Extended Reality in Industry 4.0 (ERI)

Lecture 4: Structure of 3D modeling

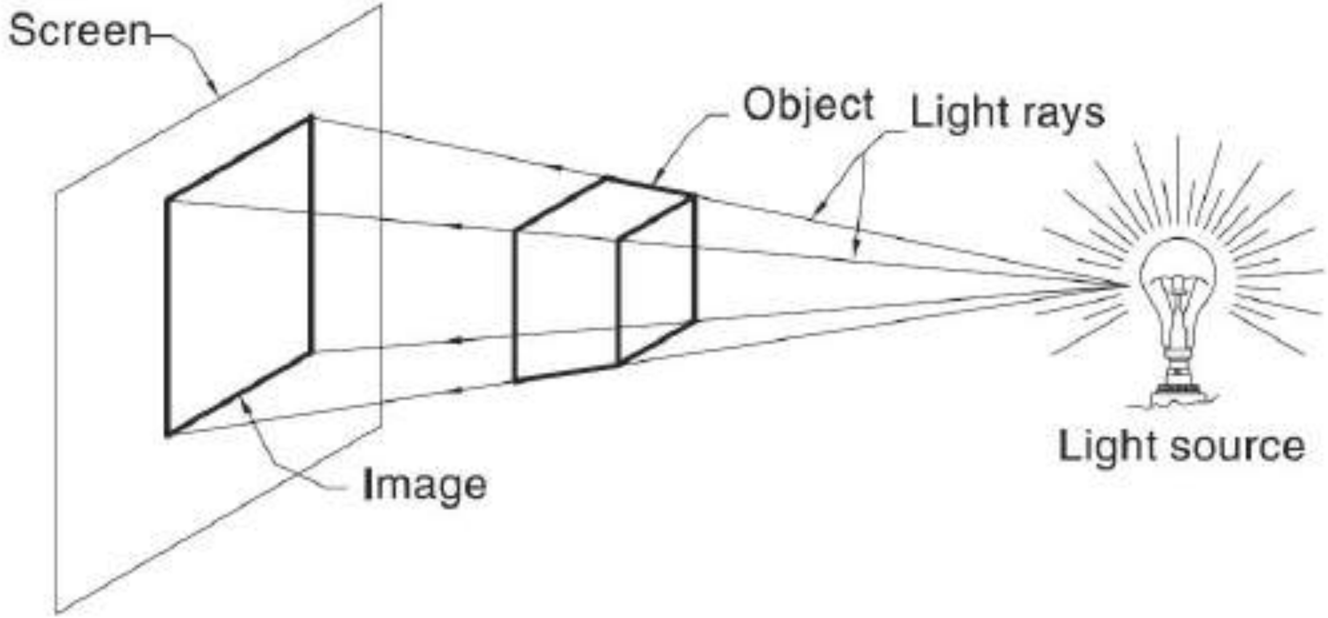
Dr. Kalpana Shankhwar, kalpana@iiitd.ac.in
Assistant Professor
Department of Human Centered Design,
IIIT Delhi

Theory of projection

- In engineering drawing, the word ‘**projection**’ means an image or the act of obtaining the image of an object.
- Technical people often refer to the image as a **view**.
- Engineers use various techniques to construct the views of an object. These techniques are grouped under various methods of projection.

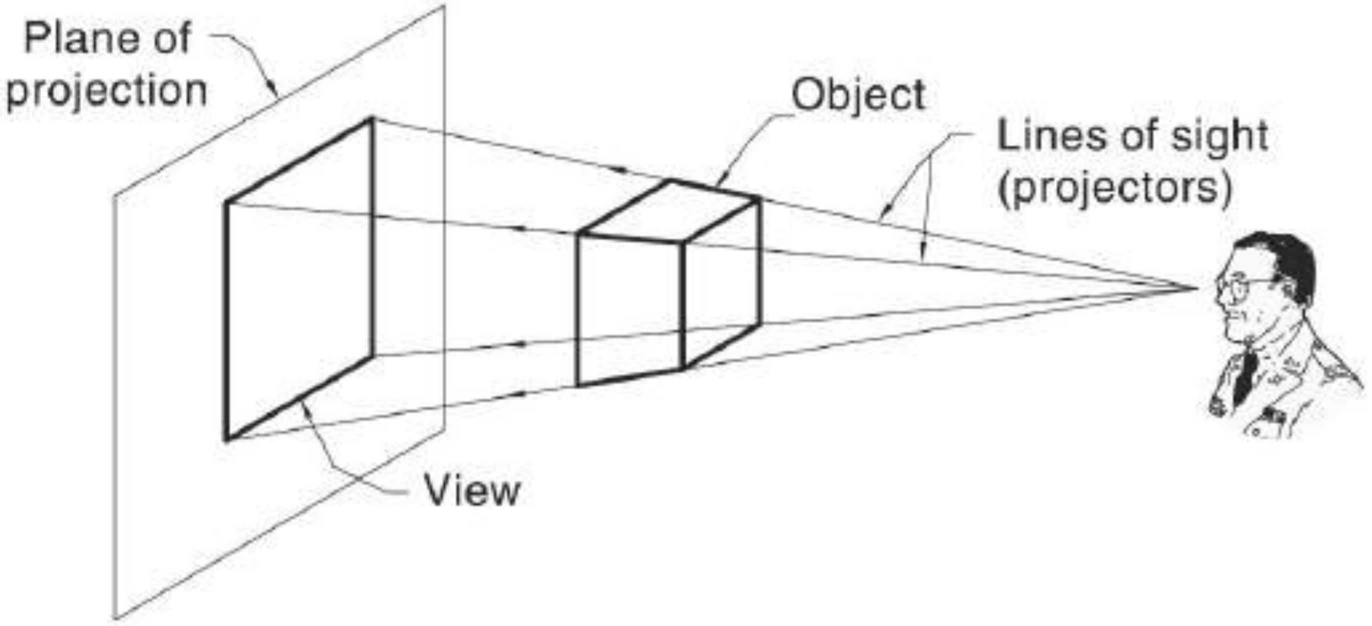
Projection system

- The light rays from the bulb strike the object and create its shadow on the screen.
- The image thus obtained represents a view of the object.
- The view appears larger than the object since the light rays are divergent.

