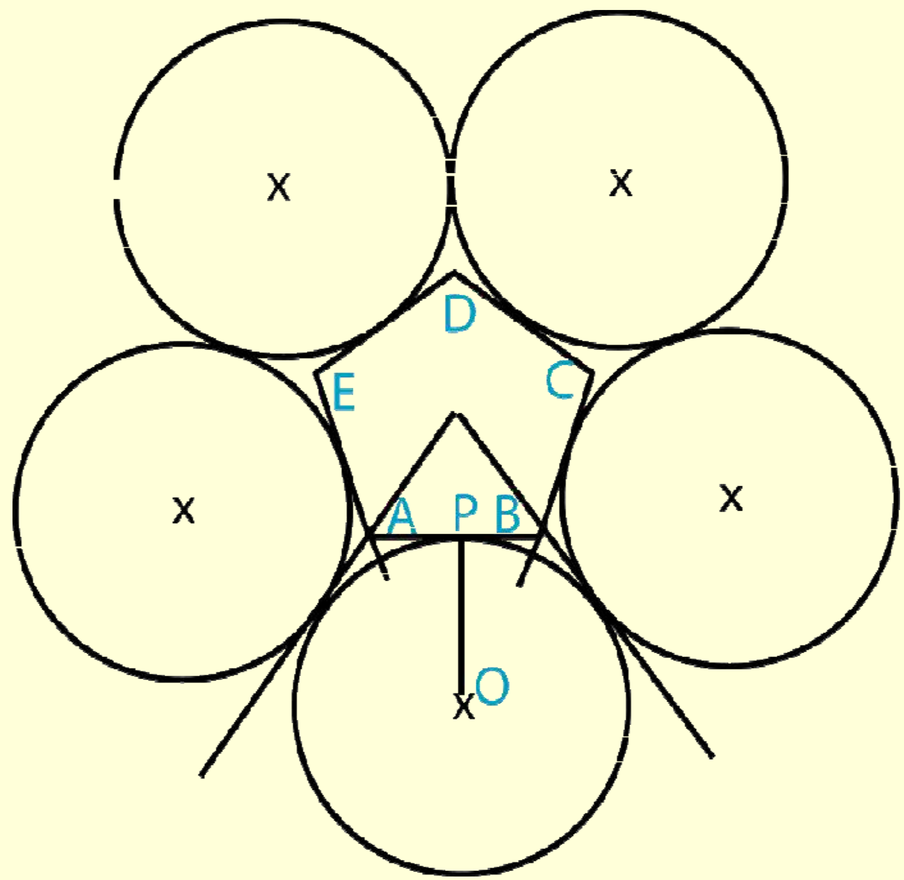
To draw a circle touching three lines inclined to each other but not forming a triangle.

- Let AB, BC, and AD be the lines.
- Draw bisectors of the two angles, intersecting at O.
- From O draw a perpendicular to any one line intersecting it at P.
- With O as center and OP as radius draw the desired circle.



Outside a regular polygon, draw the same number of equal circles as the side of the polygon, each circle touching one side of the polygon and two of the other circles.

- **Draw bisectors of two adjacent angles and produce them outside the polygon.**
- **Draw a circle touching the extended bisectors and the side AB (in this case) and repeat the same for other sides.**



Construction of an arc tangent of given radius to two given arcs

- **Given - Arcs of radii M and N. Draw an arc of radius AB units which is tangent to both the given arcs. Centers of the given arcs are inside the required tangent arc.**

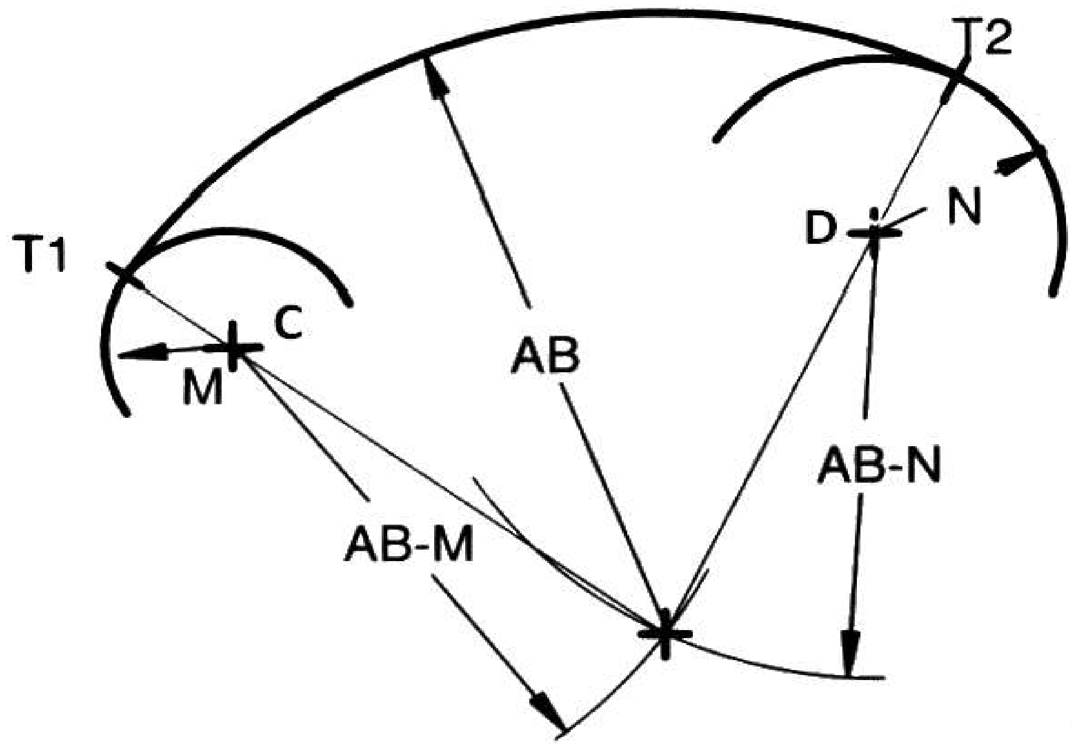
Steps:

From centers C and D of the given arcs, draw construction arcs of radii (AB – M) and (AB N), respectively.

With the intersection point as the center, draw an arc of radius AB.

This arc will be tangent to the two given arcs.

Locate the tangent points T1 and T2.



Construction of line tangents to two circles (Open belt)

Given: Circles of radii R1 and R with centers O and P, respectively.

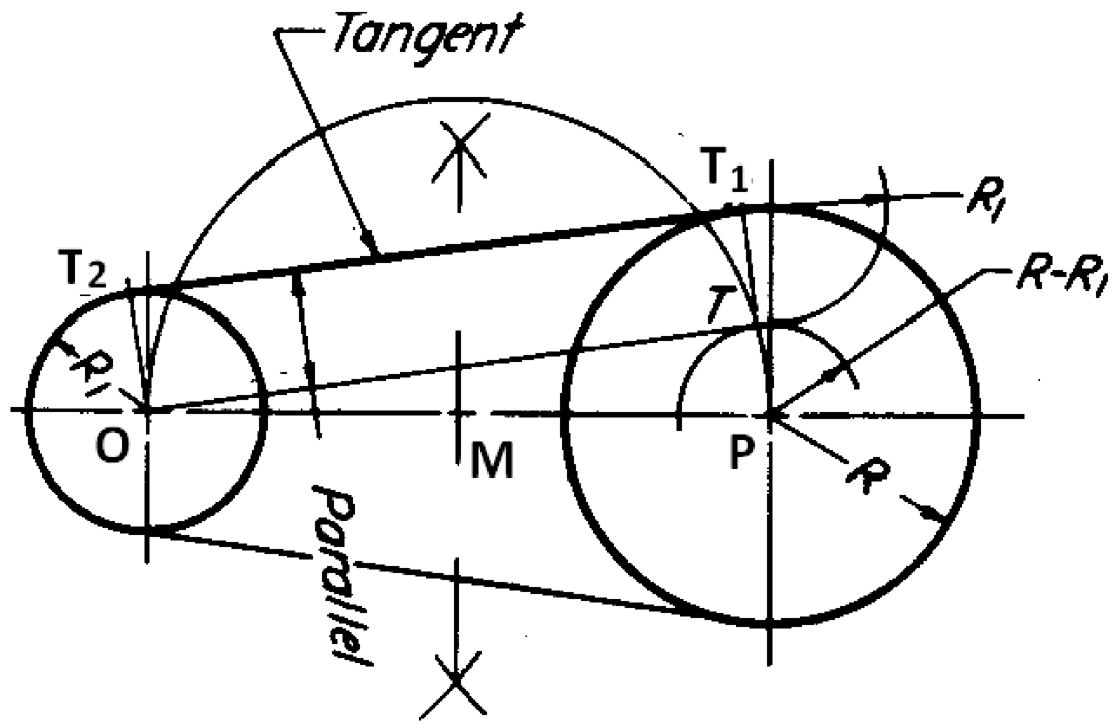
Steps:

With P as center and a radius equal to **(R-R1)** draw an arc.

Locate the midpoint of **OP** as perpendicular bisector of **OP** as "**M**".

With as centre and as radius draw a semicircle.

Locate the intersection point **T** between the semicircle and the circle with radius (**R-R1**).



draw a line **PT** and extend it to locate **T1**.

Draw **OT2** parallel to **PT1**.

The line **T1** to **T2** is the required tangent

Construction of line tangents to two circles (crossed belt)

Given: Two circles of radii R1 and R with centers O and P, respectively.

Steps:

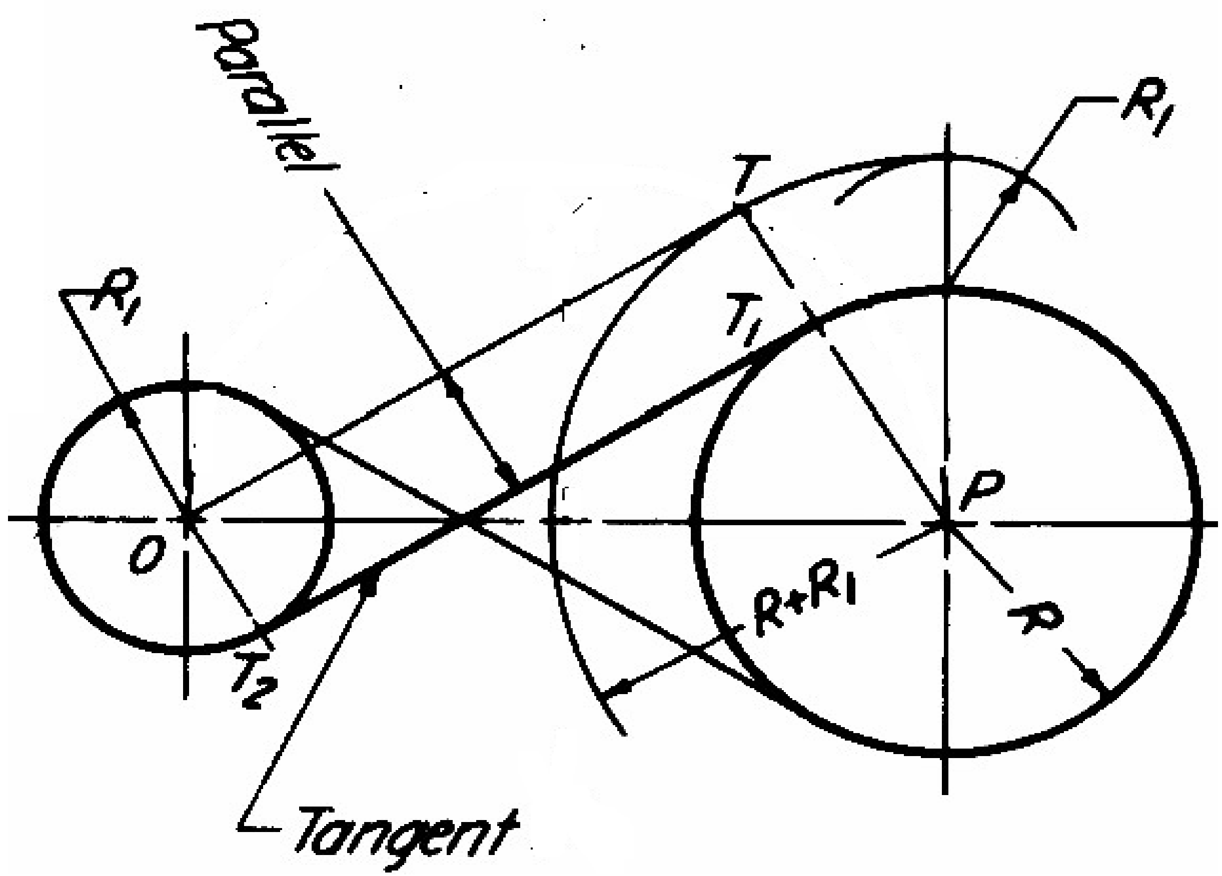
Using **P** as a center and a radius equal to **(R+ R1)** draw an arc.

Through **O** draw a tangent to this arc.

Draw a line PT cutting the circle at T_1

Through O draw a line OT_2 parallel to PT_1.

The line $\mathbf{T_1T_2}$ is the required tangent.



THANK YOU

Engineering Drawing

Lecture 3

SCALES AND Engineering Curves

Definition

A scale is defined as the ratio of the linear dimensions of the object as represented in a drawing to the actual dimensions of the same.

Necessity

- **Drawings drawn with the same size as the objects are called full sized drawing.**

- **It is not convenient, always, to draw drawings of the object to its actual size. e.g. Buildings, Heavy**

- **Hence scales are used to prepare drawing at**
    - **Full size**
    - **Reduced size**
    - **Enlarged size**

BIS Recommended Scales

Reducing scales **1:Y (Y>1)**	**1:2** **1:20** **1:200** **1:2000**	**1:5** **1:50** **1:500** **1:5000**	**1:10** **1:100** **1:1000** **1:10000**
Enlarging scales **X:1 (X>1)**	**50:1** **5:1**	**20:1** **2:1**	**10:1**
Full size scales			**1:1**

Intermediate scales can be used in exceptional cases where recommended scales can not be applied for functional reasons.

Types of Scale

- ***Engineers Scale :***

  The relation between the dimension on the drawing and the actual dimension of the object is mentioned numerically (like 10 mm = 15 m).

- ***Graphical Scale*:**

  Scale is drawn on the drawing itself. This takes care of the shrinkage of the engineer's scale when the drawing becomes old.

Types of Graphical Scale

- **Plain Scale**
- **Diagonal Scale**
- **Vernier Scale**
- **Comparative scale**

Representative fraction (R.F.)

$$R.F. = \frac{\text{Length of an object on the drawing}}{\text{Actual Length of the object}}$$

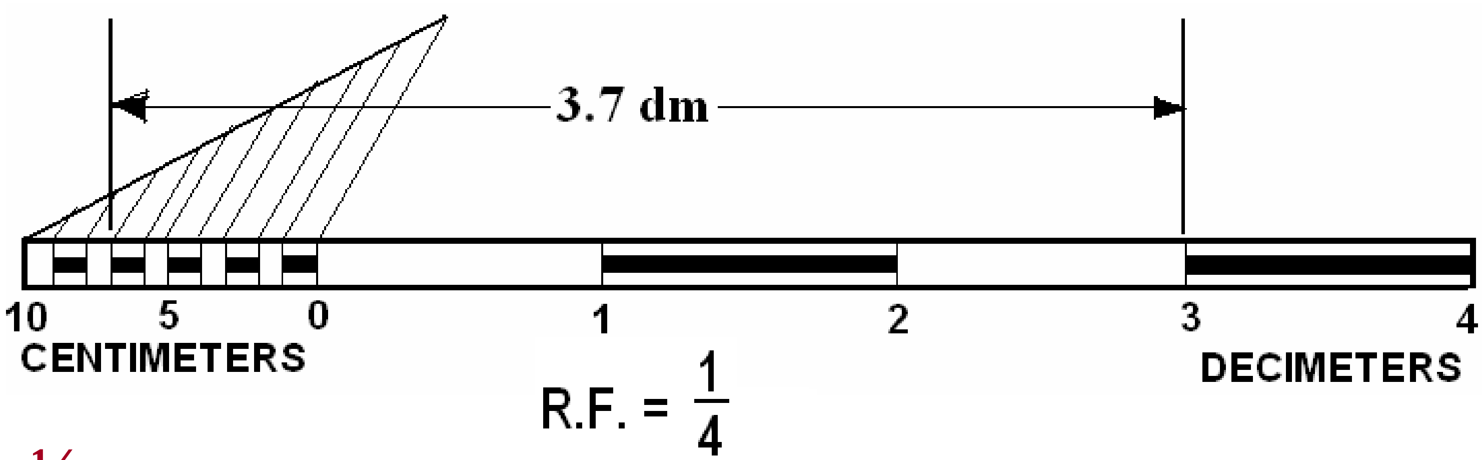
When a 1 cm long line in a drawing represents 1 meter length of the object,

$$R.F = \frac{1cm}{1m} = \frac{1cm}{1x\,100\,cm} = \frac{1}{100}$$

Plain scale

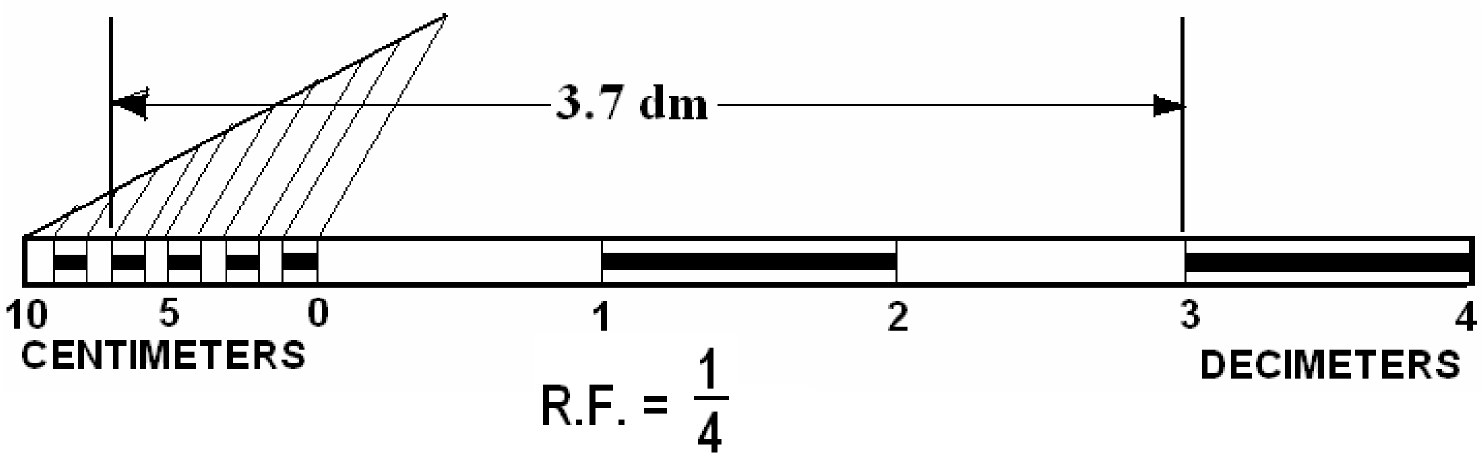
- A plain scale consists of a line divided into suitable number of equal units. The first unit is subdivided into smaller parts.
- The zero should be placed at the end of the 1st main unit.
- From the zero mark, the units should be numbered to the right and the sub-divisions to the left.
- The units and the subdivisions should be labeled clearly.
- The R.F. should be mentioned below the scale.

Construct a scale of 1:4, to show centimeters and long enough to measure up to 5 decimeters.



- R.F. = ¼
- Length of the scale = R.F. × max. length = ¼ × 5 dm = 12.5 cm.
- Draw a line 12.5 cm long and divide it in to 5 equal divisions, each representing 1 dm.
- Mark 0 at the end of the first division and 1, 2, 3 and 4 at the end of each subsequent division to its right.
- Divide the first division into 10 equal sub-divisions, each representing 1 cm.
- Mark cm to the left of 0 as shown.

Question: **Construct a scale of 1:4, to show centimeters and long enough to measure up to 5 decimeters**



- **instead of only a line.**

- **Draw the division lines showing decimeters throughout the width of the scale.**

- **Draw thick and dark horizontal lines in the middle of all alternate divisions and sub-divisions.**

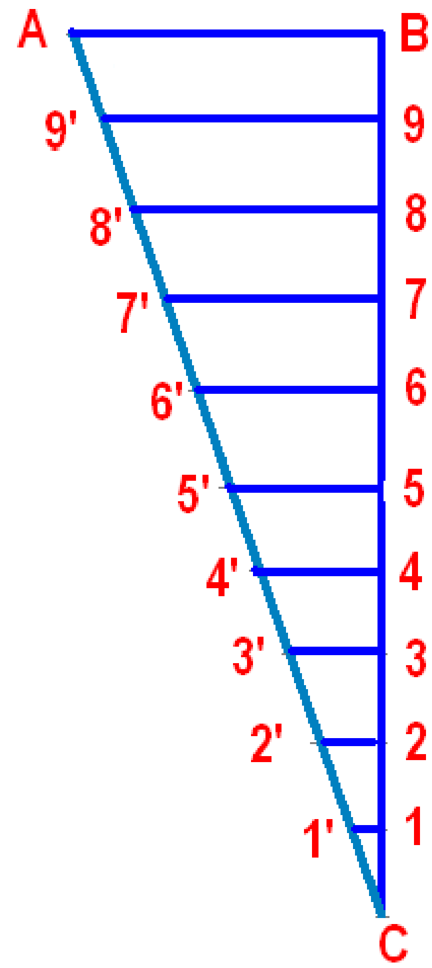
- **Below the scale, print DECIMETERS on the right hand side,** CENTIMERTERS on the left hand side, and R.F. in the middle.

Diagonal Scale

- **Through Diagonal scale, measurements can be up to second decimal (e.g. 4.35).**
- **Diagonal scales are used to measure distances in a unit and its immediate two subdivisions; e.g. *dm*, *cm* & *mm*, or *yard*, *foot* & *inch*.**
- **Diagonal scale can measure more accurately than the plain scale.**

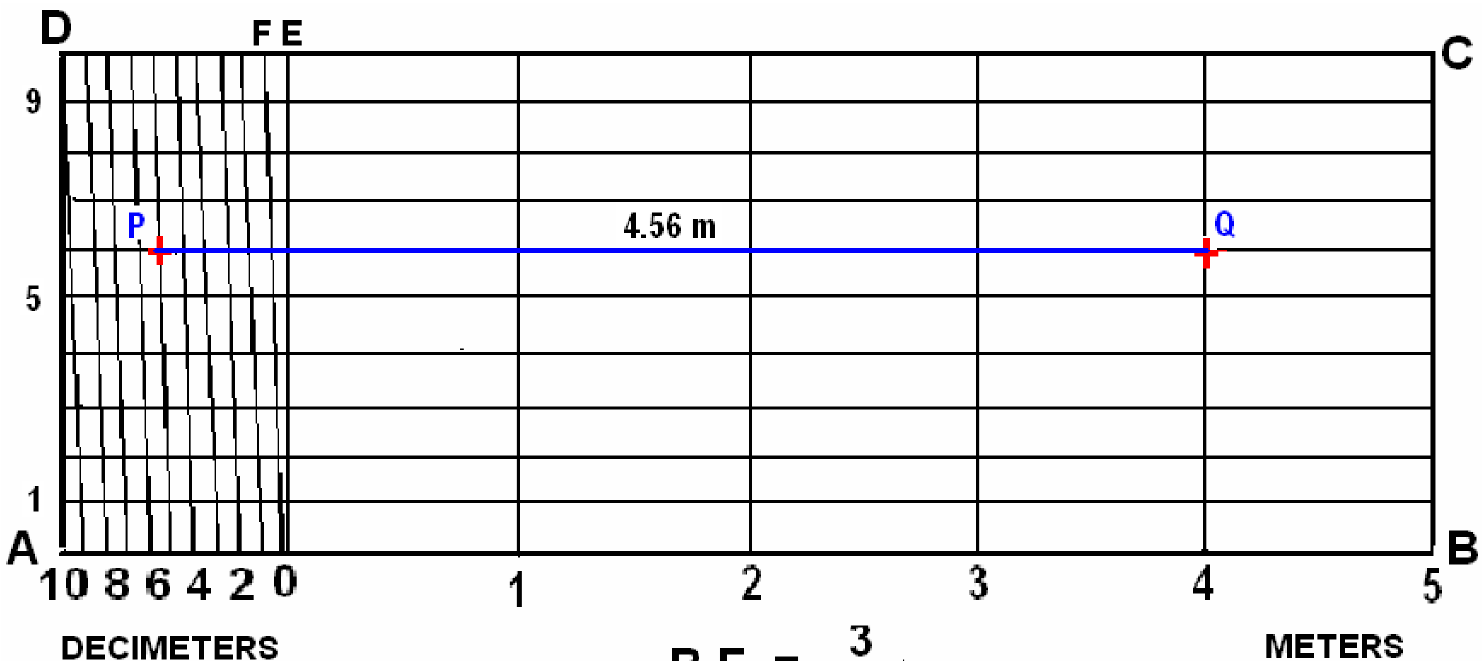
Diagonal scale…..Concept

- At end B of line AB, draw a perpendicular.
- Step-off ten equal divisions of any length along the perpendicular starting from B and ending at C.
- Number the division points 9,8,7,…..1.
- Through the points 1, 2, 3, etc., draw lines parallel to AB and cutting AC at 1´, 2´, 3´, etc.
- Since the triangles are similar; 1´1 = 0.1 AB, 2´2 = 0.2AB, …. 9´9 = 0.9AB.



- **Gives divisions of a given short line AB in multiples of 1/10 its length, e.g. 0.1AB, 0.2AB, 0.3AB, etc.**

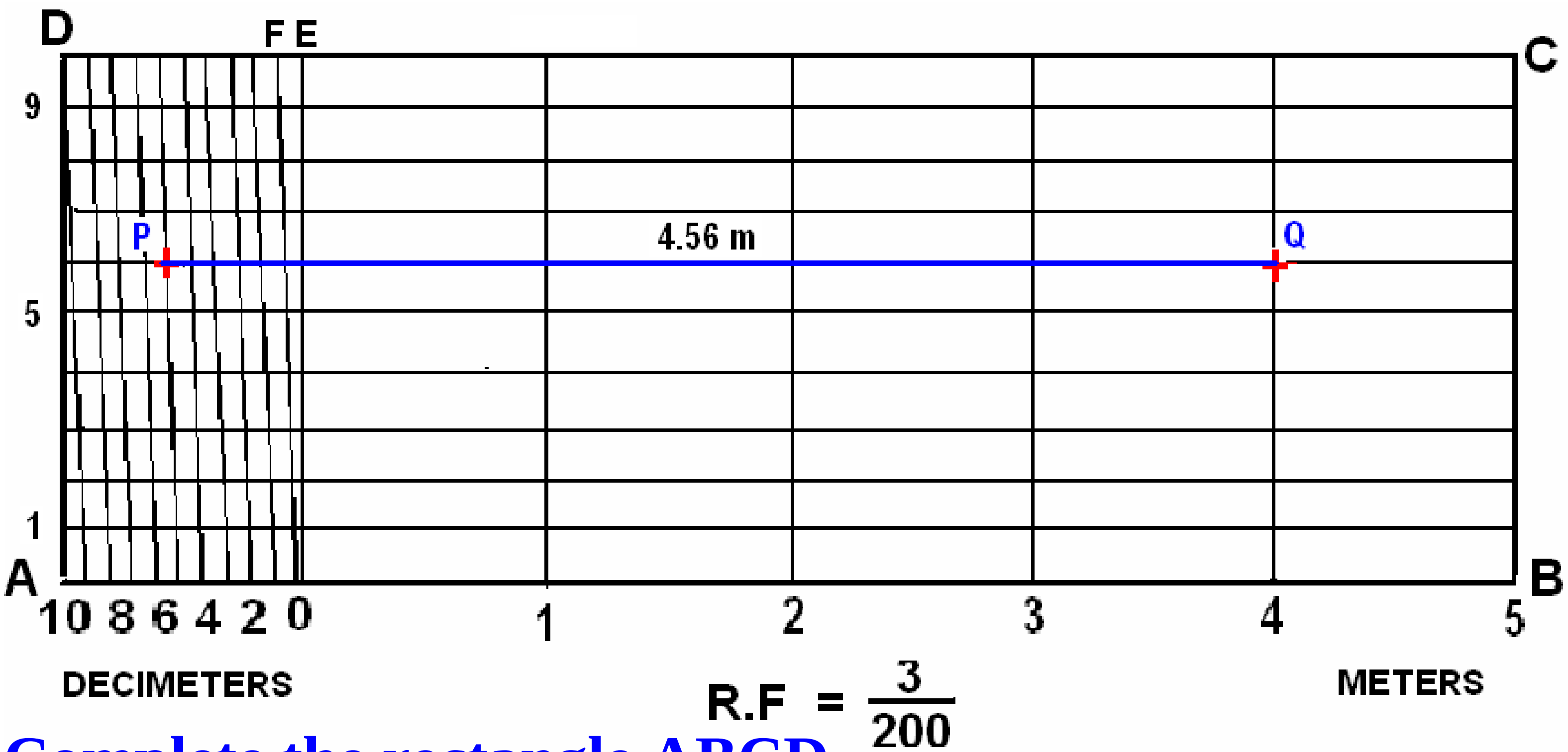
Construct a Diagonal scale of RF = 3:200 (i.e. 1:66 2/3) showing meters, decimeters and centimeters. The scale should measure up to 6 meters. Show a distance of 4.56 meters



$$R.F = \frac{3}{200}$$

- **Length of the scale = (3/200) x 6 m = 9 cm**
- **Draw a line AB = 9 cm . Divide it in to 6 equal parts.**
- **Divide the first part A0 into 10 equal divisions.**
- **At A draw a perpendicular and step-off along it 10 equal divisions, ending at D.**

Diagonal Scale



- **Complete the rectangle ABCD.**
- **Draw perpendiculars at meter-divisions i.e. 1, 2, 3, and 4.**
- **Draw horizontal lines through the division points on AD. Join D with the end of the first division along A0 (i.e. 9).**
- **Through the remaining points i.e. 8, 7, 6, … draw lines // to D9.**
- **PQ = 4.56 meters**

Vernier Scales

- **Similar to Diagonal scale, Vernier scale is used for measuring up to second decimal.**
- **A Vernier scale consists of (i) a primary scale and (ii) a vernier.**
- **The primary scale is a plain scale fully divided in to minor divisions.**
- **The graduations on the vernier are derived from those on the primary scale.**

Least count (LC) is the minimum distance that can be measured.

Forward Vernier Scale :

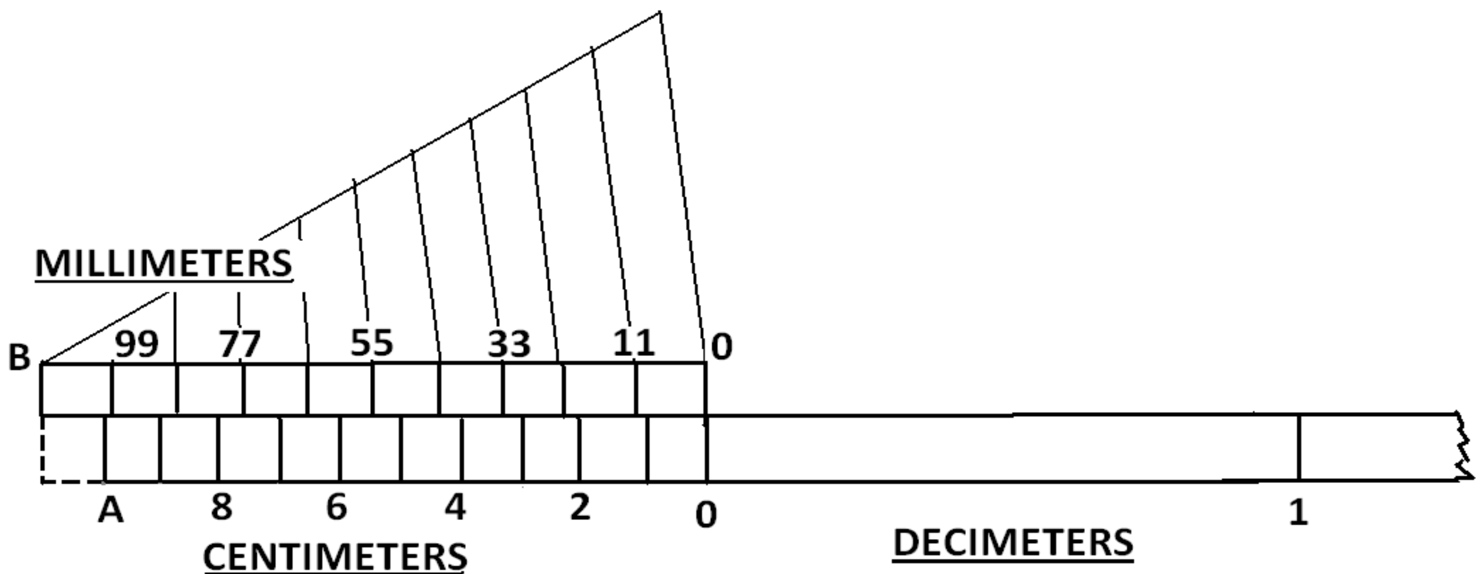
MSD>VSD; LC = MSD-VSD

Backward Vernier scale:

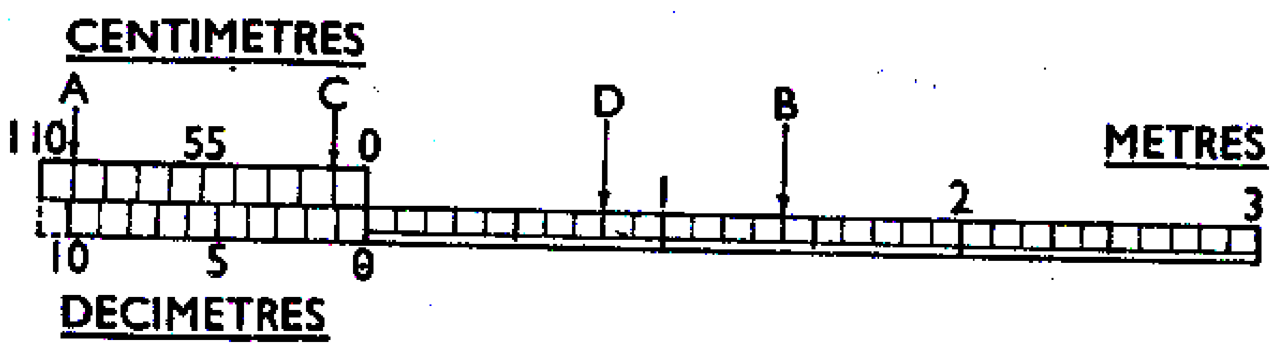
VSD>MSD; LC = VSD - MSD

Vernier scale…. Concept

- **Length A0 represents 10 cm and is divided in to 10 equal parts each representing 1 cm.**
- **B0 = 11 (i.e. 10+1) such equal parts = 11 cm.**
- **Divide B0 into 10 equal divisions. Each division of B0 will be equal to 11/10 = 1.1 cm or 11 mm.**
- **Difference between 1 part of *A0* and one part of *B0* = 1.1 cm -1.0 cm = 0.1cm or 1 mm.**

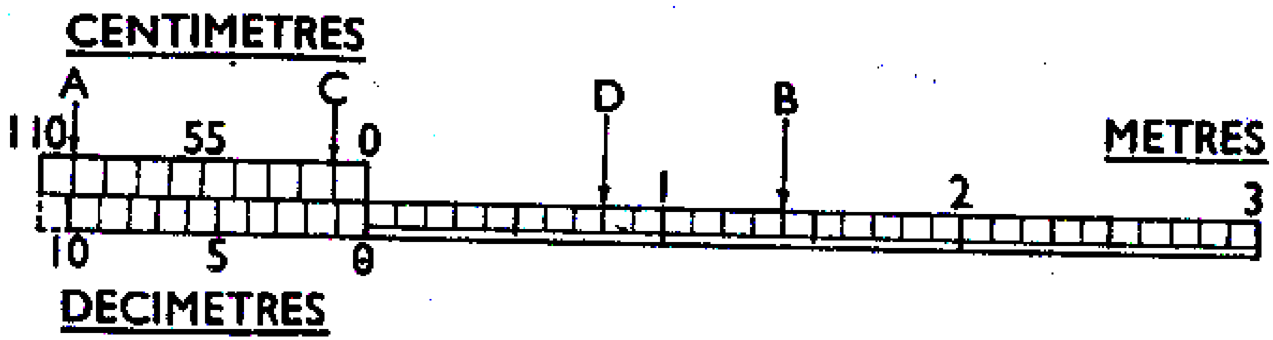


Question: **Draw a Vernier scale of R.F. = 1/25 to read up to 4 meters. On it show lengths 2.39 m and 0.91 m**



- **Length of Scale = (1/25) × (4 × 100) = 16 cm**
- **Draw a 16 cm long line and divide it into 4 equal parts. Each part is 1 meter. Divide each of these parts in to 10 equal parts to show decimeter (10 cm).**
- **Take 11 parts of dm length and divide it in to 10 equal parts. Each of these parts will show a length of 1.1 dm or 11 cm.**
- **To measure 2.39 m, place one leg of the divider at *A* on 99 cm mark and other leg at *B* on 1.4 mark. (0.99 + 1.4 = 2.39).**
- **To measure 0.91 m, place the divider at *C* and *D* (0.8 +0.11 = 0.91).**

Question: **Draw a Vernier scale of R.F. = 1/25 to read up to 4 meters. On it show lengths 2.39 m and 0.91 m**



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- **To measure 0.91 m, place the divider at *C* and *D* (0.8 +0.11 = 0.91).**

Engineering Curves

Common Engineering Curves

Parabolic shape

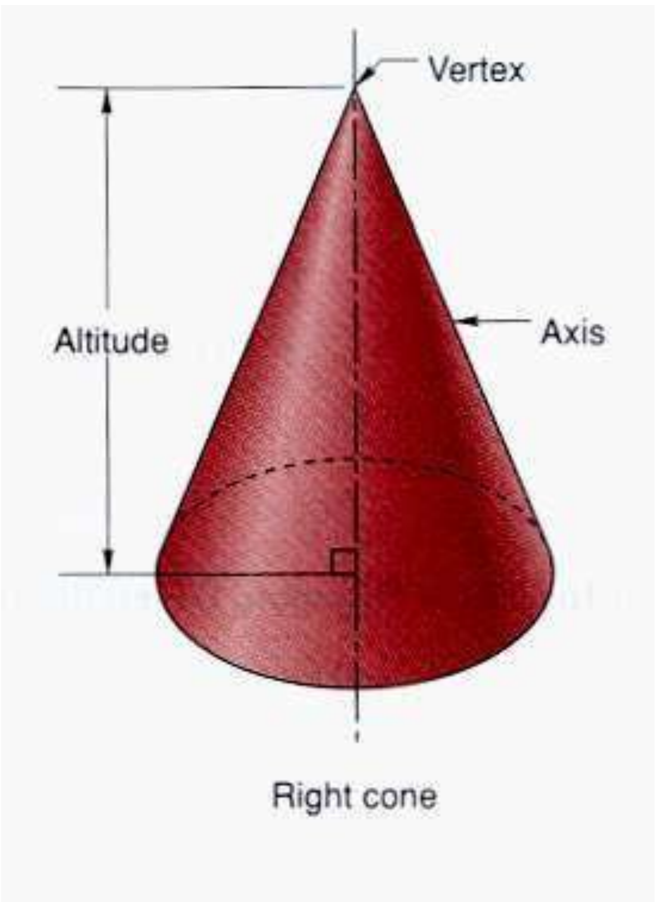
Elliptical shape

Hyperbola

spiral

Conic curves (conics)

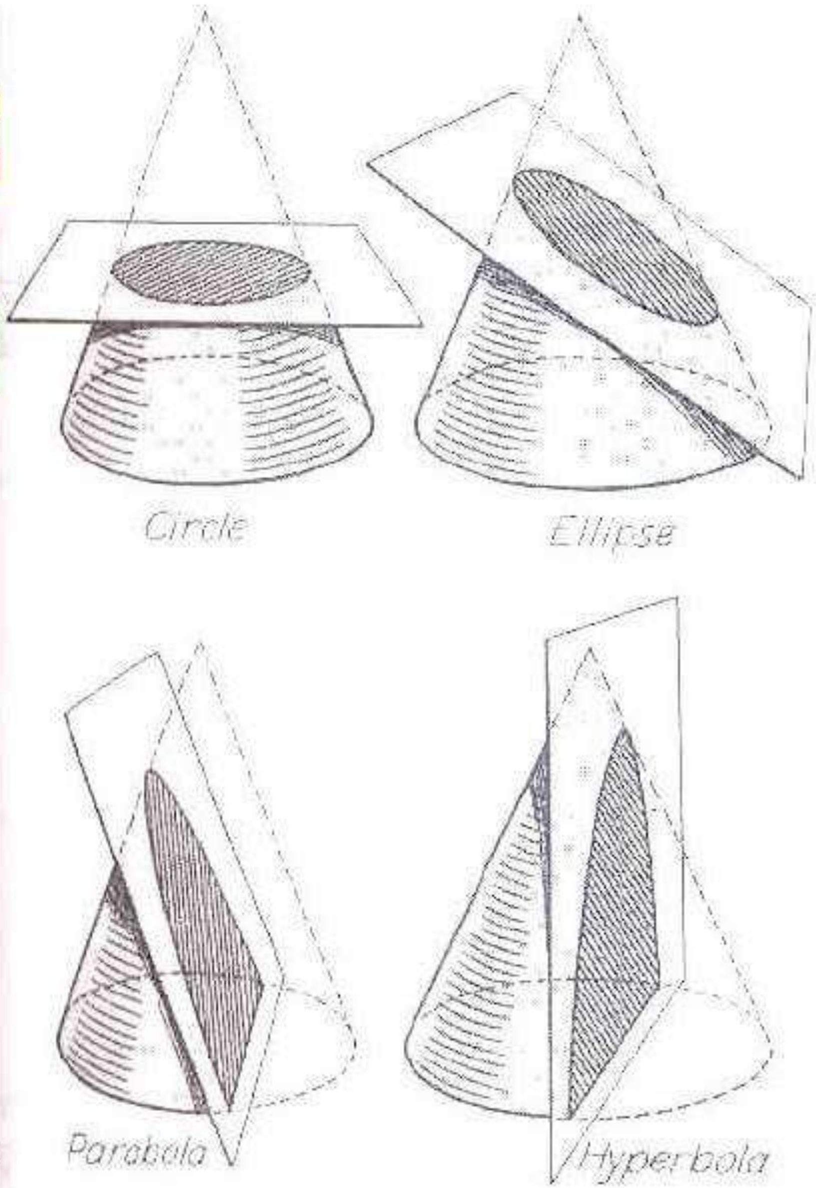
Curves formed by the intersection of a plane with a right circular cone. **e.g. Parabola, hyperbola and ellipse**



Right circular cone is a cone that has a circular base and the axis is inclined at 90^0 to the base and passes through the center of the base.

Basic Conic Shapes

- All from a CONE
  - Circle
  - Ellipse
  - Parabola
  - Hyperbola



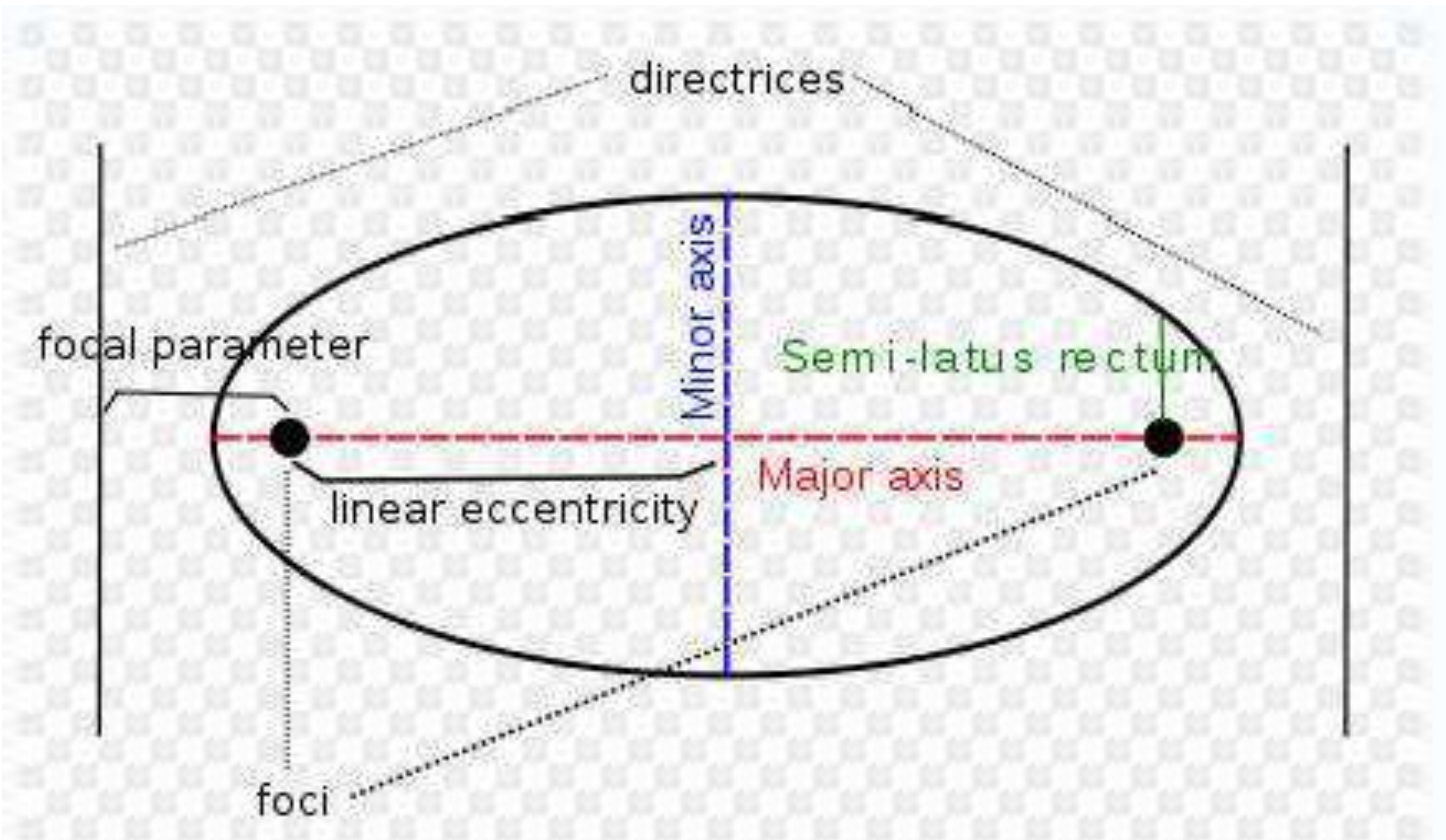
Conic sections are always "smooth". More precisely, they never contain any inflection points. This is important for many applications, such as aerodynamics, civil engg., mechanical engg, etc.

Conic

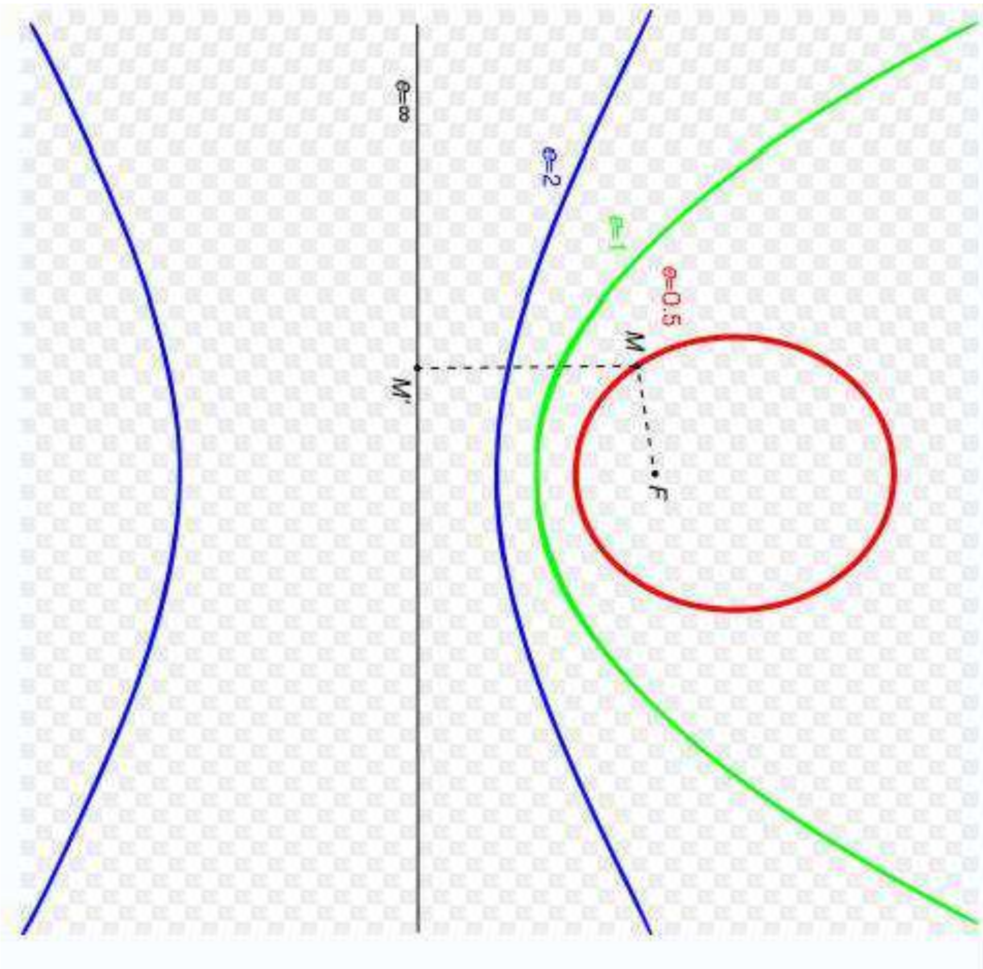
Conic is defined as the locus of a point moving in a plane such that the ratio of its distance from a fixed point and a fixed straight line is always constant.

Fixed point is called Focus

Fixed line is called Directrix



$$\text{Eccentricity} = \frac{\text{Distance of the point from the focus}}{\text{Distance of the point from the directric}}$$



When eccentricity

< 1 € Ellipse

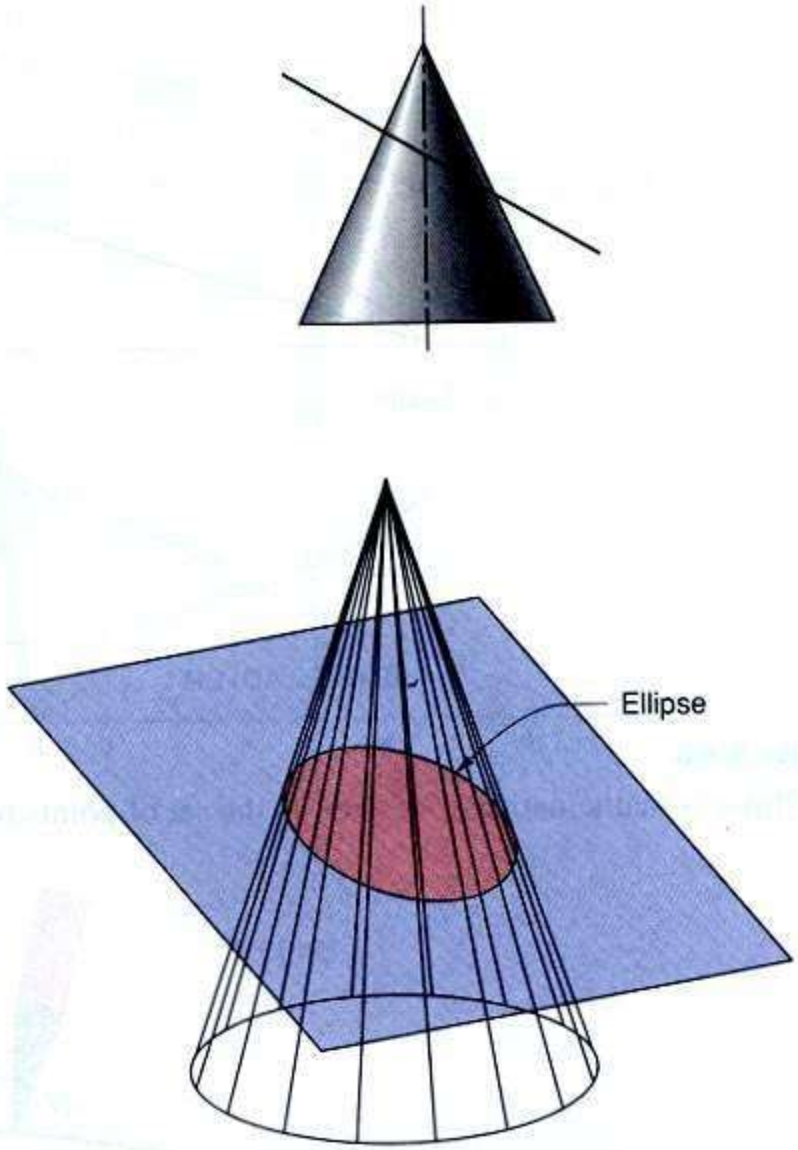
=1 € Parabola

> 1 € Hyperbola

eg. when *e*=1/2, the curve is an Ellipse, when *e*=1, it is a parabola and when e=2, it is a hyperbola.

Ellipse

An ellipse is obtained when a section plane, inclined to the axis, cuts all the generators of the cone.

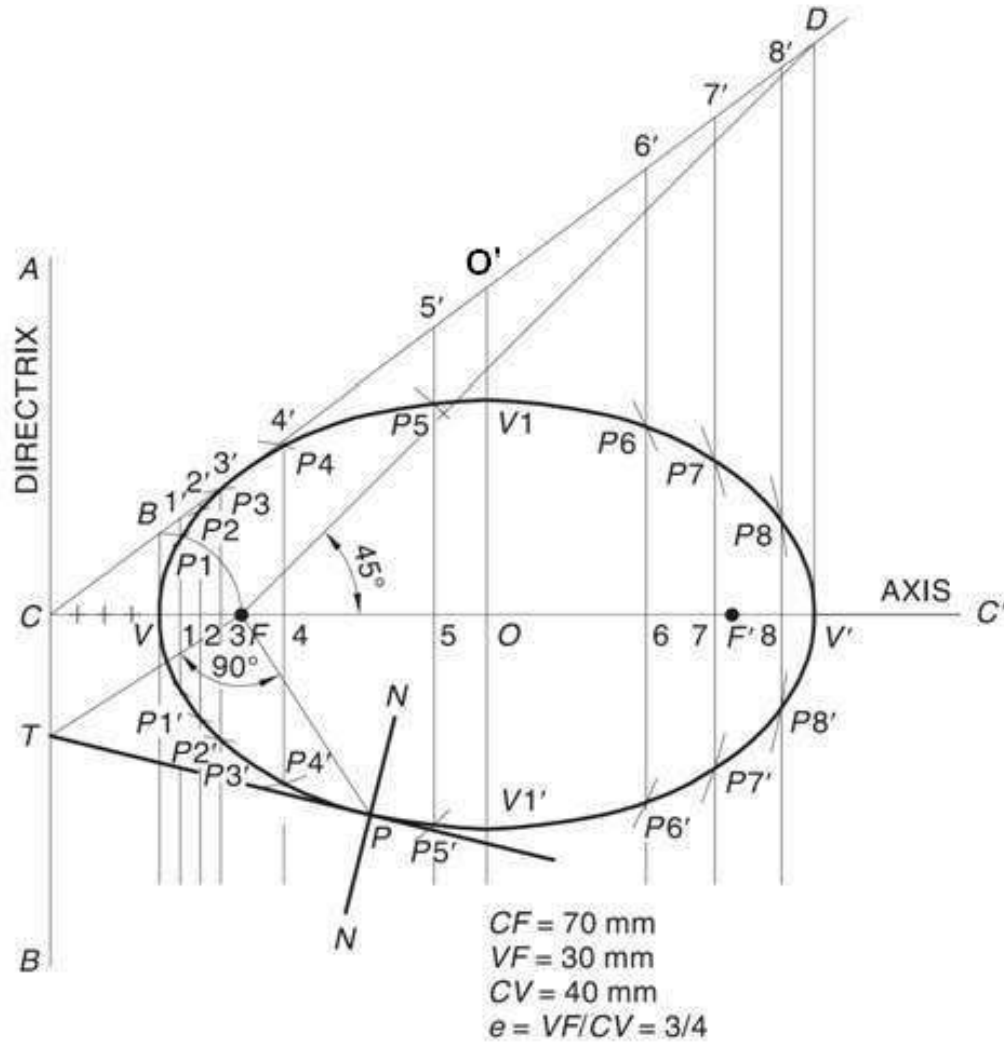


Focus-Directrix or Eccentricity Method

Given : the distance of focus from the directrix and eccentricity

Example : Draw an ellipse if the distance of focus from the directrix is 70 mm and the eccentricity is 3/4.

1. Draw the directrix AB and axis CC'
2. Mark F on CC' such that CF = 70 mm.
3. Divide CF into 7 equal parts and mark V at the fourth division from C. Now, e = FV/ CV = 3/4.
4. At V, erect a perpendicular VB = VF. Join CB. Through F, draw a line at 45° to meet CB produced at D. Through D, drop a perpendicular DV' on CC'. Mark O at the midpoint of V– V'.

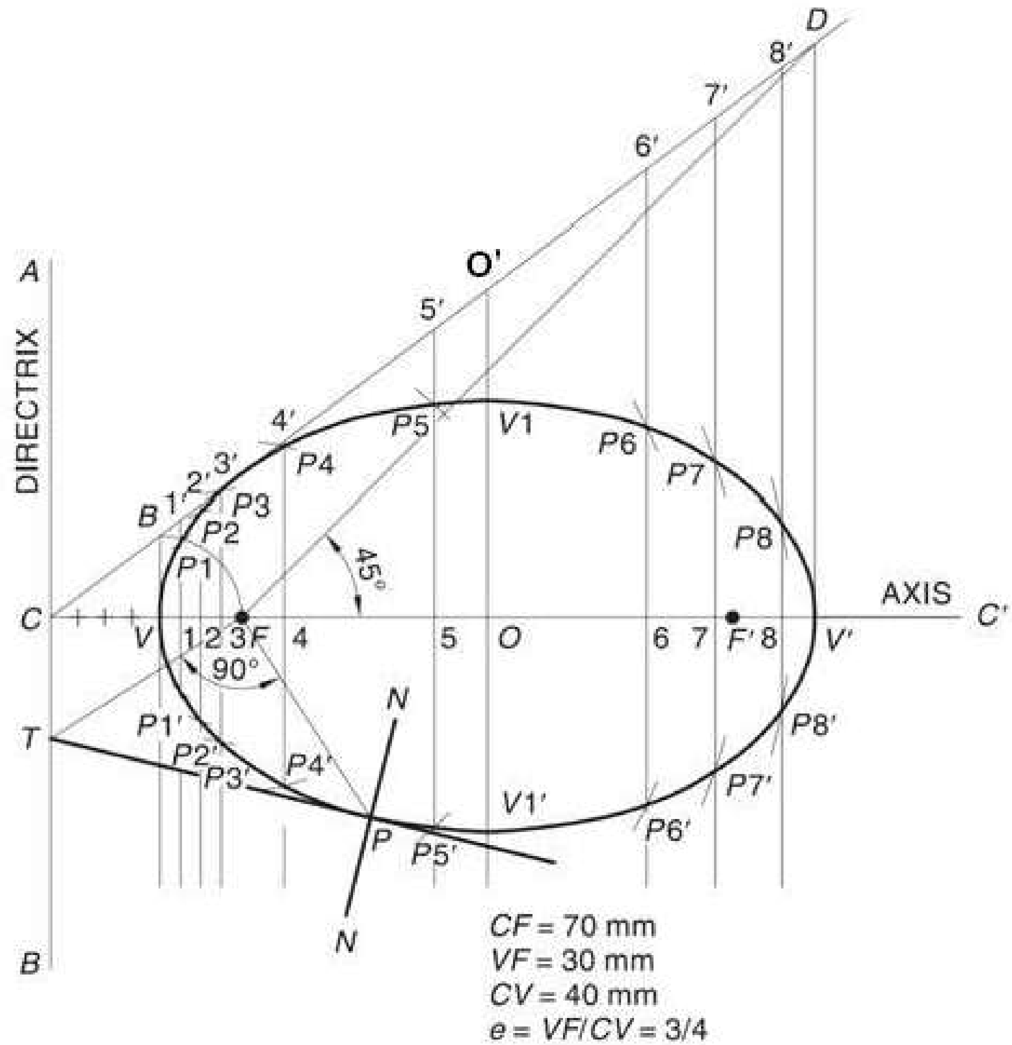


Focus-Directrix or Eccentricity Method (Continued)

5. With F as a centre and radius = 1–1', cut two arcs on the perpendicular through 1 to locate P1 and P1'. Similarly, with F as centre and radii = 2–2', 3–3', etc., cut arcs on the corresponding perpendiculars to locate P2 and P2', P3 and P3', etc. Also, cut similar arcs on the perpendicular through O to locate V1 and V1'.

6. Draw a smooth closed curve passing through V, P1, P/2, P/3, …, V1, …, V', …, V1', … P/3', P/2', P1'.

7. Mark F' on CC' such that V' F' = VF.



ME 111: Engineering Drawing

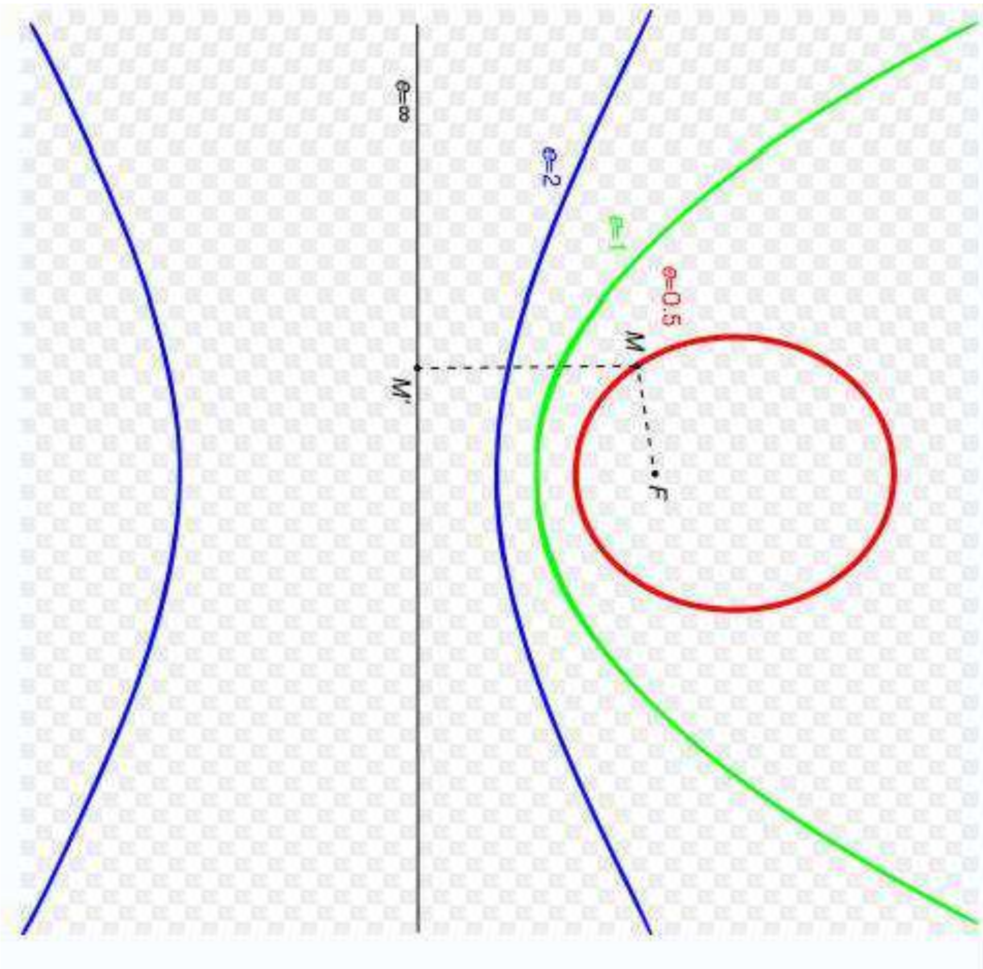
Lecture 4

08-08-2011

Engineering Curves and Theory of Projection

Indian Institute of Technology Guwahati
Guwahati – 781039

$$\text{Eccentrici ty} = \frac{\text{Distance of the point from the focus}}{\text{Distance of the point from the directric}}$$



When eccentricity

< 1 € Ellipse

=1 € Parabola

> 1 € Hyperbola

eg. when *e*=1/2, the curve is an Ellipse, when *e*=1, it is a parabola and when e=2, it is a hyperbola. [2]

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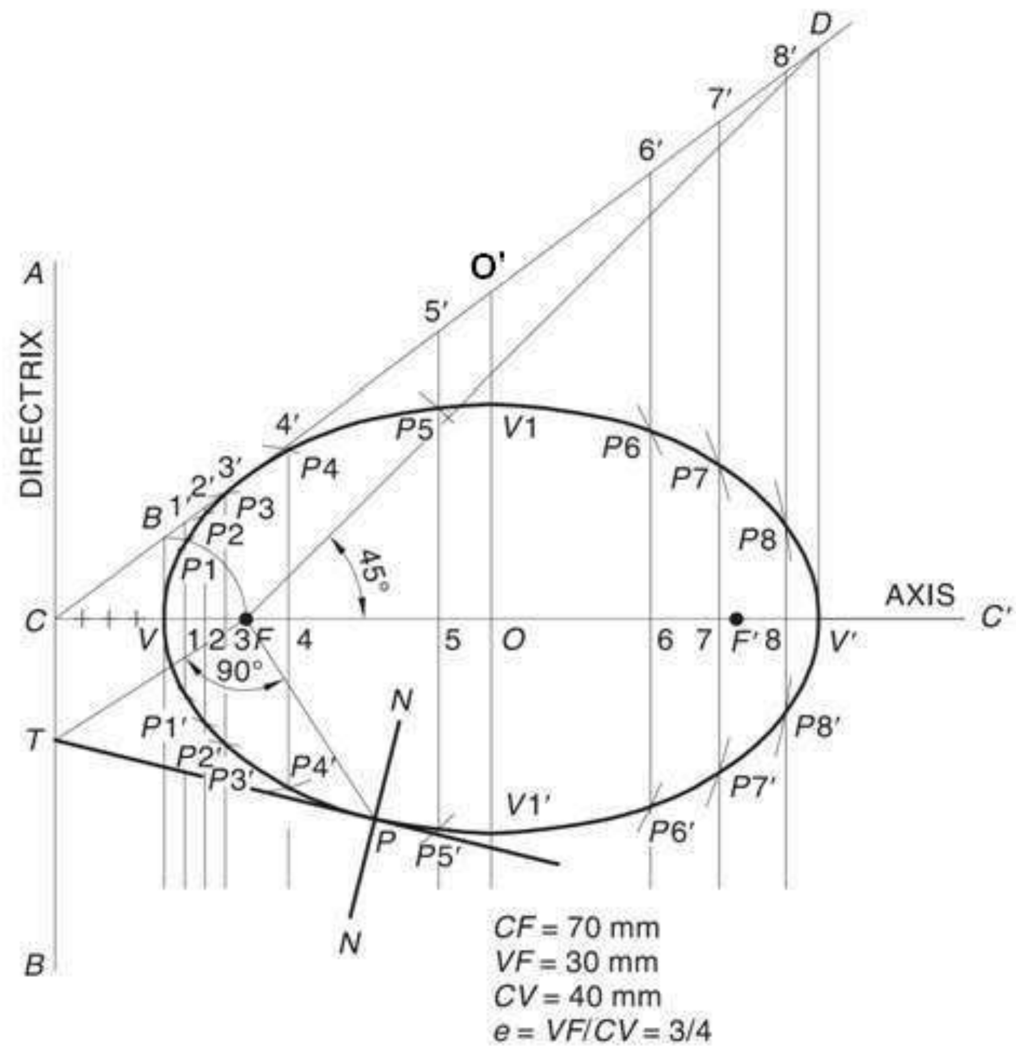

Focus-Directrix or Eccentricity Method (Continued)

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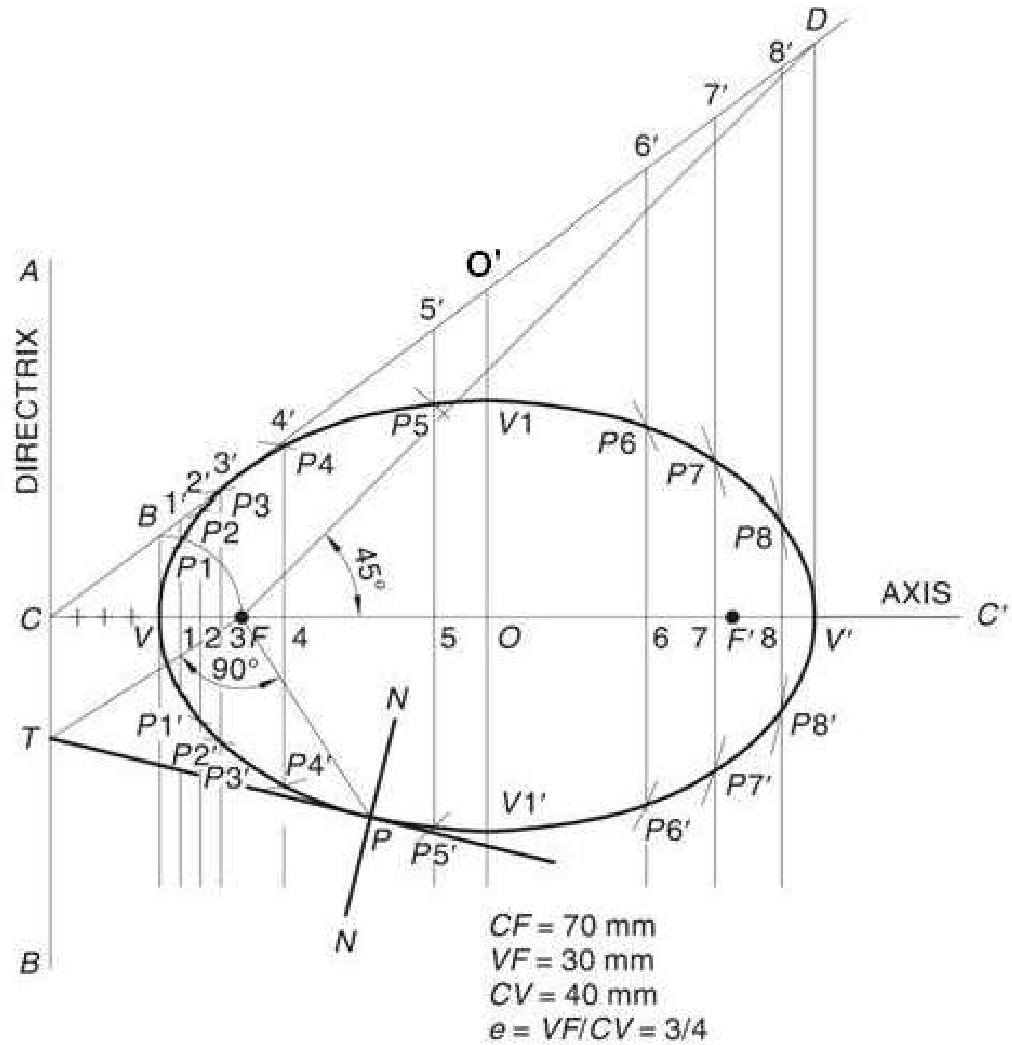
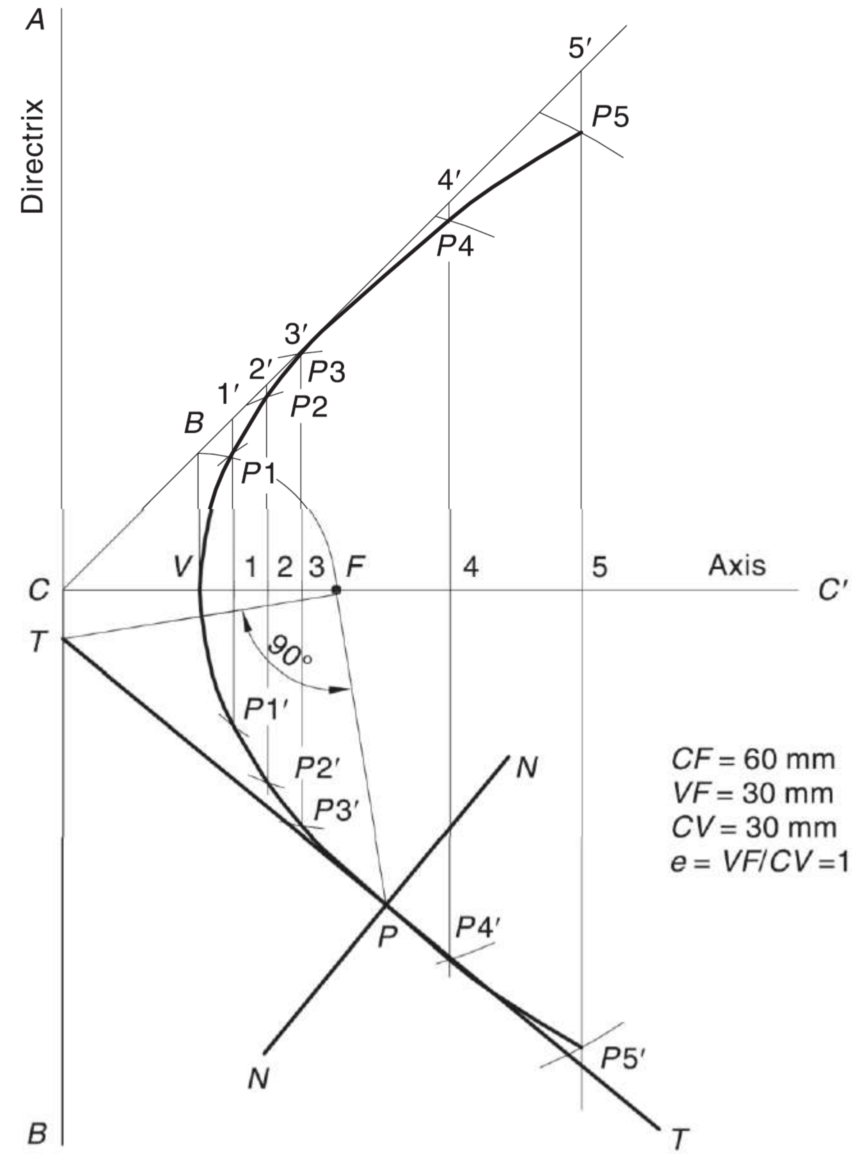
7. Mark F' on CC' such that V' F' = VF.



Constructing a Parabola (<u>Eccentricity Method</u>)

<u>Example.</u> Draw a parabola if the distance of the focus from the directrix is 60 mm.

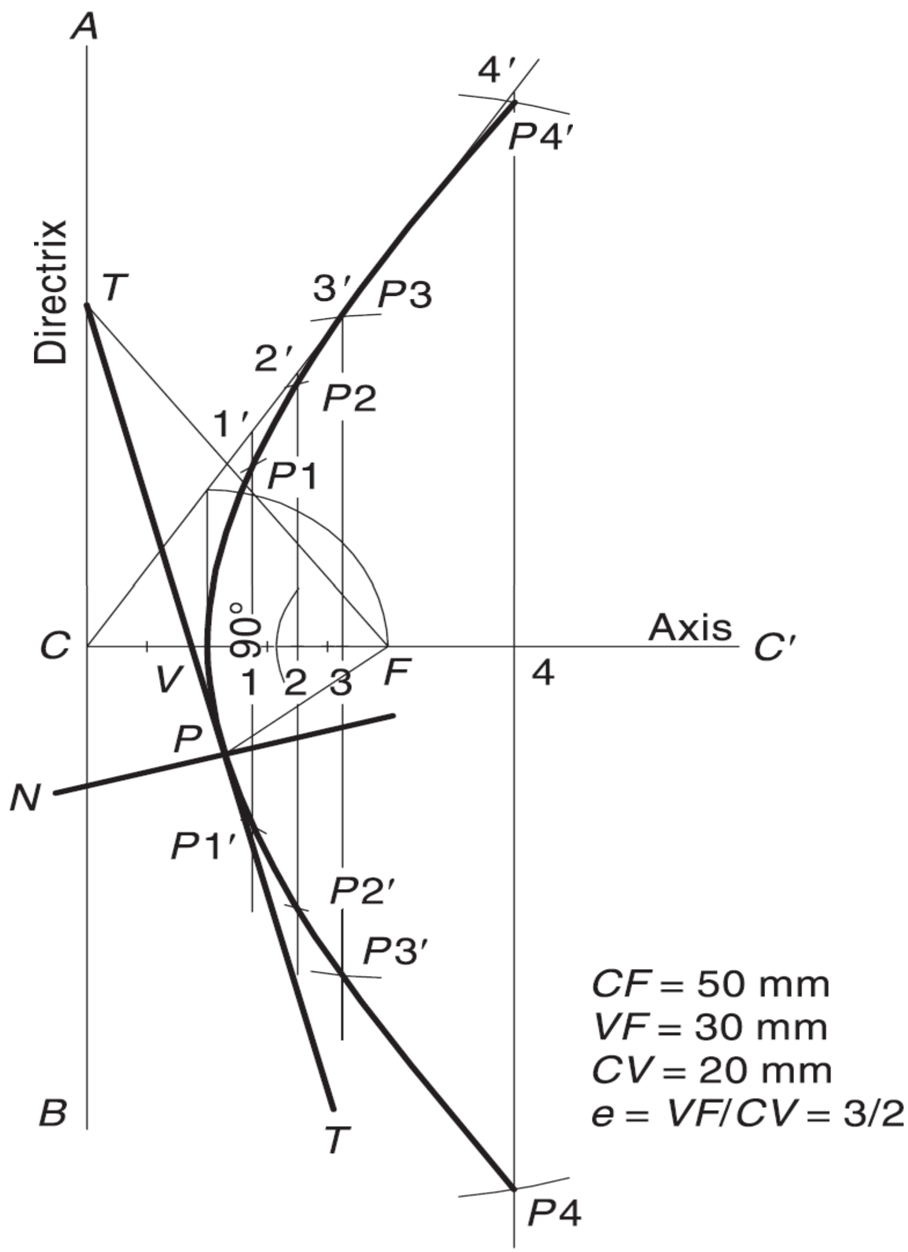
1. Draw directrix AB and axis CC' as shown.
2. Mark F on CC' such that CF = 60 mm.
3. Mark V at the midpoint of CF. Therefore, e = VF/ VC = 1.
4. At V, erect a perpendicular VB = VF. Join CB.
5. Mark a few points, say, 1, 2, 3, … on VC' and erect perpendiculars through them meeting CB produced at 1', 2', 3', …
6. With F as a centre and radius = 1–1', cut two arcs on the perpendicular through 1 to locate P1 and P1'. Similarly, with F as a centre and radii = 2–2', 3–3', etc., cut arcs on the corresponding perpendiculars to locate P2 and P2', P3 and P3', etc.
7. Draw a smooth curve passing through V, P1, P2, P3 … P3', P2', P1'.



