Engineering Graphics

Orthographic Projection — Lines and Solids

3.1 Introduction to Orthographic Projection

Orthographic projection is a method of graphically representing a three-dimensional object by means of two or more related two-dimensional views, each obtained by projecting the object with parallel projectors perpendicular (at right angles) onto a chosen plane of projection. Since a single two-dimensional view cannot fully describe the shape and size of a three-dimensional object, orthographic projection uses a set of related views (commonly the front view, top view, and side view) to completely and unambiguously represent the object's true shape, size, and features, making it the standard method used for the preparation of engineering drawings intended for manufacture and construction.

To obtain these views, two (or more) mutually perpendicular reference planes are used: the Vertical Plane (VP), onto which the front view of the object is projected, and the Horizontal Plane (HP), onto which the top view of the object is projected. These two planes intersect in a reference line, conventionally labelled XY.

Concept of First Angle and Third Angle Projection

The Horizontal Plane (HP) and Vertical Plane (VP), when extended in both directions, divide the surrounding space into four quadrants, numbered I, II, III, and IV, as shown in Figure 1. Depending on which quadrant the object is imagined to be placed in during the construction of its orthographic views, two main projection systems are used in engineering drawing practice: first angle projection and third angle projection.

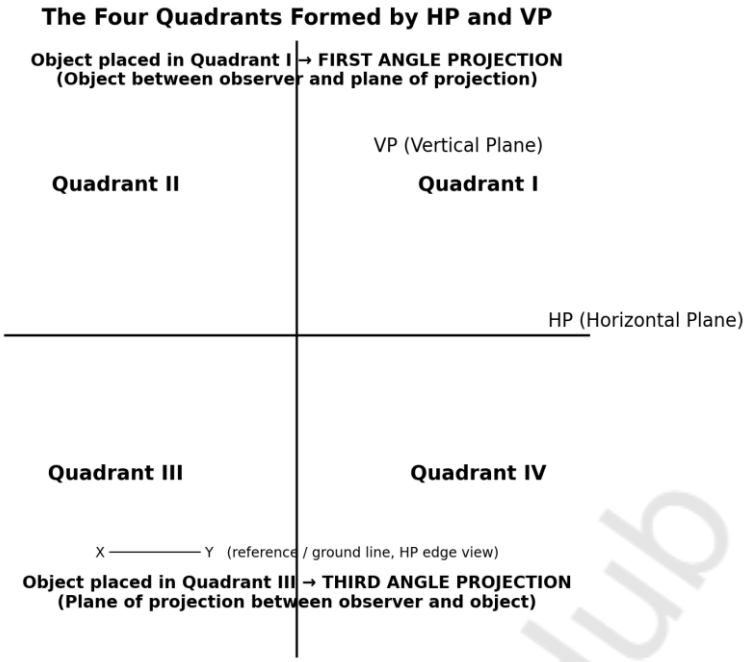

Figure 1: The four quadrants formed by HP and VP, and the corresponding positions for First Angle and Third Angle projection

Aspect	First Angle Projection	Third Angle Projection
Position of Object	Object is placed in the first quadrant, i.e. above HP and in front of VP	Object is placed in the third quadrant, i.e. below HP and behind VP
Relative Position	Object lies between the observer and the plane of projection	Plane of projection lies between the observer and the object
View Placement	Top view is drawn below the front view; the view seen from the left is drawn on the right, and vice versa	Top view is drawn above the front view; the view seen from the left is drawn on the left itself
Common Usage	Widely followed in India and most of Europe and Asia (as per Bureau of Indian Standards, BIS)	Widely followed in the United States, Canada, and some other countries (as per ASME/ANSI standards)

This textbook, in common with Indian engineering drawing practice and the relevant Bureau of Indian Standards (BIS) codes, follows the first angle method of projection throughout, and this convention is used for all the projections of lines and solids discussed in the remainder of this chapter.

