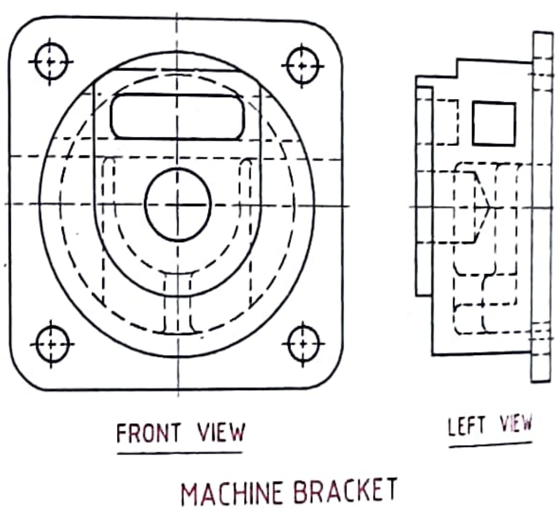
4

Development of

Lateral Surfaces of Solids

5.1 Sectioning

On the orthographic views, viz., front, top and profile views, the visible edges and faces are indicated by *continous lines*, while its interior hollow portions and invisible rear outer edges of the faces are indicated by *dashed lines*. If the interior of an object is of complex shape, there will be a network of mass of dashed lines on the orthorgaphic views as shown in *Fig.5.1*. Such a network of criss-crossing dashed lines render difficulty while reading the orthographic views; consequently the precise interpretation of the actual shape of the interior of the object will be seldom possible. In such cases, the object is *imagined* as cut into two parts by *planes* and this imaginary process of cutting separate them so as to expose its interior. This imaginary process of cutting the object is called *sectioning*. The imaginary plane which cuts the object is called the *cutting plane* or *section plane*. After the object is cut, the portion of the object that lies between the section plane and the observer is assumed as removed and the view of the remaining portion of the object (generally called the retained portion) is projected on any one of the principal planes of projection. This view which reveals the interior of the object along with its cut surfaces is called *sectional view*. Any one of the orthographic views, viz., top, front and profile views may be shown in section.

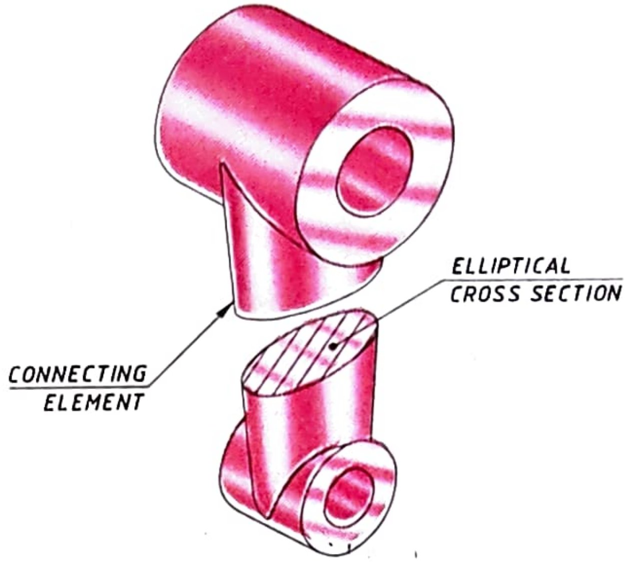


Network of Dashed Lines
Fig. 5.1

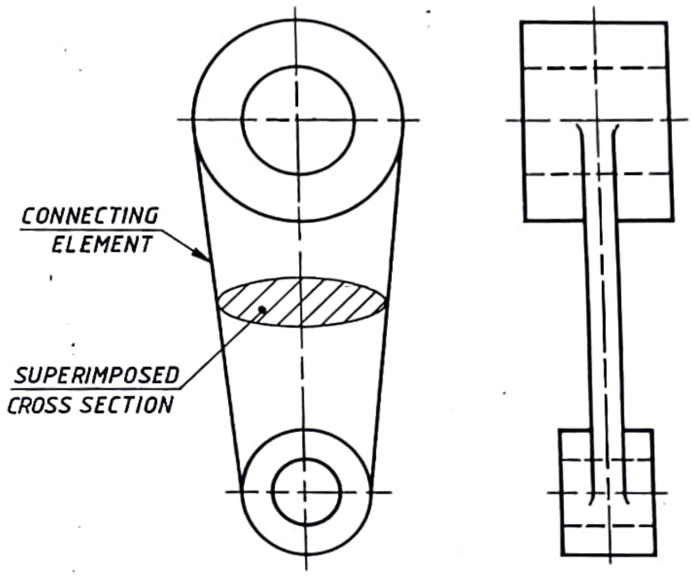
Since the sectioning is an imaginary process, only the sectional view is projected for the retained cut portion of the object however, the *other views are projected for the whole, i.e., uncut, object*. A sectional view shows the cut surfaces and all the invisible interior surfaces of the uncut object as visible.

Further in some cases, even the actual shape of the exterior surfaces of the object is not revealed in the orthorgaphic views in true form, as these exterior surfaces are rounded, a consequent lack of definite edges on the exterior of the object as shown in *Fig. 5.2.(ii)*. For example, the elliptical shape of the connecting element of the link shown in *Fig. 5.2.(i)* is not revealed in either of the orthographic views as shown in *Fig 5.2.B(ii)*. In such cases, the objects are sectioned across the portions whose true shape of the exterior surface is not revealed in the orthoraphic views. Since the object is cut across, the section is called *cross section* which is superimposed on one of the orthographic views as shown in figure.

The sectional views are drawn not only for the individual parts, but also for the assemblies of the machines to locate the relative positions of the various constituting parts forming the assembly. Such a sectional view will serve as a guide in assembling the parts of the machine itself.



(i)



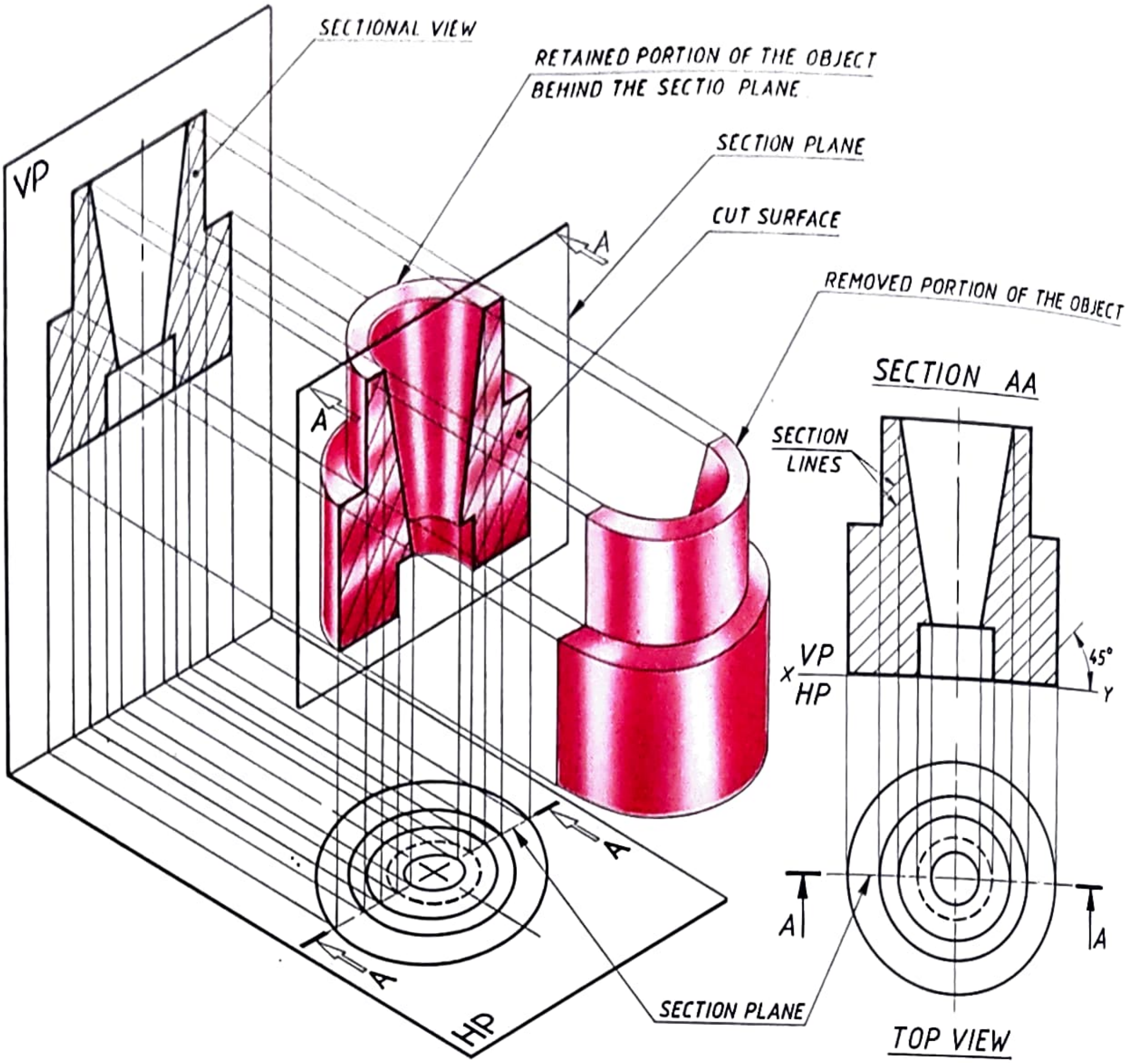
(ii)

Cross Section
Fig. 5.2

5.2 Projection of Sectional View

A sectional view of an object is obtained by projecting the retained portion of the cut object, which is left behind when the object is cut by an imaginary section plane and the portion of the object between the section plane and the observer is assumed as removed.

Fig. 5.3(i) shows the projection of the sectional front view of an object. The object is cut by a section plane *AA*. The front half of the object between the section plane and the observer is removed. The view of the retained portion of the object is projected on *VP*. *Fig. 5.3 (ii)* shows the sectional front view and the top view. The top view is projected for the whole (uncut) object.

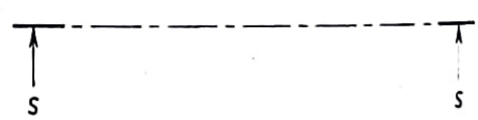


(i) (ii)

Projection of a Sectional View
Fig. 5.3

5.3 Representation of Section Plane

A section plane is conventionally represented by *a chain line thickened at the ends and thin elsewhere* with the direction of view normal to the section plane by arrows resting on the thick ends and designated by the capital letters as shown in *Fig. 5.4.*



Representation of Section Plane
Fig. 5.4

5.4 Section Lines and Hatching

A sectional view of an object comprises of both the sectioned and unsectioned surfaces. To differentiate between the sectioned and unsectioned surfaces on the sectional views, a series of thin inclined lines, called *section lines*, parallel to themselves and inclined at 45° to the horizontal, or to the main axis of the object, are drawn within the region of the cut surface as shown in *Fig. 5.3 (ii).*

This process of executing parallel section lines is called *hatching*. The spacing between the section lines has to be chosen in proportion to the area of section. In general, it would be appropriate to adopt wider spacing for large areas and closer spacing for the narrower ones. Generally an approximate spacing of about 2 mm between the section lines is recommended.

5.5 Types of Section Planes

A section plane cutting an object is indicated on the orthographic views as a *line*. A section plane if it is to be projected as a line on any one of the orthographic views, obviously it should be *perpendicular* to the principal plane of projection on which the orthographic view of the object is projected. For example, when the section plane is perpendicular to *HP*, the line representing the section plane cuts the top view of the object, or, when the section plane is perpendicular to *VP*, the line representing the section plane cuts the front view of the object, or, when the section plane is perpendicular to both *HP* and *VP*, the section plane will be represented as lines in both the top and front views. The section planes when they are *perpendicular* to one of the principal planes of projection they may be held so as to be either, *parallel* or *inclined* to the other plane of projection.

The four main types of the section planes are :

i) *Perpendicular to VP and either parallel or inclined to HP.*

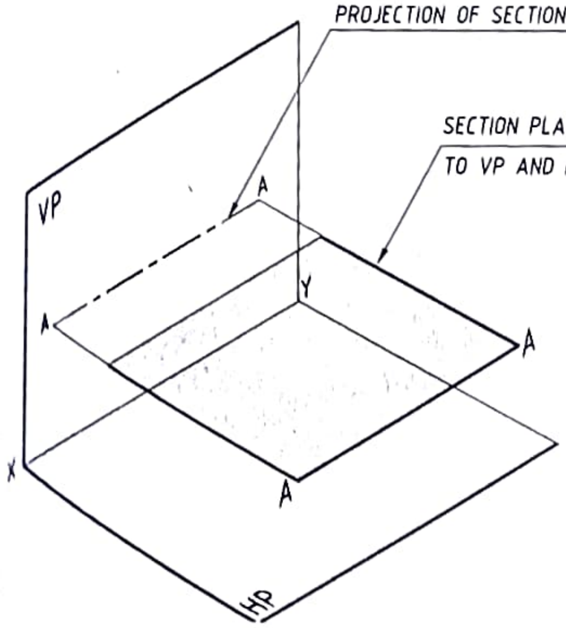
ii) *Perpendicular to HP and either parallel or inclined to VP.*

iii) *Perpendicular to both HP and VP.*

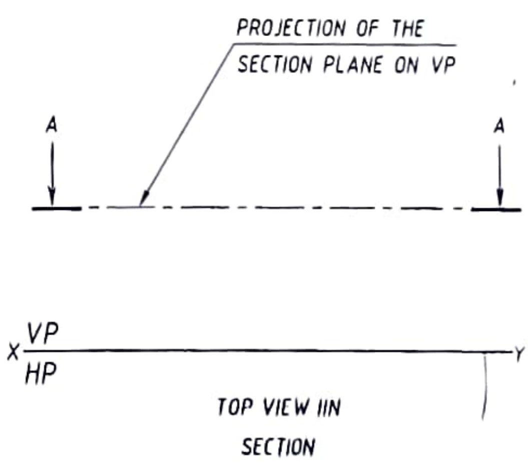
iv) *Inclined to all the three principal planes viz., VP, HP and PP.*

1. Section Plane Perpendicular to VP and Parallel to HP

When a section plane is taken perpendicular to *VP* and parallel to *HP* as shown pictorially in *Fig. 5.5. (i)*, its projection on *VP* will be a *line*. The line representing the section plane will be drawn parallel to the *XY* line as shown in the front view in *Fig. 5.5. (ii)*. When the object is cut by a section plane perpendicular to *VP*, the *top view will be in section.*



(i)
Pictorial View

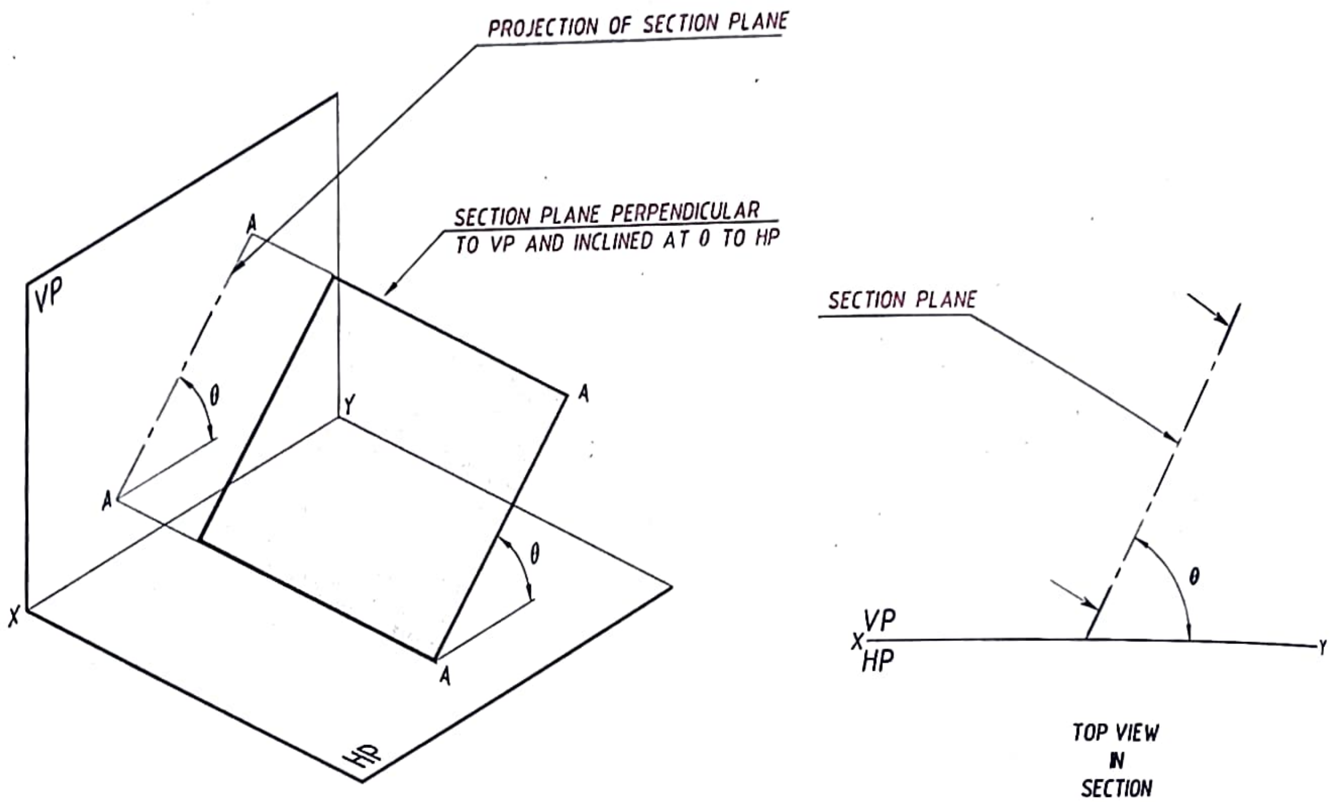


(ii)
Orthographic View

Section Plane Perpendicular to VP & Parallel to HP
Fig. 5.5

2. Section Plane Perpendicular to VP and Inclined to HP

When a section plane is taken perpendicular to *VP* and inclined at θ to *HP* as shown pictorially in *Fig. 5.6(i)*, its projection on *VP* will be a *line* inclined at θ to the *XY* line. Since the section plane is perpendicular to *VP* and inclined to *HP*, the section plane will be shown as line in the front view inclined at θ to the *XY* line and the *top view will be in section* as shown in *Fig. 5.6.(ii)*. The section plane will also be inclined to the profile plane. The profile view, which will also be in section is drawn only when specified in the problems.