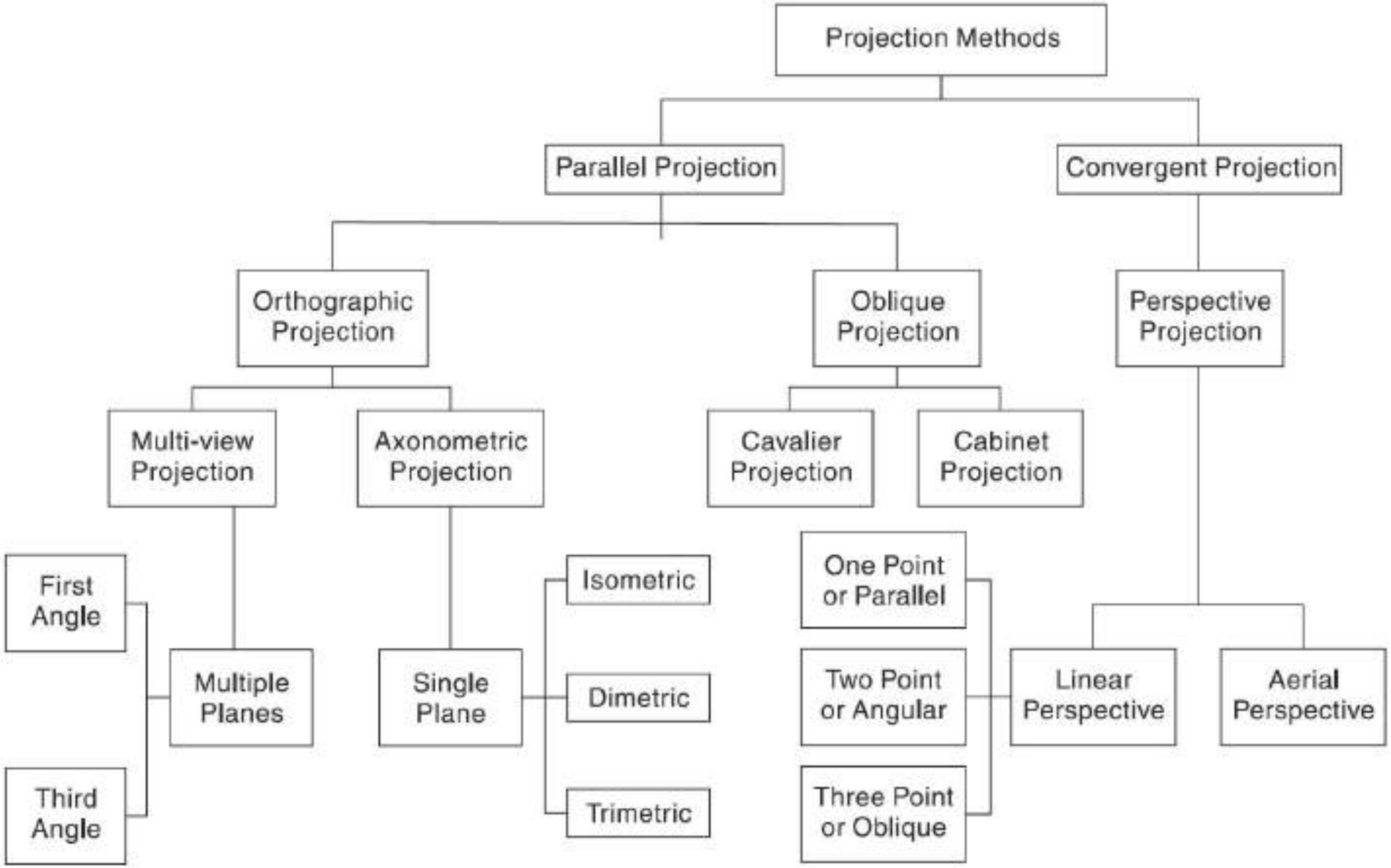


Projection system

- The light source is replaced by a person—called observer—looking toward the object.
- The lines of sight of the observer create the view of the object on the screen.
- The screen is referred as **plane of projection (POP)**.
- The lines of sight are called **projection lines** or **projectors**.
- Thus, the object, the observer and the POP are three basic elements of the projection system