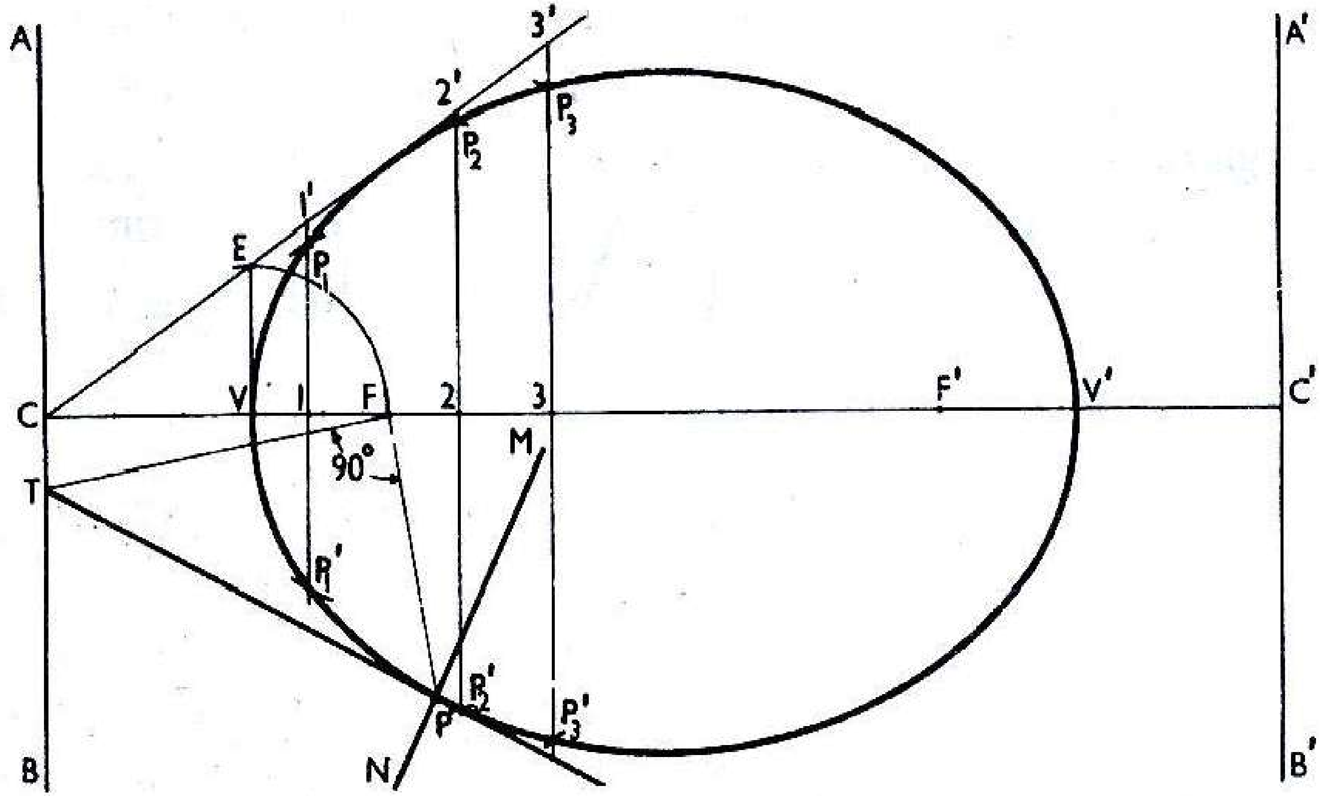
Constructing a Hyperbola (<u>Eccentricity Method</u>)

Draw a hyperbola of e = 3/2 if the distance of the focus from the directrix = 50 mm.

Construction similar to ellipse and parabola



Drawing Tangent and Normal to any conic

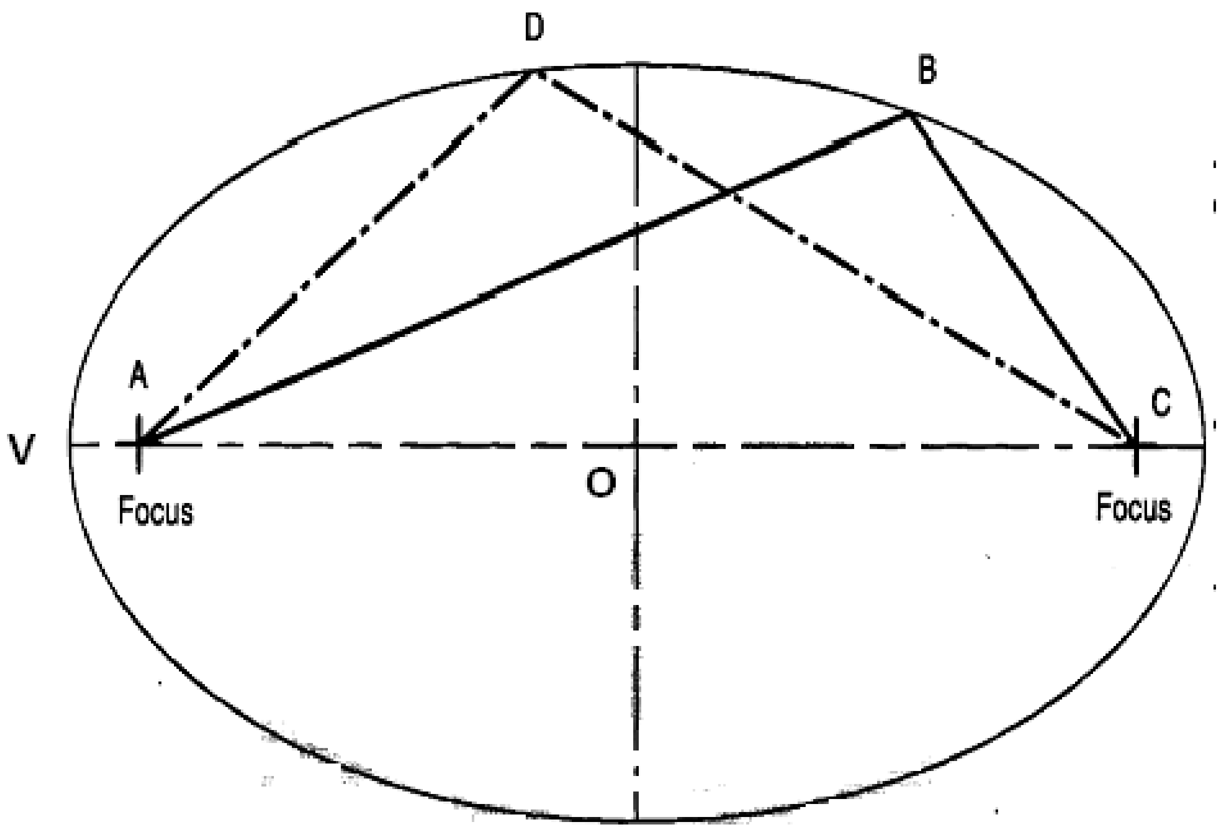


When a tangent at any point on the curve (P) is produced to meet the directrix, the line joining the focus with this meeting point (FT) will be at right angle to the line joining the focus with the point of contact (PF).

The normal to the curve at any point is perpendicular to the tangent at that point.

Another definition of the ellipse

An ellipse is the set of all points in a plane for which the sum of the distances from the two fixed points (the foci) in the plane is constant.



AB + BC = AD + DC = AV + VC

Arcs of Circle Method

Given conditions: (1) the major axis and minor axis are known **OR**

(2) the major axis and the distance between the foci are known

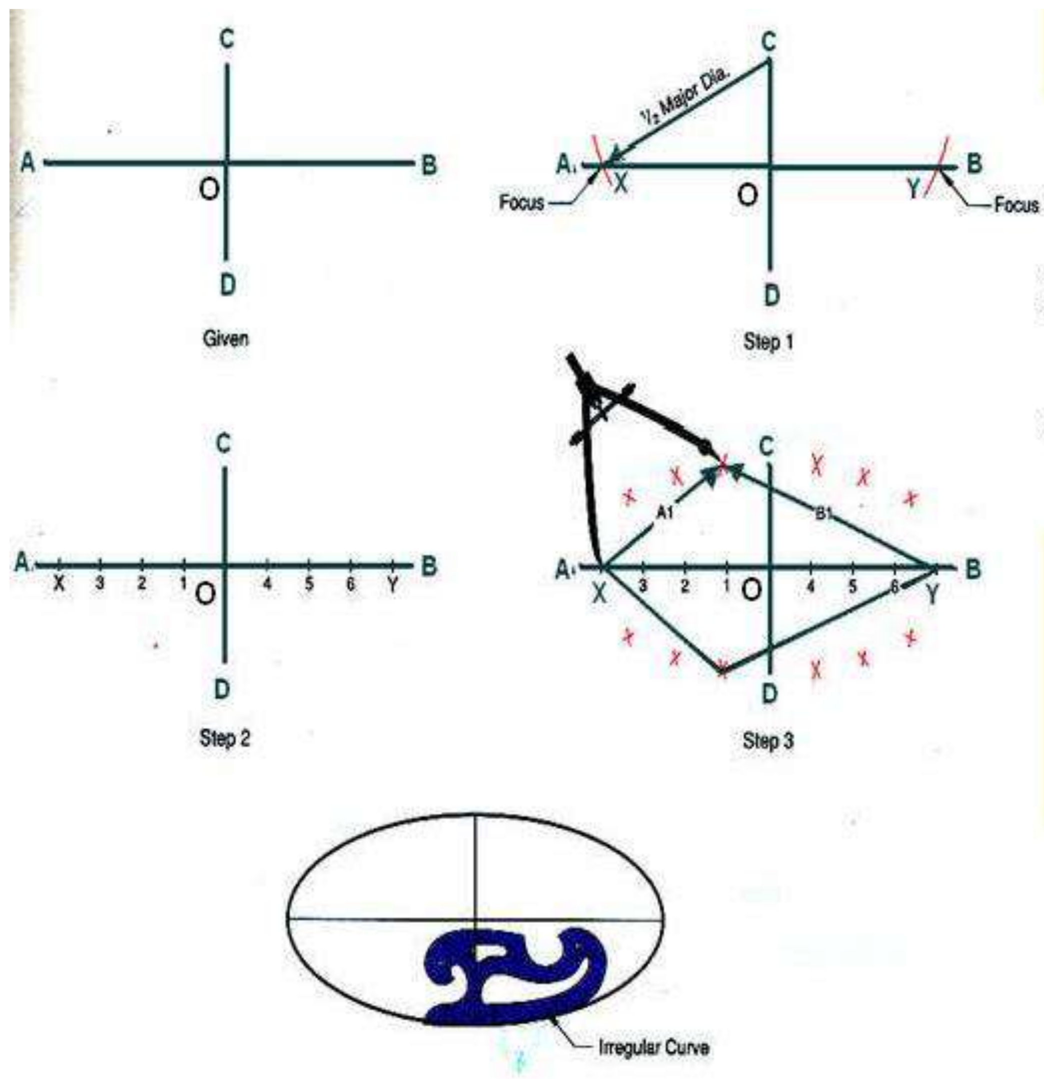
Draw AB & CD perpendicular to each other as the major diameter minor diameter respectively.

With centre as C or D, and half the major diameter as radius draw arcs to intersect the major diameter to obtain the foci at X and Y.

Mark a numbe of points along line segment XY and number them. Points need not be equidistant.

Set the compass to radius B-1 and draw two arcs, with Y as center. Set the compass to radius A1, and draw two arcs with X as center. Intersection points of the two arcs are points on the ellipse. Repeat this step for all the remaining points.

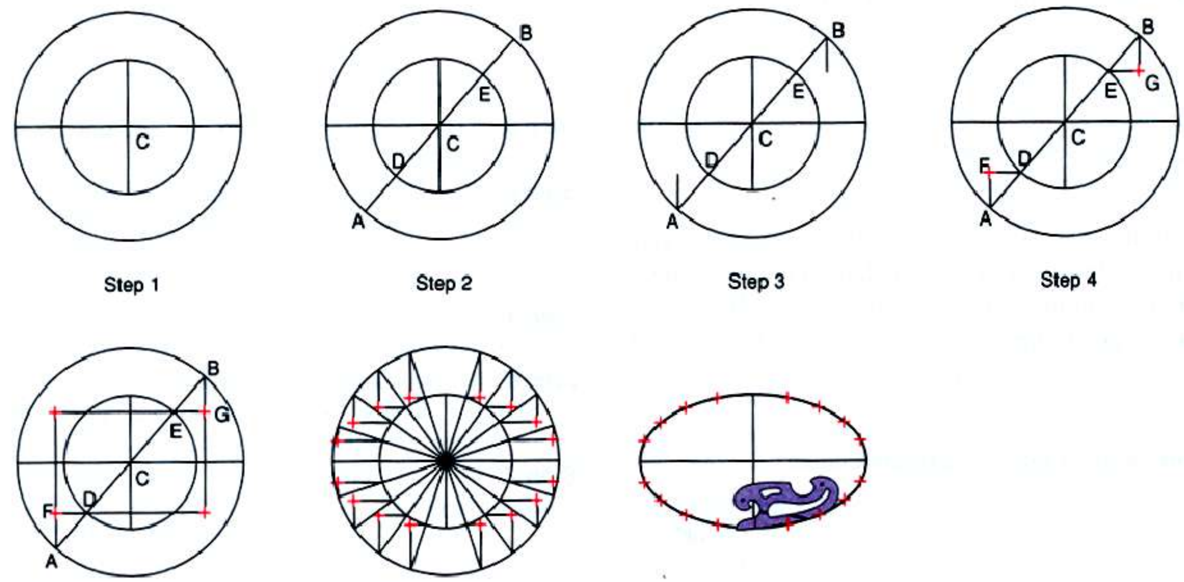
Use the French curve to connect the points, thus drawing the ellipse.



Constructing an Ellipse (Concentric Circle Method)

Given:

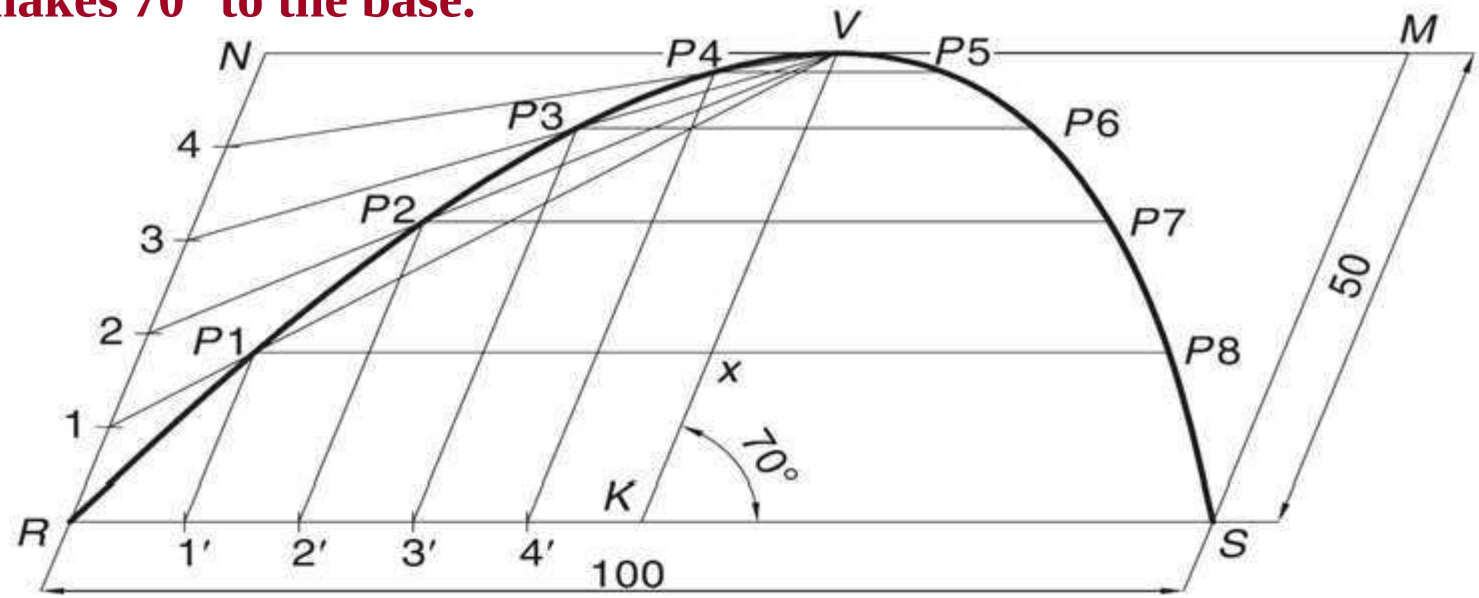
Major axis and minor axis



- **With center C, draw two concentric circles with diameters equal to major and minor diameters of the ellipse. Draw the major and minor diameters.**
- **Construct a line AB at any angle through C. Mark points D and E where the line intersects the smaller circle.**
- **From points A and B, draw lines parallel to the minor diameter. Draw lines parallel to the major diameter through D & E.**
- **The intersection of the lines from A and D is point F, and from B and E is point G. Points F & G lies on the ellipse.**
- **Extend lines FD & BG and lines AF and GE to obtain two more points in the other quadrants.**
- **Repeat steps 2-6 to create more points in each quadrant and then draw a smooth curve through the points.**

Constructing a Parabola (<u>Parallelogram Method</u>)

<u>Example</u>: Draw a parabola of base 100 mm and axis 50 mm if the axis makes 70° to the base.

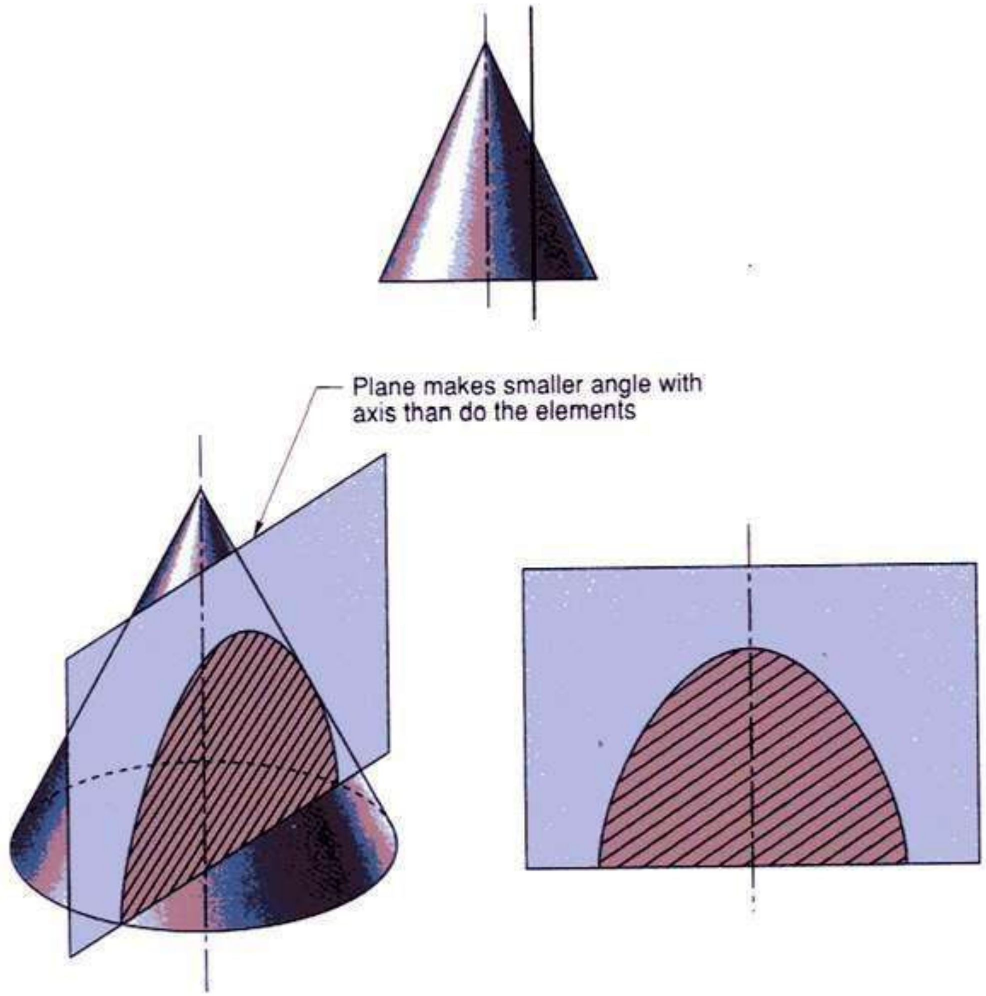


1. **Draw the base RS = 100 mm and through its midpoint K, draw the axis KV = 50 mm, inclined at 70° to RS. Draw a parallelogram RSMN such that SM is parallel and equal to KV.**
2. **Divide RN and RK into the same number of equal parts, say 5. Number the divisions as 1, 2, 3, 4 and 1', 2', 3', 4', starting from R.**
3. **Join V–1, V–2, V–3 and V–4. Through 1', 2', 3' and 4', draw lines parallel to KV to meet V–1 at P1, V–2 at P2, V–3 at P3 and V–4 at P4, respectively.**
4. **Obtain P5, P6, P7 and P8 in the other half of the rectangle in a similar way. Alternatively, these points can be obtained by drawing lines parallel to RS through P1, P2, P3 and P4. For example, draw P1– P8 such that P1– x = x– P8. Join P1, P2, P3 … P8 to obtain the parabola.**

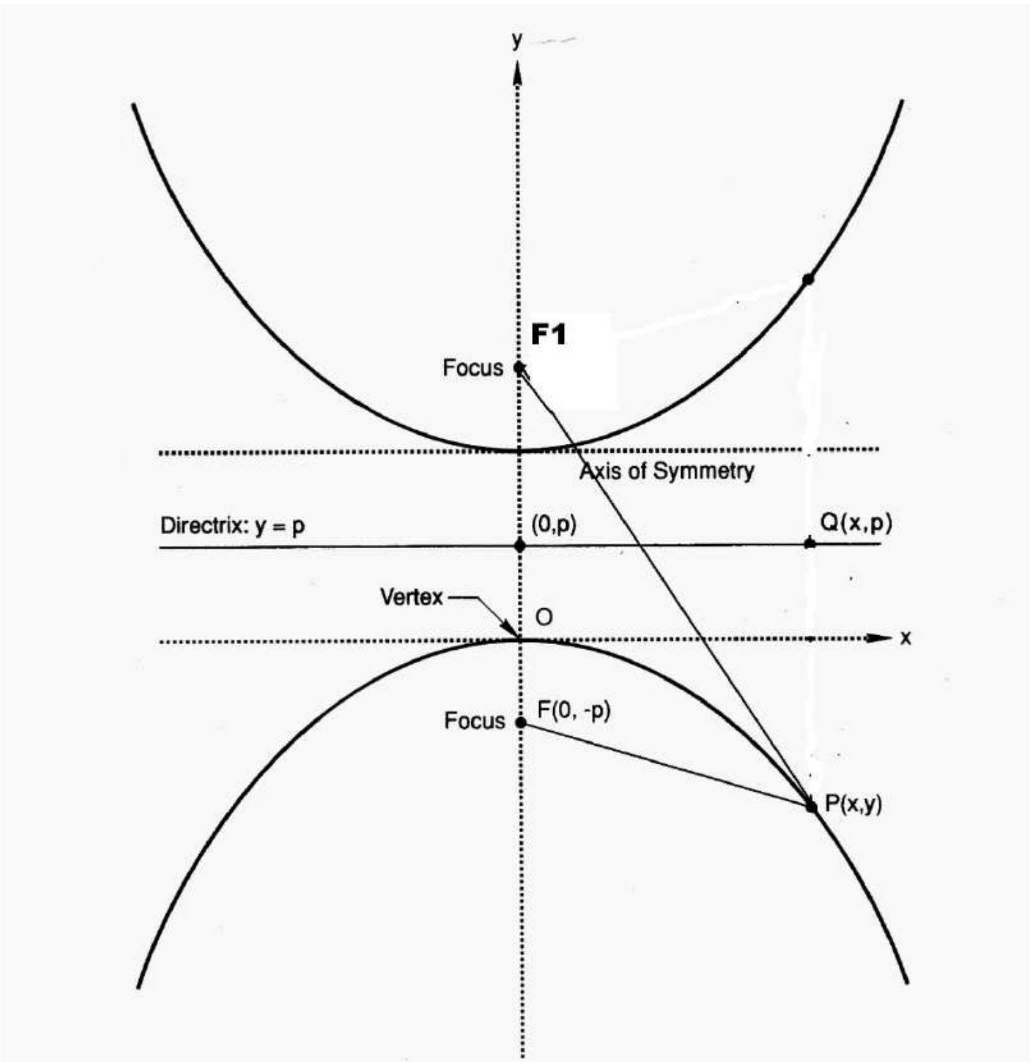
Hyperbola

A Hyperbola is obtained when a section plane, parallel/inclined to the axis cuts the cone on one side of the axis.

A Rectangular Hyperbola is obtained when a section, parallel to the axis cuts the cone on one side of the axis.



Hyperbola **Mathematical definition**



A hyperbola is defined as the set of points in a plane whose distances from two fixed points called foci, in the plane have a constant difference.

Constructing a Hyperbola

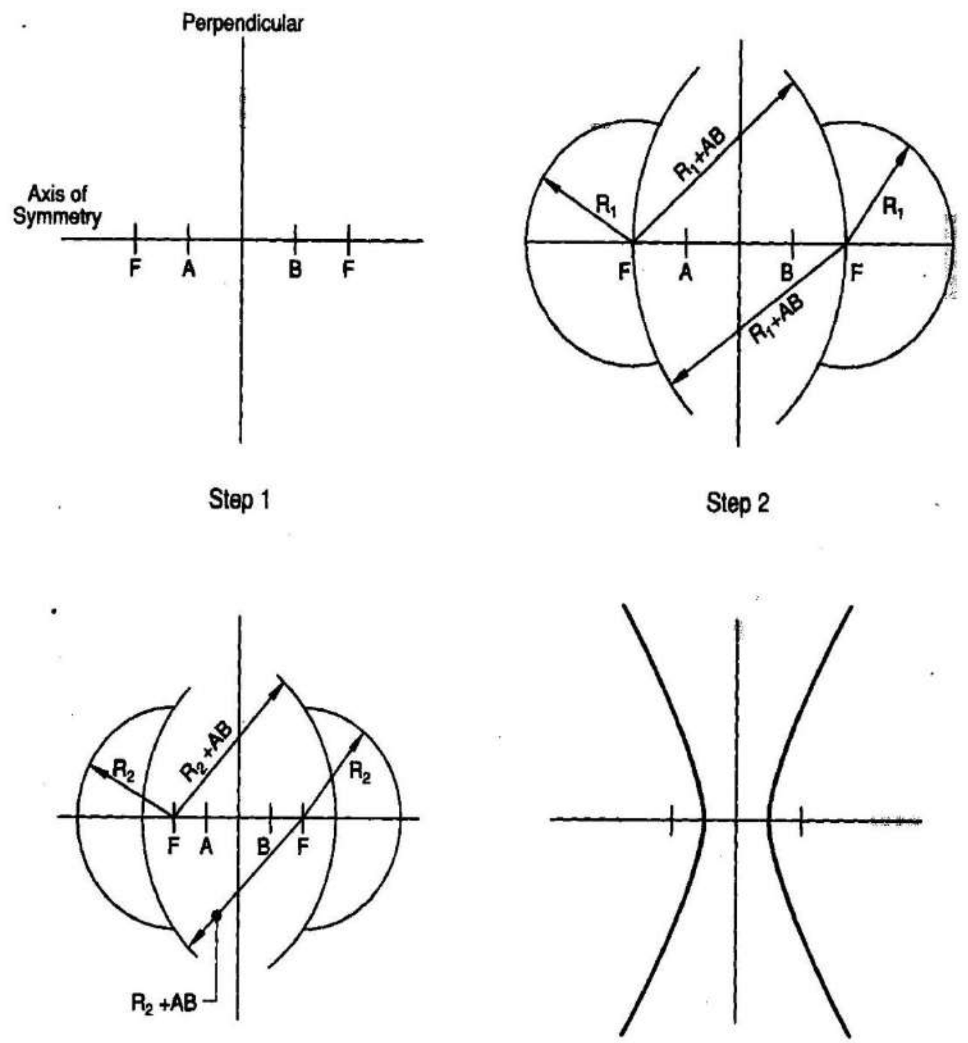
Given: Distance between Foci and Distance between vertices

Draw the axis of symmetry and construct a perpendicular through the axis. Locate focal point **F** equidistant from the perpendicular and on either side of it. Locate points **A** and **B** on the axis equidistant from the perpendicular.

AB is the distance between vertices

With F as center and radius **R1**, and draw the arcs. With **R1** + **AB**, radius, and F as center, draw a second set of arcs. The intersection of the two arcs on each side of the perpendicular are points on the hyperbola

Select a new radius **R2** and repeat step 2. Continue this process until several points on the hyperbola are marked



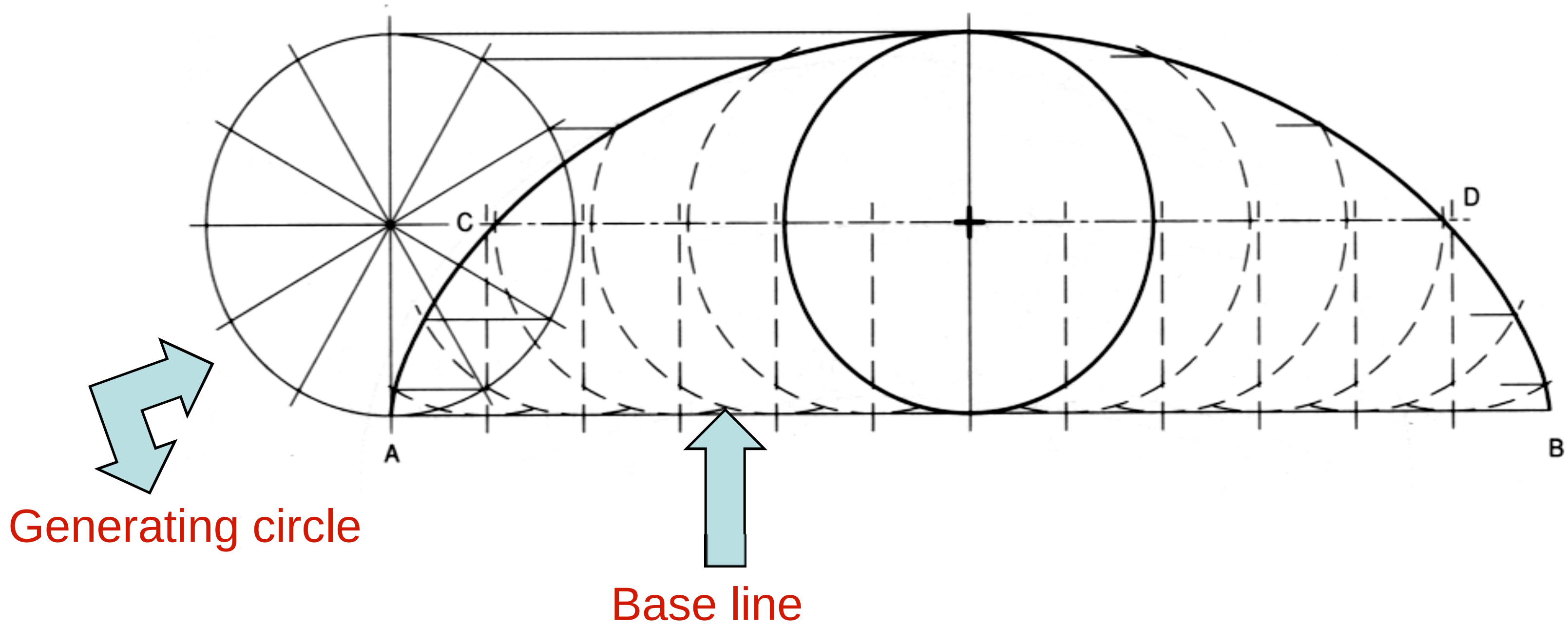
Roulettes

- **Roulettes are curves generated by the rolling contact of one curve or line on another curve or line, without slipping.**

- **There are various types of roulettes.**

- **The most common types of roulettes used in engineering practice are: Cycloids, Trochoids, and Involutes.**

Cycloid

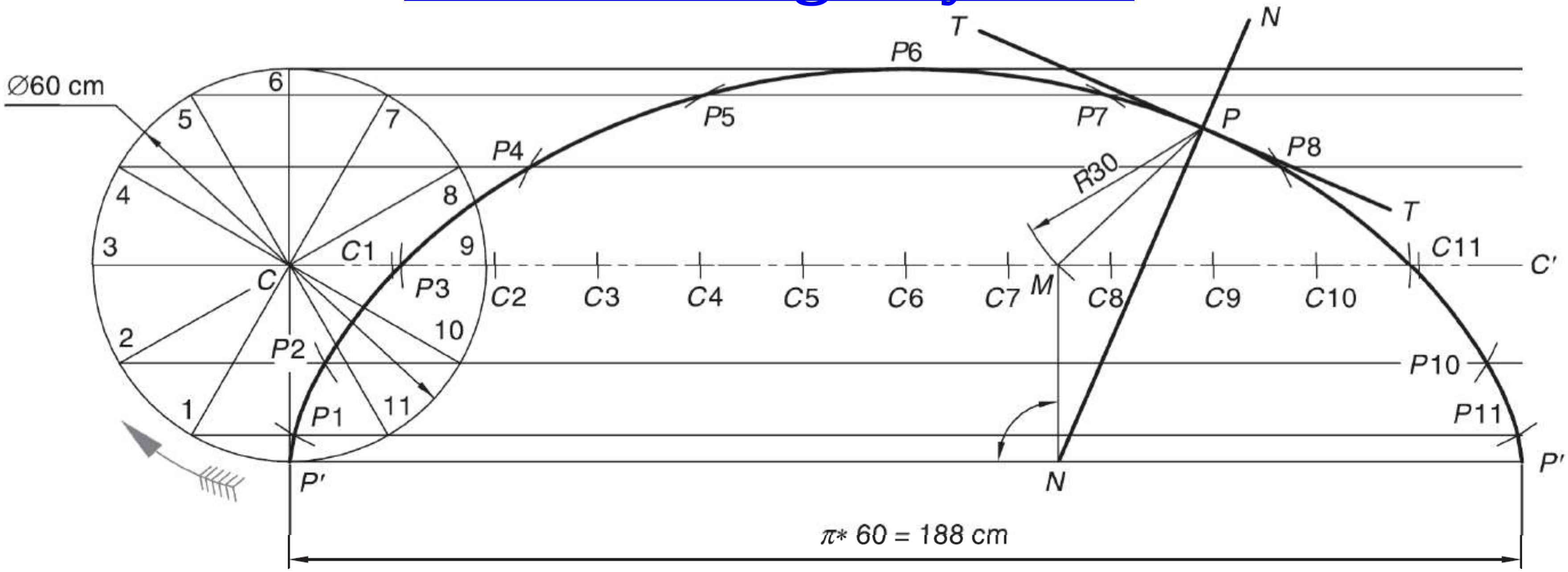


A Cycloid is generated by a point on the circumference of a circle rolling along a straight line without slipping

The rolling circle is called the Generating circle

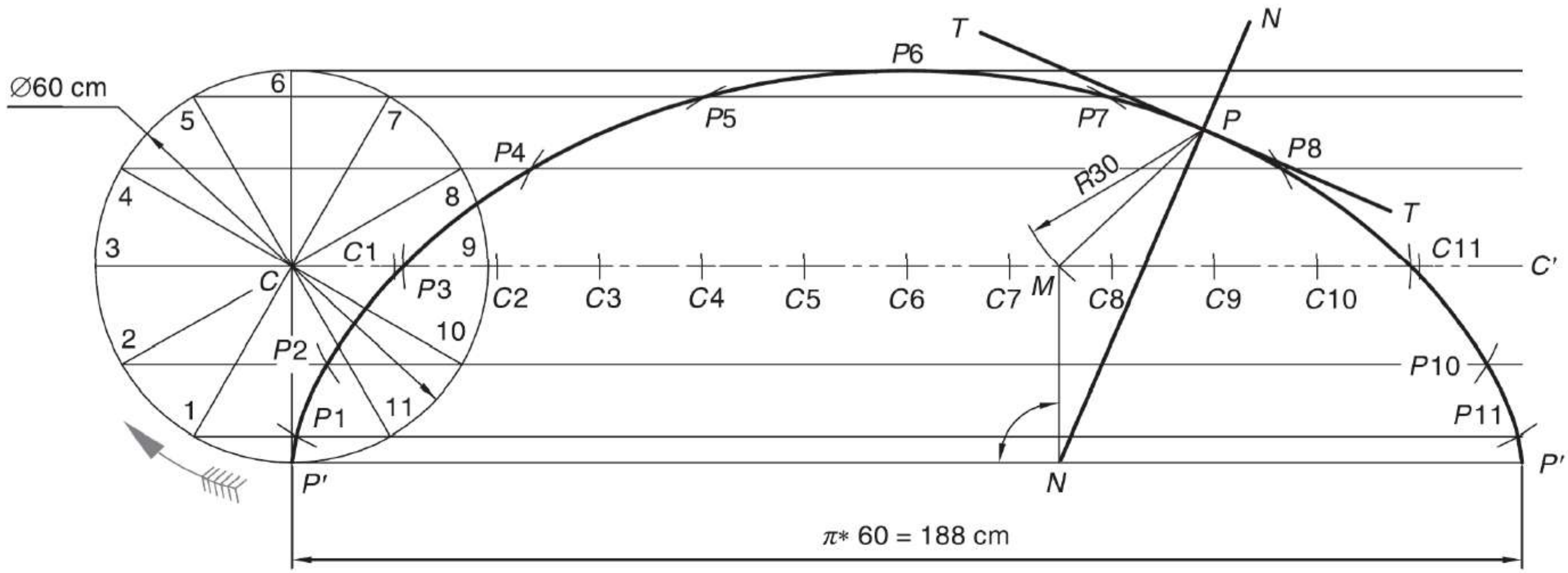
The straight line is called the Directing line or Base line

Constructing a cycloid



- Generating circle has its center at C and has a radius of C-P'. Straight line PP' is equal in length to the circumference of the circle and is tangent to the circle at point P'.
- Divide the circle into a number of equal segments, such as 12. Number the intersections of the radii and the circle.
- From each point of intersection on the circle, draw a construction line parallel to line PP' and extending up to line P'C'.
- Divide the line CC' into the same number of equal parts, and number them. Draw vertical lines from each point to intersect the extended horizontal centerline of the circle. Label each point as C1, C2, C3, …. C12.

Constructing a cycloid (contd.)

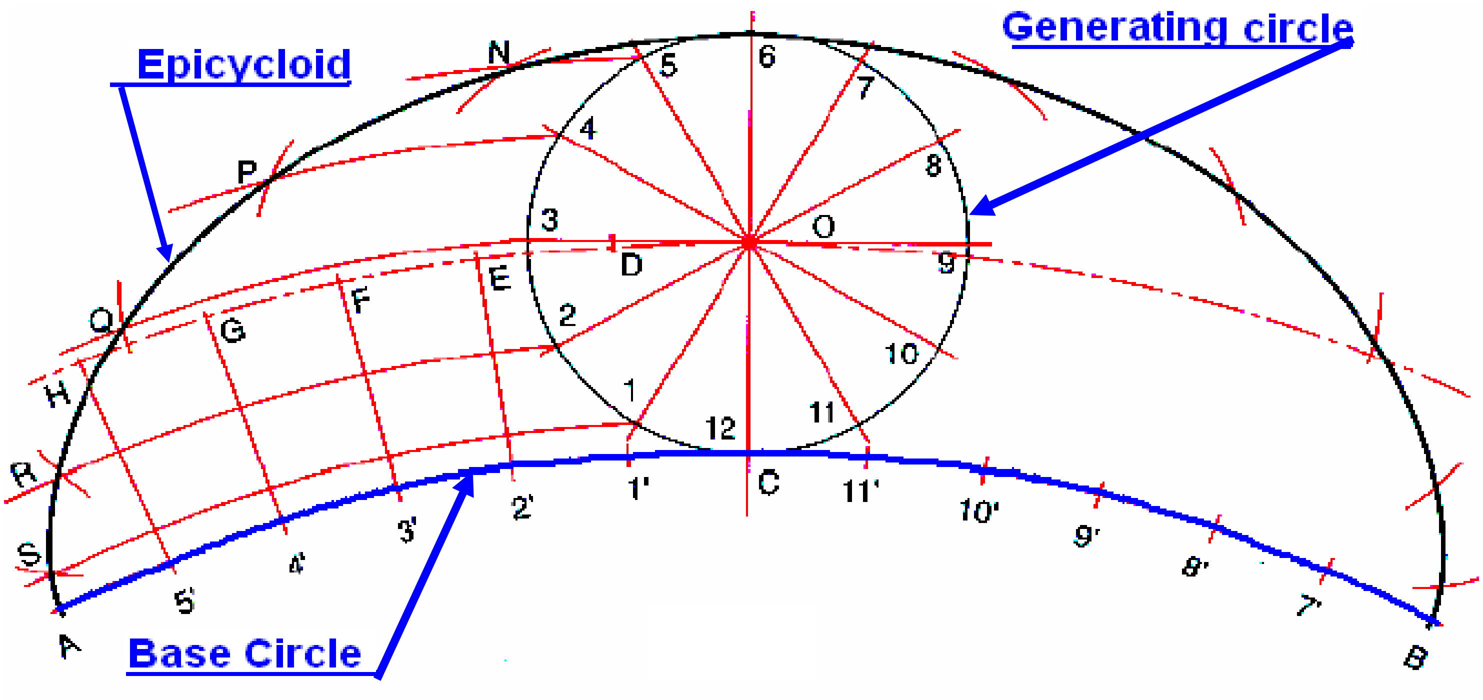


Using point C1 as the center and radius of the circle C-P', draw an arc that intersects the horizontal line extended from point 1 at P1. Set the compass at point C2, then draw an arc that intersects the horizontal line passing through point 2 at P2. Repeat this process using points C3, C4, …. C12, to locate points along the horizontal line extended from points 3, 4, 5, etc..

Draw a smooth curve connecting P1, P2, P3, etc to form the cycloid

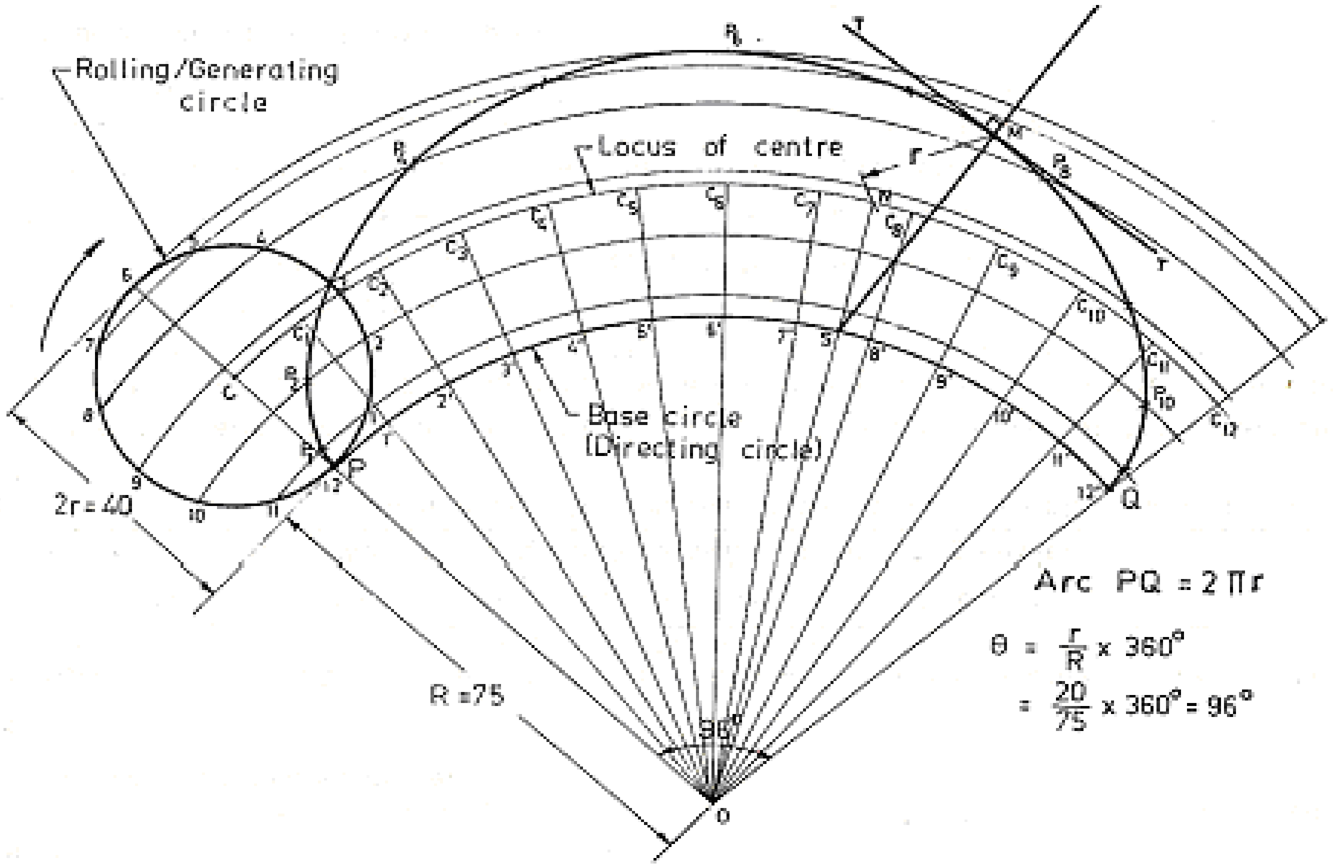
Draw normal NN and Tangent TT

Epicycloid



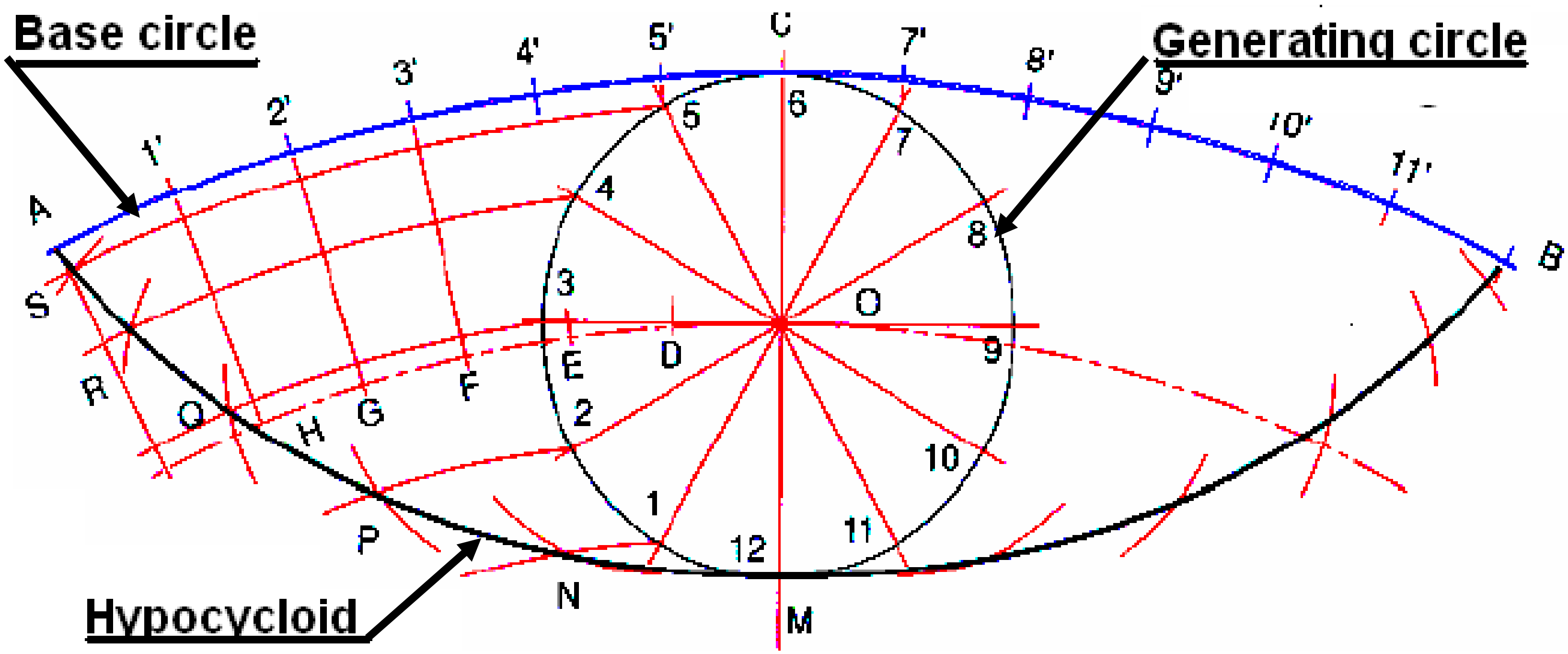
The cycloid is called Epicycloid when the generating circle rolls along another circle outside it.

Constructing an Epicycloid



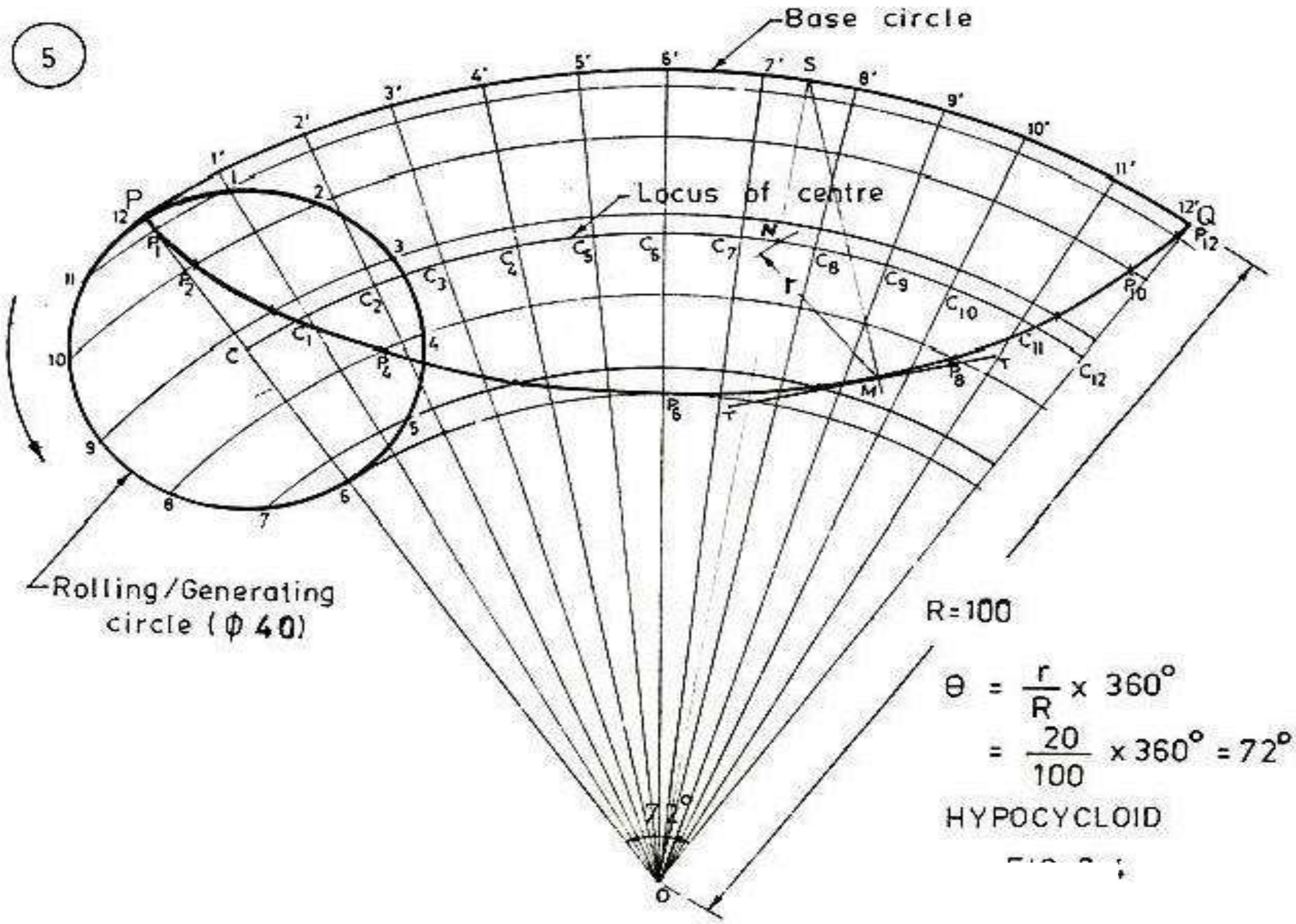
1) With O as centre and OC as radius, draw an arc to represent locus of centre.
2) Divide arc PQ in to 12 equal parts and name them as 1’, 2’, …., 12’.
3) Join O1’, O2’, … and produce them to cut the locus of centres at C1, C2, ….
4) Taking C1 as centre, and radius equal to 20 mm, draw an arc cutting the arc through 1 at P1. Similarly obtain points P2, P3,…., P12.
5) Join P1, P2….. With French curve

Hypocycloid



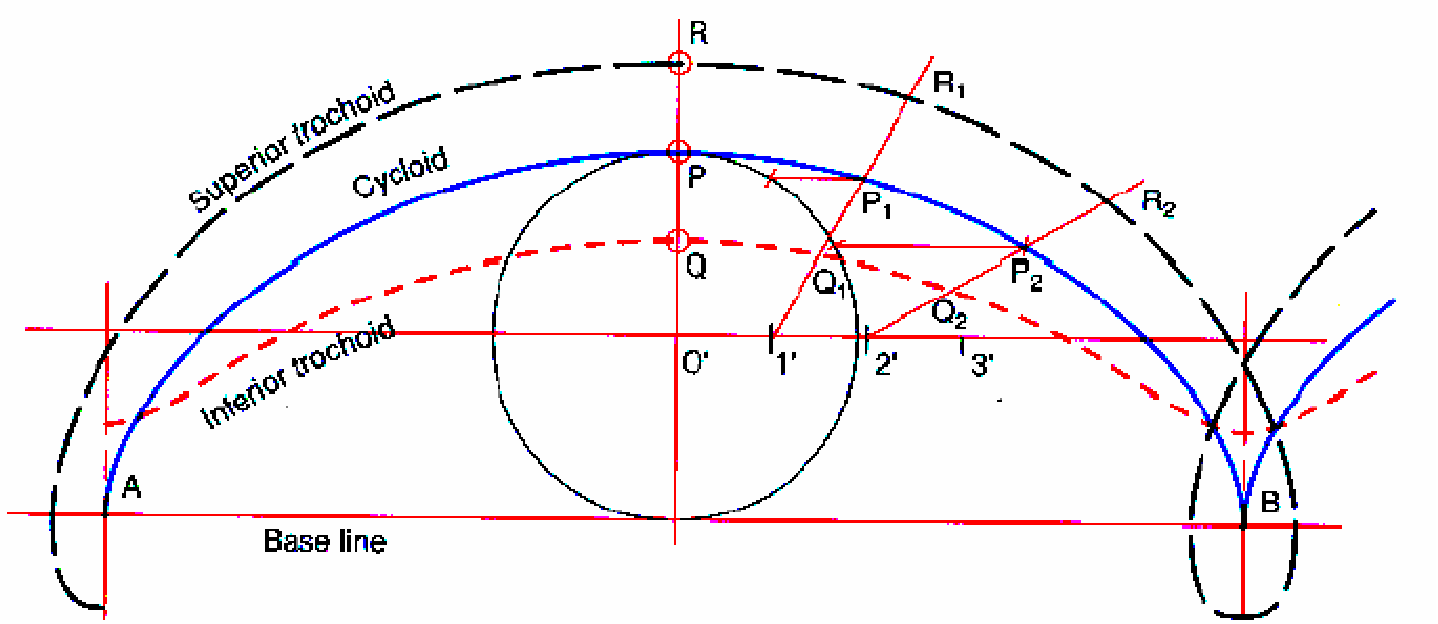
Hypocycloid is obtained when the generating circle rolls along another circle inside it.

Constructing an Hypocycloid



Construction is similar to epicycloid. The generating circle is to be drawn below the base circle

Trochoid

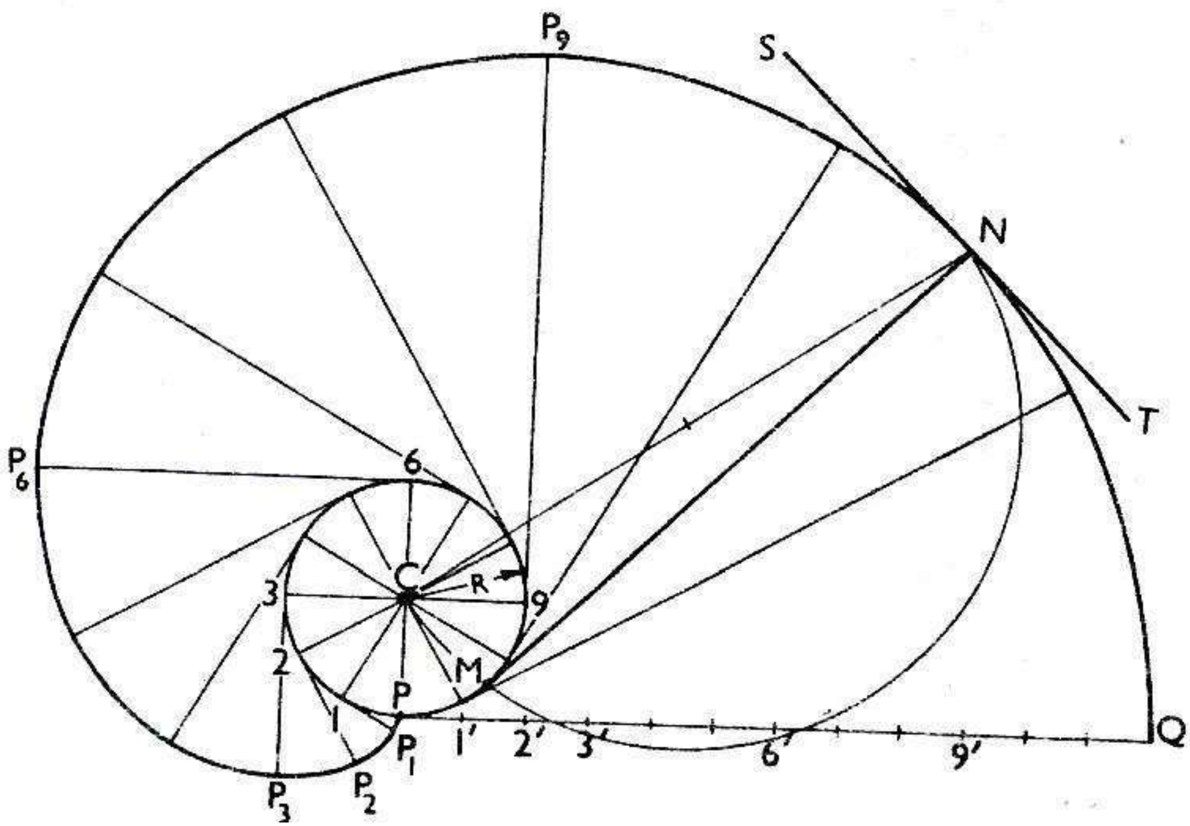


- ***Trochoid*** **is a curve generated by a point outside or inside the circle rolling along a straight line.**
- **If the point is outside the circle the curve obtained is called *Superior Trochoid***
- **If the point is inside the circle, the curve obtained is called *Inferior Trochoid***

Classification of Cycloidal curves

	Generating Circle			
		On the directing line	Outside the directing line	Inside the directing line
Generating point	On the generating circle	Cycloid	Epicycloid	Hypocycloid
	Outside the generating circle	Superior trochoid	Superior epitrochoid	Superior Hypotrochoid
	Inside the generating circle	Inferior trochoid	Inferior epitrochoid	Inferior hypotrochoid

Involute



An *Involute* is a curve traced by the free end of a thread unwound from a circle or a polygon in such a way that the thread is always tight and tangential to the circle or side of the polygon

Construction of Involute of circle

Draw the circle with c as center and CP as radius.

Draw line PQ = 2πCP, tangent to the circle at P

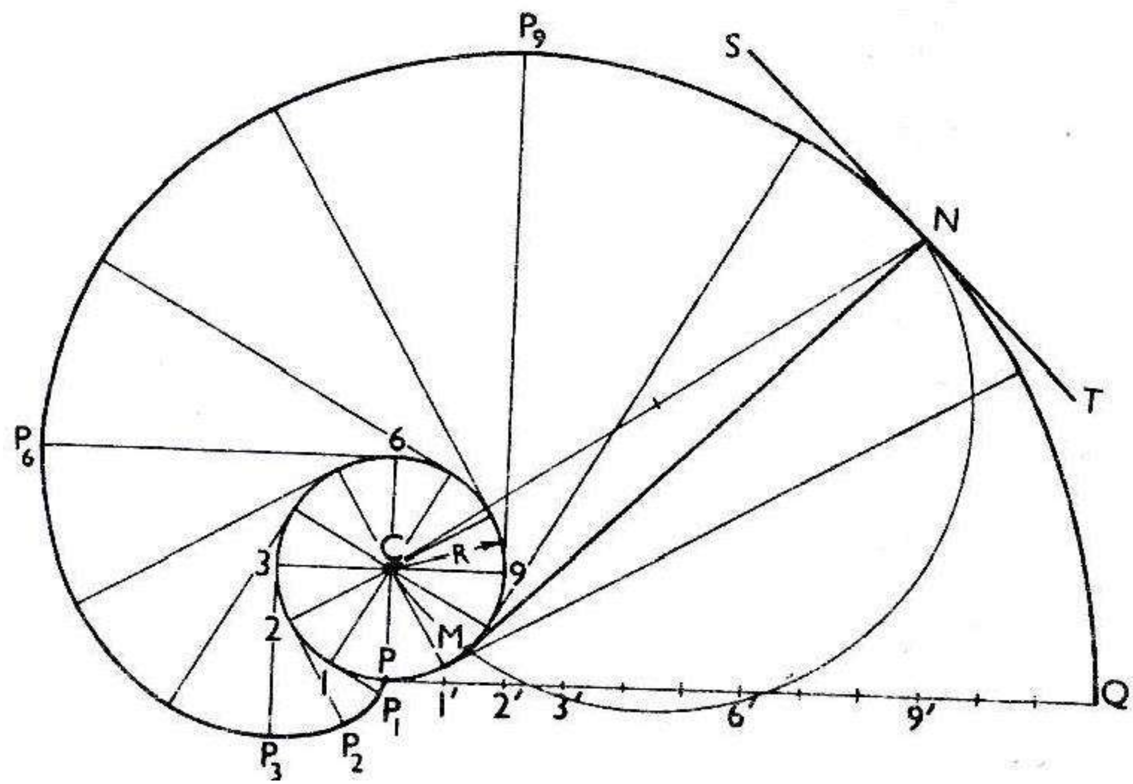
Divide the circle into 12 equal parts. Number them as 1, 2…

Divide the line PQ into 12 equal parts and number as 1´, 2´…..

Draw tangents to the circle at 1, 2,3….

Locate points P1, P2 such that 1-P1 = P1´, 2-P2 = P2´….

Join P, P1, P2….



The tangent to the circle at any point on it is always normal to the its involute.

Join CN. Draw a semicircle with CN as diameter, cutting the circle at M.
MN is the normal.

Engineering Drawing

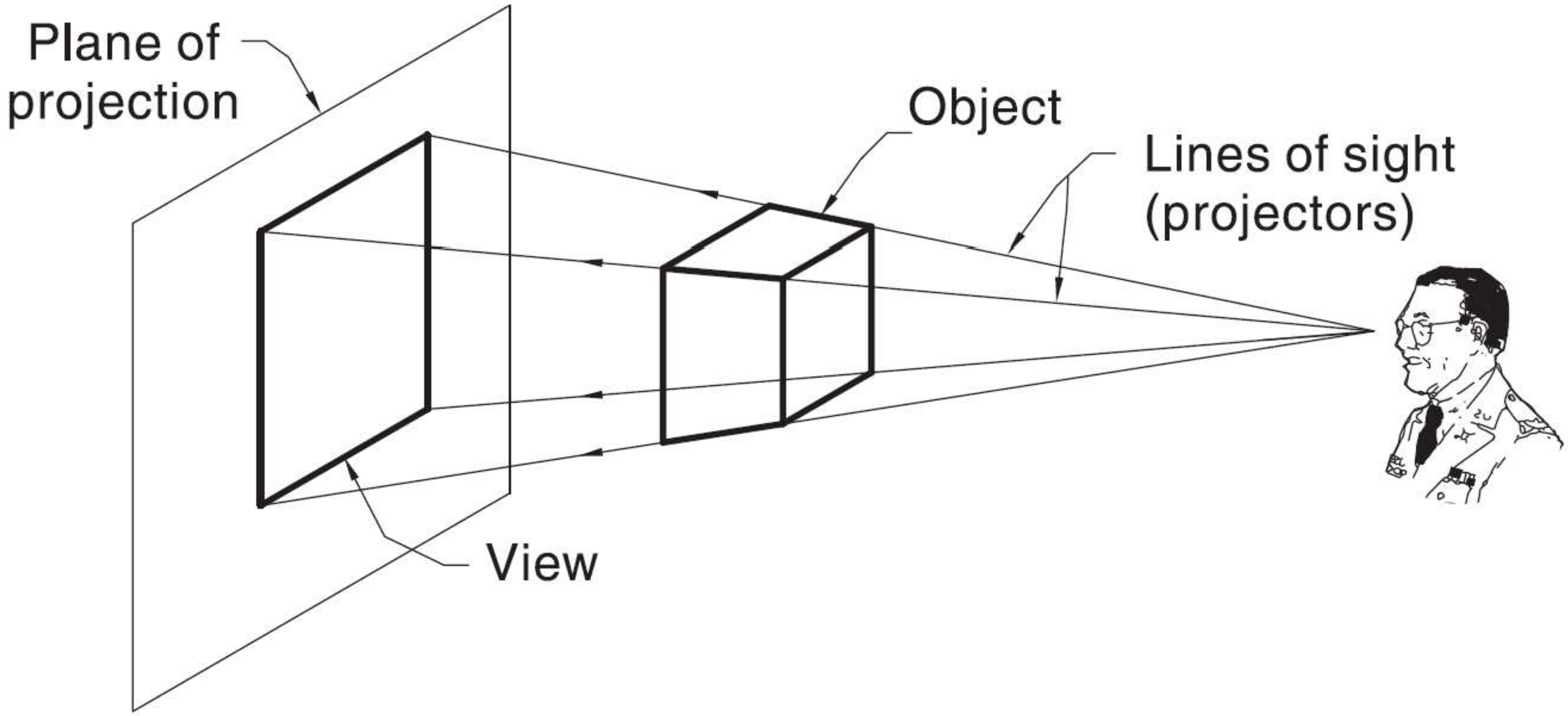
Theory of Projections

Projection theory

3-D objects and structures are represented graphically on 2-D media.

All projection theory are based on two variables:

- **Line of sight**
- **Plane of projection.**



Projection system

Plane of Projection

A plane of projection (i.e, an image or picture plane) is an imaginary flat plane upon which the image created by the line of sight is projected.

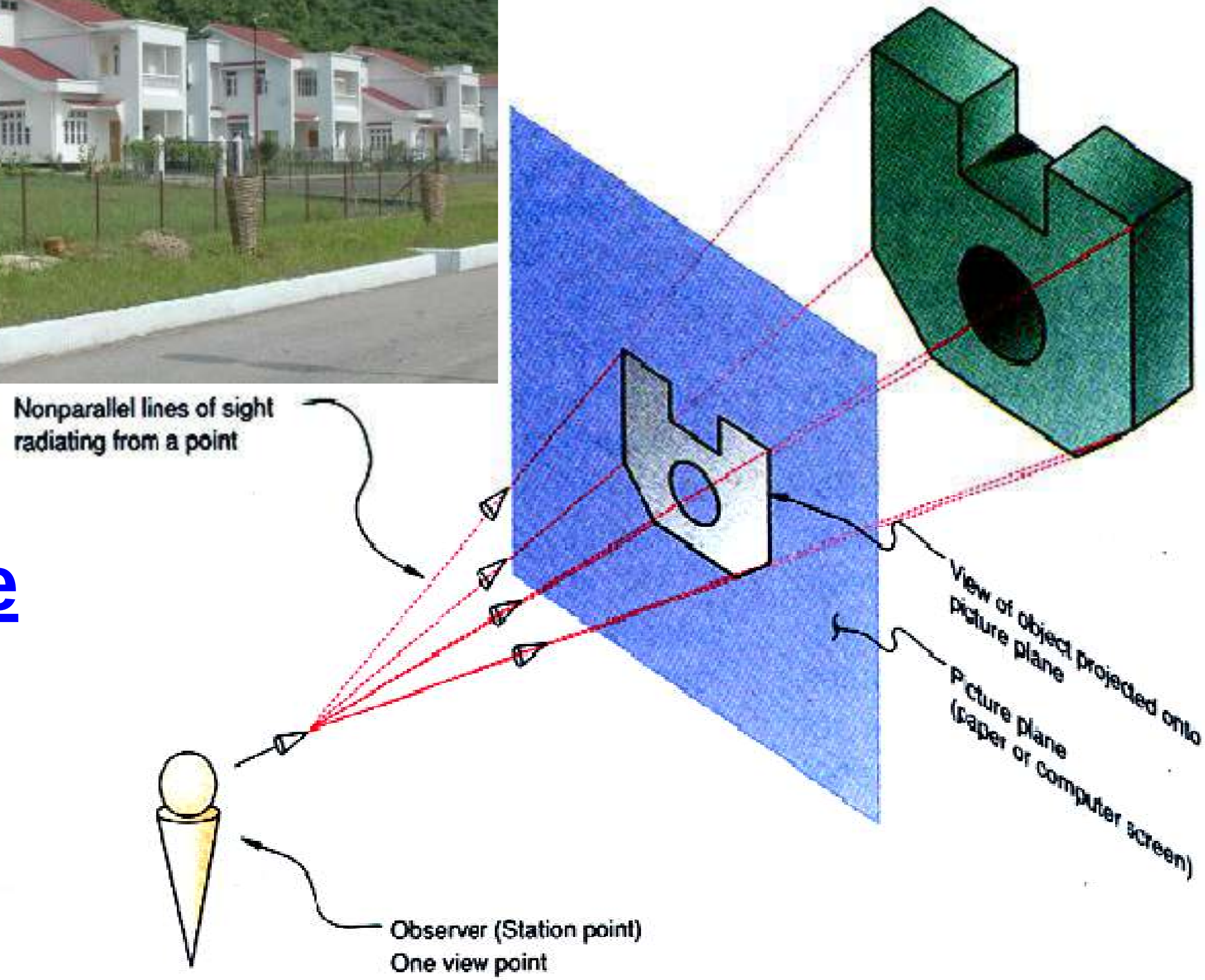
The image is produced by connecting the points where the lines of sight pierce the projection plane. In effect, 3-D object is transformed into a 2-D representation, also called projections.

The paper or computer screen on which a drawing is created is a plane of projection

Projection Methods

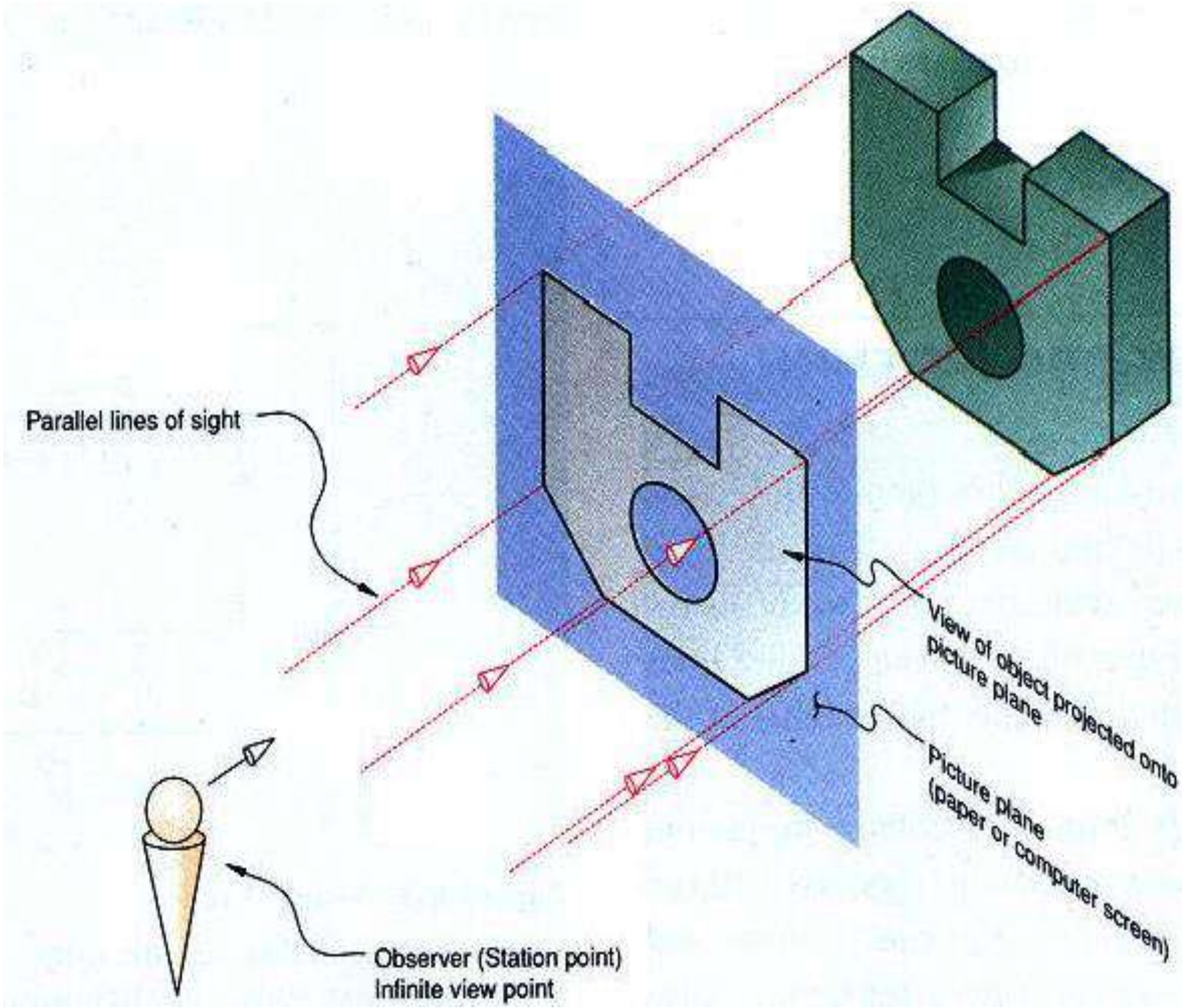
Projection methods are very important techniques in engineering drawing.

- Perspective and
- Parallel.



In perspective projection, all lines of sight start at a single point.

In parallel projection, all lines of sight are parallel.



Parallel vs Perspective Projection

Parallel projection

Distance from the observer to the object is infinite, projection lines are parallel – object is positioned at infinity.

Less realistic but easier to draw.

Perspective projection

Distance from the observer to the object is finite and the object is viewed from a single point – projectors are not parallel.

Perspective projections mimic what the human eyes see, however, they are difficult to draw.

Engineering Drawing

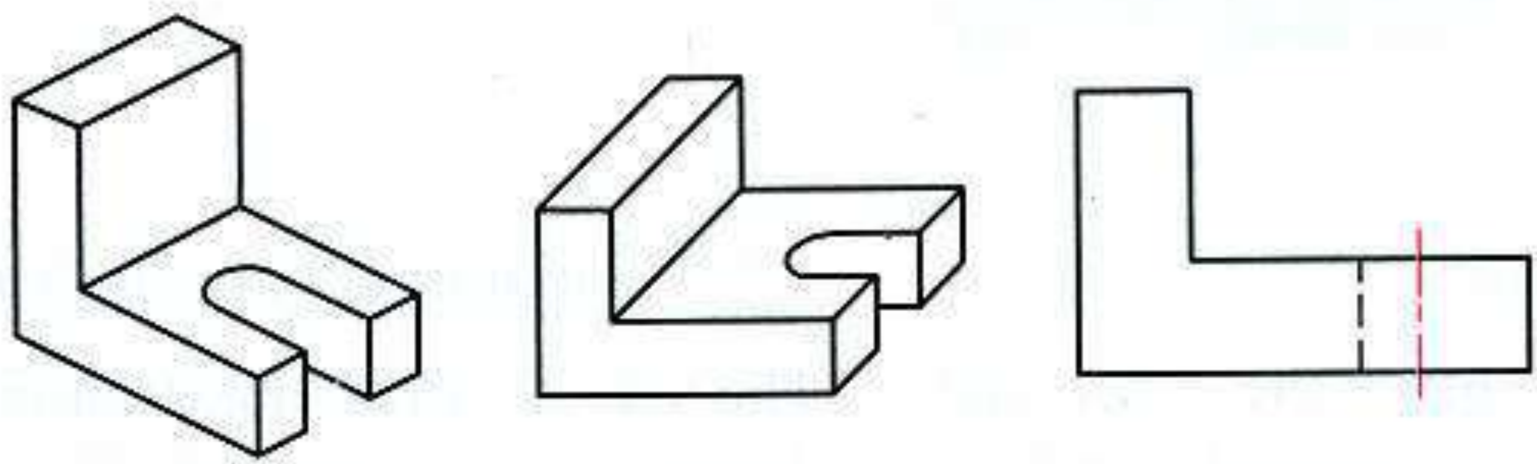
Lecture 5

Projection of Points

Orthographic Projection

A parallel projection technique in which the plane of projection is perpendicular to the parallel line of sight.