(i) Pictorial View

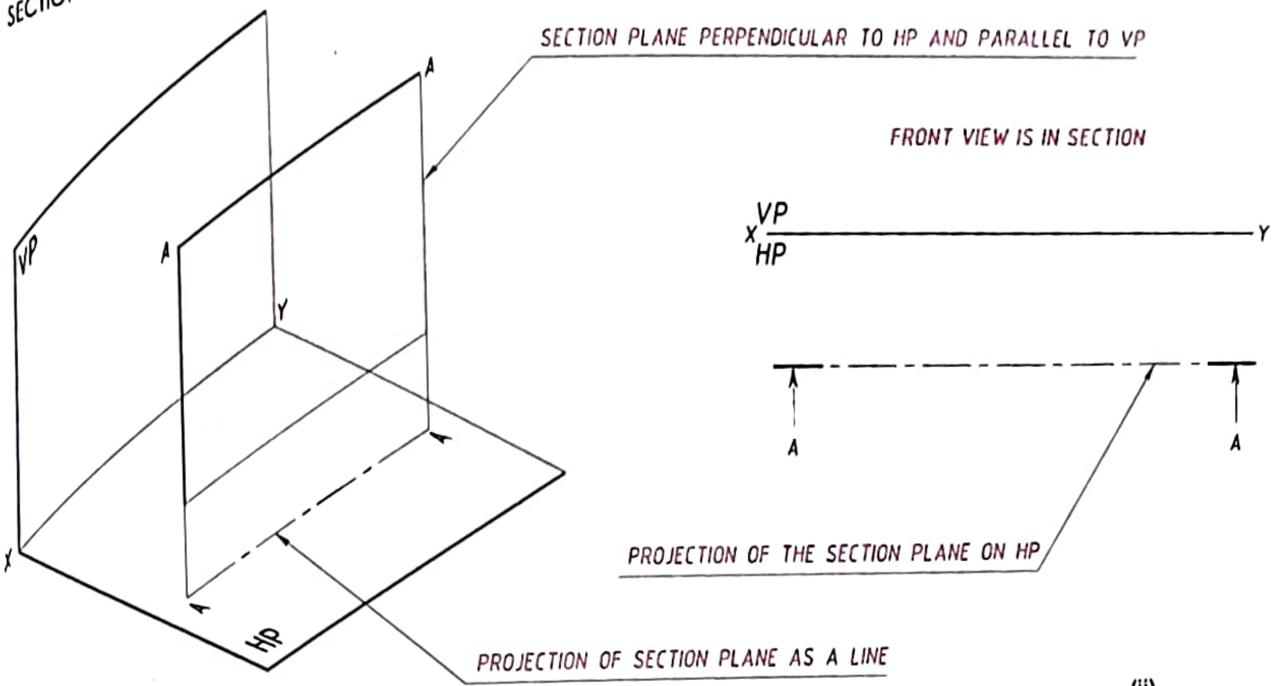
(ii) Orthographic View

Section Plane Perpendicular to VP & Inclined to HP

Fig. 5.6

3. Section Plane Perpendicular to HP and Parallel to VP

When a section plane is taken perpendicular to *HP* and parallel to *VP* as shown pictorially in *Fig. 5.7(i)*, its projection on *HP* will be a *line* parallel to the *XY* line. Since the section plane is parallel to *VP* the line representing the projection of the section plane on *HP* will be parallel to the *XY* line as shown in *Fig. 5.7(ii)*. When the object is cut by a section plane perpendicular to *HP*, the *front view will be in section*.



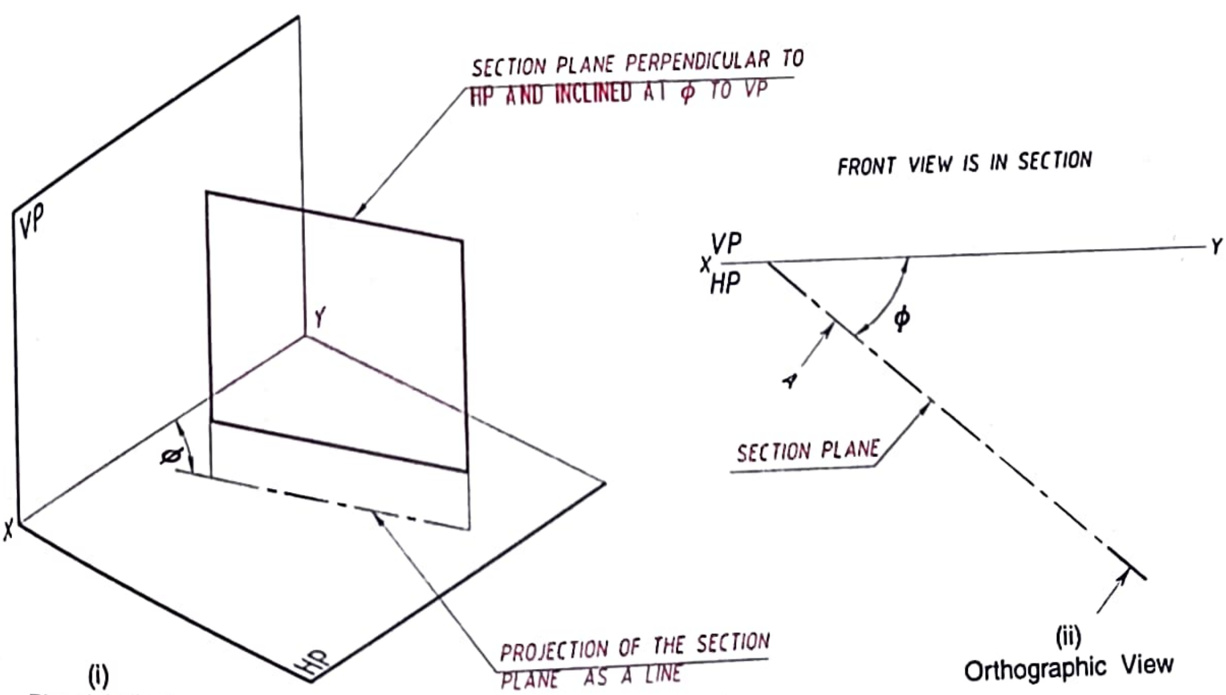
(i)
Pictorial View

(ii)
Orthographic View

Section Plane Perpendicular to HP and Parallel VP
Fig. 5.7

4. Section Plane Perpendicular to HP and Inclined to VP

When a section plane is taken perpendicular to *HP* and inclined ϕ at to *VP* as shown pictorially in *Fig. 5.8(i)*, its projection on *HP* will be a *line* inclined at ϕ to the *XY* line and inclined to *VP*, the *front view* will be in section. The section plane is also inclined to the profile plane. The profile view, which will also be in section, is drawn only when specified in the problem.



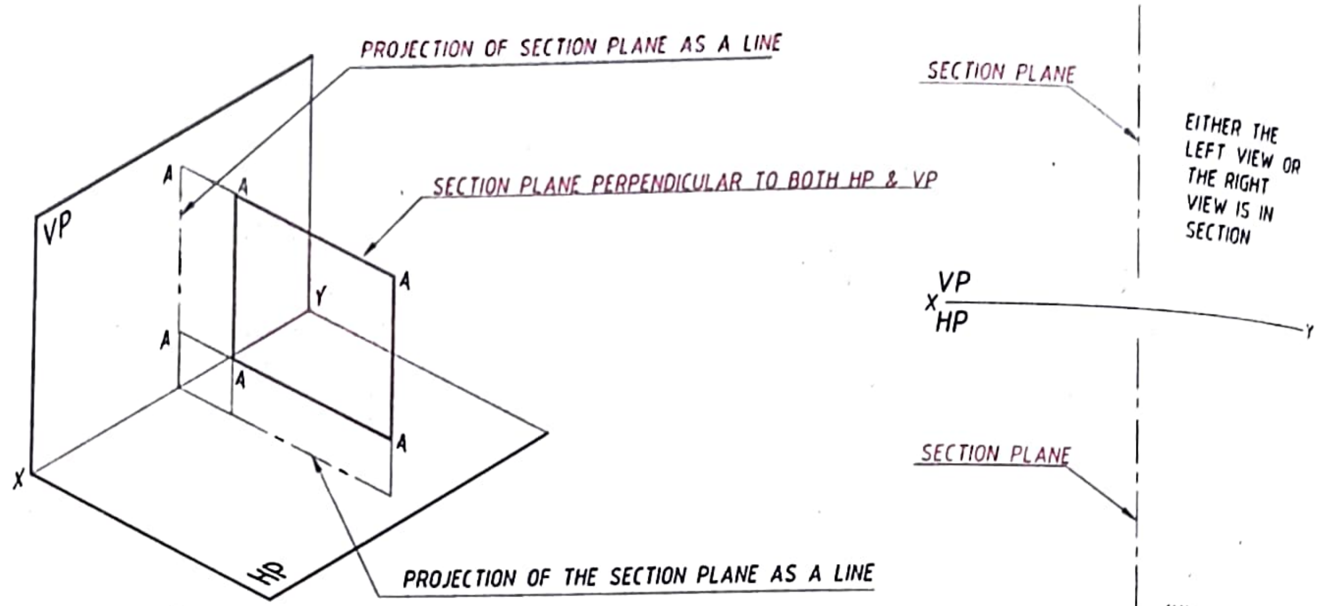
(i)
Pictorial View

(ii)
Orthographic View

Section Plane Perpendicular to HP and Inclined to VP
Fig. 5.8

5. Section Plane Perpendicular to both HP and VP

When a section plane is taken perpendicular to *both HP* and *VP* as shown pictorially in *Fig. 5.9(i)*, its projection on both *HP* and *VP* will be *lines*. When the object is cut by a section plane which is perpendicular to both *HP* and *VP*, either the *left view* or the *right view will be in section.*



(i) Pictorial View

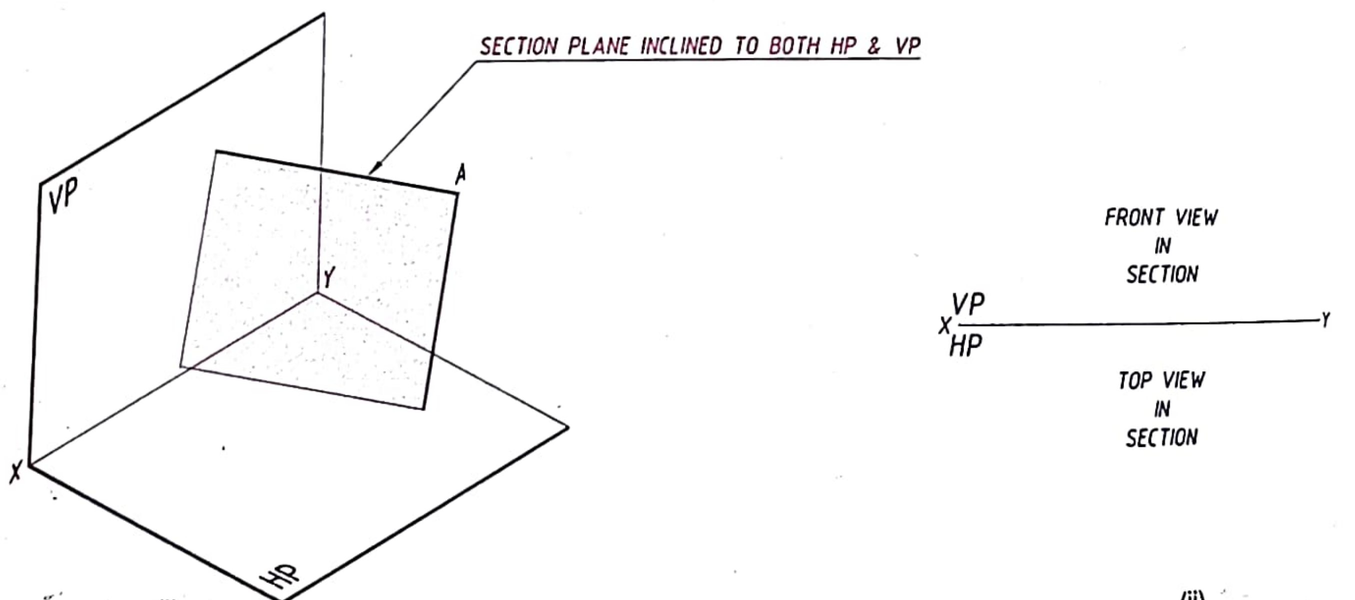
(ii) Orthographic View

Section Plane Perpendicular to both HP and VP

Fig. 5.9

6. Section Planes Inclined to both HP and VP

When a section plane is taken inclined to both *HP* and *VP* as shown pictorially in *Fig.5.10(i)*, the section plane cannot be indicated as lines in both the top and front views. Both the top and *front views are shown in section.*



(i) Pictorial View

(ii) Orthographic View

Section Plane Inclined to both HP and VP

Fig. 5.10

5.6 Procedure to draw the Sectional View

To draw the sectional view of an object, the following step-by-step procedure may be followed.

Step-by-Step Procedure :

1. Top, Front and Profile Views

Draw the top and front views of the object in the given position. If the profile view has to be shown in section, add the profile view also.

2. Section Plane

Draw the section plane as a line in the view in which it projects as a line as explained in Art.5.5. Indicate the portion of the object between the section plane and the observer which is assumed as removed by *thin lines* and the retained portion of the object by *thick lines. Although it is convention to show even the removed portion of the object by thick lines, to clearly distinguish between the removed portion and the retained portion, they are shown by thin lines in the problems.*

3. Section Points

The section points are located at the places at which the section plane intersects the different edges and faces of the object. When the section plane intersects the line representing the edge of the object, at the place of intersection there will be only *one section point.* If the section plane intersects a line representing two coinciding edges, or a face, or the base, then at the place of intersection there will be *two section points,* one on the visible edge and the other on the invisible edge. The section points thus located have to be numbered in the serial order with the visible points marked first and the invisible points marked afterwards in the cyclic order.

4. Projection of Section Points

The section points thus obtained as explained in the previous step are projected to the other corresponding view to obtain the corresponding section points on the respective edges. These section points obtained on the other views are connected in the serial order to obtain a closed figure. This closed figure represents the *cut surface.* The cut surfaces are hatched as explained in *Art* 5.4. The retained portion of the object are shown by dark lines. The view which reveals the cut surfaces of the object is the required sectional view.

5.7 True Shape of Section

When a section plane is parallel to one of the principal planes of projection, the sectional view projected on the principal plane to which the sectional plane is held parallel, will show the cut surface in its *true shape.* For example, when the section plane is held parallel to *VP,* the sectional front view will show the true shape of the cut surface. Similarly when the section plane is parallel to *HP,* the sectional top view will show the true shape of the cut surface. When a sectional plane is parallel to a profile plane, the sectional profile view will show the true shape of the cut surface. But when a section plane is *inclined* to any one of the principal planes projection, the secional view will *not* show the cut surface in true shape. In such cases, the true shape of section is obtained by projecting the cut surface on an auxiliary plane setup parallel to the given inclined section plane. If a section plane is inclined to *HP,* an auxiliary inclined plane *(AIP)* is setup parallel to the given inclined section plane. If a section plane is inclined to *VP,* an auxiliary vertical plane *(AVP)* is setup parallel to the given inclined section plane.

5.8 Procedure to draw the True Shape of Section

To draw the true shape of section the following step-by-step procedure may be followed.

Step-by-Step Procedure

1. Sectional View

Project the top and front views showing one of them in section as explained in *Art. 5.6, Page 8.*

2. Auxiliary Plane

Setup an auxiliary plane parallel to the given section plane at any convenient distance from it, i.e., draw X_1Y_1 line parallel to the line representing the section plane at any convenient distance from it.

3. Projection of True Shape

Draw the projector lines perpendicular to the line representing the section plane at all the section points in the view in which the section plane is projected as a line. On these projecor lines, measure off the distances of each of the section points from X_1Y_1 line equal to their corresponding distances from the *XY* line in the view in which the cut surface appears in its apparent shape. Connect these section points in the auxiliary view and the enclosed area is hatched.

DEVELOPMENT OF LATERAL SURFACES OF SOLIDS

5.9 Pattern and Sheet Metal Work

Many industries like, automobile, aircraft, ship building, packaging, etc., and some of the general engineering jobs such as, piping and ducting works in air-conditioning and ventilating systems, fabrication of funnels, bins, hoppers, storage tanks, chimneys, boilers, etc., involve sheet metal fabrication. To make a sheet metal object, first the sheet has to be cut to a particular shape which is formed by laying all of its lateral surfaces one adjacent to the other on it, and then after bending, forming folding appropriately, is finally joined by soldering or welding or riveting or using adhesives. The *form* of the sheet obtained *by laying all the outer surfaces of the object together provided with suitable allowances for seams and joints* is called *pattern*. The pattern of an object (to be fabricated) either is drawn on a paper and then transferred on to a metal sheet, or is laid directly on a metal sheet itself. All other processes, viz., cutting, bending, forming, folding and joining involved in the fabrication of a sheet metal object is called *sheet metal work.*

5.10 Pattern Drafting and Development

Drawing a pattern for the fabrication of a sheet metal object using basic geometry and principles of engineering drawing is called *pattern drafting.* The technique employed to know the shape of the pattern for a given object is, to *unfold all the outer surfaces of the object so as to lie on a plane.* This process of unfolding all the surfaces of the object is called *developing* an object and the *plane figure* formed by developing an object is called *development*. When suitable allowances are provided for the seams and the joints on a development, it becomes a *pattern.* Since the knowledge of the shape of the development of prisms, pyramids, cylinders, cones spheres etc., will be useful in laying the patterns of various types of sheet metal objects, the principle of developing these geometrical solids by different methods are dealt here.

5.11 Methods of Development

The four different methods of developments are : *(i) Parallel line development*, *(ii) Radial line development*, *(iii) Triangulation development* and *(iv) Approximate development*.

The *parallel line method* of development is used to develop the surfaces of *cubes, prisms, cylinders and objects of such related surfaces*. The *radial line method* of development is used to develop the surfaces of *pyramids, cones and objects of such related surfaces*. The *triangulation method* of development is used to develop the surfaces of *transition pieces*. The *approximate method* of development is used to develop the surfaces of objects of *double curved or warped surfaces such as sphere, paraboloid, ellipsoid*, etc. The triangulation and approximate methods of development are out of purview of this book and hence not dealt here.

5.12 Development of Cut Objects

When the development of only a portion of an object is required, then the development of the whole object is drawn first and then the development pertaining to the removed portion of the object is cutout from the development of the whole object.

Cut Solids

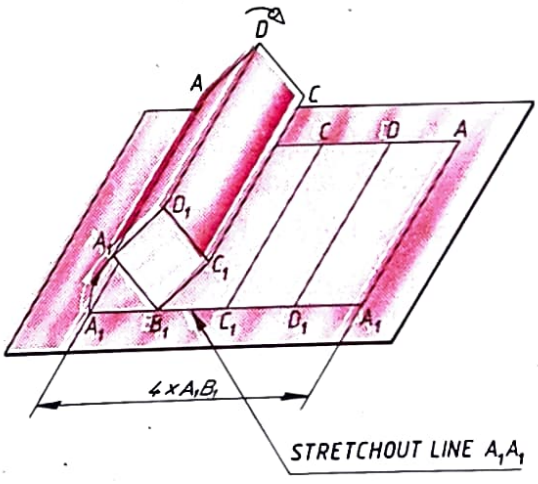
When the solids like prisms, pyramids, cones and cylinders are cut such that their *cut surfaces are inclined to the axis*, the cut portion of the solids having the base are called *truncated solids — truncated prism, truncated pyramid, truncated cylinder, and truncated cone*. When the same set of solids are cut such that the *cut surfaces are perpendicular to their axes*, the cut portion of the solids having the base, are called *frustum of solids*. In the development, the portions pertaining to the removed portions are shown in *thin lines* and the remaining which will be retained are shown by *thick lines*.

5.13 Parallel Line Development

In this method of development, the object is rolled on its lateral surfaces along a straight path, called *stretch-out line*, over a plane surface. When the object rolls over a plane surface, each of the lateral edges or generators and faces will come in contact with the plane surface, as the object rolls over it. The area of the plane surface actually covered by the object when it rolls by *one complete revolution* will be equal to the total area of all the lateral surfaces of the whole object, and will be the *development* of the object itself. The length of the stretch-out line will be equal to the *girth* or *perimeter* of the object. The surfaces of the cubes, prisms, cylinders and such other related surfaces will be developed by this method.

5.14 Development of Prisms

Fig. 5.11 shows the rolling of a *square prism* over a plane surface. When the prism rolls by one complete rotation, the total area covered by it will be equal to its development. The area covered will be equal to *four times the area of a rectangular face* of the prism. Therefore the *development of the prism* is obtained by laying *a number of rectangles one adjacent to the other, equal to the number of sides of the prism*. The sides of these rectangles in the development will be equal to the *length of sides of the base of the prism and other side will be equal to height of the prism*.