Classification of Projection methods

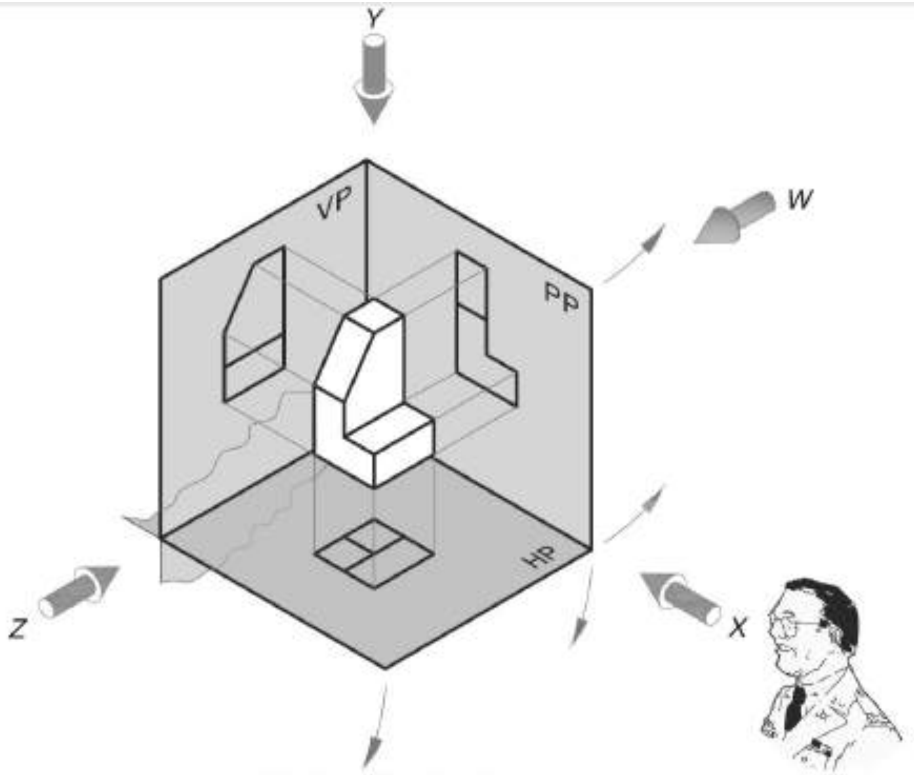


Projection system

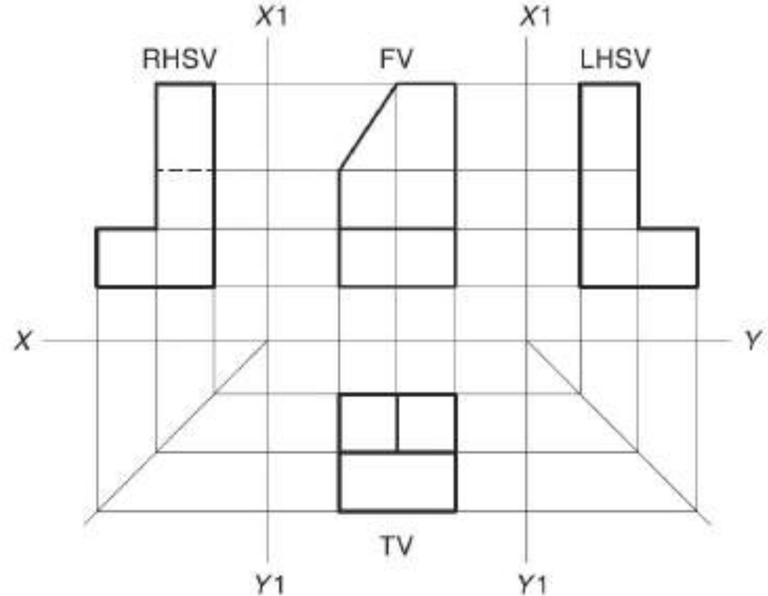
1. **Parallel projection –** the projectors are parallel to each other.

a. **Orthographic projection -** In orthographic projection, mutually parallel projectors are perpendicular to the POP.

I. **Multiview projection -** In multiview projection, two or more views of an object are drawn on different POPs. The object is oriented in such a way that two of its dimensions will be visible in any one view.



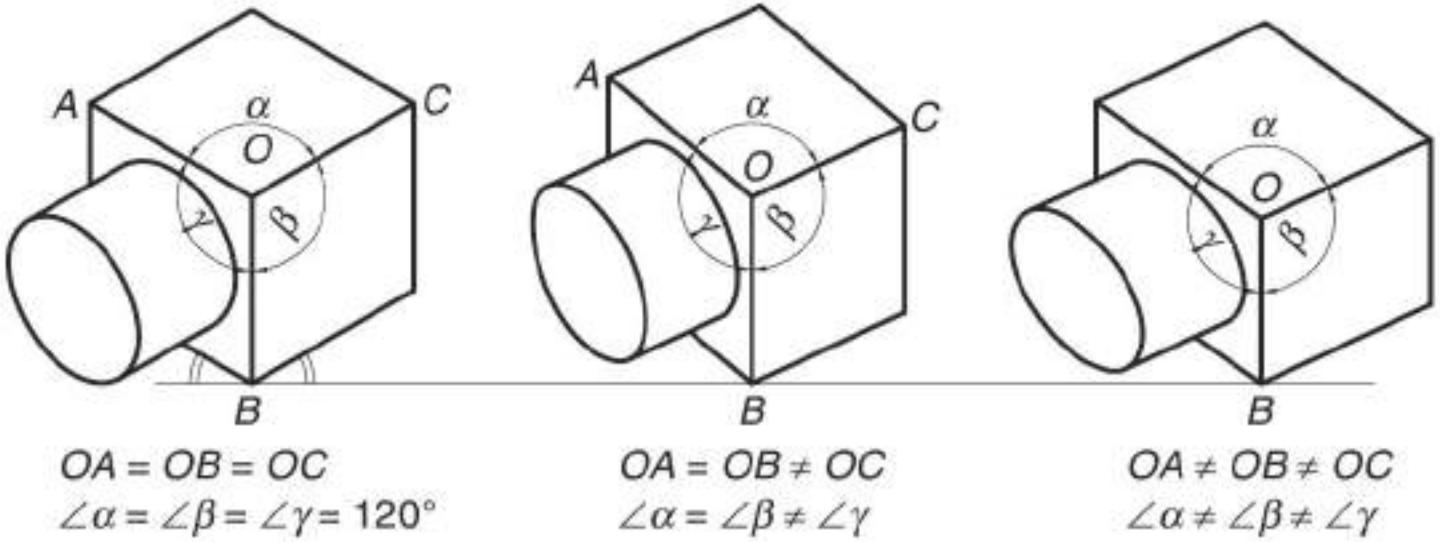
(a) Object in First Angle



Projection system

II. **Axonometric projection –** In axonometric projection, only one view showing all the three dimensions of an object is drawn on a POP. The orientation of the object is kept in such a way that its three mutually perpendicular edges will remain inclined to the POP

- **Isometric projection –** If three mutually perpendicular edges of an object make equal inclinations with the POP, the axonometric projection is called isometric projection.