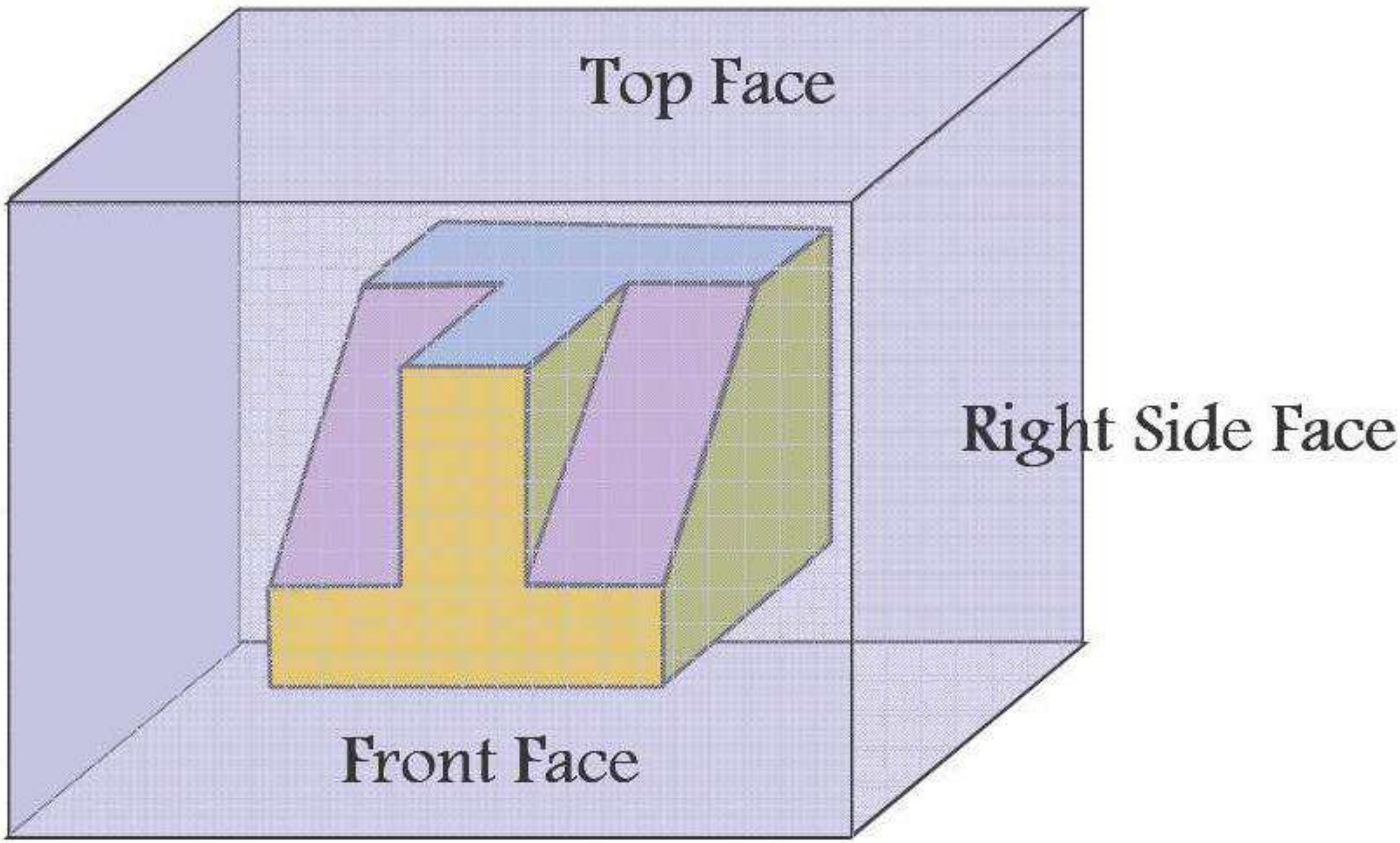
Orthographic projection technique can produce either pictorial drawings that show all three dimensions of an object in one view, or multi-views that show only two



Isometric Oblique Multiview

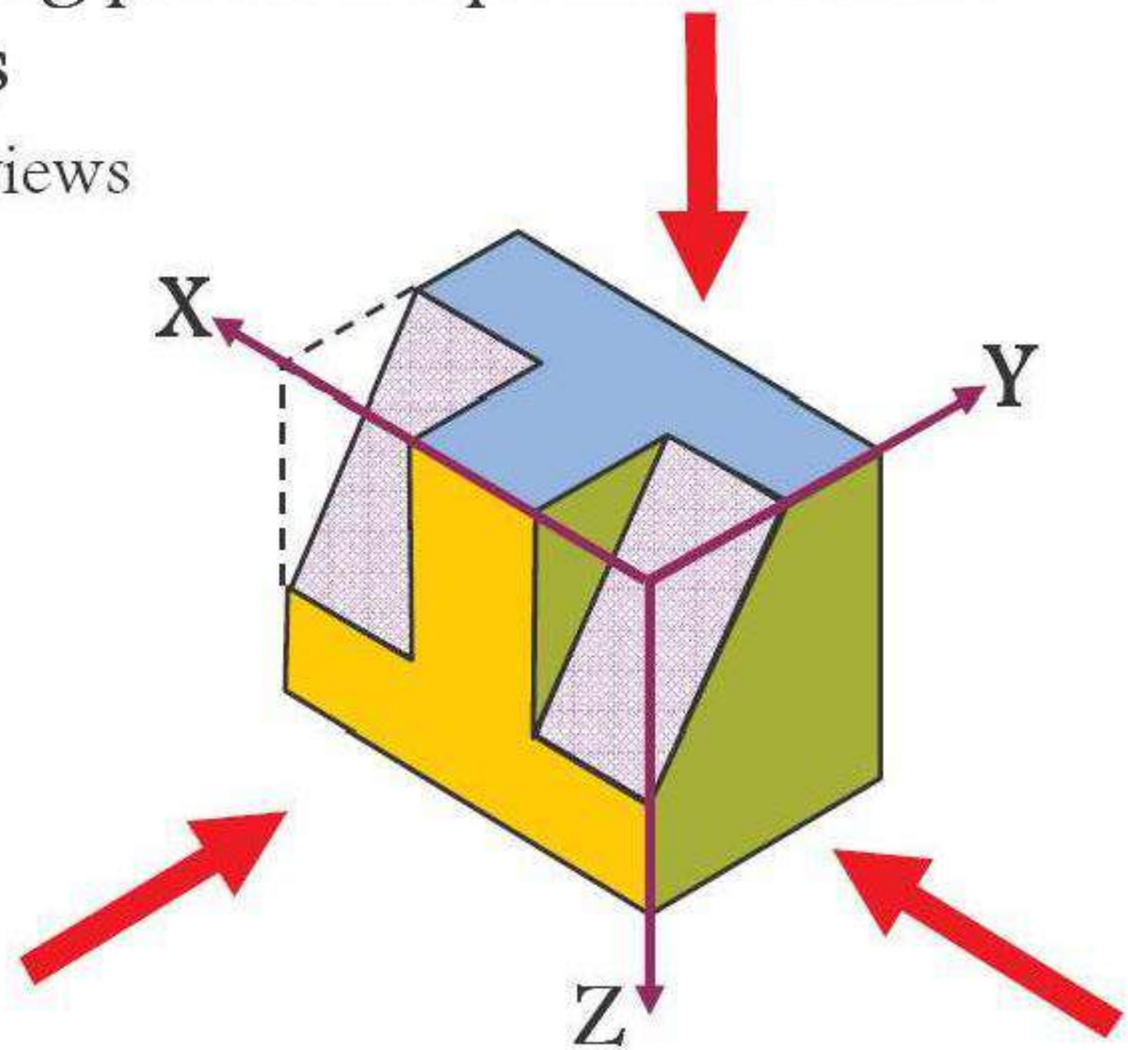
Transparent Viewing Box

- Viewing faces



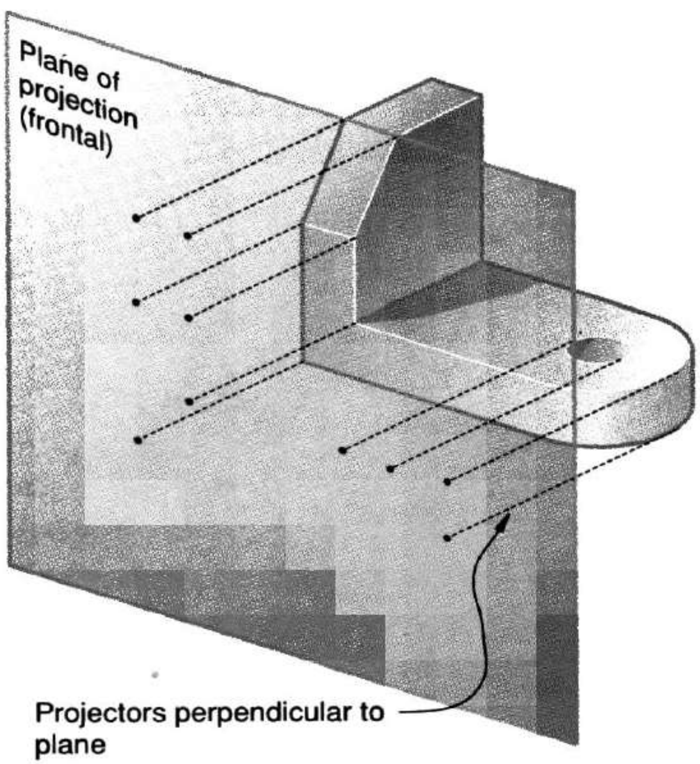
Orthographic projections

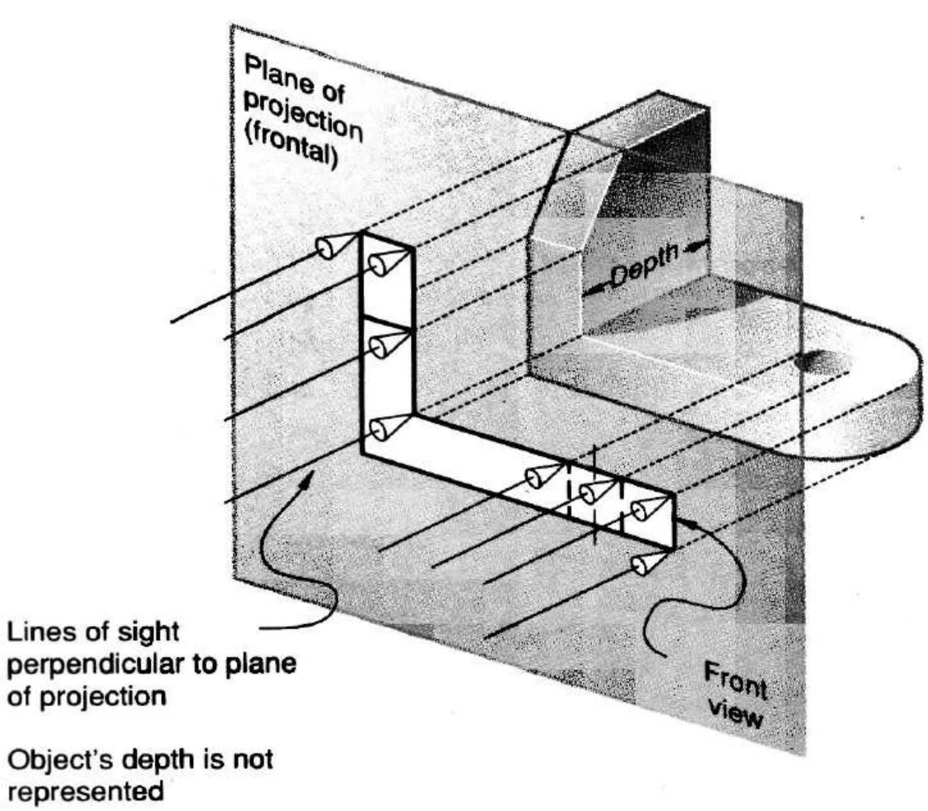
- When the viewing planes are parallel to these principal planes
  - Orthographic views



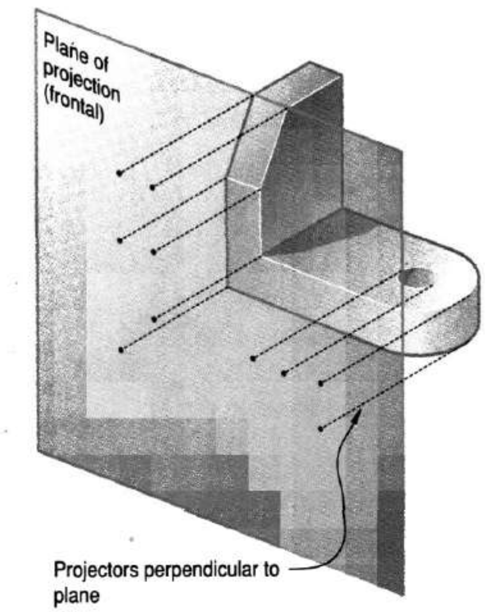
Multi-view Projection

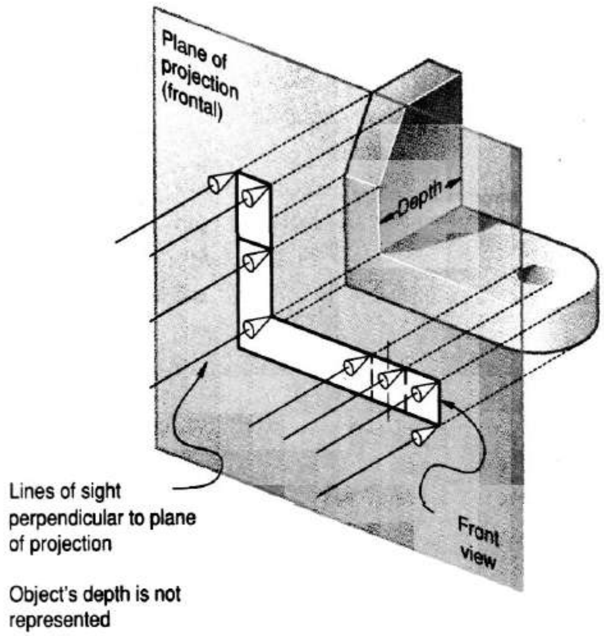
In an orthographic projection, the object is oriented in such a way that only two of its dimensions are shown. The dimensions obtained are the true dimensions of the object

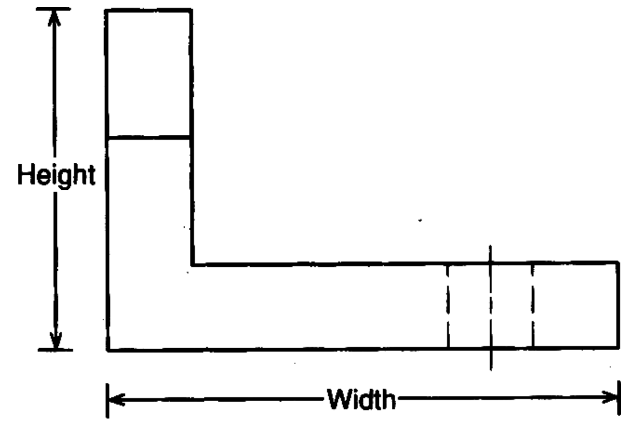




Frontal plane of projection







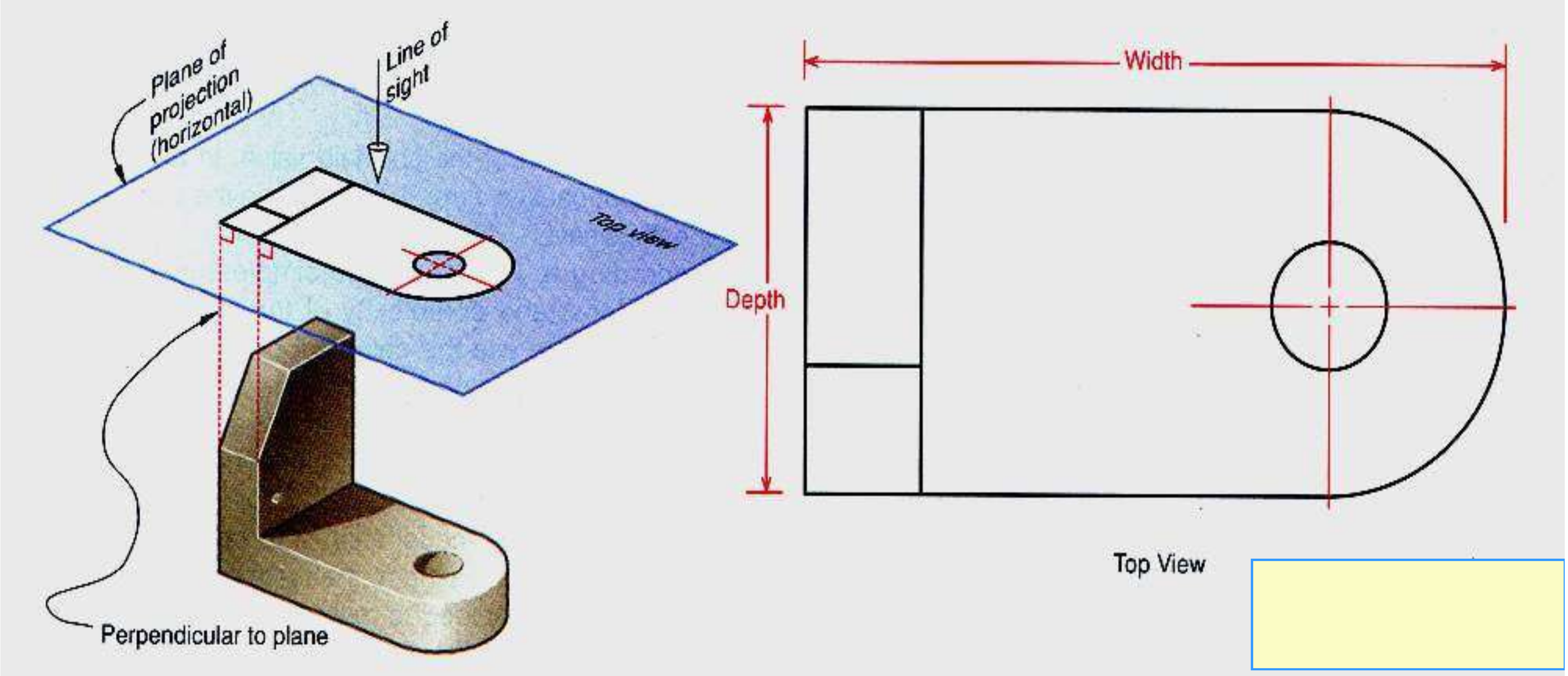
Frontal plane of projection is the plane onto which the Front View (FV) of the multi-view drawing is projected.

Front view of an object shows the width and height dimensions.

Horizontal plane of projection

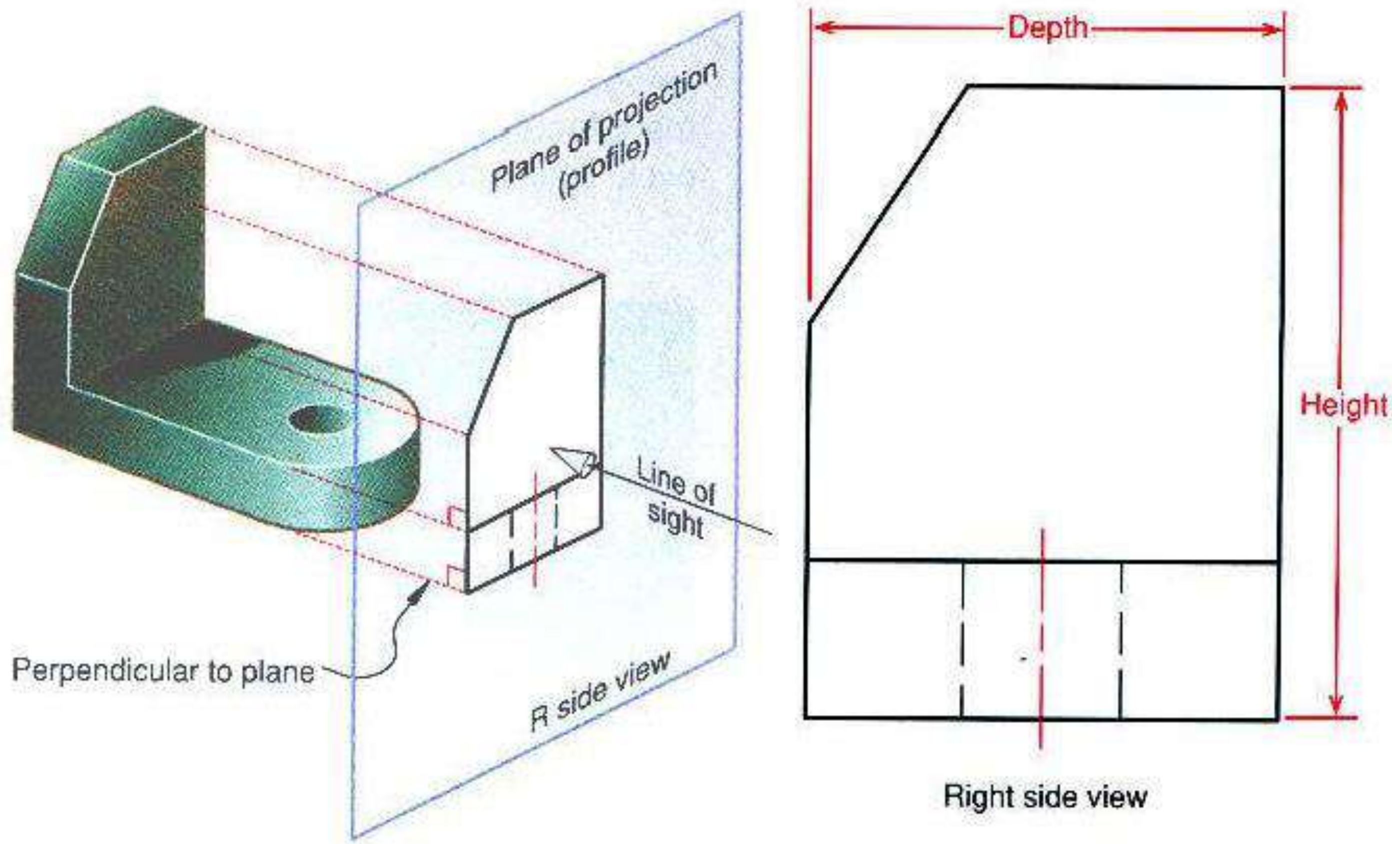
Horizontal plane of projection is the plane onto which the Top View of the multi-view drawing is projected.

Top view of an object shows the width and depth dimensions.



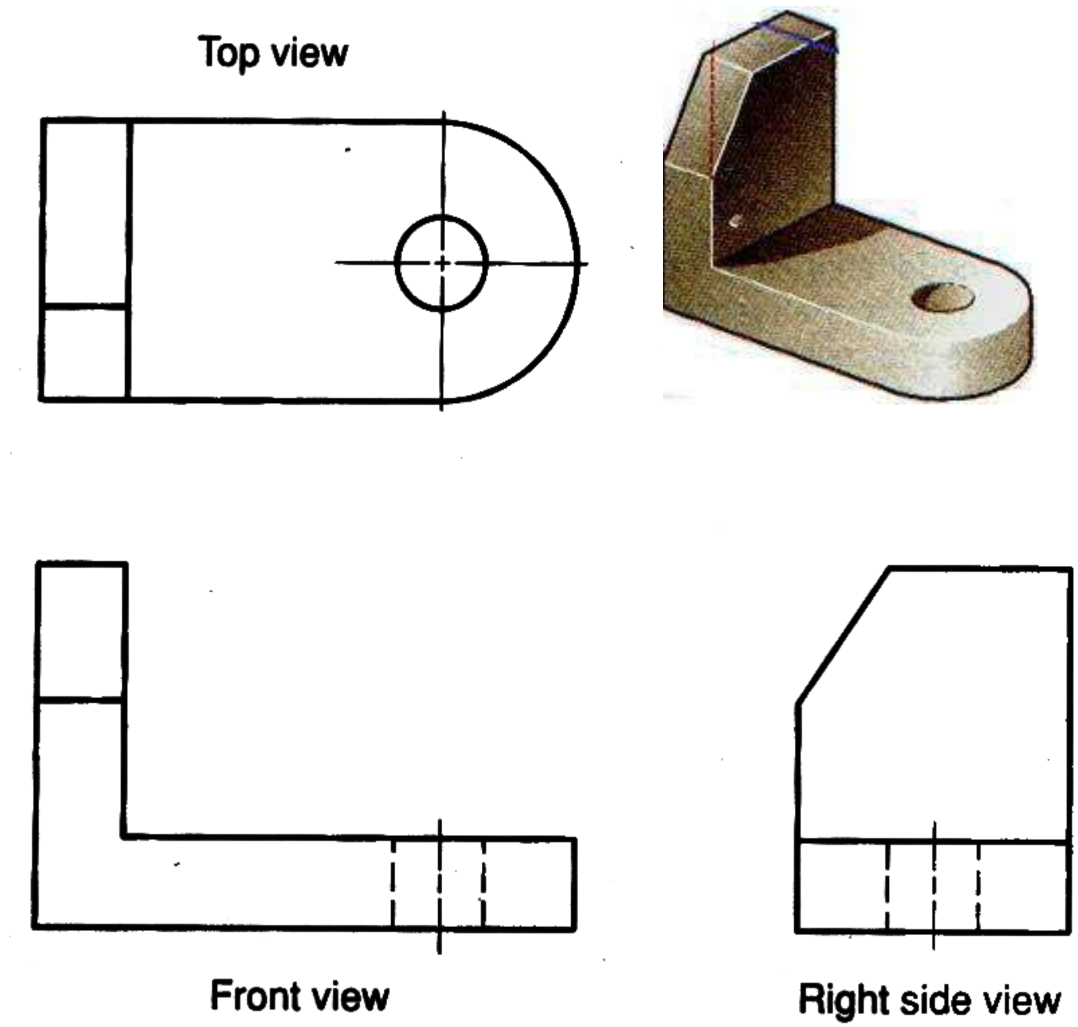
Profile plane of projection

In multi-view drawings, the right side view is the standard side view used. The right side view of an object shows the depth and the height dimensions. The right side view is projected onto the profile plane of projection, which is a plane that is parallel to the right side of the object.



Orientation of views from projection planes

Top view is always positioned and aligned with the front view, and side view is always positioned to the side of and aligned with the front view.



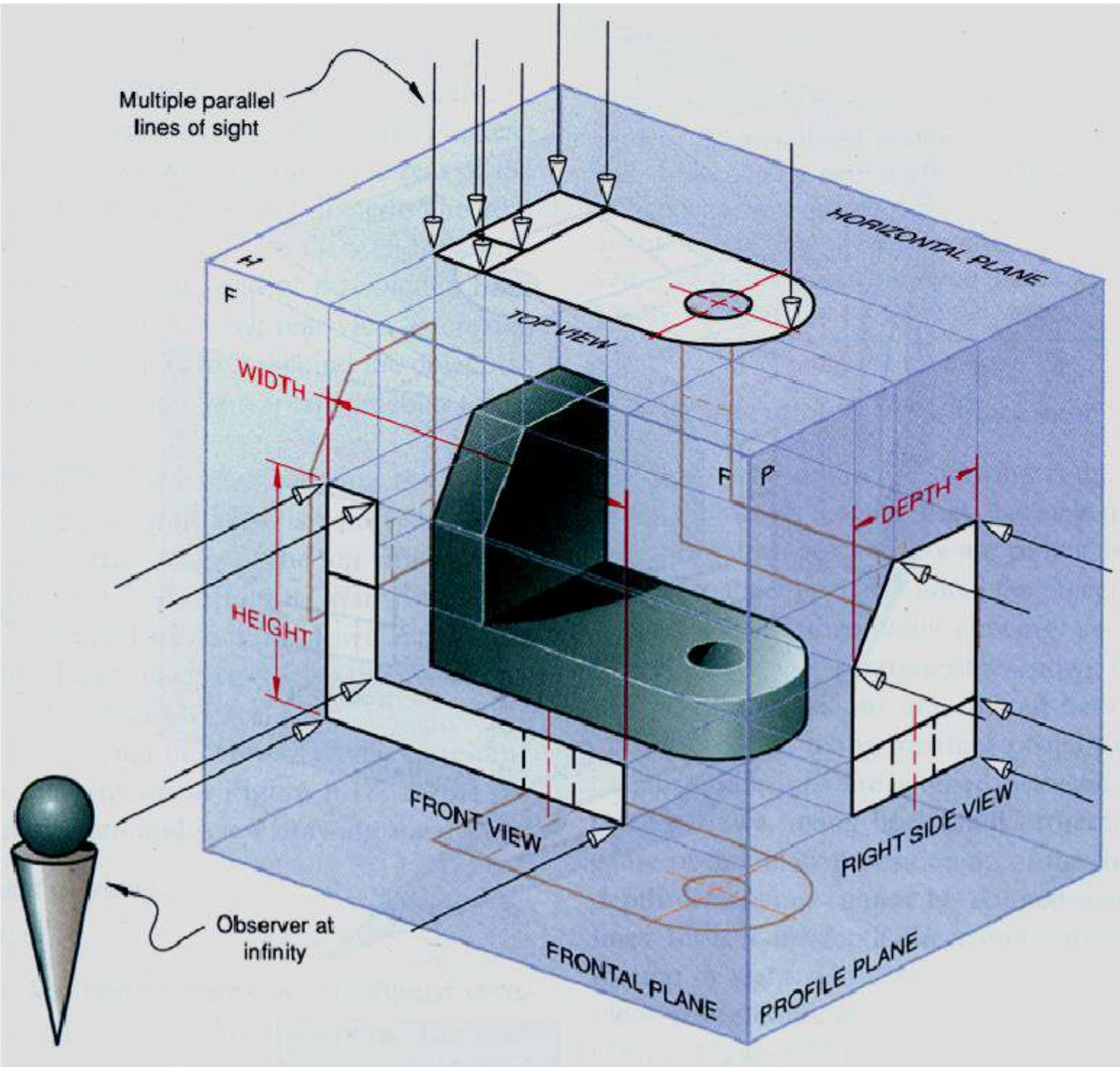
Six Principal views

The plane of projection can be oriented to produce an infinite number of views of an object. However, some views are more important than others.

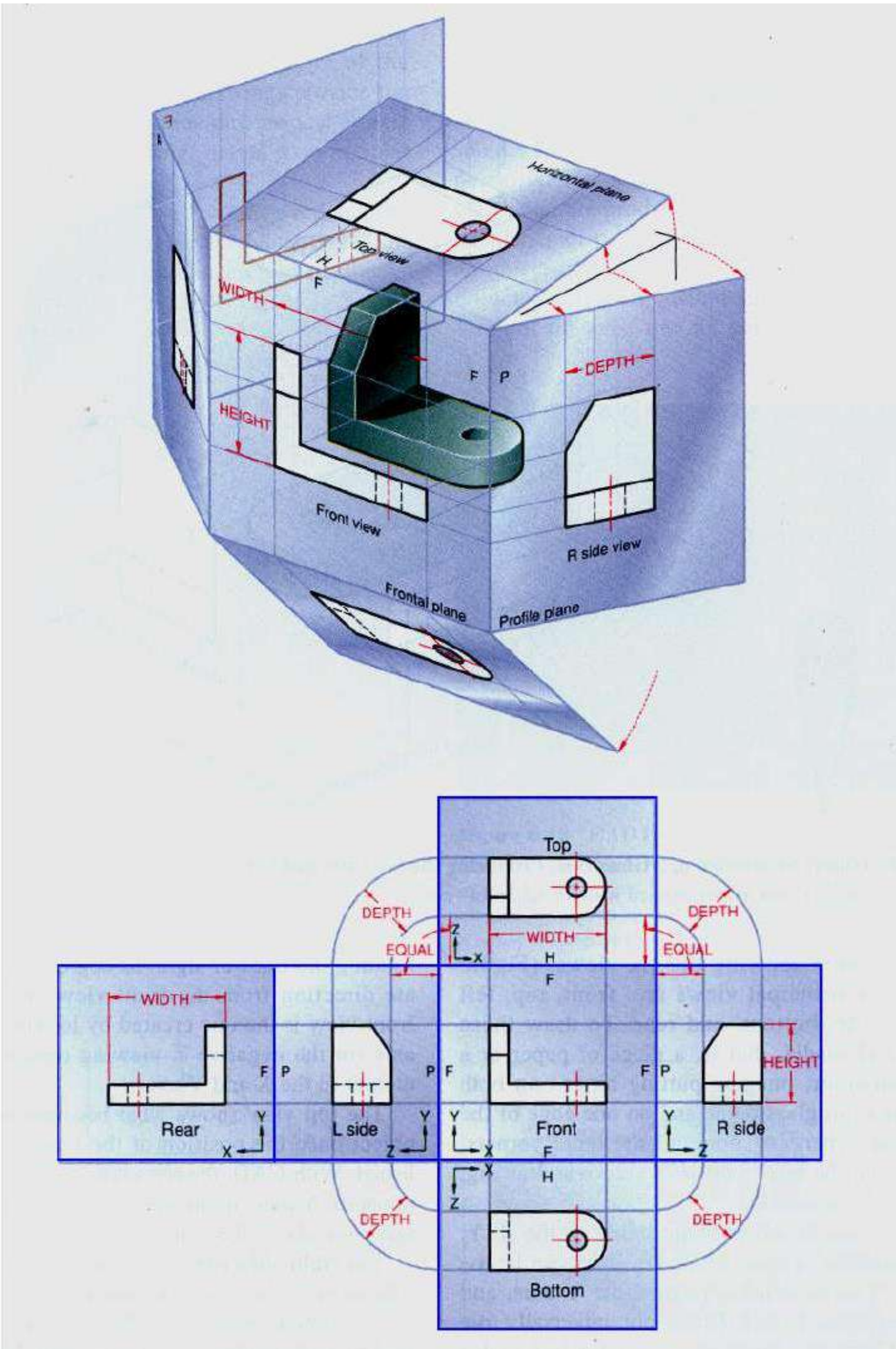
These principal views are six mutually perpendicular views that are produced by six mutually perpendicular

Imagine suspending an object in a glass box with major surfaces of the object positioned so that they are parallel to the sides of the box, six sides of the box become projection planes, showing the six views – front, top, left, right, bottom and rear.

Six Principal Views



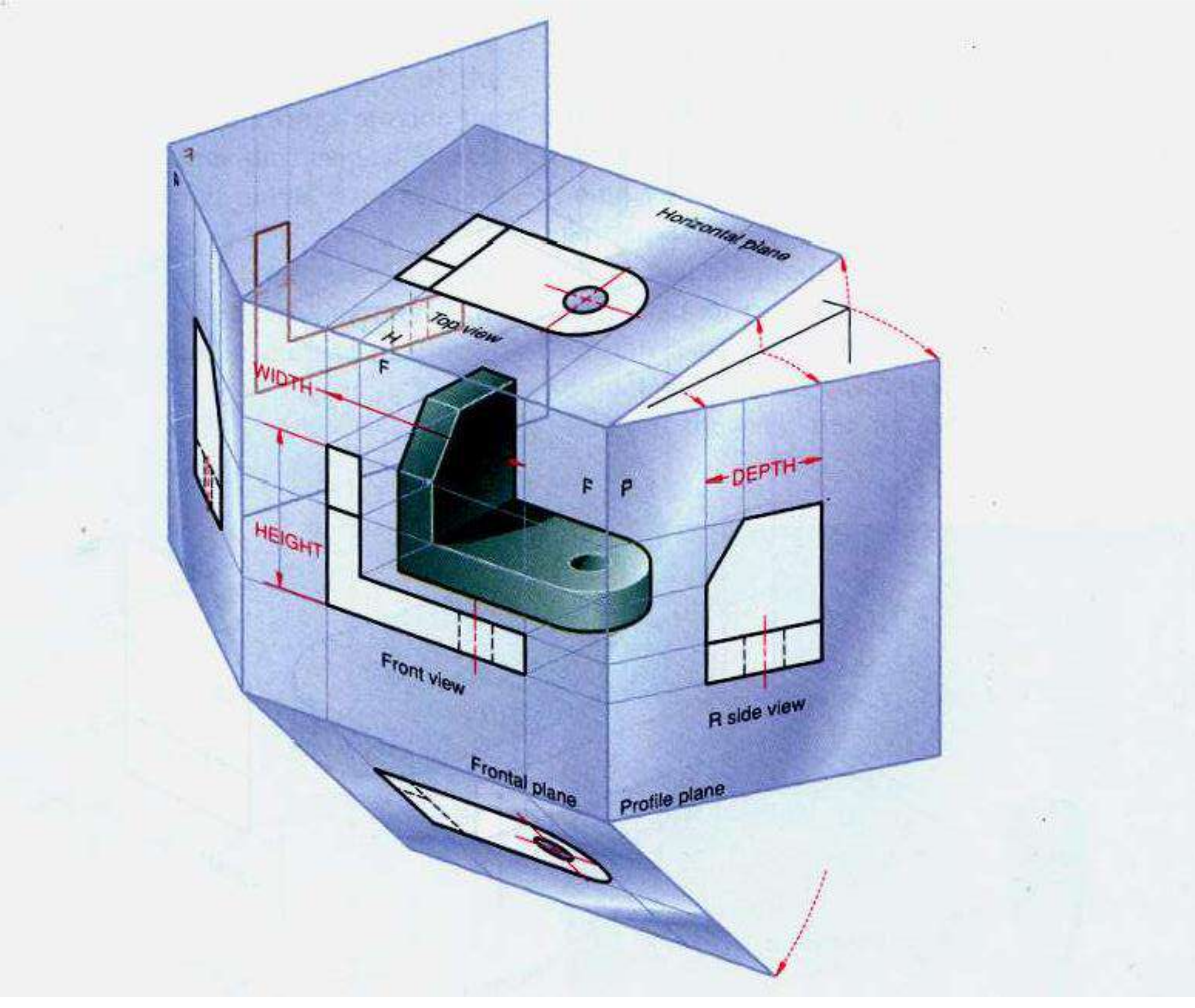
Object is suspended in a glass box producing six principal views: each view is perpendicular to and aligned with the adjacent views.

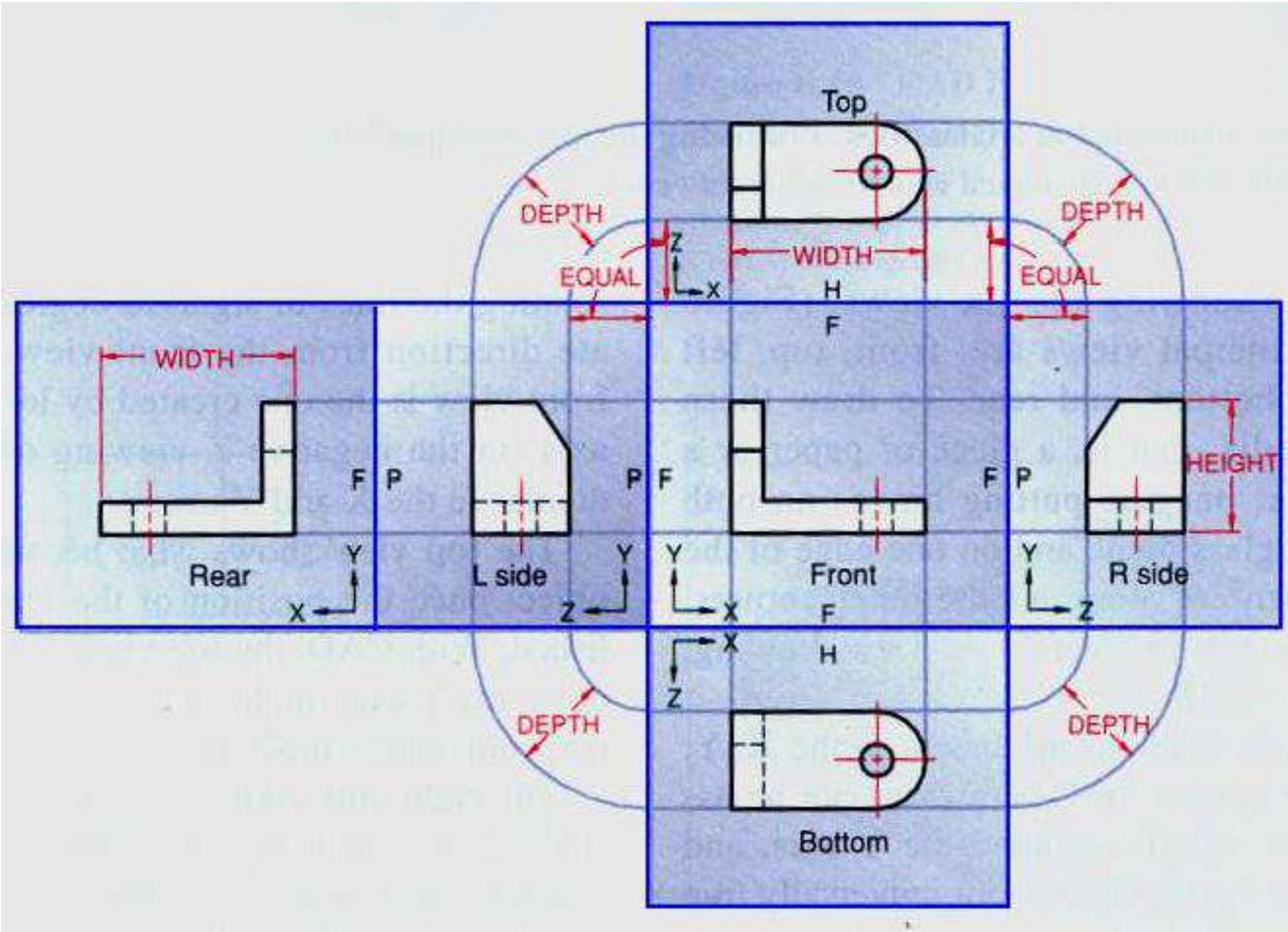


Unfolding the glass box to produce six-view drawing

Top, front and bottom views are all aligned vertically and share the same width dimension.

Rear, left side, front and right side views are all aligned horizontally and share the same height dimension.

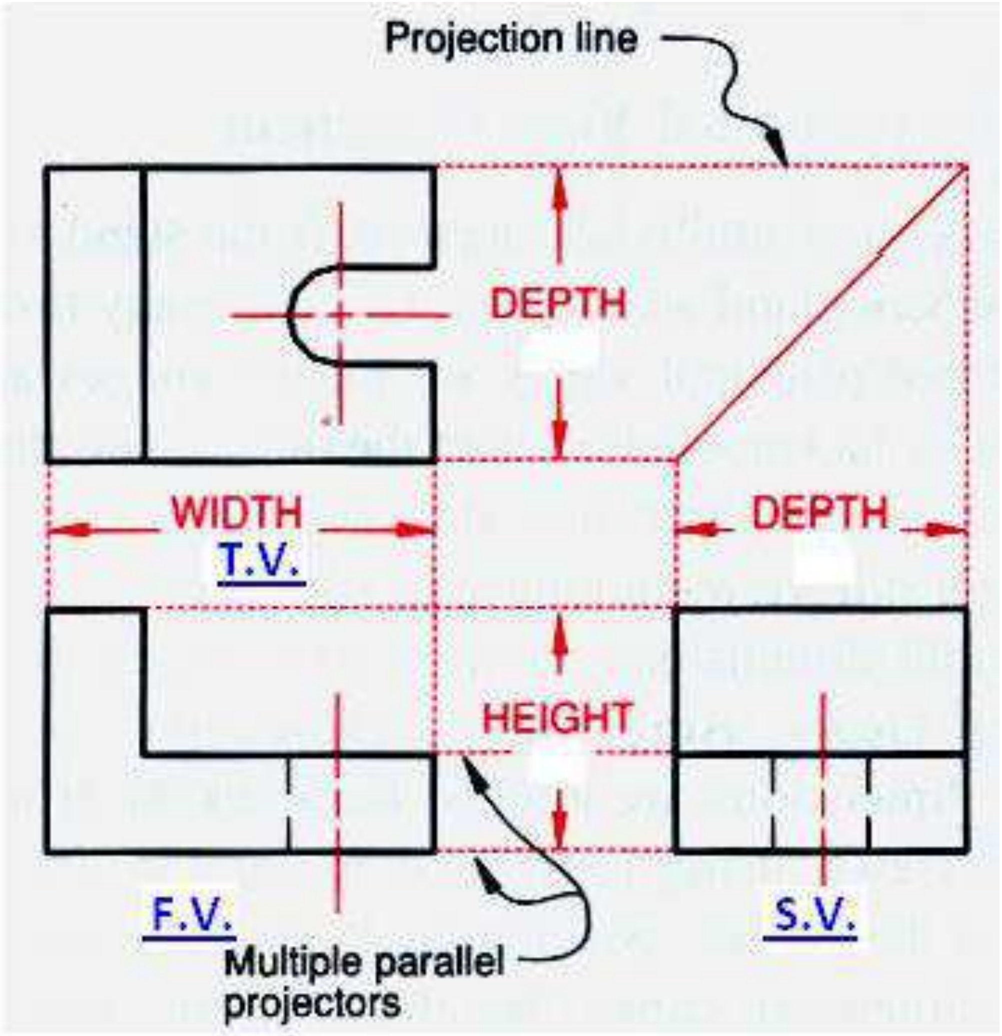

Horizontal plane
Top view
H
F
WIDTH
HEIGHT
DEPTH
F
P
Front view
R side view
Frontal plane
Profile plane



Top
DEPTH
EQUAL
WIDTH
H
F
DEPTH
EQUAL
WIDTH
F
P
P
F
F
P
HEIGHT
Rear
L side
Front
R side
X
Y
Z
F
H
DEPTH
DEPTH
Bottom

Conventional view placement

The three-view multiview drawing is the standard used in engineering and technology, because many times the other three principal views are mirror images and do not add to the knowledge about the object.

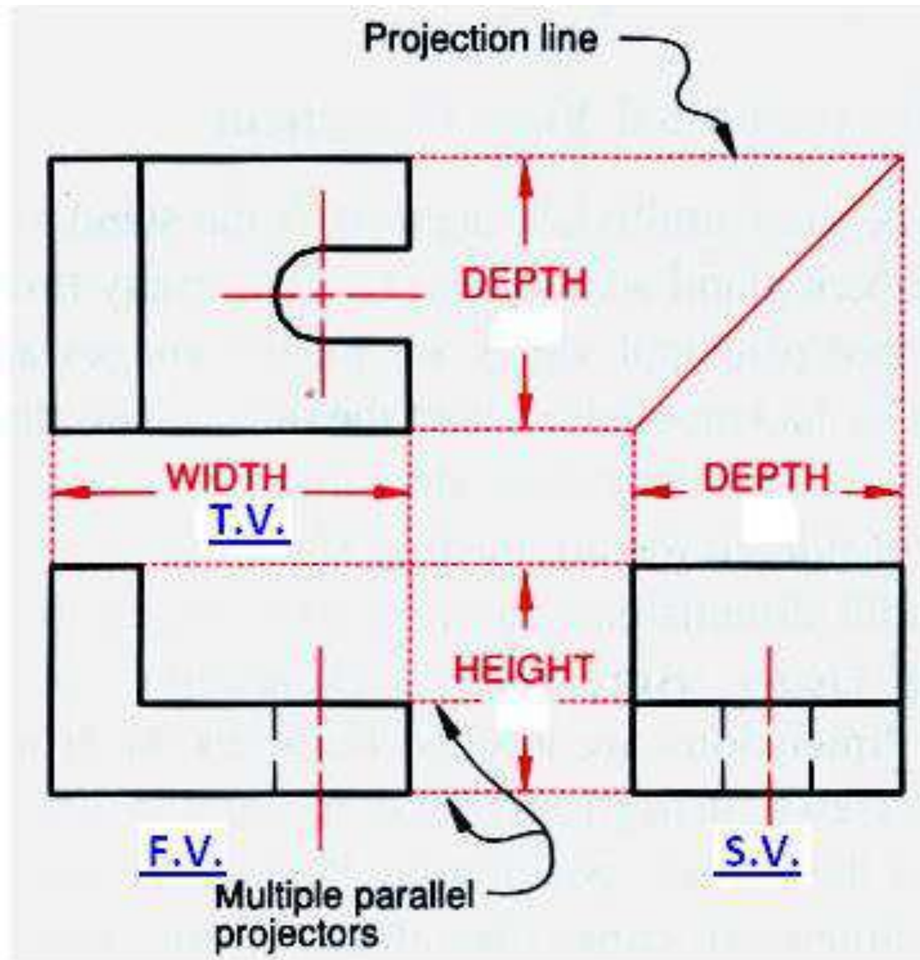


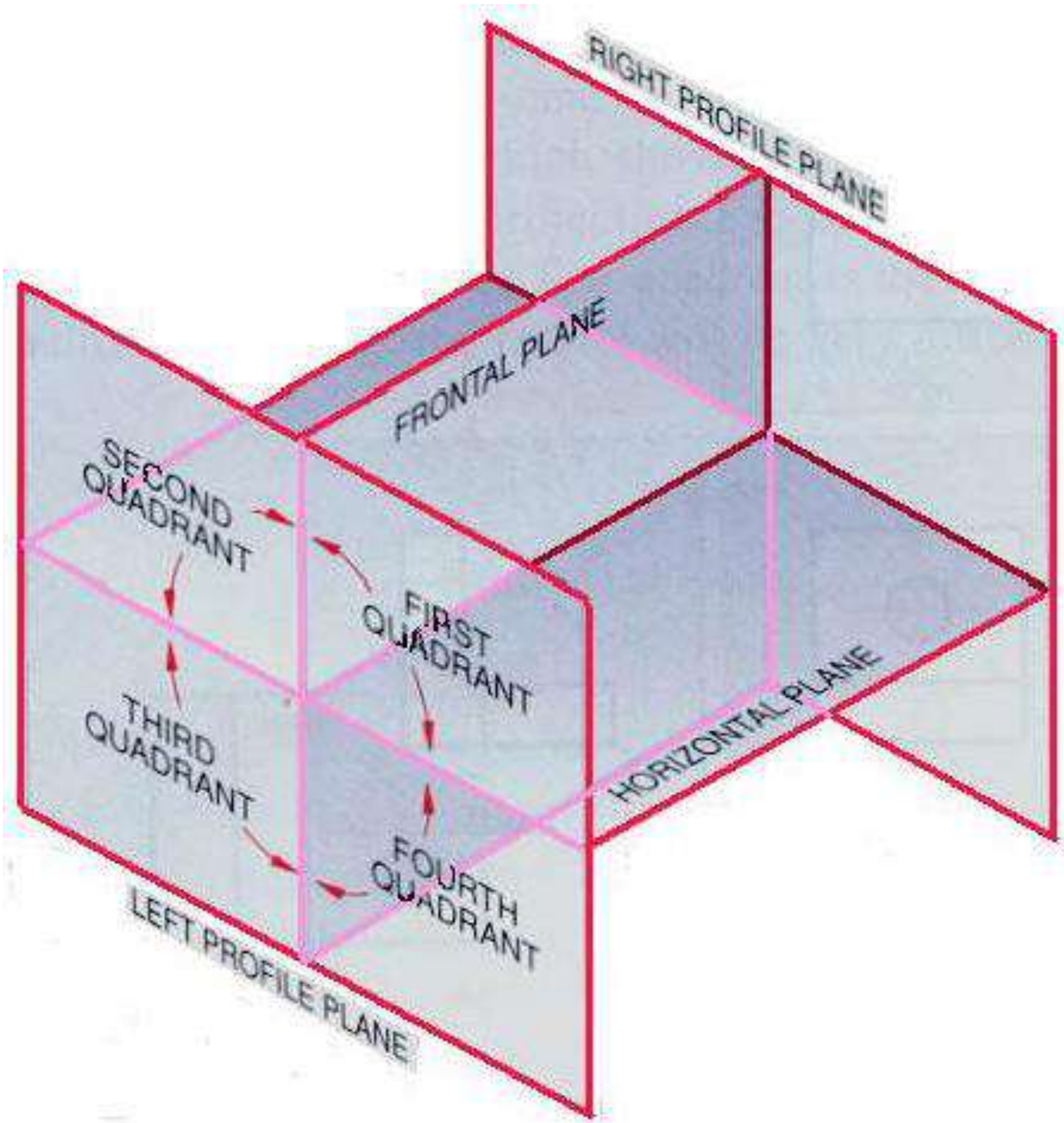
The standard views used in a three-view drawing are the top, front and the right side views

The width dimensions are aligned between the front and top views, <u>using vertical projection lines.</u>

The height dimensions are aligned between the front and the profile views, <u>using horizontal projection lines</u>.

Because of the relative positioning of the three views, the depth dimension cannot be aligned using projection lines. Instead, the depth dimension is measured in either the top or right side view.



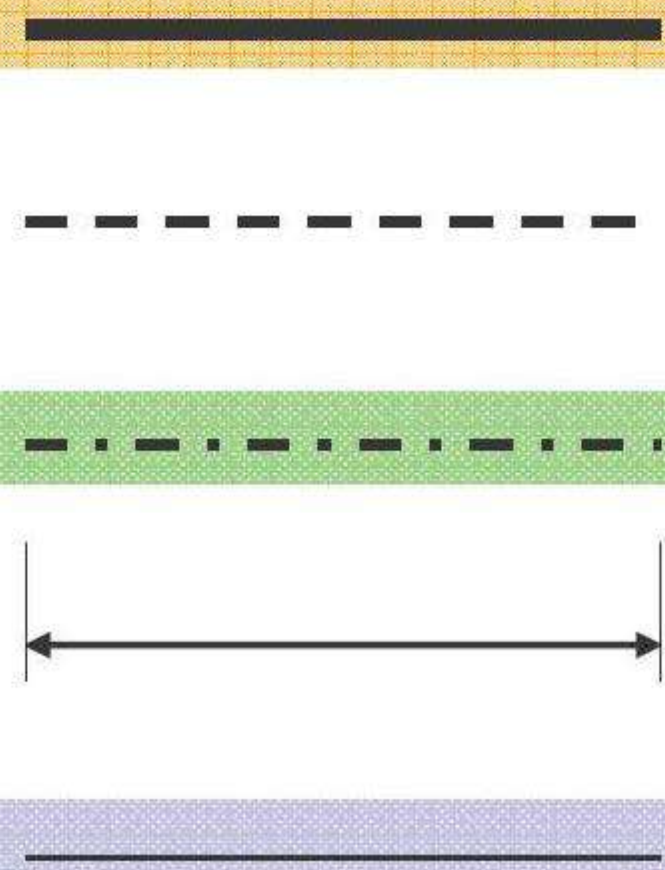


The principal projection planes and quadrants used to create first- and third-angle projection drawings

Orthographic projection and Projection of points

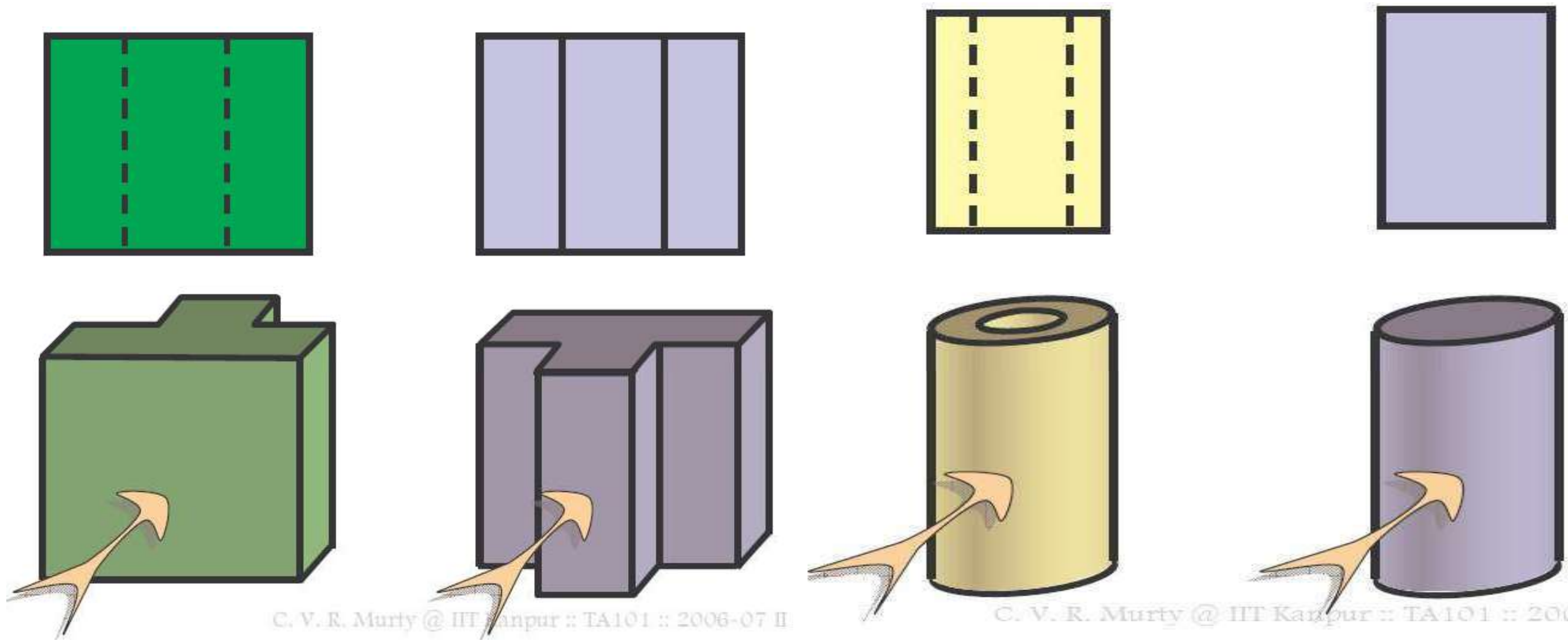
Lines

- Five types of line styles used
  - Visible lines
  - Hidden lines
  - Centerlines
  - Dimension lines
  - Construction lines

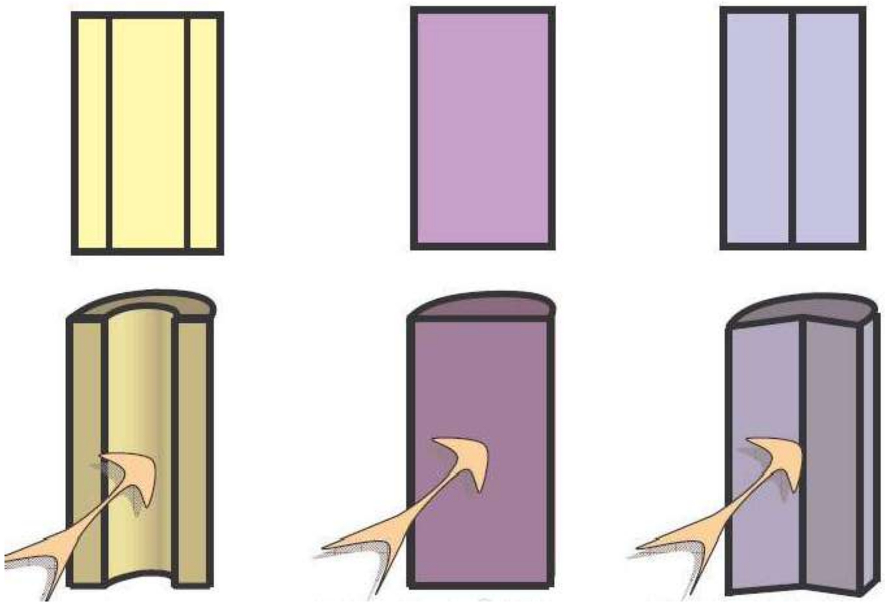


Visible & Hidden lines

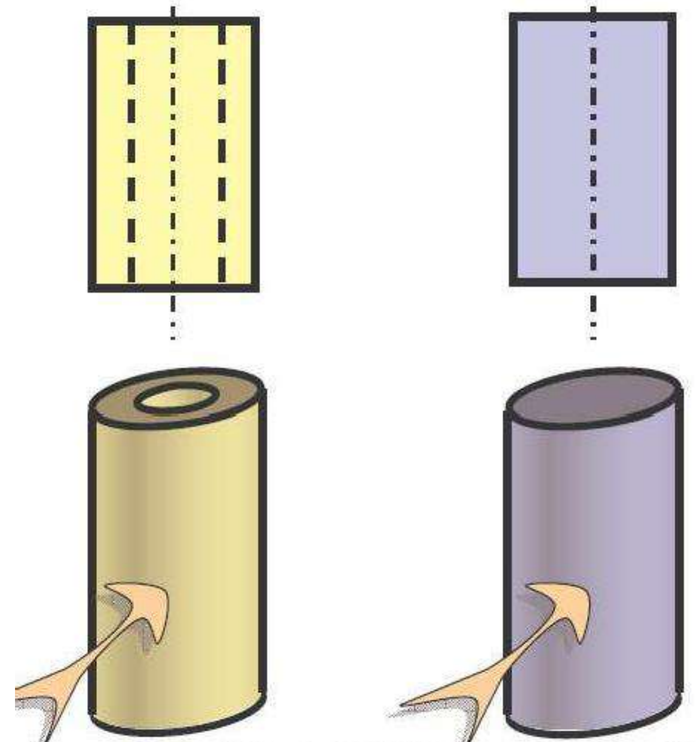
– Boundaries



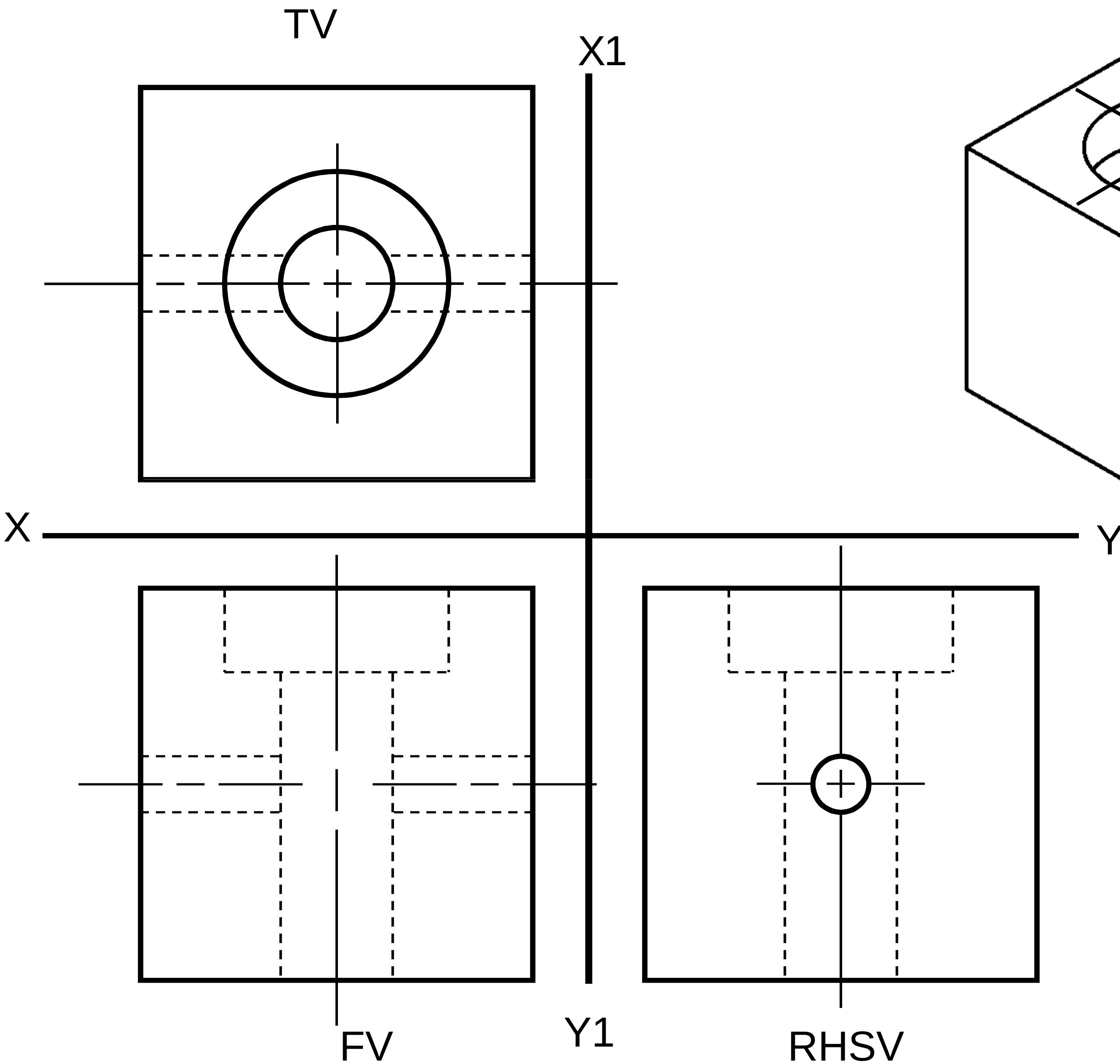
– Surfaces meet

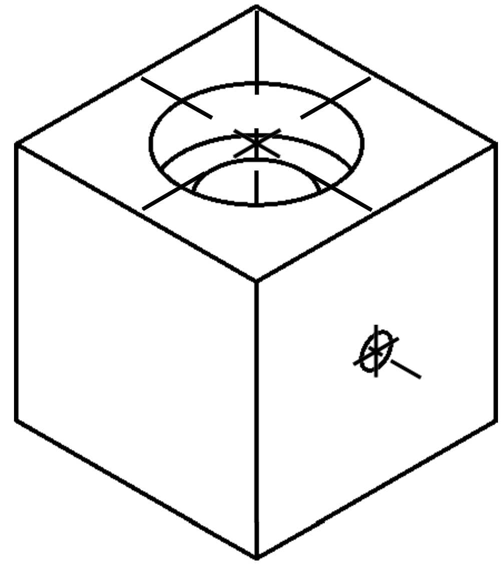


- Centerlines
  – Axial Symmetry

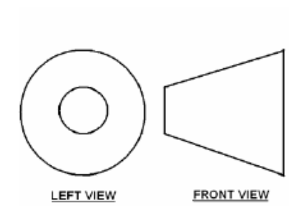


Example



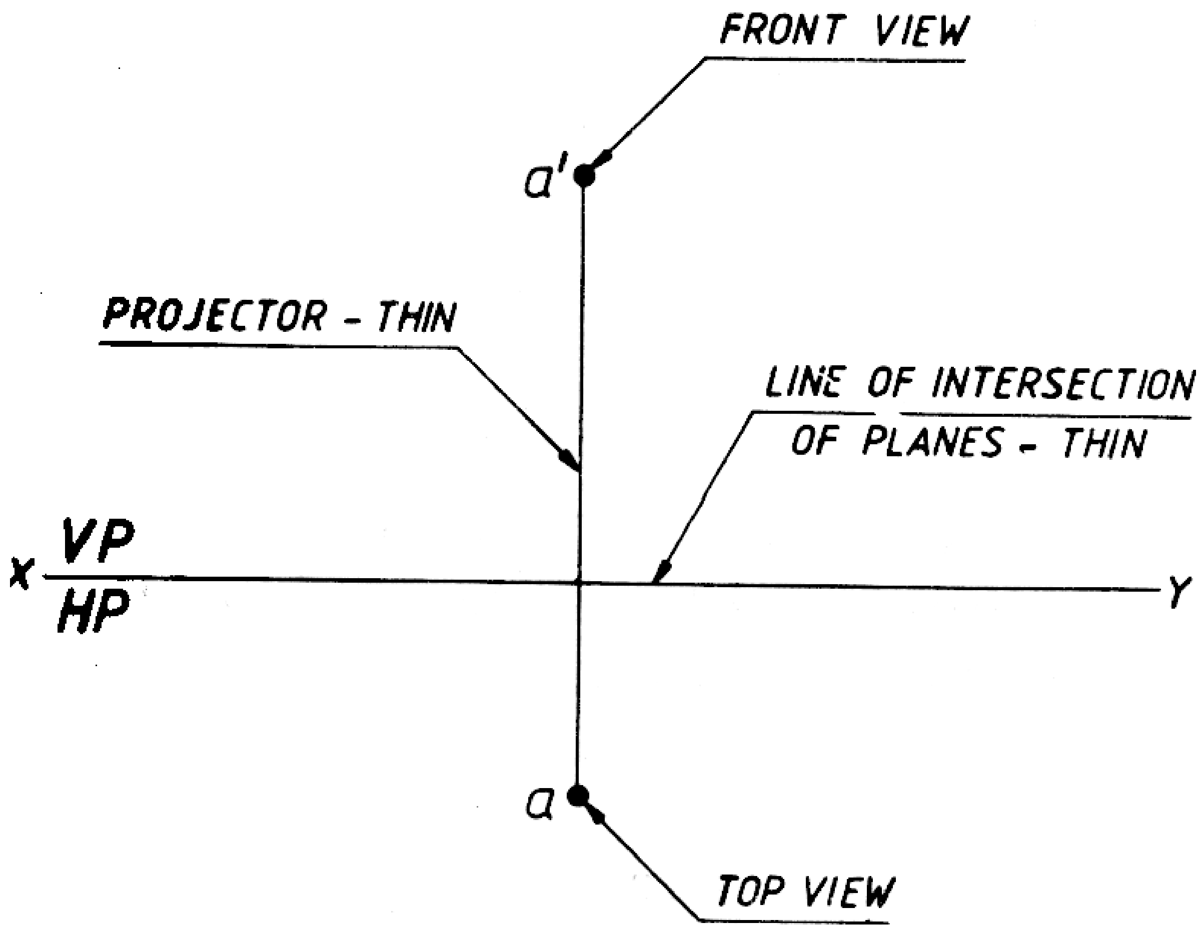


1. **Visible**
2. **Hidden**
3. **Center**



Conventions

Convention



- **Projectors and the lines of the intersection of planes of projections are shown as thin lines.**

Precedence of Lines

- *Visible lines* take precedence over all other lines

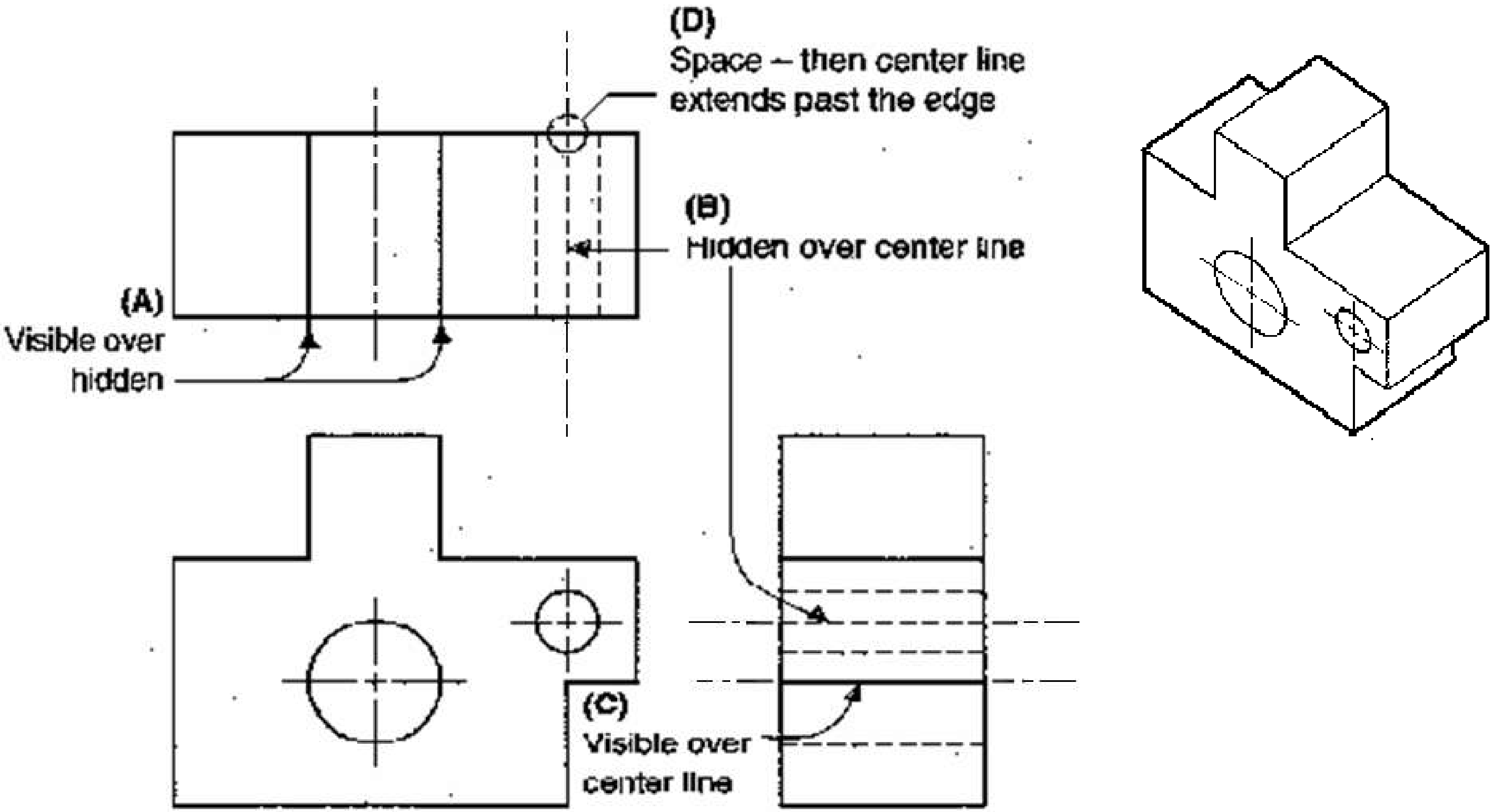
0.70 mm

0.35 mm

- *Center lines* have lowest precedence

0.35 mm

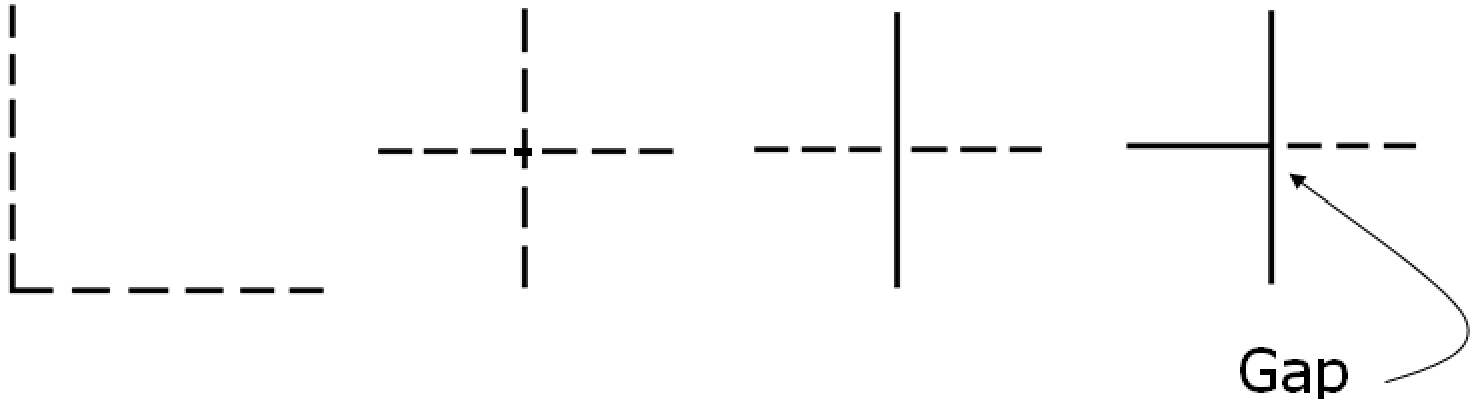
Example: *Application of Precedence*



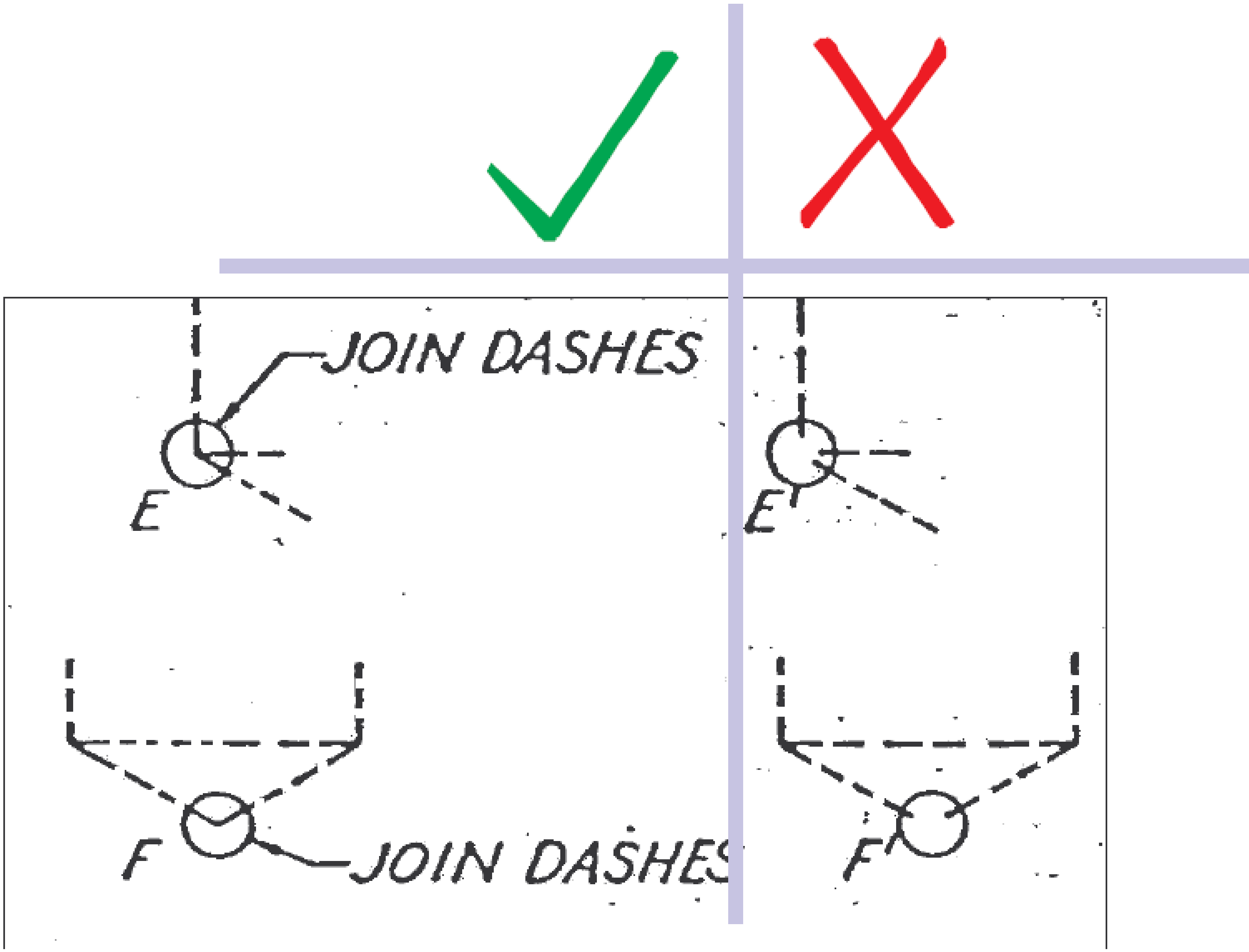
Intersecting Lines in Orthographic Projections

