Unit 1

Development of Surfaces-1

Structure

1.1 Introduction

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1.3 Development of a Surface

1.4 Application of Development of surfaces in Engineering products

1.5 Development of Prism

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1.1 Introduction

The knowledge of development of surfaces is very useful in the sheet metal industry, where products like utensils, cans, buckets, hoppers, domes, etc. are manufactured. Imagine an industry where domestic refrigerators are manufactured. The ultimate shape of a refrigerator is made from the sheet metal. Its door is first made on a plain sheet and then cut and folded to form the door. To make a funnel out of a sheet, what should be the shape of the sheet which, when folded, forms the final shape of the funnel? A tailor first prepares a development drawing on a cloth to cut and stitch the correct shape and size of a shirt. A development gives the shape and plane area of the material which enables the cost to be estimated. Development should be such as to allow the minimum waste of material when the shape is cut out.

1.2 Objectives

At the end of this chapter you will be able to study:

- Development of a Surface
- Application of Development of surfaces in Engineering products
- Development of Prism
- Development of a Cylinder
- Development of a Pyramid
- Development of a Cone
- Development of a Cube

1.3 Development of a Surface

If a solid is wrapped by thin paper in such a way that the paper does not have wrinkles and also it is not overlapping anywhere, then remove the paper and spread it on a plain surface. The shape of the paper is called the lateral development of that solid or pattern. If the development of the top and the bottom of the solid is also included, then it is called the total development of the
surface. Due to the fact that there is no distorting of the surface in the process of development, every line on the development must necessarily show the true length of the corresponding line on the surface. It is a coordinal principle which must always be kept in mind in constructing all the true developments.

1.4 Application of Development of surfaces in Engineering products

A layout of the complete surface of a three dimensional object on a plane is called the development of the surface or flat pattern of the object. The development of surfaces is very important in the fabrication of articles made of sheet metal.

The objects such as containers, boxes, boilers, hoppers, vessels, funnels, trays etc., are made of sheet metal by using the principle of development of surfaces. In making the development of a surface, an opening of the surface should be determined first. Every line used in making the development must represent the true length of the line (edge) on the object.

The steps to be followed for making objects, using sheet metal are given below:

1. Draw the orthographic views of the object to full size.
2. Draw the development on a sheet of paper.
3. Transfer the development to the sheet metal.
4. Cut the development from the sheet.
5. Form the shape of the object by bending.
6. Join the closing edges.

Note: In actual practice, allowances have to be given for extra material required for joints and bends. These allowances are not considered in the topics presented in this chapter.

1.5 Development of Prism

To draw the development of a square prism of side of base 30mm and height 50mm.

Construction (Fig.1.1)
1. Assume the prism is resting on its base on H.P. with an edge of the base parallel to V.P and draw the orthographic views of the square prism.

2. Draw the stretch-out line 1-1 (equal in length to the circumference of the square prism) and mark off the sides of the base along this line in succession 1-2, 2-3, 3-4 and 4-1.

3. Erect perpendiculars through 1, 2, 3 etc., and mark the edges (folding lines) I-A, 2-B, etc., equal to the height of the prism 50 mm.

4. Add the bottom and top bases 1234 and ABed by the side of an) of the base edges.
1.6 Development of a Cylinder

Procedure

(a) Draw a plan and elevation of a cylinder with the given dimensions.

(b) Divide a circle (of the plan) in a number of equal parts (say 8) by drawing diameters. Project these divisions in the elevation. Each line in the elevation represents a generator.

![Diagram showing division of a circle into equal parts and projection in elevation]

(c) Draw horizontal lines on the side of the elevation. These lines are called stretch-out lines (A A and A₁, A₁). The length of these lines is equal to the circumference of the cylinder $\pi \times D$, where D is the diameter of the cylinder.

(d) Divide the stretch-out line into the same number of equal parts in which the plan circle has been divided (here, eight parts).

(e) The rectangle (A A A₁ A₁), so obtained, is the development of the lateral surface of the cylinder.
1.6.1 Development of the Surface of a Truncated Cylinder

Procedure

(a) Draw the front and top views of a truncated cylinder.

(b) Divide the base circle into a number of equal parts and project the generator on the front view.

c) Mark the points of intersection $a_1, b_1, c_1$, etc, between the generators and the truncated zone of the cylinder.

(a) Draw the stretch-out line equal to the circumference of the base of the cylinder.

(b) Divide the stretch-out line into the same number of equal parts as that of the base and draw the generators through them.

(c) Locate the points $A_1, B_1$, and $C_1$, etc. by a smooth curve.
1.7 Development of a Pyramid

A pyramid is a geometric solid with slant surfaces as isosceles triangles meeting at a point called apex and a base called polygon. A right and regular pyramid is that whose axis is perpendicular to the base and the base is a regular polygon. A right regular triangular, square, pentagonal and hexagonal pyramid is shown in Figures 1.7(a), (b), (c) and (d) respectively.