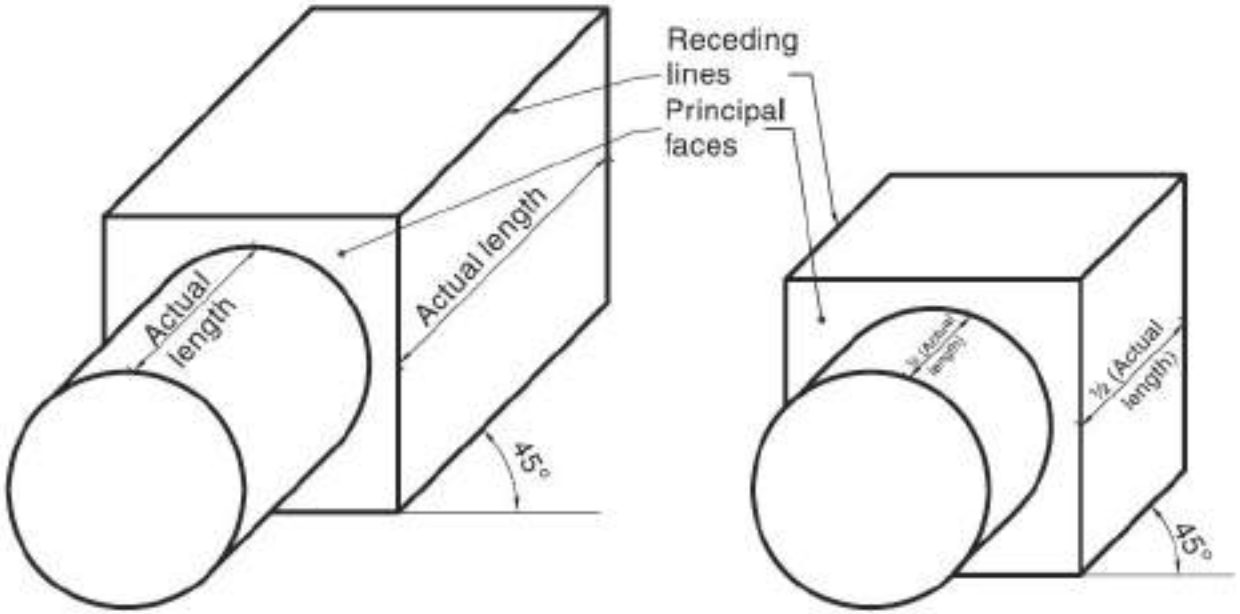


(a) Isometric, (b) Dimetric and (c) Trimetric

Projection system

b. **Oblique projection -** In oblique projection, mutually parallel projectors are inclined (oblique) to the POP at 30°, 45° or 60°.

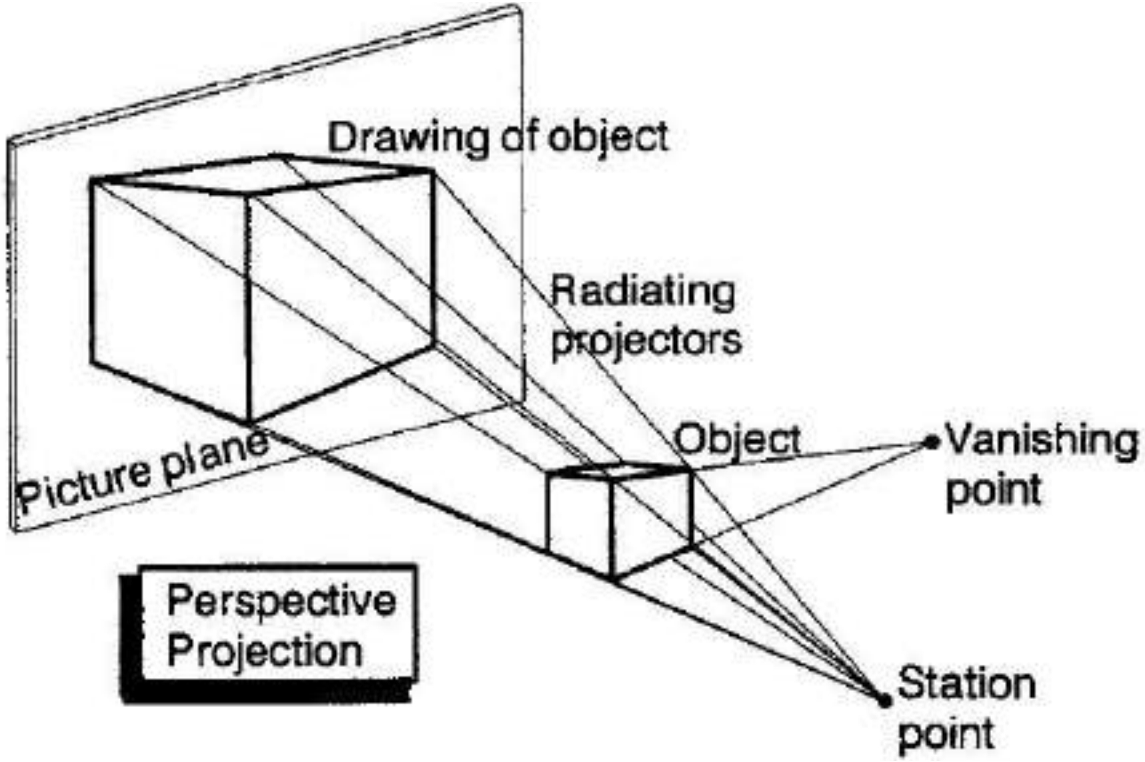
- Unlike axonometric projection, one of the faces of the object is kept parallel to the POP.
- The face parallel to the POP is called principal face.