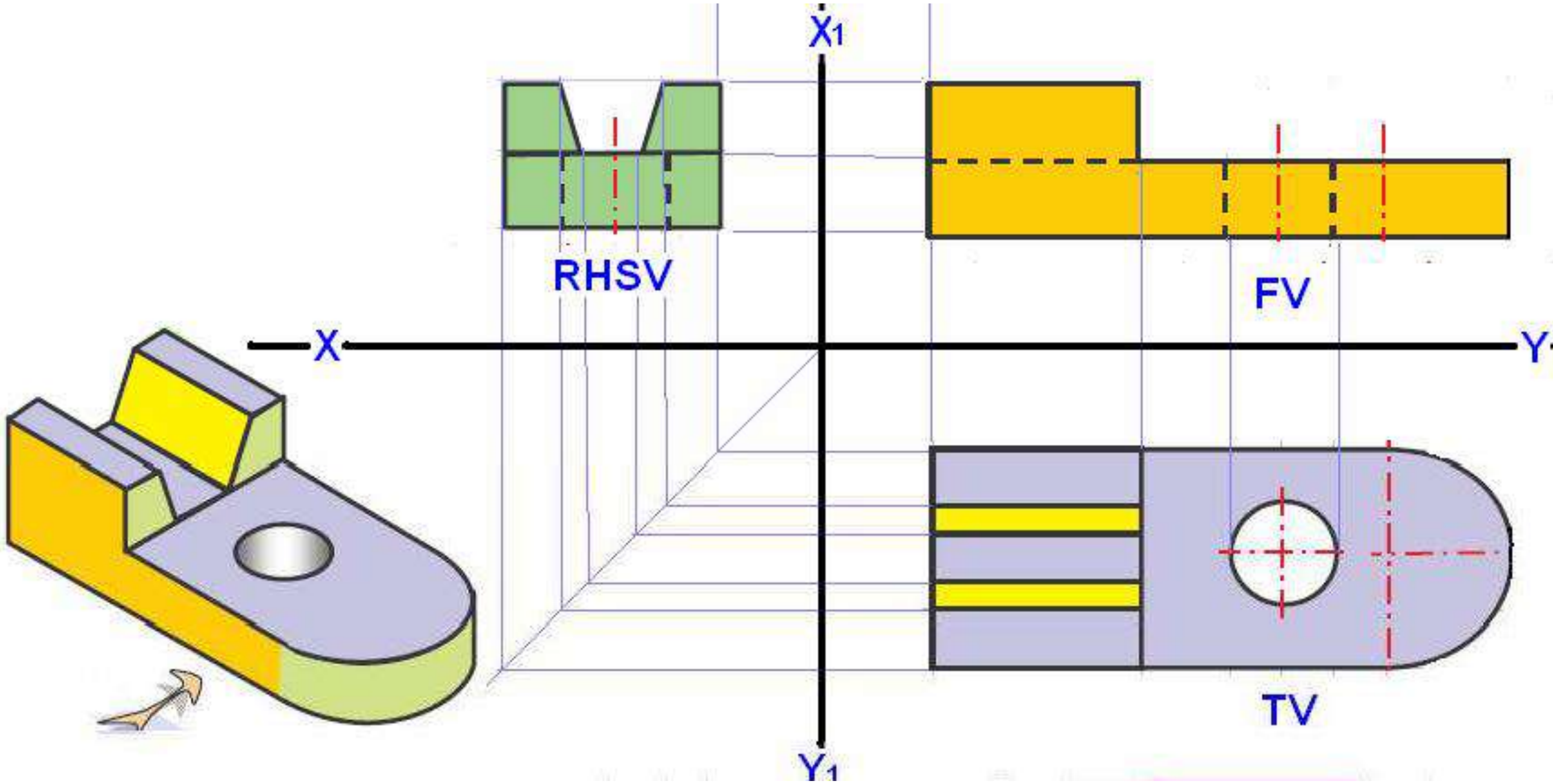
Solid Line Intersections

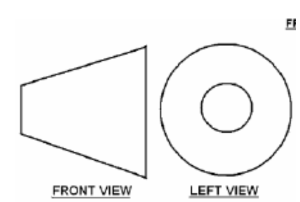
Dashed Line Special Case Intersections



Intersection of hidden line




X1
RHSV
FV
X
Y
TV
Y1


FRONT VIEW
LEFT VIEW

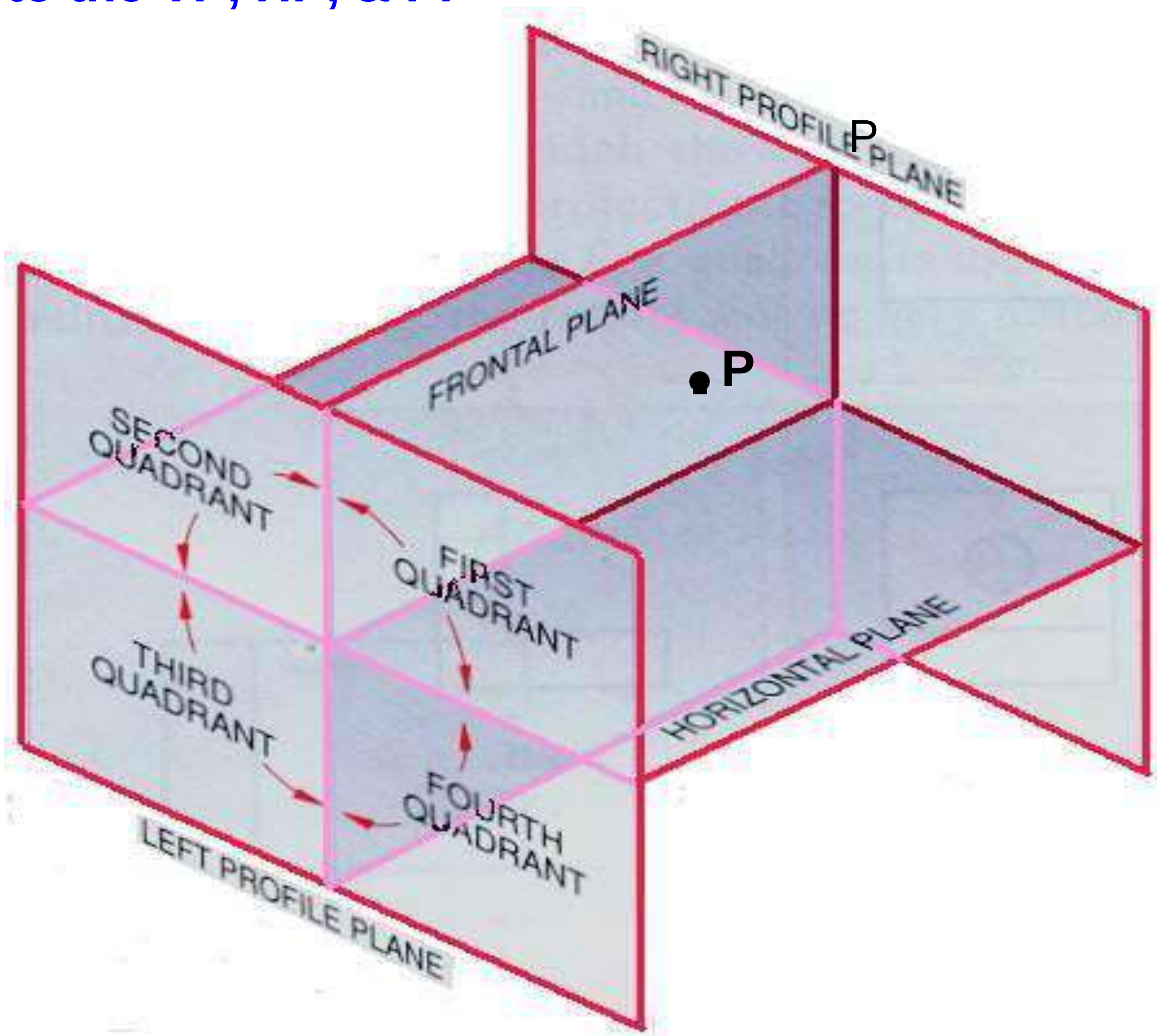
Projection of Points

(Orthographic)

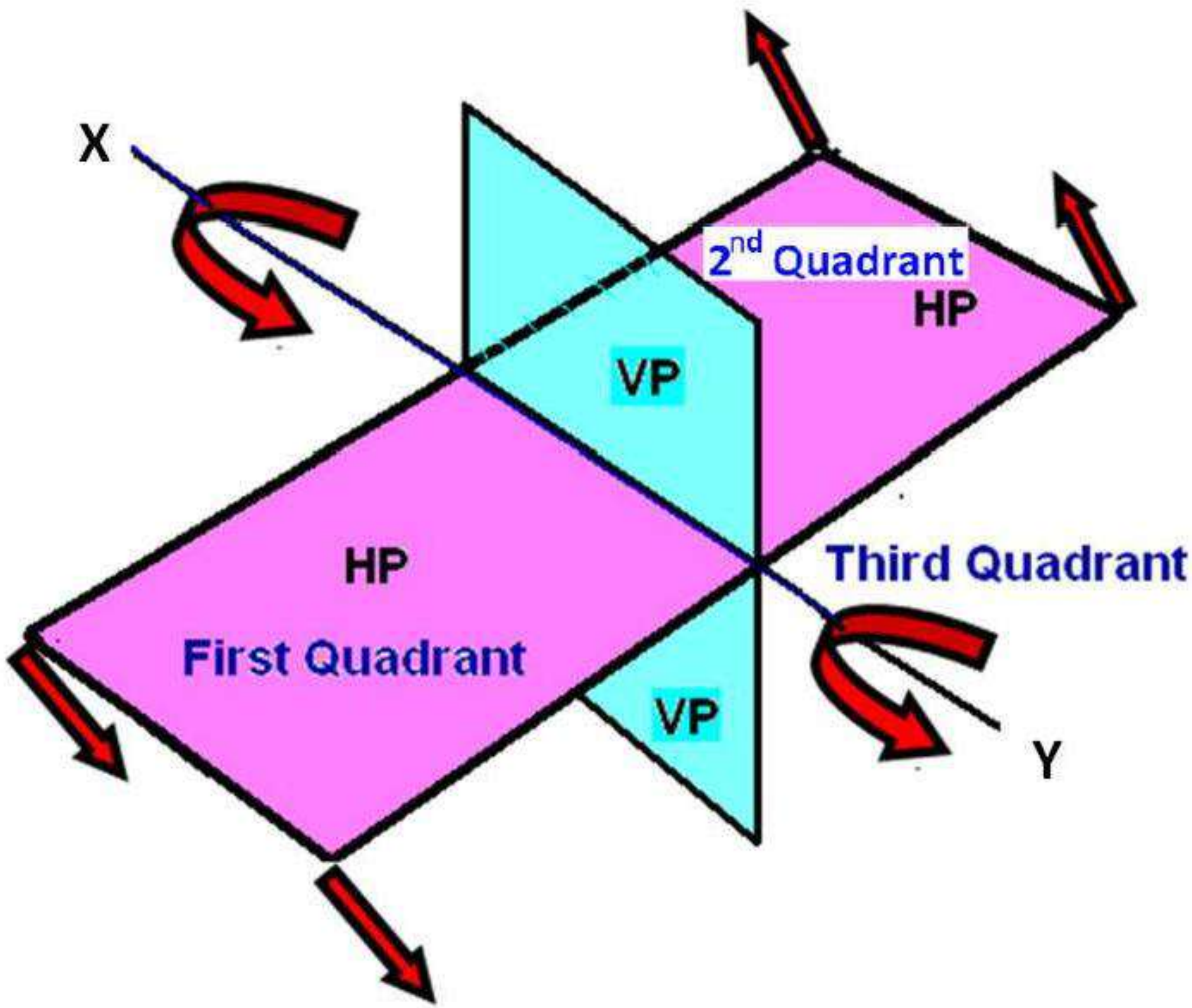
A POINT

Define its position with respect to the coordinates.

With respect to the VP, HP, & PP



Direction of rotation of the HP

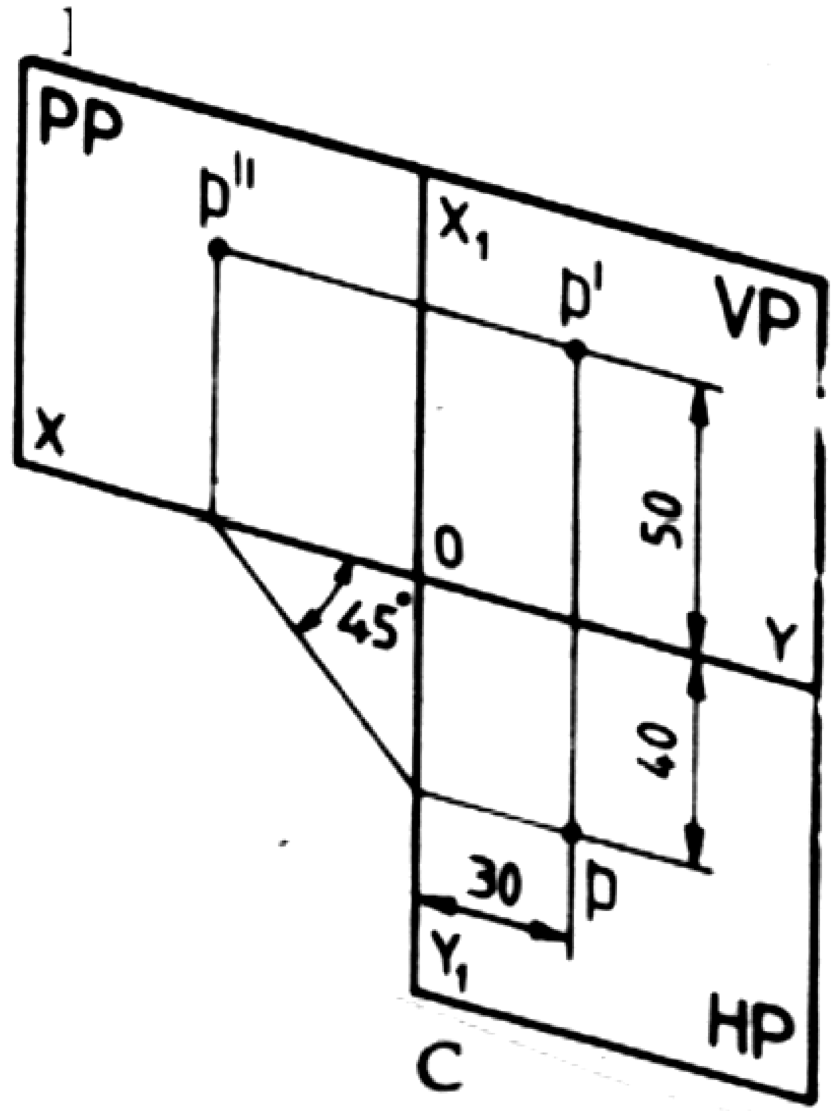


Convention

- **Top views are represented by only small letters eg. *a*.**
- **Their front views are conventionally represented by small letters with dashes eg. *a´***
- **Profile or side views are represented by small letters with double dashes eg. *a´´***

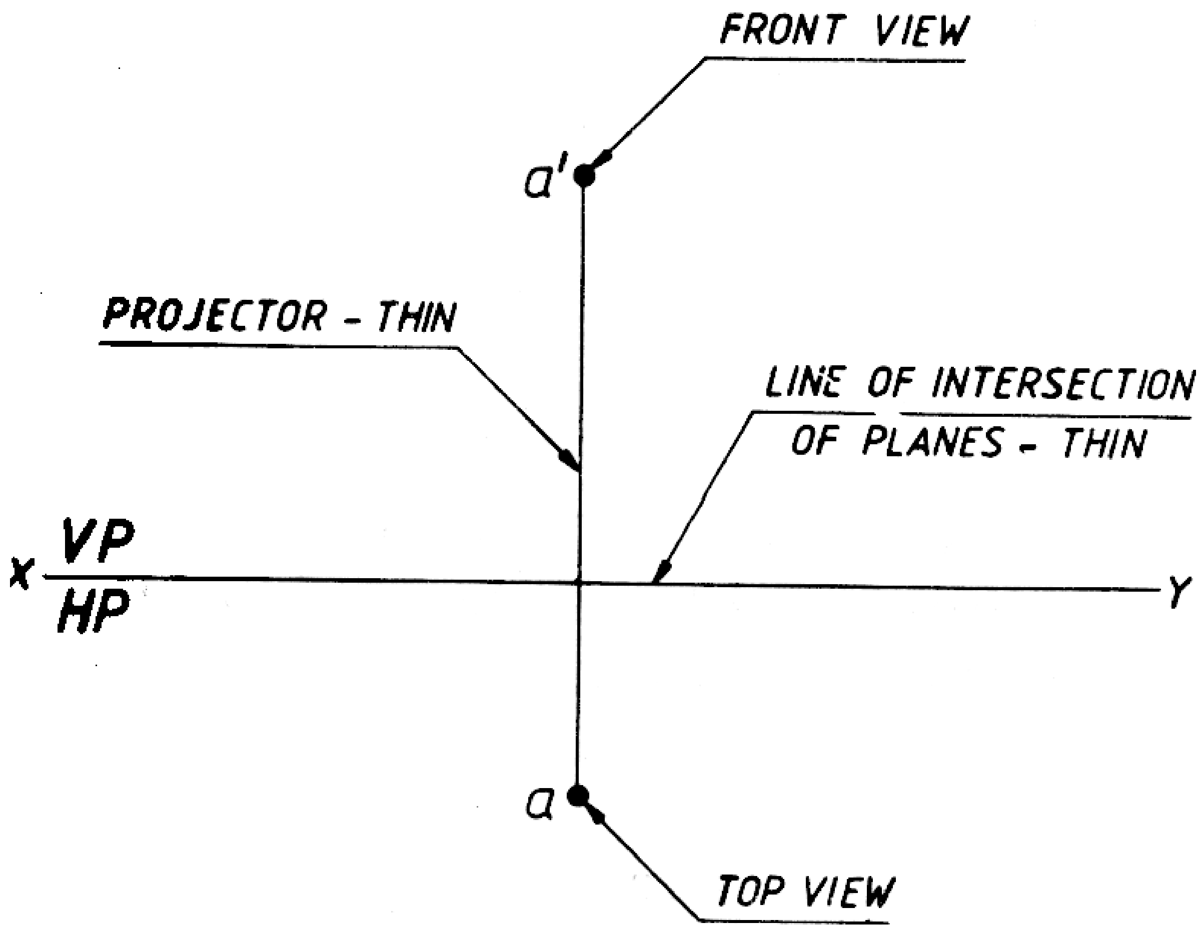
Convention

- The line of intersection of HP and VP is denoted as XY.
- The line of intersection of VP and PP is denoted as X_1Y_1



HP & PP Completely rotated

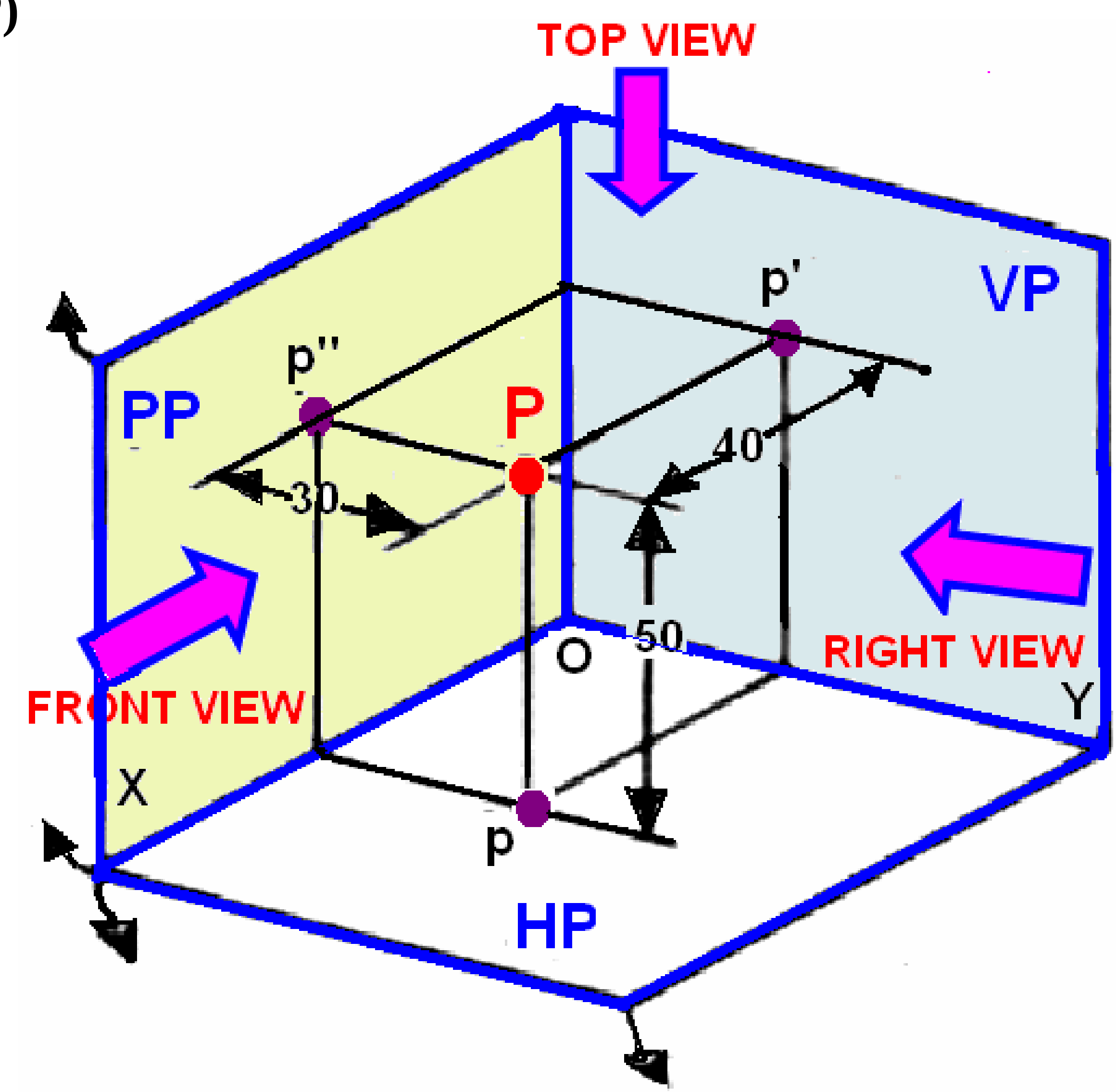
Convention



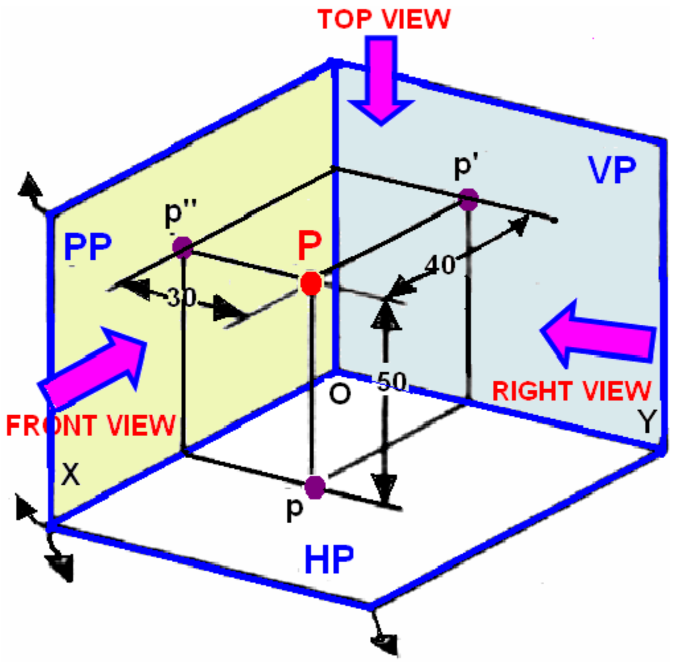
- Projectors and the lines of the intersection of planes of projections are shown as thin lines.

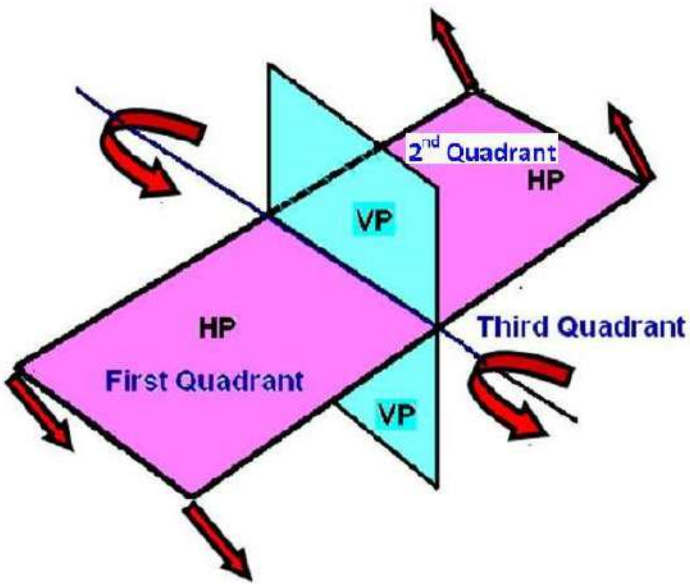
Point in the First quadrant

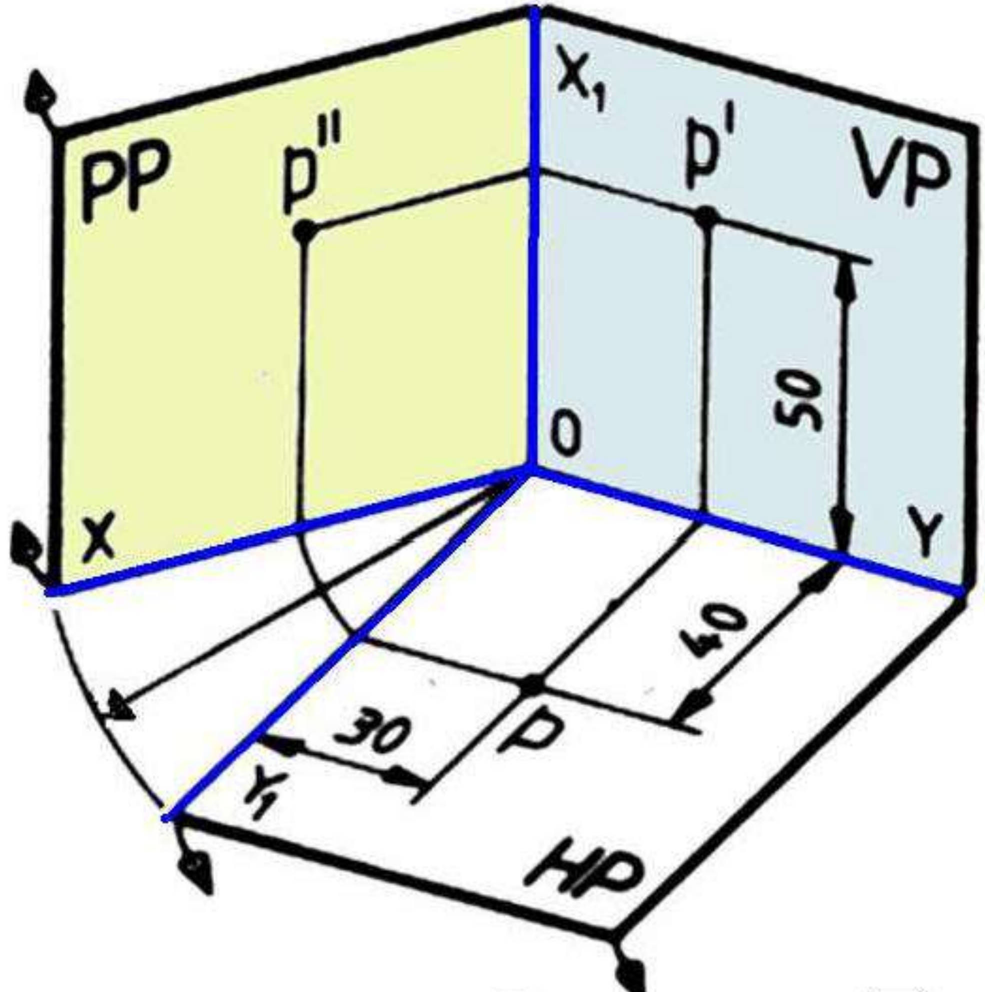
Point P is 40 mm in front of VP, 50 mm above HP, 30 mm in front of left profile plane (PP)



Point in the First quadrant



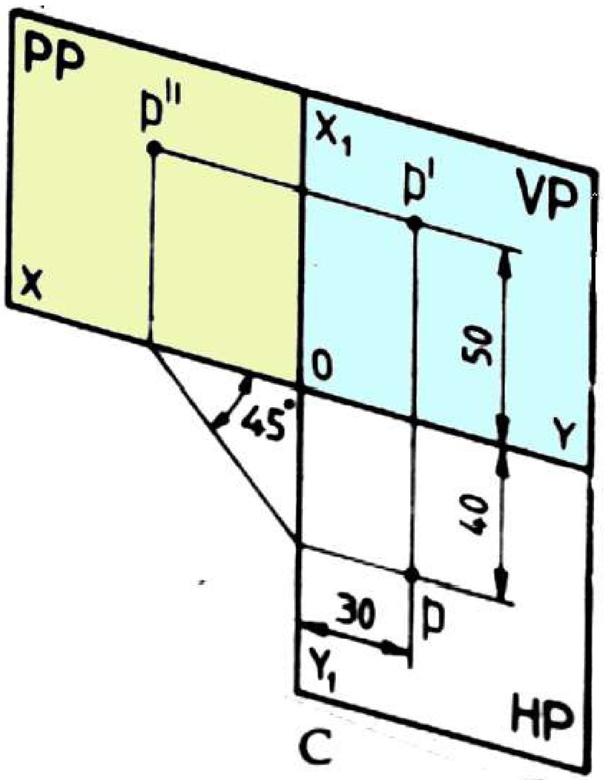




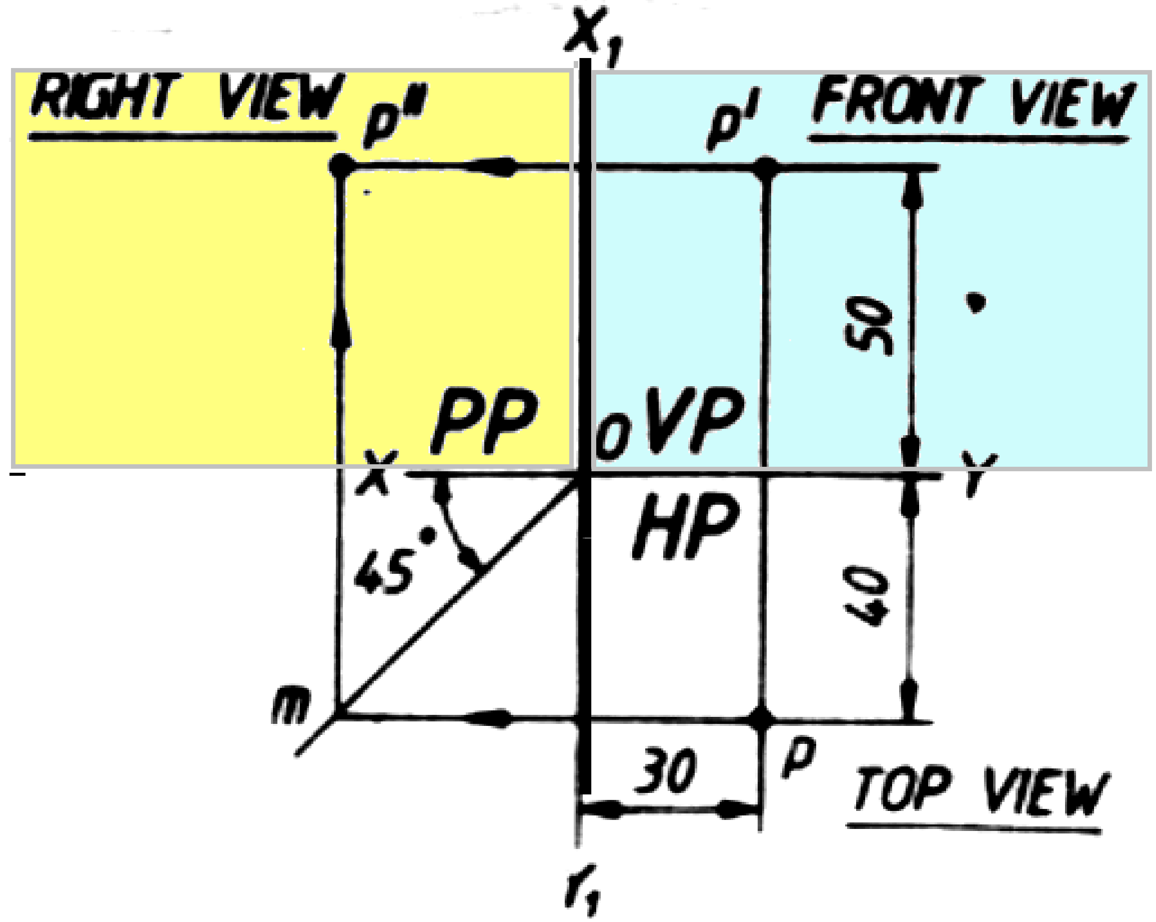
B

HP & PP Partly rotated

Point in the First quadrant



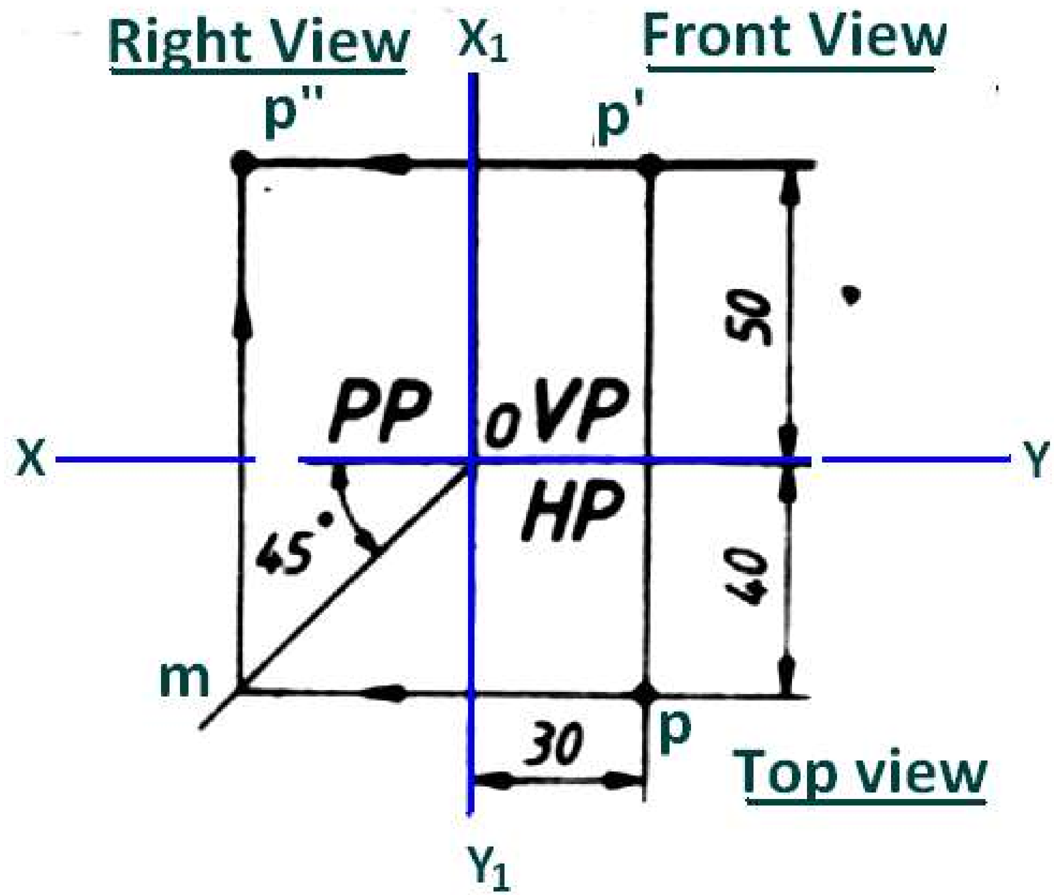
HP & PP Completely rotated



Point in the First quadrant

Procedure

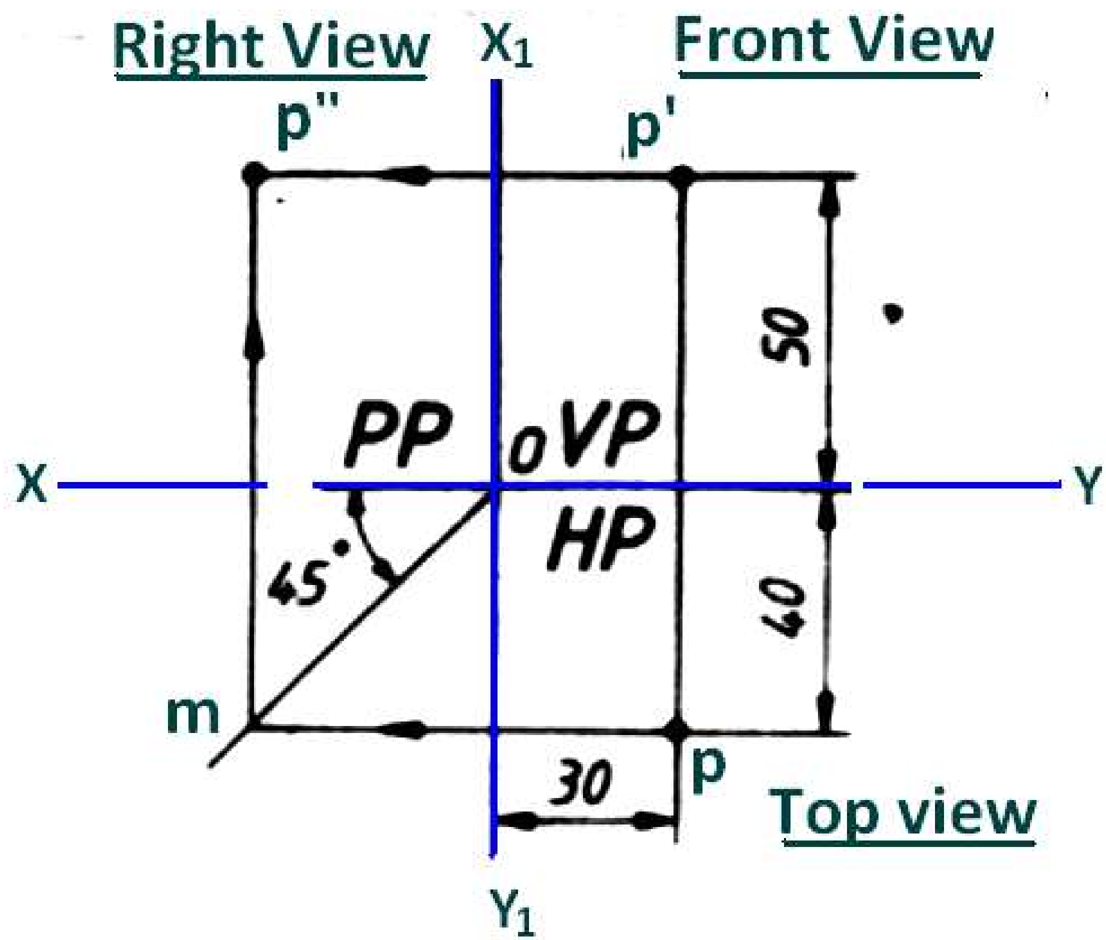
- Draw a thin horizontal line, XY, to represent the line of intersection
- Draw X1Y1 line to represent the line of intersection of VP and PP.
- Draw the Top View (p).
- Draw the projector line
- Draw the Front View (p´)



Point in the First quadrant

Procedure

- To project the right view on the left PP, draw a horizontal projector through p to intersect the 45 degree line at m.
- through m draw a vertical projector to intersect the horizontal projector drawn through p´ at p´´.
- p´´ is the right view of point P



THINK ??

Engineering Drawing

Lecture 6

Projection of Lines

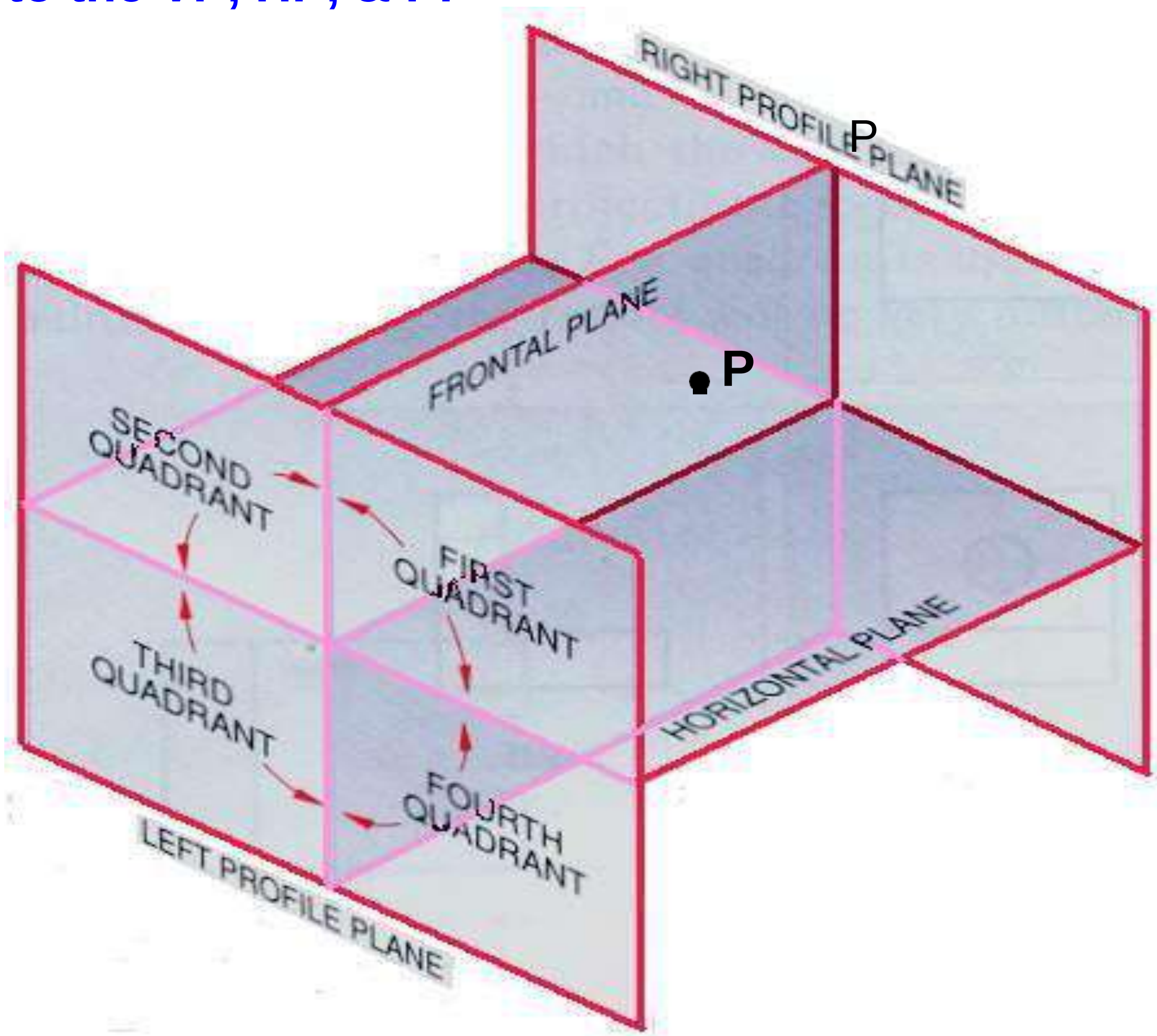
Projection of Points

(Orthographic)

A POINT

Define its position with respect to the coordinates.

With respect to the VP, HP, & PP



Direction of rotation of the HP

Convention

- **Top views are represented by only small letters eg. *a*.**

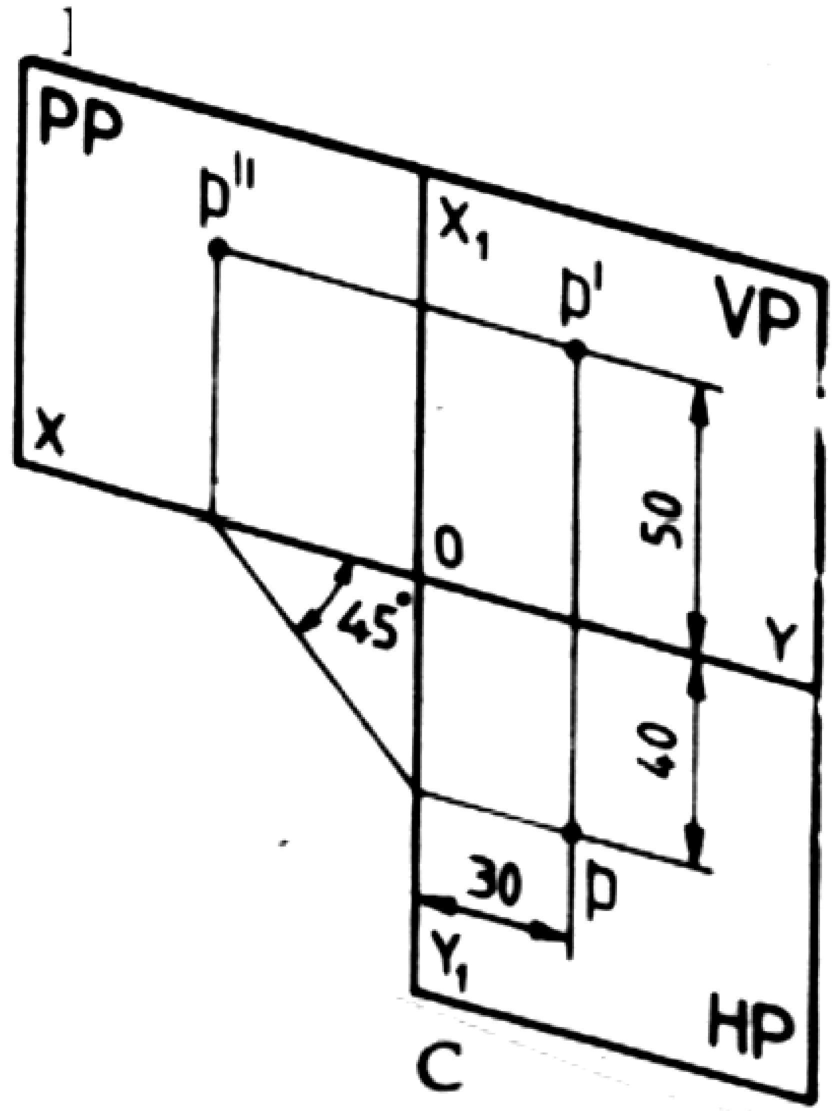
- **Their front views are conventionally represented by small letters with dashes eg. *a*´**

- **Profile or side views are represented by small letters with double dashes eg. *a*´´**

Convention

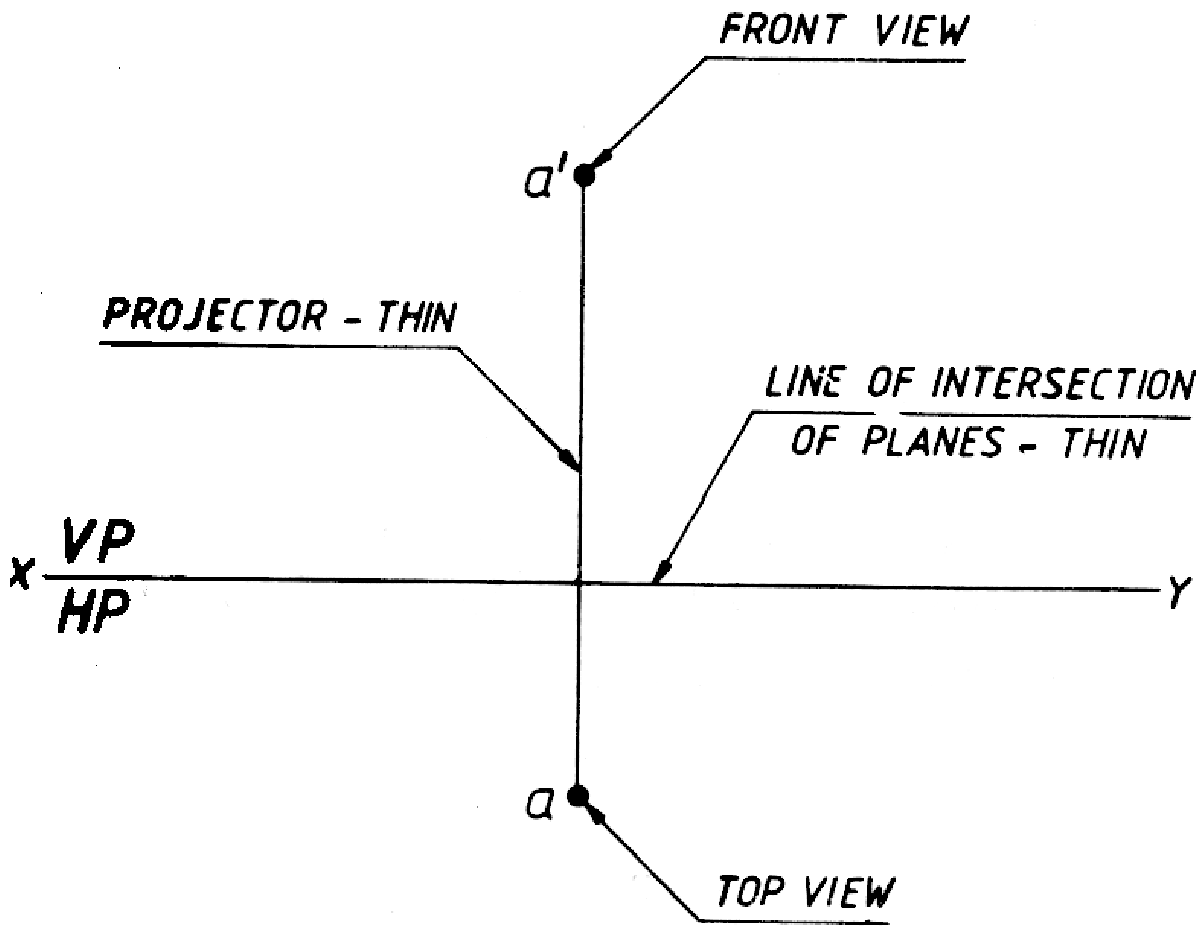
- **The line of intersection of HP and VP is denoted as XY.**

- **The line of intersection of VP and PP is denoted as X_1Y_1**



HP & PP Completely rotated

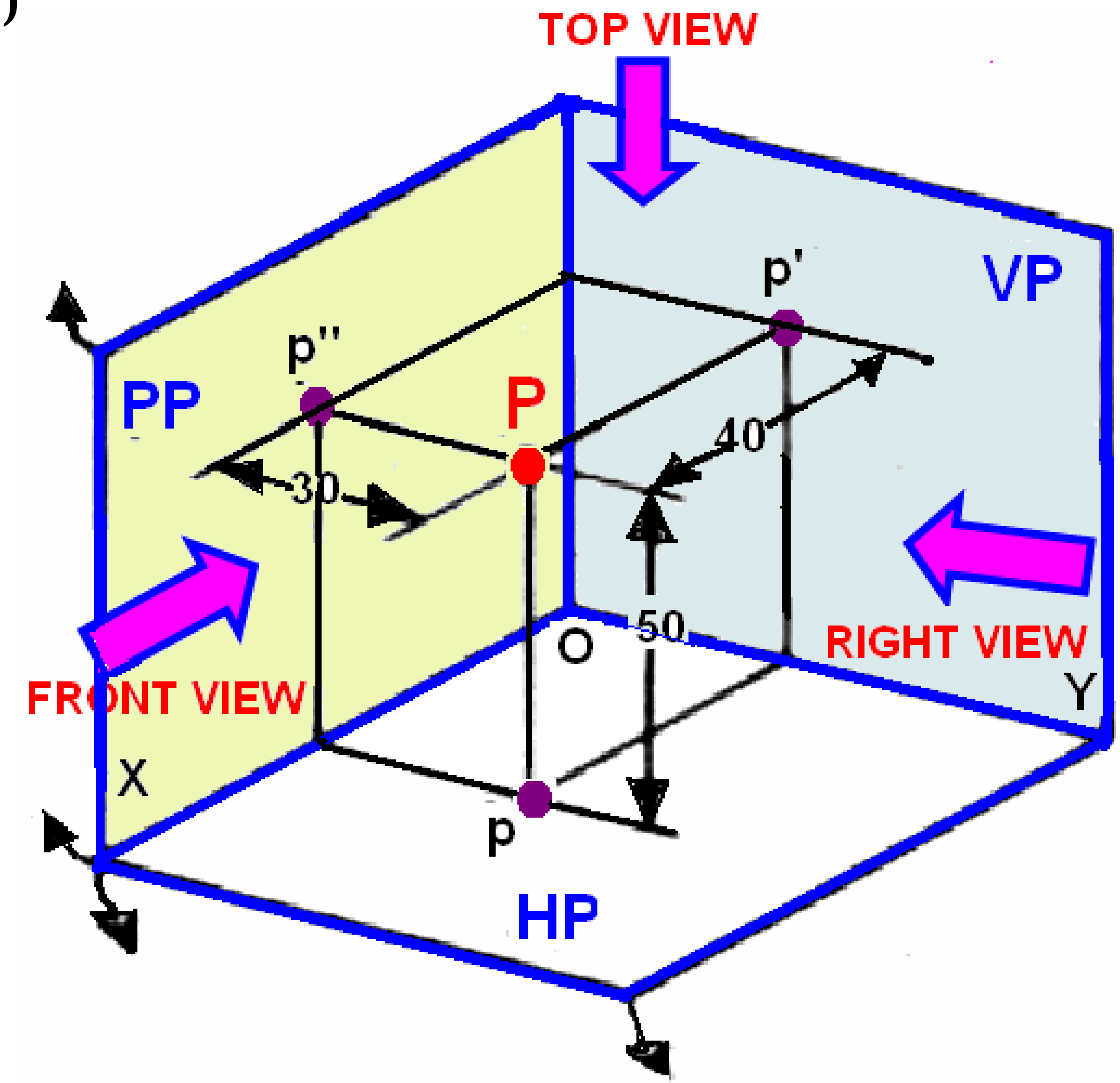
Convention



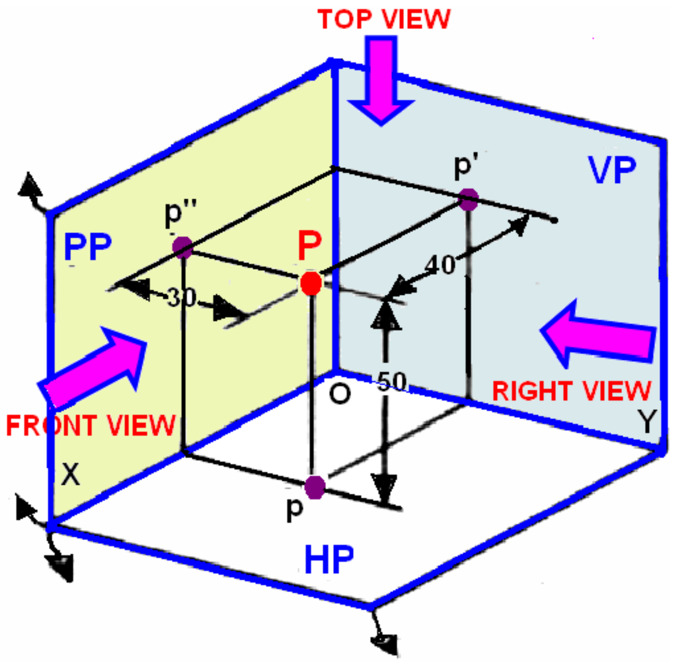
- **Projectors and the lines of the intersection of planes of projections are shown as thin lines.**

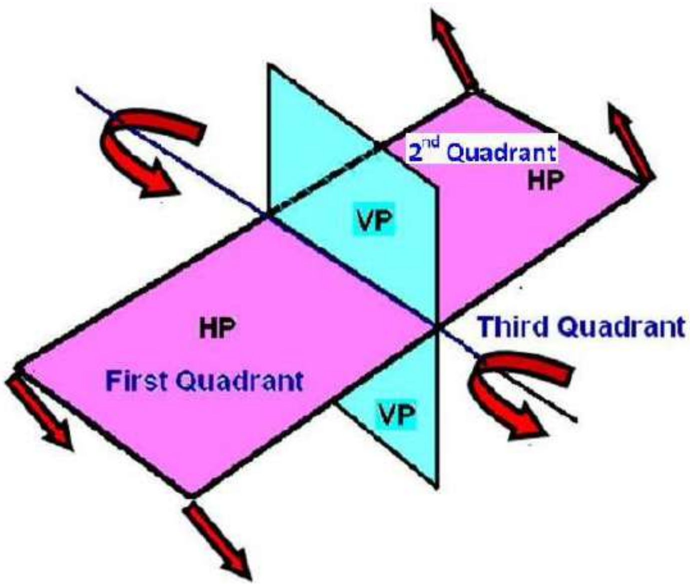
Point in the First quadrant

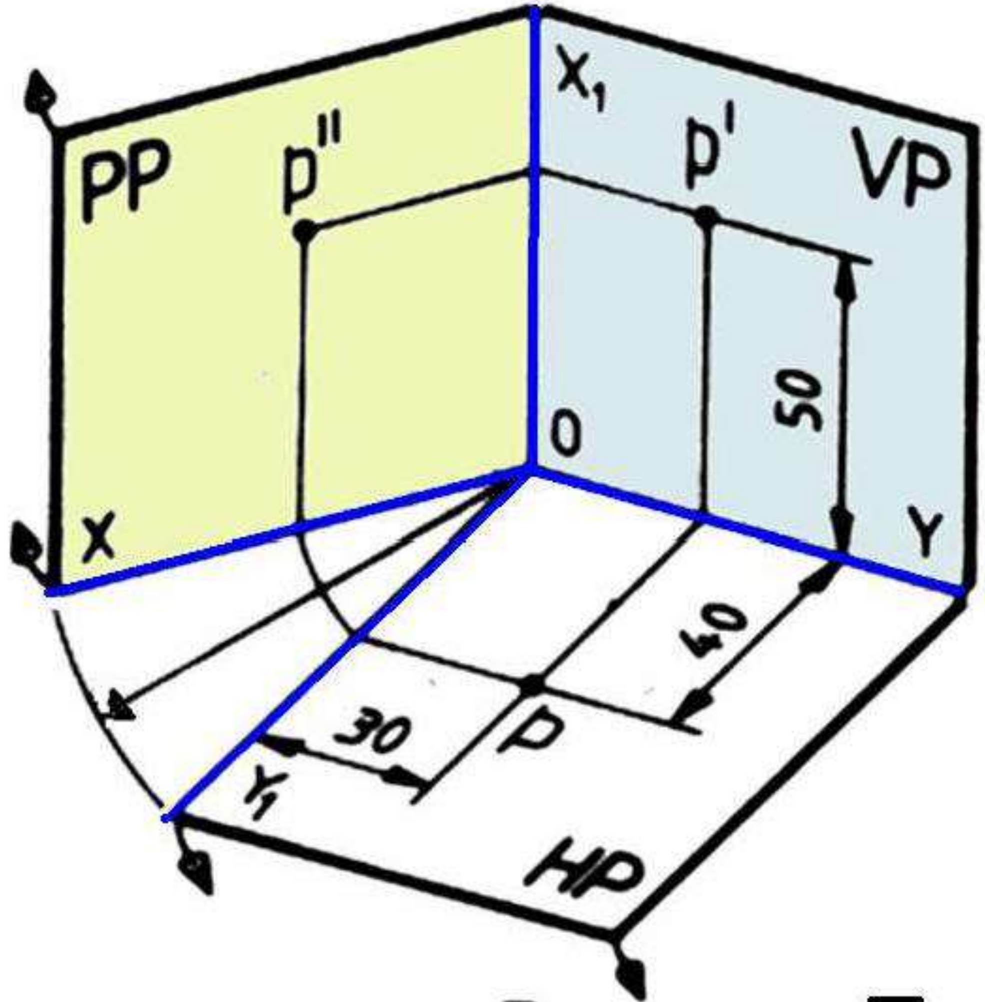
Point P is 40 mm in front of VP, 50 mm above HP, 30 mm in front of left profile plane (PP)



Point in the First quadrant

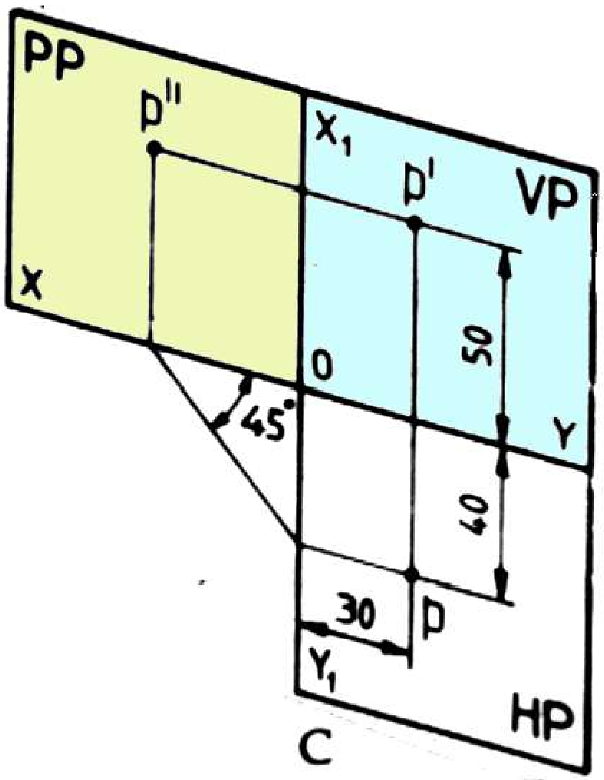






B
HP & PP Partly rotated

Point in the First quadrant

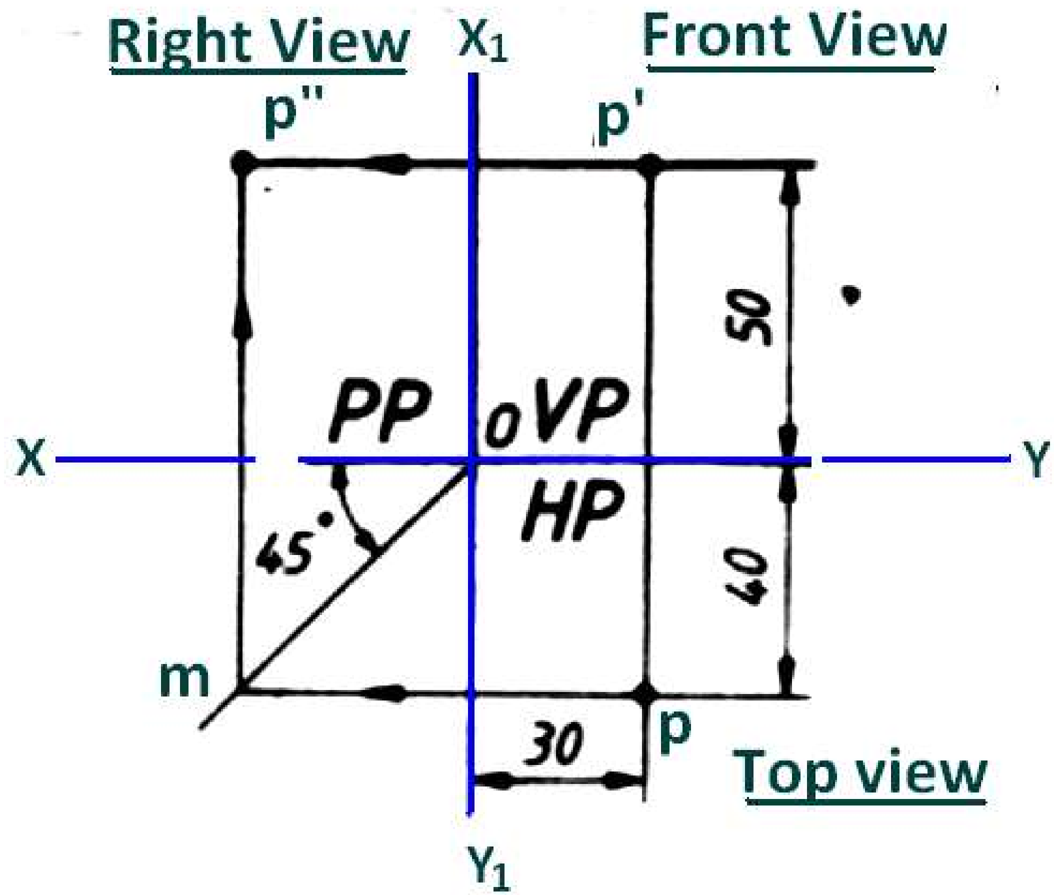


HP & PP Completely rotated

Point in the First quadrant

Procedure

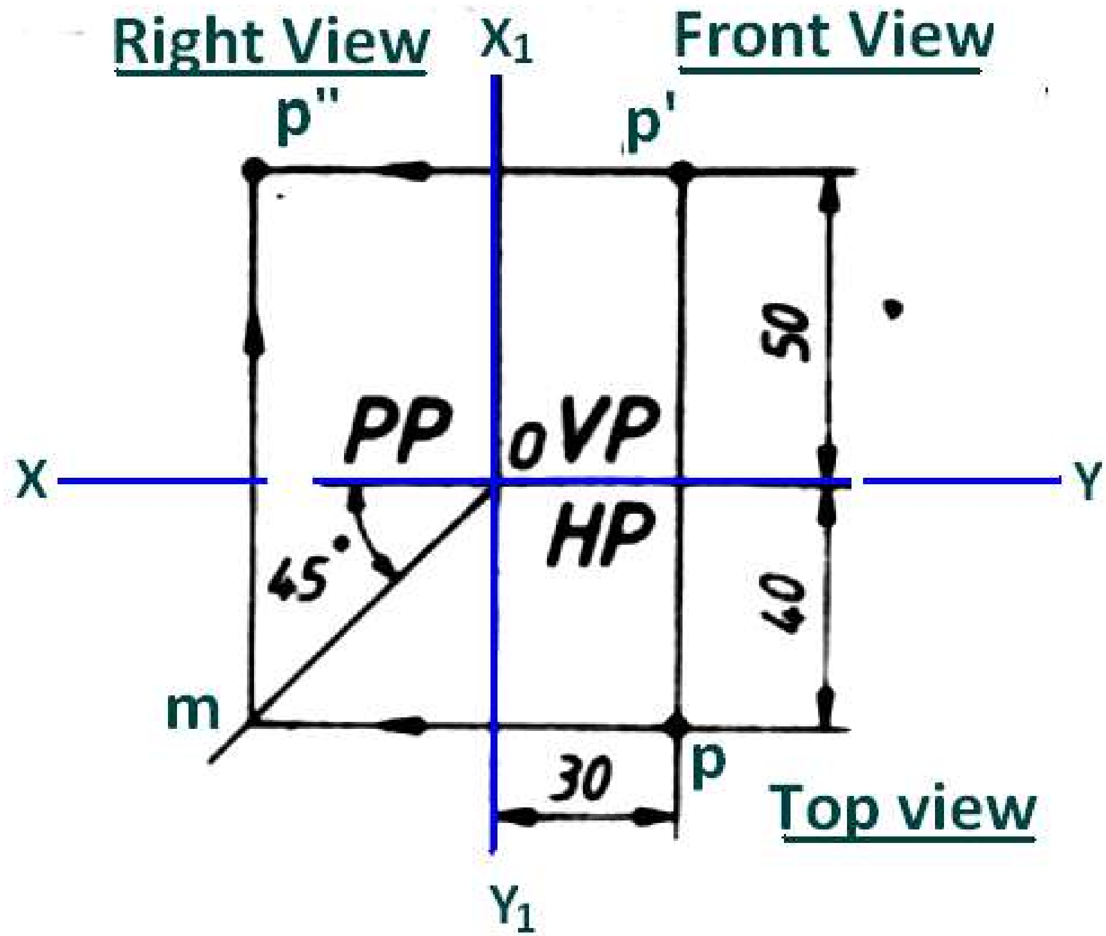
- Draw a thin horizontal line, XY, to represent the line of intersection
- Draw X1Y1 line to represent the line of intersection of VP and PP.
- Draw the Top View (p).
- Draw the projector line
- Draw the Front View (p´)



Point in the First quadrant

Procedure

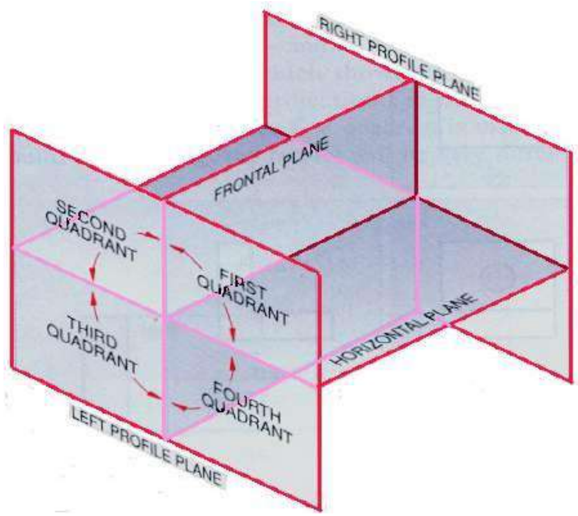
- To project the right view on the left PP, draw a horizontal projector through p to intersect the 45 degree line at m.
- through m draw a vertical projector to intersect the horizontal projector drawn through p´ at p´´.
- p´´ is the right view of point P

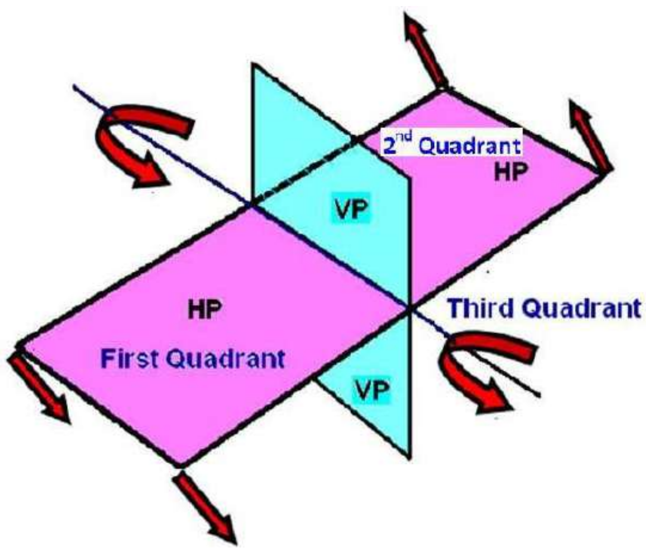


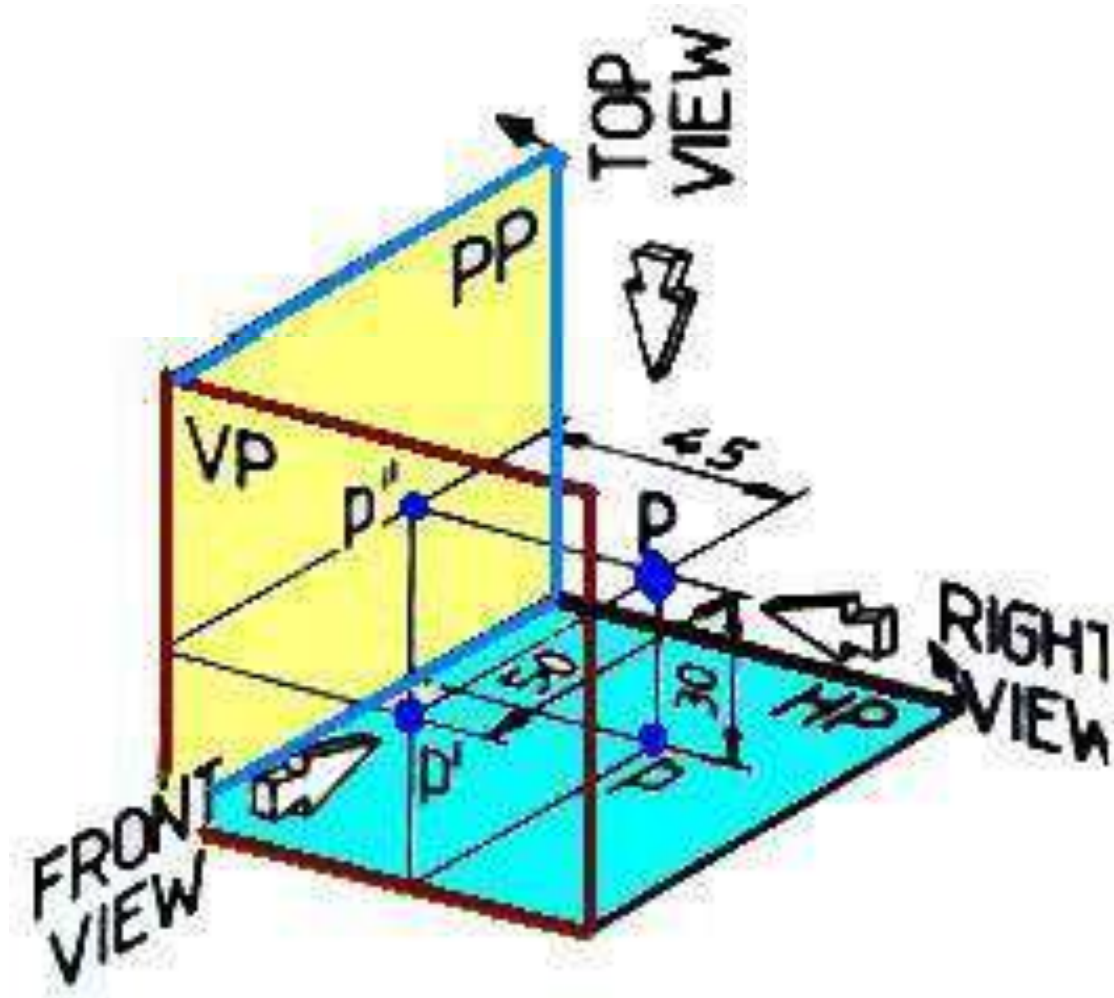
Point in the Second quadrant

point P is 30 mm above HP, 50 mm behind VP and 45 mm in front of left PP

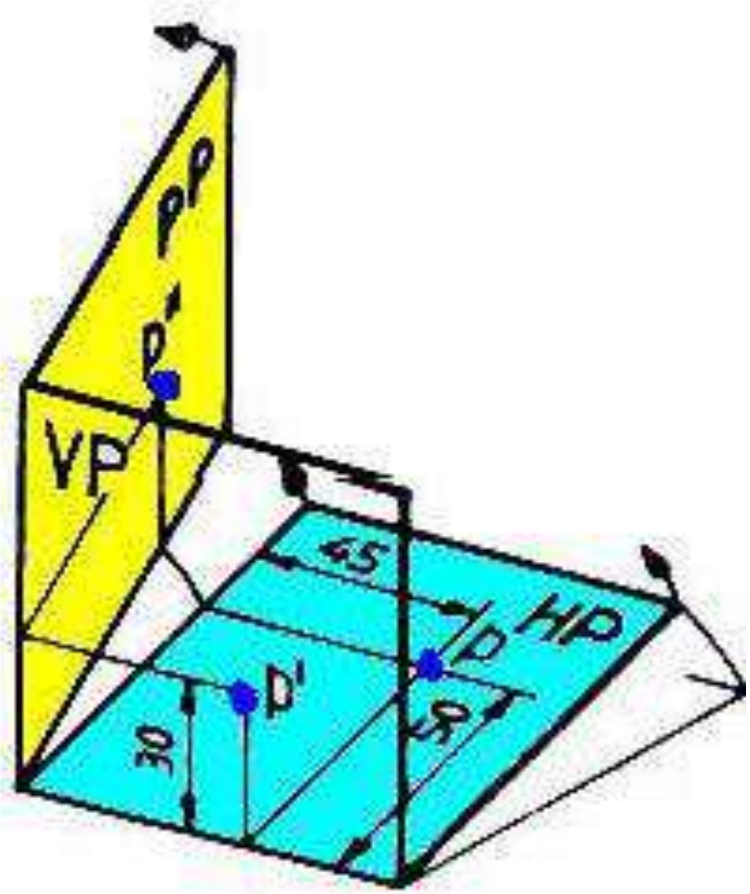
Since point P is located behind VP, the VP is assumed transparent.