![Fig. 1.7](image)

1.7.1 Development of the Surface of a Square Pyramid

Procedure

(a) Draw the front and top view of the square pyramid.

b) For determining the true length of the slant edge 2.0, rotate the line 0-2° about 0 till it becomes parallel to HP. Say, the new position is 0-2°.
Project $2^\circ$ in the elevation and on the locus (horizontal line) of 2". The new point of intersection is 2" with 0". The length 0"-2" is the true length of the slant edge 0.

Take radius equal to the true length of the slant edge, i.e. 0'-2", and with any centre 01 draw an arc of a circle. Select any point 1 on the arc and join it with 01. With 1 as the centre and the radius equal to the base side of the pyramid (i.e. 50 mm), cut four divisions on the arc of the circle and mark them 1, 2, 3, 4 etc. Join 1, 2, 3 and 4 with 01. Join 1 with 2, 2 with 3, 3 with 4 and 4 with 1 by straight lines. These four isosceles triangles represent the lateral development of the pyramid.

1.7.2 Development of the Surface of a Truncated Pyramid

Procedure

(a) Draw the plan and elevation of the prism of Height H and side of base length L (Right regular square pyramid), base 1, 2, 3, 4 and apex as 0.

(b) It is cut by a horizontal cutting plane cutting the slant edges at a, b, c, d in plan and at a’, b’, c’, d’ in elevation.
(c) None of the line 01, 02, 03 or 04 show the true length of the slant edge. Therefore, draw any one line say 01 horizontal (Parallel to XY) and determine the true length 0′ 1′. Through a’ draw a horizontal line and obtain the true length o a1′.

(d) With o as center and radius o′1’ (true slant height) draw arc and mark 1, 2, 3, 4 and obtain the development of lateral surface of the pyramid.

(e) With o as center and radius o’ a” draw an arc cutting 01, 02, 03, and 04 at A, B, C, and D respectively. Draw line AB, BC, CD and DA and complete the development.

### 1.8 Development of a Cone

**Construction (Fig. 1.8)**

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

The cube is a regular polyhedra consisting of six equal faces, each a square.

Procedure

(d) Draw the elevation and plan of a cube resting on its base in HP with two of its vertical faces parallel to VP as shown in Figure 1.9(a).

(e) Mark the top and the bottom face as a, b, c, d and e, f, g, h, respectively, in plan and elevation.
(f) Note carefully the corners of the cube which are lettered. Develop the surface along the edges EF, FG, GH, EH and DC to get the complete development of the cube as in Figure 6.2(b).

![Diagram](image.png)

**Fig 1.9**

### 1.10 Summary

If a solid is wrapped by thin paper in such a way that the paper does not have wrinkles and also it is not overlapping anywhere, then remove the paper and spread it on a plain surface. The shape of the paper is called the lateral development of that solid or pattern. If the development of the top and the bottom of the solid is also included, then it is called the total development of the surface.

### 1.11 Keywords

- Surface
- Prism
- Cylinder
1.12 Exercise

1. A frustrum of a square pyramid has its base 50 mm side, top 25 mm side and height 60 mm. It is resting with its base on HP, with two of its sides parallel to VP. Draw the projections of the frustrum and show the development of its lateral surface.

2. A cone of diameter 60 mm and height 80 mm is cut by a section plane such that the plane passes through the mid-point of the axis and tangential to the base circle. Draw the development of the lateral surface of the bottom portion of the cone.

Unit 2
Development of Surface-2

Structure

2.1 Introduction

2.2 Objectives

2.3 Methods of development

2.4 Developments of lateral surfaces of right solids

2.5 Summary

2.6 Keywords
2.1 Introduction

Imagine that a solid is enclosed in a wrapper of thin material, such as paper. If this covering is opened out and laid on a flat plane, the flattened-out paper is the development of the solid. Thus, when surfaces of a solid are laid out on a plane, the figure obtained is called its development.
Fig. 2.1

Fig. 2-1 shows a square prism covered with paper in process of being opened out. Its development (fig. 2-2) consists of four equal rectangles for the faces and two similar squares for its ends. Each figure shows the true size and shape of the corresponding surface of the prism. The development of a solid, thus represents the actual shape of all its surfaces which, when bent or folded at the edges, would form the solid.

Hence, it is very important to note that every line on the development must be the true length of the corresponding edge on the surface.