3.1 Projections of Lines (First Angle Method)

The projections of a straight line depend on its position and inclination relative to the two reference planes, HP and VP. In this chapter, the discussion is limited to lines with both end

points situated in the first quadrant. The appearance of the front view (FV) and top view (TV) of a line varies according to its position, as summarised in the table below:

Position of Line	Front View (FV)	Top View (TV)
Parallel to both HP and VP	Shows true length, parallel to XY	Shows true length, parallel to XY
Parallel to VP, inclined to HP	Shows true length, inclined to XY at the true angle θ with HP	Shows foreshortened length, parallel to XY
Parallel to HP, inclined to VP	Shows foreshortened length, parallel to XY	Shows true length, inclined to XY at the true angle ϕ with VP
Inclined to both HP and VP	Shows foreshortened length, inclined to XY	Shows foreshortened length, inclined to XY (true length and true inclinations require further construction)

Two of the most fundamental cases — a line parallel to both reference planes, and a line parallel to one plane but inclined to the other — are illustrated below:

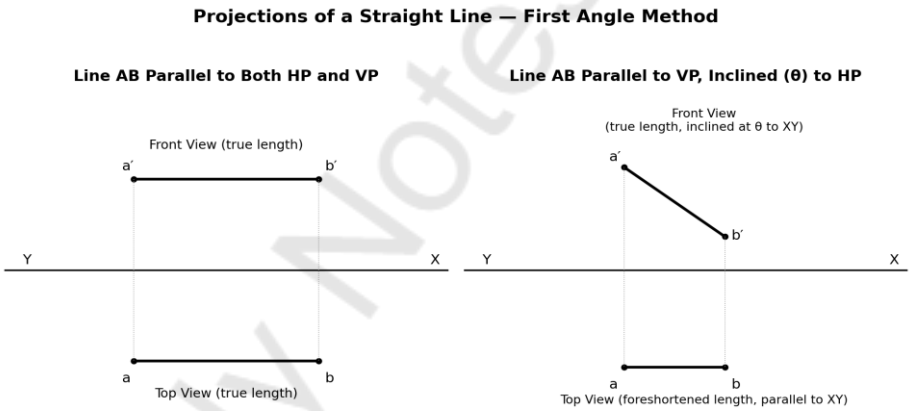

Figure 2: Projections of a straight line — parallel to both HP and VP (left), and parallel to VP, inclined to HP (right)

As Figure 2 illustrates, whenever a line is parallel to a particular reference plane, its projection on that plane shows the true length of the line; whenever a line is inclined to a reference plane, its projection on that plane shows a foreshortened (shorter than actual) length. This general principle — that true length is seen only in a view where the line is parallel to the plane of projection, while an inclined line always projects as a foreshortened length — forms the basis for solving all problems involving the projection of lines, including the more advanced case of a line inclined to both HP and VP simultaneously.

3.2 Projections of Solid Bodies (First Angle Method)

This section deals with the orthographic projections of three common regular solids — a regular polygonal pyramid, a cylinder, and a cone — in the case where the axis of the solid is inclined to only one reference plane (taken here as HP), while remaining parallel to the other reference plane (VP).

The standard procedure for constructing such projections, known as the change of position method, is carried out in two stages, described below:

Stage	**Construction Approach**
Stage 1 — Simple Position	The solid is first drawn in a simple position, with its axis perpendicular to HP (and hence parallel to VP), so that the top view shows the true shape of the base (regular polygon, circle) and the front view shows the true height of the solid.
Stage 2 — Inclined Position	Using the change of position method, the front view obtained in Stage 1 is redrawn tilted at the given angle of inclination to HP, keeping the same outline shape; a new top view is then projected from this inclined front view, in line with the corresponding points of the Stage 1 top view.

This two-stage approach is used because it is far simpler to establish the correct proportions and true shape of a solid's views when its axis is first drawn perpendicular to a reference plane; the resulting views can then be systematically tilted and re-projected to obtain the views corresponding to the actual inclined position required by the problem, without needing to work out the inclined geometry directly from first principles.

