**Orthographic projection** is a means of representing a three-dimensional (3D) object in two dimensions (2D). It is the projection by parallel rays onto a plane at right angles to the rays.

Learning Outcomes

Students should be able to:

- Demonstrate an understanding of the planes of reference
- Complete the orthographic views of a basic solid in 1st angle projection.

A pictorial view of a shaped solid is shown. The object is positioned 15mm from the vertical plane.

- a) Draw an elevation looking in the direction of A.
- b) Draw an end elevation looking in the direction of B.
- c) Draw a plan projected from (a) above.

*Use your compass to step off the distances from the pictorial view.*
Pictorial views of three objects which have been modelled in SolidWorks are shown. In each case, the object has been positioned relative to the three planes of reference.

For each model, open the SolidWorks files (Orthographic Projection 2.1, 2.2 & 2.3). Use the model to:

(a) Draw an elevation projected onto the Vertical Plane.
(b) Draw an end elevation projected onto the End Vertical Plane.
(c) Draw a plan projected onto the Horizontal Plane.

In the case of Orthographic Projection 2.2, project an end elevation looking in the direction of arrow A as well.

Learning Outcomes
Students should be able to:
- Present drawings in first angle orthographic conventional views
- Represent 3D objects in logically arranged two dimensional views
The black and white images to the right show a series of polycubic solids in different formations. When a bright light is shone in front, above and to the side of the solids a dark shadow is cast on the VP, HP and EVP respectively. These 2D images represent the elevations, plans and end views.

Take your time to go through these images and then, apply a similar technique to the coloured, pictorial views below. Use the square grid supplied to draw the elevations, plans and end-views. All solids are resting on the HP.

Remember, the elevation is taken in the direction of the arrow A, the end-view in the direction of arrow B and the plan from the elevation.

Learning Outcomes
Students should be able to:
- Convert from 3D to 2D,
- Arrange a series of orthographic views from pictorial polycubical solids.
1. Draw an elevation looking in the direction of arrow A, an end view in the direction of arrow B and a plan projected from the elevation.
2. Given the elevation looking in the direction of arrow A and end view in the direction of arrow B, project a plan from the end elevation.
3. Given the elevation and plan, project an end view looking in the direction of arrow B and complete the pictorial view of the object.

Learning Outcomes
Students should be able to:
- Convert from 3D to 2D
The 3D graphic shows the pictorial view of a proposed office development for a multi-national company. It is based on regular octagonal prisms joined by a square based atrium in the form of a prism.

The incomplete plan and elevation of the building are shown across.

(a) Reproduce the given plan and elevation full size.
(b) Complete the plan to show the cut portion.
(c) Project an end elevation looking in the direction of arrow A.

Learning Outcomes

Students should be able to:
- Demonstrate their knowledge of prisms using orthographic projection.
- Solve a problem involving the intersection of prisms by a simply inclined plane.
In geometry, a **prism** is a **polyhedron** made of a **polygonal** base, a **translated** copy, and faces joining corresponding sides. Thus these joining faces are **parallelograms**.

**All sections parallel to the base faces are the same.**

A **right prism** is a prism in which the joining edges and faces are perpendicular to the base face. This applies if the joining faces are **rectangular**. If the joining edges and faces are not perpendicular to the base face, it is called an **oblique prism**.

Fig. 1 shows a simplified, aerial view of Park Avenue in New York City. Note how all the buildings are represented as prisms (triangular based, square based, octagonal based and irregular based).

**Learning Outcomes**

Students should be able to:
- Demonstrate their knowledge of prisms using orthographic projection.

Located in Prague, Czech Republic, **The Dancing House** (Fig. 2) was originally called “Fred and Ginger,” as it vaguely resembles a pair of dancers. It was designed by **Frank Gehry** and is loosely based on prismatic solids which were later distorted.

Fig. 3 shows the Baptistery in Parma, Italy. It is an octagonal building with a facade of pink Verona Marble constructed between 1196 and 1270 by Benedetto Antelami.

**Fig. 1** shows a photograph of a hexagonally based garden gazebo in the form of a prism. It is surmounted by a hexagonally based pyramid (roof). The incomplete plan of the structure is shown. All of the vertical surfaces of the prism are inclined to the VP.

(a) Complete the plan and project an elevation. The height of the prism is 53mm and the apex of the pyramid is 97mm above the HP.
(b) Project an end view.
(a) Three tennis balls with a diameter of 40mm are to be packaged in a cylindrical container. Draw the elevation, plan and end elevation of the cylinder in an upright position.

(b) The 3D graphics on this page show the newly built Dublin Convention Centre. It was designed by the leading Irish-American architect, Kevin Roche and is situated on the river Liffey in the heart of Dublin Docklands. The 8 story glass atrium takes the form of a cylinder which has been inclined to the horizontal plane.

Given the elevation of the building with the axis inclined at an angle of 60° to the HP, complete the end elevation and plan.