The knowledge of development of surfaces is essential in many industries such as automobile, aircraft, ship building packaging and sheet-metal work. In construction of boilers, bins, process-vessels, hoppers, funnels, chimneys etc., the plates are marked and cut according to the developments which, folded, form the desired objects. The form of the sheet obtained by laying all the outer surfaces of the solid with suitable allowances for the joints is known as pattern.

Only the surfaces of polyhedra (such as prisms and pyramids) and single-curved surfaces (as of Cones and cylinders) can be accurately developed. Warped and double-curved surfaces are undevelopable. These can however be approximately developed by dividing them up into a number of parts.

2.2 Objectives

At the end of this chapter you will be able to study:

- Methods of development
- Developments of lateral surfaces of right solids

2.3 Methods of development
The following are the methods of development:

**Parallel development:** It is employed in case of prisms and cylinders in which stretch-out-line principle is used, Lines A-A and A₁-A₁ in fig. 2-2 are called the stretch-out lines.

![Fig. 2.2](image)

**ii. Radial-line development:** It is used for pyramids and cones which the true length of the slant edge or the generator as radius.

**iii. Triangulation development:** This is used to develop transition pieces. This is simply a method of dividing a surface into a number of triangles and transferring them into the development.

**iv. Approximate method:** It is used to develop objects of double curved or warped surfaces as sphere, paraboloid, ellipsoid, hyperboloid and helicoid.

2.4 Developments of lateral surfaces of right solids

The methods of drawing developments of surfaces of various solids are explained by means of the following typical problems. Only the lateral surfaces of the solids (except the cube) have
been developed. The ends or bases have been omitted. They can be easily incorporated if required.

(i) **Cube**: The development of the surface of a cube consists of six equal squares, the length of the side of the squares being equal to the length of the edge of the cube.

**Problem 1.** Draw the development of the surface of the part P of the cube, the front view of which is shown in fig. 2-3(i)

![Fig. 2.3](image)

Name all the corners of the cube and also the points at which the edges are cut.

(i) Draw the stretch-out lines A-A and E-E directly in line with the front view, and assuming the cube to be whole, draw four squares for the vertical faces one square for the top and another for the bottom as shown in fig. 2-3(ii).

(ii) Name all the corners. Draw a horizontal line through 1 to cut AE at 1 and DH at 4. a b is the true length of the edge. Hence, mark a point 2 on AB and 3 on CD such that A2 a 2 and C3 c 3. Mark the point 3 on CD in the top square also.

(iii) Draw lines 1-2, 2-3, 3-4 and 4-1, and complete the development as shown. Keep lines for the removed portion, viz. A1, A2, 3D, D4 and DA thin and fainter.
Problem 2: Draw the development of the surface of the part P of the cube shown in two views in fig. 2-4(i).

Name all the corners of the cube and also the points at which the edges are cut. Draw the development assuming the cube to be whole [fig. 2-4(ii) as explained in problem 1.

i. Draw horizontal lines through Points 1, 2 and 5 to cut AE in 1, BF in 2 and DH in 5 respectively. Lines b’c’ and c’d’ do not show the true lengths of the edges. The sides of the square in the top view show the true length. Therefore mark points 3 in BC and 4 in CD such that B3 = b3 and C4 = c4.

ii. Draw lines joining 1, 2, 3 etc. in correct sequence and complete the required development. Keep the lines for the removed part fainter.

iii. Prisms: Develop of the lateral surface of a prism consists of the same number of rectangles in contact as the number of the sides of the base of the prism. One side of the rectangle is equal to the length of the axis and the other side equal to the length of the side of the base.
**Problem 3:** Draw the development at the lateral surface of the pentagonal prism shown in fig. 2-5(i).

Name the corners of the prism and the points at which are cut.

i) Draw the development assuming the prism to be whole 2-5(ii). It is made up of five equal rectangles

ii) Draw horizontal lines through points 1, 2 etc to cut the lines for the corresponding edges in the development at points 1, 2 etc.

iii) Draw lines joining these points and complete the development as shown.

![Fig. 2.5](attachment:image)

**Problem 4.** Draw the development of the lateral surface of the part P of the triangular prism shown in fig. 2-6(i).

Draw the development of the lateral surface of the whole prism (fig. 2-6(ii)) and obtain points 1, 2 and 3 on it. Draw lines 1B, Cl, D2, 2-3 and 3D, and complete the development as shown.
(iii) Cylinders: The development of the lateral surface of a cylinder is a rectangle having one side equal to the circumference of its base-circle and the other equal to its length.