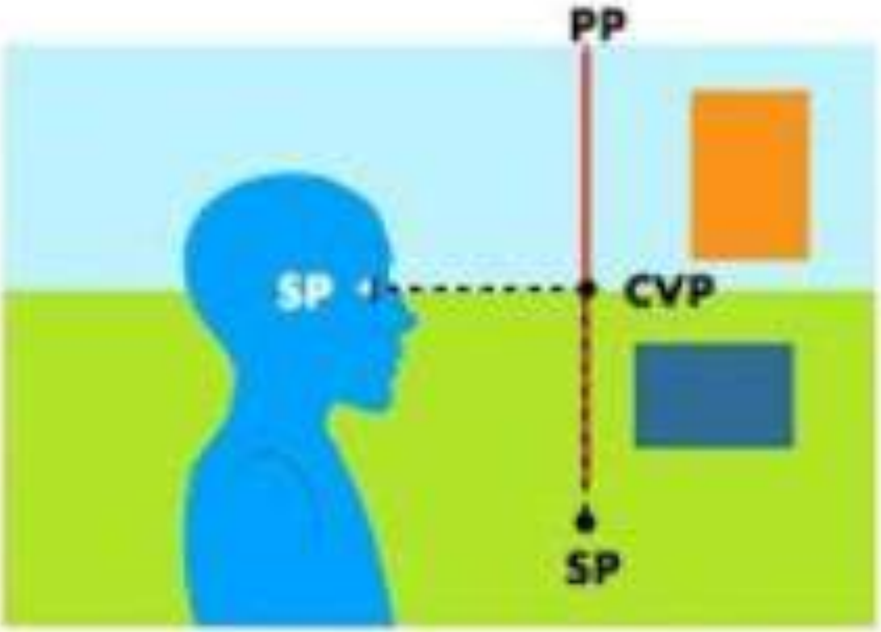
(a) Cavalier Projection and (b) Cabinet Projection

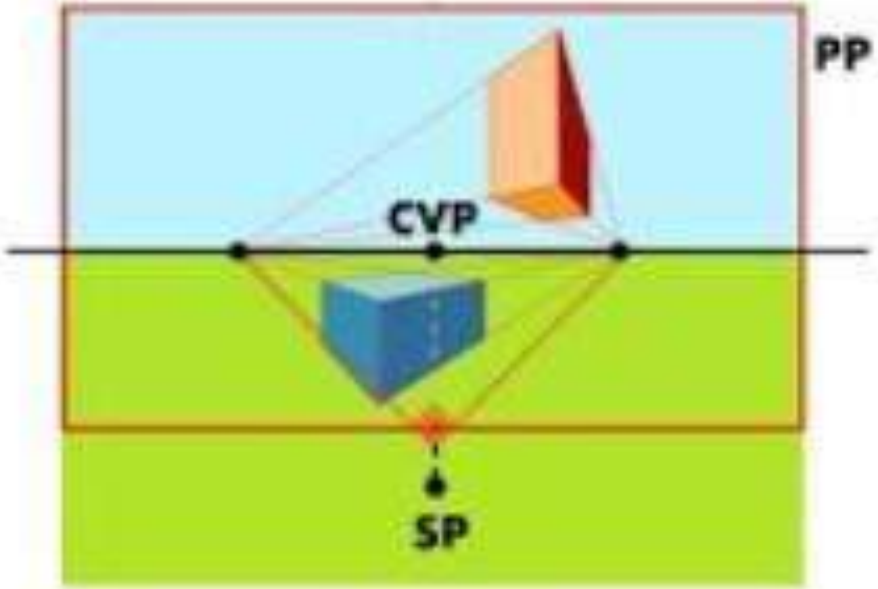
Projection system

2. **Convergent projection -** In convergent projection, the projectors are not parallel to each other but converge to a point, called **station point**. The station point essentially coincides with the observer's eye.
   - The parallel edges of the object are seen to be converging at a point, called **vanishing point**. The object appears smaller and smaller as its distance from the observer increases.
   - The most common type of convergent projection is called **perspective projection**.