Learning Outcomes
Students should be able to:
- Draw the elevation and plan of a right cylinder in an upright position.
- Complete the projections of a cylinder with its axis inclined to the HP.
Learning Outcomes
Students should be able to:
- Draw the elevation, plan and end view of a truncated cylinder.

Given the plan of a right cylinder:
(a) Determine the front elevation when the altitude is 85mm and when the elevation is truncated from the top, right corner at an angle of 45° to the H.P.
(b) Determine an end elevation in the direction of the arrow A.
   (i) What shape is the curve in the end elevation?
   (ii) When would the curve become an ellipse?
(c) Determine the true shape of the cut surface.
A **pyramid** is a solid where the outer surfaces are triangular and converge at a point. The base of a pyramid can be trilateral, quadrilateral, or any polygon shape, meaning that a pyramid has at least three outer surfaces (at least four faces including the base). The square pyramid, with square base and four triangular outer surfaces, is a common version.

**Learning Outcomes**

Students should be able to:

- Apply the principles of orthographic projections in determining the elevation, plan and end view of a proposed solid.
- Apply the principles of horizontal sections.

The photograph above shows the **National Memorial** to members of the **Defences Forces**, Merrion Square, Dublin. The pyramid shape of the memorial, which was designed by Brian King, captures historic references to burial and is a standing testament to the dead. It also reflects the shape of a military tent.

(a) Given the plan of the memorial, construct an elevation. The apex of the pyramid is 100mm above the HP.

(b) Construct an end elevation. Include the masonry joints (horizontal sections) and glass in each view.
The **Louvre Pyramid** is a large glass and metal pyramid, surrounded by three smaller pyramids, in the main courtyard of the Louvre Palace in Paris. The large pyramid serves as the main entrance to the Louvre Museum. Completed in 1989, it has become a landmark of the city of Paris. Commissioned by the President of France François Mitterrand in 1984, it was designed by the architect I. M. Pei. The structure, which was constructed entirely with glass segments, reaches a height of 20.6 metres its square base has sides of 35 metres. It consists of 603 rhombus-shaped and 70 triangular glass segments.

The pyramid and the underground lobby beneath it (as seen from the photographs opposite) feature in Dan Brown’s novel, The Da Vinci Code. It featured the recurring themes of cryptography, keys, symbols, codes, and conspiracy theories in relation to the pyramid.

**Learning Outcomes**

Students should be able to:

- Apply the principles of orthographic projection in determining the elevation, plan and end view of a proposed solid.
- Apply the principles of inclined sections and dihedral angles.

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**Given the plan of the Louvre Pyramid showing its glass segments:**

(a) Construct an elevation and end elevation in the direction of A. The apex is 65mm above the HP.

(b) Determine the dihedral angle between surfaces A and B.
The Leaning Tower of Pisa is an example of a tilted cylinder. When constructed initially it stood vertically but over the years the tower leaned to one side (inclined) due to poor foundations. Complete the plan of the cylindrical part of the tower below when the axis of the cylinder is parallel to the Vertical Plane.

Learning Outcomes
Students should be able to:
- Recognize and represent an oblique prism of an everyday object.
- Locate a line of intersection between two surfaces.

The 3D graphic across shows a building which is based on an oblique prism. It also shows a brick tower which intersects the prism at the front.

(a) Project an elevation looking in the direction of arrow A using the start position given below.
(b) Project a plan of the building.
(c) Project an end-elevation of the building in the direction of arrow B.

Sketch the traces of the plane containing the surface A.
(a) A specialised skip is often used for transporting concrete about a site. The skip’s shape, based on an oblique rectangular pyramid, allows the concrete to be easily placed when pouring.

Complete the elevation, plan and end elevation of the skip from the given dimensions.

(b) The photograph across shows a woman’s shoe. The heel of this shoe is based on an oblique cone with a cylinder as the tip.

Complete the elevation, plan and end elevation of the heel.

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Learning Outcomes

Students should be able to:
- Represent an oblique rectangular pyramid and an oblique cone in two dimensions from given information.
Learning Outcomes

Students should be able to:
- Project an auxiliary elevation of a surface from plan.
- Sketch the traces of an auxiliary plane.

(a) The photograph shows a directional road sign which is commonly seen at roundabouts. The arrows indicate to drivers the direction to follow. Commonly, these signs are positioned at an inclination to drivers so as to give them a clear indication of the required direction. The sign below is setup in an inclined position in plan. Complete the elevation of the road sign given the true shape of the arrow below.

(b) The photograph over shows a house which has had an extension added to the right. The extension is designed so that a door with a semi-circular arch is placed in the centre of the wall. Complete the house plans of this extension by determining the elevation of this arch.
The pictorial shows a set of children’s wooden building blocks. Three of the wooden blocks have been stacked to form the shape over.

Project an auxiliary elevation of these blocks when viewed in the direction of arrow A.

**Learning Outcomes**

Students should be able to:
- Demonstrate an understanding of auxiliary projection
- Complete the auxiliary projection of the building blocks.