**Problem** Develop the lateral surface of the truncated cylinder shown in fig. 2-7(i).
i. Divide the circle in the top view into twelve equal parts. Project the division-points to the front view and draw the generators. Mark points a, b and b1, c and c1 etc. in which the generators are cut.

ii. Draw the development of the lateral surface of the whole cylinder along with the generators fig 2-7(ii). The length of the line 1-1 is equal to $\pi \times D$ (circumference of the circle). This length can also be marked approximately by stepping off with a bow divider, twelve divisions, each equal to the chord-length ab. (The length thus obtained is about 1% shorter than the exact length; but this is permitted in drawing work.)

iii. Draw horizontal lines through points a, b and b1 etc. to cut the corresponding generators in points A, B and B1 etc. Draw a smooth curve through the points thus obtained. The figure 1-A-A-1 is the required development.

**Problem:** Draw the development of the lateral of the part P of the cylinder shown in, fig. 2-8(i).

![Fig.2.8](image)
Draw the develop as explained in problem B. Positions of the points at which the upper end of the cylinder is cut should be obtained from the top view. Mark these points viz., F and F₁, on the line 1₁-1₁, between points 5₁ and 6₁ and between 8₁ and 9₁ in such a way that 6₁F = 6₁f and 8₁F₁ = 8₁f₁. Draw curves FA and F₁A passing through these points and complete the required development as shown.

Fig. 2.9

iv) Pyramids: The development of the lateral surface of id consists of a number of equal isosceles triangles in contact. The base and the sides of each triangle are respectively equal to the edge of the base and the slant edge pyramid.

The true length of a slant edge of pyramid can be measured from the front view, if the top view of that edge is parallel to xy; and it can be measured from the top view, if the slant edge is parallel to xy in the front view.

Methods of drawing the development of the lateral surface of a pyramid:

i. With any point 0 as centre and radius equal to the true length of the slant edge of the pyramid, draw an arc of the circle. With radius equal to the true length of the side of the base, step-off (on this arc) the same number of divisions as the number of sides of the base.
ii. Draw lines joining the division-points with each other in correct sequence and also with the centre for the arc. The figure thus formed (excluding the arc) is the development of the lateral surface of the pyramid.

**Problem 15.** Draw the development of the lateral surface of the part P of the triangular pyramid shown in fig. 2-10(i). The line o 1 in the front view is the true length of the slant edge because it is parallel to xy in the top view. The true length of the side of the base is seen in the top view.

i) Draw the development of the lateral surface of the whole pyramid [fig. 2.10(ii)] as explained above. On 01 mark a point A such that OA = o a (with which o 3 coincides) is not the true length of slant edge.

ii) Hence, through b, draw a line parallel to the base and cutting o a at b. o b is the true length of o b as well as o c. Mark a point B in O2 and C in O3 such that OB = OC = o b.

iii) Draw lines AB, BC and CA and complete the required development as shown. Keep the arc and the lines for the removed part fainter.
**Problem** Draw the development of the lateral surface of the frustum of the square pyramid shown in fig. 2-11(i).

(i) Determine the position of the apex. None of the lines in the front view shows the true length of the slant edge. Therefore, draw the top view and make any one line (for the slant edge) horizontal, i.e. parallel to xy and determine the true length o l₁. Through a, draw a line parallel to the base and obtain the true length o a. 

ii) With O as centre and radius o l₁, draw an arc and obtain the development of the lateral surface of the whole pyramid [fig. 2-11(ii)]. 

iii) With centre O and radius o a, draw an arc cutting O1, O2 etc. at points A, B etc. respectively.

iv) Draw lines AB, BC, CD and DA and complete the required development. Note that these lines are respectively parallel to lines 1-2, 2-3 etc.
v) **Cone:** The development of the curved surface of a cone is a sector of a circle, the radius and the length of the arc of which are respectively equal to the slant height and the circumference of the base-circle of the cone.

**Problem:** Draw the development of the lateral surface of the truncated cone shown in fig. 2-12(i).

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

i. Draw the base-circle in the top view and divide it into twelve equal parts.

ii. With any point O as centre and radius equal to o1 or o7, draw an arc of the circle (fig. 2.12(ii)). The length of this arc should be equal to the circumference of the base-circle. This can be determined in two ways.

iii. Calculate the subtended angle $\theta$ by the formula,
Cut-off the arc so that it subtends the angle $\theta$ at the centre and divide it into twelve equal parts.

iv. Step-off with a bow-divider twelve equal divisions on the arc, each, equal to one of the divisions base-circle (This will give an approximate length of the circumference. Note that the base-circle should not be divided into less than twelve equal parts.)

v. Join the division-points with $0$, thus completing the development of the whole cone with twelve generators shown in it (fig. 2.12(ii))

vi. The truncated portion of the cone may be deducted from this development by marking the positions of points at which generators are cut and then drawing a curve through them. For example, generators $02$ and $0 - 12$ in the front view are cut at points $b$ and $b_1$ which coincide with each other. The true length of $0b$ may be obtained by drawing a line through $b$, parallel to the base and cutting $07$ at $b$. Then $0b$ is the true length of $0b$.

vii. Mark points $B$ and $B_1$ on generators $O2$ and $O-12$ respectively such that $OB = 0B_1$ $0b$. Locate all points in the same way and draw a smooth curve through them. The figure enclosed this curve and the arc is the development of the truncated cone.