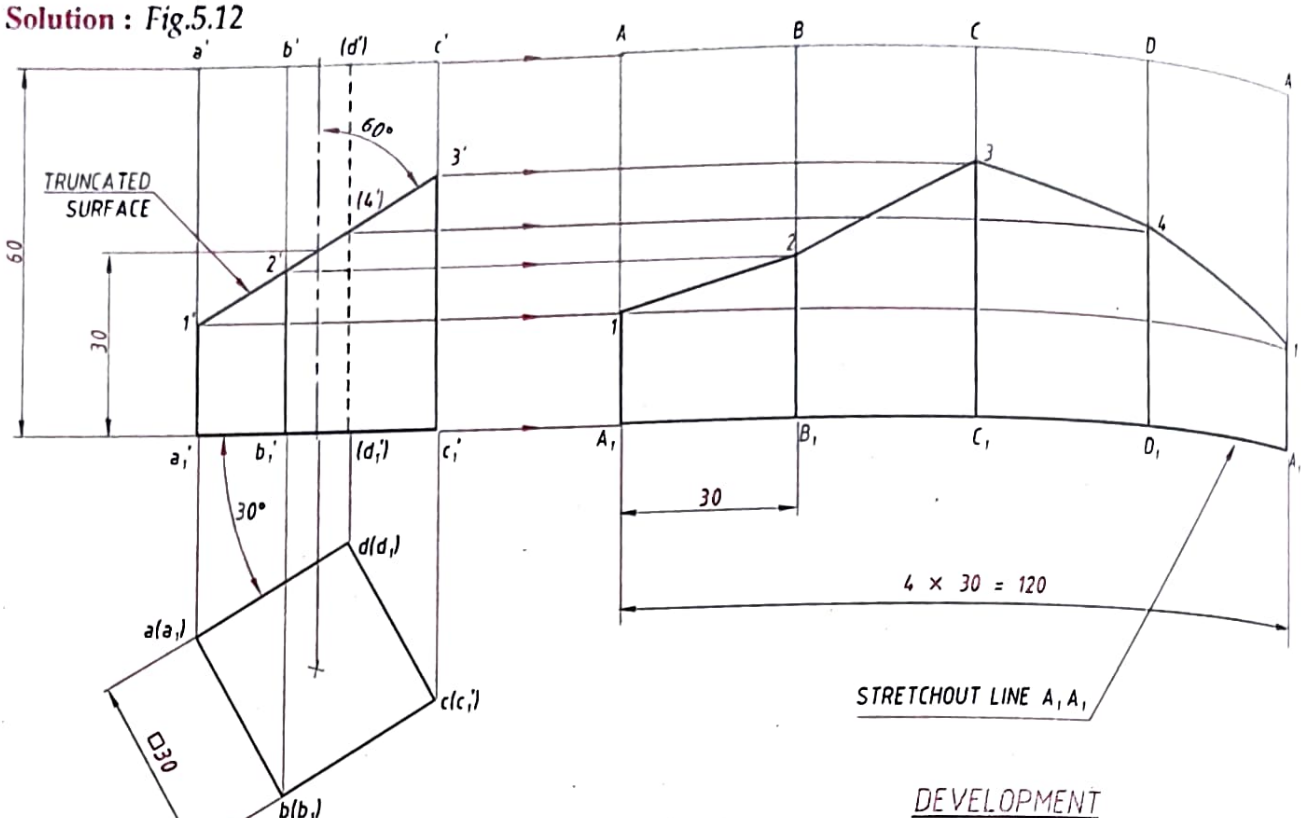


Development of a Prism
Fig. 5.11

Problem 1

Develop the lateral surfaces of the truncated portion of a vertical square prism 30 mm sides and 60 mm high placed with one of its front rectangular faces inclined at angle of 30° from A to B at an angle of 30° to VP. The truncated surface is at 60° to the axis of the prism at its mid-height.

Solution : *Fig.5.12*



All dimensions in mm

Fig. 5.12

Draw the top and front views of the prism in the given position. In the front view draw the truncated surface passing through the axis at the mid height of the prism and inclined at 60° to its axis. The truncated surface cuts the vertical edges $a'a_1'$ at $1'$, $b'b_1'$ at $2'$, $c'c_1'$ at $3'$, and $d'd_1'$ at $4'$. The length of the stretch-out line A_1A_1 is equal to *four times the sides of square abcd*. On A_1A_1 step off successively B_1, C_1, D_1 of length equal to the side of the square *abcd*. Draw A_1A, B_1B, C_1C, D_1D and A_1A perpendicular to A_1A_1 to represent the vertical edges of the prism. Now project the points $1'$, $2'$, $3'$, and $4'$ in the front view to the corresponding edges in the development to get points 1, 2, 3 and 4 respectively, and connect these points. The area $A_112341A_1$, is the development of the lower portion of the lateral surfaces of the truncated prism.

Solid Edge V18

Solid Edge Procedure :

I Draw the Top and Front Views of the prism

Step 1: Invoke the Line Command and draw a horizontal line of length 350 mm. Exit the Line Command.

Step 2: Click on any convenient point to represent the point $a(a_1)$ of the top view. In the Ribbon bar, enter 30 mm in the length option and a value of 30° in the angle option. This completes the line ad. In the Ribbon bar, enter 30 mm in the length option and drag the cursor down to the right in such a

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Solid Edge V18

way that you get a ⊾ (Pependicular) symbol. Click to complete the line dc. In the Ribbon bar, enter 30 mm in the length option and drag the cursor down to the left in such a way that you get a Pependicular symbol ⊾. Click to complete the line *cb*. Drag and click on point a to complete the line ba or ab.

Step 3: We have to now find the center of the prism in the top view. Without ending the line sequence draw a line starting from the point $a(a_1)$ and click on point $c(c_1)$ to complete the diagonal line *ac*. Right click to exit the line sequence. Click on point $b(b_1)$, drag and click on point $d(d_1)$ to complete the diagonal line *bd*. Exit the Line Command. Invoke the Point Command and click on the intersection of the diagonal lines to create the point $o(o_1)$. Exit the Point command. Delete the diagonal lines.

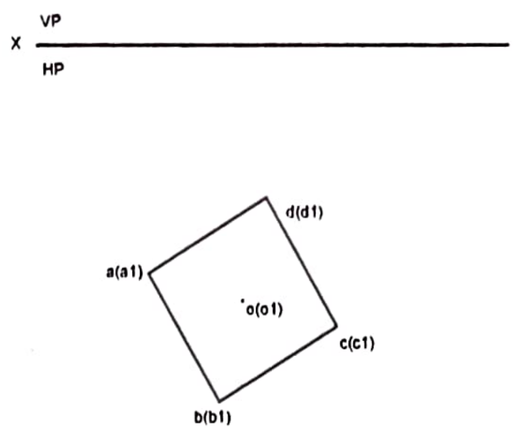

Fig. 5.13

Step 4: Invoke the Text Command and create the text objects $a(a_1)$, $b(b_1)$, $c(c_1)$, $d(d_1)$ and $o(o_1)$. Exit the Text command. This completes the Top View as shown in *Fig. 5.13*

Step 5: Invoke the Line Command and click on the point $a(a_1)$ of the top view and drag the cursor vertically upwards to meet the *XY* line at point a_1'. Right click to exit the line sequence. Similarly draw vertical projector lines from points $b(b_1)$, $c(c_1)$, $d(d_1)$, and $o(o_1)$ to meet the *XY* line at points b_1', c_1', d_1', and o_1'. Right click to exit the line sequence. Click on the point a_1' and drag the cursor to the right to meet at point c_1'. From this point, drag the cursor vertically upwards and in the Ribbon bar, enter 60 mm in the length option which is equal to the length of the full prism. This completes the line $c_1'c'$. From the point c', drag the cursor to the left to a point a' which is in vertical alignment with the point a_1' (Keep the Alignment indicator ON). Click to complete the line $c'a'$. From the point a', drag the cursor vertically downwards to meet the *XY* line at point a_1'. Right click to exit the line sequence. Click on the point b_1' and drag the cursor vertically upwards to meet the line $a'c'$ at point b'. Similarly draw the lines $o_1'o'$ and $d_1'd'$. Right click to exit the line sequence. Click on the midpoint of the line $o'o_1'$. In the length option of the Ribbon bar, enter a suitable length above 40 mm and in the angle option, enter 30°. Exit the Line Command.

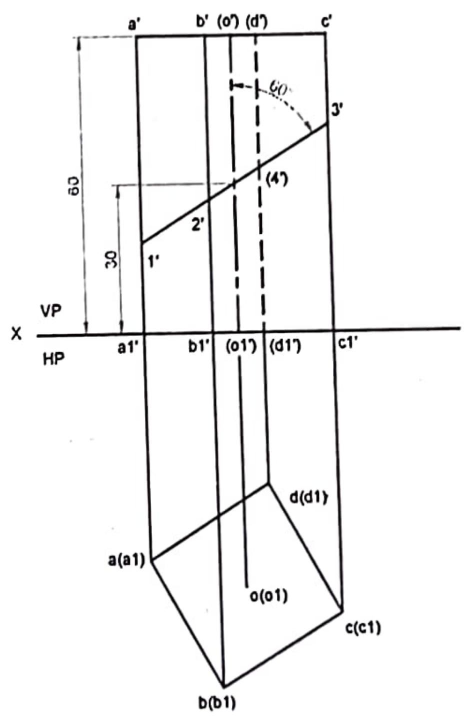

Fig. 5.14

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Solid Edge V18

Step 6: Invoke the Extend to Next Command and go on clicking on the inclined line just drawn till it gets extended to the point *1'*. Exit the Extend to Next Command. Invoke the Trim command and click on the extra portion of the inclined line as shown in *Fig 5.14* to trim this portion. Exit the Trim Command. Click on the line $o'o_1'$ and change its linetype to center linetype. Click on the line *d'd1'* and change its linetype to dashed linetype.

Invoke the Text Command and create the text objects $a_1', b_1', c_1', (d_1'), (o_1'), a', b', c', (d'), (o')$, $1', 2', 3'$ *and* $(4')$. Exit the Text command. This completes the Front View as shown in *Fig. 5.14.*

II Draw the Development drawing

Step 7: Invoke the Line Command and click on any point on the *XY* line to the right of the front view just drawn. From this point, drag the cursor vertically upwards and in the Ribbon bar, enter 60 mm in the length option which is equal to the length of the full prism. This completes the line A_1A. Exit the Line Command.

Step 8: Invoke the Offset Command and click on the line A_1A to select it. In the distance option enter a value of 30 mm. Click on the Accept button. Click to the right of the line A_1A to create line B_1B. Similarly create line C_1C to the right of the line B_1B and create the line D_1D to the right of the line C_1C. Finally create the line A_1A to the right of the line D_1D. Exit the Offset Command. Invoke the Line Command and click on the point A and project it horizontally to the right to the end point A as shown in the *Fig 5.15.*

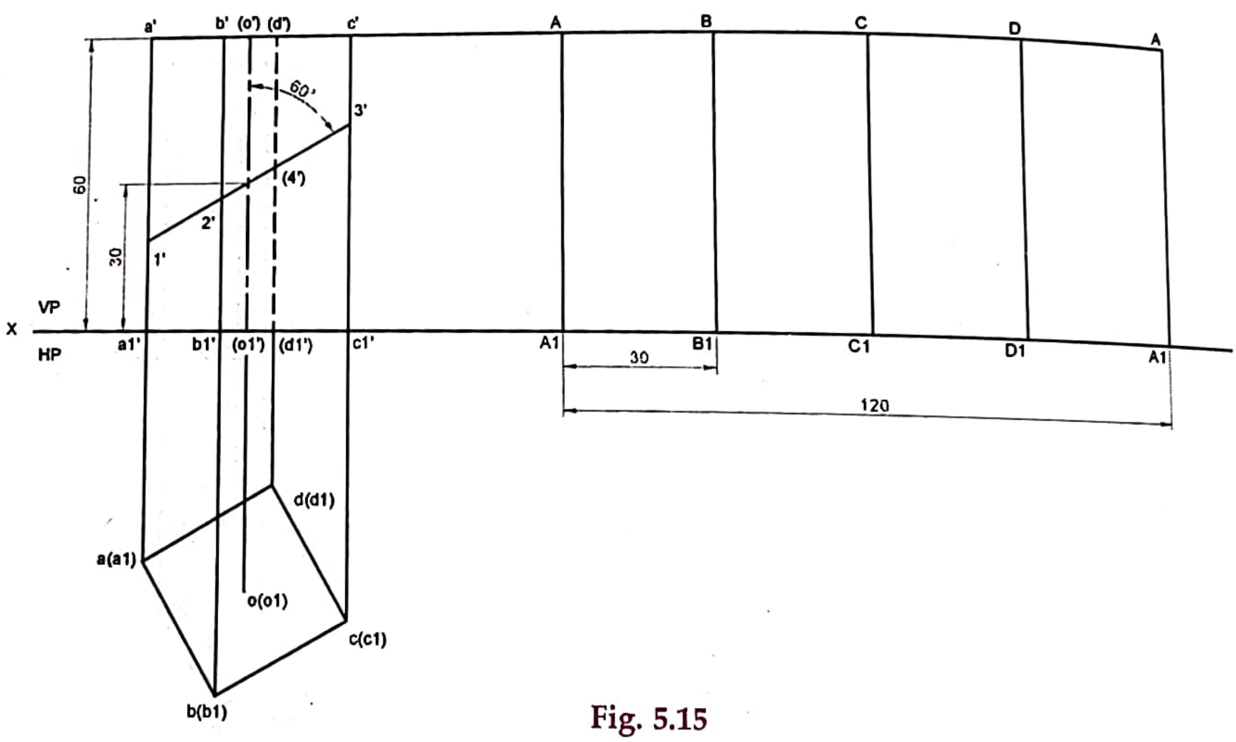


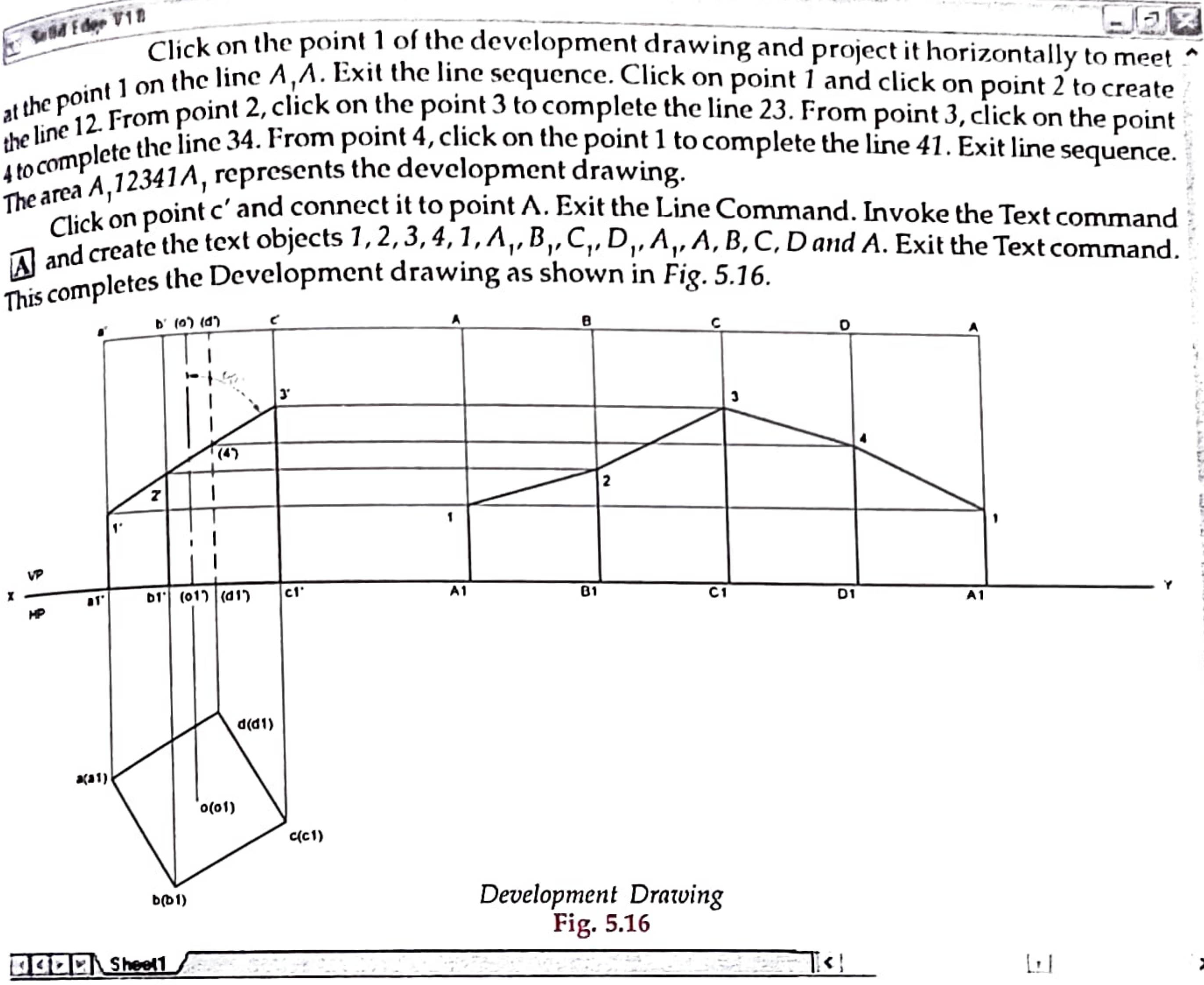
Fig. 5.15

Step 9: Click on the point 1' of the front view and project it horizontally to meet at the point 1 on the line *A1A* in the development drawing. Exit the line sequence. Click on the points 2', 3' and (4') of the front view and project it horizontally to meet at the points 2, 3 and 4 on the lines B_1B, C_1C and D_1D in the development drawing. Exit the Line sequence.

Sheet1

Click on the point 1 of the development drawing and project it horizontally to meet at the point 1 on the line A_1A. Exit the line sequence. Click on point 1 and click on point 2 to create the line 12. From point 2, click on the point 3 to complete the line 23. From point 3, click on the point 4 to complete the line 34. From point 4, click on the point 1 to complete the line 41. Exit line sequence. The area $A_112341A_1$ represents the development drawing.

Click on point c′ and connect it to point A. Exit the Line Command. Invoke the Text command and create the text objects $1, 2, 3, 4, 1, A_1, B_1, C_1, D_1, A_1, A, B, C, D$ and A. Exit the Text command. This completes the Development drawing as shown in *Fig. 5.16*.