drawsh studio

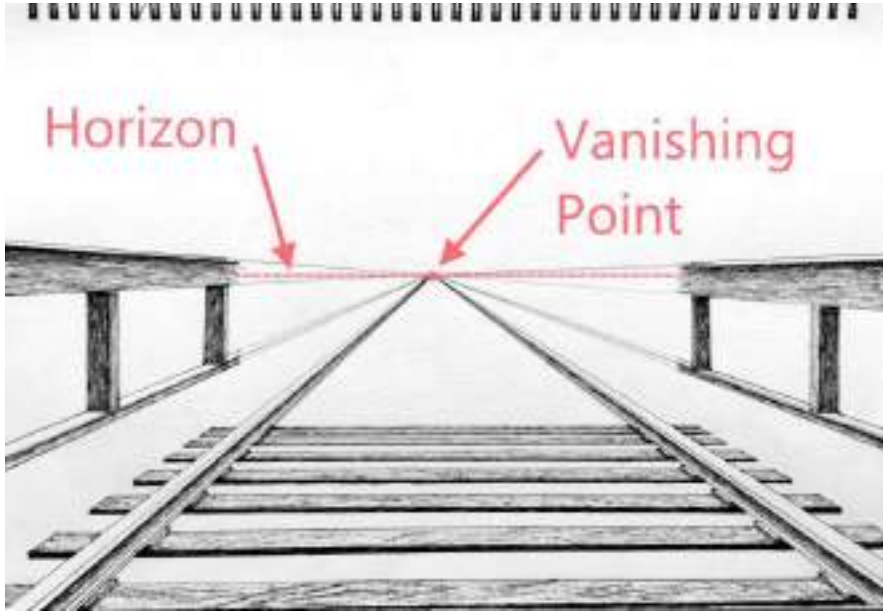


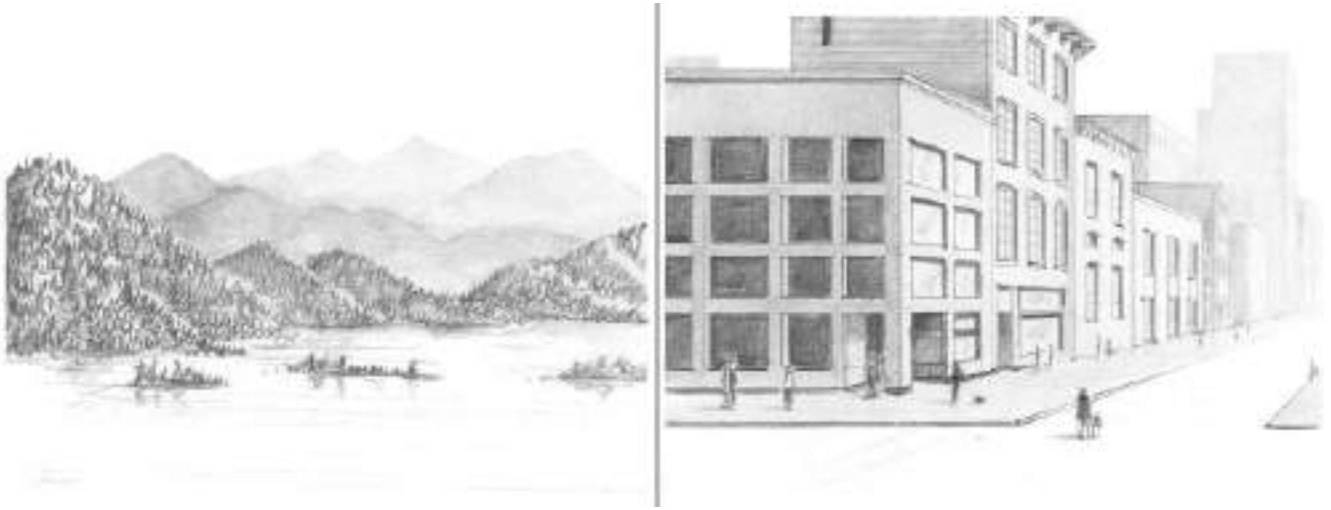


Station Point

Projection system

- **Linear perspective projection -** In linear perspective, the size of the object seen bears constant ratio with its distance from the observer. Linear perspective uses one or two or three vanishing points to obtain the perspective view of an object.
- **Arial perspective projection -** In aerial perspective, the effect of atmosphere is taken into account while drawing the view of an object. As the distance between an object and the station point increases, the contrast between the object and its background decreases. Therefore, the illusion of depth is created by softening contours and reducing the colour contrasts.





Perspective viewing

- Any corner of the building includes the three principal directions. In the most general case—the three-point perspective—parallel lines in each of the three principal directions converge to a finite **vanishing point** (Figure 5.10(a)). If we allow one of the principal directions to become parallel to the projection plane, we have a two-point projection (Figure 5.10(b)), in which lines in only two of the principal directions converge.
- Finally, in the one-point perspective (Figure 5.10(c)), two of the principal directions are parallel to the projection plane, and we have only a single vanishing point.