**Problem**: Draw the development of the lateral surface of the part $P$ of the cone shown in fig. 2-13(i)
Draw the development as explained in the above problem (fig. 2-13(ii)). For the points at which the base of the cone is cut, mark points A and A₁ on the arcs 2-3 and 11-12 respectively such that A2 = A₁-12= a2. Draw the curve passing this through the points A, B, C etc. The figure enclosed between this curve and the arc A-A₁, is the required development.

2.5 Summary

The following are the methods of development

- Parallel development
- Radial-line development
- Triangulation development
- Approximate method

2.6 Keywords

- Parallel development
- Radial-line development
- Triangulation development
- Approximate method
2.7 Exercise

1. Draw the development of the lateral surface of the part P of each of the solids, the front views of which are shown in fig. 1 and described below.

(a) A cube, one vertical face inclined at 30 to the VP
(b) A pentagonal prism, a side of the base parallel to the V.P.
(c) A hexagonal prism, two faces parallel to the V.P.
(d) A square prism, length of the side of the base 20mm and all faces equally inclined to the V.P.

Unit 3

Screw Threads

Structure

3.1 Introduction

3.2 Objectives

3.3 Terminology used in the screw threads

3.4 Triangular Threads

3.5 ISO metric screw thread
3.1 Introduction

The designers interpret the requirements shown on the proposal drawing, study the accompanying specifications, and begin thinking out solutions. The solutions are recorded in technical sketches. In the technical sketch the designer puts down the important factors - general shapes, clearances to be checked, structural investigations, functional requirements and basic manufacturing processes that may be used. The designer must exercise ingenuity in making approximations before an accurate stress analysis is made to decide actual sizes. Technical sketches are not discarded, they are valuable because they record most of the ideas and the directions that contribute to the final design. As much thinking and planning as possible should be shown in the rough sketches. This expedites a more direct solution and lessens the possibility of having to change design principles completely on the carefully drawn layout.
3.2 Objectives

At the end of this chapter you will be able to study:

- Terminology used in the screw threads
- Triangular Threads
- Types of Nut
- Washer
- Bolt
- Locking arrangement for nut
- Rivets and Rivetted Joints.

3.3 Terminology used in the screw threads

A screw thread, often shortened to thread, is a helical structure used to convert between rotational and linear movement or force. A screw thread is a ridge wrapped around a cylinder or cone in the form of a helix, with the former being called a straight thread and the latter called a tapered thread. More screw threads are produced each year than any other machine element.

The mechanical advantage of a screw thread depends on its lead, which is the linear distance the screw travels in one revolution. In most applications, the lead of a screw thread is chosen so that friction is sufficient to prevent linear motion being converted to rotary, that is so the screw does not slip even when linear force is applied so long as no external rotational force is present. This characteristic is essential to the vast majority of its uses. The tightening of a fastener's screw thread is comparable to driving a wedge into a gap until it sticks fast through friction and slight plastic deformation.

Thread Terminology
A. FULL DIAMETER SHANK:
   Equal to major diameter of thread. Produced by cut thread or by roll thread on extruded blank. Characteristic of machine bolts and cap screws.

B. UNDERSIZED SHANK:
   Equal approximately to pitch diameter of thread. Produced by roll threading a non-extruded blank. Characteristic of machine screws.

C. PITCH DIAMETER: The simple, effective diameter of screw thread. Approximately half way between the major and minor diameters.

D. MAJOR DIAMETER: The largest diameter of a screw thread.

E. MINOR DIAMETER: The smallest diameter of a screw thread.
LEAD: The distance a screw thread advances axially in one turn.

CUT THREAD: Threads are cut or chased; the unthreaded portion of shank will be equal to major diameter of thread.

ROLLED THREAD: Threads are cold formed by squeezing the blank between reciprocating serrated dies. This acts to increase the major diameter of the thread over and above the diameter of unthreaded shank (if any), unless an extruded blank is used. Classes of thread are distinguished from each other by the amounts of tolerance and allowance specified. External threads or bolts are designated with the suffix "A"; internal or nut threads with "B".

CLASSES 1A and 1B: For work of rough commercial quality where loose fit for spin-on-assembly is desirable.

CLASSES 2A and 2B: The recognized standard for normal production of the great bulk of commercial bolts, nuts and screws.

CLASSES 3A and 3B: Used where a closed fit between mating parts for high quality work is required.