Development Drawing

Fig. 5.16

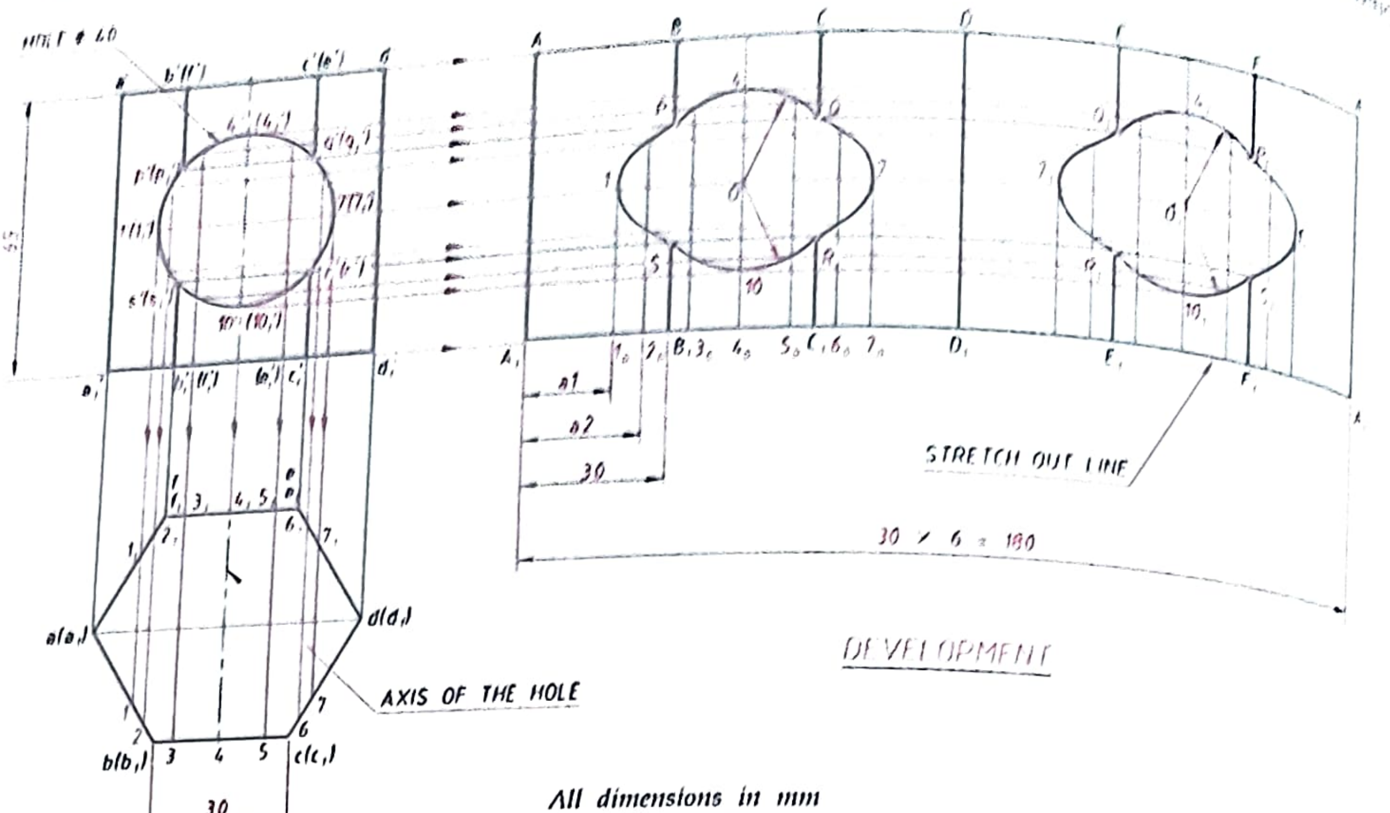
Problem 2

A vertical hexagonal prism of 30 mm side of base and axis 65 mm long has one of its rectangular faces parallel to VP and nearer to it. A circular through hole of 40 mm diameter is drilled through the prism completely such that the axis of the hole bisects the axis of the prism at right angles and is perpendicular to VP. Draw the development of the prism showing the shape of the hole on it.

Solution : *Fig. 5.17*

Draw the top and front views, and the development of the hexagonal prism as shown in figure. When a through hole is drilled in the prism, actually *two holes* are produced on the lateral faces of the prism. One of the holes lies on the *front three rectangular faces* and the other will lie on the *rear three rectangular faces*. In this case, one of the holes will lie on the front rectangular faces $ABB_1A_1 - BCC_1B_1 - CDD_1C_1$ and the other hole lies on the rectangular faces $AFF_1A_1 - FEE_1F_1 - EDD_1E_1$.

To obtain the actual shape of the holes in the development, the circle representing the hole in the front view is divided into twelve equal parts. The division points are named as $1', 2', 3'$, etc., on the front hole and $1_1', 2_1', 3_1'$, etc., on the rear hole. Project these division points to the top view.



All dimensions in mm
Fig. 5.17

Measure off distances $a1 = A1_D$, $a2 = A2_D$ etc., on the stretch-out line AA_1 in the development. Draw the verticals through 1_D, 2_D, etc. Draw the horizontals from $1'$, $2'$, etc., to cut the verticals drawn through 1_D, 2_D, etc, at 1, 2, etc., on the development. Project the critical points p', q', r' and s' to the respective lateral edges on the development. Since the portions of the hole on the rectangular faces BCC_1B_1 and FEE_1F_1 are arcs of circles, with O and O_1 as centres, draw arcs P-4-Q and S-10-R. A similar curve is obtained on the rear rectangular faces $AFF_1A_1 - FEE_1F_1 - EDD_1E_1$ as shown in the development.

Solid Edge V18

Solid Edge Procedure :

I Create the XY line

Step 1 : Invoke the Line Command and draw a horizontal Line from left to right of length 400 mm. Exit the Line Command.

II To draw the Top View

Step 2 : Invoke the Line Command and click a point below the XY line at a convenient distance. In the length option fo the Ribbon bar, enter a value of 30 mm. Click to complete the line *bc*. Now, drag the cursor to the right upwards. In the Ribbonbar, enter the value of length to be 30 mm in the length option and angle as 60°. Click to complete the line *cd*. In the Ribbon bar, enter the value of length to be 30 mm in the léngth option and angle as 120°. Click to complete the line *de*. Now, in the Ribbon bar, enter a value of 30 mm in the length option and the angle as 180°. Click to complete the line *ef*. In the Ribbon bar, enter 30 mm in length option and angle as -120°. Click to complete the line *fa*. Now drag the cursor and join point *b* to complete the line ab and also the hexagon. Right click to exit line sequence.

Sheet1

Solid Edge V18

Step 3: Now, we have to find the center of the hexagon. For this, click on the point *f* and drag to join point *c*. This creates the line fc. Right click to exit the line sequence. Click on the point *e*, drag and click on the point *b*. This completes the line eb. Right click to exit the line sequence. Click on the midpoint of the line ef and drag down to meet at the midpoint of the line bc. This represents the axis of the circular hole. Exit the line command. Click on the line just drawn and change its linetype to the center linetype.

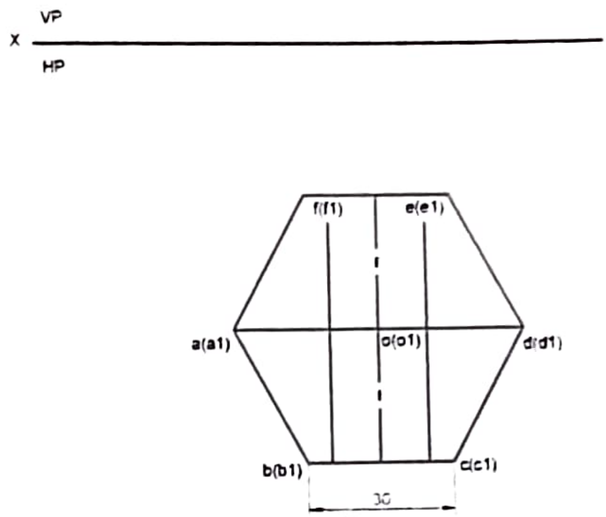


Fig. 5.18

Step 4: Invoke the Point Command and click on the intersection of the just drawn lines *fc* and *eb*. This creates the point object $o(o_1)$ which represents the axis of the hexagonal prism under consideration. Exit the point command. Delete the lines *fc* and *eb*.

Step 5: Invoke the Text Command A and create the text objects $a(a_1),b(b_1),c(c_1),d(d_1),e(e_1),f(f_1)$ and $o(o_1)$. Exit the Text Command. You have now completed the top view as shown in the *Fig. 5.18*

III To Draw the Front View

Step 6: Invoke the Line Command and click on the point $a(a_1)$ of the just drawn top view. Project it upwards to meet the XY line at point a_1'. Click to complete the projector line aa_1'. Right click to exit the line sequence. Similarly, draw projector lines from the points $o(o_1)$, $b(b_1)$,$c(c_1)$ and $d(d_1)$ to meet the XY line at points (o_1'), $b_1'(f_1')$, $c_1'(e_1')$ and d_1' respectively. Right click to exit the line sequence.

Step 7: Click on the point d_1' and drag horizontally to the left to point a_1'. Click on a_1' to complete the line $d_1'a_1'$. Project the line vertically upwards from point a_1' to a point a' (with the value of 65 mm entered in the length option of the Ribbon bar). This completes the line $a_1'a$.

Step 8: From the point a', draw a horizontal line to the right upto a point d' with is in horizontal alignment with the point d_1' (keeping the Alignment Indicator ON). Click to complete the line $a'd'$. From point d', draw a line progressing vertically downwards to meet the XY line at the point d_1'. Right click to exit the line sequence.

Step 9: Now, click on the point $b_1'(f_1')$ and project it upwards vertically to join the line $a'd'$ at $b'(f')$. Click to complete the line $b_1'b'$. Right click to exit the line sequence. Similarly, create the lines $o_1'o$ and $c_1'c'$. Exit the Line Command. Click on the line $o_1'o'$ and change its line type to center line type.

Step 10: Invoke the Text Command A and create the text objects $a',b'(f'),(o'),c'(e'),d',d_1'$, $c_1'(e_1'),(o_1'),b_1'(f_1'),a_1', p'(p_1'), q'(q_1'), r'(r_1')$ and $s'(s_1')$. Exit the text command.

Step 11: We have to now draw the circular hole. For this, invoke the Circle by Center Point Command and click on the midpoint of the line $o'o_1'$ to specify the center of the circle. In the diameter option of the Ribbon bar, enter 40 mm to specify the diameter of the circular hole. Exit the Circle Command.

Sheet1

Solid Edge V18

Step 12 : Invoke the Trim command and trim the protions of the lines $b'b_1'$ and $c'c_1'$ which intersect with the circle as shown in the Fig 4.1 Exit the Trim command.

Step 13 : Divide the circle into 12 equal parts by the procedure explained in the earlier Chapters.

Invoke the Text Command and create the text objects $1'(1_1'), 2'(2_1'), 3'(3_1'), 4'(4_1'), 5'(5_1'), 6'(6_1'), 7'(7_1'), 8'(8_1'), 9'(9_1'), 10'(10_1'), 11'(11_1')$ *and* $12'(12_1')$. Exit the text command.

Step 15 : Invoke the Line Command and project vertical line from points $1'(1_1'), 2'(2_1'), 3'(3_1'), 4'(4_1'), 5'(5_1'), 6'(6_1')$, *and* $7'(7_1')$ of the front view and project them to the top view to meet at the points $1, 2, 3, 4, 5, 6, 7, 1_1, 2_1, 3_1, 4_1, 5_1, 6_1$ *and* 7_1. Exit the Line command.

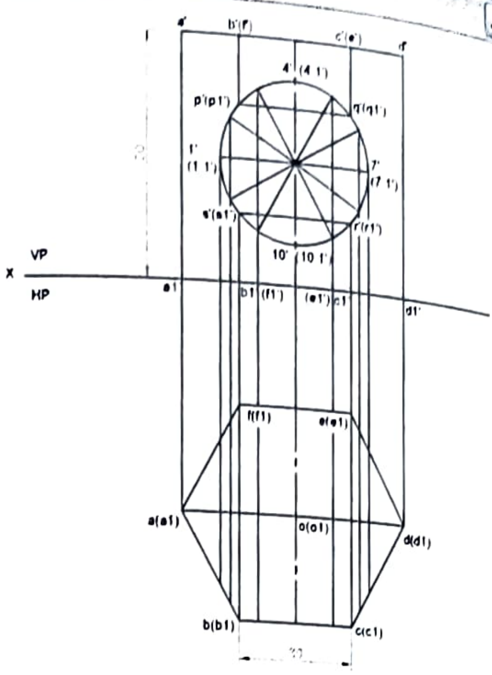


Fig. 5.19

Step 16 : Invoke the Text Command and create the text objects $1, 2, 3, 4, 5, 6, 7, 1_1, 2_1, 3_1, 4_1, 5_1, 6_1$ *and* 7_1 in the top view. Exit the text command.

This completes the Front View with the circular hole in the center as shown in *Fig. 5.19.*

IV Draw the Development drawing

Step 17 : Invoke the Line Command and click on any point on the *XY* line to the right of the front view just drawn. From this point, drag the cursor vertically upwards and in the Ribbon bar, enter 65 mm in the length option which is equal to the length of the full prism. This completes the line A_1A. Exit the Line command.

Step 18 : Invoke the Offset Command and click on the line A_1A to select it. In the distance option enter a value of 30 mm. Click on the Accept button . Click to the right of the line A_1A to create line B_1B. Similarly create offset lines C_1C, D_1D, E_1E, F_1F to the right with the same offset distance. Finally create the line A_1A to the right of the line F_1F. Exit the Offset Command. Invoke the Line Command . Click on the point A and project it horizontally to the right to the end point A as shown in the *Fig 5.20.*

Step 19 : Click on the point $1'$ of the front view and project it horizontally to meet at the point 1 on the line A_1A in the development drawing. Exit the line sequence. Click on the points $2', 3'$ and $(4')$ of the front view and project it horizontally to meet at the points 2, 3 and 4 on the lines B_1B, C_1C and D_1D in the development drawing. Exit the Line sequence.

Step 20 : Click on the point $1'$ of the development drawing and project it horizontally to meet at certain point on the line A_1A (the last line). Exit the line sequence. Draw similar horizontal projector lines from points $2'(2_1'), p'(p_1'), 3'(3_1'), 10'(10_1'), 11'(11_1'), s'(s_1')$ *and* $12'(12_1')$. Exit line sequence.

These horizontal projected lines will meet at points P and S on the line BB_1, at points Q and R on the line CC_1, at points Q_1 and R_1 on the line EE_1 and at points P_1 and S_1 on the line FF_1. We have to now find the points $1, 4, 7, 10, 1_1, 4_1, 7_1$ and 10_1.

Sheet1

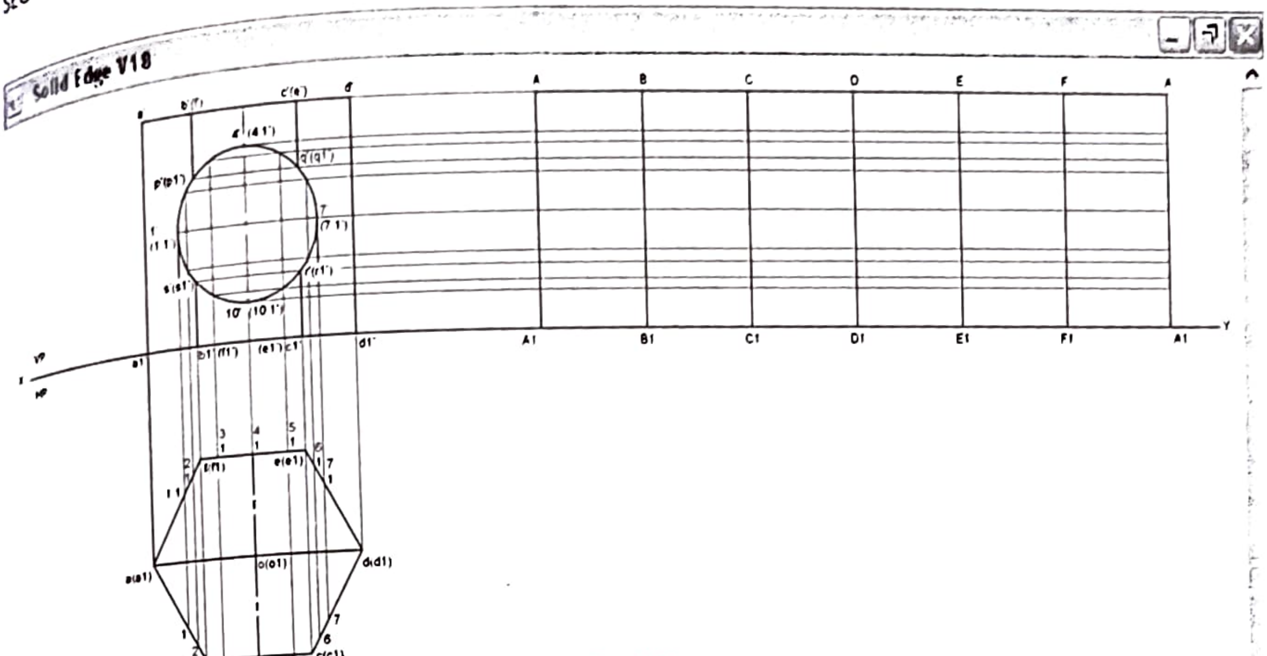


Fig. 5.20

Step 21 : Invoke the Measure Distance Command and click on the point $a(a_1)$ of the top view and then click on point 1_1. Measure this distance to be equal to 20 mm. Similarly, measure the distances $a2_1$, $b2$ and $b3$ to be equal to 25.36 mm, 4.64 mm and 5 mm respectively. Exit the Measure Distance command.

Step 22 : Invoke the Offset Command and click on the line AA_1. In the distance option, enter 20 mm (equal to the measured distance of $a1_1$ in Step 21) and click on the Accept button and click on the right of the line AA_1 to create the offset line. The intersection of this offset line with the horizontal projector line drawn from point $1'(1_1')$ of the front view is the point 1 in the development drawing. Exit the Offset command.

Step 23 : Invoke the Offset command and click on the line BB_1. In the distance option, enter 4.64 mm (equal to the measured distance of $b2$ in Step 21) and click on the Accept button and click on the left of the line BB_1 to create the offset line. The intersection of this offset line with the horizontal projector lines drawn from the points $2'(2_1')$ and $12'(12_1')$ of the front view gives the points 2 and 12 in the development drawing. Exit the Offset command.

Step 24 : Invoke the Offset Command and click on the line BB_1. In the distance option, enter 5 mm (equal to the measured distance of $b3$ in Step 21) and click on the Accept button and click on the right of the line BB_1 to create the offset line. The intersection of this offset line with the horizontal projector lines drawn from the points $3'(3_1')$ and $11'(11_1')$ of the front view gives the points 3 and *11* in the development drawing. Exit the Offset Command.

Step 25 : Invoke the Offset Command and click on the line BB_1. In the distance option, enter 15 mm (equal to half the distance of BC) and click on the Accept button and click on the right of the line BB_1 to create the offset line. The intersection of this offset line with the horizontal projector lines drawn from the points $4'(4_1')$ and $10'(10_1')$ of the front view gives the points 4 and 10 in the development drawing. Exit the Offset command.

Step 26 : Invoke the Offset Command and click on the line CC_1. In the distance option, enter 5 mm (equal to the measured distance of $c5 = b3$ in Step 21) and click on the Accept button and click on the left of the line CC_1 to create the offset line. The intersection of this offset line with the horizontal projector lines drawn from the points $5'(5_1')$ and $9'(9_1')$ of the front view gives the points 5 and 9 in the development drawing. Exit the Offset Command.

Solid Edge V18

Step 27: Invoke the Offset command and click on the line CC_1. In the distance option, enter 4.64 mm (equal to the measured distance of $c6 = b2$ in Step 21) and click on the Accept button and click on the right of the line CC_1 to create the offset line. The intersection of this offset line with the horizontal projector lines drawn from the points $6'(6_1')$ and $8'(8_1')$ of the front view gives the points 6 and 8 in the development drawing. Exit the Offset command.

Step 28: Invoke the Offset command and click on the line DD_1. In the distance option, enter 20 mm (equal to the measured distance of $d7_1 = a1_1$ in Step 21) and click on the Accept button and click on the left of the line DD_1 to create the offset line. The intersection of this offset line with the horizontal projector line drawn from point $7'(7_1')$ of the front view is the point 7 in the development drawing. Exit the Offset command.

Invoke the Text command [A] and create the text objects $1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 1_1, 2_1, 3_1, 4_1, 5_1, 6_1, 7_1, 8_1, 9_1, 10_1, 11_1, 12_1, A, B, C, D, E, F, A, A_1, B_1, C_1, D_1, E_1, F_1, A_1, P, Q, R, S, P_1, Q_1, R_1$, and S_1 in the development drawing. Exit the text command.