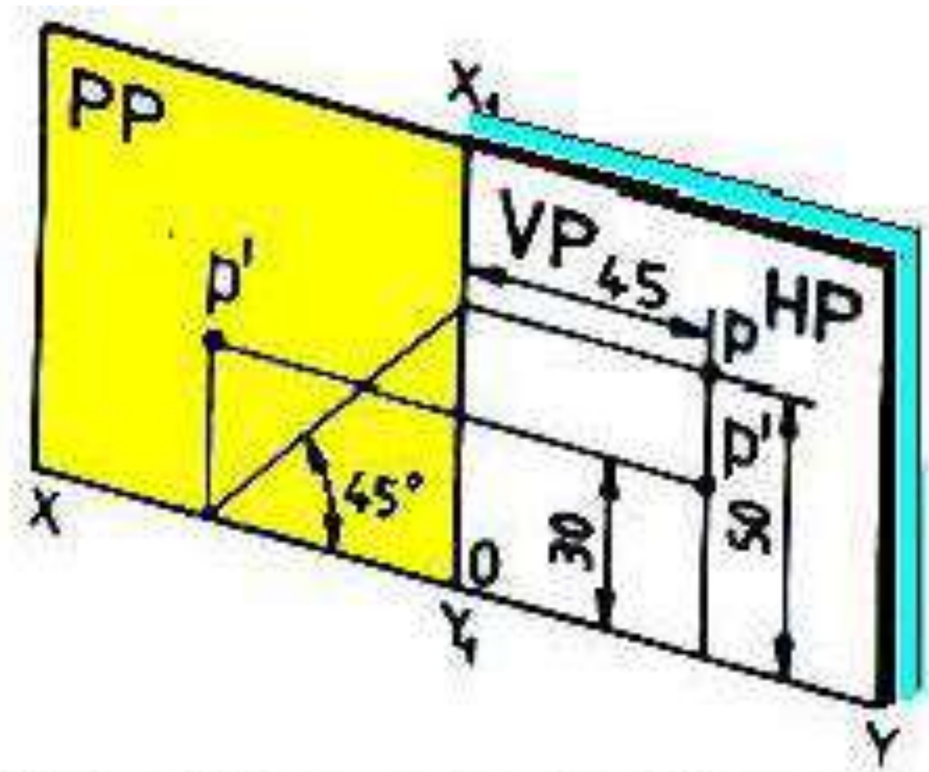






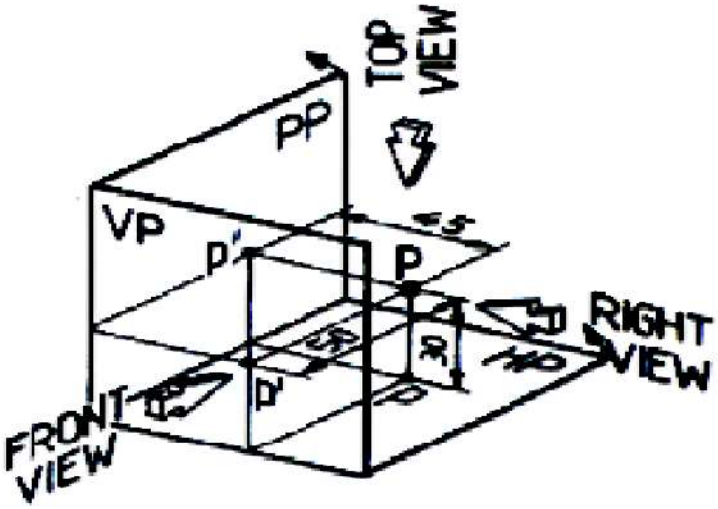
Direction of rotation of the HP



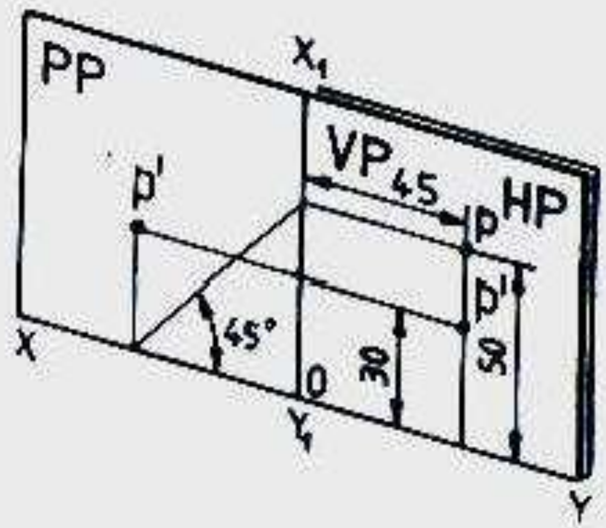


HP & PP Completely Rotated

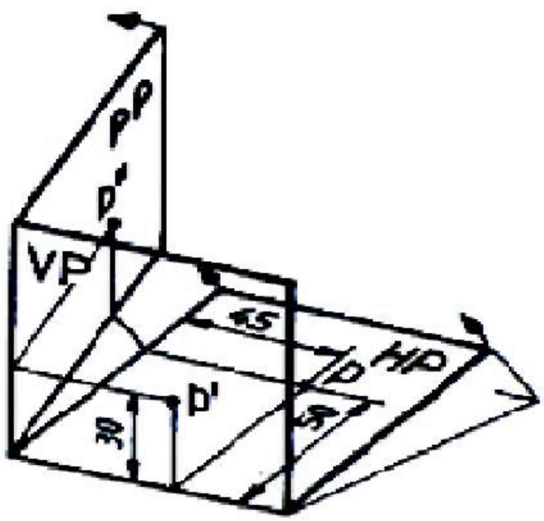
Point in the Second quadrant



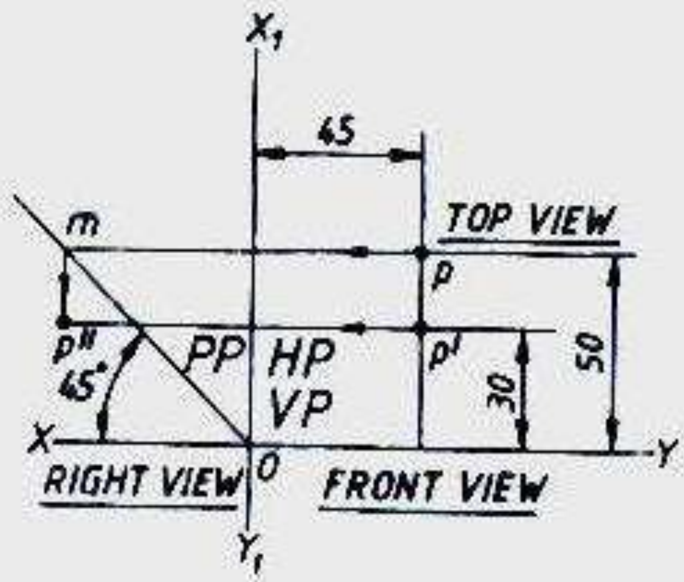
Point in the II Quadrant



HP & PP Completely Rotated



HP & PP Partly Rotated

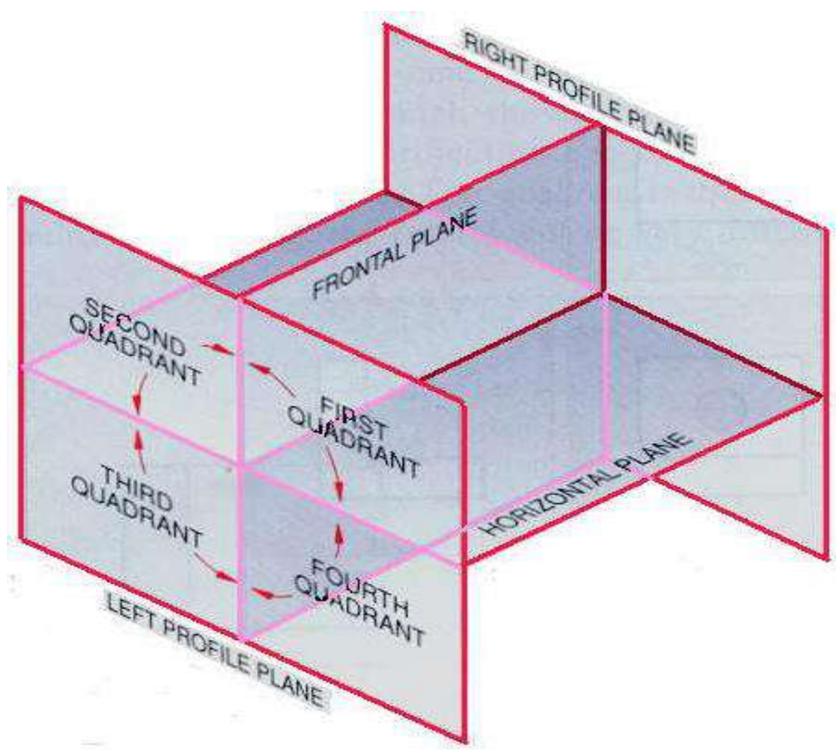


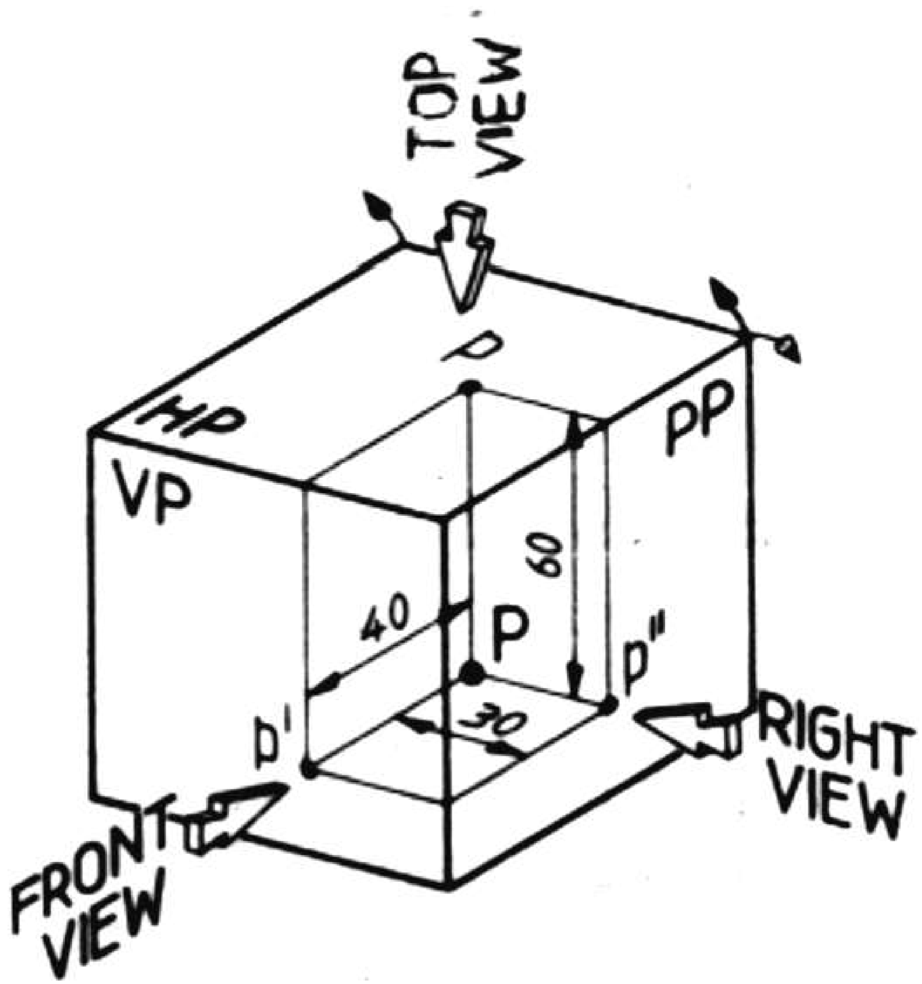
Orthographic Projection

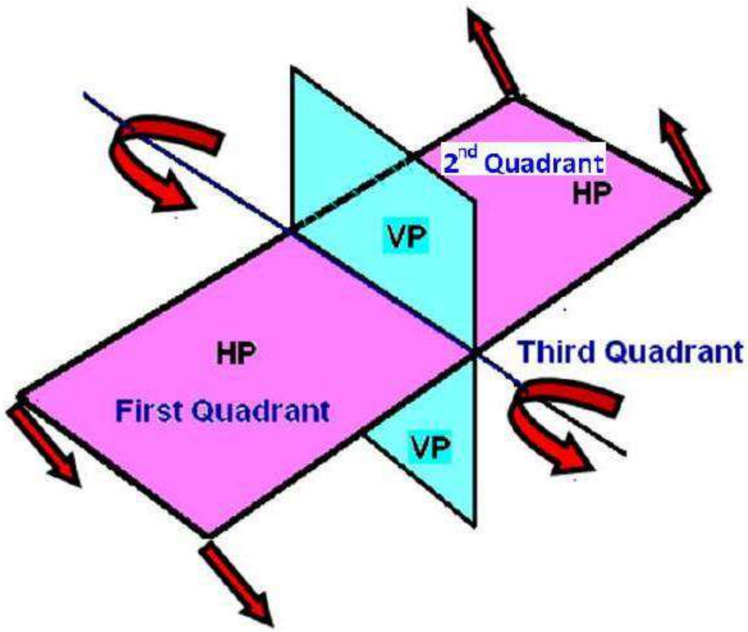
Point in the Third quadrant

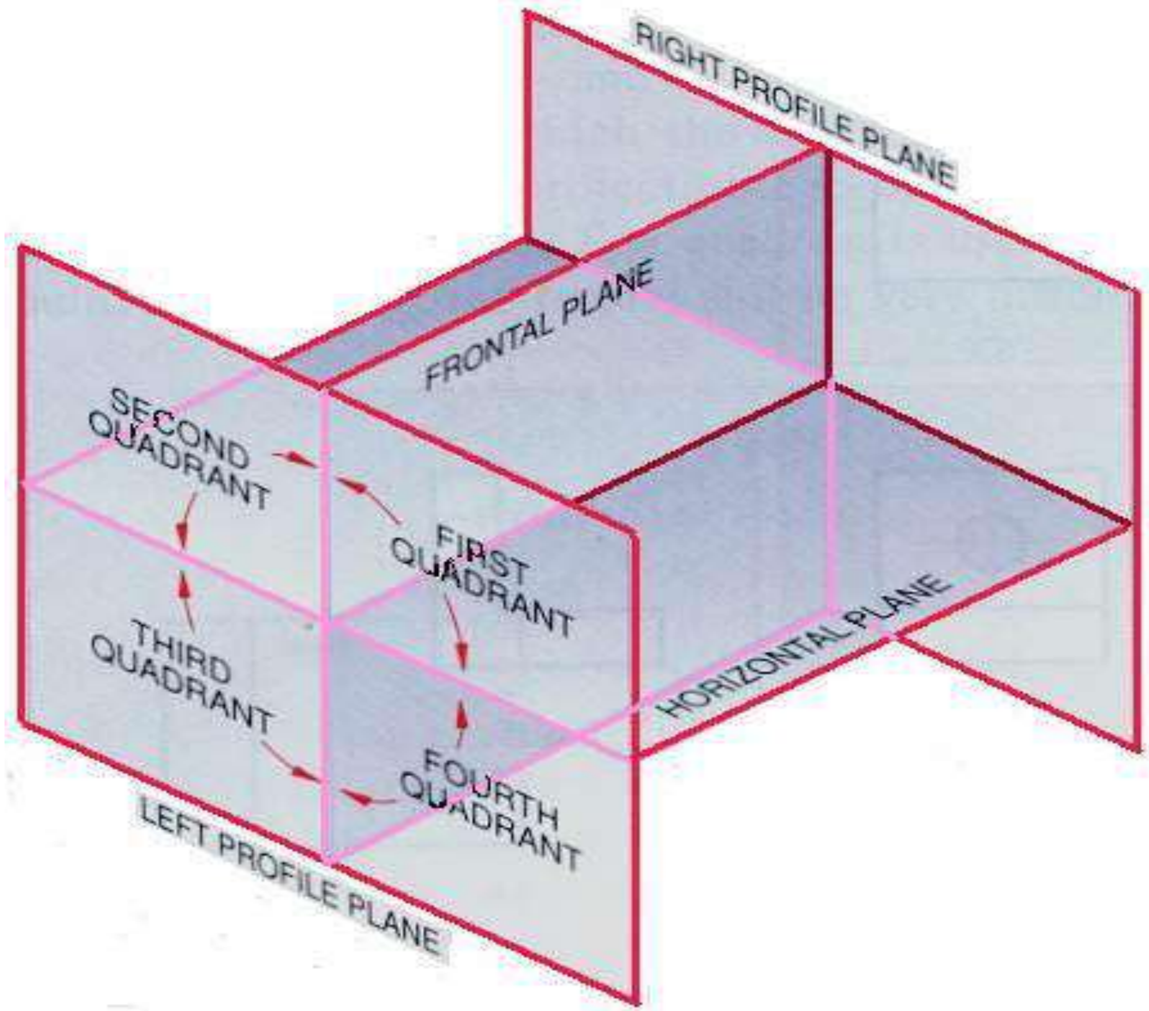
point P is 40 mm behind VP, 60 mm below HP and 30 mm behind the right PP.

Since the three planes of projections lie in between the observer and the point P, they are assumed as transparent planes.

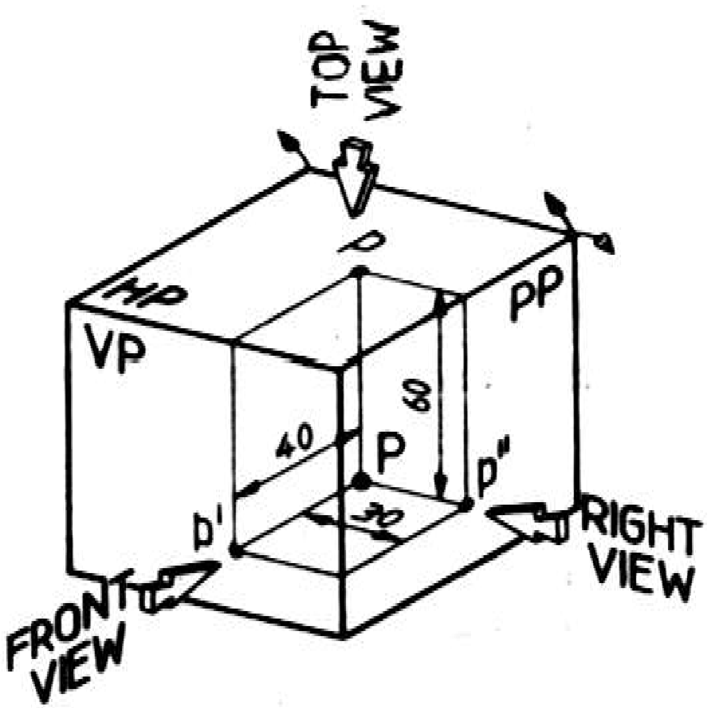




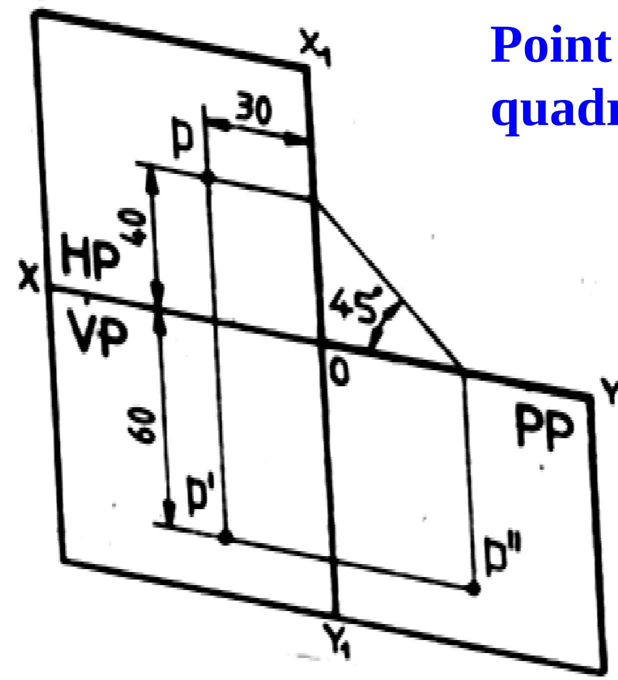

2nd Quadrant
HP
VP
HP
First Quadrant
Third Quadrant
VP


RIGHT PROFILE PLANE
FRONTAL PLANE
SECOND QUADRANT
FIRST QUADRANT
THIRD QUADRANT
FOURTH QUADRANT
HORIZONTAL PLANE
LEFT PROFILE PLANE

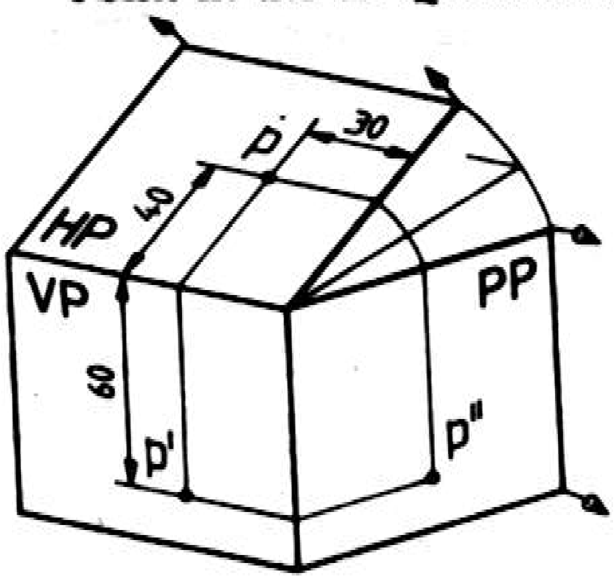
Point in 3rd quadrant



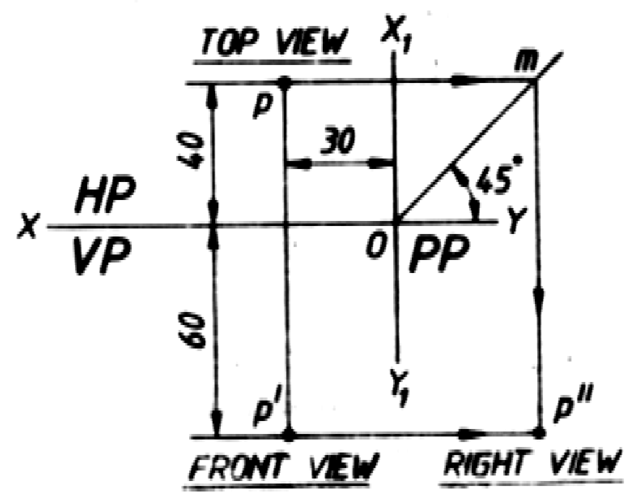
Point in the III QuadRant



HP & PP Completely Rotated



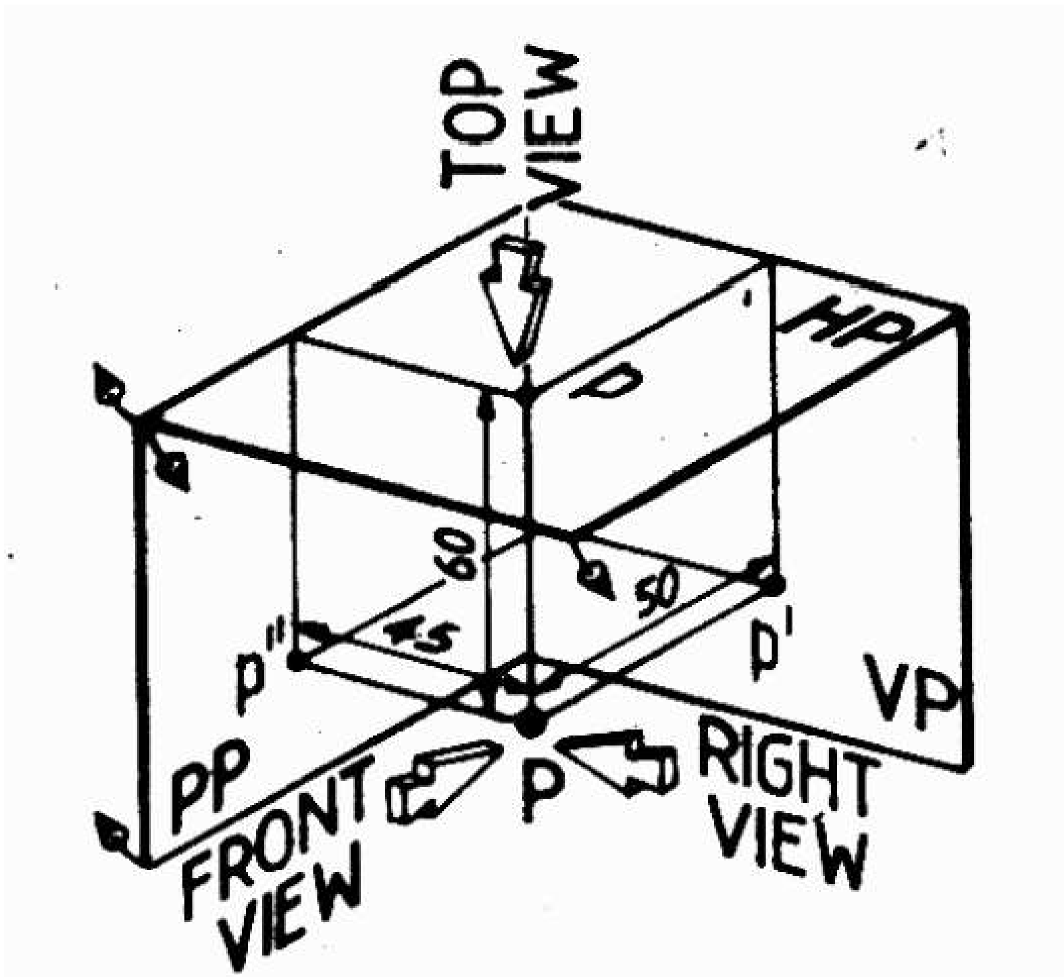
HP & PP Partly Rotated

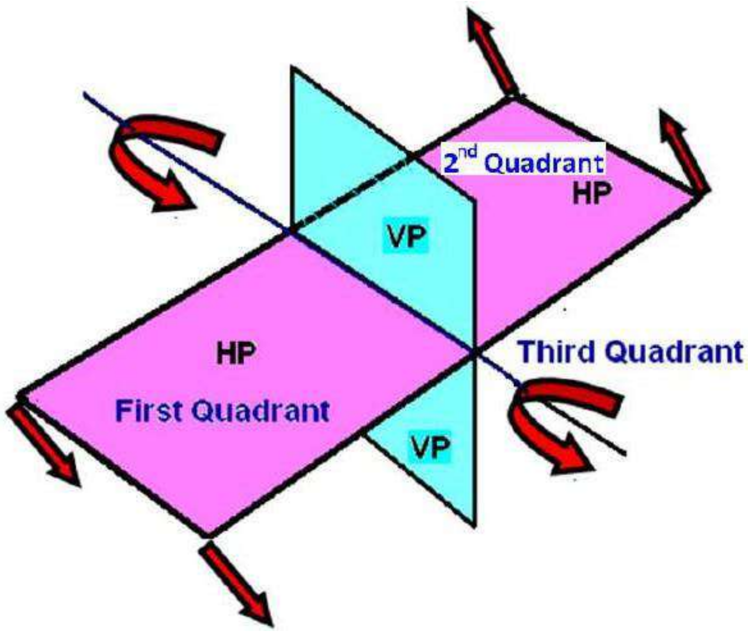


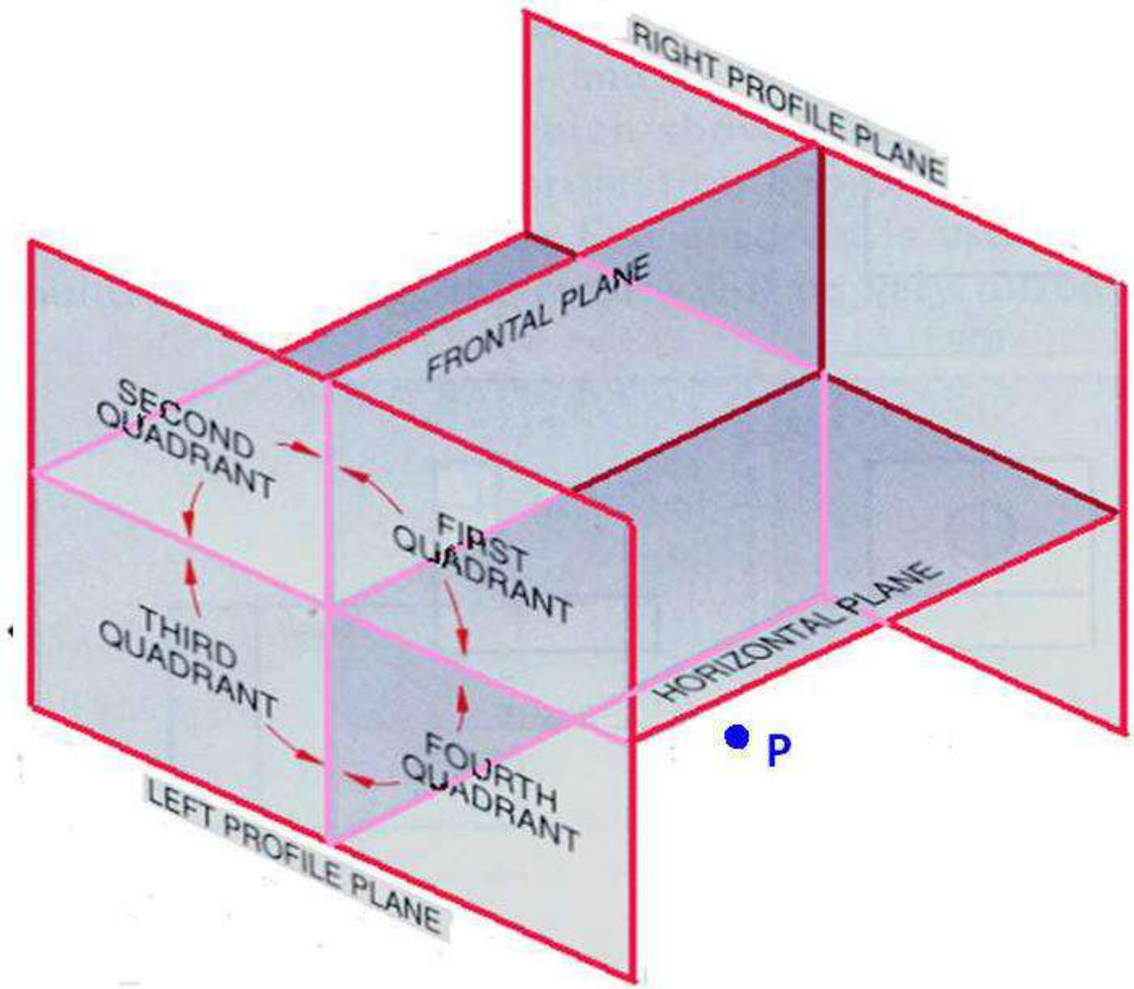
Orthographic Projection

Point in the Fourth quadrant

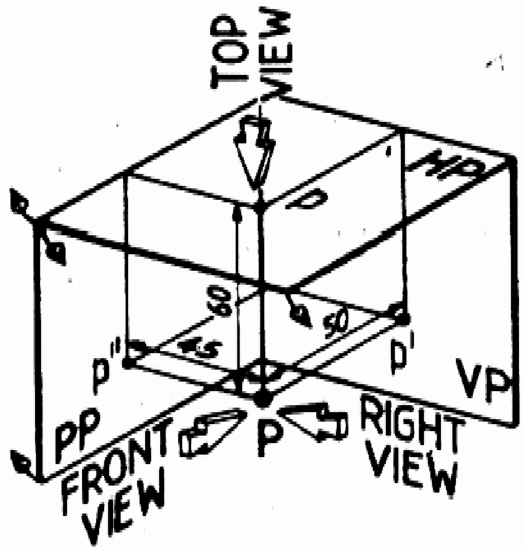
point P is 60 mm below HP, 50 mm in front of VP, 45 mm in front of the left PP.



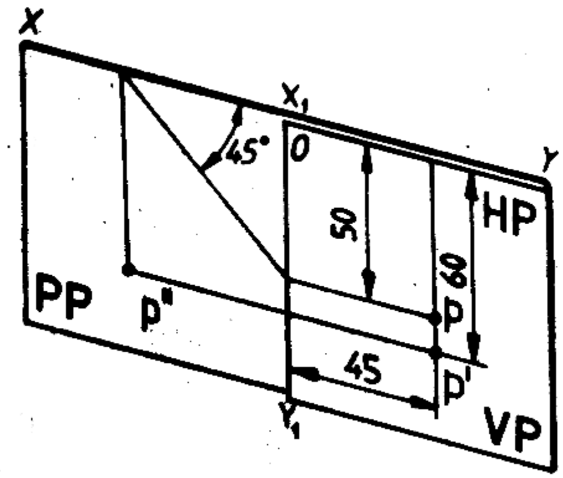

2nd Quadrant
HP
VP
HP
First Quadrant
Third Quadrant
VP


RIGHT PROFILE PLANE
FRONTAL PLANE
SECOND QUADRANT
FIRST QUADRANT
THIRD QUADRANT
FOURTH QUADRANT
HORIZONTAL PLANE
P
LEFT PROFILE PLANE

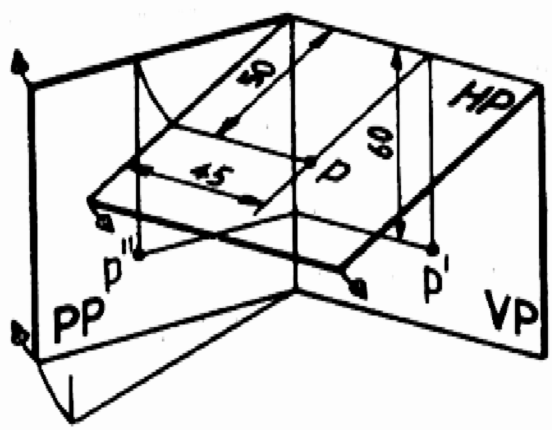
Point in the Fourth quadrant



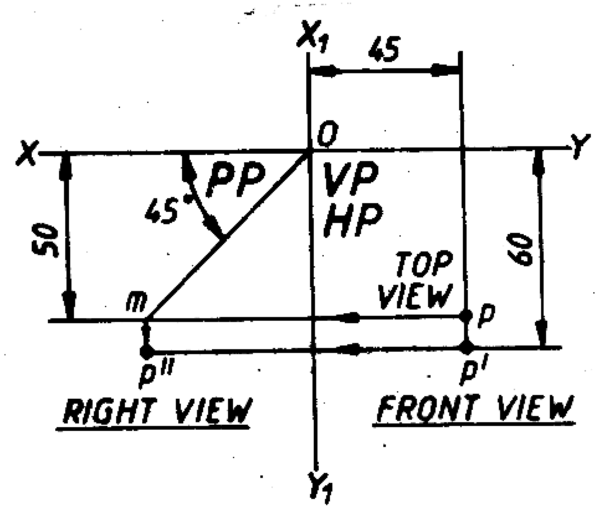
Point P in the IV Quadrant



HP & PP Completely Rotated



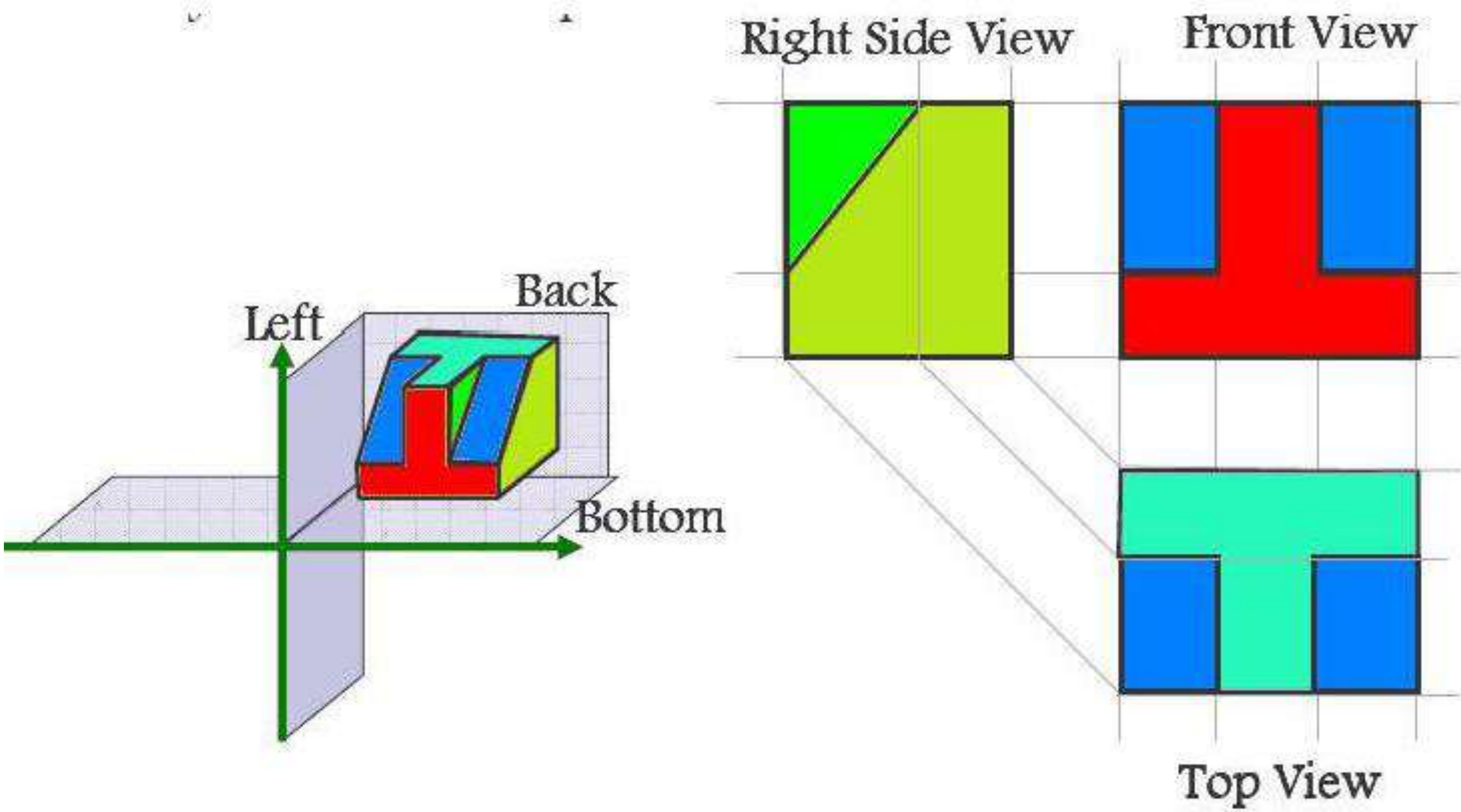
HP & PP Partly Rotated



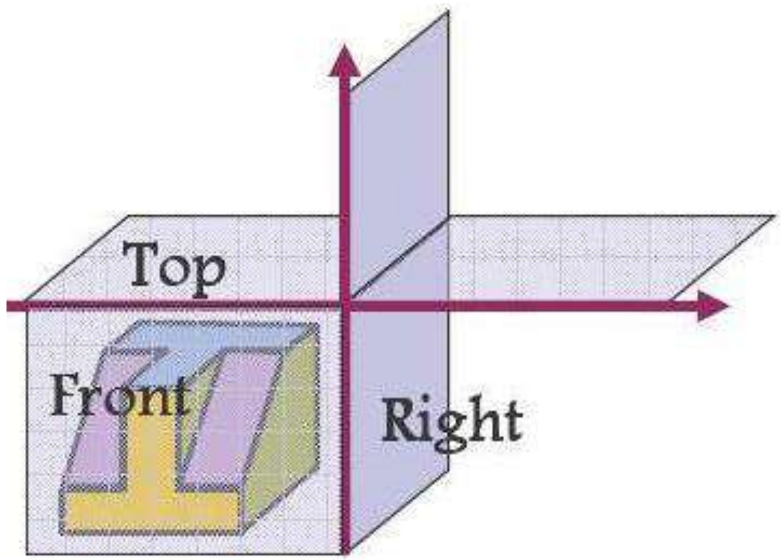
Orthographic Projection

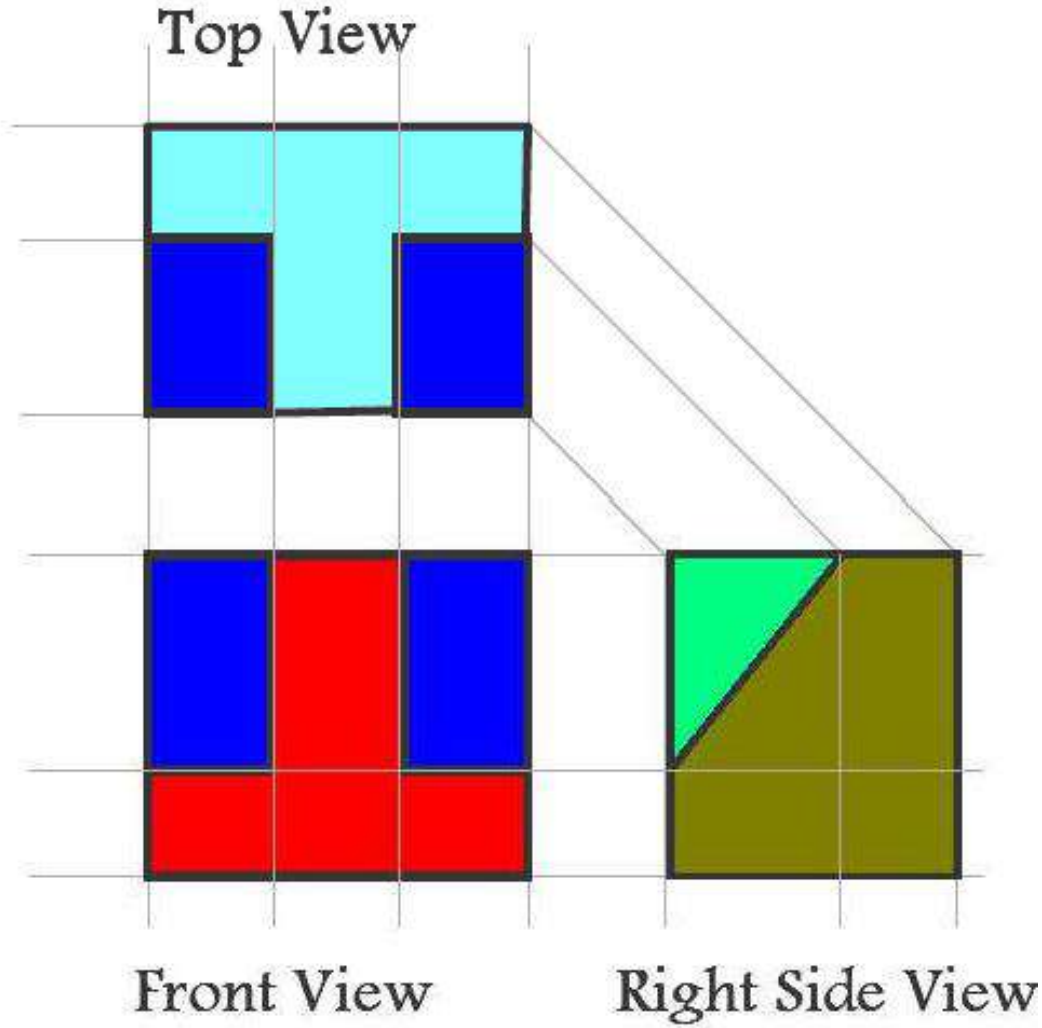
First Angle Projection

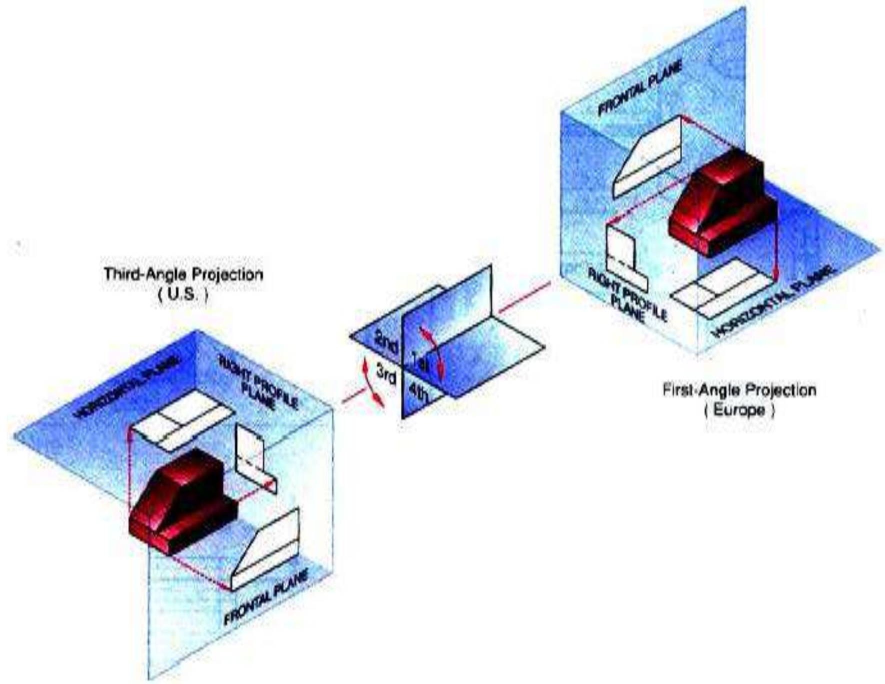
Object in the first quadrant



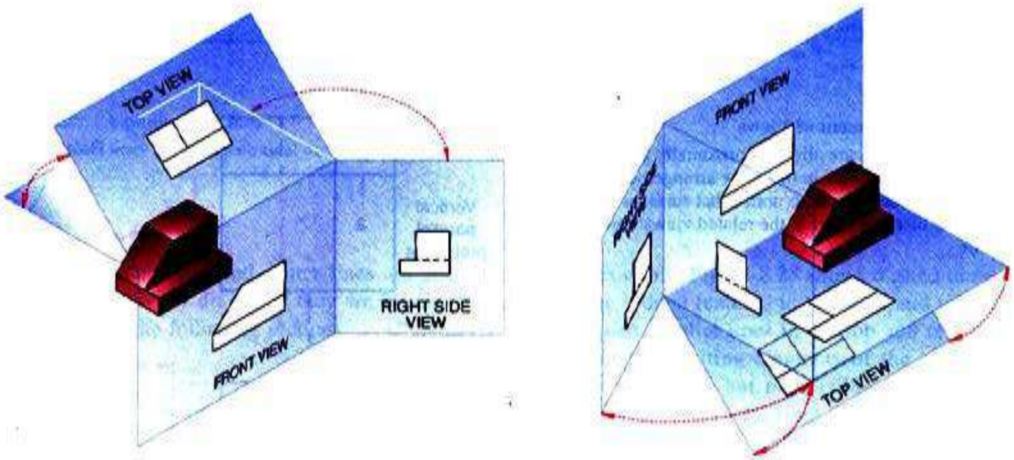
- THIRD Angle Projection
  - Object behind plane







Placing the object in the third quadrant puts the projection planes between the viewer and the object.



(A) Third-Angle Projection

(B) First-Angle Projection

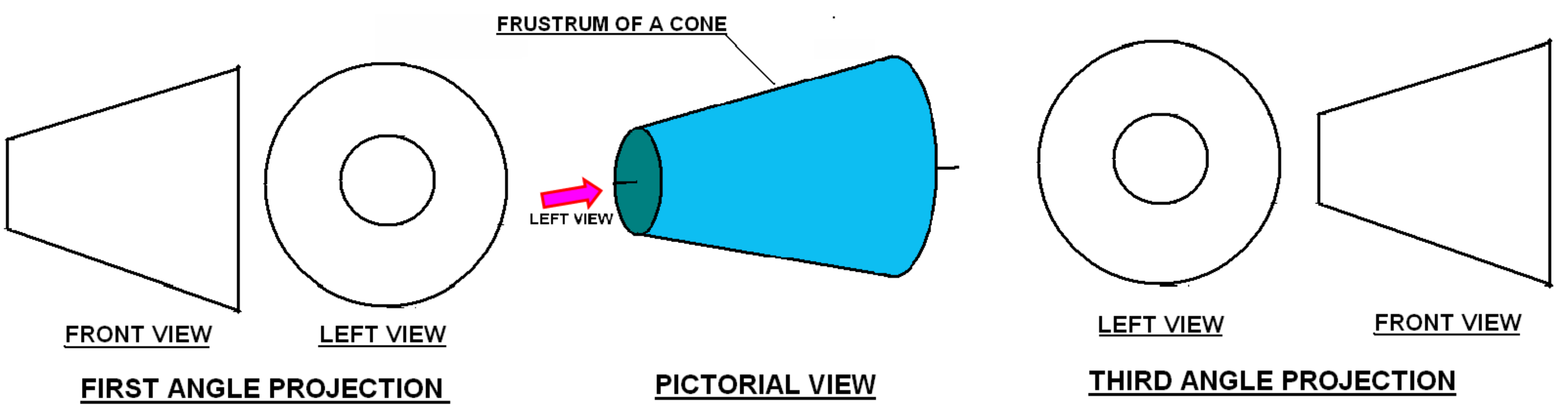
When placed in the first quadrant, the object is between the viewer and the projection planes.

Difference between first- and third-angle projections

First angle projection	Third-angle projection
Object is kept in the first quadrant.	Object is assumed to be kept in the third quadrant.
Object lies between observer and the plane of projection.	Plane of projection lies between the observer and the object.
The plane of projection is assumed to be non-transparent.	The plane of projection is assumed to be transparent.
Front (elevation) view is drawn above the XY line	Front (elevation) view is drawn below the XY line
Top (plan) view is drawn below the XY line	Top (plan) view is drawn above the XY line
Left view is projected on the right plane and vise versa	Left view is projected on the left plane itself.
Followed in India, European countries	Followed in USA

Symbol of projection

The method of projection used should be indicated in the space provided for the purpose in the title box of the drawing sheet. The symbol recommended by BIS is to draw the two sides of a frustum of a cone placed with its axis horizontal.



Projections of Lines

Straight line

Locus of a point, which moves linearly the shortest distance between any two given points.

Location of a line

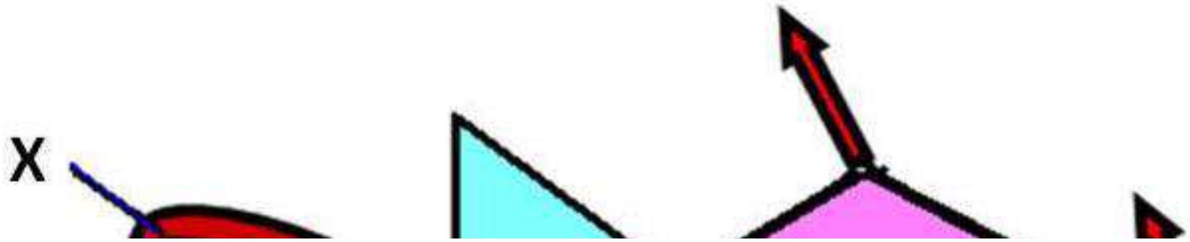
The location of a line in projection quadrants is described by specifying the distances of its end points from the VP, HP and PP.

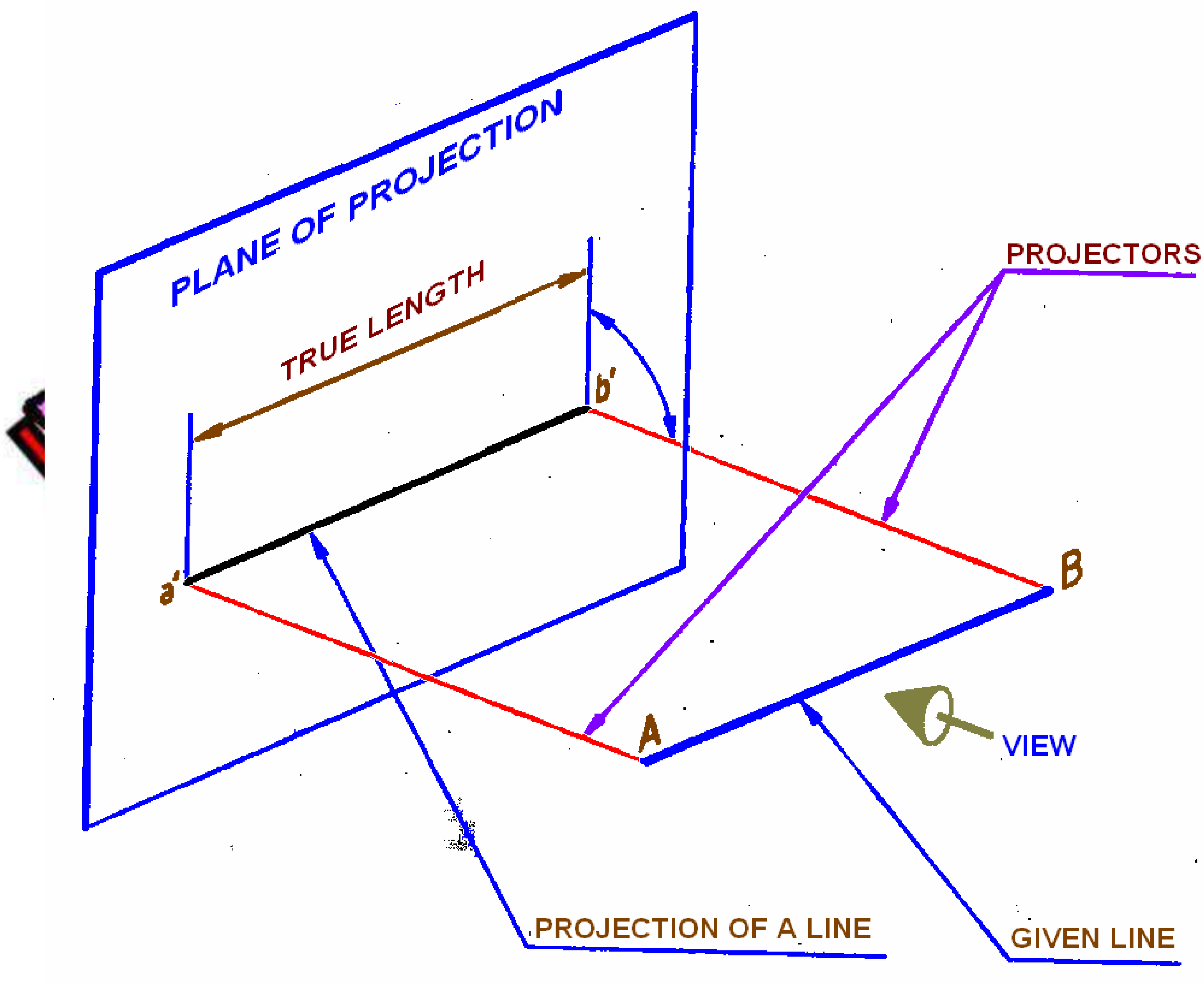
- **Parallel to both the planes.**
- **Parallel to one plane and perpendicular to the other.**
- **Parallel to one plane and inclined to the other.**
- **Inclined to both the planes.**

Projection of a line

- **Obtained by projecting its end points on planes of projections and then connecting the points of projections.**

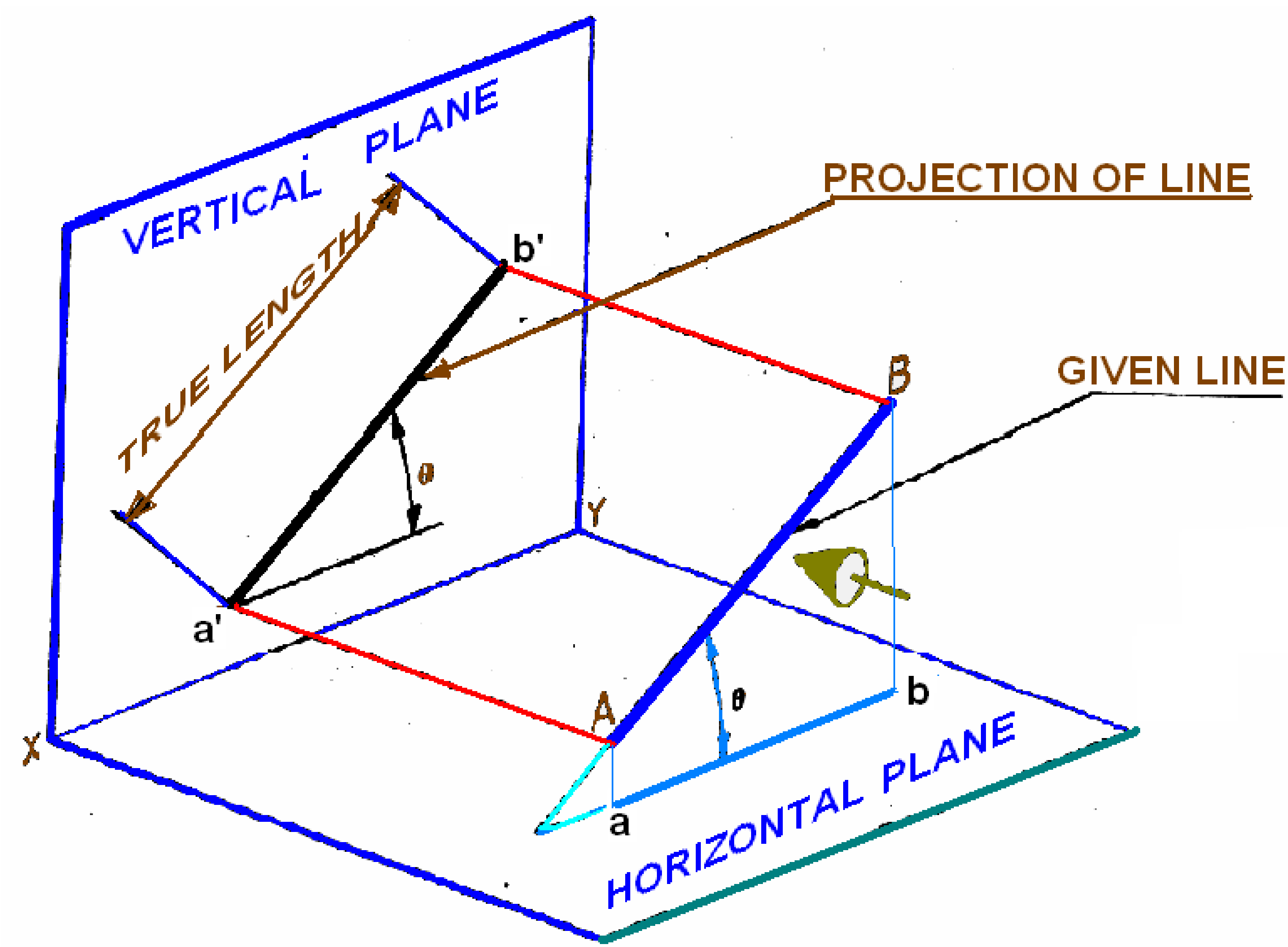
- **The projected length and inclination of a line, can be different compared to its true length and inclination.**





Line parallel to a plane

Line inclined to a plane

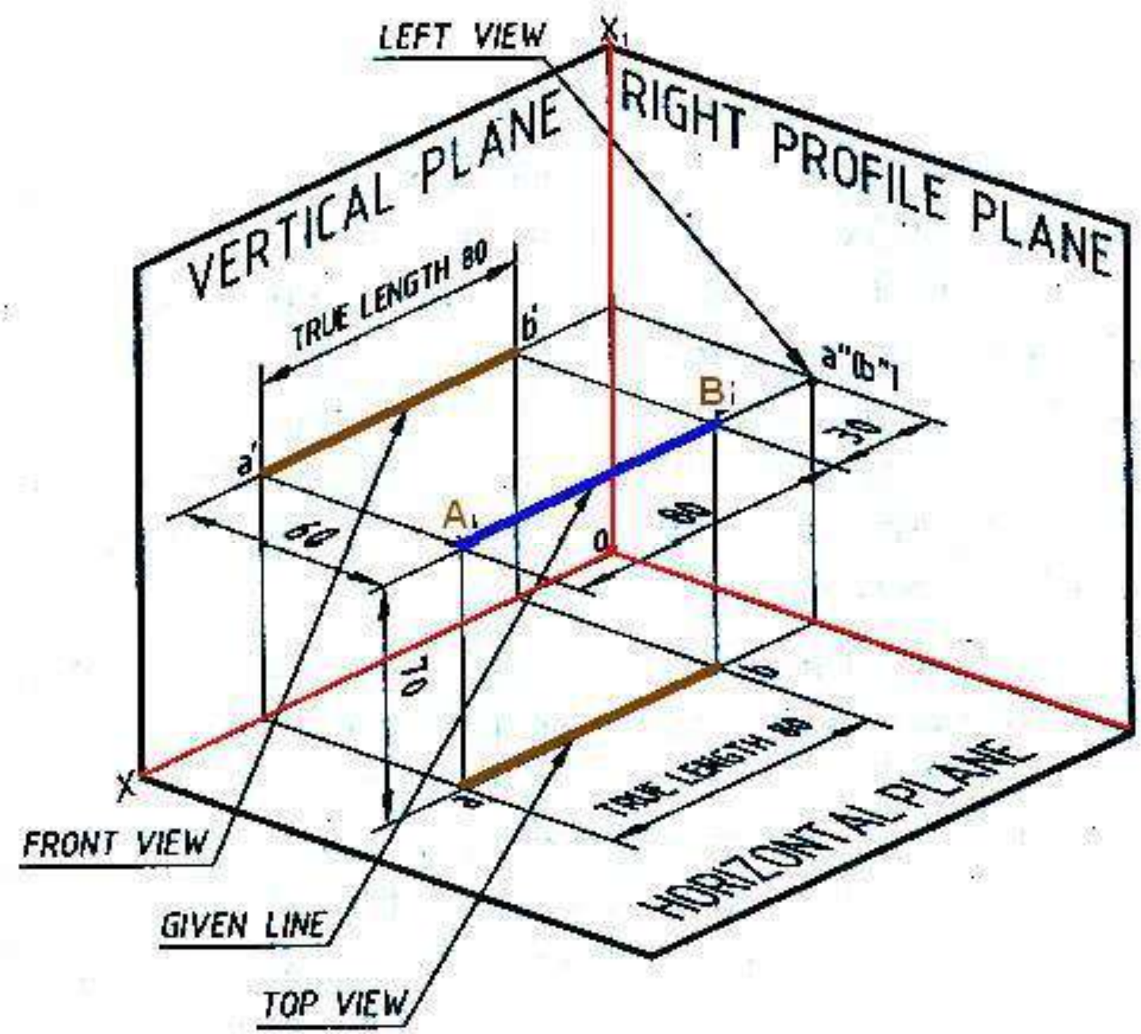


Line parallel to both HP & VP

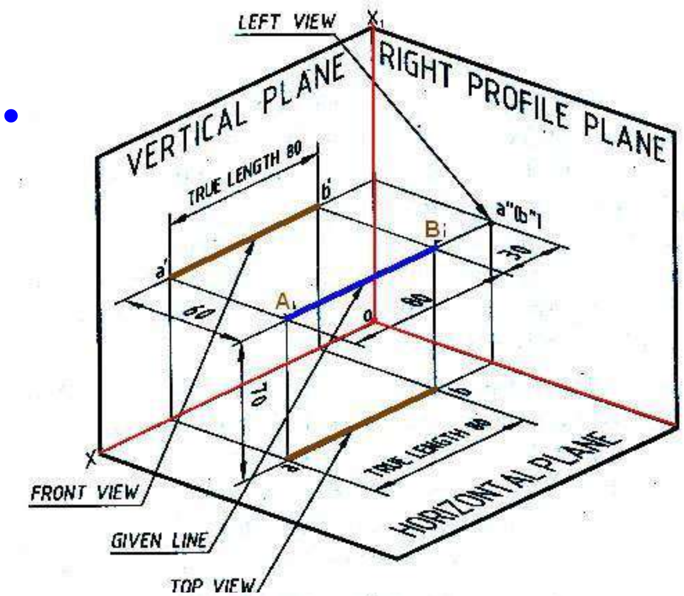
Line of 80 mm length is placed parallel to both HP and VP.

The line is 70 mm above HP, 60 mm in front of VP.

end B is 30 mm in front of right PP.

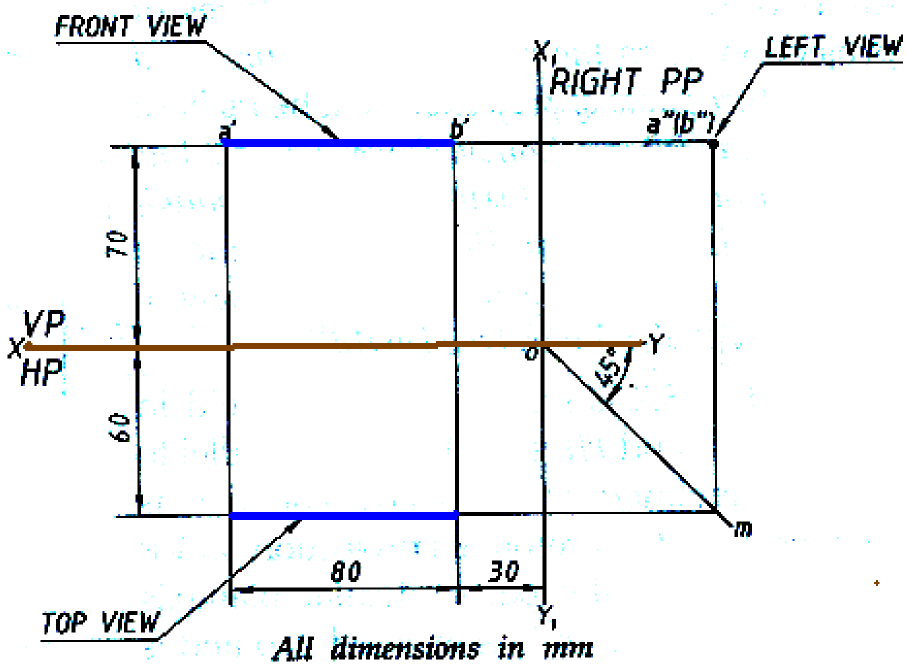


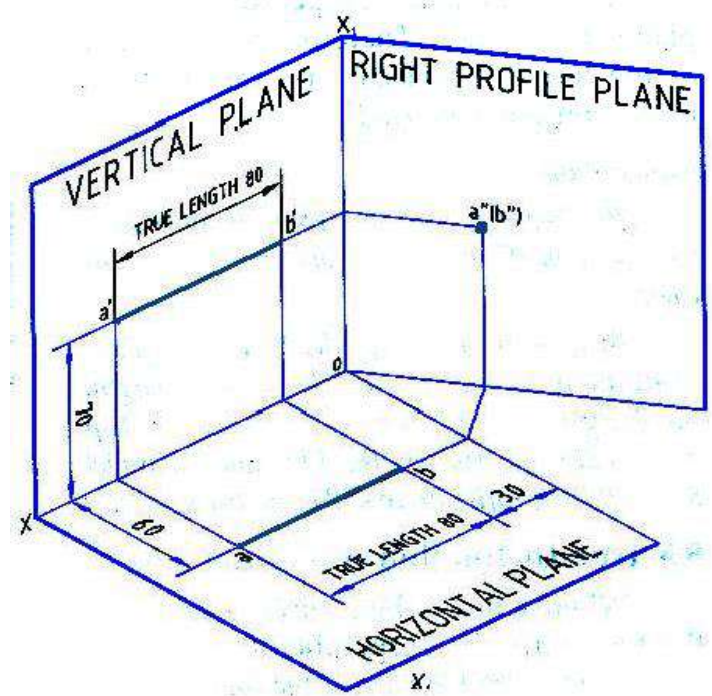
Line parallel to both HP & VP…



Since the line is parallel to both HP and VP, both the front view a'b' and the top view ab are in true lengths.

Since the line is perpendicular to the right PP, the left side view of the line will be a point a´´(b´´).



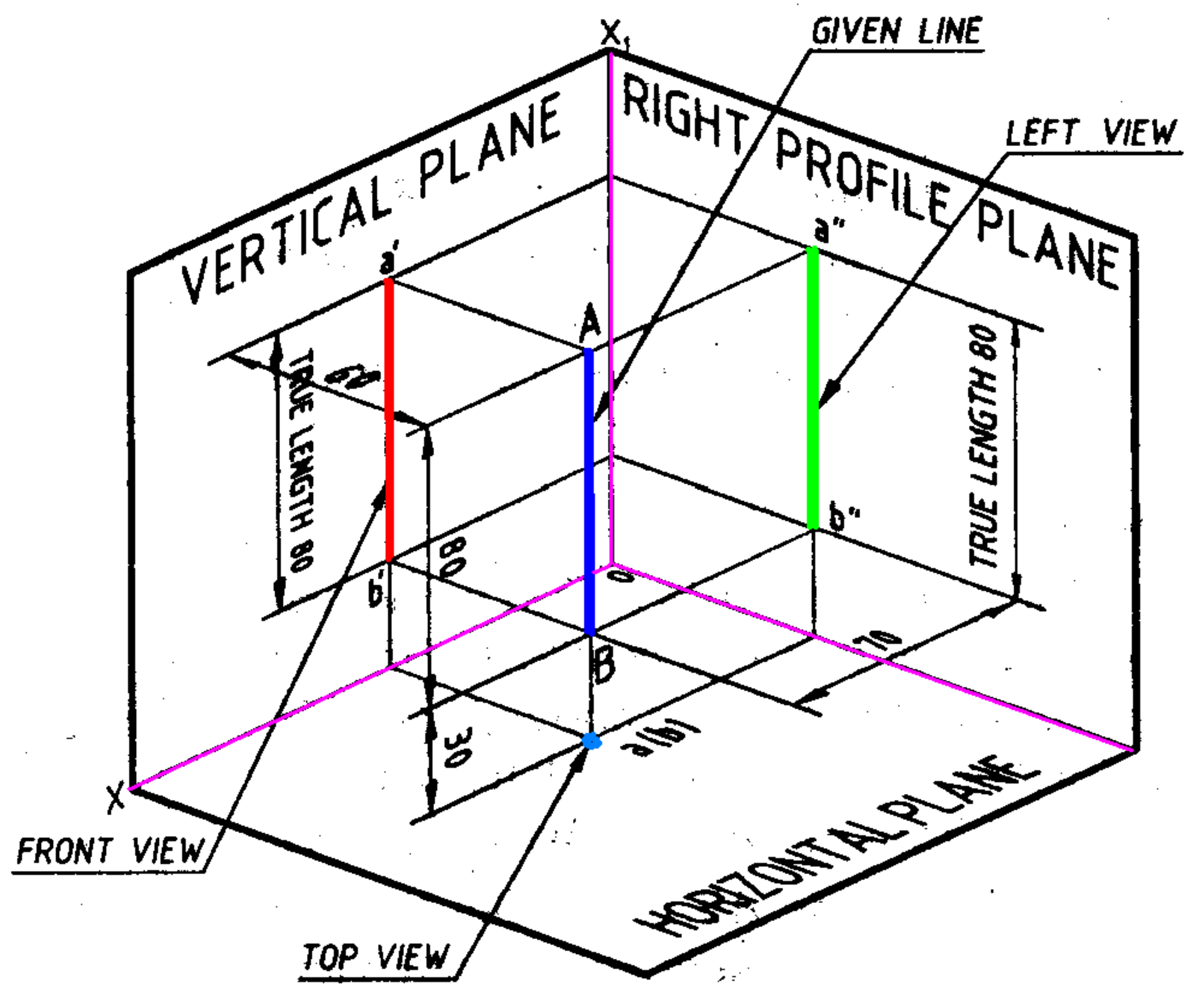


Line perpendicular to HP & parallel to VP

Line of 80 mm length placed parallel to VP and perpendicular to HP.

The line is 60 mm in front of VP and 70 mm in front of right PP.

The lower end of the line is 30 mm above HP.



Line perpendicular to HP & parallel to VP…

Draw the front view a'b' = 80 mm perpendicular to the XY line, with the lower end b' lying 30 mm above the XY line.

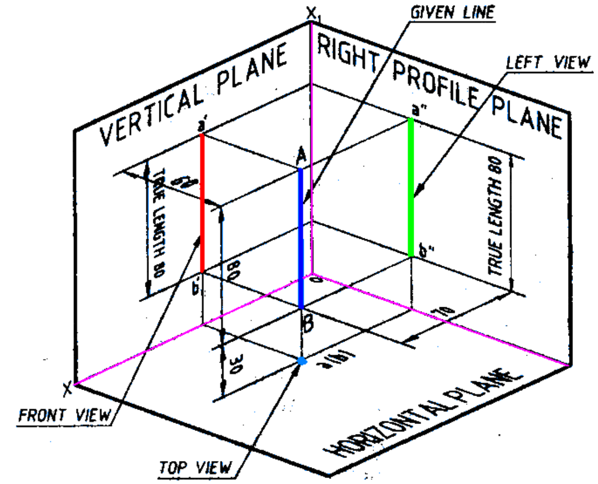
Project the top view of the line which will be a point a(b) at a distance of 60 mm below XY line.

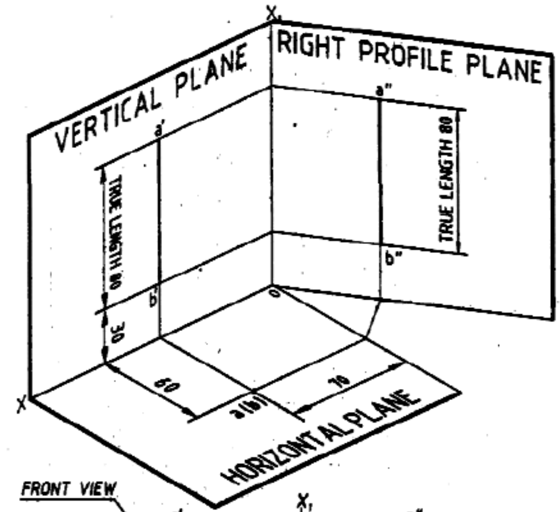
Since the line is 70 mm in front of the right PP draw the X1Y1 line at a distance of 70 mm on the right- side of the front view.

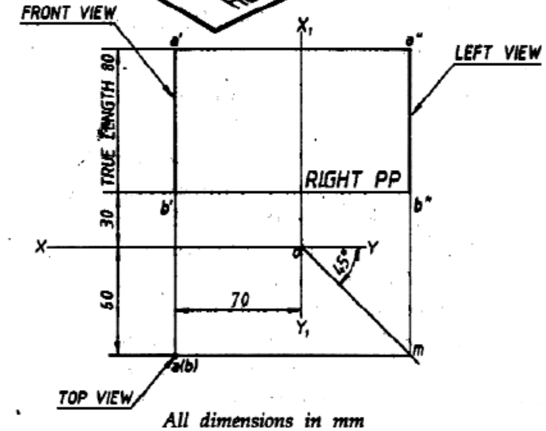
Through 0 the point of intersection of XY and X1Y1, lines draw a 45° line.

Draw the horizontal projector through a(b) to cut the 45 degree line at m.

Draw the horizontal projectors through a' and b' to intersect the vertical projector drawn through m at a´´ and b´´. a´´b´´ is the left view of the line AB.







Line parallel to one plane and inclined to the other

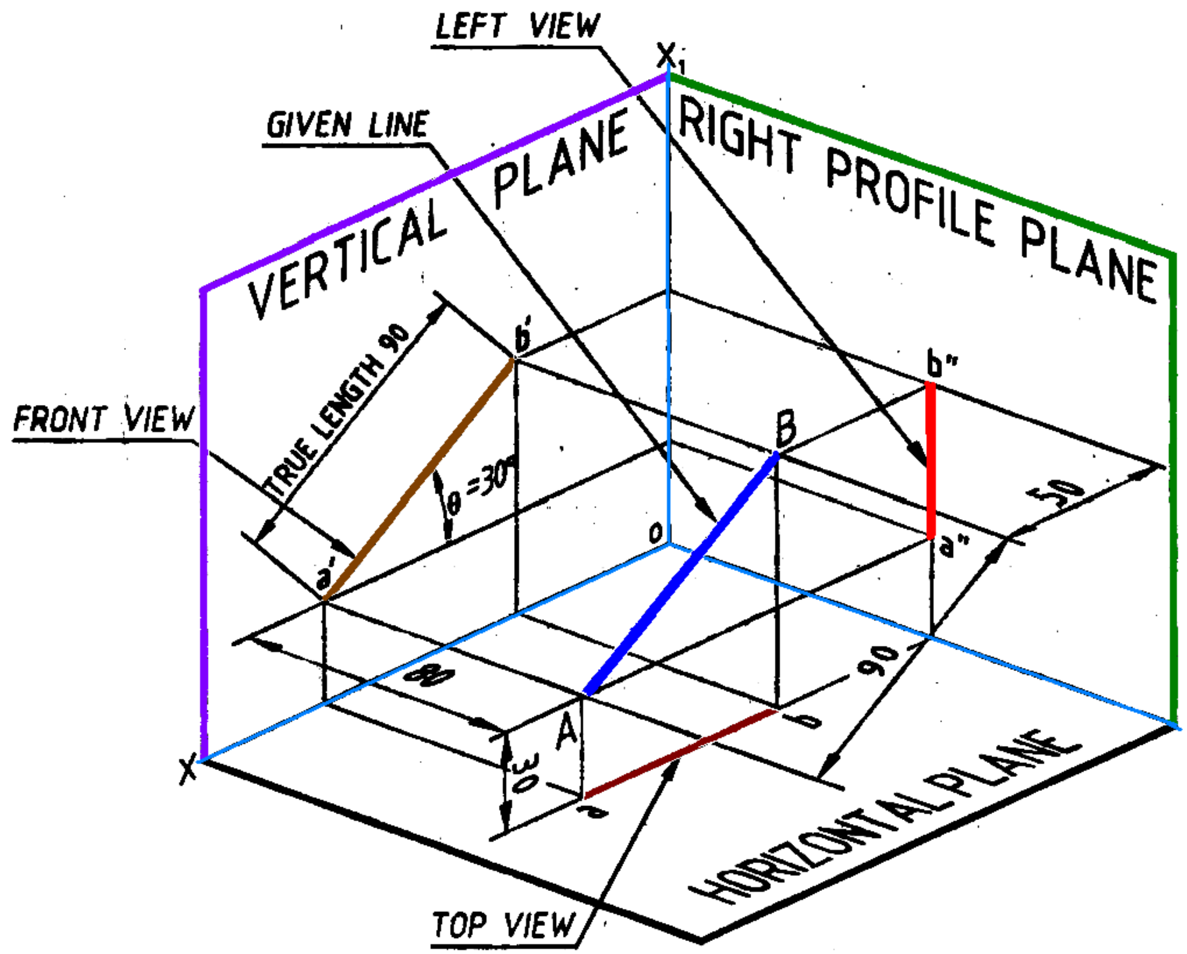
Line parallel to VP and inclined to HP….