CLASS 4: A theoretical rather than practical class, now obsolete.

CLASS 5: For a wrench fit. Used principally for studs and their mating tapped holes. A force fit requiring the application of high torque for semi-permanent assembly.

3.4 Triangular Threads

The principle of the screw thread has been known for a very long time. Archimedes in ancient Greece knew all about it. The practical problems associated with cutting internal and external screw threads to match prevented widespread use of nuts and bolts until quite recent times. Blacksmiths and engineers of only a century ago avoided screw threads if they could. If they had to make them, a nut would only fit the bolt it was made for. The Industrial Revolution brought standardization and the quantity production of screw threads became possible. Unfortunately, the users of screw threads never agreed on common standards. Today there is more of a standard, but there are still exceptions. Obviously, metric threads differ from those based on inches. Bicycle parts, for instance, are still made with different threads than other things.
Most thread forms are triangular, but these do not all have the same angles. There are other forms, mainly in larger sizes. For general use, triangular threads suit most purposes and screwing tackle is available to cut them. Threads are mostly known by diameter and a number indicating threads per inch. The diameter is that of the rod on which an external thread is cut. A thread described as $\frac{1}{4} \times 20$ means one cut on a $\frac{1}{4}$-inch rod with 20 threads ml inch of length. The hole in which a matching thread would be cut would have to start smaller. This is the tapping size. For the $\frac{1}{4}$-inch thread, the tapping size in most metals should be 13/64 inch. It might have to be slightly larger in hard steel, and could be slightly smaller in softer metals. A table is usually provided with screwing tackle, indicating the size drill to use.

3.5 ISO metric screw thread

The design principles of ISO general-purpose metric screw threads ("M" series threads) are defined in international standard ISO 68-1. Each thread is characterized by its major diameter $D$ and its pitch $P$. ISO metric threads consist of a symmetric V-shaped thread. In the plane of the thread axis, the flanks of the V have an angle of 60° to each other. The outermost 1/8 and the innermost 1/4 of the height $H$ of the V-shape are cut off from the profile.

The relationship between the height $H$ and the pitch $P$ is found using the following equation:

$$H = \cos(30^\circ) \cdot P = \frac{\sqrt{3}}{2} \cdot P \approx 0.866 \cdot P$$

In an external (male) thread (e.g., on a bolt), the major diameter $D_{\text{maj}}$ and the minor diameter $D_{\text{min}}$ define maximum dimensions of the thread. This means that the external thread must end flat at $D_{\text{maj}}$, but can be rounded out below the minor diameter $D_{\text{min}}$. Conversely, in an internal (female) thread (e.g., in a nut), the major and minor diameters are minimum dimensions, therefore the thread profile must end flat at $D_{\text{min}}$ but may be rounded out beyond $D_{\text{maj}}$. 
The minor diameter $D_{\text{min}}$ and effective pitch diameter $D_p$ are derived from the major diameter and pitch as

$$D_{\text{min}} = D_{\text{maj}} - 2 \cdot \frac{5}{8} \cdot H = D_{\text{maj}} - \frac{5\sqrt{3}}{8} \cdot P \approx D_{\text{maj}} - 1.082532 \cdot P$$

$$D_p = D_{\text{maj}} - 2 \cdot \frac{3}{8} \cdot H = D_{\text{maj}} - \frac{3\sqrt{3}}{8} \cdot P \approx D_{\text{maj}} - 0.649519 \cdot P$$

**Designation**

A metric ISO screw thread is designated by the letter M followed by the value of the nominal diameter $D$ ($D_{\text{maj}}$ in the diagram above) and the pitch $P$, both expressed in millimetres and separated by the multiplication sign, $\times$ (e.g., M8×1.25). If the pitch is the normally used "coarse" pitch listed in ISO 261 or ISO 262, it can be omitted (e.g., M8). Tolerance classes defined in ISO 965-1 can be appended to these designations, if required (e.g., M500–6g in external threads). External threads are designated by lowercase letter, $g$ or $h$. Internal threads are designated by upper case letters, $H$ or $G$.

### 3.6 Screw Fastening

A **screw**, or **bolt**, is a type of **fastener** characterized by a **helical** ridge, known as an **external thread** or just **thread**, wrapped around a cylinder. Some screw threads are designed to mate with a complementary thread, known as an **internal thread**, often in the form of a **nut** or an object that has the internal thread formed into it. Other screw threads are designed to cut a helical groove in a softer material as the screw is inserted. The most common uses of screws are to hold objects together and to position objects.