Step 30: Invoke the Arc by Center Point Command and click on the point O as the center point. Then in the radius option of the ribbonbar, enter 20 mm and click on the points *P* and *Q* to create an arc P-4-Q.

Step 31: With the Arc by Center Point Command click on the point O as the center point. Then in the radius option of the ribbonbar, enter 20 mm and click on the points *S* and *R* to create an arc S-10-R. Exit the Arc by Center point command.

Step 32: Invoke the Curve Command and click on the points *Q*, *6*, *7*, *8* and *R* to create a smooth curve *Q-6-7-8-R*. Exit the Curve Command. Again invoke the Curve Command and click on the points *P*, *2*, *1*, *12* and S to create a smooth curve P-2-1-12-S. Exit the Curve Command.

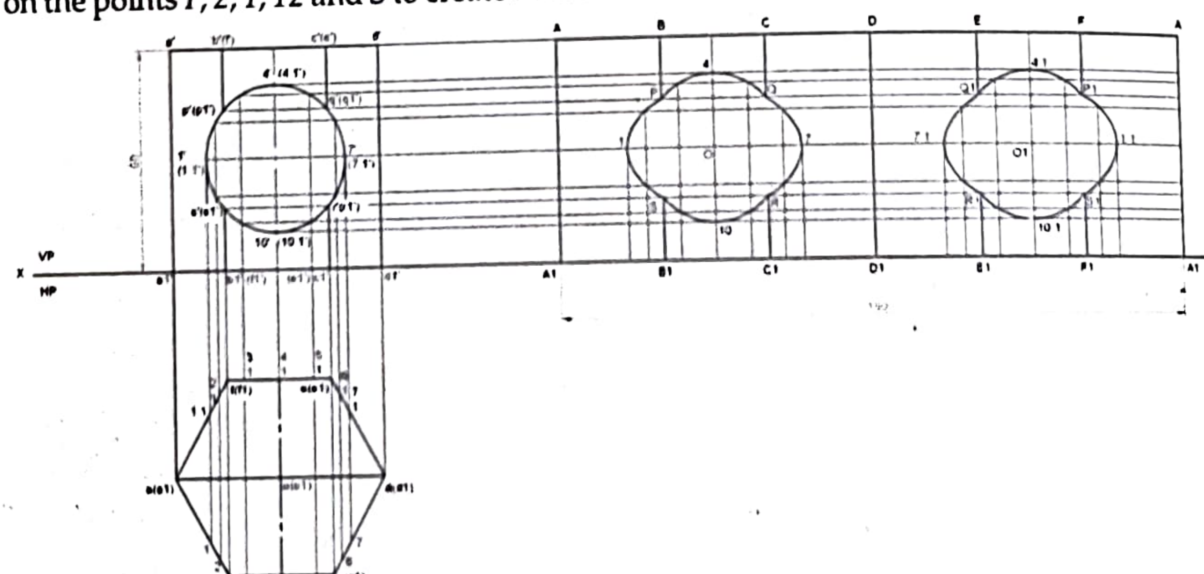


Fig. 5.21

Step 33: Invoke the Offset Command . Draw offset lines in a similar fashion as explained in the steps 21 to 28 for the area DAA_1D_1. Exit the Offset Command. Create the curves Q_1-4_1-P_1, R_1-10_1-S_1, P_1-1_1-S_1 and R_1-7_1-Q_1 using the Curve Command as explained in the steps 30 to 32. Exit the Curve Command.

Step 34: Invoke the Trim command and trim the portions *PS*, *QR*, Q_1R_1 and P_1S_1. Exit the Trim command. Select all the projector lines and change its line width to 0.25 mm. This completes the development drawing as shown in the *Fig. 5.21*.

Sheet1

5.15 Development of Cylinders

Fig. 5.22 shows the rolling of a cylinder on its curved surface over a plane surface. When the cylinder rolls without slipping by *one complete revolution*, it covers a linear distance equal to the *circumference of the base circle* of the cylinder. The *area* covered by it in one revolution, will be a *rectangle* of sides equal to the circumference of the base circle and the height of the cylinder. Thus the development of a cylinder is a *rectangle of sides equal to the circumference of the base circle and height of the cylinder.*

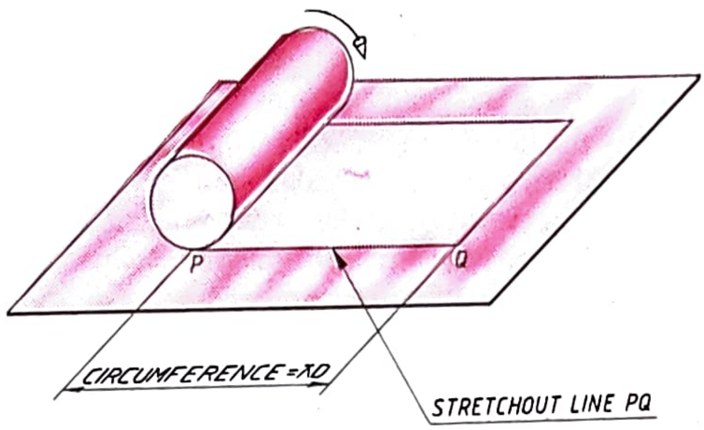
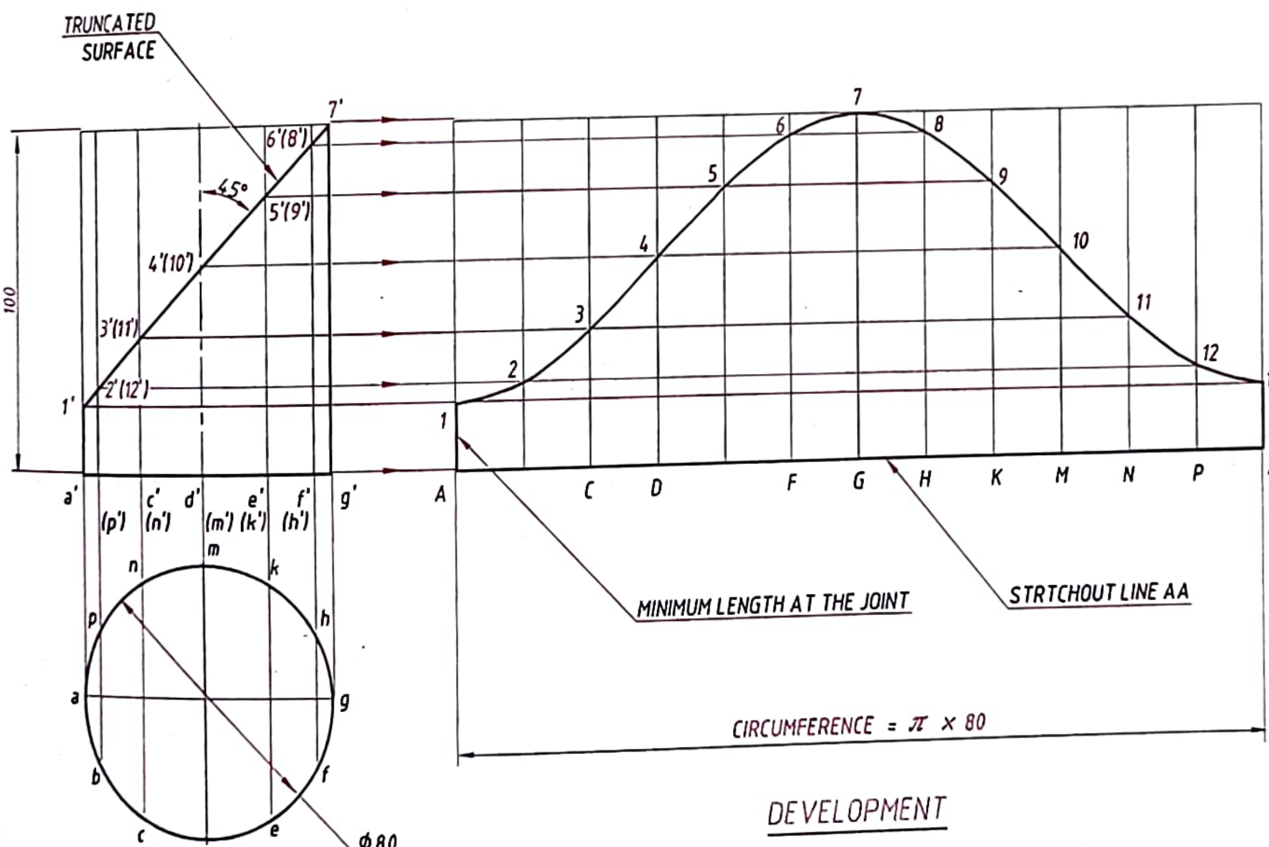


Fig. 5.22

Problem 3

Draw the development of the truncated portion of a vertical cylinder of 80 mm diameter and 100 mm high. The truncated surface is inclined at 45° to the axis and passes through the top end of one of the extreme generators in the front view. Draw the development of the lateral surface of the truncated cylinder providing a minimum length at the joint.

Solution : *Fig.* 5.23



All dimensions in mm
Fig. 5.23

Draw the top and front views of the cylinder. Divide the cylinder circle into twelve equal parts Project these division points to the front view and draw the vertical generators through them. Since the first generator is assumed through the division point a', and the joint should be provided with a minimum length, the inclined truncated surface is drawn through the top end of the right extreme end generator so as to be inclined at 45° to the axis.

Draw the development of the complete cylinder and divide the stretch-out line *AA* into twelve equal parts. Draw verticals to represent the generators at the division points *A, B, C*, etc. Draw the projectors through the section points *1', 2', 3'*, etc. in the front view to get *1, 2, 3*, etc. on the respective generators in the development. Join the points *1, 2, 3*, etc. on the development by a smooth curve.

Solid Edge V18

Solid Edge Procedure :

I Draw the Top and Front Views of the Cylinder

Step 1 : Invoke the Line Command and draw a horizontal line of length 350 mm. Exit the Line command.

Invoke the Circle by Center Point Command . Click on any convenient point below *XY* line as the center point of the circle. In the diameter option of the Ribbonbar, enter a value of 80 mm and click to complete the circle. Exit the circle command. Invoke the Point Command and click on the center of the circle to create the point object $o(o_1)$ which represents the axis of the cylinder. Exit the point command. Invoke the Text command A and create the text object $o(o_1)$. Exit the text command.

Step 4 : We have to divide the circle into 12 equal parts. For this, draw a line by invoking the Line Command and click on the left quadrant point of the circle. When you more the cursor to the left fof the circle, it will show a symbol . Drag the cursor horizontally and click at the right quadrant point indicated again by the symbol. This completes the diameter *ag* as shown below in *Fig*. Exit the Line Command.

Step 5 : Invoke the Rotate Command and click on the Line *ag*. In the Ribbonbar, click on the copy option and in the step angle option, enter 30°. Now click on the center of the circle and the right quadrant point. Note that the position angle in the Ribbon bar is at 0°. Now, go on clicking in the counter-clockwise direction to draw rotated lines each at step angle of 30°. This divides the circle into 12 equal parts as shown in *Fig.5.24*. Exit the Rotate Command.

Step 6 : Invoke the Text Command A and create the text objects *a,b,c,d,e,f,g,h,k,m,n, p* and $o(o_1)$. Exit the Text command. This completes the Top View as shown in Fig 5.24.

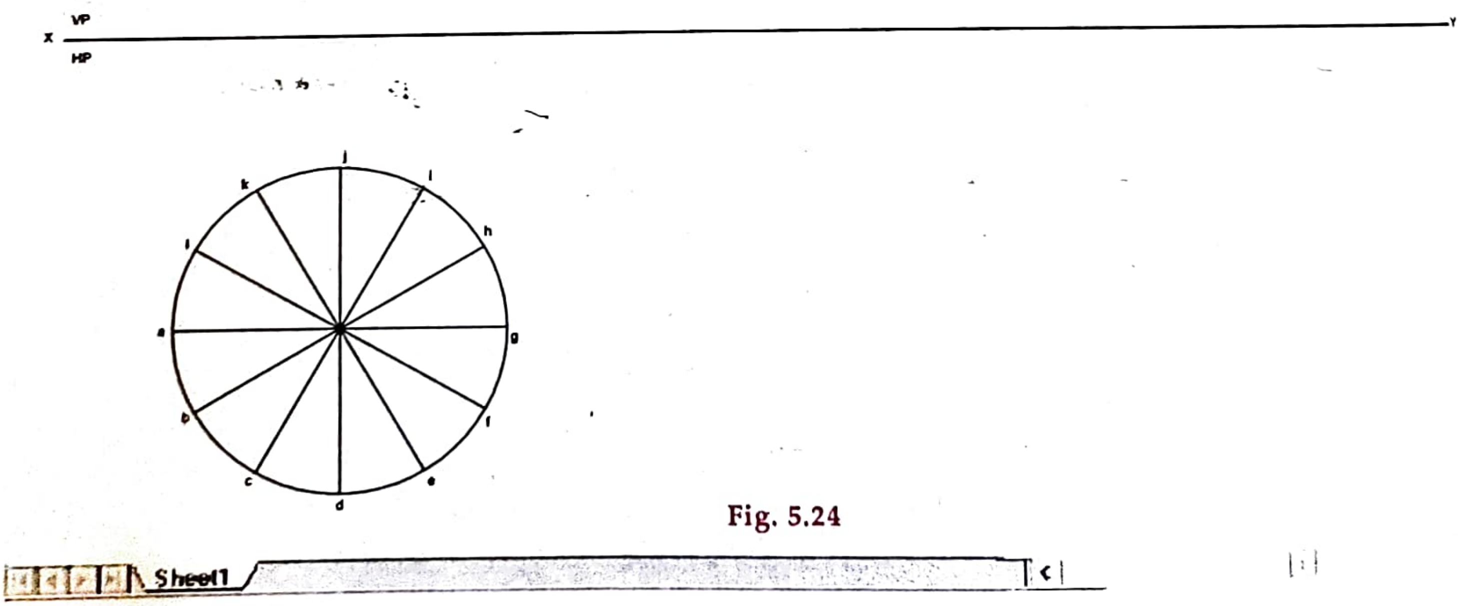


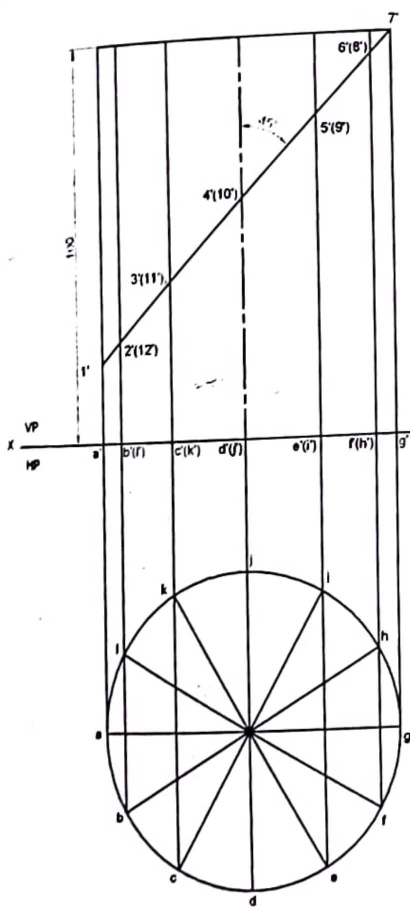
Fig. 5.24

Solid Edge V18

Step 7 : Invoke the Line Command and click on the point *a* and drag vertically upwards and click on the XY line to meet at point *a'*. This completes the line *aa'*. Similarly, project the vertical lines from points b, c, d, e, f and g to meet the XY line at points a', b'(p'), c'(n'), d'(m'), e'(k'), f'(h') and g'. Right click to exit the line sequence.

Step 8 : Click on the point a' and drag the cursor horizontally to the right and click on the point g'. From the point g' project a vertical line of length 100 to meet at point. From this point, drag to the left and in the length option of the ribbonbar enter 80 mm. Darg vertically down and click on the point a'. Exit the line sequence. Draw vertical lines progressing upwards from points b'(p'), c'(n'), d'(m'), e'(k'), f'(h') and g' with each line having a length of 100 mm. Exit the line sequence. Click on the upper right extreme point and in the ribbonbar, enter a convenient length of say 100 mm in the length option and in the angle option, enter -135°. This cuts the vertical line coming from point a' as shown in Fig. 5.25. Exit the Line Command. Click on the center line and change its linetype to center line. Invoke theTrim Command and trim the extra portion of the inclined line. Exit the Trim Command. The inclined line cuts the vertical generator lines at the points 1', 2'(12'), 3'(11'), 4'(10'), 5'(9'), 6'(8') and 7'.

Step 9 : Invoke the Text Command and create the text objects *a', b'(p'), c'(n'), d'(m'), e'(k'), f'(h'), g', 1', 2'(12'), 3'(11'), 4'(10'), 5'(9'), 6'(8') and 7'*. Exit the Text Command.



All dimensions in mm

Fig. 5.25

Sheet1

Solid Edge V18

II Draw the Development drawing

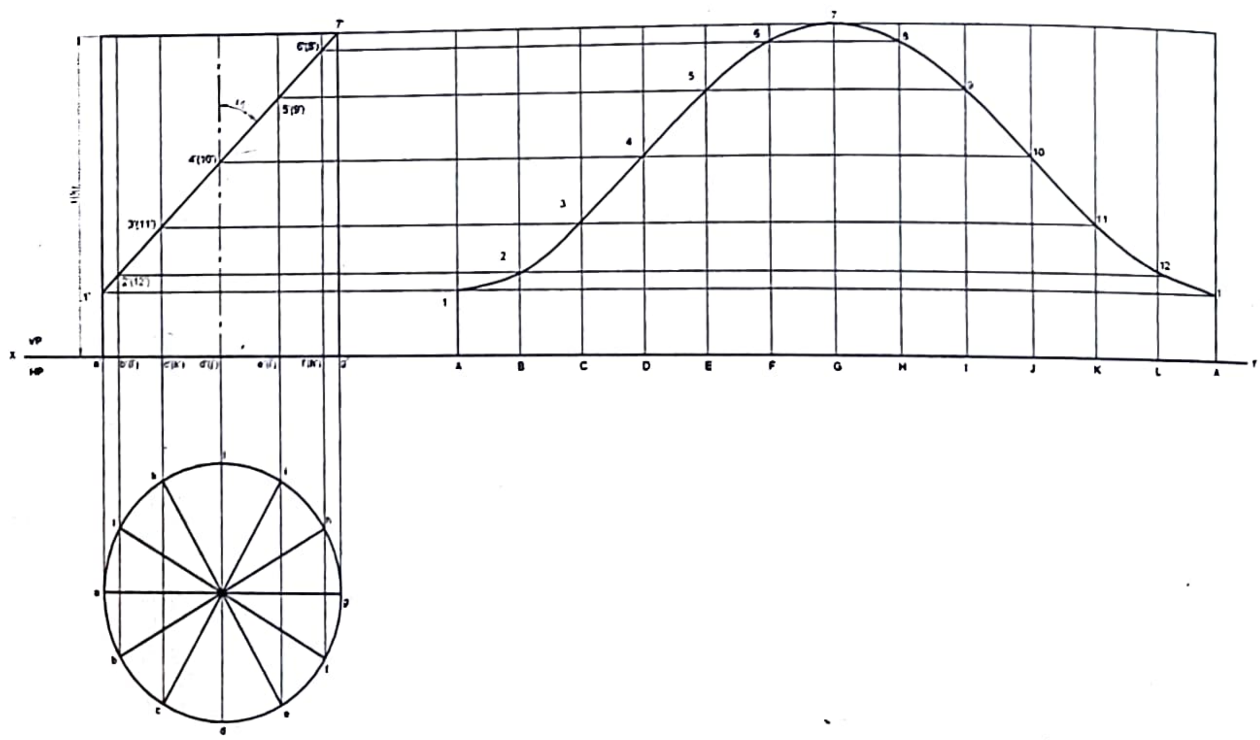
Step 10 : Invoke the Line Command and click on any point on the XY line to the right of the front view just drawn. From this point, drag the cursor vertically upwards and in the Ribbon bar, enter 100 mm in the length option which is equal to the height of the cylinder. This completes the vertical line from point A. Exit the Line Command.