A line AB, 90 mm long is inclined at 30 degrees to HP and is parallel to VP.

The line is 80 mm in front of VP.

The lower end A is 30 mm above HP.

The upper end B is 50 mm in front of the right PP.



Line parallel to VP and inclined to HP….

Mark a', the front view of the end A, 30 mm above HP.

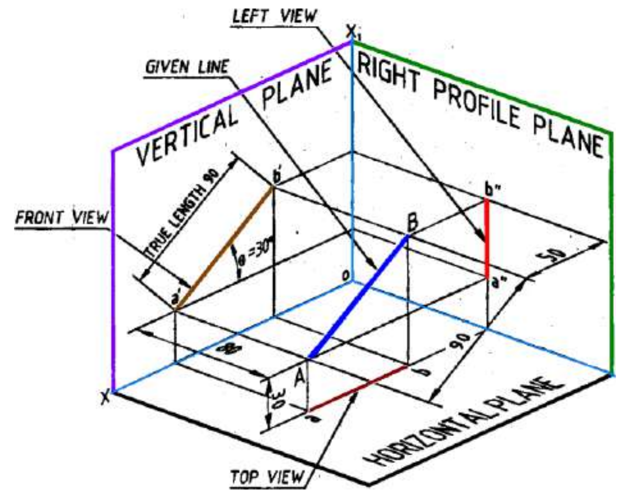
Draw the front view a´b´ = 90 mm inclined at 30° to XY line.

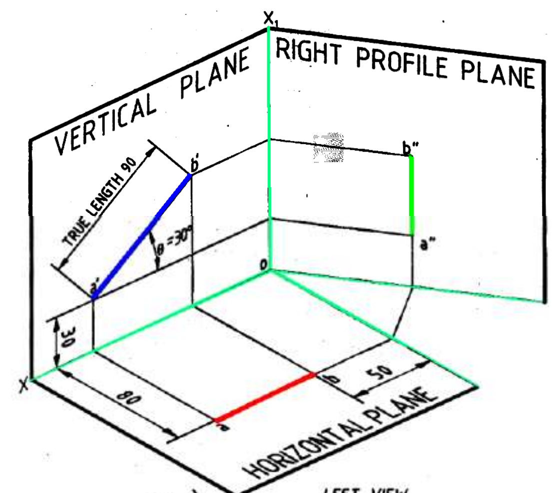
Project the top view ab parallel to XY line. The top view is 80 mm in front of VP.

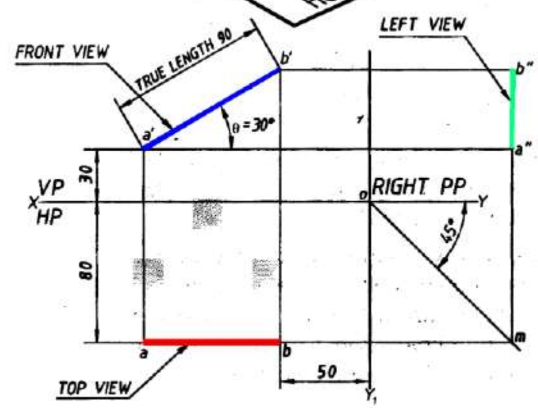
Draw the X Y line at a distance of 50 mm from a'.

Draw a 45° line through o. Draw the horizontal projector through the top view ab to cut the 45 ° line at m. Draw a vertical projector through m.

Draw the horizontal projectors through a' and b' to intersect the vertical projector drawn through m at a´´ and b´´. Connect a´´b´´ which is the left side view.





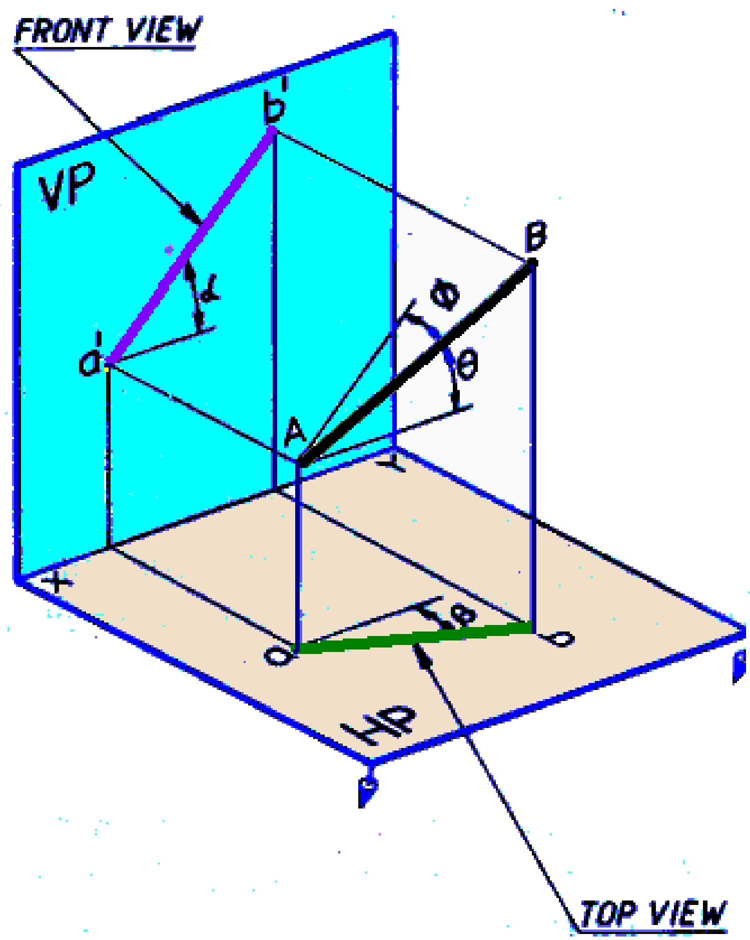


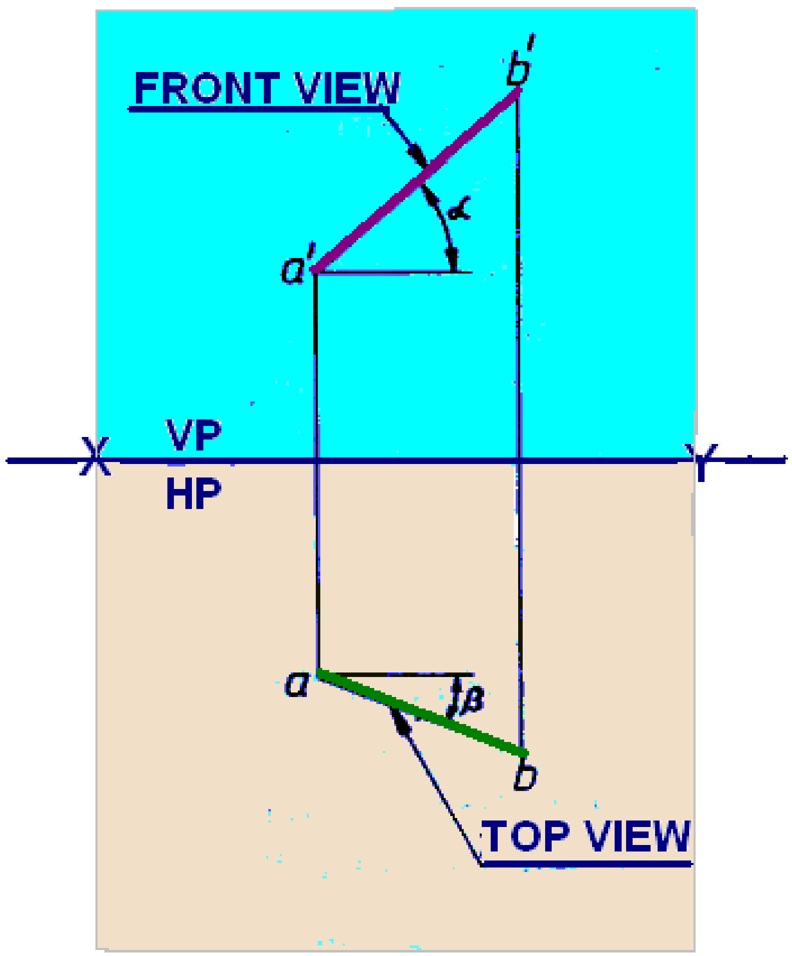
All dimensions in mm

Line inclined to HP and VP

Apparent Inclinations: α and β

Apparent Lengths: ab, a´b´

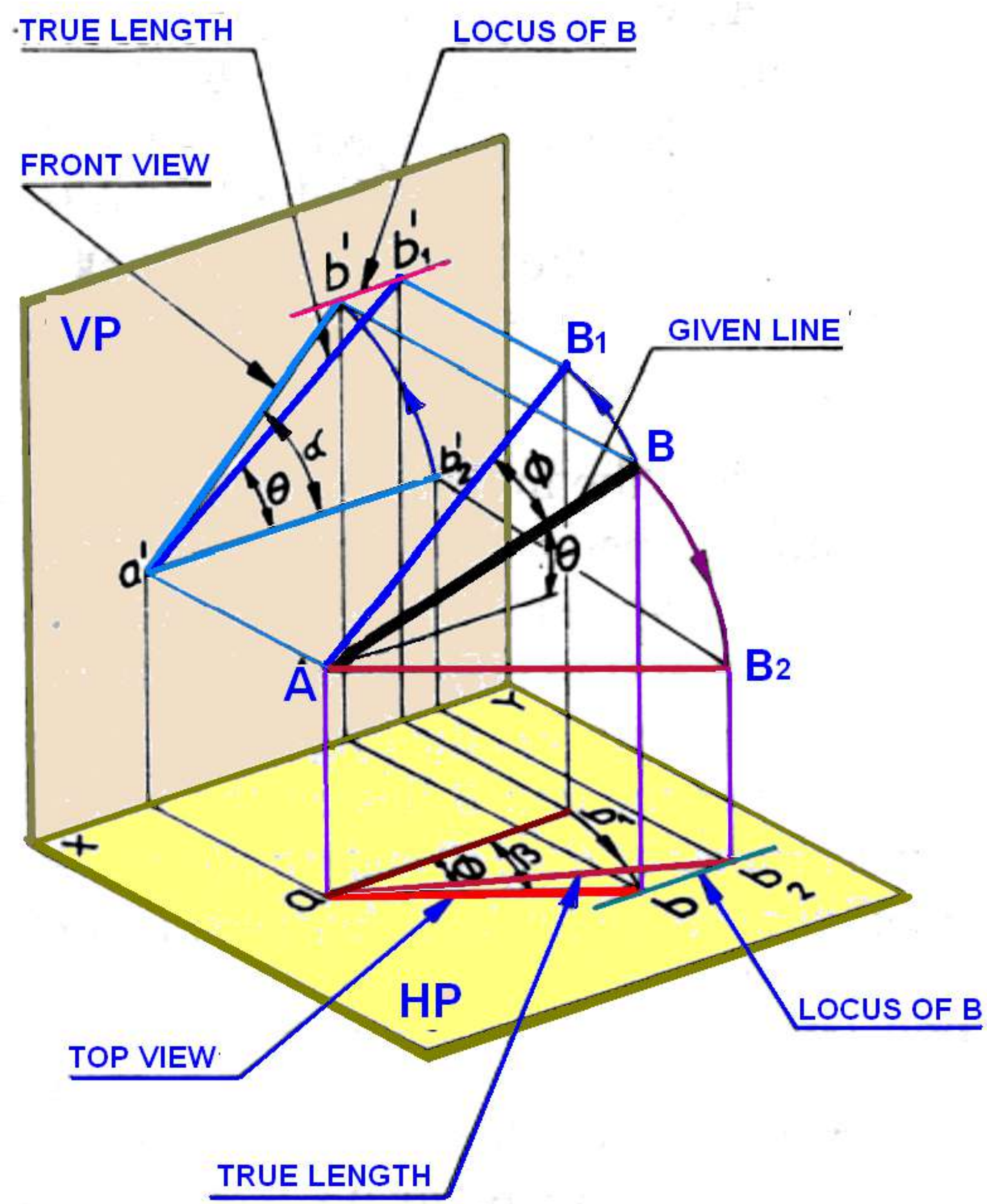




Line inclined to HP and VP…….

Draw the projections of a line AB inclined to both HP and VP, whose true length and true inclinations and locations of one of the end points, say A are given.

Since the line AB is inclined at θ to HP and ϕ to VP – its top view ab and the front view a´b´ are not in true lengths and they are also not inclined at angles θ to HP and ϕ to VP.



PRACTICE

Engineering Drawing

Lecture Slides

Engineering Drawing

Lecture 7

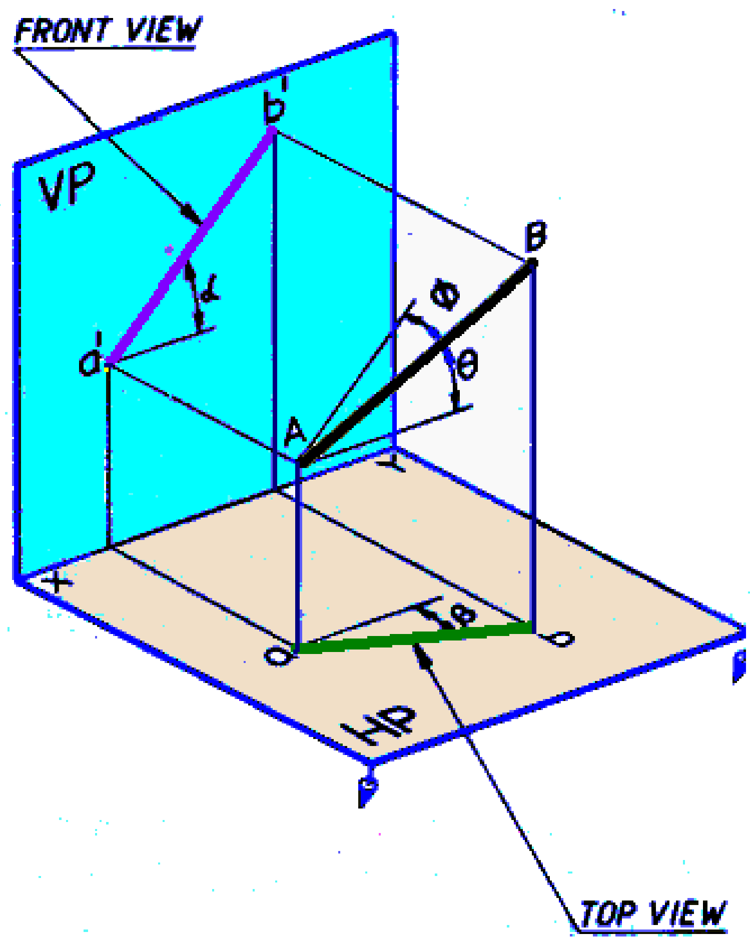
Projection of Lines Contd.

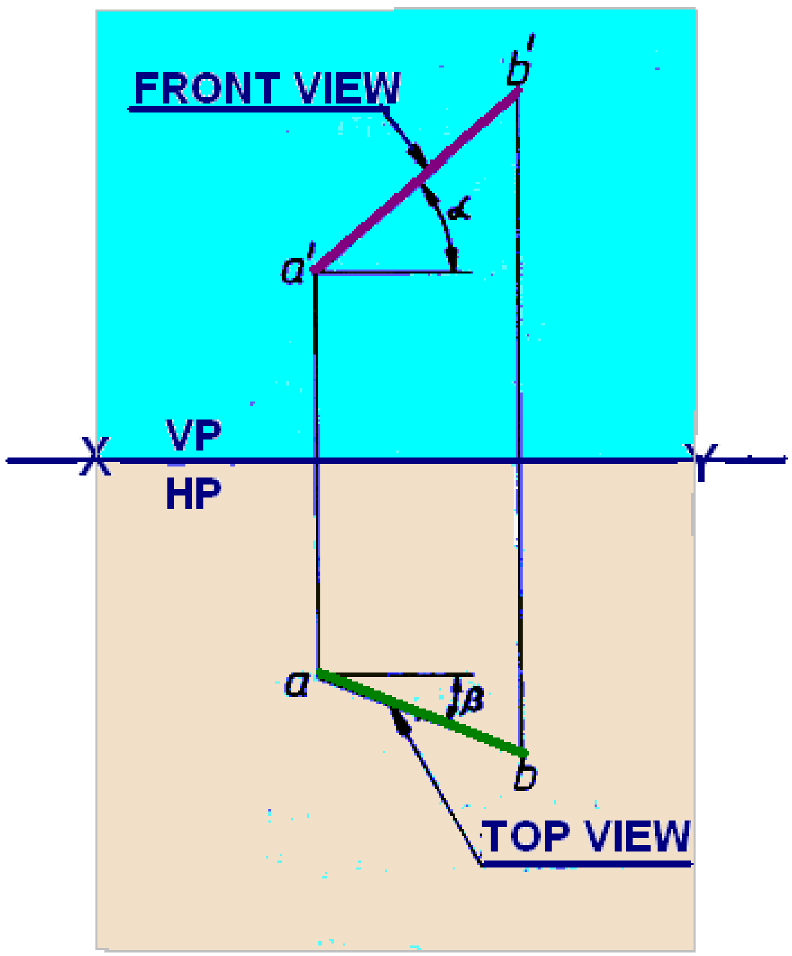
Projections of Lines

Line inclined to HP and VP

Apparent Inclinations: α and **β**

Apparent Lengths: ab, a´b´

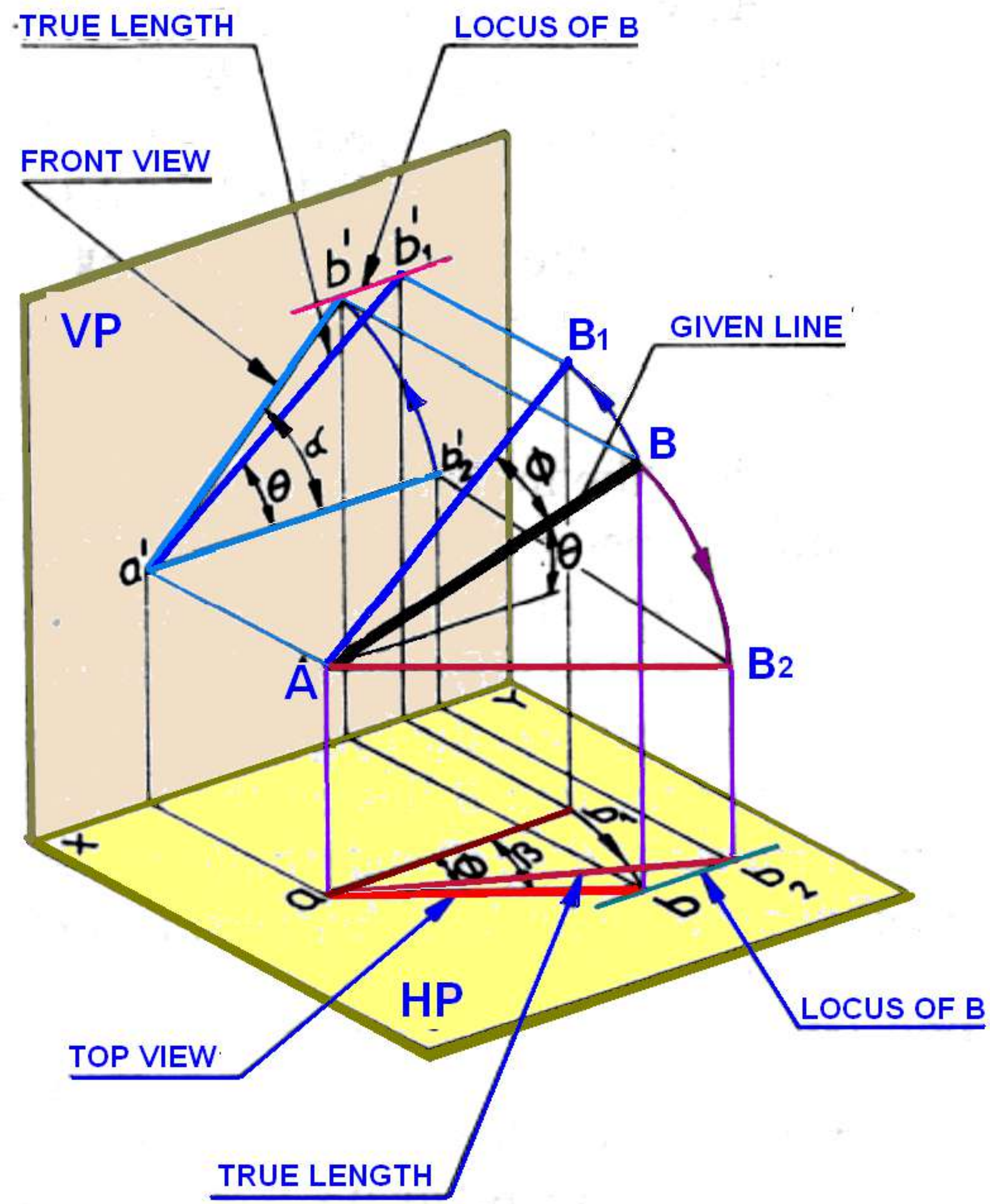




Line inclined to HP and VP…….

Draw the projections of a line AB inclined to both HP and VP, whose true length and true inclinations and locations of one of the end points, say A are given.

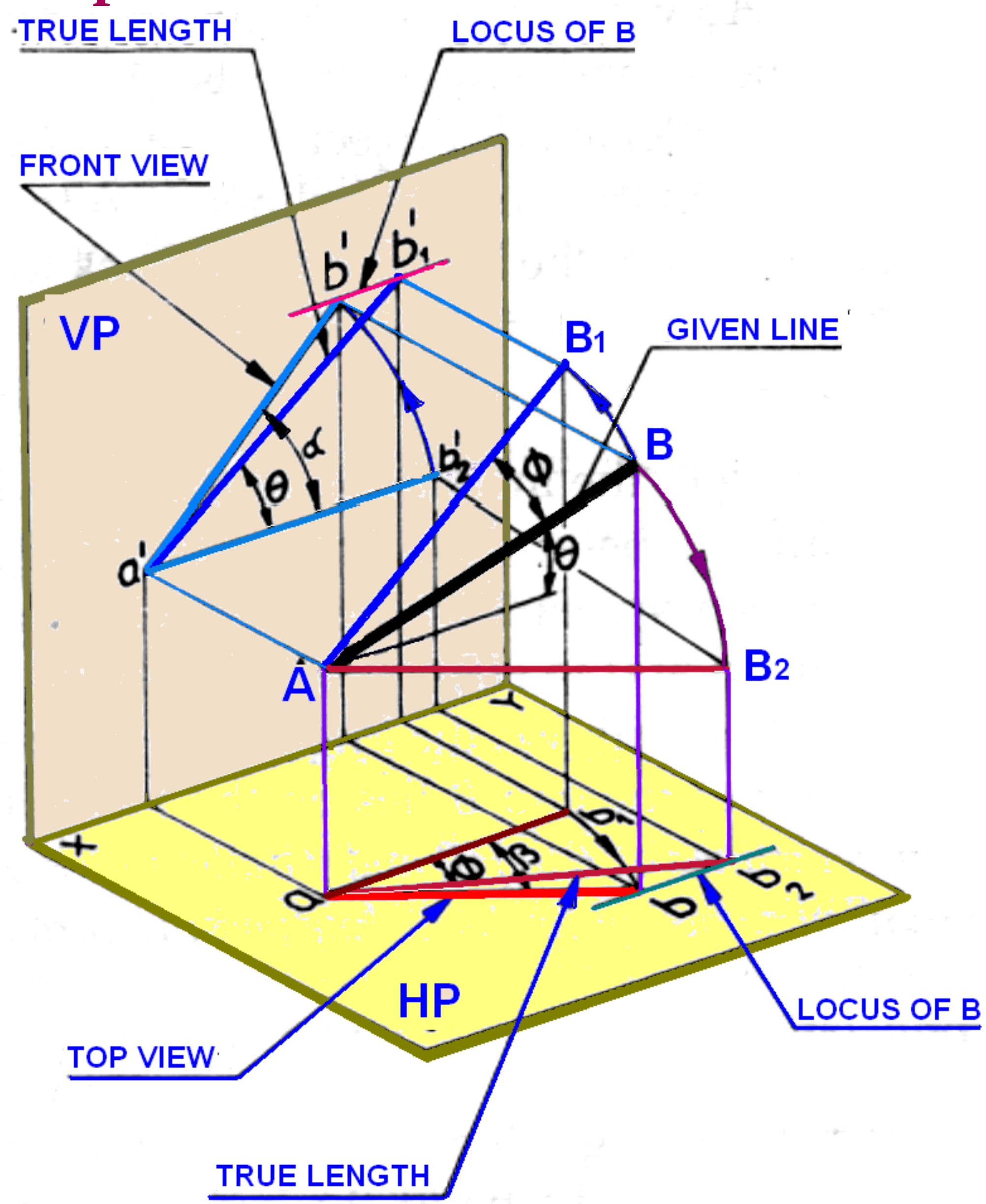
Since the line AB is inclined at θ to HP and ϕ to VP – its top view ab and the front view a´b´ are not in true lengths and they are also not inclined at angles θ to HP and ϕ to VP.



Line inclined to HP and VP…….

Step 1: Rotate the line AB to make it parallel to VP.

Rotate the line AB about the end A, keeping θ, the inclination of AB with HP constant till it becomes parallel to VP. This rotation of the line will bring the end B to the new position B1.



AB_1 is the new position of the line AB when it is inclined at θ to HP and parallel to VP.

Project AB_1 on VP and HP. Since AB_1 is parallel to VP, $a'b_1'$, the projection of AB_1 on VP is in true length inclined at θ to the XY line, and ab_1, the projection of AB_1 on HP is parallel to the XY line. Now the line is rotated back to its original position AB.

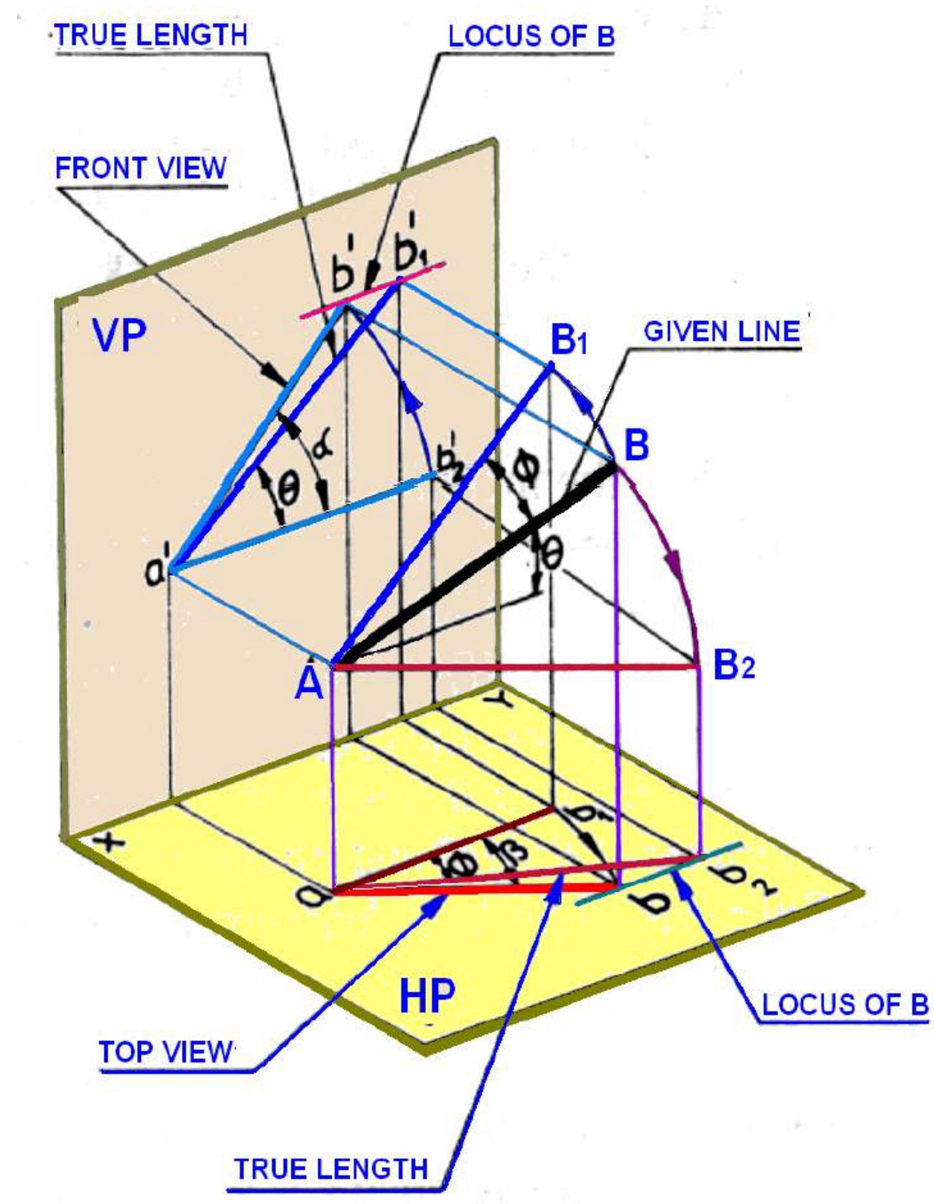
Line inclined to HP and VP…….

Step 2: Rotate the line AB to make it parallel to HP.

Rotate the line AB about the end A keeping ϕ the inclination of AB with VP constant, till it becomes parallel to HP. This rotation of the line will bring the end B to the second new Position B2.

AB_2 is the new position of the line AB, when it is inclined at ϕ to VP and parallel to HP.

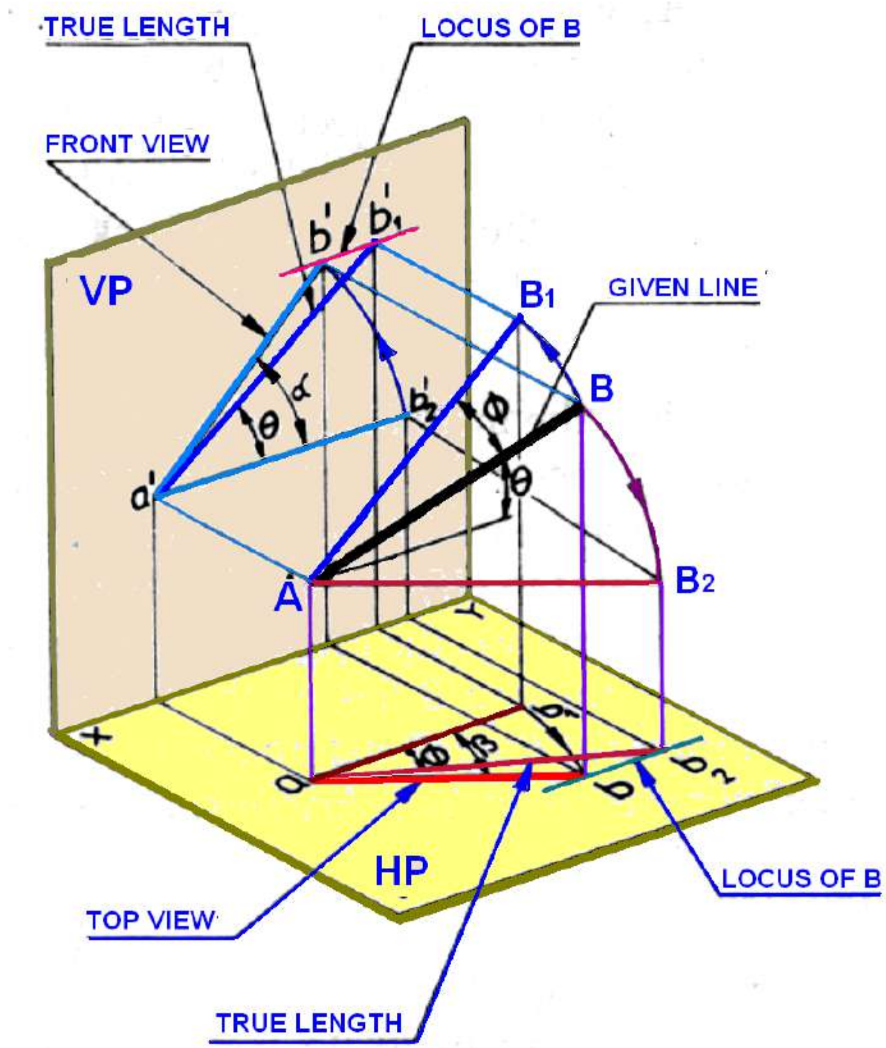
Project AB2 on HP and VP. Since AB2 is parallel to HP, ab2, the projection of AB2 on HP is in true length inclined at ϕ to XY line, and $a'b_2'$ the projection of AB_2 on VP is parallel to XY line. Now the line is rotated back to its original position AB.



Line inclined to HP and VP…….

Step 3: Locus of end B in the front view

When the line AB is swept around about the end A keeping θ, the inclination of the line with the HP constant, by one complete rotation, the end B will always be at the same vertical height above HP, and the locus of the end B will be a circle which appears in the front view as a horizontal line passing through b'.

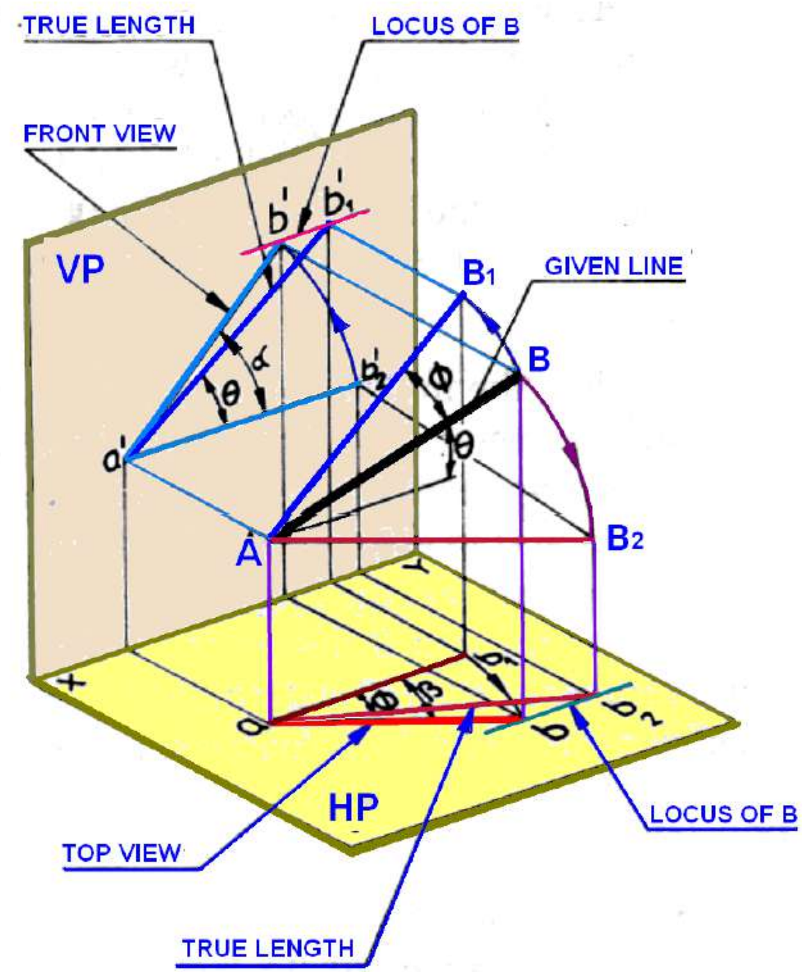


As long as the line is inclined at θ to HP, whatever may be the position of the line (i.e., whatever may be the inclination of the line with VP) the length of the top view will always be equal to ab1 and in the front view the projection of the end B lies on the locus line passing through b1'.

Thus ab_1, the top view of the line when it is inclined at θ to HP and parallel to VP will be equal to ab and b´, the projection of the end B in the front view will lie on the locus line

Line inclined to HP and VP…….

Step 4: Locus of end B in the top view



When the line AB is swept around about the end A keeping ϕ the inclination of the line with the VP constant, by one complete rotation, the end B will always be at the same distance in front of VP and the locus of the end B will be a circle which appears in the top view as a line, parallel to XY, passing through b.

As long as the line is inclined at ϕ to VP, whatever may be the position of the line (i.e., whatever may be the inclination of the line with HP), the length of the front view will always be equal to $a'b_2'$ and in the top view the projection of the end B lies on the locus line passing through b_2.

Thus $a'b_2'$ the front view of the line when it is inclined at ϕ to VP and parallel to HP, will be equal to $a'b'$ and also b, the projection of the end B in the top view lies on the locus line passing through b_2.

Line inclined to HP and VP…….

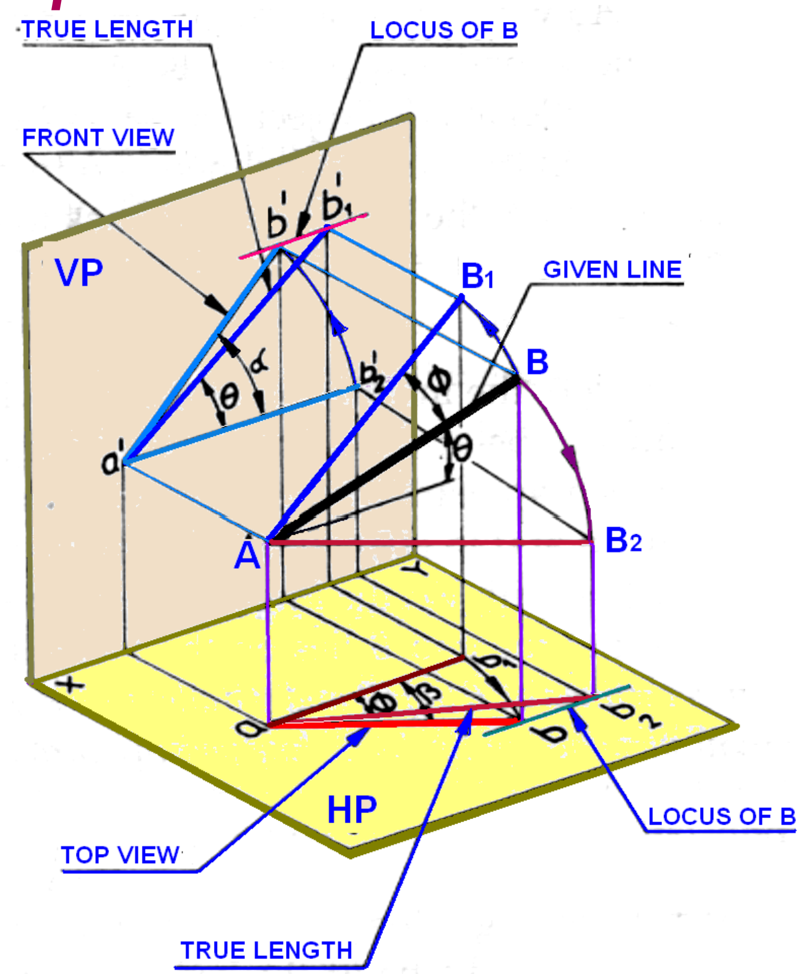
Step 5: To obtain the top and front views of AB

- From the above two cases of rotation it can be said that

(i) the length of the line AB in top and front views will be equal to **ab_1** and **$a'b_2'$** respectively and

(ii) the projections of the end **B**, (i.e., **b** and **b‘)** should lie along the locus line passing through **b_2** and **b_1´** respectively.

- **With center a, and radius ab_2 draw an arc to intersect the locus line through b_2 at b. Connect ab the top view of the line AB.**
- Similarly with center **a'**, and radius **$a'b_2'$** draw an arc to intersect the locus line through **b_1'** at **b´**. Connect **a'b'** the front view of the line **AB**.

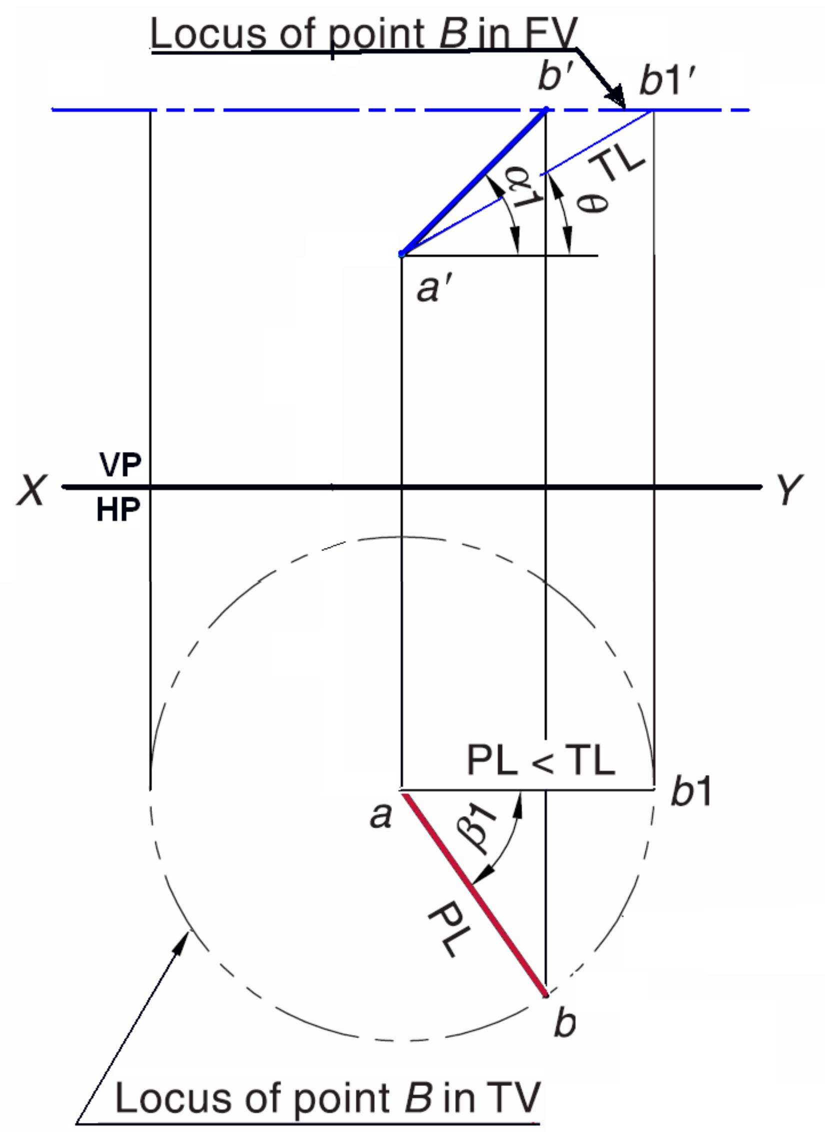


Line inclined to HP and VP

Orthographic projection

1. As the location of one of the end points (i.e. **A)** with respect to **HP** and **VP,** is given, mark **a** and **a´**, the top and the front views of point **A**.

2. Suppose the line **AB** is assumed to be made parallel to **VP** and inclined at **θ** to **HP**. The front view of the line will be equal to the true length of the line and also, the inclination of the line with HP is seen in the front view. Draw **a'b₁'** passing through **a'** at **θ** to **XY** line and equal to the true length of **AB**. a'b_1' is projected down to get ab_1, the top view parallel to the XY line.



Line inclined to HP and VP…….

Orthographic projection…..

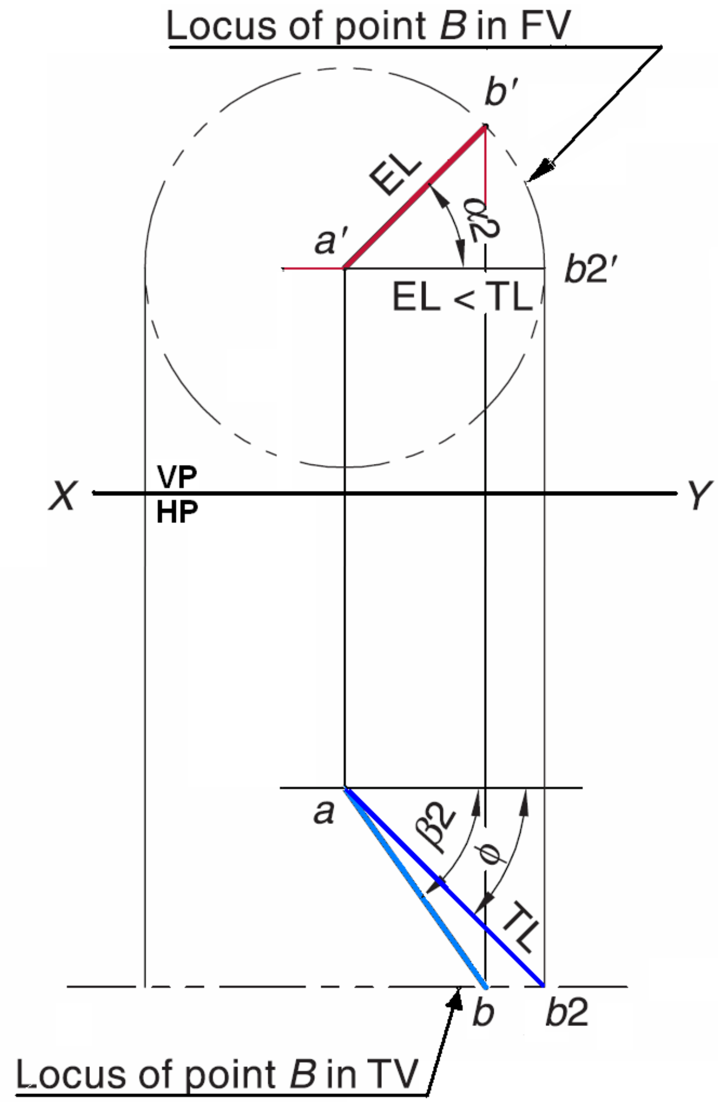
3. Now the line **AB** is assumed to be made parallel to **HP** and inclined at **ϕ** to **VP**. The top view of the line will be equal to the true length of the line and also **ϕ**, the inclination of the line with **VP** is seen in the top view.

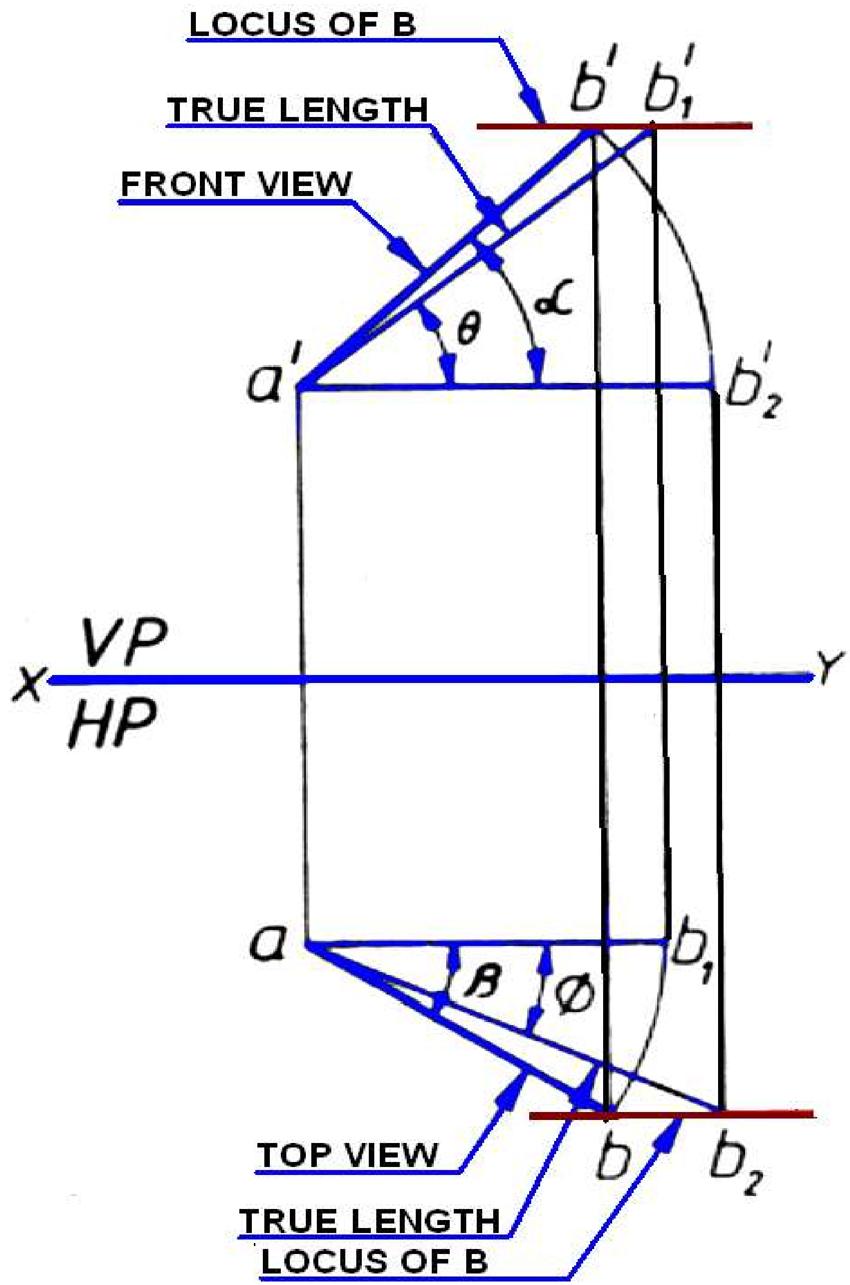
4. Draw **ab₂** passing through **a** at **ϕ** to the **XY** line and equal to the true length of **AB**. ab2, is projected up to get a'b2', the front view parallel to the XY line.

5. Draw the horizontal locus lines through b_2, and b_1'.

6. With center **a** and radius $\mathbf{ab_1}$, draw an arc to cut the locus line drawn through $\mathbf{b_2}$ at **b**. Connect **ab**, the top view of the line **AB.**

7. With center **a'** and radius $\mathbf{a'b_2}$´, draw an arc to cut the locus line drawn through $\mathbf{b_1}$**'** at **b'.** Connect **a'b'**, the front view of the line **AB**.





LOCUS OF B
TRUE LENGTH
FRONT VIEW
b'
b'1
a'
b'2
θ
α
X
VP
HP
Y
a
b1
β
Ø
b
b2
TOP VIEW
TRUE LENGTH
LOCUS OF B

To Find True length and true inclinations of a line

- Given : The top and front views of a line are given
- This is of great importance since some of the engineering problems may be solved by this principle.

- The problems may be solved by

  (i) **Rotating line method** or

  (ii) Rotating trapezoidal plane method or

  (iii) **Auxiliary plane method**.

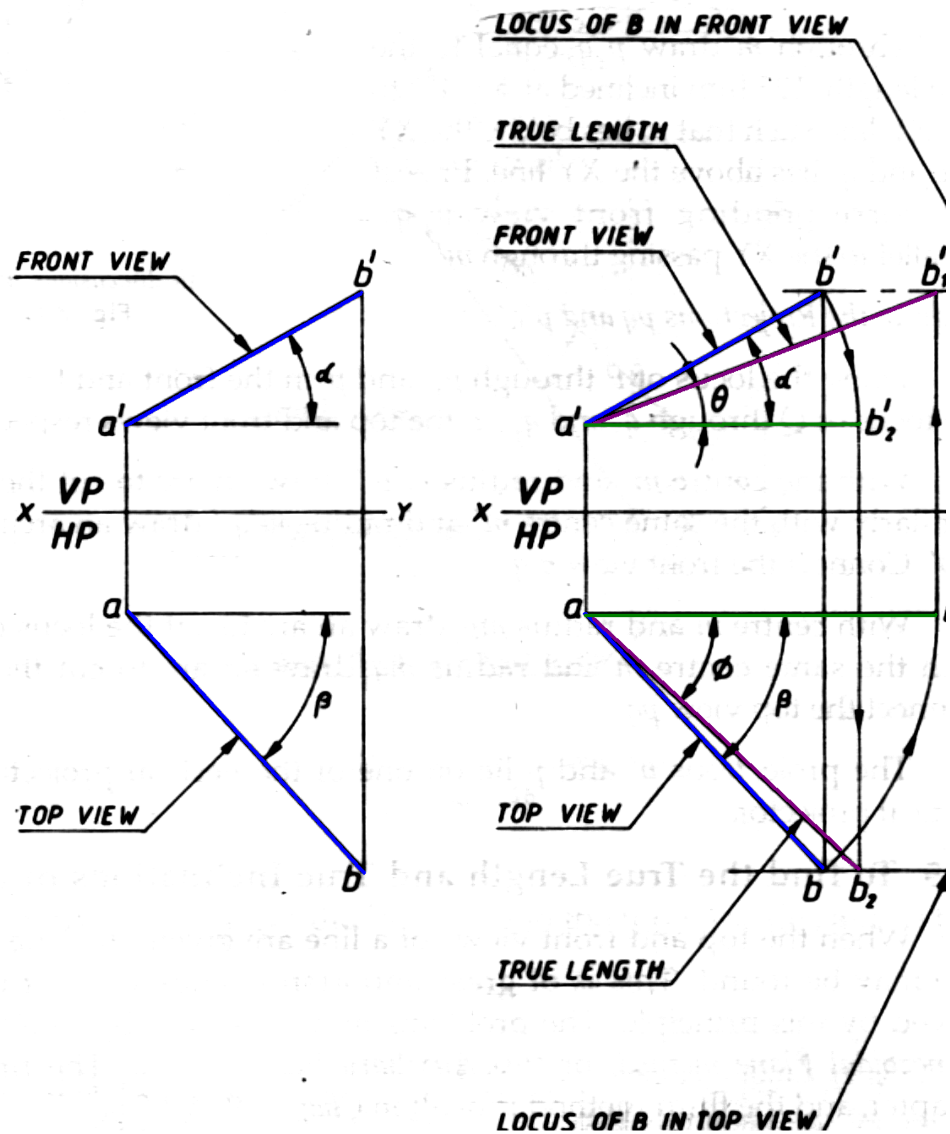
- The top and front views of the object can be drawn from the following data: (a) **Distance between the end projectors**, (b) **Distance of one or both the end points from HP and VP** and (c) **Apparent inclinations of the line.**

Rotating line method

The method of obtaining the top and front views of a line, when its true length and true inclinations are given.

When a view of a line is parallel to the XY line, its other view will be in true length and at true inclination.

By following the above procedure, in the reverse order, the true length and true inclinations of a line from the given set of top and front views can be found.



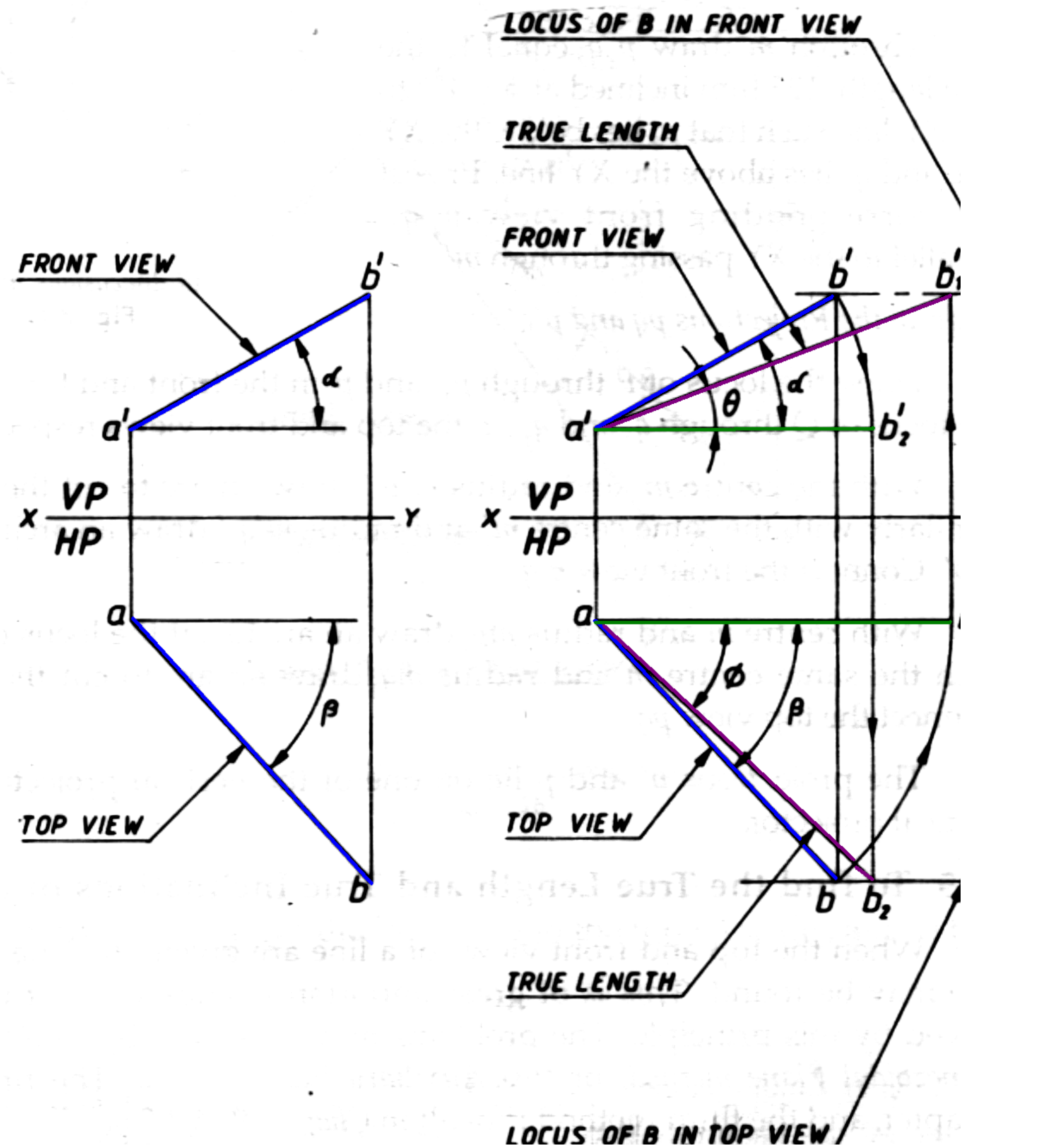
Step by Step Procedure

Top and front views

Draw the top view ab and the front view a'b' as given

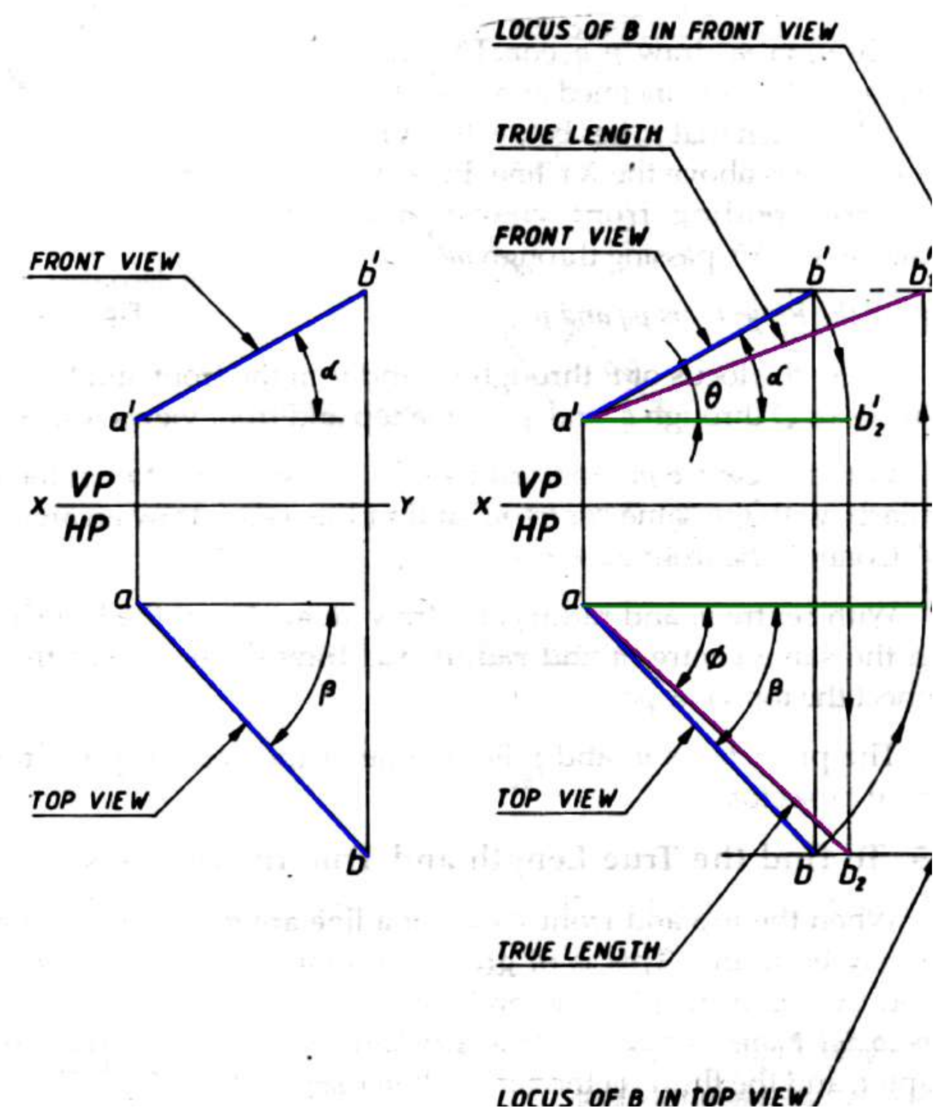
2. Rotation of the top view

With center **a** and radius **ab** rotate the top view to the new position **ab$_1$** to make it parallel to the **XY line**. Since **ab$_1$** is parallel to the **XY** line, its corresponding front view will be in true length and at true inclination.



3. Rotation of the front view

Similarly, with center **a'** and radius **a'b**' rotate the front view to the new position **a'b₂'** parallel to the **XY** line. Since **a'b₂'** is parallel to the **XY** line, its corresponding top view will be in true length and at true inclination.



In this position, the line will be parallel to **HP** and inclined at ϕ to **VP**. Through **b** draw the locus of **B** in the top view. Project **b₂'** to get **b₂,** in the top view. Connect **ab**₂ which will be in true length and true inclination ϕ which the given line **AB** makes with **VP.**

Traces of a line

The trace of a line is defined as a point at which the given line, if produced, meets or intersects a plane.

When a line meets HP, (or if necessary on the extended portion-of HP), the point at which the line meets or intersects the horizontal plane, is called horizontal trace (HT)of the line and denoted by the letter H.

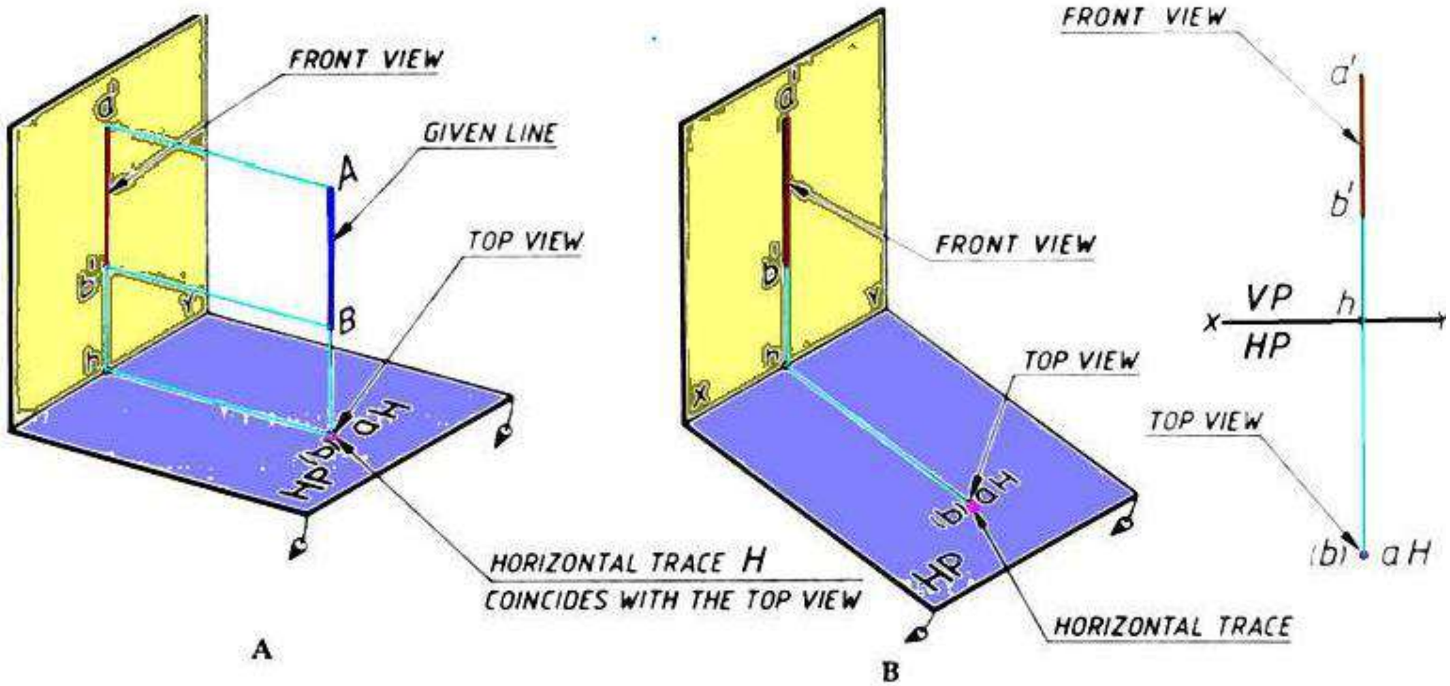
When a line meets VP (or if necessary on the extended portion of VP), the point at which the line meets or intersects the vertical plane, is called vertical trace (VT) of the line and denoted by the letter V.

When the line is parallel to both HP and VP, there will be no traces on the said planes. Therefore the traces of lines are determined in the following positions of the lines.

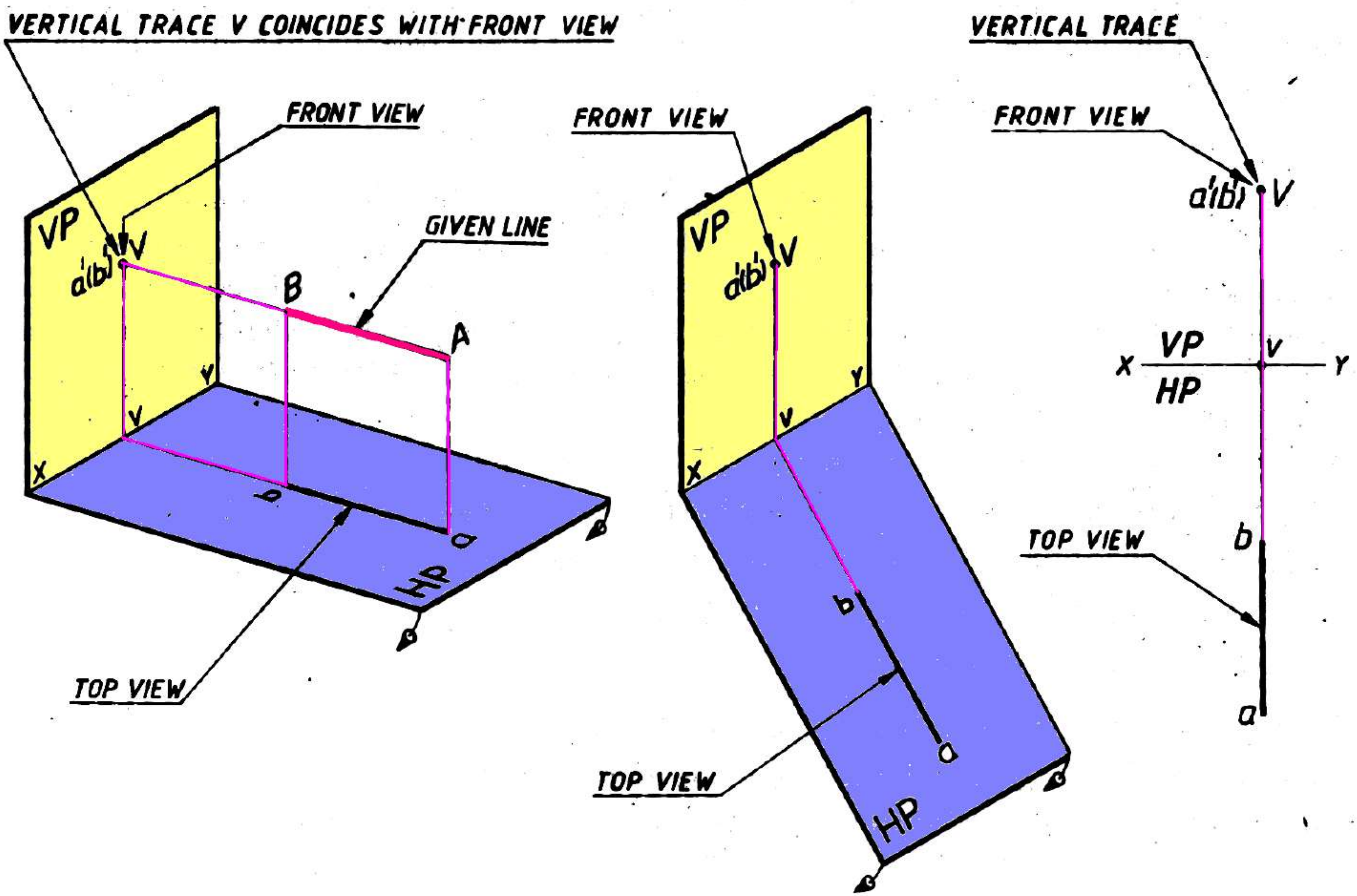
- **Lines perpendicular to one plane and parallel to the other.**
- **Lines inclined to one plane and parallel to the other.**
- **Lines inclined to both the planes.**

Trace of a line perpendicular to one plane and parallel to the other

Since the line is perpendicular to one plane and parallel to the other, the trace of the line is obtained only on the plane to which it is perpendicular, and no trace of the line is obtained on the other plane to which it is parallel.



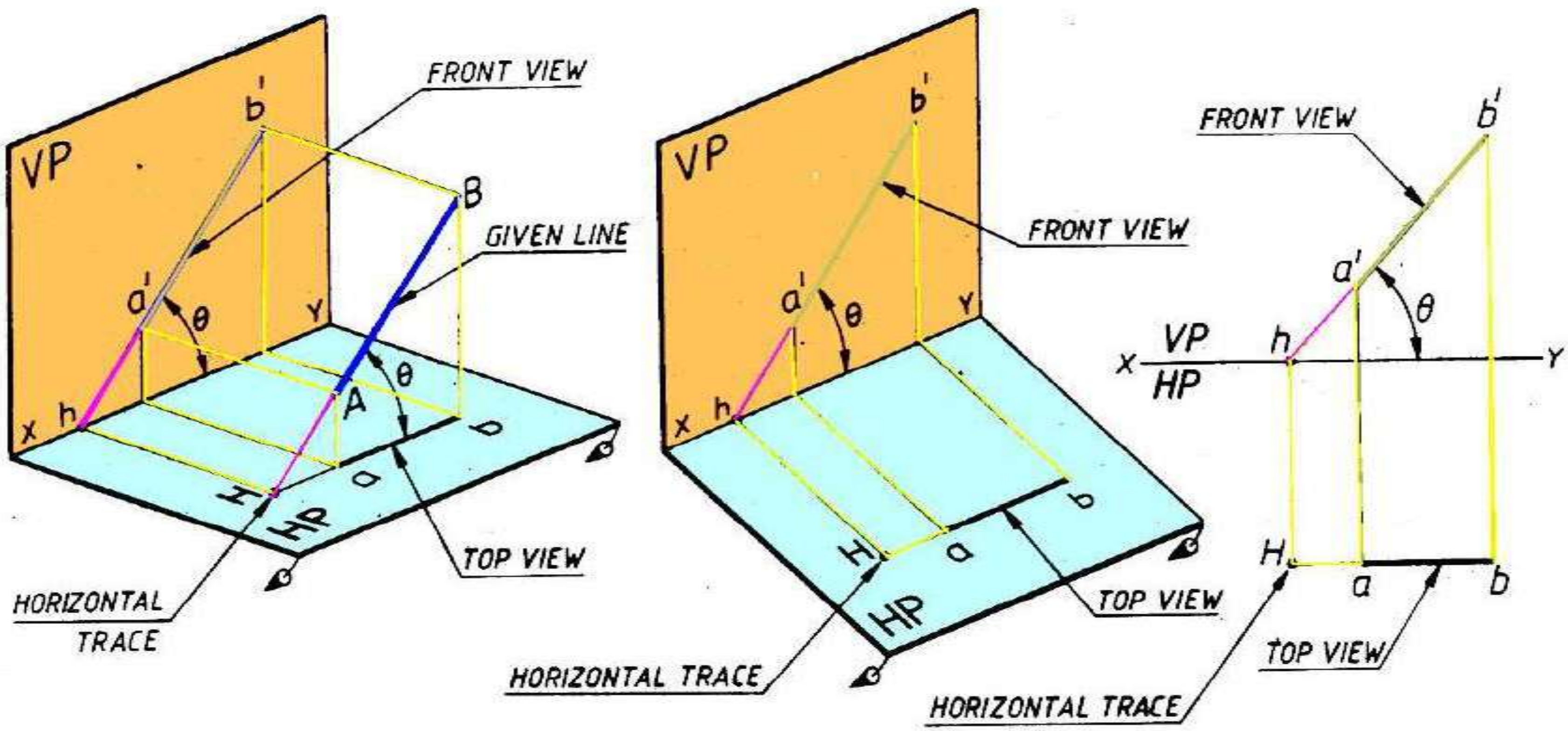
TRACE of the line perpendicular to the VP



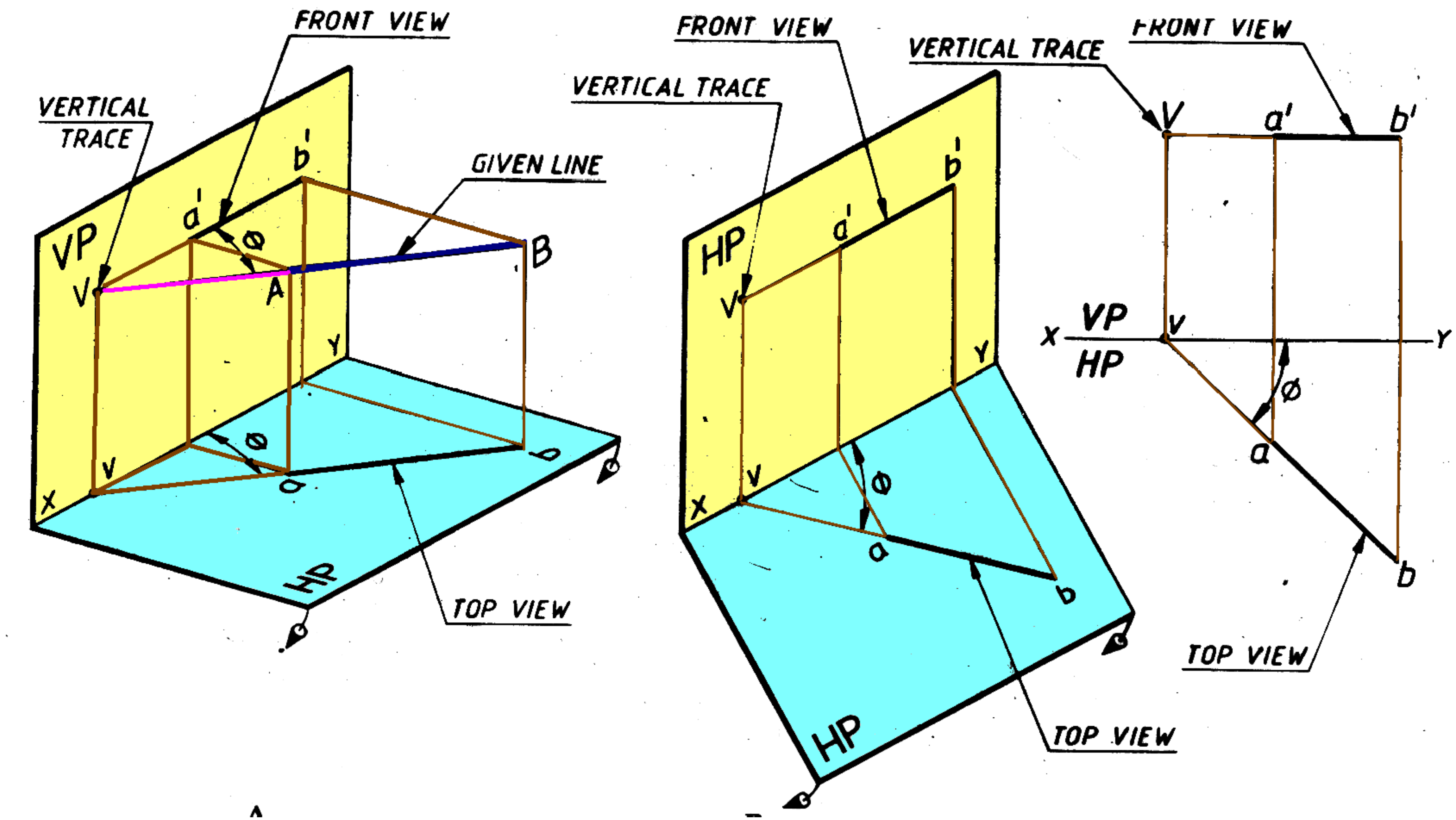
Traces of a line inclined to one plane and parallel to the other

When the line is inclined to one plane and parallel to the other, the trace of the line is obtained only on the plane to which it is inclined, and no trace is obtained on the plane to which it is parallel.