### 3.7 Types of Nut

**Hexagonal nut**
A standard six sided nut.

Square nut

A square nut is a four-sided nut. Compared to standard hex nuts, square nuts have a greater surface in contact with the part being fastened, and therefore provide greater resistance to loosening (though also greater resistance to tightening). They are also much less likely to become rounded-off after repeated loosening/tightening cycles. Square nuts are typically mated with square-headed bolts. Their easy square design helps in smooth removal and installation. Square nuts are used along with flat washers in order to avoid destruction because of sharp edges and help in increasing strength of fastener.
Flange nut

A **flange nut** has a wide **flange** at one end that acts as an integrated, non-spinning washer. This serves to distribute the pressure of the nut over the part being secured, reducing the chance of damage to the part and making it less likely to loosen as a result of an uneven fastening surface. **MATERIAL USED:** These nuts are mostly hexagonal in shape and are made up of hardened steel and coated with zinc.

![Flange nut image](image1)

Cap nuts

A nut with a finished top that covers the end of the bolt. Bolts must be in the proper length.

![Cap nut image](image2)

Capstan nut

A nut resembling the head of a capstan and operated by a bar inserted in one of several holes about its periphery

Wingnut
Wingnut is a nut with a pair of wings to enable it to be turned without tools, used where frequent adjustments are needed or part removal can be made quickly at some later stage.

3.8 Washer

A washer is a thin plate (typically disk-shaped) with a hole (typically in the middle) that is normally used to distribute the load of a threaded fastener, such as a screw or nut. Other uses are as a spacer, spring, wear pad, preload indicating device, locking device, and to reduce vibration (rubber washer). Washers usually have an outer diameter (OD) about twice the length of their inner diameter (ID).

Washers are usually metal or plastic. High quality bolted joints require hardened steel washers to prevent the loss of pre-load due to Brinelling after the torque is applied.

3.9 Bolt
Bolt, is a type of fastener characterized by a helical ridge, known as an external thread or just thread, wrapped around a cylinder. Some screw threads are designed to mate with a complementary thread, known as an internal thread, often in the form of a nut or an object that has the internal thread formed into it. Other screw threads are designed to cut a helical groove in a softer material as the screw is inserted. The most common uses of screws are to hold objects together and to position objects.

3.10 Types of Bolts

Hexagonal Headed bolts

A standard wrench head bolt with a hexagonal head.

Square Bolts
Square head machine bolts were the industry standard prior to hex bolts gaining prominence. Square bolts are now most commonly used for aesthetic purposes to provide a rustic look in a new structure or to match existing fasteners in an older structure. Square lag screws are also used for these purposes.

Cup Head Square Neck Bolt/Carriage Bolts

Cup Head Square Neck Bolts, which is widely used in both marine as well as treated wood applications because of their heavy galvanization. Apart from that, these are also used in numerous other industries. These consist of rounded head with four nubs or fins, which prevent the bolt from turning in the timber. Backed by our experienced technical experts, we are capable of customizing these on the parameters of various grades, shapes, sizes and thickness.
**T- Bolts**

These bolts are procured from established vendors and are fabricated in compliance with international quality standards. Our range of T-Bolts is quality tested on various parameters to ensure defect free assortment reaches at client’s end. T-Bolts offered by us are widely used in various sectors such as refineries, petrochemicals, pesticides, fertilizers and many more. These are highly acknowledged for their salient features such as accurate construction, heat and moisture resistance, efficient performance and long functional life. Our range of T-Bolts is precision engineered in T-Bolt shapes, and is available in custom made specifications as per customer’s requirements.

**Countersunk Bolts**

Countersunk bolts are used when a smooth surface is required. Common applications include: bridge decking, walkways, and railing.
Hook Bolt

A bolt with a hook or L band at one end and threads at the other to fit a nut.

Eye Bolt

An eye bolt is a screw with a loop on one end and threads on the other end. Eye bolts are commonly used to attach cables to objects, for instance attaching a string to the back of a painting to allow the painting to hang from a nail on a wall.
3.11 Locking arrangement for nut

When nuts screwed on to bolts are subjected to vibrations, they have a tendency to get loose. In such cases, some arrangements are needed for locking the nuts in position.

Nuts can be locked in position by:

(i) Increasing pressure and thereby also increasing frictional force between the threads of the nut and those of the bolt (which are assembled together). Examples of this are lock nuts, sawn nuts and spring washers.

(ii) Providing a stop to prevent either the rotation or the axial movement of the nut. Examples of this are split pins, slotted nuts, castle nuts and locking plates. Let us look at these examples.