Step 11 : Invoke the Offset command and click on the line just drawn to select it. In the distance option enter a value of 20.93 mm (which is $\pi x (80)/12$). Select the chain option. Click on the Accept button . Go on clicking on the right till you see that the stretchout line is divided into 12 equal parts. Exit the Line sequence. Click on the point A and project it horizontally to the right to the end point *A*.

Step 12 : Click on the point *1'* of the front view and project it horizontally to meet at the point 1 on the vertical line drawn from A in the development drawing. Exit the line sequence. Click on the points *2'(12'), 3'(11'), 4'(10'), 5'(9'), 6'(8')* and *7'* of the front view and project it horizontally to meet at the points *2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12* and *1* on the respective vertical lines drawn from ponts *B, C, D, E, F, G, H, K, M, N, P* and *A* in the development drawing. Exit the Line Command.

Step 13 : Invoke the Curve Command and click on the points *1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12* and *1* to draw a smooth curve joining all these points. Exit the Curve command.

Step 14 : Invoke the Text Command and create the text objects *1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, A, B, C, D, E, F, G, H, K, M, N, P* and *A*. Exit the Text Command. This completes the Development drawing as shown in *Fig. 5.26*.



Development drawing
Fig. 5.26

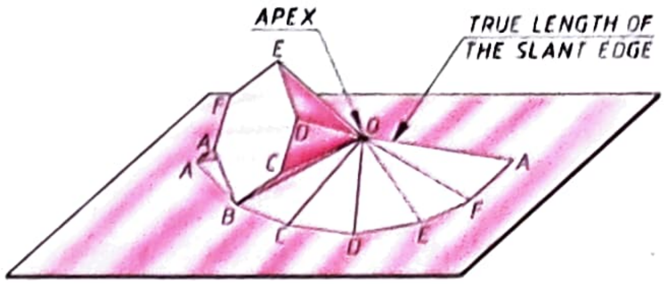
Sheet1

5.16 Radial Line Development

In this method, objects like pyramids, cones, and objects of such other related surfaces are developed. These objects are rolled over a plane surface with their apex being hinged at a point. The lateral surfaces covers a *sector of a circle* with the apex point being its centre.

5.17 Development of Pyramids

Fig. 10.27 shows the rolling of a hexagonal pyramid on its lateral surfaces over a plane surface with its apex being hinged at a point. The development consists of six isosceles triangles with their sides equal to the length of the slant edges and the base equal to the sides of the base of the pyramid.

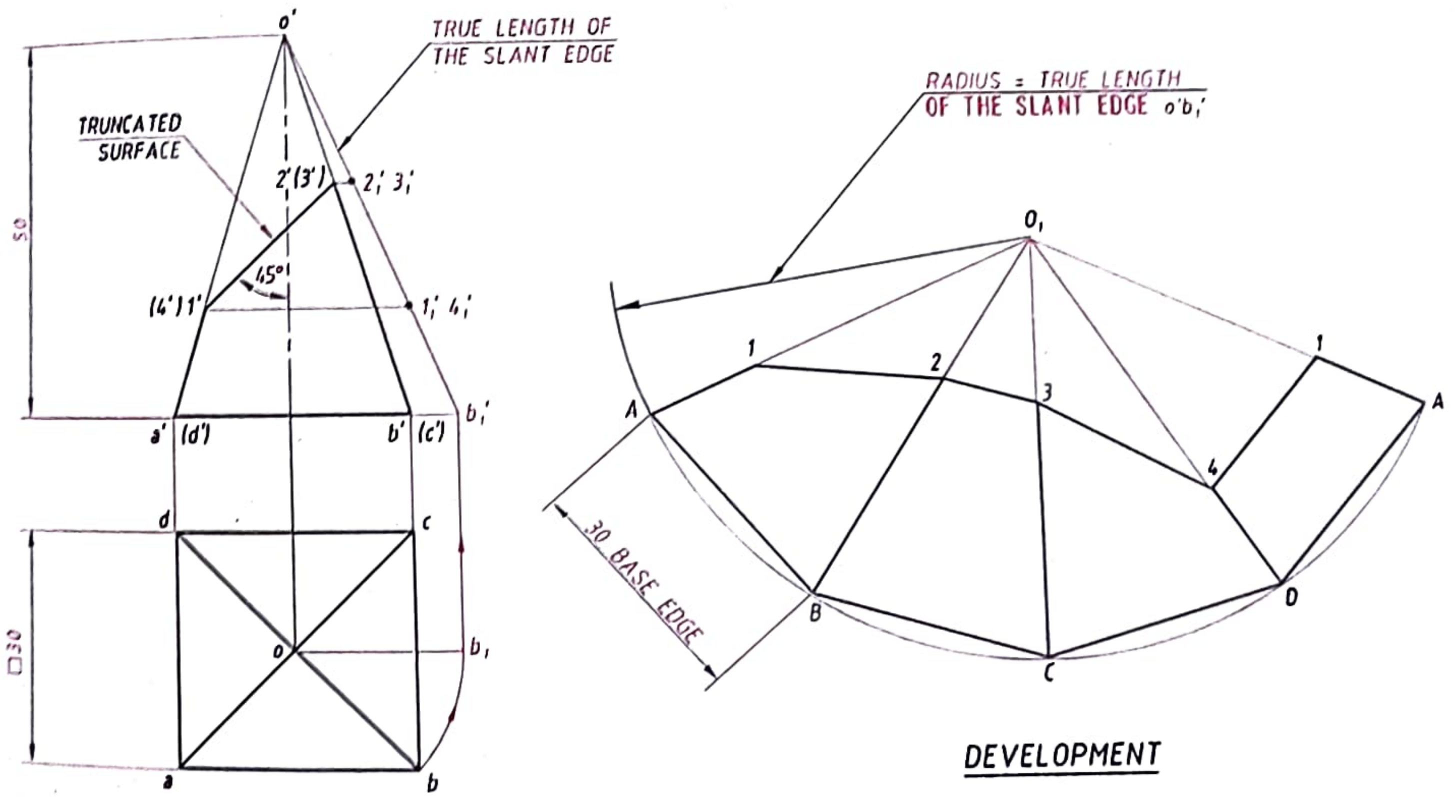


Development of a Pyramid
Fig. 5.27

Problem 4

Draw the development of the truncated portion of a square pyramid of 30 mm side of base and height 50 mm rests with its base on HP with one of the edges of the base parallel to VP. The truncated surface is inclined at 45° to the axis and bisecting it.

Solution : *Fig. 5.28*



All dimensions in mm
Fig 5.28

Draw the top and front views of the square pyramid in the given position. Since none of the slant edges in the top view are horizontal, *none of the slant edges* in the front view are in *true length*. Therefore the *true length of the slant edges* should be found. To find the *true length* of the *slant edge*, rotate one of the slant edges in the top view to make it horizontal, for example, *ob* is rotated to the horizontal position to ob_1. The point b_1 in the top view is projected to the front view to get b_1'. Connect $o'b_1'$ which will be equal to the true length of the slant edge of the pyramid.

To draw the development:

With any point O_1 as centre and radius equal to the *true length* of the slant edge $o'b_1'$ draw an arc. Draw the first slant edge O_1A in any convenient position (angle). With the radius equal to the length of the base edge 30 mm cut the development arc successively starting from *A* at *B*, *C*, *D* and *A*. Connect the slant edges O_1A, O_1B, O_1C, O_1D, O_1A and the base edges *AB*, *BC*, *CD* and *DA*.

Since the points $1'$, $2'$, $3'$ and $4'$ in the front view lie on the slant edges which are *not in true length*, they are projected to the *line* representing the true length of the *slant edge* $o'b_1'$ to get $1_1'$, $4_1'$, $2_1'$ and $3_1'$. In the front view the distances $o'1_1'$, $o'2_1'$, $o'3_1'$ and $o'4_1'$ are measured on the respective *true length slant edges* in the *development* O_1A, O_1B, O_1C and O_1D to get the points 1, 2, 3 and 4. Join the points 1-2-3-4-1 to complete the development as shown in figure.

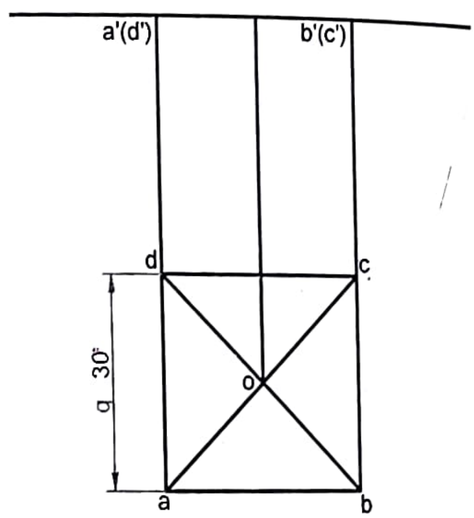
Solid Edge V18

Solid Edge Procedure :

I To draw the Top and Front views

Step 1: Invoke the Line Command and draw a horizontal Line from left to right of length 150 mm. Exit the Line Command.

Step 2: Invoke the Line Command and click a point below the horizontal line at a convenient distance. Drag the cursor horizontally and in the length option of the Ribbonbar, enter a value of 30 mm. Click to complete the line *dc*. Now, drag the cursor to the downwards. In the Ribbonbar, enter the value of length to be 30 mm in the length option and click to complete the line *cb*. Drag the cursor to the left horizontally and in the ribbonbar, enter a value of 30 mm in the length option and click to complete the line *ba*. Drag the cursor vertically upwards and click on the point d to complete the square abcd. Right click to exit line sequence.



All dimensions in mm
Fig 5.29

Step 3: Click on the point *d*, drag and click on the point *b* to complete the line *bd*.. Right click to exit the line sequence. Click on the point *a*, drag and click on the point *c* to complete the line *ac*. Exit the Line Command.

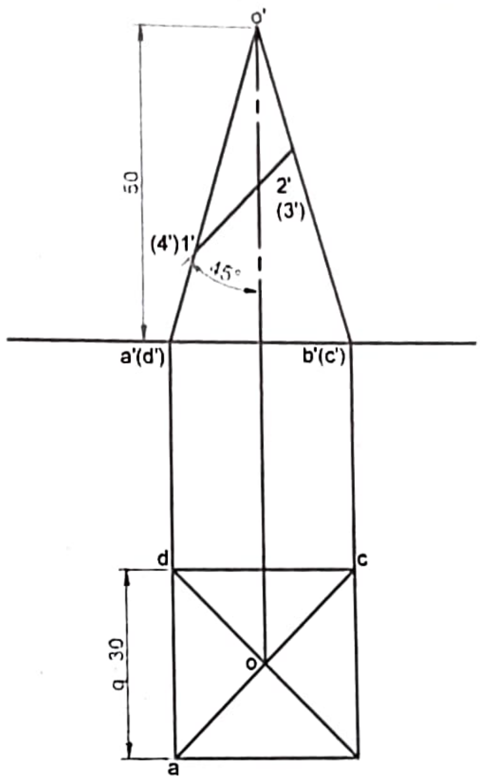
Step 4: Invoke the Text Command A and create the text objects *a, b, c, d and o*. Exit the Text Command. You have now completed the top view as shown in the *Fig.5.29*

Step 5: Invoke the Line Command and click on the point *a* of the just drawn top view. Project it upwards to meet the horizontal line at point *a'(d')*. Click to complete the projector line *aa'*. Right click to exit the line sequence. Similarly, draw projector lines from the points *o and c* to meet the horizontal line at points *o' and b'(c')* respectively. Right click to exit the line sequence.

Sheet1

Solid Edge V18

Step 6: Click on the point $b'(c')$ and drag horizontally to the left to point a'. Click on a' to complete the line $b'a'$. Right click to exit the line sequence. Click on the midpoint of the line $a'b'$ and project it vertically upwards. Enter a value fo 50 mm in the length option of the Ribbonbar. Click to complete the axis line. From the point o', drag and click on the point a' to complete the line $o'a'$. Right click to exit the line sequence. Click on the point $b'(c')$, drag the cursor and click on the point o' to complete the line $o'b'$. Right click to exit the line sequence. Click on the midpoint of the axis lineand choose a suitable length of say 20 mm (you can choose your own length) in the length option of the Ribbon bar and enter 45° in the angle option. Exit the Line Command.



All dimensions in mm

Fig 5.30

Step 7: Invoke the Extend To Next Command and click on the inclined line just drawn to make it extend to the slant edge $o'a'$. Exit the Extend To Next Command.

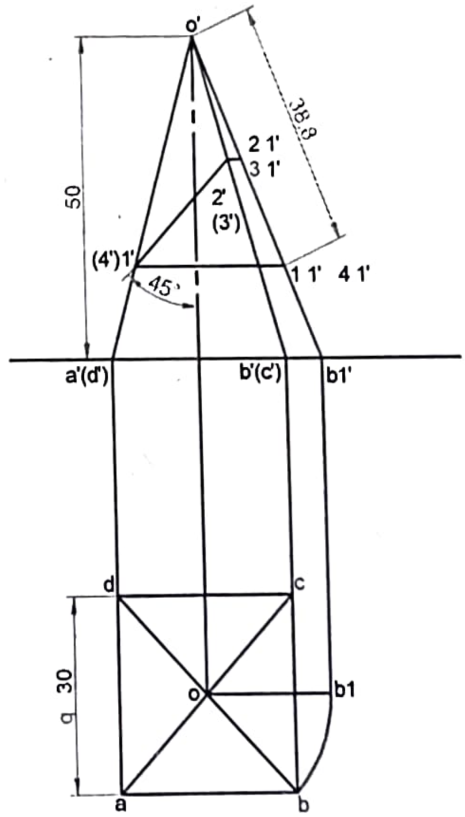
Step 8: Invoke the Trim command and trim the unwanted portion above the slant edge $o'b'$ of the front view. Exit the Trim command.

The inclined line cuts the square pyramid at the points $1'(4')$ and $2'(3')$. Click on the axis line and change its line type to center line type.

Step 9: Invoke the Text command and create the text objects $a'(d')$,$b'(c')$, o', $1'(4')$ and $2'(3')$. Exit the text command. This creates the Front View as shown in *Fig.* 5.30.

II To draw the True length of the slant edges

Step 10: Invoke the Line Command and click on the point o of the top view. Drag the cursor horizontally to the right of the point o and in the ribbonbar, enter a suitable length of 30 mm (You can choose your own length) in the length option and click to complete a horizontal line. Exit the Line Command.



All dimensions in mm

Fig 5.31

Step 11: Invoke the Arc by Center Point Command and click on the point o as the center and then click on the point b which sets the radius as ob. Draw an arc starting from the point b in the counter-clockwise direction to meet the horizontal line at point b_1. Exit the Arc by Center Point Command.

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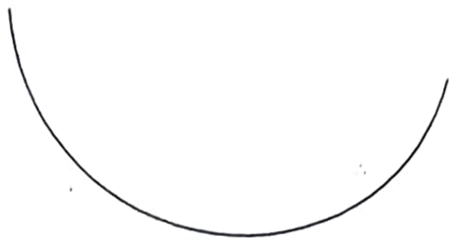
Solid Edge V18

Step 12 : Invoke the Line Command and click on the point b_1 of the top view. Drag the cursor vertically upwards to meet the base line (XY line) at point b1′. From point b_1', drag the cursor and click on the point o′ to complete the line $o'b_1'$. Right click to exit the line sequence. Click on the point 2′(3′) and drag it horizontally to meet the line o′b1′ at the point $2_1'(3_1')$. Right click to exit the line sequence. Click on the point 1′(4′) and drag it horizontally to meet the line $o'b_1'$ at the point $1_1'(4_1')$. Exit the Line Command. The line $o'b_1'$ represents the true length of the slant edge.

Step 13 : Invoke the Text command and create the text objects $b1, b1', 1_1'(4_1')$ and $2_1'(3_1')$ as shown in *Fig. 5.31*. Exit the text command.

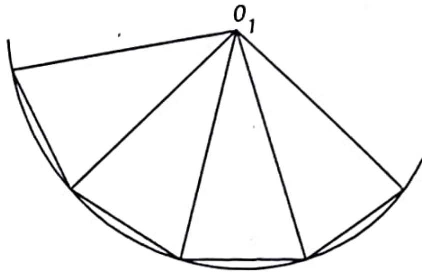
II

Step 14 : We have to first measure the true length of the line. For this click on the line o′b1′ and note its length to be equal to 54.14 mm. Invoke the Arc by Center Point Command and click on any point in free drawing sheet space to the right of the front view just drawn. This point will be the center of the arc O_1. In the radius option of the ribbonbar, enter a value of 54.14 mm and draw an arc in the counter-clockwise direction with your own defined sweep angle as shown in the Fig 5.32. Here we have chosen a sweep angle of 160°.



All dimensions in mm
Fig 5.32

Step 15 : Invoke the Line Command and click on the point O_1. Drag the cursor and click on the arc just drawn at any point on the left of the arc with the symbol appearing. This is the point A. From this point drag the cursor to the lower right and in the ribbonbar, enter a value of 30 mm in the length option and click on the circumference of the arc at a point B where the arc intersects the line. This completes the line *AB*. Drag the cursor and click on the point O_1 to complete the line O_1B. Similarly draw the lines BC, O_1C, CD, O_1D, DA, O_1A as shown in the *Fig 5.33*. Exit the line command.



All dimensions in mm
Fig 5.33

Step 16 : We have to now measure the distances $o'1_1'(=o'4_1')$ and $o'\,2_1'(=o'3_1')$. Invoke the Measure Distance Command and click on the point o′. Drag the cursor and click on the point $2_1'$ to measure the length equal to 20.82 mm. Similarly measure the distance $o'1_1'$ to be 38.67 mm. Exit the Measure Distance Command.

Step 17 : Invoke the Arc by Center Point Command and click on the point O_1 as the center and in the radius option of the Ribbon bar, enter 38.67 mm. Draw an arc to cut the line O_1A at point 1. Now, click on the point O_1 as the center and in the radius option of the Ribbon bar, enter 20.82 mm. Draw an arc to cut the line O_1B at point 2. Similarly, with suitable radii draw the arcs to cut the lines O_1C, O_1D and O_1A at points *3*, *4* and *1* respectively. Exit the Arc by Center Point Command.

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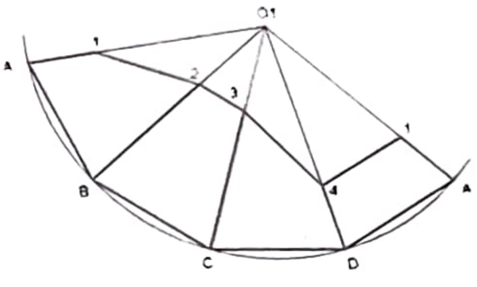
Solid Edge V18

Step 18 : Invoke the Line command and click on the point 1, drag the cursor and click on the point 2 to complete the line 12. Drag and click on the point 3 to complete the line 23. Draw lines 34 and 41 similarly. Exit the Line Command.

Step 19 : Invoke the Text Command and create the text objects *A, B, C, D, A, 1, 2, 3, 4 and 1*. Exit the Text Command.

Step 20 : Invoke the Trim Command and trim the unwanted line and arc portions. Exit the Trim Command. Select all the projector lines and change its line width to 0.25 mm. This completes the development drawing as shown in the Fig. 5.34.