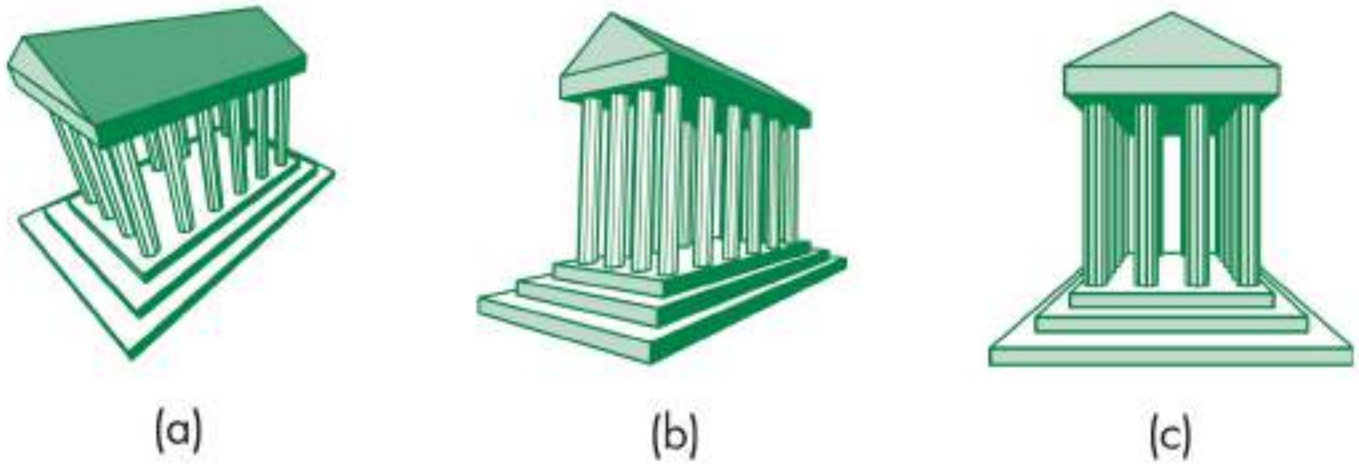
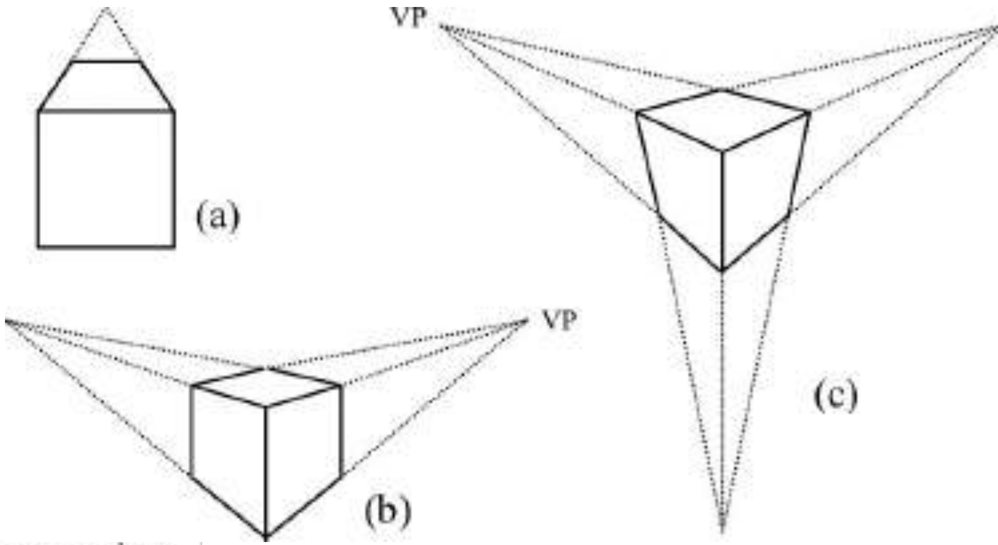
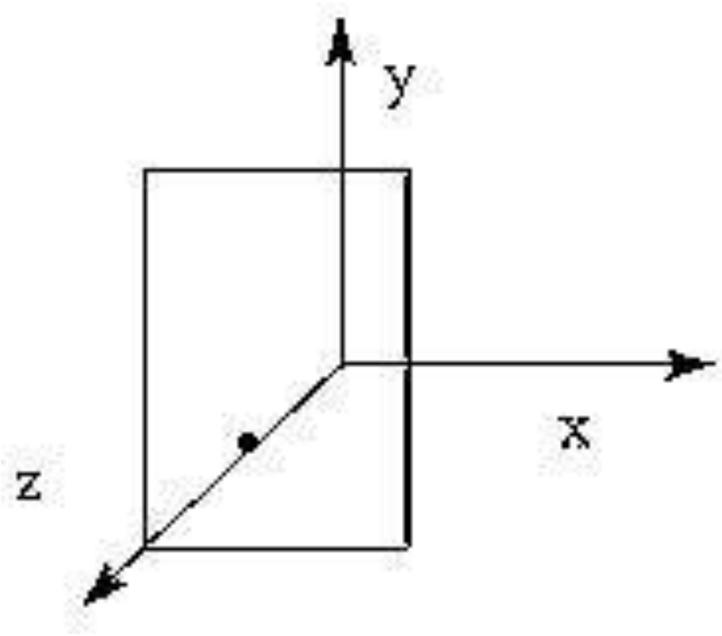


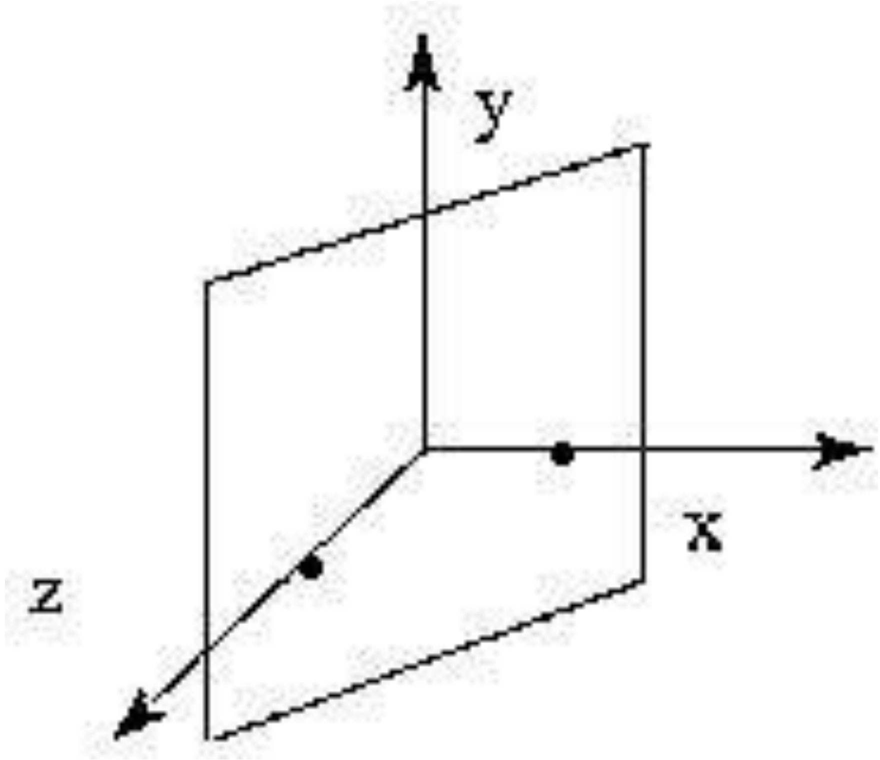
FIGURE 5.10 Classical perspective views. (a) Three-point. (b) Two-point. (c) One-point.