A. Line inclined at θ to **HP** and parallel to **VP**



Line inclined at ϕ to VP and parallel to HP

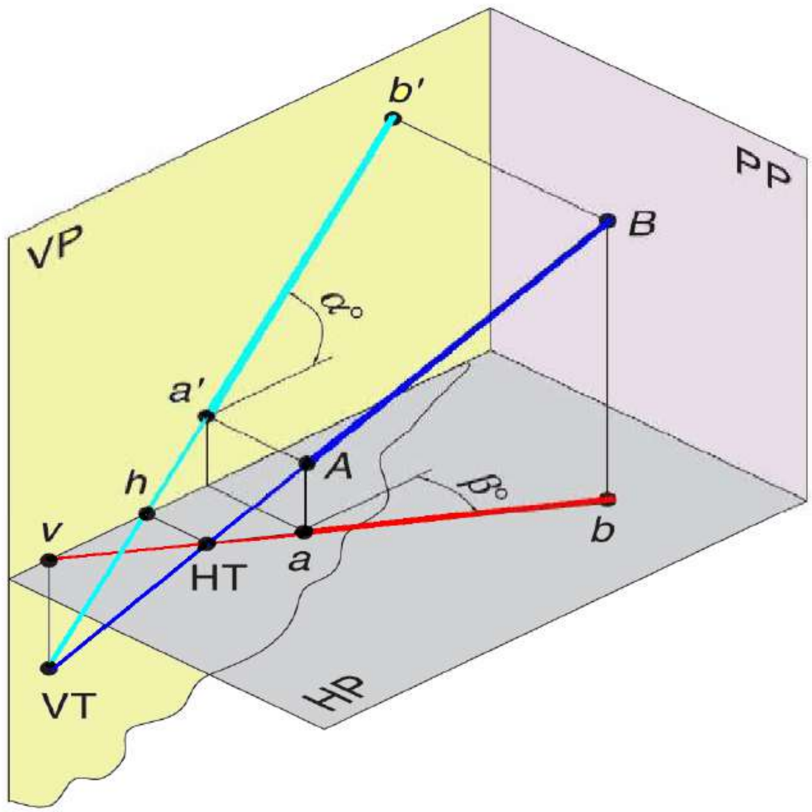


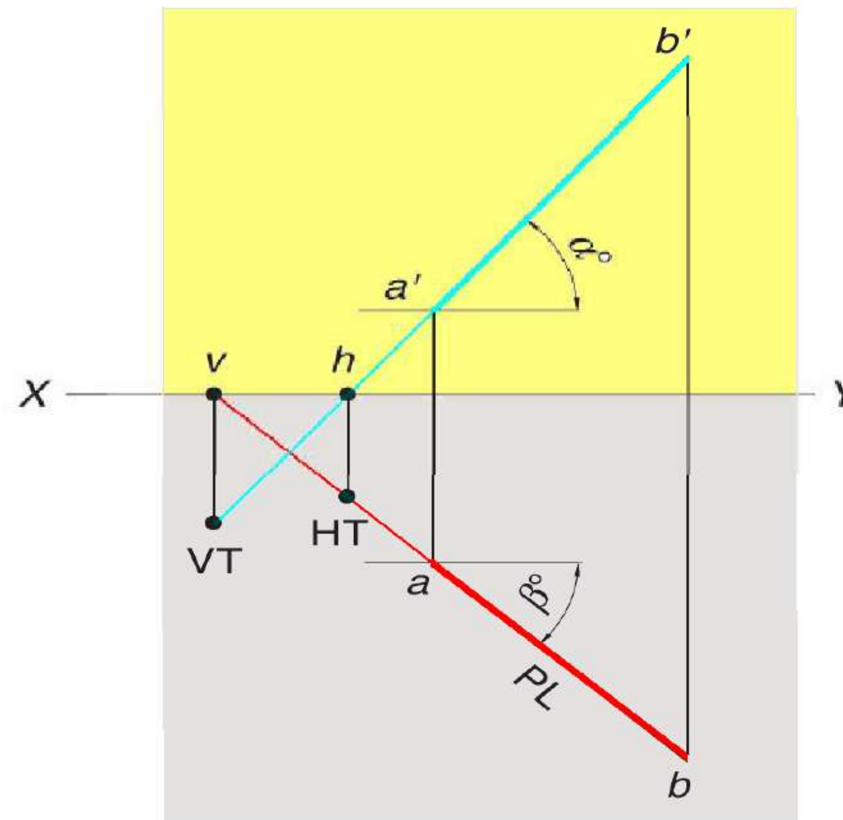
Traces of a line inclined to both the planes

Line inclined at θ to HP and φ to VP.

The line when extended intersects HP at H, the horizontal trace, but will never intersect the portion of VP above XY line, i.e. within the portion of the VP in the 1st quadrant. Therefore VP is extended below HP such that when the line AB is produced it will intersect in the extended portion of VP at V, the vertical trace.

In this case both HT and VT of the line AB lie below XY line.





Projection of Planes

Plane surface (plane/lamina/plate)

- A two dimensional surface having length and breadth with negligible thickness.
- Is formed when any three non-collinear points are joined.
- Is bounded by straight/curved lines and may be either a regular figure or an irregular figure.
- *Regular plane surface* - all the *sides are equal.*
- *Irregular plane surface - sides will be unequal.*

Positioning of a Plane surface

- **A plane surface may be positioned in space with reference to the three principal planes of projection in any of the following positions:**

  - ***Parallel to one of the principal planes and perpendicular to the other two.***

  - ***Perpendicular to one of the principal planes and inclined to the other two.***

  - ***Inclined to all the three principal planes.***

Projections of a Plane surface

- A plane surface held *parallel* to a *plane of projection* - it will be *perpendicular* to the other two planes of projection.
    - The *view* of the plane surface projected on the plane of projection to which it will be perpendicular will be a *line*, called the *line view* of a plane surface.
    - *When a plane surface is held with its surface parallel to one of the planes of projection, the view of the plane surface projected on it will be in true shape because all the sides or the edges of the plane surface will be parallel to the plane of projection on which the plane surface is projected.*
- *A plane surface inclined to a plane of projection - the view of the plane surface projected on it will be in apparent shape, called apparent shape view of the plane surface.*

TERMS USED IN PROJECTIONS OF PLANES

- **True Shape** **The actual shape of a plane is called its *true shape*.**
- **Inclination with the HP:** **It is the acute angle the plane makes with the HP.**
- **Inclination with the VP** **It is the acute angle the plane makes with the VP.**
- **Traces of the Plane** **The traces of a plane are the lines of intersections of the plane with the RPs.**
- **A plane may have a horizontal trace or vertical trace or both.**
- **Horizontal Trace (HT)** **The real or imaginary line of intersection of a plane with the HP is called *horizontal trace* of the plane. HT is always located in the TV.**
- **Vertical Trace (VT)** **The real or imaginary line of intersection of a plane with the VP is called *vertical trace* of the plane. VT is always located in the FV.**
- **Line View or Edge View** **The view of a plane seen as a line is called *line view* or *edge view* of the plane. One view of a perpendicular plane is always an edge view.**

A: Plane surface parallel to one plane and perpendicular to the other two

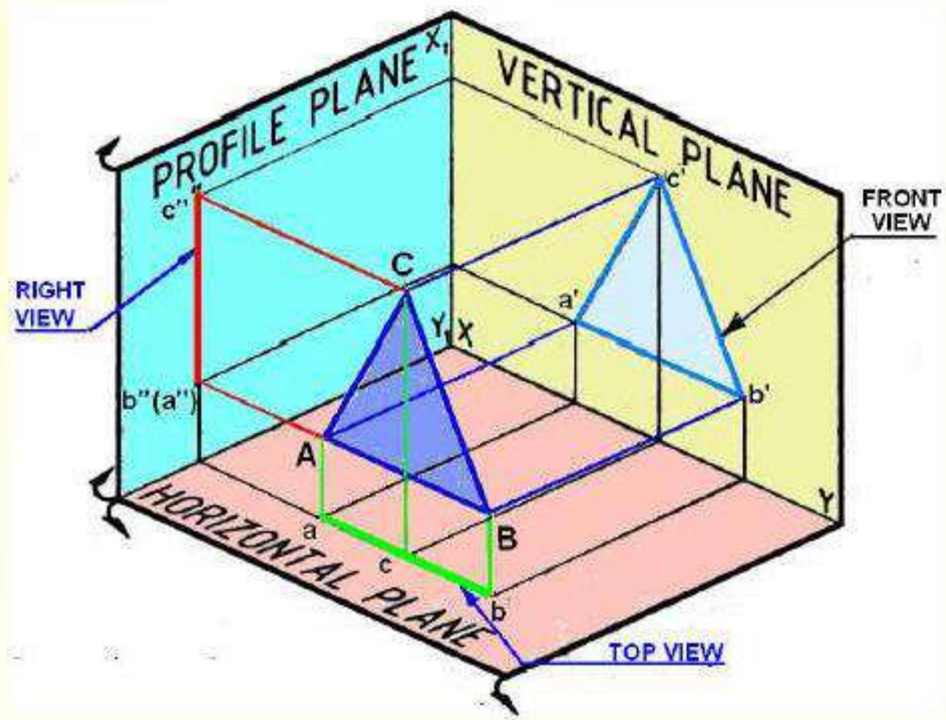
Plane parallel to VP and perpendicular to both HP and PP

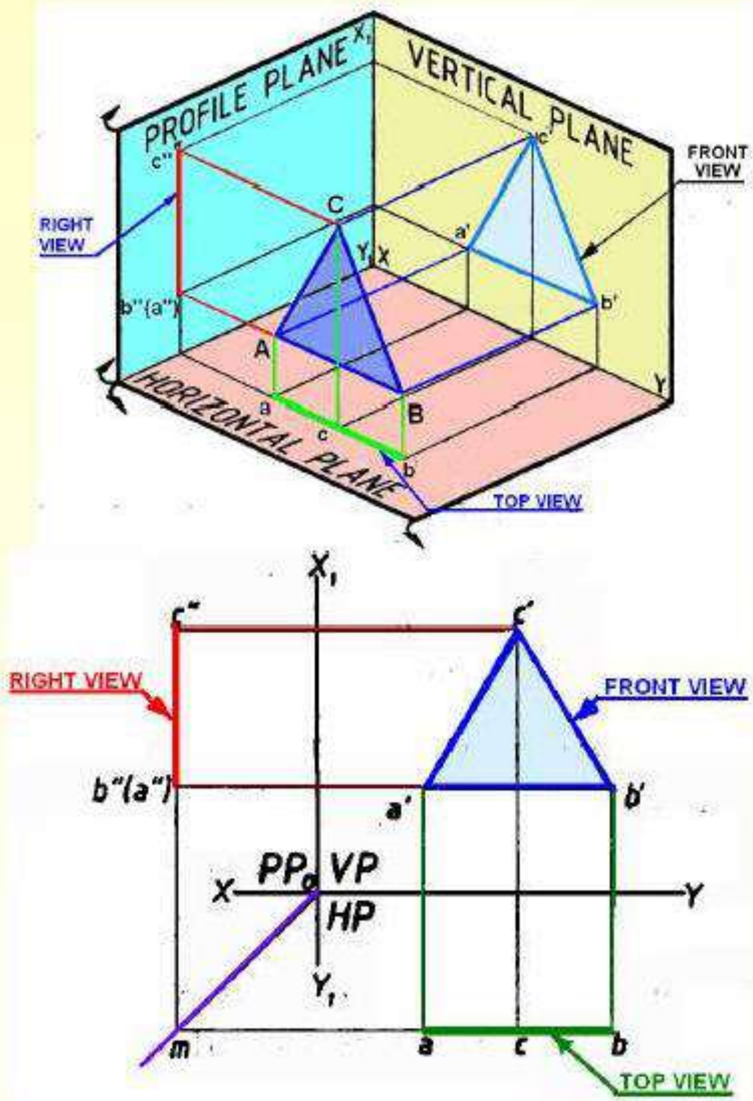
A triangular lamina (plane surface) placed in the first quadrant - its surface is parallel to **VP** and perpendicular to both **HP** and left **PP**.

a'b'c' - front view, *abc* – top view and *a"b"c"* – side view

Front view - *a'b'c'* - in true shape – plane is *parallel to VP*

Top and side views - projected as lines – plane is perpendicular to *HP* and *PP*





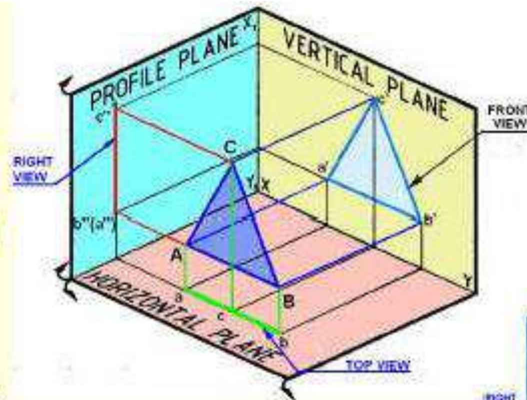
After projecting the triangular lamina on VP, HP and PP, both HP and PP are rotated about XY and X_1Y_1 lines till they lie in-plane with that of VP.

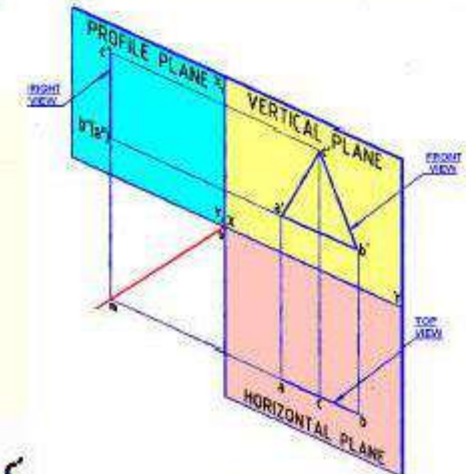
Orthographic projections

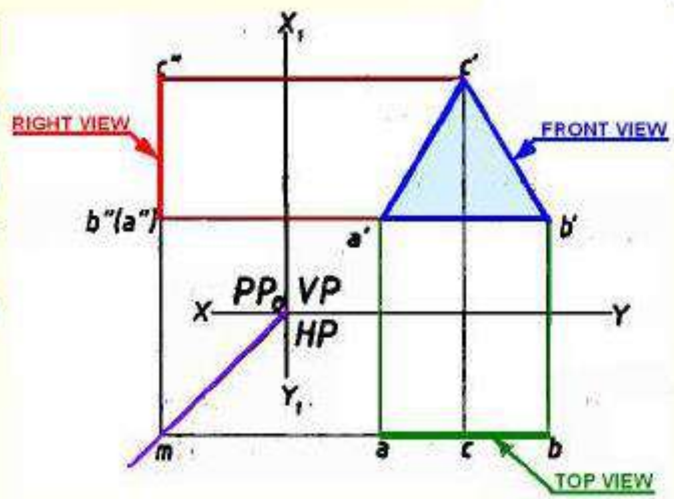
Draw XY and X_1Y_1 lines and mark *HP*, *VP* and left *PP*.

Draw the triangle *a'b'c'* in true shape to represent the front view at any convenient distance above the XY line.

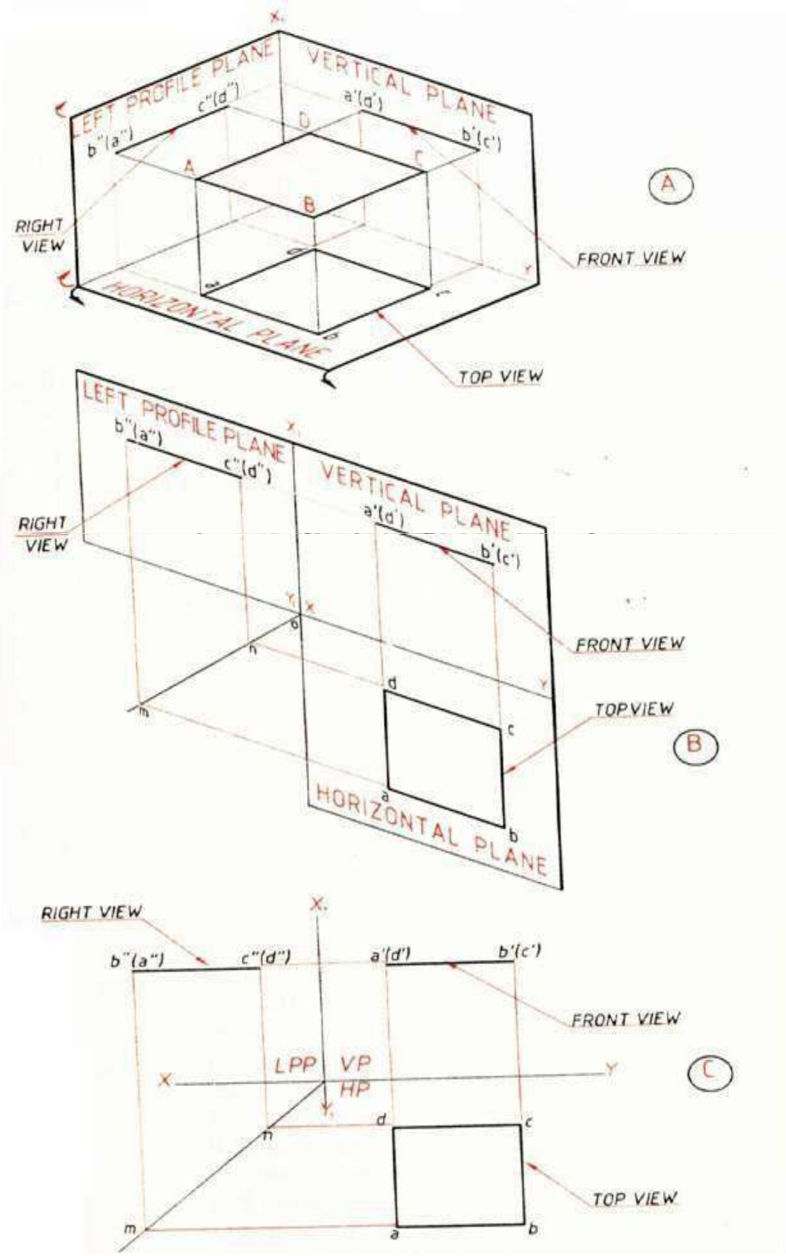
In the top view the triangular lamina appears as a line parallel to the XY line. Obtain the top view *acb* as a line by projecting from the front view at any convenient distance below the XY line.







2. Plane parallel to HP and perpendicular to both VP and PP



A square lamina (plane surface) placed in the first quadrant - its surface is parallel to HP and perpendicular to both VP and left PP.

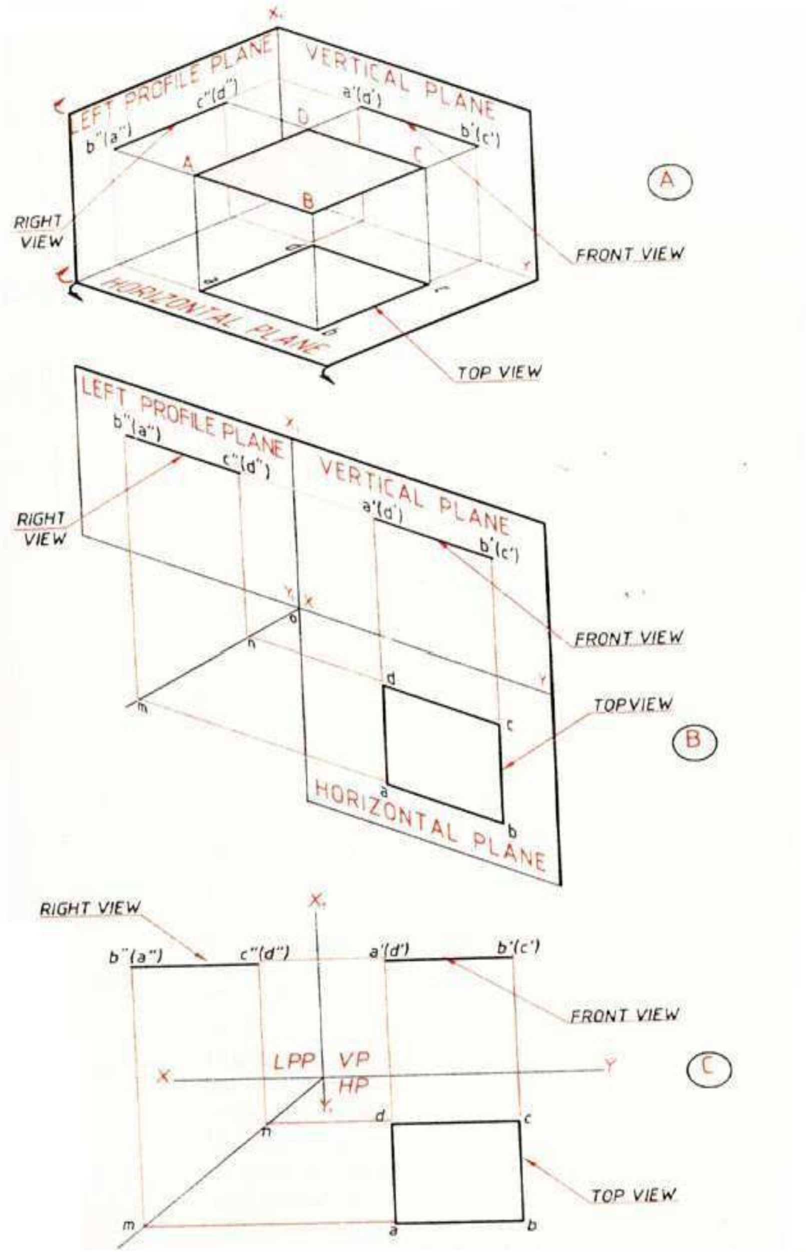
abcd – top view,

a'(d')b'(c') - front view, and

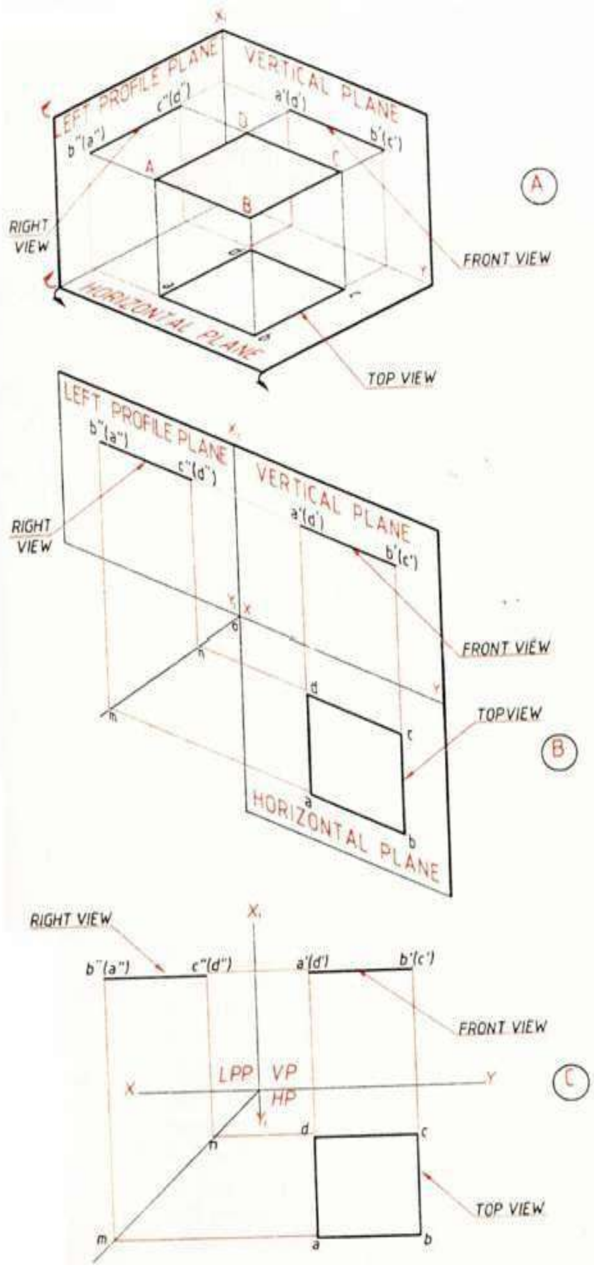
b''(a'')c''(d'') – side view

Top view – abcd - in true shape – plane is parallel to HP

Front and side views - projected as lines – plane is perpendicular to VP and PP



After projecting the square lamina on **VP, HP and PP**, both **HP** and **PP** are rotated about **XY** and **X_1Y_1** lines till they lie in-plane with that of **VP.**



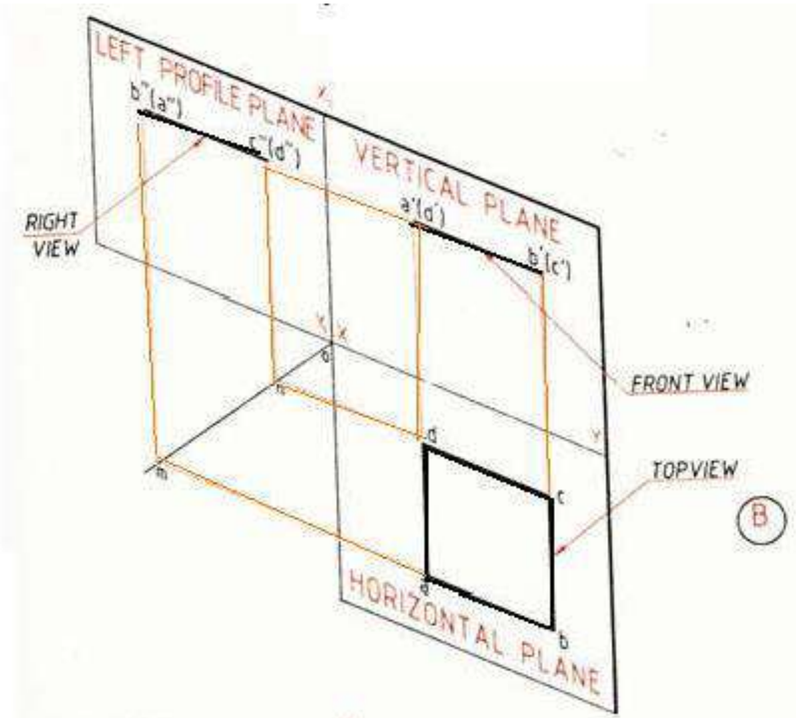
Orthographic projections

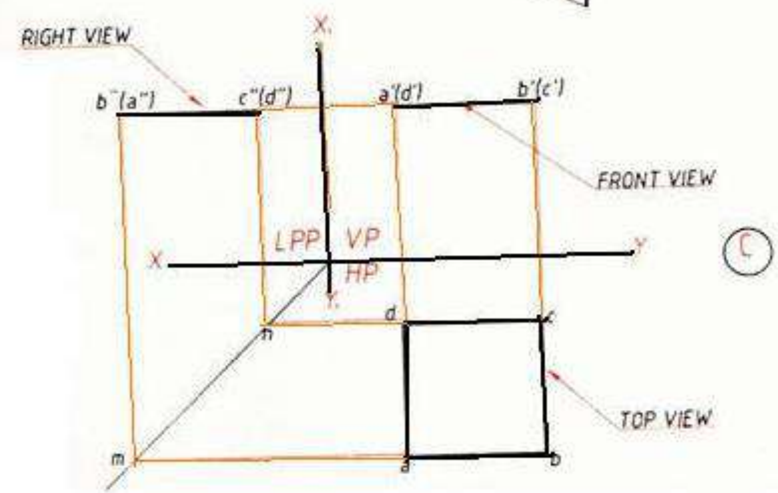
Draw **XY** and **X_1Y_1** lines and mark ***HP, VP*** and left ***PP*** .

Draw the square **abcd** in true shape to represent the top view at any convenient distance below the **XY** line.

In the front view, the square lamina appears as a *line parallel* to the **XY** line. Obtain the front view as a line *a'(d')b'(c') by* projecting from the top view, parallel to the **XY** line at any convenient distance above it.

In the front view, the rear corners **D** and **C** coincide with the front corners **A** and **B**, hence **d'** and **c'** are indicated within brackets.



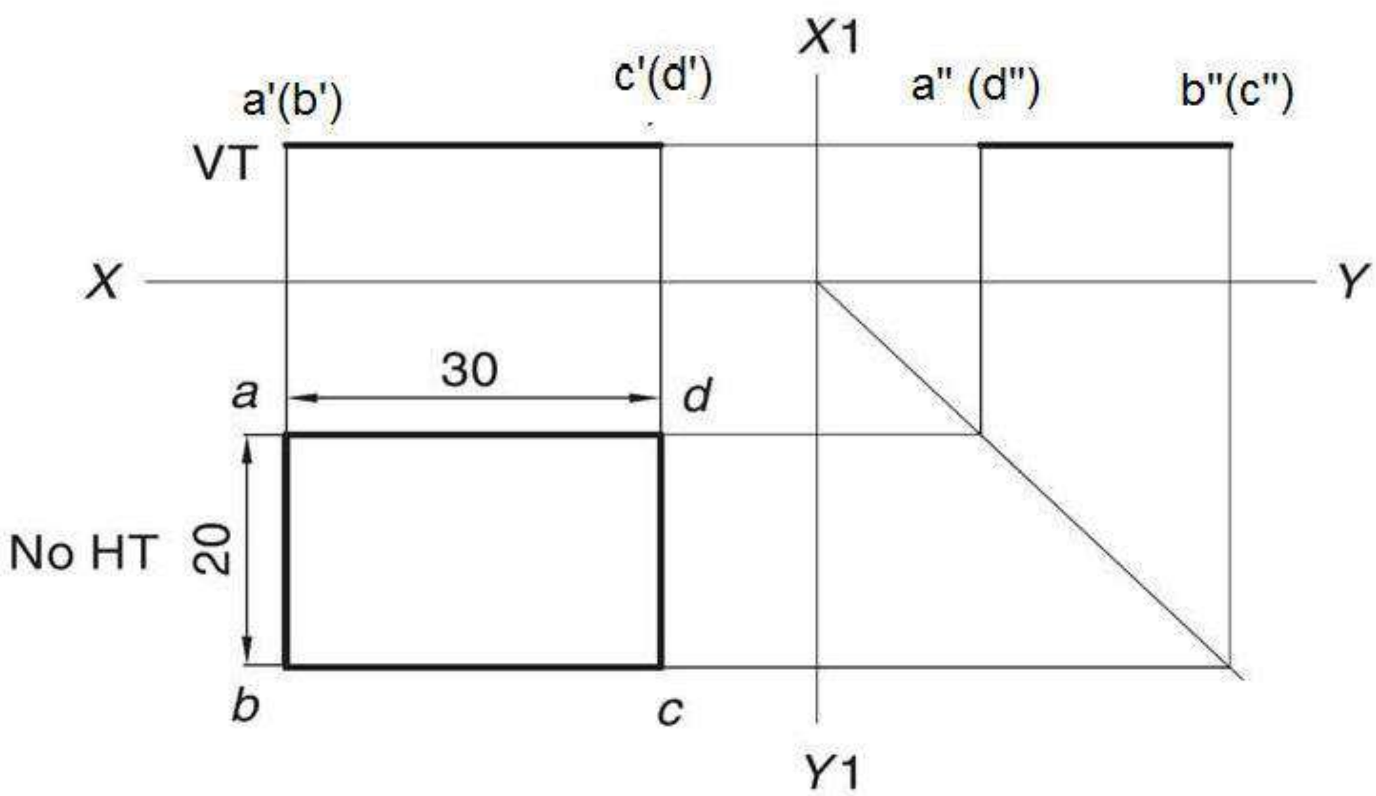


Since the square lamina is also perpendicular to left *PP*, the right view projected on it will also be a *line* perpendicular to X_1Y_1 line.

Project the right view as explained in the previous case. In right view, the corners A and D coincide with the corners B and C respectively, hence *(a')* and (d'), are indicated within brackets.

Example.1

A rectangle ABCD of size 30 mm x 20mm is parallel to the HP and has a shorter side AB perpendicular to the VP. Draw its projections



PRACTICE

Engineering Drawing

Lecture 8

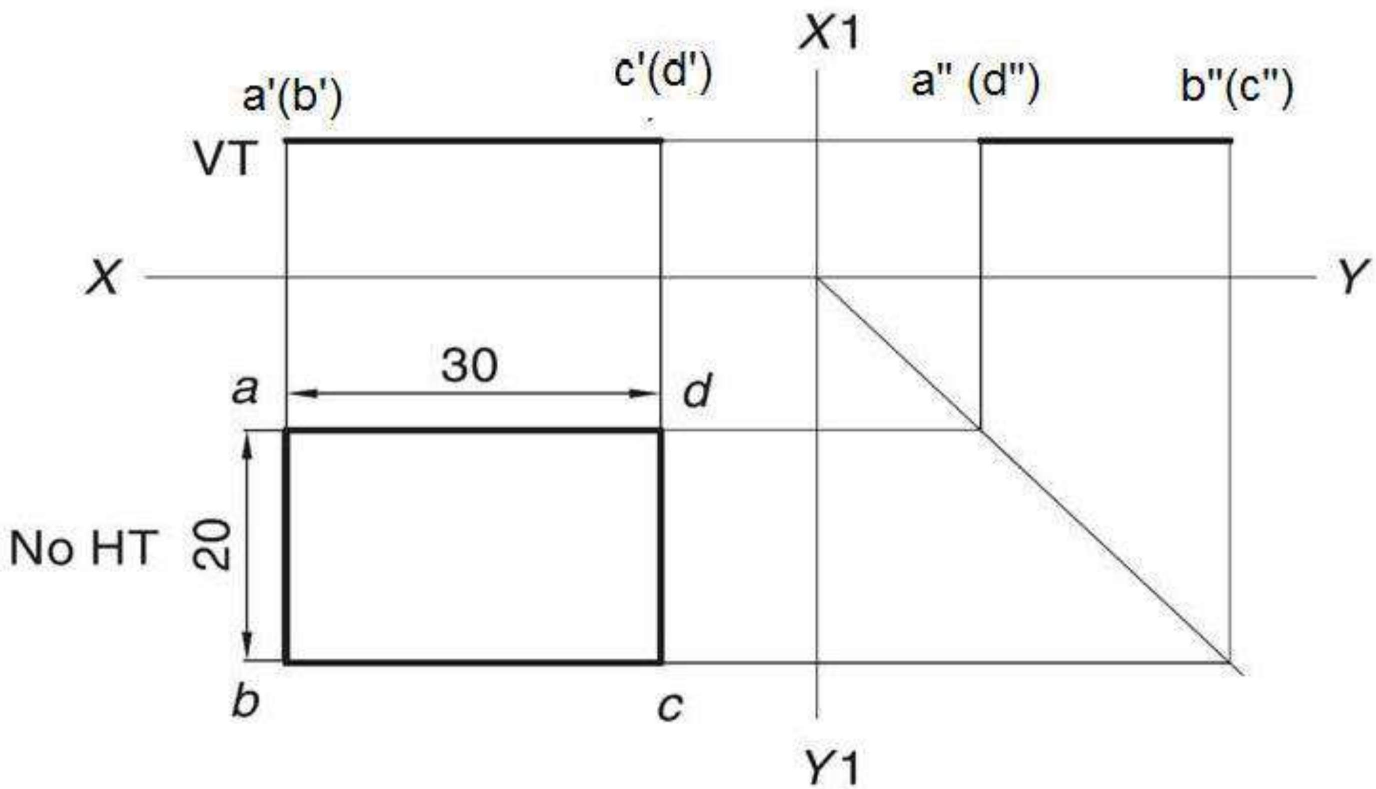
Projection of Planes

Positioning of a Plane surface

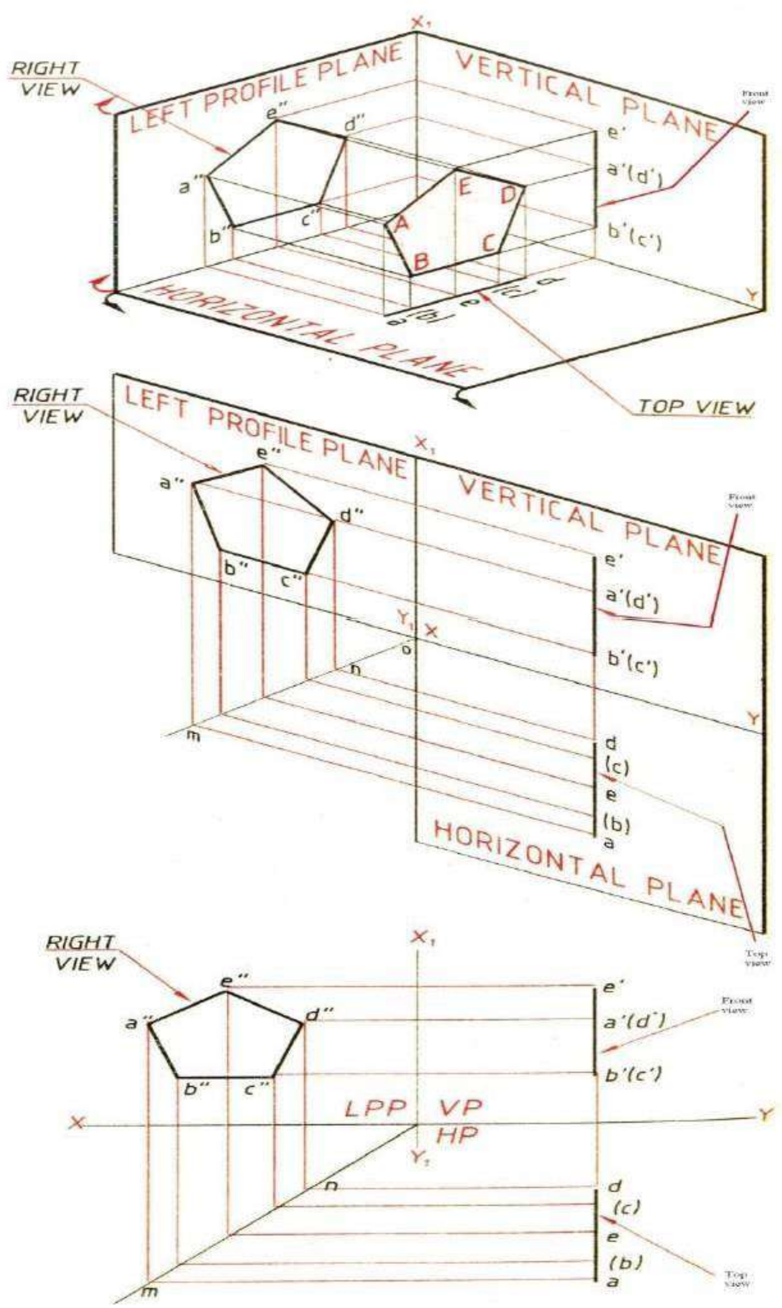
- **A plane surface may be positioned in space with reference to the three principal planes of projection in any of the following positions:**
  - ***Parallel to one of the principal planes and perpendicular to the other two.***
  - ***Perpendicular to one of the principal planes and inclined to the other two.***
  - ***Inclined to all the three principal planes.***

Example.1

A rectangle ABCD of size 30 mm x 20mm is parallel to the HP and has a shorter side AB perpendicular to the VP. Draw its projections



3. Plane parallel to PP and perpendicular to both HP and VP

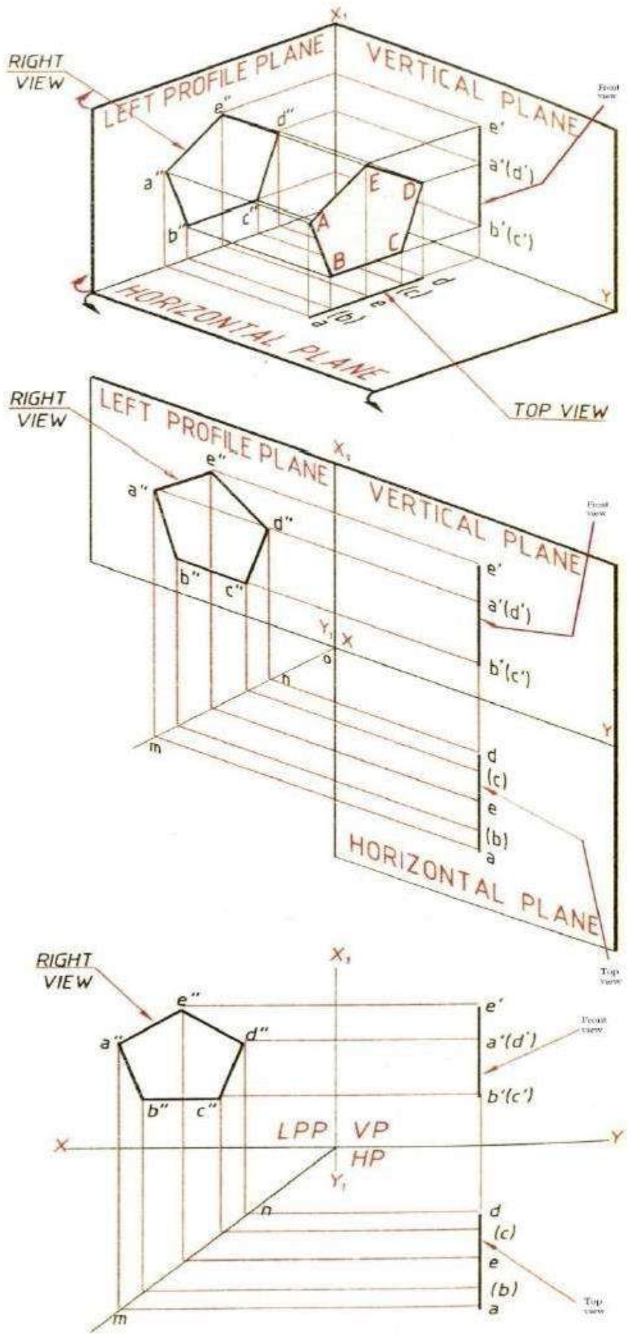


A pentagon lamina (plane surface) placed in the first quadrant - its surface is parallel to **left PP** and perpendicular to both **VP** and **HP.**

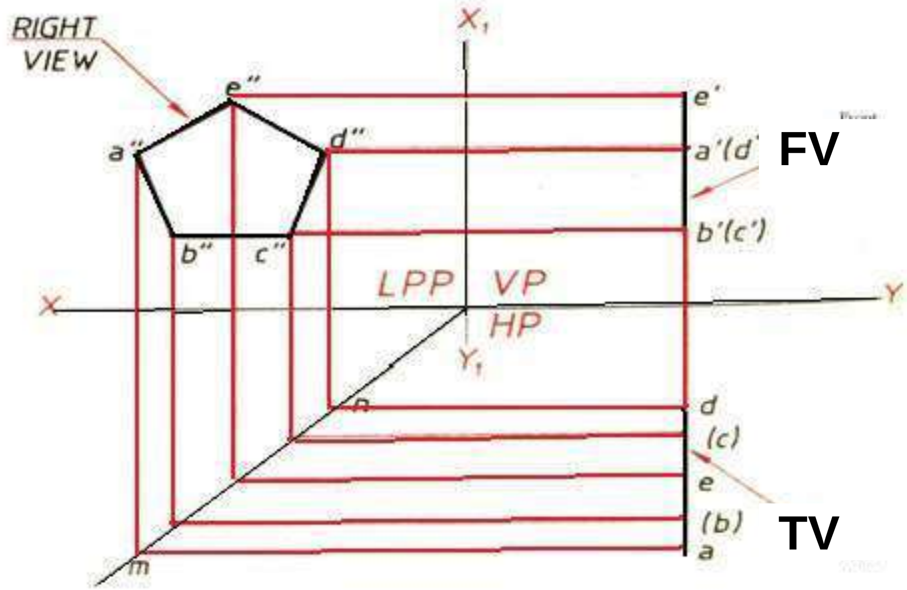
a''b''c''d''e'' – side view **a(b)e(c)d** – top view, and **b'(c')a'(d')e'** - front view,

Side view – **a''b''c''d''e''** - in true shape – plane is **parallel** to **PP.**

Front and top views - projected as lines – plane is perpendicular to **VP** and **HP.**



After projecting the pentagon lamina on VP, HP and PP, both HP and PP are rotated about XY and X_1Y_1 lines till they lie in-plane with that of VP.



Orthographic projections

Draw **XY** and **X_1Y_1** lines, and mark ***HP, VP*** **and left *PP*.**

Draw the pentagon a"b"c"d"e" in true shape to represent the side view at any convenient distance above the XY line and left of X_1Y_1 line.

The top and front views of the lamina appear as lines perpendicular to XY line.

Obtain the front view b'(c')a'(d')e' as a line projecting from the right view at any convenient distance from the X_1Y_1 line.

In the front view, the rear corners D and C coincide with A and B respectively, hence d' and c' are indicated within brackets.

Since the pentagon lamina is also perpendicular to HP, the top view also appears as a line. Project the top view from the right and front views.

B: Plane surface perpendicular to one plane and inclined to the other two

1. Plane inclined at ϕ to VP and perpendicular to HP

A triangular lamina (plane surface) placed in the first quadrant - its surface is inclined at ϕ to VP and perpendicular to the HP.

Since the lamina is inclined to VP, it is also inclined to left PP at (90 - ϕ).

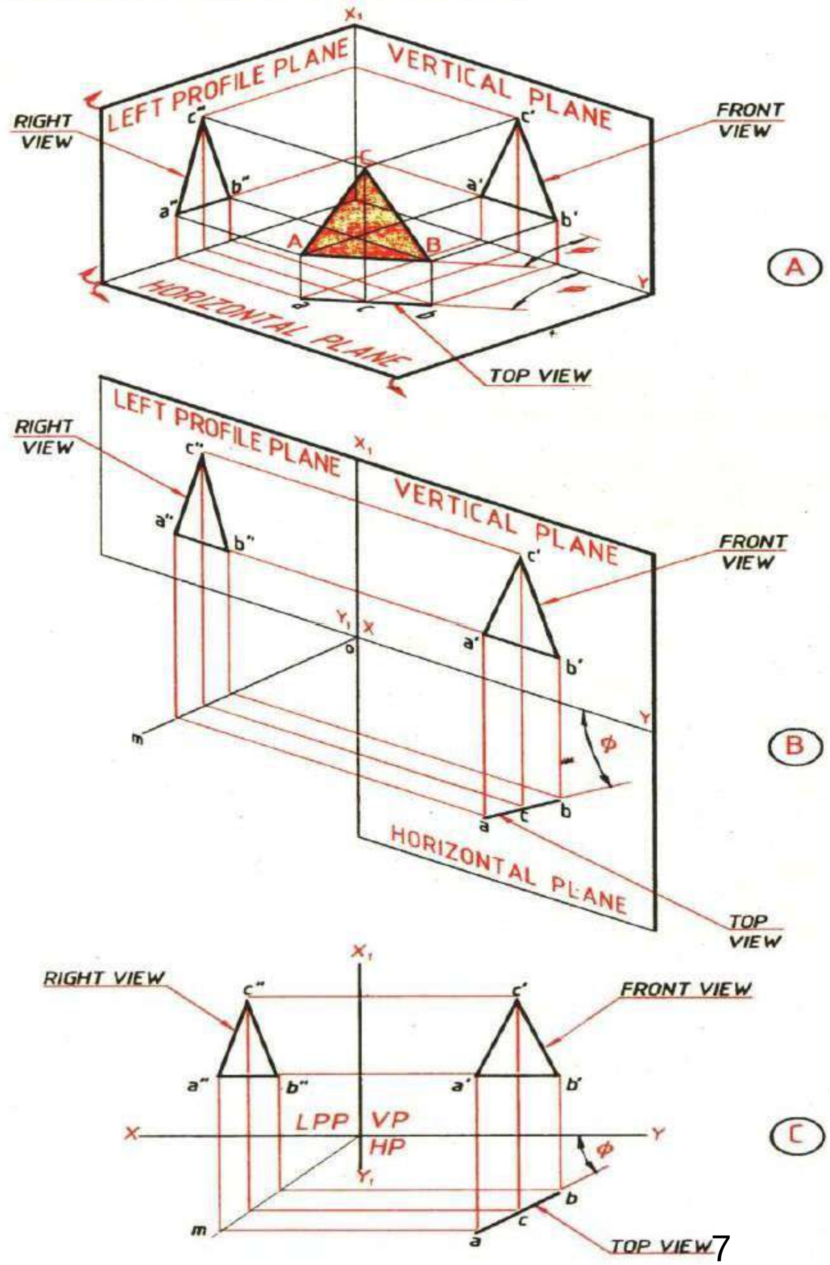
The triangular lamina ABC is projected onto VP, HP and left PP.

a'b'c' – is the front view projected on on VP.

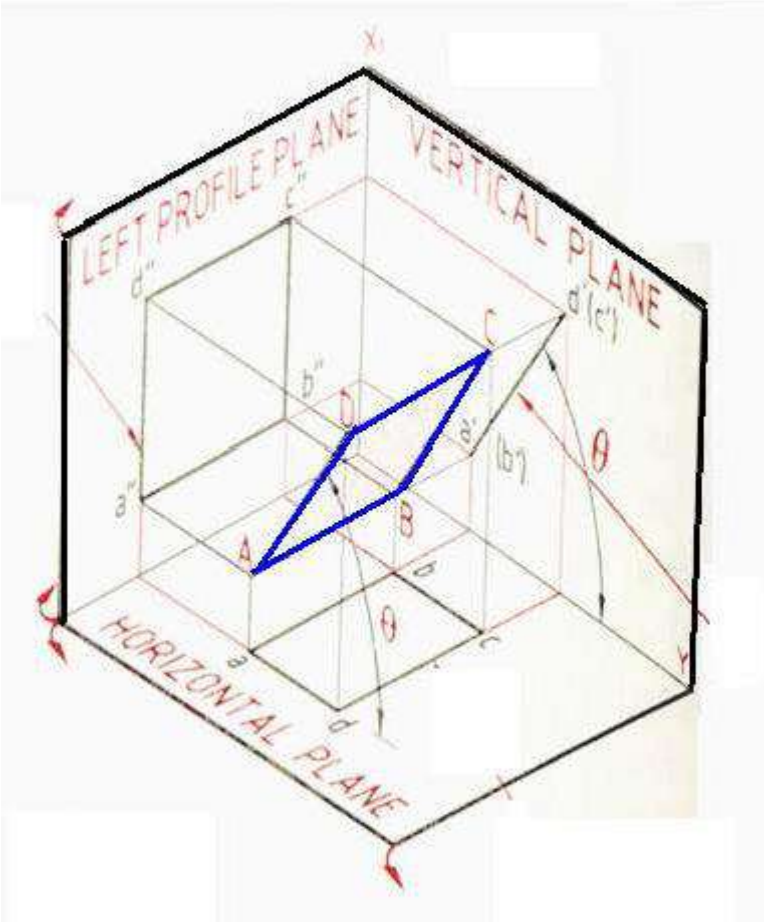
a"b"c" – is the right view projected on left PP

Since lamina is inclined to VP and PP, front and side views are not in true shape.

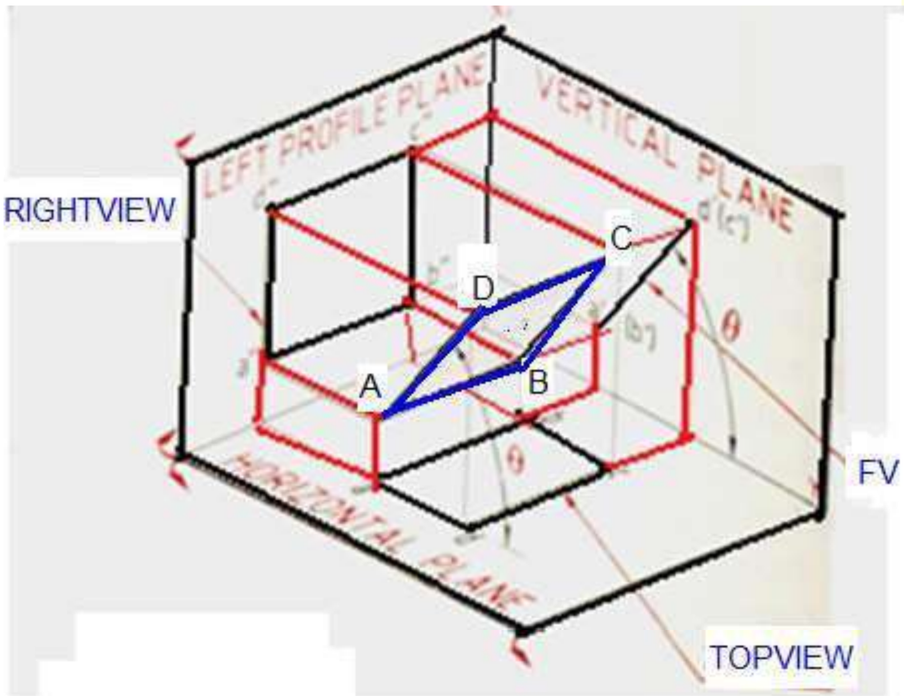
Since lamina is perpendicular to HP, its top view is projected as a line *acb*

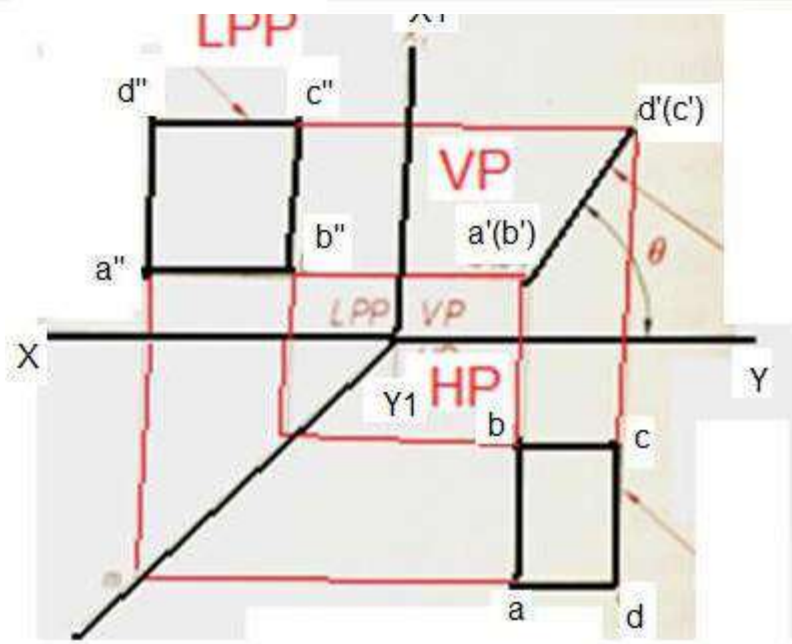


2. Plane inclined at θ to HP and perpendicular to VP



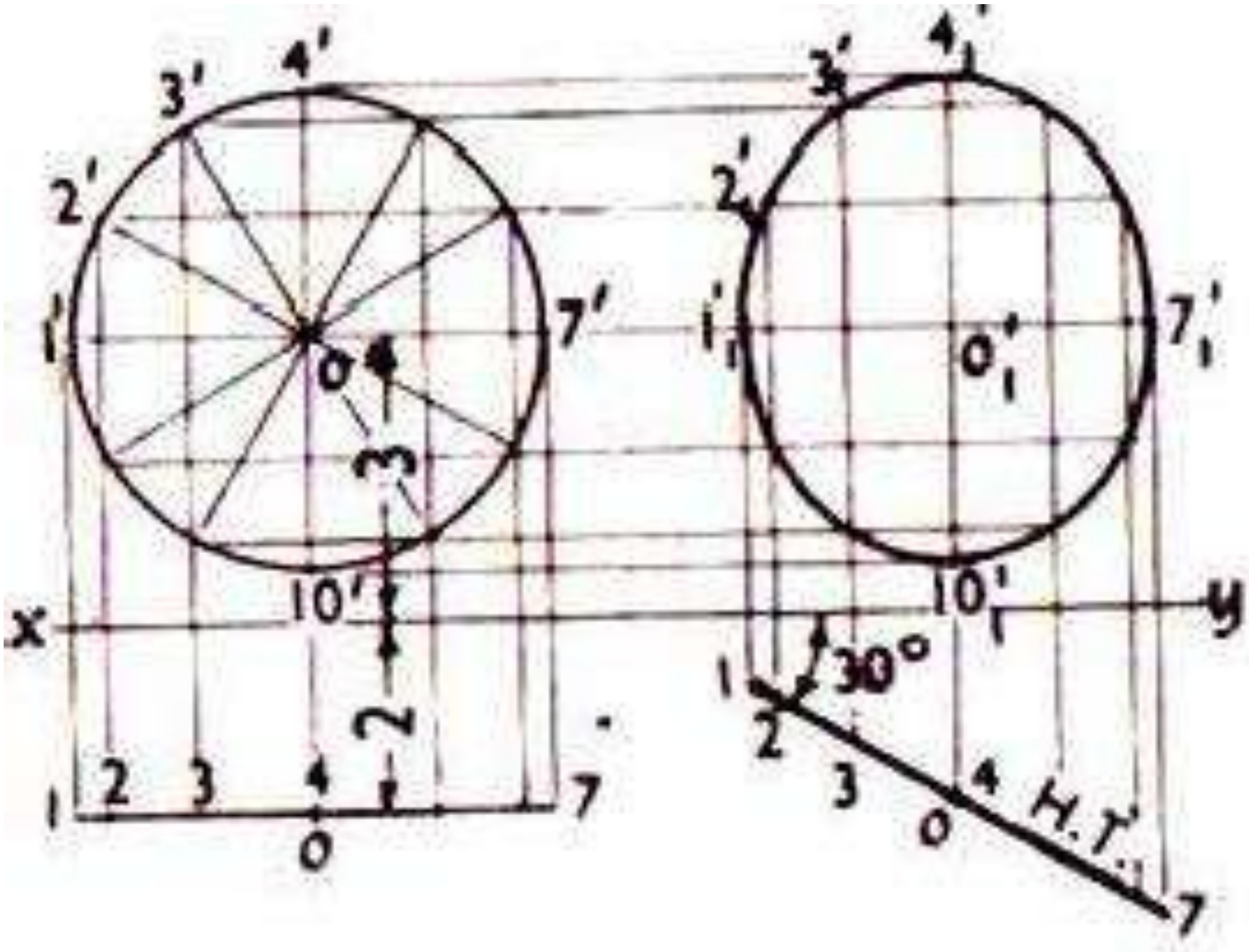
Since the lamina is inclined to HP at θ, it is also inclined to the left PP at (90- θ). The square lamina is projected on to VP, HP and left PP. abcd is the top view projected on the left PP. Since the lamina is perpendicular to VP, its front view is projected as a line a'(b')d'(c'). The corners B and C coincide with A and D.



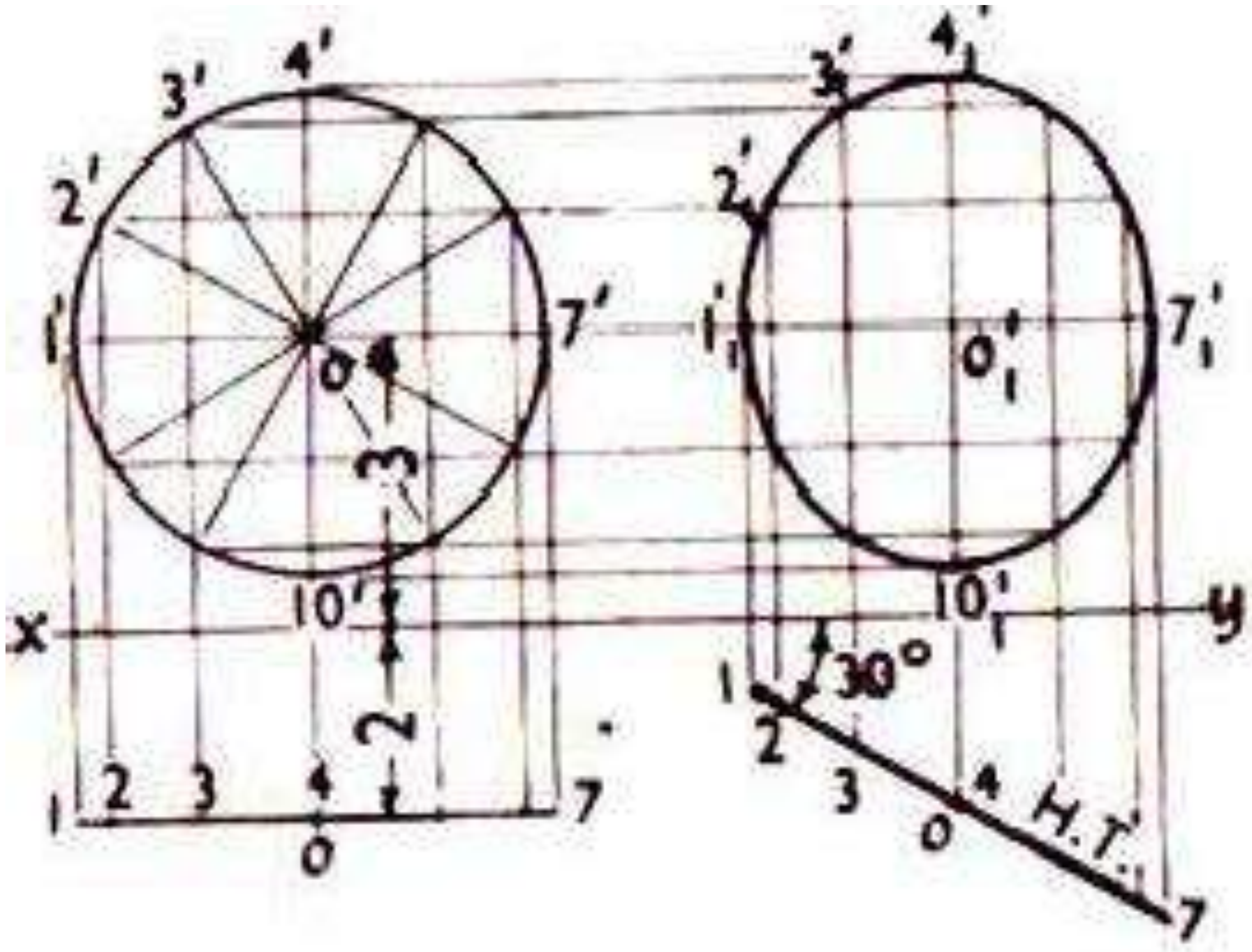


After projecting the square lamina on VP, HP and left PP, both HP and left PP are rotated about the XY and X_1Y_1 line respectively till they lie inplane with that of the VP.

Example.2 : Draw the projection of a circle of 5 cm diameter, having its plane vertical and inclined at 30 to the VP. Its center is 3 cm above the HP and 2 cm in front of the VP.



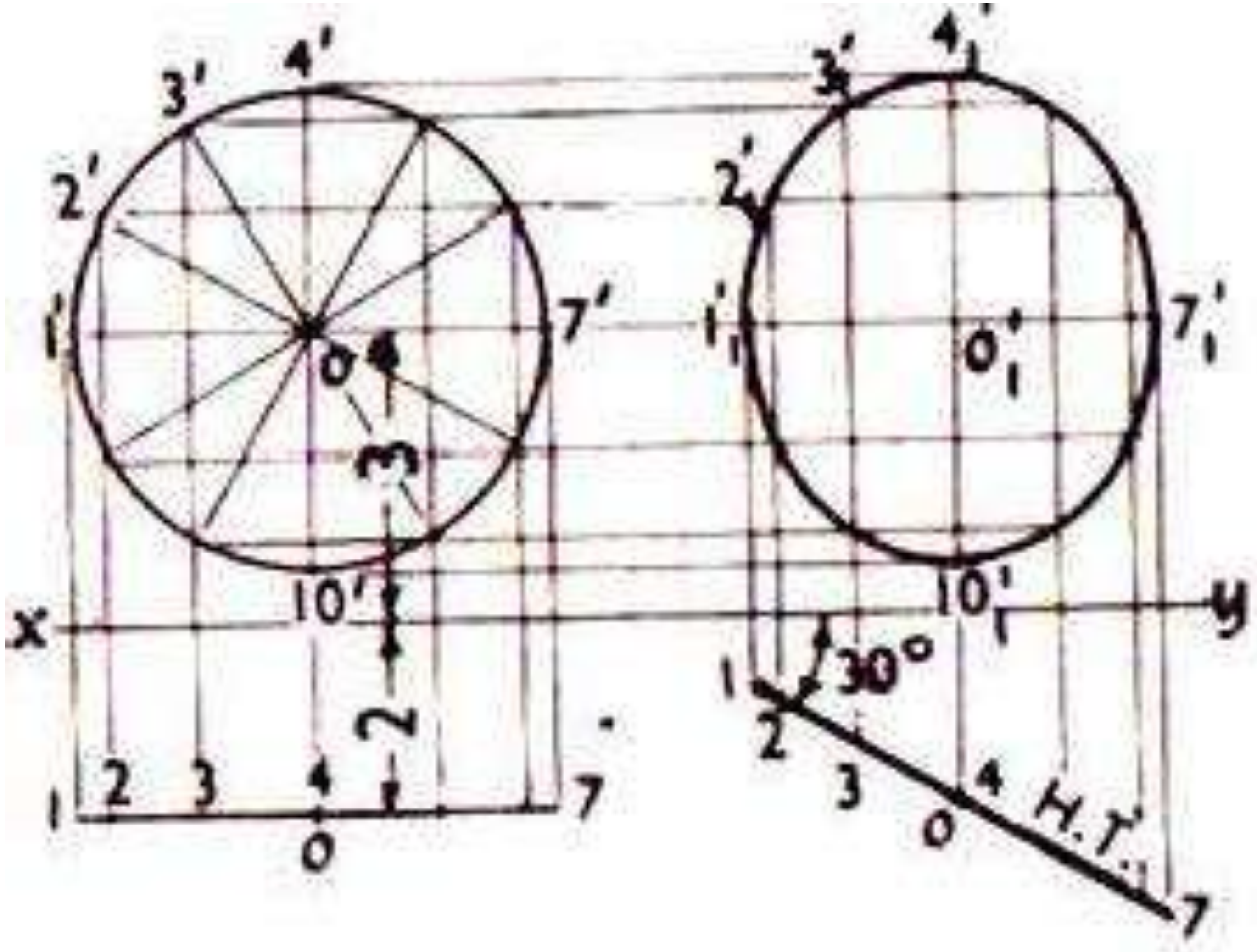
Let us first assume that the plane is perpendicular to HP and parallel to VP. So in top view a straight line and in front view the circle.



Divide the circle into 12 equal parts and name them 1´, 2´, 3´, 4´ etc.

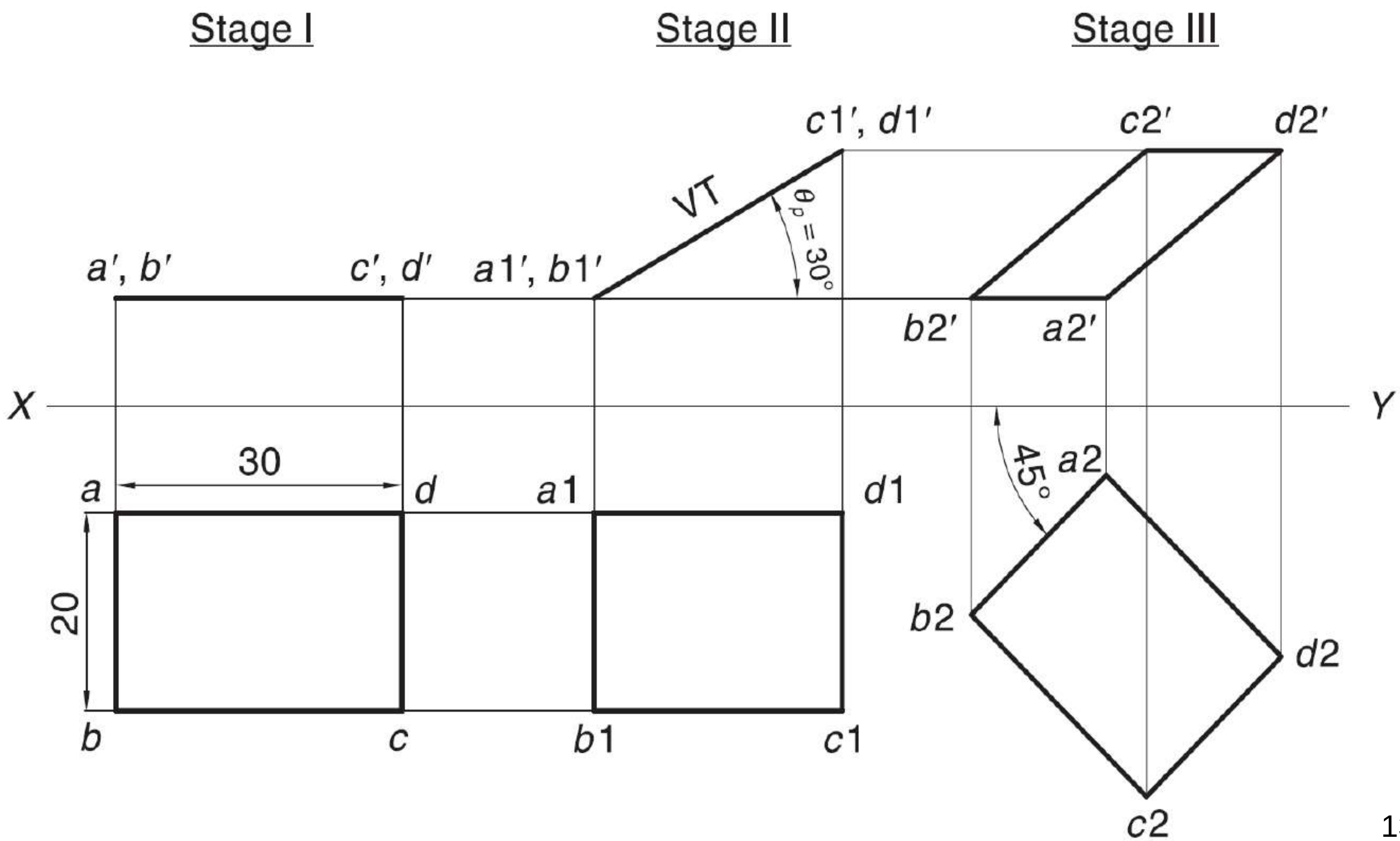
Project these points to top view.

Rotate the top view by 30° to the XY line (because it is inclined to VP at 30°)

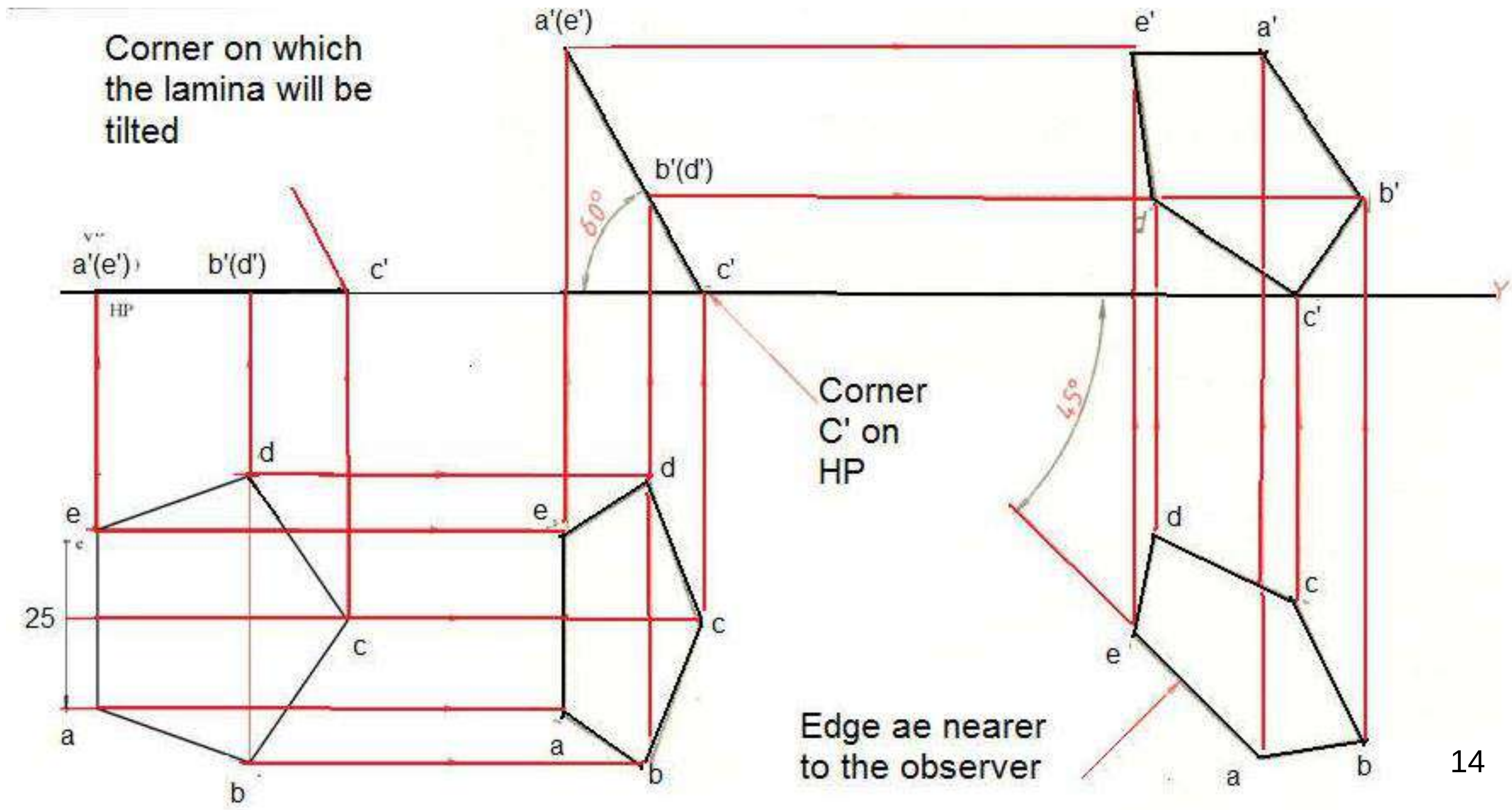


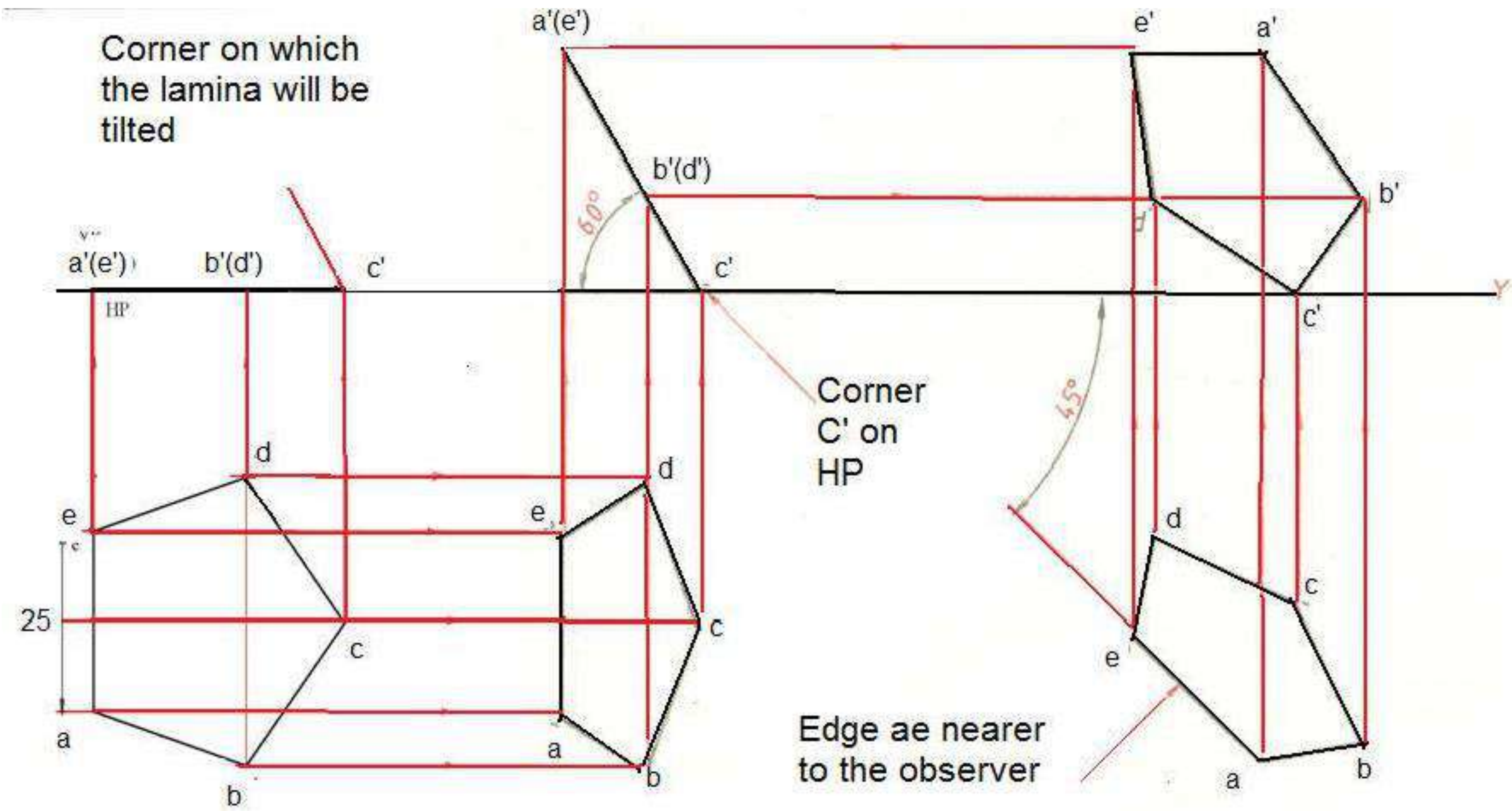
Project the points to front view to get the final front view.