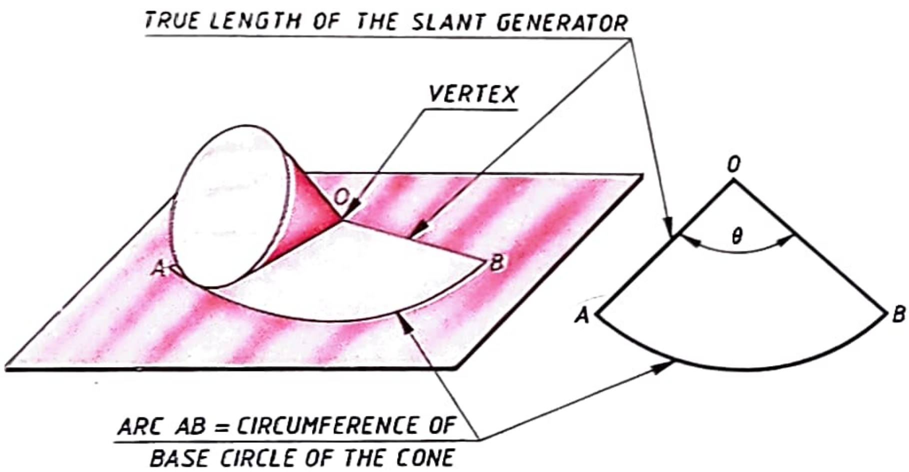
All dimensions in mm

Fig 5.34

Sheet1

10.13 Development of Cones

Fig.5.35A shows the rolling of a cone over a plane surface with the vertex of the cone hinged at a point. The *area* covered by the cone in *one rotation* will be a *sector of a circle* which will be the development of the cone. The *radius* of the sector will be equal to the *true length of the slant generator of the cone* and the *length of the arc* will be equal to the *circumference of the base circle of the cone*. Although the true length of the arc of the circumference of the base circle can be calculated, it will be difficult to measure the length of the arc equal to the length of the circumference of the base circle of the cone. Therefore, instead of measuring the length of the arc equal to the circumference of the base circle, the *angle θ* subtended by the *arc of length equal to the circumference of the base circle* is taken on the development. The subtended angle θ is calculated as follows. *Fig. 5.35B* shows the development of a cone.



A B

Development of a Cone

Fig. 5.35

Let R = True length of the slant generator of the cone. This length is measured from the view in which the cone is projected as a triangle.

r = Radius of the base circle of the cone.

θ = Angle subtended by the arc AB.

Now, Circumference of the base circle of radius $r = 2\pi r$

Circumference of the circle of radius $R = 2\pi R$

Now, Circumference of the base circle of radius $r = 2\pi r$

Circumference of the circle of radius $R = 2\pi R$

$$\therefore\ 2\pi r \text{ subtends an angle } \theta = \frac{2\pi r}{2\pi R} \times 360^\circ \text{ at O}$$

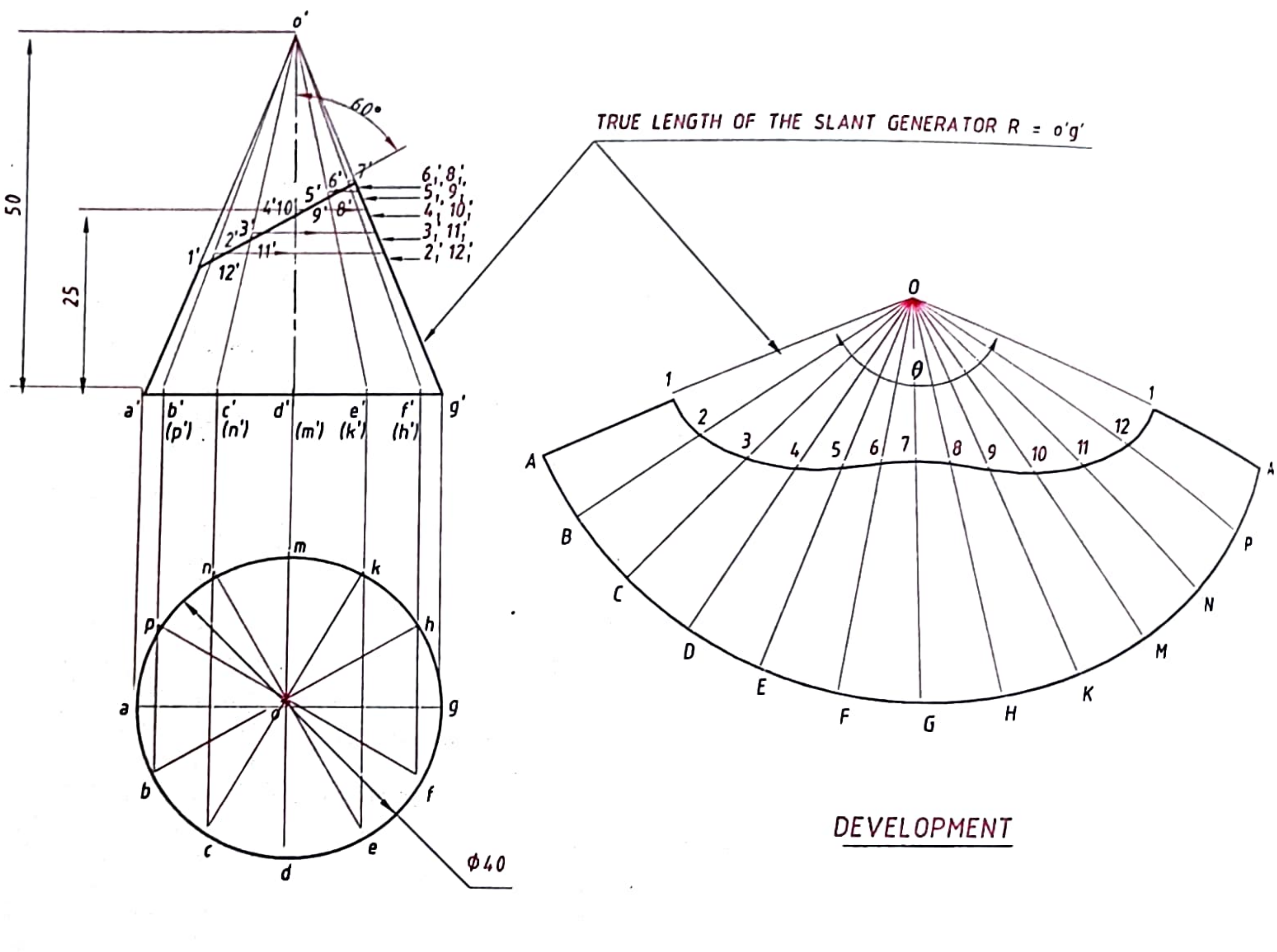
$$\therefore\ \theta = \frac{r}{R} \times 360^\circ = 360^\circ \times \frac{\text{Radius of the Base Circle of Cone}}{\text{True length of the Slant Generator of Cone}}$$

With O as centre and radius R, draw an arc of a circle such that the arc subtends θ at O.

Problem 5

Draw the development of the lateral surface of a truncated vertical cone, 40 mm diameter of base and height 50 mm. The truncated flat surface of the cone bisects at 60° to its axis.

Solution : *Fig.5.35*



All dimensions in mm
Fig.5.36

Draw the top and front views of the cone. Divide the base circle of the cone into twelve equal parts and through the division points draw the twelve generators both in the top and front views. Draw the truncated surface inclined at 60° to the axis of the cone bisecting it. Mark the points $1'$, $2'$, $3'$, etc. at the points at which the *generators* of the cone are cut by the truncated surface.

The development of the complete cone is drawn as follows. The *true length* of the *slant generator* will be equal to $o'a'$ or $o'g'$. Calculate the *subtended angle* θ of the arc which is to be measured in the development from the formula given in previous page.

With centre at any point O as centre and radius equal to the true length of the slant generator, draw an arc of circle OAA subtending θ at O. Since the cone is divided into twelve equal parts, divide θ also into twelve equal parts by drawing the generators OA, OB, OC, etc. To mark the position of the points on the generators, the true distances either from the apex or from the respective base ends must be found. Since, except the end generators $o'a'$ and $o'g'$, the *length* of the *other generators* in the front view will *not be equal to the true length of the slant generator of the cone*. The distance $o'1'$ on $o'a'$ is measured equal to $O1$ on OA. Similarly $o'7'$ on $o'g'$ is measured equal to $O7$ on OG. The distances of the other points $2'$, $3'$, $4'$, $5'$, $6'$, $8'$, $9'$, $10'$, $11'$, $12'$ lying on the respective generators $o'b'$, $o'c'$, $o'd'$, $o'e'$, $o'f'$, $o'h'$, $o'k'$, $o'm'$, $o'n'$, $o'p'$ from the apex o' in the front view cannot be measured directly, because *these generators are not projected in true length* in the front view. Therefore the points $2'$, $3'$, $4'$, $5'$, $6'$, $8'$, $9'$, $10'$, $11'$ and $12'$ are projected to $o'g'$, the true length of the slant generator, to get $2_1'$, $3_1'$, $4_1'$, $5_1'$, $6_1'$, $8_1'$, $9_1'$, $10_1'$, $11_1'$, $12_1'$ on it. The distances $o'2_1'$, $o'3_1'$, $o'4_1'$, etc. measured on $o'g'$ are transferred on the respective generators in the development to get 2, 3, 4, etc. Passing through these points draw a smooth curve and complete the development.

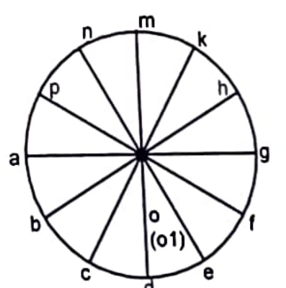
Solid Edge V18

Solid Edge Procedure :

I

Step 1 : Invoke the Line Command and draw a horizontal line of length 120 mm. Exit the Line Command.

Step 2 : Invoke the Circle by Center Point Command. Click on any convenient point below the horizontal line as the center point of the circle. In the diameter option of the Ribbonbar, enter a value of 40 mm and click to complete the circle. Exit the circle command. Invoke the Point Command and click on the center of the circle to create the point object $o(o_1)$ which represents the axis of the cylinder. Exit the Point Command. Invoke the Text Command and create the text object $o(o_1)$ as shown in *Fig* 5.37. Exit the Text Command.



All dimensions in mm

Fig.5.37

Step 3 : We have to divide the circle into 12 equal parts. For this, draw a line by invoking the Line Command and click on the left quadrant point of the circle. When you more the cursor to the left of the circle, it will show a symbol. Drag the cursor horizontally and click at the right quadrant point indicated again by the symbol. This completes the diameter *ag* as shown in Fig 5.37. Exit the Line Command.

Step 4 : Invoke the Rotate Command and click on the Line *ag*. In the Ribbon bar, click on the copy option and in the step angle option, enter 30°. Now click on the center of the circle and the right quadrant point. Note that the position angle in the Ribbon bar is at 0°. Now, go on clicking

Sheet1

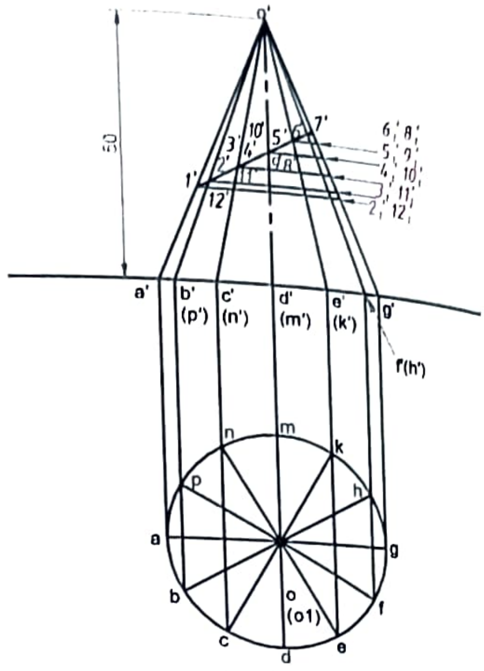
Solid Edge V18

in the counter-clockwise direction to draw rotated lines each at step angle of 30°. This divides the circle into 12 equal parts as shown in *Fig.4*. Exit the Rotate Command.

Step 5 : Invoke the Text Command [A] and create the text objects *a,b,c,d,e,f,g,h,k,m,n, p and o(o_1)*. Exit the Text Command. This completes the Top view as shown in *Fig 5.38*.

Step 6 : Invoke the Line Command ⁄ and click on the point *a*. Drag the cursor vertically upwards to meet the horizontal line at point *a'*. Right click to exit the line sequence. Draw similar vertical lines from the points *d* and *g* to meet the horizontal line at points *d'(m')* and *g'* respectively. Right click to exit the line sequence.

Step 7 : Click on the point *d'(m')* and drag the cursor vertically upwards to a distance of 50 mm. Click to complete the axis line o_1'*o'* . From the point *o'*, draw a line to meet the point *g'*. Exit the line sequence. From the point *o'*. draw a line *o'a'*. From point *a'*, draw a horizontal line to meet the point *g'*. Draw the vertical projector lines from points *b,c,e, and f* to meet the horizontal line at points *b'(p'), c'(n'),e'(k') and f'(h')*. Exit the line sequence and draw the inclined lines *o'b'*, *o'c'*, *o'e'* and *o'f'*. Exit the Line Command. Invoke the Text Command [A] and create the text objects *a',b'(p'),c'(n'),d'(m')(o1'),e'(k'),f'(h'), g'* and *o'*. Exit the Text Command. Click on the Line *o'*o_1*'* and change its linetype to the center line type.



All dimensions in mm
Fig.5.38

Step 8 : Invoke the Line command ⁄ and click on the midpoint of the line o'd'. Drag the cursor to the upper right past the line *o'g'* and in the Ribbon bar, enter a convenient length of say 25 mm (you can choose your own length) in the length option and 30° in the angle option. Exit the Line command.

Step 9 : Invoke the Extend To Next Command and click on the inclined line just drawn to make it extend to the line *o'a'*. Exit the Extend To Next Command.

Step 10 : Invoke the Trim Command and trim the unwanted portion above the line o'g' of the front view. Exit the Trim Command. The inclined line cuts the cone at the points *1', 2'(12'), 3'(11'), 4'(10'), 5'(9'), 6'(8')* and *7'*.

Step 11 : Invoke the Text Command [A] and create the text objects *1', 2'(12'), 3'(11'), 4'(10'), 5'(9'), 6'(8')* and *7'*. Exit the Text Command. This creates the Front View as shown in *Fig. 5.38*.

II Draw the Development drawing

Step 12 : We have to first measure the true length of the line. For this click on the line o'g' and note its length to be equal to 53.85 mm. Invoke the Arc by Center Point Command and click on any point in free drawing sheet space to the right of the front view just drawn. This point will be the

Sheet1

Solid Edge V18

center of the arc O. In the radius option of the Ribbon bar, enter a value of 53.85 mm and draw an arc in the counter-clockwise direction with the sweep angle θ. We can calculate θ as follows:

$$\theta = \frac{r}{R} \times 360^\circ = \frac{\textit{Radius of the Base Circle of Cone}}{\textit{True length of the Slant Generator of Cone}} \times 360^\circ$$

$$= \frac{20\ mm}{53.85\ mm} \times 360^\circ = 133.7^\circ$$

So, enter the value 133.7° in the sweep option. This completes the arc. Exit the Arc by Center Point Command.

Step 13 : Divide the arc with the sweep angle θ (=133.7°) into twelve equal parts. For this, invoke the Line command and click on the point O. Drag the cursor and click the end of the arc just drawn. This is the point A. Exit the line command. Click on the line *OA* and invoke the Circular Pattern Command . In the Ribbon bar, enter count to be equal to 13 and angle equal to 133.7°. Click on the point *O*. Click on Finish button to see that the arc is divided into 12 equal parts as shown in the *Fig 5.39*.

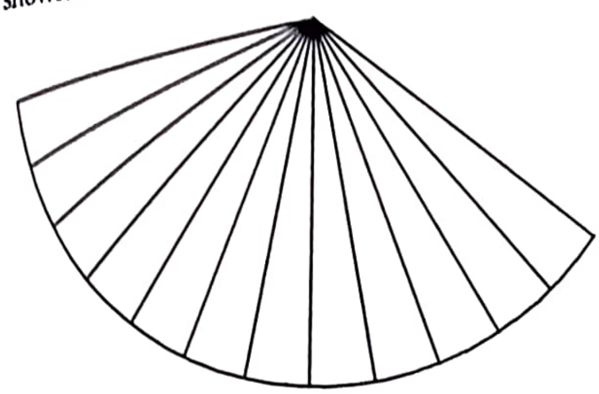
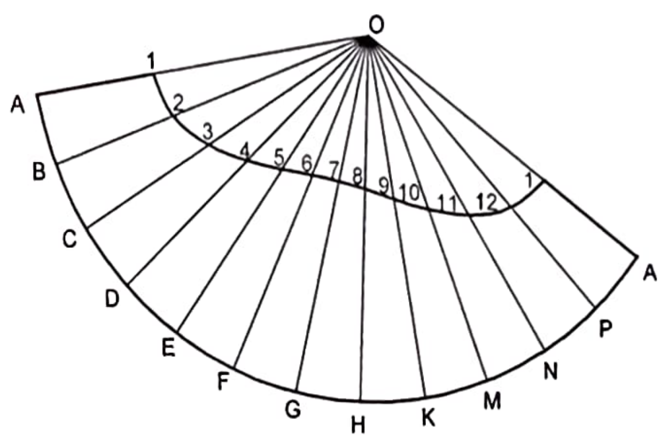


Fig.5.39



Development Drawing
Fig.5.40

Step 14 : We have to now measure the distances *o'1', o' 2' (=o'12'), o'3'(=o'11'), o'4'(=o'10'), o'5'(=o'9'), o'6'(=o'8')* and *o'7'*. For this invoke the Measure Distance Command and measure the distances. Exit the Measure Distance Command.

Step 15 : Invoke the Arc by Center Point Command and click on the point *O* as the center and in the radius option of the Ribbon bar, enter the measured value of *o'1'*. Draw an arc to cut the line *OA* at point 1. Now, click on the point O as the center and in the radius option of the ribbonbar, enter the measured value of *o'2'*. Draw an arc to cut the line *OB* at point 2. Similarly, with suitable radii draw the arcs to cut the lines *OC, OD, OE, OF, OG, OH, OK, OM, ON, OP* and *OA* at points *3, 4, 5, 6, 7, 8, 9, 10, 11, 12* and 1 respectively. Exit the Arc by Center Point Command.

Step 16 : Invoke the Curve Command and click on the points 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 1 to draw a smooth curve. Exit the Curve Command.

Step 17 : Invoke the Text Command and create the text objects *A, B, C, D, E, F, G, H, K, M, N, P, A, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 1*. Exit the Text Command.