**Auxiliary Elevations** are obtained by changing the viewing position of an object relative to the Vertical Plane.

The view located must be projected onto a plane— **Auxiliary Vertical Plane**. The inclination of this plane to the Vertical Plane is determined by the viewing position.

The **Auxiliary Vertical Plane** is perpendicular to the viewing position (projection). This plane is represented by an XY line (X1 - Y1), which is on the HP.

A horizontal section plane explains clearly why the heights in the elevation and auxiliary elevation are equal. Thus, the heights can be transferred onto the auxiliary vertical plane from elevation.
(a) The photograph over on the left shows a bread bin which is a common household item. The shape of the bread bin is based on a cuboid and a cylinder.

Project an auxiliary elevation of the bread bin when the viewing position is at A in plan.

(b) Advertising is used by companies at every opportunity to market their products. The 3D graphic shows a rotating advertising board which is based on the shape of a triangular prism.

(i) Project an auxiliary elevation to find the true shape of surface B.

(ii) A car company wishes to advertise its circular logo on surface B. The centre of the circle (radius 18mm) is located at the centre of surface B. Draw the projections of the logo in plan and elevation.

(i) Complete the sketch of the Auxiliary Vertical Plane used for the auxiliary elevation of the bread bin in the reference planes shown.

(b) Indicate the position of the X_Y1 line.
The 3D graphic shows a docking station and MP3 player. The shape of the docking station and MP3 are based on a cuboid. The elevation and plan of the components are shown below.

Project an auxiliary plan of the unit when viewed in the direction shown.

Learning Outcomes

Students should be able to:
• Apply the principles of auxiliary projection to locate the auxiliary plan of an object.

Auxiliary Plans are obtained by changing (rotating) the viewing position of the plan of an object. This view is projected onto a plane which is perpendicular to the viewing direction — Auxiliary Horizontal Plane.

XY line (X1-Y1) is the connection between the Vertical Plane and Auxiliary Horizontal Plane.

The planes are flattened out so that the projected views can be seen.
Learning Outcomes

Students should be able to:
- Project a true shape using an auxiliary plan
- Project and locate points between views

(a) The photograph shows a sound system amplifier which bands use when performing. The speaker is inclined to enhance the projection of the sound.

(i) Complete the plan of the amplifier.
(ii) Project a true shape of the surface S on the amplifier.
(iii) Draw the outline of the amplifier rim on surface S in plan (rim width is 5mm)

(b) The photograph over shows a cooking timer.

(i) Draw the true shape of the surface R on the timer.
(ii) The circular dial has a radius of 25mm and is positioned in the center of surface R. Draw the projections of this circle in plan.
The photograph below shows a rubix cube sitting on the horizontal plane.

Draw the plan and elevation of the cube given the line \( \text{ab} \) as one of its base edges.

The photograph above shows a building which has elements of its design based on the cube. These cubes have been inclined to the horizontal plane and aligned together to form the upper part of the building.

Given the traces of the plane \( \text{VTH} \) and one edge \( \text{ab} \) of the base of the cube resting on this plane, draw the projections of the cube.

Sketch a pictorial solution of the problem in the box.

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**Learning Outcomes**

Students should be able to:
- Define the term ‘cube’ - a 3D object bounded by six square faces.
- Draw the elevation and plan of a cube.
- Apply the principle of auxiliary projection and planes.

The photograph over shows a structure which is based on the rubix cube. The cube is inclined to the ground (Horizontal Plane).

Draw the projections of the cube which has its base inclined at 30° to the horizontal plane. The edge \( \text{ab} \) forms one of the base edges with point \( \text{a} \) is on the HP.
Learning Outcomes
Students should be able to:
- Define 'tetrahedron' - a 3D object bounded by 4 equilateral triangular faces.
- Construct a regular tetrahedron on horizontal and inclined planes
- Apply the principle of auxiliary projection in solving problems.

The photograph shows a light shade which is hung from the ceiling. The design of this shade is based on a truncated tetrahedron supported by a cylinder. The tetrahedron has been truncated by a horizontal plane.

Given the plan outline of the tetrahedron and the position of the horizontal cutting plane. Construct the plan and elevation of the light shade.

The photograph shows a teabag. The shape of this teabag is based on a regular tetrahedron. Construct a tetrahedron of side 50mm, given one base line \( ab \) on the horizontal plane.

Shown in the photograph is an ornament which is based on a tetrahedron. The tetrahedron is to be rotated so the base forms a 25° with the horizontal plane.

(i) Construct the tetrahedron given the edge \( ab \) on the horizontal plane.
(ii) Construct the traces of the plane that will contain the edge \( ab \) and the apex of the tetrahedron.
Learning Outcomes

Students should be able to:

- Draw the projections of inscribed and circumscribed spheres of a cube and tetrahedron.

Given the projections of a regular tetrahedron:
(a) Determine the projections of the sphere that circumscribes it.
(b) Determine the projections of the inscribed sphere.

Given the projections of a cube:
(a) Determine the projections of the sphere that circumscribes it.
(b) Determine the projections of the inscribed sphere.