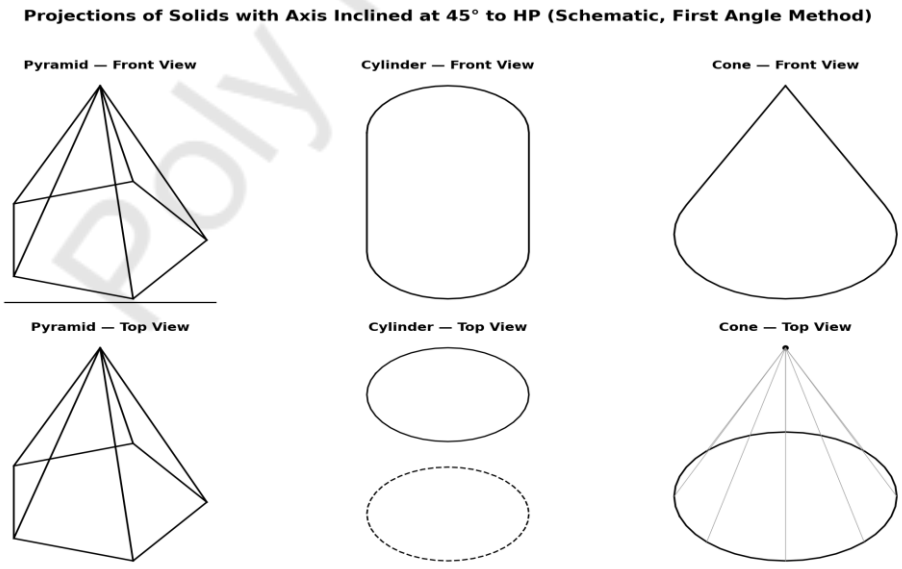

Figure 3: Schematic front views and top views of a pentagonal pyramid, a cylinder, and a cone, each with axis inclined at 45° to HP (illustrative; hidden lines omitted for clarity)

As shown in Figure 3, when the axis of a solid is inclined to HP:

- The front view shows the outline of the solid tilted at the given angle of inclination, generally no longer appearing as a simple, symmetric shape as it would in the perpendicular (simple) position.
- The top view appears foreshortened and distorted in comparison with the true-shape top view obtained when the axis was perpendicular to HP, since the base of the solid is no longer parallel to HP in the inclined position.
- For a pyramid, the visible and hidden lateral edges must be carefully identified and represented (using appropriate line conventions, as discussed in Section 1.2) in both views.
- For a cylinder, the circular top and bottom rims project as ellipses (or, in special orientations, as approximately elliptical/oval outlines) in the top view, while the front view shows the outline traced by the extreme (silhouette) generators of the curved surface.
- For a cone, the front view shows the outline traced by the extreme generators from the base to the apex, while the top view shows the base as an ellipse, together with the apex projected as a point, with a selection of generator lines typically drawn to help visualise the surface of the cone.

Mastery of this two-stage change of position method, applied consistently to pyramids, cylinders, cones, and other solids, forms an essential foundation for solving the wide range of solid projection problems encountered in engineering drawing, including more advanced problems involving inclination to both reference planes simultaneously.

4. Multiple Choice Questions (MCQs)

Answer the following questions by selecting the most appropriate option.

1. Orthographic projection is a method of representing a three-dimensional object by means of:

A) A single perspective sketch
B) Two or more related two-dimensional views, each obtained by projecting perpendicular to a plane
C) A photograph only
D) A single isometric view

2. In first angle projection, the object is imagined to be placed in the:

A) First quadrant, between the observer and the plane of projection
B) Third quadrant, behind the plane of projection
C) Second quadrant only
D) Fourth quadrant only

3. In third angle projection, the plane of projection is imagined to lie:

A) Behind the object, away from the observer

B) Between the observer and the object

C) Exactly on the object's surface

D) Nowhere in particular

4. In first angle projection, the top view is conventionally placed:

A) Above the front view

B) Below the front view

C) To the extreme left of the front view

D) Not drawn at all

5. In third angle projection, the top view is conventionally placed:

A) Below the front view

B) Above the front view

C) Diagonally opposite the front view

D) Overlapping the front view

6. First angle projection is the standard followed as per:

A) ASME/ANSI standards used mainly in the USA

B) Bureau of Indian Standards (BIS), widely used in India and most of Europe/Asia