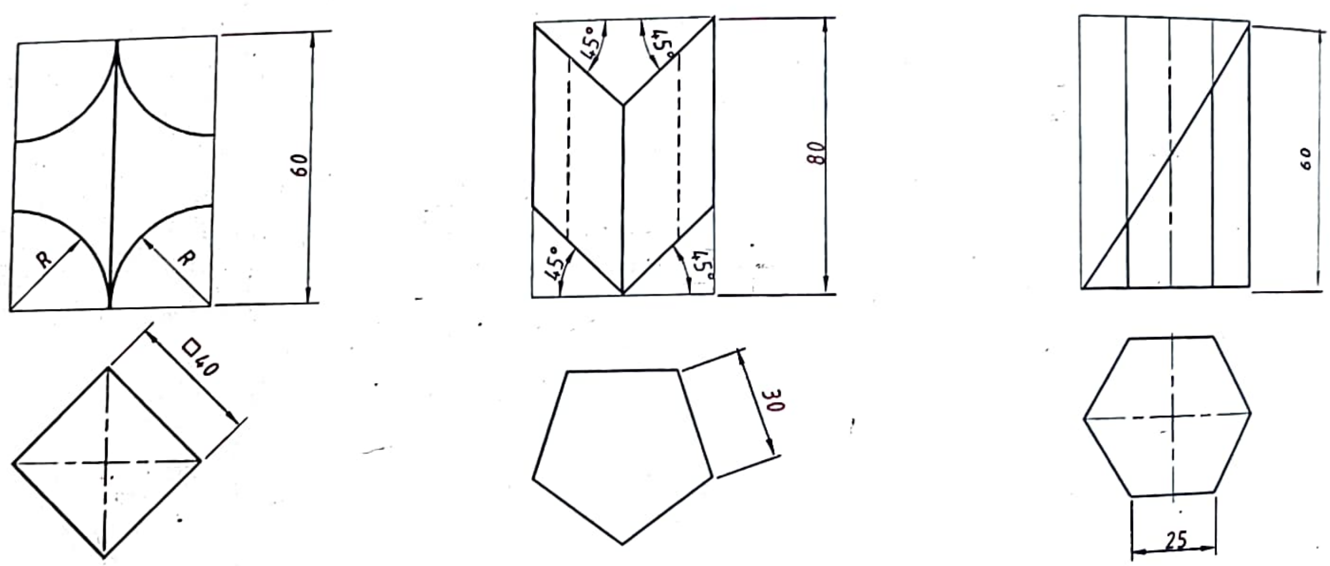
Step 18 : Delete the arcs that you had drawn from point O to various points from A to A. Select all the projector lines and change its line width to 0.25 mm. This completes the development drawing as shown in the *Fig. 5.40*.

Sheet1

EXERCISE 5

Development of Prisms

1. A pentagonal prism of 30 mm side of base and height 50 mm lies with its base on HP such that one of the rectangular faces is inclined at 30° to VP. It is cut to the shape of a truncated prism with the truncated surface inclined at 30° to the axis so as to pass through a point on it 30 mm above the base. Develop the truncated portion of the prism so as to produce a one-piece development.
2. A vertical pentagonal prism 30 mm side of base and height 60 mm has one of its rectangular faces parallel to *VP* and nearer to it. A through square hole of 25 mm sides is made in the centre of the prism such that the axis of the hole bisects the axis of the prism at right angles. The edges of the hole are equally inclined to *HP*. Draw the development of the prism showing the shape of the hole produced by it.
3. A regular pentagonal prism of height 60 mm and base edge 30 mm rests with its base on HP. The vertical face closest to *VP* is parallel to it. Draw the development of the truncated prism with its truncated surface inclined at 60° to its axis and bisecting it.
4. A hexagonal prism 30 mm side of base and axis 60 mm stands vertically with one of its rectangular faces parallel to *VP*. Two semicircular holes of diameter 50 mm are drilled through the lateral faces of the prism such that the top face and the base of the prism contain the flat portions of the semicircular hole and their axes intersect the axis of the prism at right angles. Draw the development of the lateral faces of the prism showing the true shapes of the holes on it.
5. *Fig. 5.41* shows the top and front views of the following prisms. Draw the development of the retained portions of the prism which are shown in dark lines.
(i) Square prism. *Fig.5.41A.* (ii)Pentagonal prism *Fig. 5.41B.* (iii) Hexagonal prism. *Fig. 5.41C.*



A B C

All dimensions in mm

Fig. 5.41

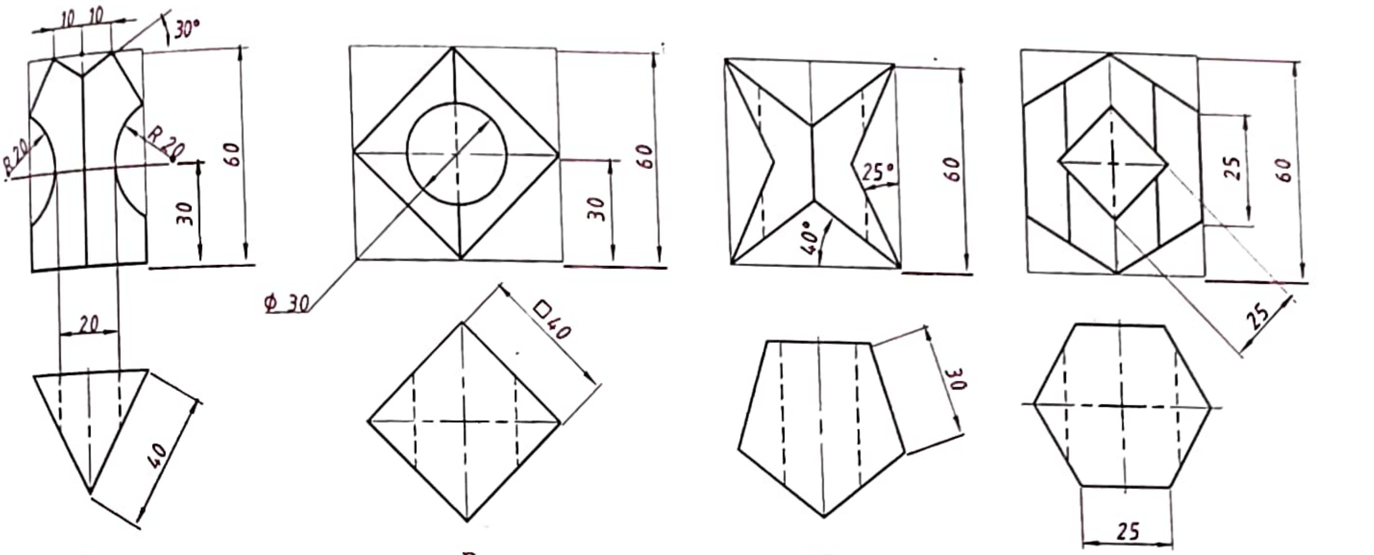
6. *Fig. 5.42* shows the front views of the following prisms. Draw the development of the retained portions of the prism which are shown in dark lines.

   a) A triangular prism with one of its rectangular faces parallel to *VP* and nearer to it is cut as shown in *Fig. 5.42A.*

   b) A square prism with all of its lateral faces making equal inclinations with *VP* is cut as shown in *Fig. 5.42B.*

   c) A pentagonal prism with one of its rectangular faces parallel to *VP* and nearer to it is cut as shown is *Fig.5.42C.*

   d) A hexagonal prism with two of its parallel faces parallel to *VP* is cut as shown in *Fig. 5.42D.*



All dimensions in mm

Fig. 5.42

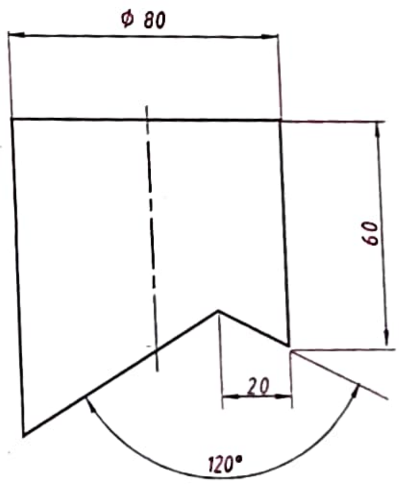
Development of Cylinders

7. A cylinder of 50 mm diameter of base and 60 mm height rests with its base on *HP*. A through square hole is drilled on the lateral surface of the cylinder in such a way that the axis of the hole bisects the axis of the cylinder at right angles. The sides of the hole are equally inclined to *HP* and measures 30 mm. Develop the lateral surface of the cylinder showing the shapes of the holes on it.

8. A vertical chimney of circular section of 400 mm diameter joins a roof sloping at 35° to the horizontal. The shortest portion of the chimney over the roof is 300 mm. Determine the shape of the sheet metal from which the chimney can be made. Use 1 : 10 scale.

9. *Fig. 5.43* shows the front view of a model of a steel chimney of diameter 80 mm made from a flat thin sheet metal fitted over an inclined plane roof.

   Develop the portion of the chimney and determine the true shape of the hole in the flat faces of the roof. Use 1 : 1 scale.

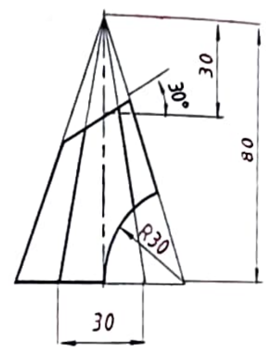


All dimensions in mm

Fig.5.43

Development of Pyramids

10. A square pyramid base 40 mm side and axis 65 mm long has its base on *HP* and all the edges of the base are equally inclined to *VP*. It is cut to the truncated shape with the truncated surface inclined at 45° to its axis bisecting it. Draw the development of the pyramid.
11. *ABCD* is a trapezium whose sides are *AB* = 50 mm, *BC* = 40 mm, *CD* = 30 mm and *DA* = 40 mm, *AB* is parallel to *CD*. This trapezium has a circle of 20 mm diameter at the intersection of its diagonals. This figure represents the front view of the frustum of a square pyramid with hole at the centre. Obtain the development of its surface.
12. A frustum of a square pyramid has its base 50 mm side, top 20 mm side and height 50 mm. Draw the development of its lateral surface. Also draw the projections of the frustum, when its axis is vertical and a side of base is parallel to *VP*, showing the line joining the mid point of a top edge of one face with the mid point of the bottom edge of the opposite face by the shortest distance in the developed surface. Measure the length of the shortest distance.
13. A hexagonal pyramid, base side 30 mm and height 80 mm, is resting with its base on *HP* and an edge of base inclined at 40° to *XY*. It is cut to into a truncated pyramid with the truncated surface indicated in the front view at a point on the axis 30 mm from the apex and inclined at 40° to *XY*. Draw the projections and show the development of the lateral surface of the remaining portion of the pyramid.
14. A hexagonal pyramid 40 mm side of base and axis 90 mm long is resting on its base on *HP* with one of the edges of the base perpendicular to *VP*. The pyramid is tilted about that edge so that the axis makes 30° to *HP*. It is cut to produce a horizontal surface passing through the mid point of the axis. Develop the lateral surface of the remaining portion of the pyramid.
15. A hole 30 mm diameter is made through the centre of a pentagonal pyramid perpendicular to the axis of the pyramid such that the axis of the hole intersects the axis of the pyramid. The right pyramid has 30 mm sides regular pentagonal base and axis 80 mm long. Develop the lateral surface of the pyramid with the hole in it. The axis of the hole is parallel to one side of the base of the pentagonal pyramid.
16. *Fig.5.44* shows the front view of a truncated hexagonal pyramid of 30 mm side of base and height 80 mm. Draw the development of the lateral surface of the truncated pyramid.



All dimensions in mm

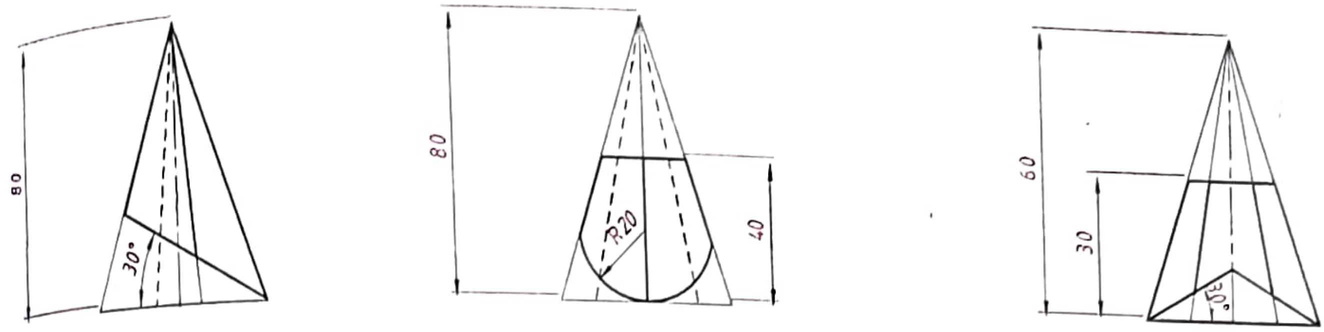
Fig. 5.44

17. A vertical axis hopper has the top portion for 100 mm depth in the form of a square box of 1000 mm side and the next 400 mm depth in the from of the frustum of a hollow square pyramid tapering to a square of 200 mm side and finally extending in the form of a hollow square prism of 200 mm side for bottom 150 mm depth. Develop the surface of the hopper.
18. The inside of a hopper of a flour mill is to be lined with a thin sheet. The top and bottom of the hopper are regular pentagons with each side equal to 400 mm and 300 mm respectively. The height of hopper is 400 mm. Draw the shape to which the thin sheet is to be cut so as to fit into the hopper.
19. *Fig. 5.45* shows the front views of the following pyramids. Draw the development of the retained portions of the prism which are shown in dark lines.

    a) *Fig. 5.44A* shows the front of a square pyramid of 40 mm side of base and height 80 mm is placed with its base on *HP* such that one of the base edges inclined at 30° to *VP*.

b) *Fig. 5.45B* shows the front of a pentagonal pyramid of 30 mm side of base and height 80 mm is placed with its base on *HP* such that one of the base edges is parallel to *VP*.

c) *Fig. 5.45C* shows the front of a hexagonal pyramid of 25 mm side of base and height 80 mm is placed with its base on *HP* such that one of the base edges parallel to *VP*.



A B C

All dimensions in mm
Fig. 5.45

Development of Cones

20. A right circular cone 55 mm diameter and 75 mm high stands on its base on *HP*. It is cut to the shape of the truncated cone with its truncated surface inclined at 45° to the axis lying at a distance of 20 mm from the apex of the cone. Obtain the development of the lateral surface of the truncated cone.

21. A cone of 60 mm diameter and 80 mm height is standing vertically on *HP*. A hole of 40 mm diameter is drilled through the cone such that the axis of the circular hole is perpendicular to *VP* and meets the axis of the cone at a point 20 mm above the base. Draw the development of the lateral surface of the cone with the hole.

22. An equilateral triangle of 50 mm sides having a 20 mm diameter circle at its centre represents the front view of the cone with a circular hole in it. Draw the development of its lateral surface.

23. A right circular cone of base 60 mm diameter and 60 mm height stands vertically with its base on *HP*. A semicircular hole of 36 mm diameter is cut through the cone such that the axis of the hole is parallel to *HP* and perpendicular to *VP* and intersecting the axis of the cone 20 mm above the base. The flat surface of the hole is parallel to *HP* and perpendicular to *VP* and the circular end of the hole lies towards the base. Draw the development of the cone showing the shape of the hole on it.

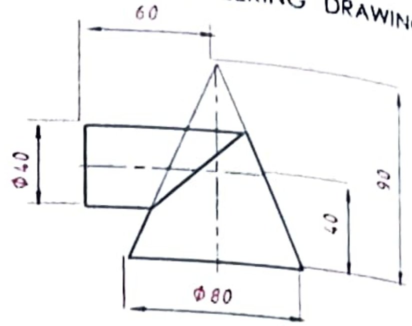
24. A right circular cone of 60 mm diameter and 90 mm height rests with its base on *HP*. A point *P* initially situated at the extreme right end of the base moves around the surface of the cone and finally comes back to the starting point. Find the length of the shortest path the point *P* will take in covering the distance along the surface of the cone. Also show the path in the top and front views.

25. The inside of the hopper of a flour mill is to be lined with a sheet. The top and bottom of the hopper are circular with each equal to 60 cm diameter and 40 cm diameter respectively. The height of the hopper is 56 cm. Draw the shape of the sheet to which it is to be cut so as to fit in the hopper.

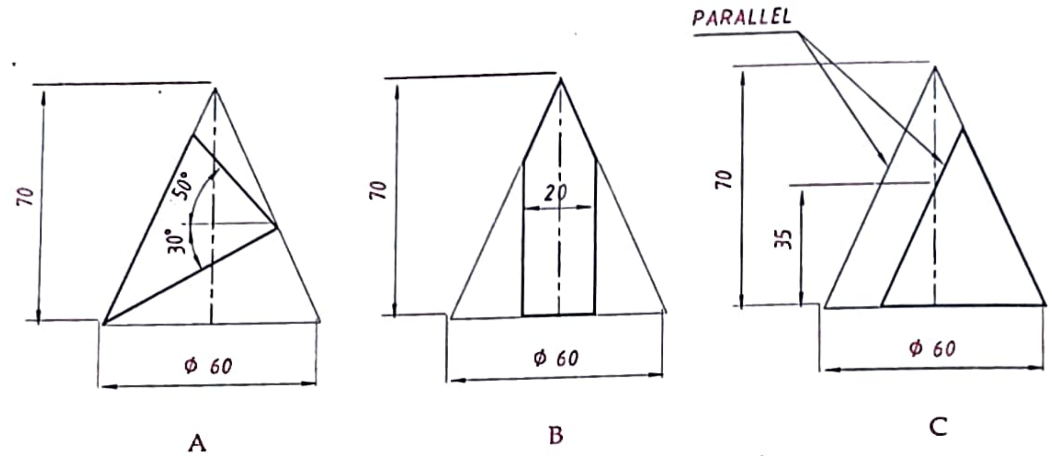
26. A funnel is to be made of sheet metal. The funnel tapers from 60 mm diameter to 30 mm diameter to a height of 25 mm and from 30 mm diameter to 20 mm diameter to a height of 50 mm. The bottom of the funnel is beveled off to a plane inclined at 45° to the axis. Draw the development of the funnel.

27. Draw the development of the joint shown in *Fig. 5.46.*

28. Draw the development of the lateral surface of the portion of the cones shown in thick lines in *Fig. 5.47A, B, C & D.*

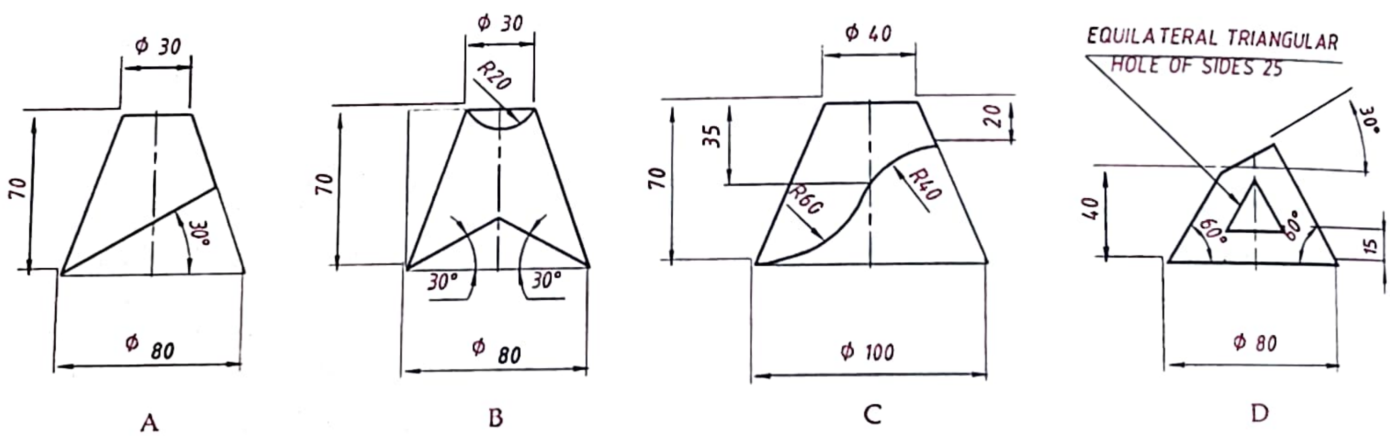


All dimensions in mm
Fig.5.46



All dimensions in mm
Fig. 5.47

29. Draw the development of the lateral surface of the portion of the cones in *Fig. 5.48A, B,C & D.*



All dimensions in mm
Fig. 5.48