Example: A rectangle ABCD of size 30 mm x 20 mm is inclined to the HP at 30°. Its shorter side AB is parallel to the HP and inclined at 45° to the VP. Draw the projections of the rectangle.



Example 4. A Pentagonal plane lamina of edge 25 mm is resting on HP with one of its corners touching it such that the plane surface makes an angle of 60° with HP. Two of the edges containing the corner on which the lamina rests make equal inclinations with HP. When the edge opposite to this corner makes an angle of 45° with VP and nearer to the observer, draw the TV and FV of the lamina.





A. The lamina is resting on HP.

B. The lamina rests with corner C on HP such that lamina is inclined at 60° to
HP. Edge ae is perpendicular to XY line.

C. Lamina is rotated such that edge AE is inclined at 45° to VP and redrawn.

THANK YOU

Engineering Drawing

Lecture 9

Projections on Auxiliary Planes

Need for Auxiliary Planes

- Sometimes none of the three principal orthographic views of an object show the different edges and faces of an object in their true sizes, since these edges and faces, are not parallel to any one of the three principal planes of projection.

- In order to show such edges and faces in their true sizes, it becomes necessary to set up ***additional planes of projection*** other than the three principal planes of projection in the positions which will show them in true sizes.

- If an edge or a face is to be shown in true size, it should be parallel to the plane of projection.
- Hence the additional planes are set up so as to be parallel to the edges and faces which should be shown in true sizes.
- These additional planes of projection which are set up to obtain the true sizes are called ***Auxiliary Planes****.*
- The views projected on these **auxiliary planes** are called

The auxiliary view method may be applied

- *To find the true length of a line.*
- *To project a line which is inclined to both HP and VP as a point.*
- *To project a plane surface or a lamina as a line.*

Types of auxiliary planes

Usually the auxiliary planes are set up such that they are ***parallel*** to the edge or face which is to be shown in true size and ***perpendicular*** to any one of the three principal planes of projection

Therefore, the selection of the auxiliary plane as to which of the principal planes of projection it should be perpendicular, obviously depends on the shape of the object whose edge or face that is to be shown in true size.

If the auxiliary plane selected is **perpendicular** to **HP** and **inclined** to ***VP**, the views of the object projected on the **auxiliary plane** is called ***auxiliary front view*** and the auxiliary plane is called ***auxiliary vertical plane*** and denoted as ***AVP.***

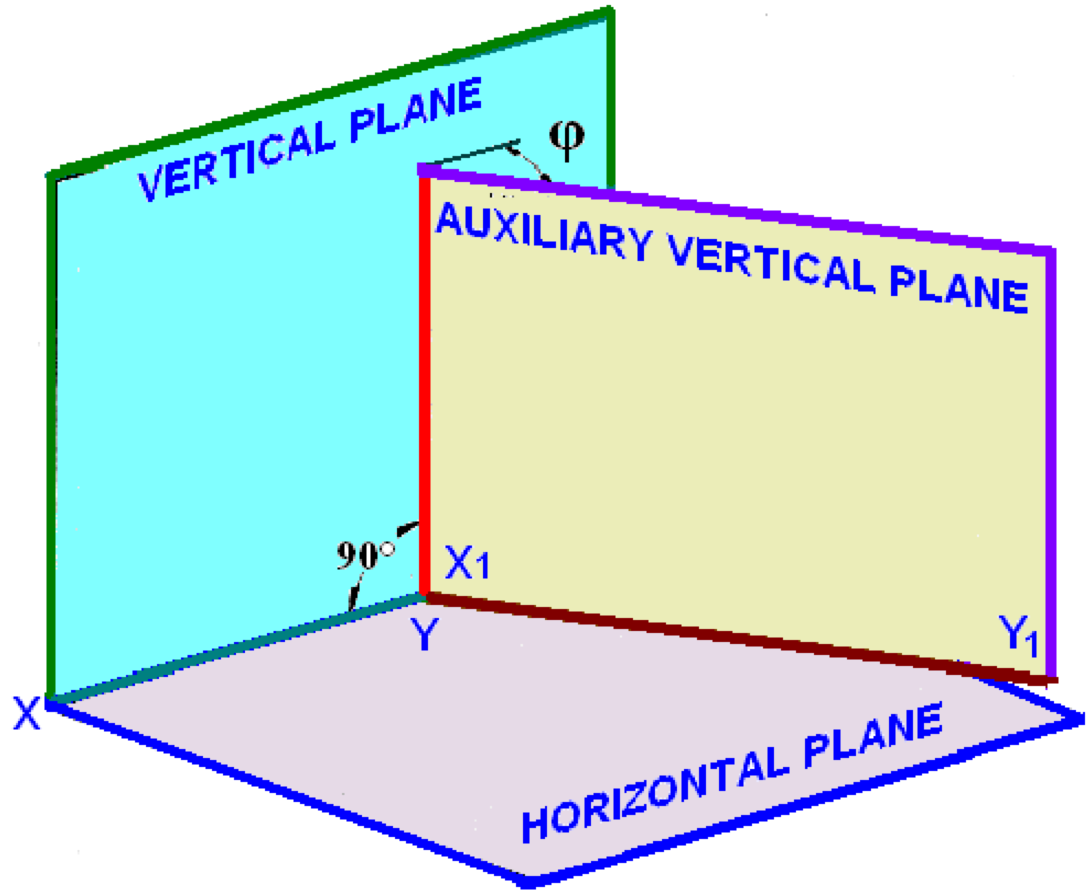
If the auxiliary plane is **perpendicular** to **VP** and **inclined** to **HP**, the view of the object projected on the auxiliary plane is called ***auxiliary top view*** and the **auxiliary plane** is called ***auxiliary inclined plane*** and denoted as ***AIP**.*

Auxiliary Vertical Plane

AVP is placed in the first quadrant with its surface perpendicular to **HP** and inclined at ϕ to **VP**.

The object is to be placed in the space in between **HP**, **VP** and **AVP**. The **AVP** intersects **HP** along the $\mathbf{X_1Y_1}$ line.

The direction of sight to project the auxiliary **front view** will be normal to AVP.



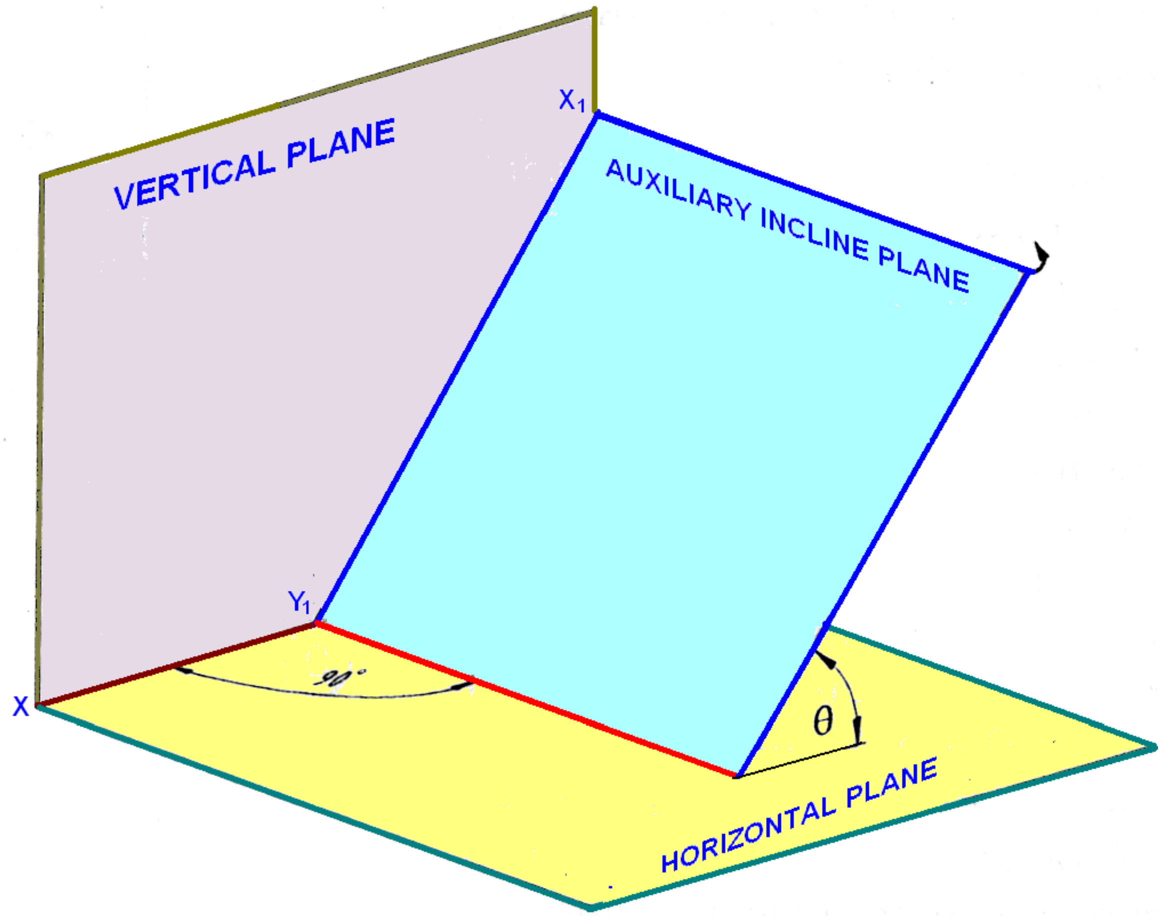
After obtaining the top view, front view and auxiliary front view on **HP**, **VP** and **AVP**, the **HP,** with the **AVP** being held perpendicular to it, is rotated so as to be in-plane with that of **VP**, and then the **AVP** is rotated about the $\mathbf{X_1Y_1}$ line so as to be in-plane with that of already rotated **HP**

Auxiliary Inclined Plane

AIP is placed in the first quadrant with its surface perpendicular to **VP** and inclined at θ to **HP**.

The object is to be placed in the space between **HP**, **VP** and **AIP**.

The **AIP** intersects the **VP** along the $\mathbf{X_1Y_1}$ line.



The direction of sight to project the auxiliary **top view** will be normal to the **AIP**.

After obtaining the top view, front view and auxiliary top view on ***HP, VP*** *and* ***AIP, HP*** is rotated about the **XY** line independently (detaching the AIP from HP).

The AIP is then rotated about $\mathbf{X_1Y_1}$ line independently so as to be in-plane with that of **VP**.

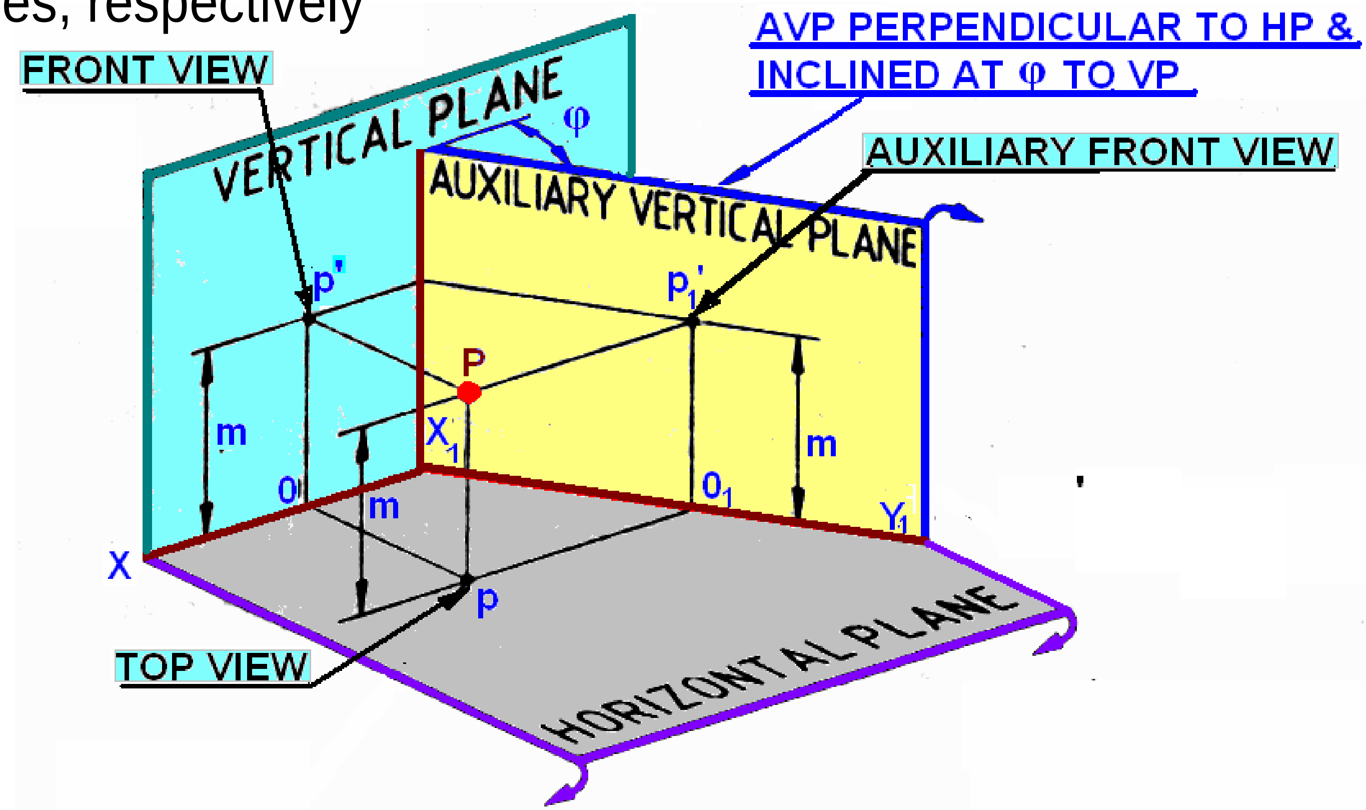
Projection of Points on Auxiliary Planes

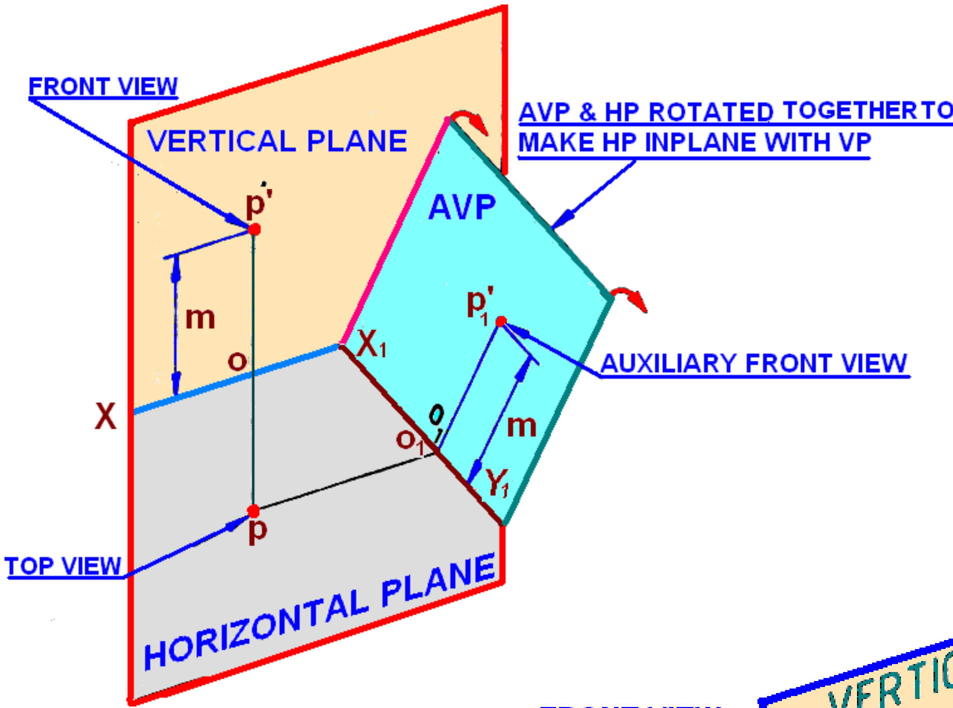
Projection on AVP

Point **P** is situated in the first quadrant at a height **m** above **HP**. An auxiliary vertical plane ***AVP*** is set up perpendicular to **HP** and inclined at ϕ to ***VP***. The point **P** is projected on ***VP***, ***HP*** and ***AVP***.

p' is the projection on ***VP***, ***p*** is the projection on **HP** and $\mathbf{P_1'}$ is the projection on ***AVP***.

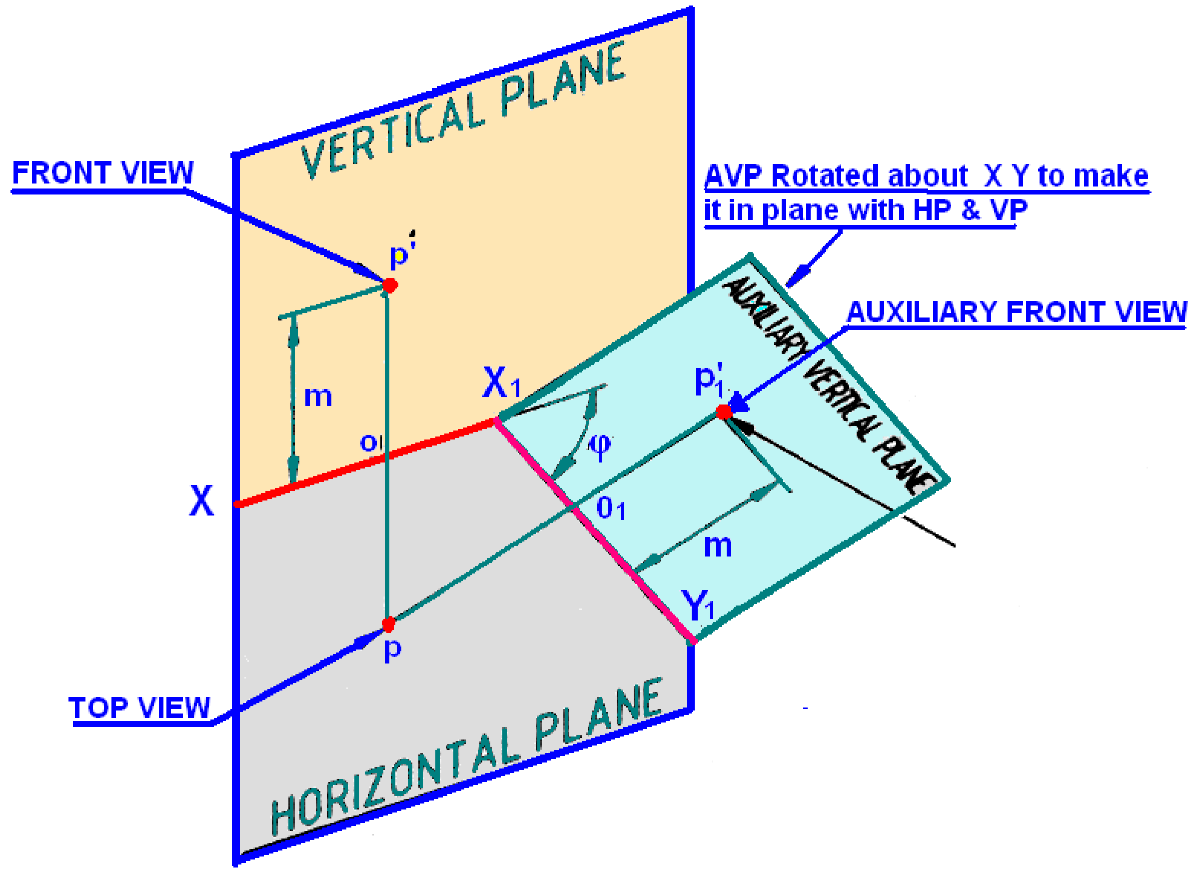
Since point is at a height **m** above **HP**, both **p'** and $\mathbf{p_1'}$ are at a height **m** above the **XY** and $\mathbf{X_1Y_1}$ lines, respectively





HP is rotated by **90** degree to bring it in plane of **VP**.

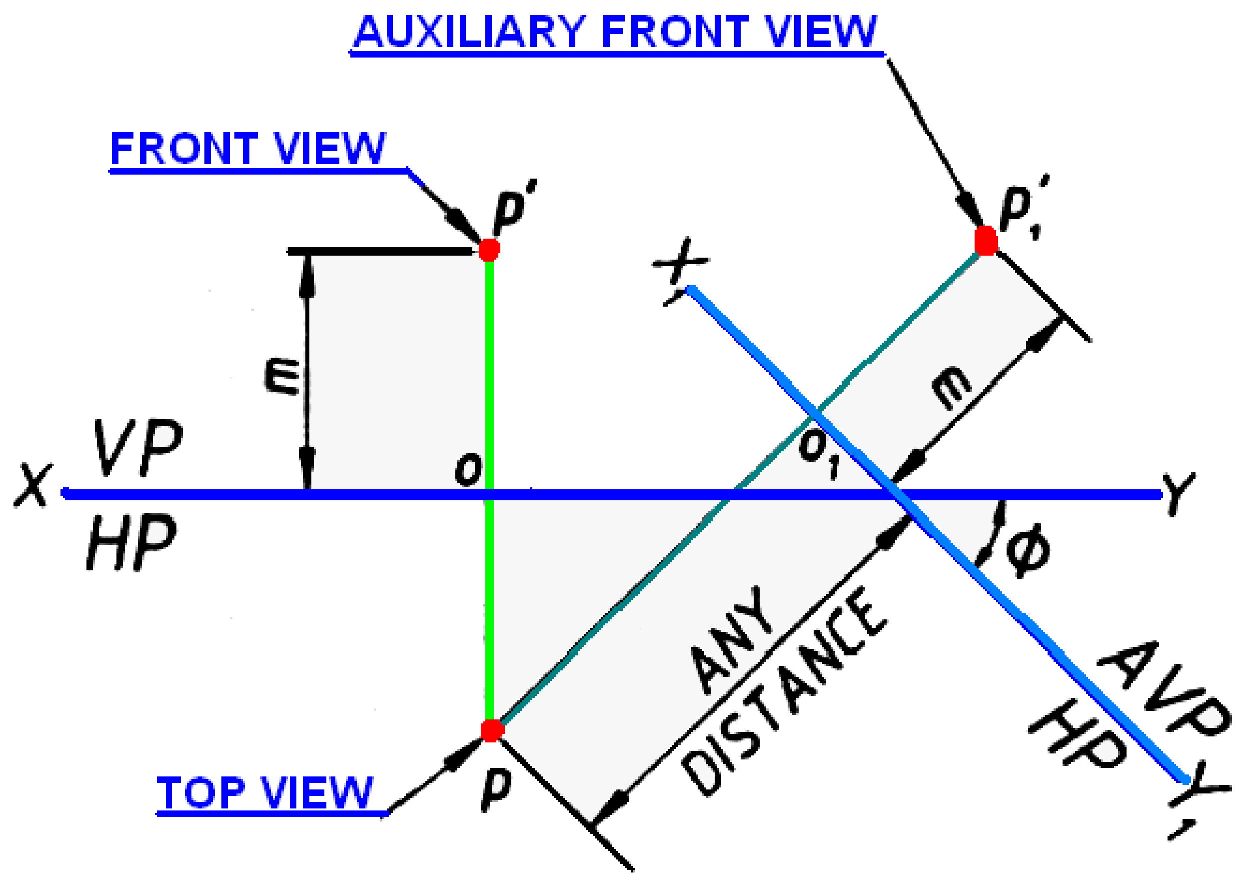
After the **HP** lies in-plane with **VP**, the **AVP** is rotated about the **X_1Y_1**, line, so that it becomes in-plane with that of both **HP** and ***VP***.



Orthographic projections

Draw the **XY** line and mark **p** and **p'**, the top and front views of the point **P**.

Since **AVP** is inclined at ϕ to *VP*, draw the X_1Y_1 line inclined at ϕ to the **XY** line at any convenient distance from **p**.



Since point **P** is at a height **m** above **HP**, the auxiliary front view $\mathbf{p_1'}$ will also be at a height **m** above the $\mathbf{X_1Y_1}$ line.

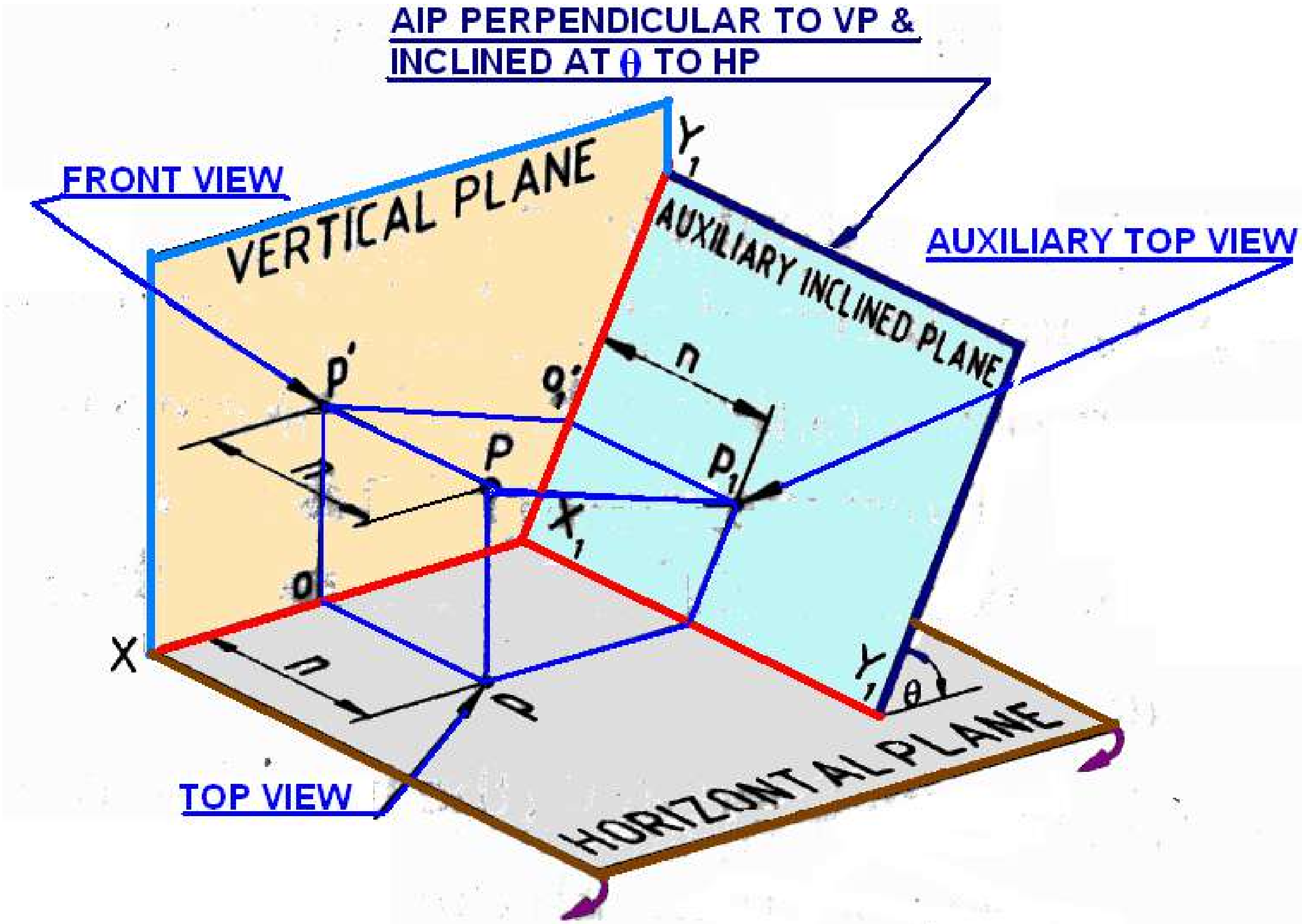
Therefore, mark $\mathbf{P_1'}$ by measuring $\mathbf{o_1p_1' = op' = m}$ on the projector drawn from **p** perpendicular to the $\mathbf{X_1Y_1}$ line.

Projection on AIP

Point **P** is situated in first quadrant at a distance **n** from **VP**. An auxiliary plane ***AIP*** is set up perpendicular to **VP** and inclined at θ to ***HP***. The point **P** is projected on ***VP***, ***HP*** and ***AIP***.

p' is the projection on ***VP***, ***p*** is the projection on **HP** and **P_1** is the projection on ***AIP***.

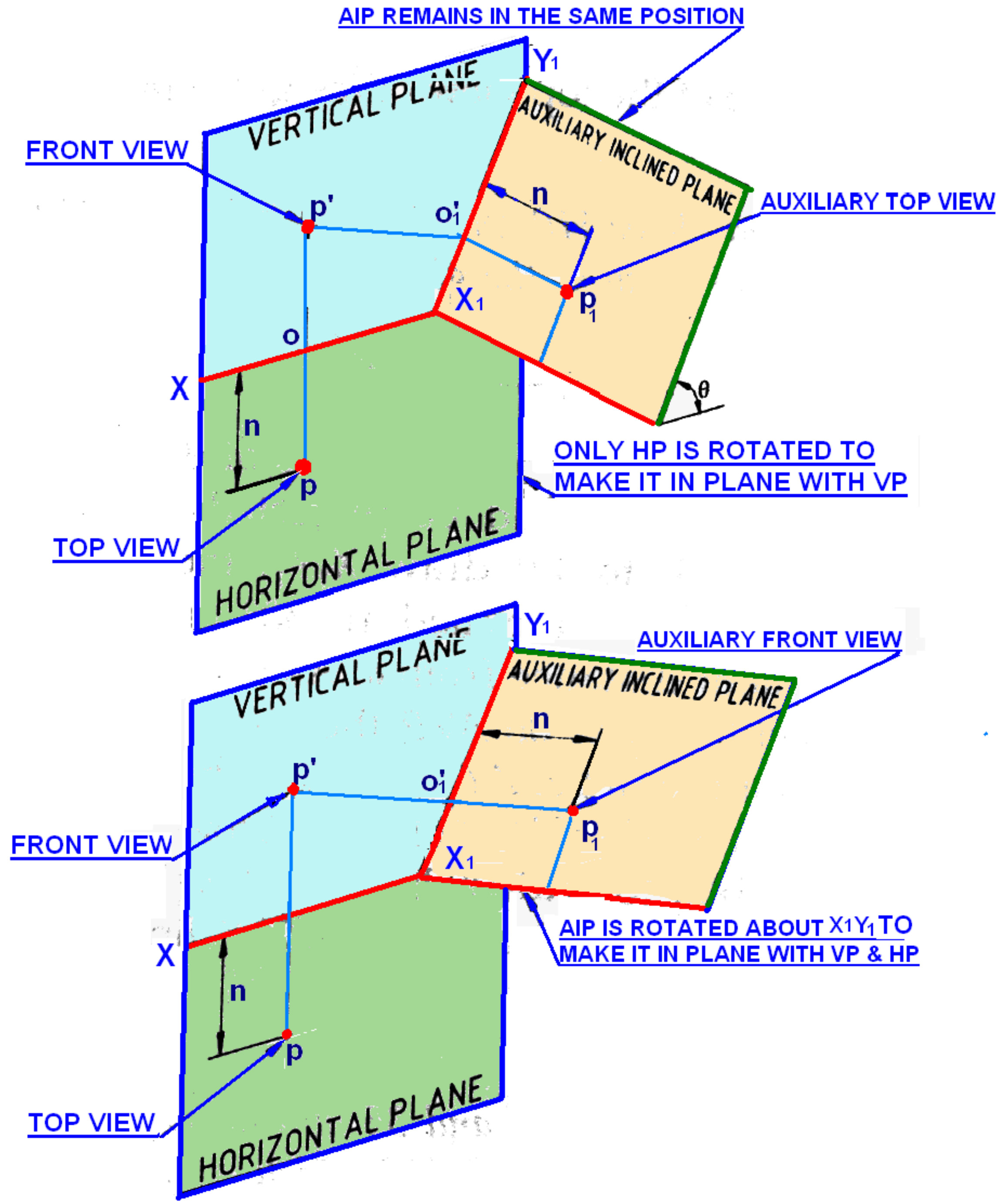
Since the point is at a distance **n** from **VP**, both **p** and **p_1** are at a distance **n** above the **XY** and **X_1Y_1** lines, respectively



HP is rotated by 90 degree about **XY** line to bring it in plane with **VP**.

After the **HP** lies in-plane with **VP**, the ***AIP*** is rotated about the $\mathbf{X_1Y_1}$, line, so that it becomes in-plane with that of both **HP** and ***VP***.

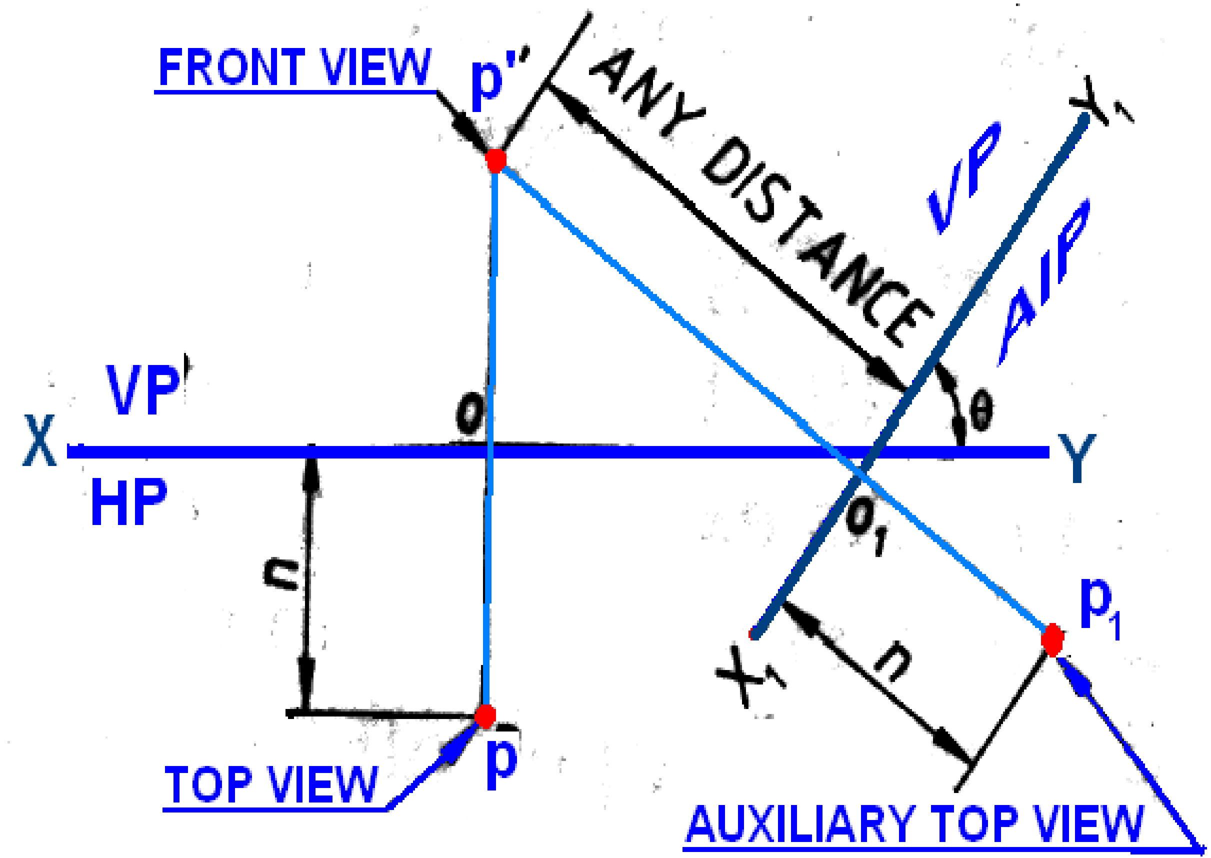
p and **p'** lie on a vertical projector perpendicular to the **XY** line, and **p'** and $\mathbf{p_1}$ lie on a projector perpendicular to the $\mathbf{X_1Y_1}$ line which it self is inclined at θ to **XY** line.



Orthographic projections

Draw the **XY** line and mark **p** and **p'**, the top and front views of the point **P**.

Since **AIP** is inclined at θ to ***HP***, draw the $\mathbf{X_1Y_1}$ line inclined at θ to the **XY** line at any convenient distance from **p'**.



Since point **P** is at a distance **n** infront of **VP**, the auxiliary top view $\mathbf{p_1}$ will also be at a distance **n** from the $\mathbf{X_1Y_1}$ line.

Therefore, mark $\mathbf{P_1}$ by measuring $\mathbf{o_1p_1=op = n}$ on the projector drawn from **p'** perpendicular to the $\mathbf{X_1Y_1}$ line.

Step by step procedure to draw auxiliary views

Auxiliary front view	Auxiliary top view
• Draw the top and front views.	• Draw the top and front views
• Draw $\mathbf{X_1Y_1}$ line inclined at ϕ (the inclination of AVP with VP) to the **XY** line.	• Draw $\mathbf{X_1Y_1}$ line inclined at θ (the inclination of *AIP with* HP) to **XY** line.
• Draw the projectors through the **top views** of the points perpendicular to the $\mathbf{X_1Y_1}$ line.	• Draw the projectors through the **front views** of the points perpendicular to the $\mathbf{X_1Y_1}$ line.
• The auxiliary front view of a point is obtained by stepping off a distance from the $\mathbf{X_1Y_1}$ line equal to the distance of the **front view** of the given point from the **XY** line.	• The auxiliary top view of a point is obtained by stepping off a distance from $\mathbf{X_1Y_1}$ line equal to to the distance of the **top view** of the given point from the **XY** line

Projection of lines on auxiliary planes

The problems on projection of lines inclined to both the planes may also be solved by the auxiliary plane methods.

In this method, the line is always placed parallel to both **HP**

auxiliary plane will be perpendicular to **VP** and inclined at θ to **HP**, i.e., **AIP**, and the other will be perpendicular to **HP** and inclined at ϕ (true inclination) or β (apparent inclination) to **VP**.

Problem 1:

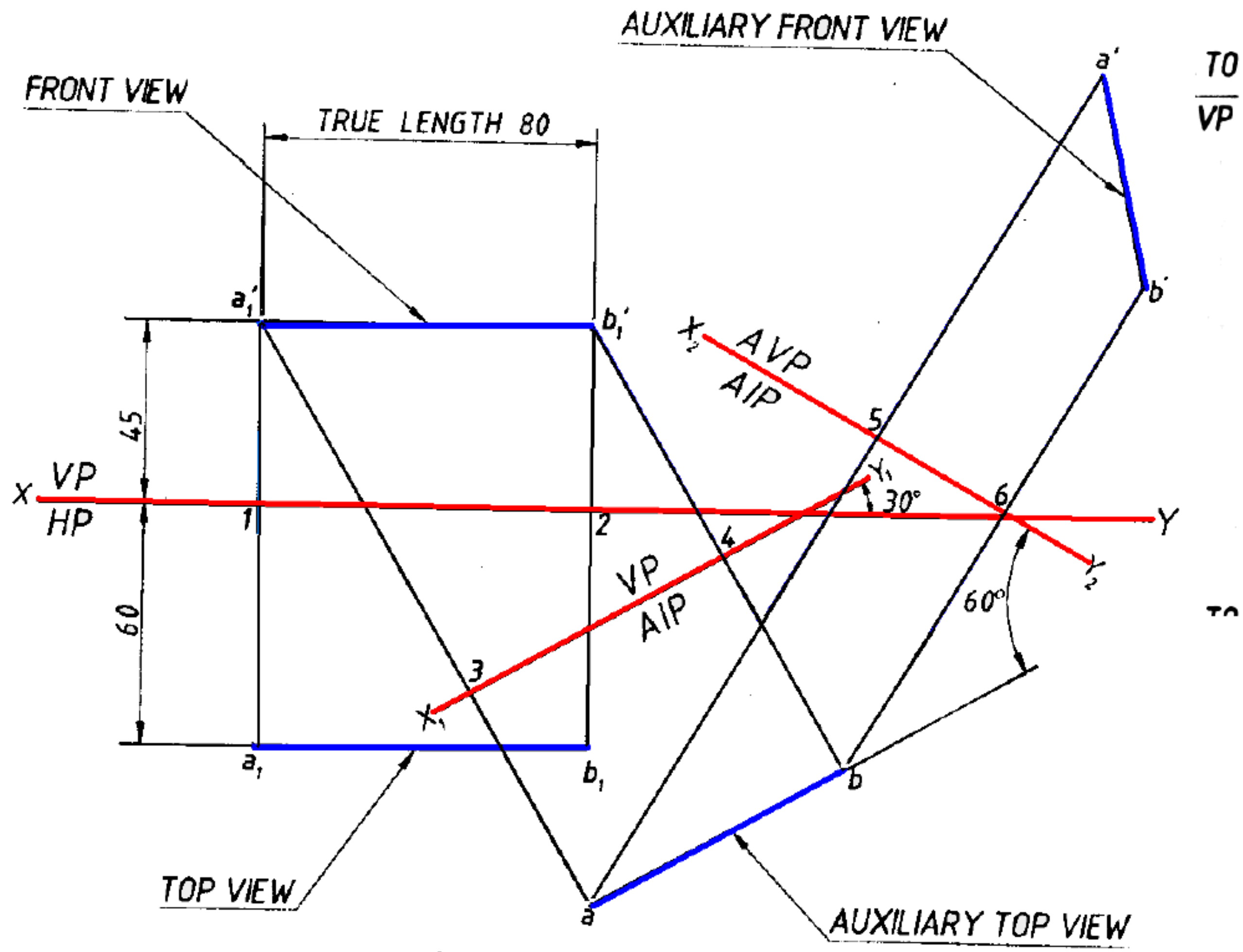
Draw the projections of a line **80 mm** long inclined at **30^0** to **HP** and its top view appears to be inclined at **60^0** to **VP**. One of the ends of the line is **45** mm above **HP** and **60** mm infront of **VP**. Draw its projections by auxiliary plane method

Solution

Draw the top and front views of one of the ends, say A, 45 mm above HP and 60 mm infront of VP.

Assume that the line is parallel to both HP and VP and draw its top and front views.

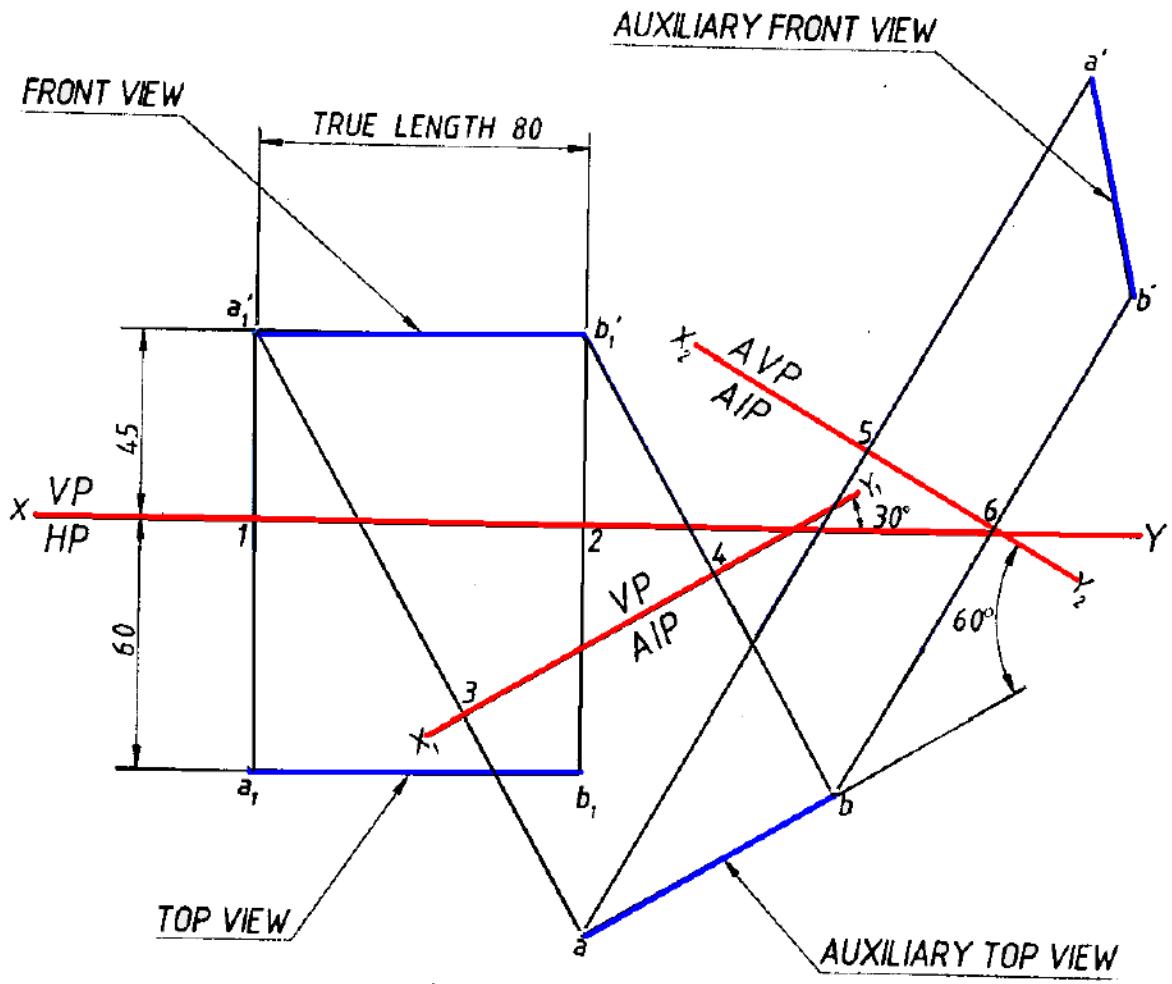
Since the line is to be inclined at 30^0 to HP, set up an AIP inclined at 30^0 to HP and perpendicular to VP.



Draw X_1Y_1 line inclined at 30^0 to **XY** line at any convenient distance from it.

To project an auxiliary top view on AIP, draw projections from **a_1'** and **b_1'** perpendicular to X_1Y_1 line, and on them step off **$1a_1=3a$** and **$2b_1=4b$** from the X_1Y_1 line.

Connect **ab** which will be the auxiliary top view.



Since the top view of the line appears inclined to VP at 60^0, draw the X_2Y_2 line inclined at 60^0 to the auxiliary top view **ab** at any convenient distance from it. Draw the projections from **a** and **b** perpendicular to X_2Y_2 and on them step off **5a' = 3a_1'** and **6b'=4b_1'**. Connect **a'b'** which will be the auxiliary front view.

Problem 2:

A line AB 60 mm long has one of its extremities 60 mm infront of VP and 45 mm above HP. The line is inclined at 30^0 to HP and 45^0 to VP. Draw the projections of the line by the auxiliary plane method.

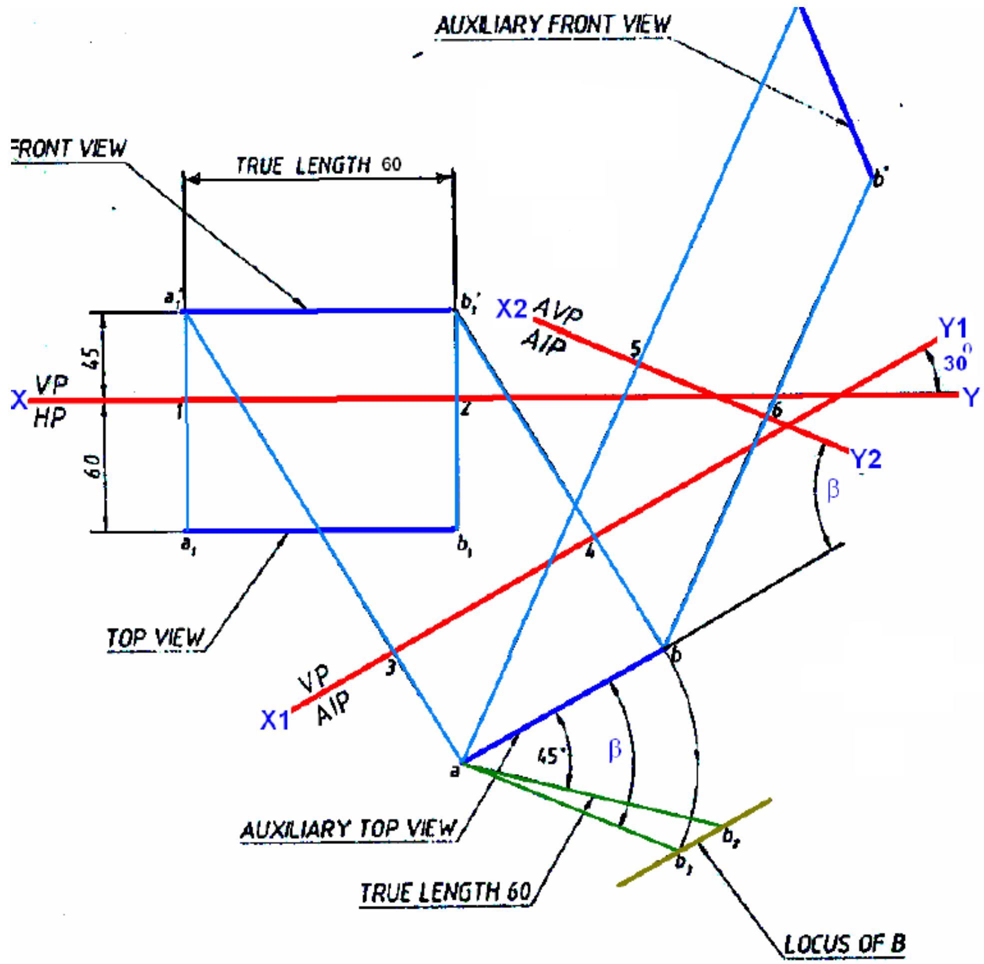
Solution

Let A be one of the extremities of the line AB at distance 60 mm infront of VP and 45 mm above HP.

Mark a_1 and a_1' the top and the front views of the extremity A.

Initially the line is assumed to be parallel to HP and VP.

a_1b_1 and a_1'b_1' are the projections of the line in this position.

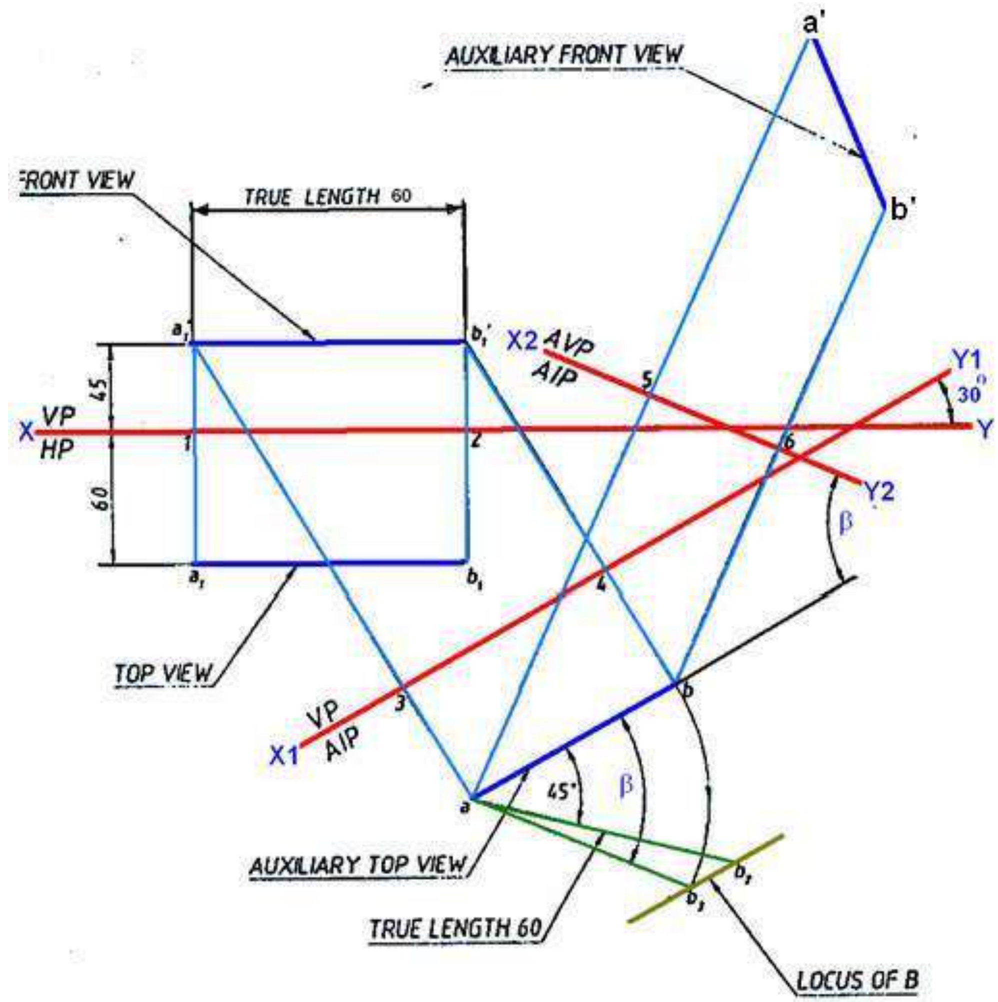


Then instead of rotating the line so as to make it inclined to both the planes, an AIP is set up at an angle θ, which the line is supposed to make with HP and the auxiliary top view is projected on it.

To draw the Auxiliary Top View on AIP

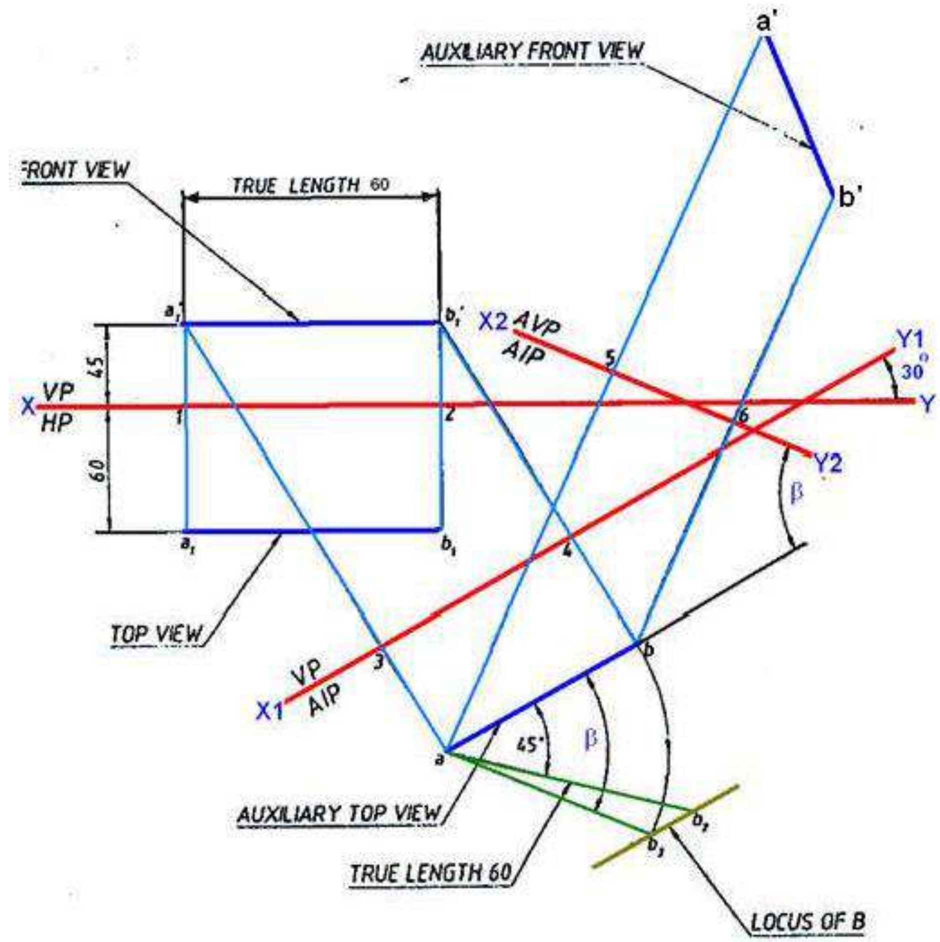
Draw X_1Y_1 line inclined at $\theta = 30^0$ to the XY line. Mark AIP and VP. Project the auxiliary top view ab The projections ab on the AIP and $a_1'b_1'$ on VP are the auxiliary view and the front view of the line when it is inclined at θ to HP and parallel to VP.

Since the line is inclined at true inclination ϕ to VP, to project the auxiliary front view an AVP inclined at ϕ to VP should be setup.



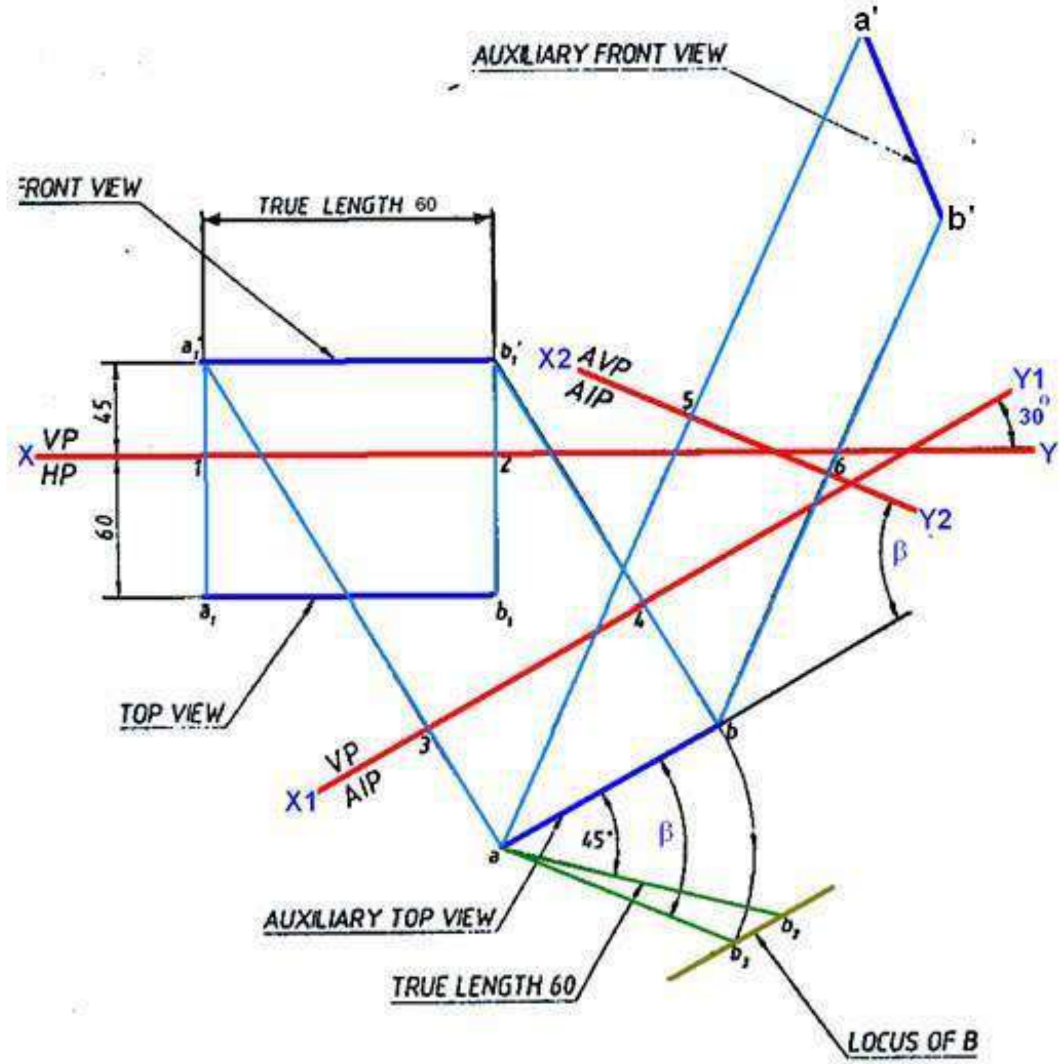
To draw the Auxiliary F.V. on AVP

Already the line is inclined at θ to *AIP* and parallel to VP. If the line is to be inclined at ϕ to VP, *an* AVP inclined at ϕ to the given line should be setup. But we know that *when* a line is inclined to both the planes, they will not be inclined at true inclinations to the *XY* line, instead they will be at apparent inclinations with the XY line. Therefore X_2Y_2, the line of intersection of *AIP and* AVP cannot be drawn directly at ϕ to *ab.*



The apparent inclination β *of ab* with the X_2Y_2 line should be found out. To find β, through a draw ab_2 equal to 60 mm, the true length of AB inclined at ϕ = 45^0 to *ab.*

Through ***b*₂**, draw the locus of ***B*** parallel to X_1Y_1 line. With center ***a*** and ***radius ab*** strike an arc to intersect the locus of ***B at b*₃**. Connect ***ab*₃** and measure its inclination β with ***ab.*** Now draw the ***X*₂*Y*₂** line inclined at ***β to ab****. Mark AVP and AIP on either side of* ***X*₂*Y*₂**. Project the auxiliary front view **a'b'.** **ab** and ***a'b'*** are the required projections.



Shortest distance between two lines

Two lines may be ***parallel***, *or* ***intersecting***, *or* ***non-parallel*** *and* ***non-intersecting***.

When the lines are intersecting, the point of intersection lies on both the lines and hence these lines have no shortest distance between them.

Non-parallel and non-intersecting lines are called ***Skew Lines***.

The parallel lines and the skew lines have a *shortest distance between them*.

The shortest distance between the two lines is the shortest perpendicular drawn between the two lines.

Shortest distance between two parallel lines

The shortest distance between two parallel lines is equal to the length of the perpendicular drawn between them.

If its true length is to be measured, then the two given parallel lines should be shown in their point views.

If the point views of the lines are required, then first they have to be shown in their true lengths in one of the orthographic views.

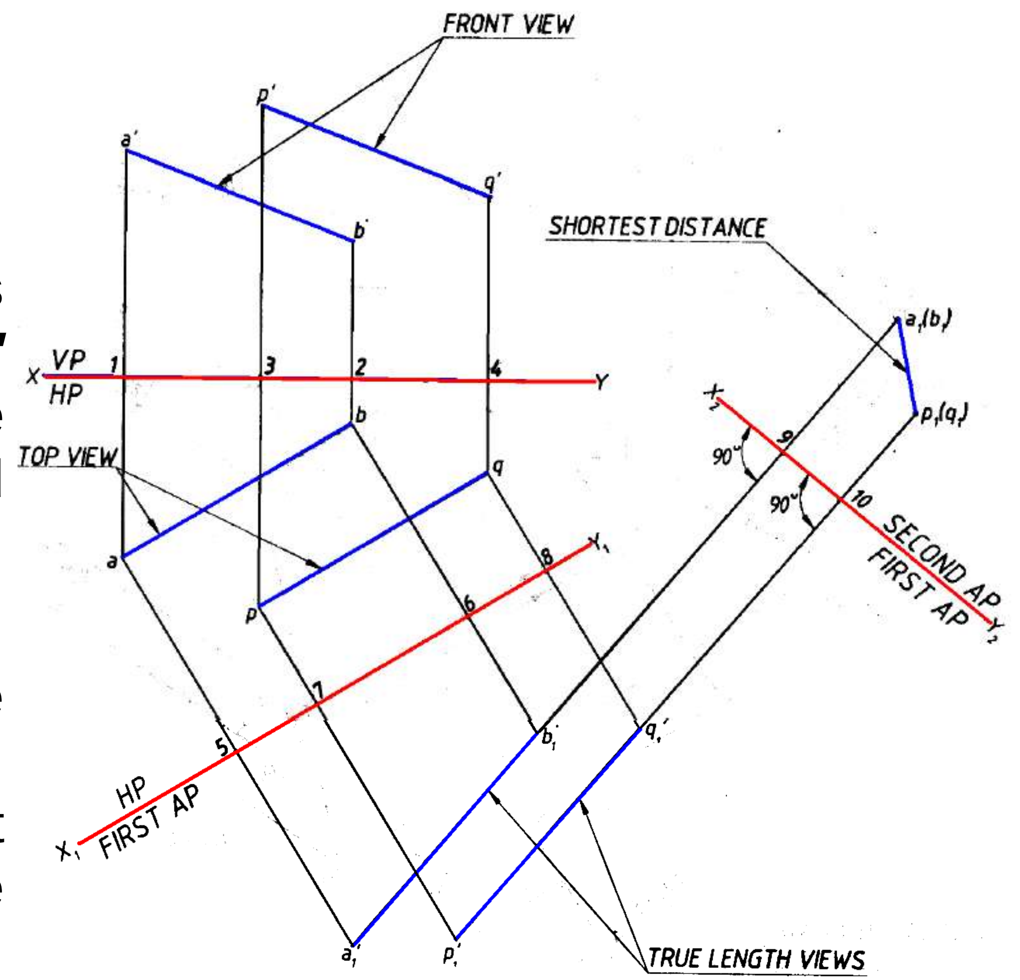
If none of the orthographic views show the given lines in their true lengths, an auxiliary plane parallel to the two given lines should be set up to project them in their true lengths on it.

Even the auxiliary view which shows the lines in their true lengths may not show the perpendicular distance between them in true length. Hence another auxiliary plane perpendicular to the two given lines should be set up. Then the lines appear as points on this auxiliary plane and the distance between these point views will be the shortest distance between them.

Shortest distance between two parallel lines

Projections of a pair of parallel lines **AB** and **PQ** are shown. ***ab** and **a'b'*** are the top and front views of the line ***AB**. **pq** and **p'q'*** are the top and front views of the line **PQ**.

Since the top and front views of the lines are inclined to the **XY** line, neither the top view nor the front view show the lines in their true lengths.



To show these lines in their true lengths, an auxiliary plane, parallel to the two given lines, should be set up parallel to the projections of the lines either in the top view or front view.

In this case the auxiliary plane is set up so as to be parallel to the two given lines in top view

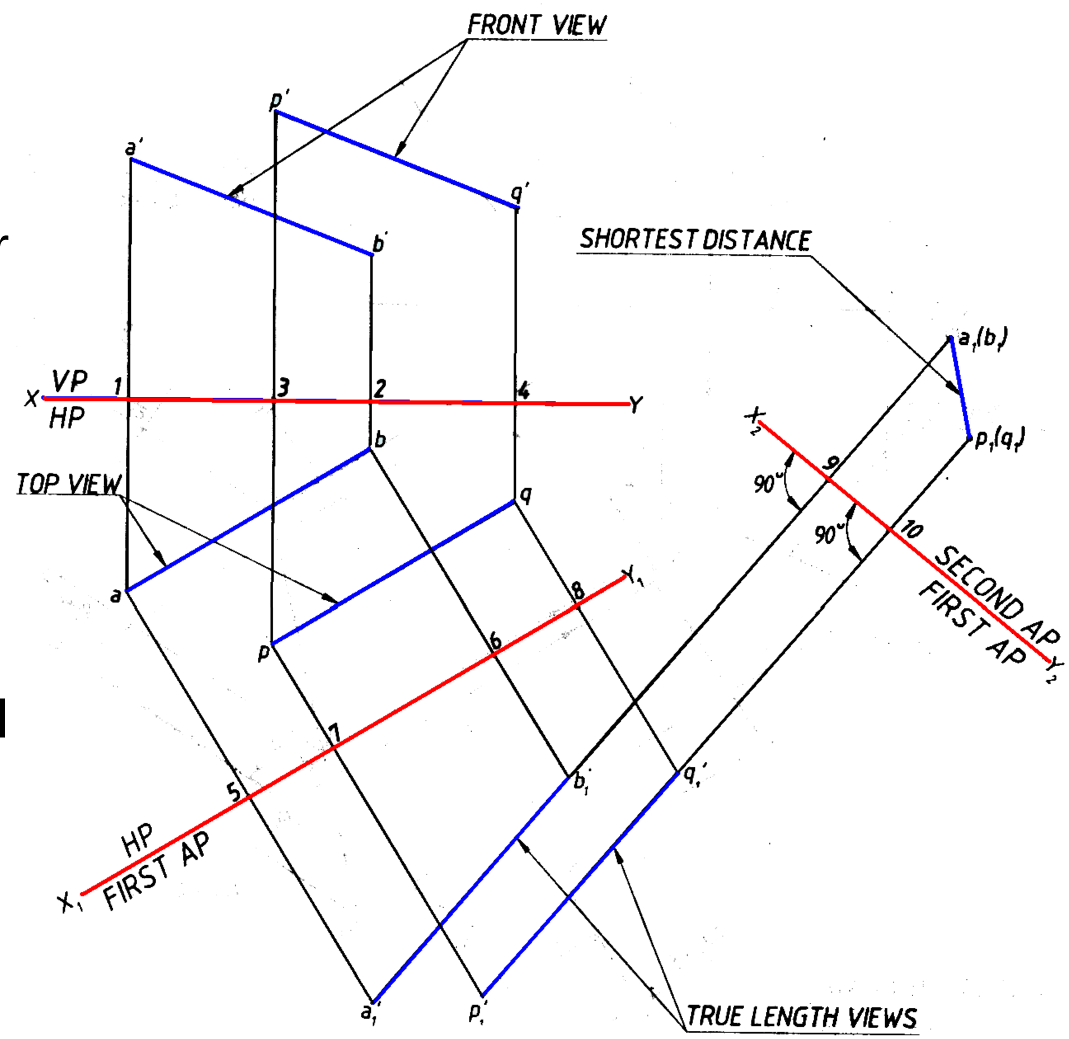
Draw the $\mathbf{X_1Y_1}$ line parallel to **ab** and **pq** at any convenient distance from them.

Through the points **a, b, p** and **q,** draw projector lines perpendicular to $\mathbf{X_1Y_1}$ line.

Measure $\mathbf{5a_1'=1a_1'}$ along the projector drawn through a from the $\mathbf{X_1Y_1}$ line, and $\mathbf{6b_1'=2b'}$ along the projector drawn through **b** from the $\mathbf{X_1Y_1}$ line.

Connect $\mathbf{a_1'b_1'}$ which will be equal to the true length of the line **AB**.

Similarly by measuring $\mathbf{7p_1' = 3p'}$ *and* $\mathbf{8q_1' = 4q'}$ obtain $\mathbf{p_1'q_1'}$ the true length view of the line **PQ**.



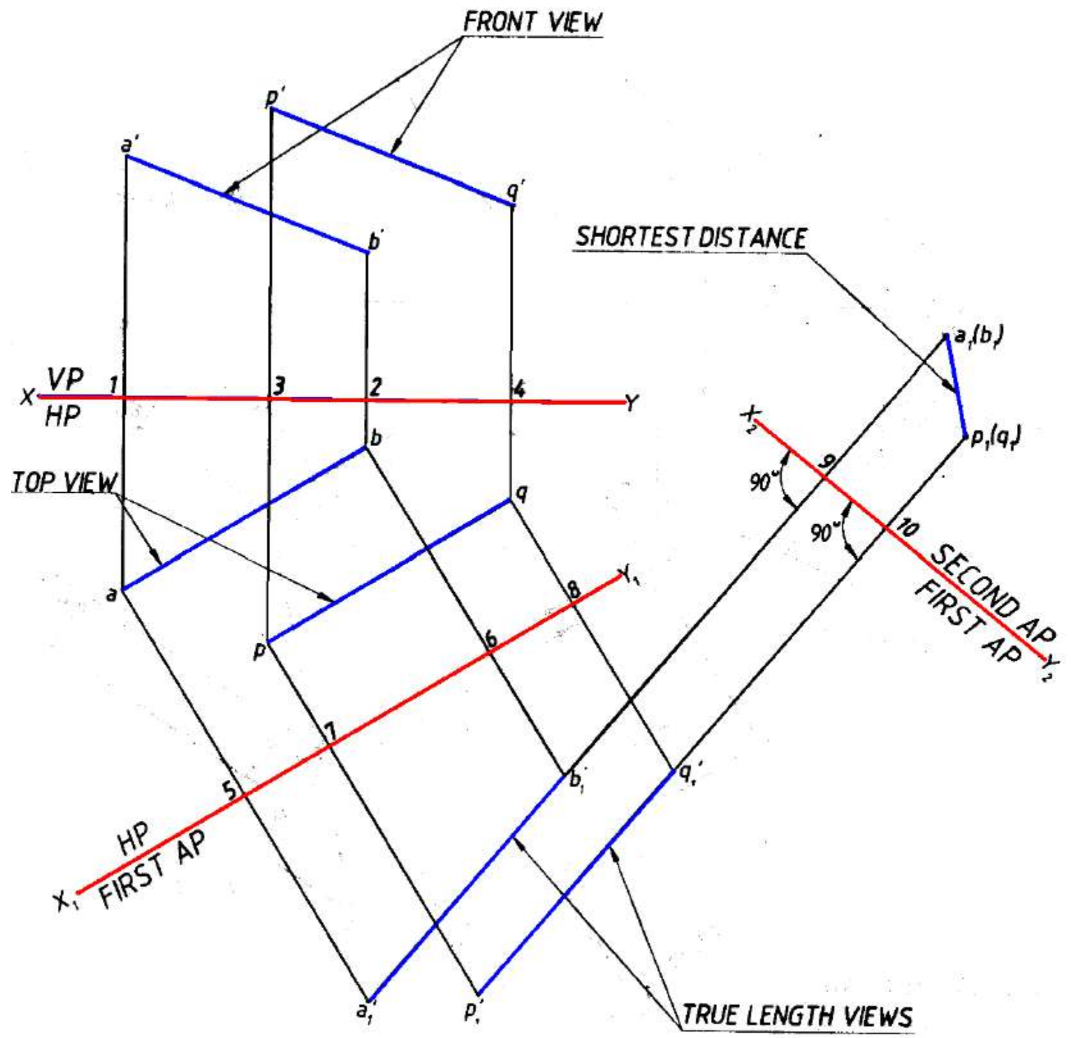
The line **AB** and **PQ** are shown in their true lengths, and now an another auxiliary plane perpendicular to the two given lines should be set up to project their point views on it.

Draw the line **X_2Y_2** perpendicular to ***a_1'*b$_1$'** and **p_1'q_1'** at any convenient distance from them.

Produce ***a_1'b_1'*** *and* **p_1'q_1'**.

Measure **a5 = *b6* = *9a_1*** along **a_1'b_1'** produced from **X_2Y_2**. Similarly obtain the point,view **p1(q1)** by measuring **p1(10)=*p7* = q8.**

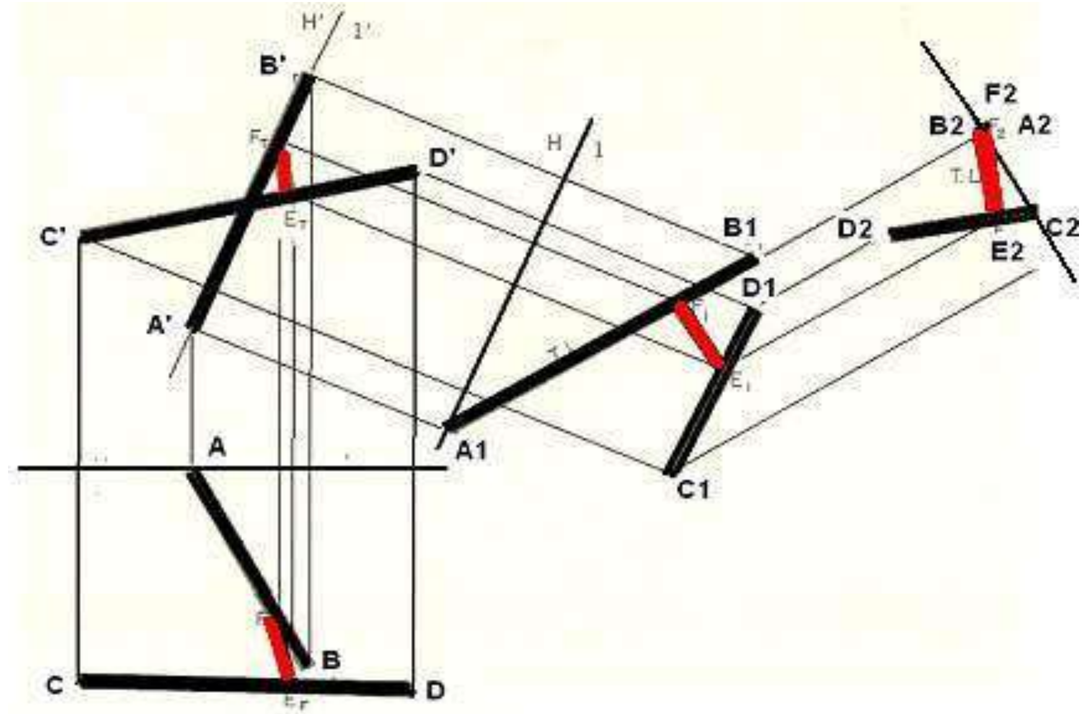
Connect ***p1a1*** the required shortest distance between the lines **AB** and **PQ** in its true length



Shortest distance between two skew lines

Projections of two skew lines AB and CD are shown as A'B', C'D' and AB and CD.

Determine the shortest distance EF between the line segments



First an Auxiliary A_1B_1 is made showing the true length of AB.
A second auxiliary view showing the point view of AB is projected.
For this draw the reference line normal to A_1B_1 and draw the projectors C_2 D_2 (of C_1 and D_1).
The shortest distance F_2E_2 can be established perpendicular to CD.
To project FE back to the Front and Top Views, FE is first projected in first auxiliary plane by first projecting point E, which is on CD, from the second to the first auxiliary view and then back to the front and top views.

THANK YOU