C) No recognised standard at all

D) Only aerospace design standards

7. When a straight line is parallel to both HP and VP, its front view and top view both show:

A) A foreshortened length

B) The true length of the line, each parallel to the XY line

C) A single point

D) An inclined line of unknown length

8. When a straight line is parallel to VP and inclined to HP, its front view shows:

A) The foreshortened length

B) The true length, inclined to XY at the true angle with HP

C) A single point

D) A curved line

9. When a straight line is parallel to VP and inclined to HP, its top view shows:

A) The true length, inclined to XY

B) A foreshortened length, parallel to XY

C) A single point

D) The true length, perpendicular to XY

10. The reference line XY used in orthographic projection represents:

A) The line of intersection of HP and VP

B) The axis of the object being drawn

C) A random construction line with no significance

D) The line of sight of the observer

11. When constructing the projections of a solid whose axis is inclined to one reference plane, the solid is generally first drawn in:

A) The final inclined position directly, without any intermediate stage

B) A simple position, with the axis perpendicular to that reference plane, before being tilted

C) A random, arbitrary orientation

D) Isometric view only

12. In the change of position method for solids inclined to HP, the new top view is obtained by projecting from:

A) The original (Stage 1) top view directly

B) The redrawn, inclined front view (Stage 2)

C) A completely unrelated sketch

D) The side view only

13. For a pentagonal pyramid resting on its base with axis perpendicular to HP, the top view shows:

A) A triangle

B) The true shape of the pentagonal base

C) A circle

D) A single straight line

14. For a cone resting on its base with axis perpendicular to HP, the front view generally appears as:

A) A circle

B) A triangle (isosceles), representing the outline of the cone

C) A rectangle

D) A pentagon

15. For a cylinder resting on its base with axis perpendicular to HP, the top view appears as:

A) A rectangle

B) A circle, representing the true shape of the circular base

C) A triangle

D) An ellipse only

Answer Key

1. B) Two or more related two-dimensional views, each obtained by projecting perpendicular to a plane | 2. A) First quadrant, between the observer and the plane of projection | 3. B) Between the observer and the object | 4. B) Below the front view |

5. B) Above the front view | 6. B) Bureau of Indian Standards (BIS), widely used in India and most of Europe/Asia | 7. B) The true length of the line, each parallel to the XY line | 8. B) The true length, inclined to XY at the true angle with HP | 9. B) A foreshortened length, parallel to XY | 10. A) The line of intersection of HP and VP | 11. B) A simple position, with the axis perpendicular to that reference plane, before being tilted | 12. B) The redrawn, inclined front view (Stage 2) | 13. B) The true shape of the pentagonal base | 14. B) A triangle (isosceles), representing the outline of the cone | 15. B) A circle, representing the true shape of the circular base

5. Broad / Long Answer and Practical Questions

1. Explain the concept of orthographic projection, and describe the purpose of representing a three-dimensional object using multiple two-dimensional views.

2. Explain the concept of first angle projection, describing the relative position of the object, the observer, and the plane of projection.

3. Explain the concept of third angle projection, describing the relative position of the object, the observer, and the plane of projection.

4. Distinguish between first angle projection and third angle projection, particularly with respect to the placement of the top view relative to the front view.

5. Draw the projections (front view and top view) of a line AB, 60 mm long, parallel to both HP and VP, located 30 mm above HP and 40 mm in front of VP.

6. Draw the projections (front view and top view) of a line AB, 70 mm long, parallel to VP and inclined at 40° to HP, with end A on HP and 20 mm in front of VP.

7. Explain the four standard cases for the projection of a straight line (parallel to both planes; inclined to HP, parallel to VP; parallel to HP, inclined to VP; inclined to both planes), describing the general appearance of the front view and top view in each case.

8. Explain the general procedure (change of position method) used to draw the projections of a solid whose axis is inclined to one reference plane, using the example of a pentagonal pyramid.

9. Draw the projections (front view and top view) of a cylinder of base diameter 40 mm and height 60 mm, resting on HP with its axis inclined at 45° to HP.

10. Draw the projections (front view and top view) of a cone of base diameter 50 mm and height 65 mm, resting on HP with its axis inclined at 45° to HP.