(I) Locking by a check nut or a lock nut: Figure 19.49 shows an arrangement where a nut is locked in position with the help of another nut called the lock nut. A lock nut is chamfered on both the hexagonal faces. An ordinary nut is sawed on a bolt in the usual way and then the lock nut is screwed over it and tightened. Holding this nut by a spanner, the first nut is then turned back by another spanner. As a result the threads of the two nuts press the threads of the bolt in opposite directions and lock themselves in these positions. In this arrangement, the axial load is carried by the second nut which should be of normal height while the height of the other nut may be half or two-third of the normal height.
Figure 3.11.2 shows the lock nut in the proper position. But, a smaller nut at the bottom necessitates the use of a thin spanner. As a compromise, both the nuts are made of the same height equal to about 0.8 times the normal height.
(II) **Locking by a sawn nut or wiles nut**: As shown in Figure 3.11.3, a sawn nut is an ordinary hexagonal nut with a saw cut starting.

### 3.13 Rivets and Rivetted Joints.

Rivets are considered to be permanent fasteners. Riveted joints are therefore similar to welded and adhesive joints. When considering the strength of riveted joints similar calculations are used as for bolted joints.

Rivets have been used in many large scale applications including shipbuilding, boilers, pressure vessels, bridges and buildings etc. In recent years there has been a progressive move from riveted joints to welded, bonded and even bolted joints. A riveted joint, in larger quantities is sometimes cheaper than the other options but it requires higher skill levels and more access to both sides of the joint.

There are strict standards and codes for riveted joints used for structural/pressure vessels engineering but the standards are less rigorous for using riveted joints in general mechanical engineering.

A rivet is a cylindrical body called a shank with a head. A hot rivet is inserted into a hole passing through two clamped plates to be attached and the head is supported whilst a head is formed on the other end of the shank using a hammer or a special shaped tool. The plates are thus permanently attached. Cold rivets can be used for smaller sizes the - forming processes being dependent on the ductility of the rivet material...
When a hot rivet cools it contracts imposing a compressive (clamping) stress on the plates. The rivet itself is then in tension the tensile stress is approximately equal to the yield stress of the rivet material.

**Strength of riveted joint**

The notes below are assuming that the plate loads are withstood by the rivets. In practice the loads are generally withstood by friction between the plates under the compressive force of the contracted rivets. The calculations provided below are simplified but provide relatively conservative joint strength value. There is still a need to complete fatigue assessments on joints when relevant.

**Joint Types**

There are two basic types of axial riveted joint the lap joint and the butt joint.

![Riveted Lap Joint and Riveted Butt Joint](image)

The selection of the number of rivets used for a joint and the array is simply to ensure the maximum strength of the rivets and the plates. If ten small arrayed rivets on a lap joint were replaced by three large rivets across a plate the plate section area (in tension) would clearly be significantly reduced...

**3.14 Summary**

A **screw thread**, often shortened to **thread**, is a **helical** structure used to convert between rotational and linear movement or force. A screw thread is a ridge wrapped around
a **cylinder** or **cone** in the form of a helix, with the former being called a *straight* thread and the latter called a *tapered* thread. More screw threads are produced each year than any other machine element.

A **rivet** is a permanent mechanical **fastener**. Before being installed a rivet consists of a smooth **cylindrical** shaft with a head on one end. The end opposite the head is called the *buck-tail*. On installation the rivet is placed in a punched or pre-drilled hole, and the tail is *upset*, or *bucked* (i.e. deformed), so that it expands to about 1.5 times the original shaft diameter, holding the rivet in place. To distinguish between the two ends of the rivet, the original head is called the *factory head* and the deformed end is called the *shop head* or buck-tail.

### 3.15 Keywords

- Square nut
- Flange nut
- Cap nuts
- Capstan nut
- Square Bolts
- T- Bolts
- Countersunk Bolts
- Hook Bolt

### 3.16 Exercise

1) Explain Terminology used in the screw threads
2) Define Triangular Threads
3) List the Types of Nut
4) Define Washer, Bolt
5) Give Types of Bolts
6) Explain Locking arrangement for nut

Unit 4

Free Hand Sketching

Structure

4.1 Introduction
4.1 Introduction

Freehand sketching is one of the effective methods to communicate ideas irrespective of the branch of study. The basic principles of drawing used in freehand sketching are similar to those used in drawings made with instruments. The sketches are self explanatory in making them in the sequence shown (Fig. 4.1 to 4.12).

Fig. 4.1 Sketching Straight Lines
Fig. 4.2 Sketching a Square

Fig. 4.3 Sketch of parallelogram and rhombus
Fig. 4.4 Sketching a Circle
Fig. 4.5 Sketching a Pentagon
Fig. 4.6 Sketching a hexagon and ellipse.
Fig. 4.7 Sketching a cube.
Fig. 4.8 Sketching a hexagonal prism.
Fig. 4.9 Sketching a pentagonal pyramid
Fig. 4.10 Sketching a hollow cylinder and a cone.

Fig. 4.11 Sketching a Ball Peen Hammer

Fig. 4.12 Sketching a Cutting Plier

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