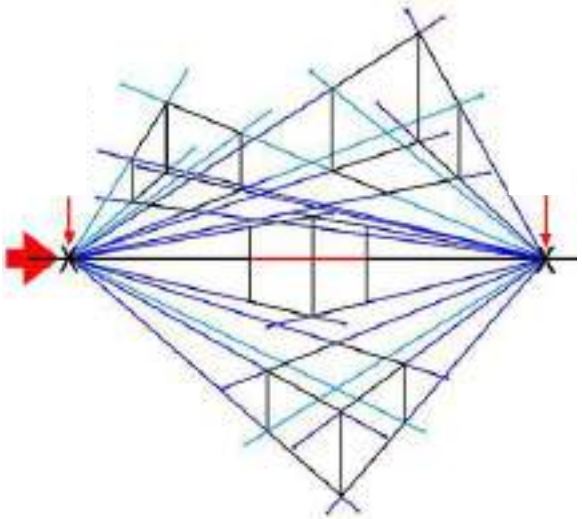


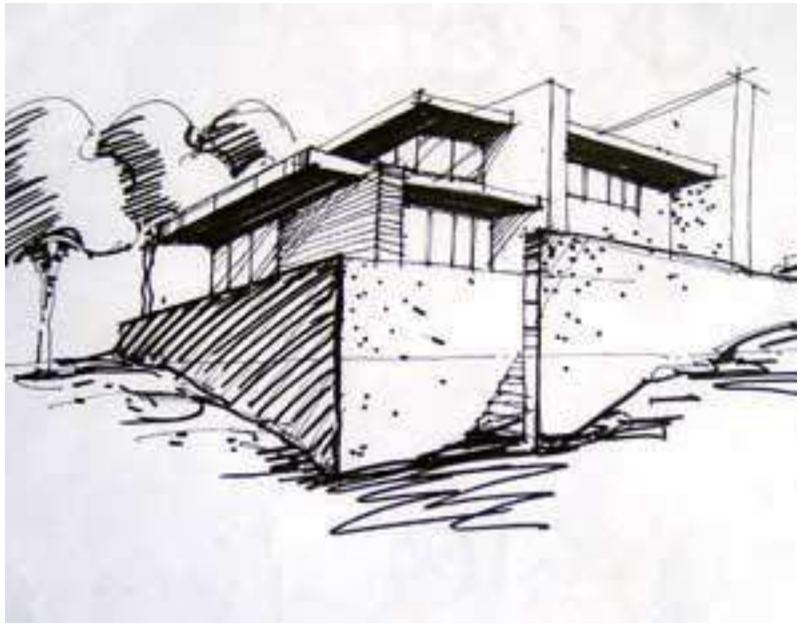
One point perspective



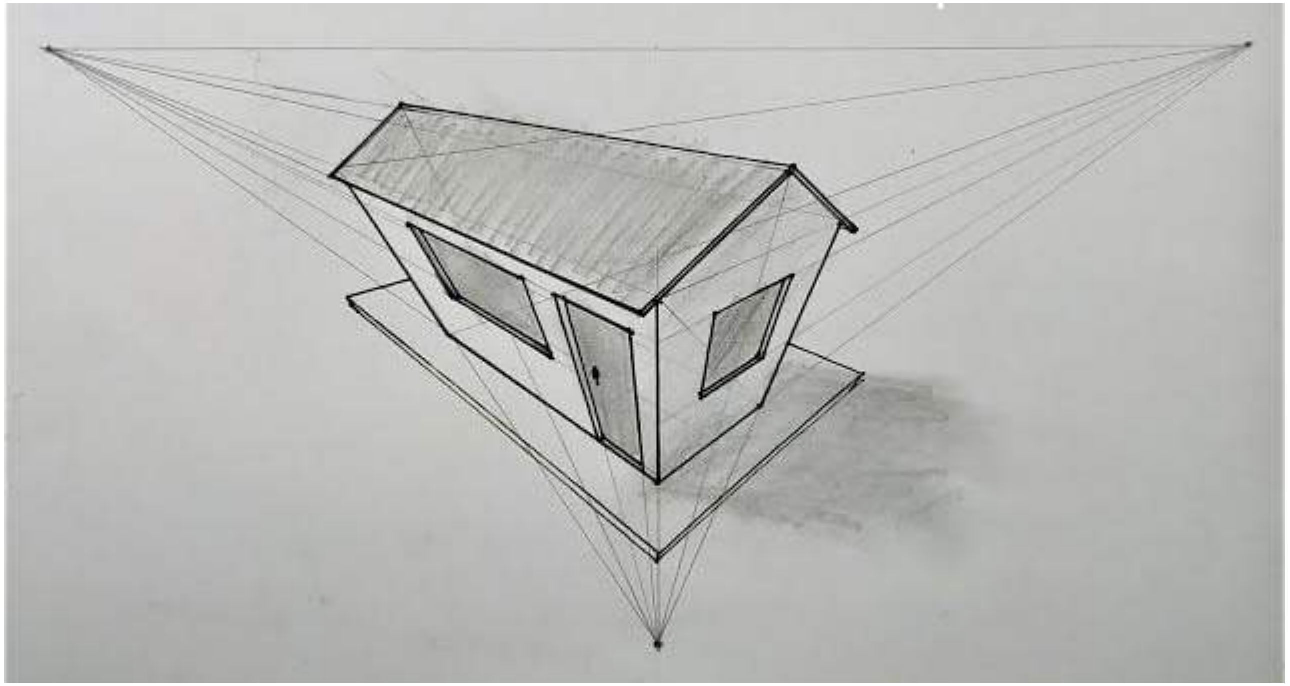
Two point perspective







Three point perspective



Principal planes

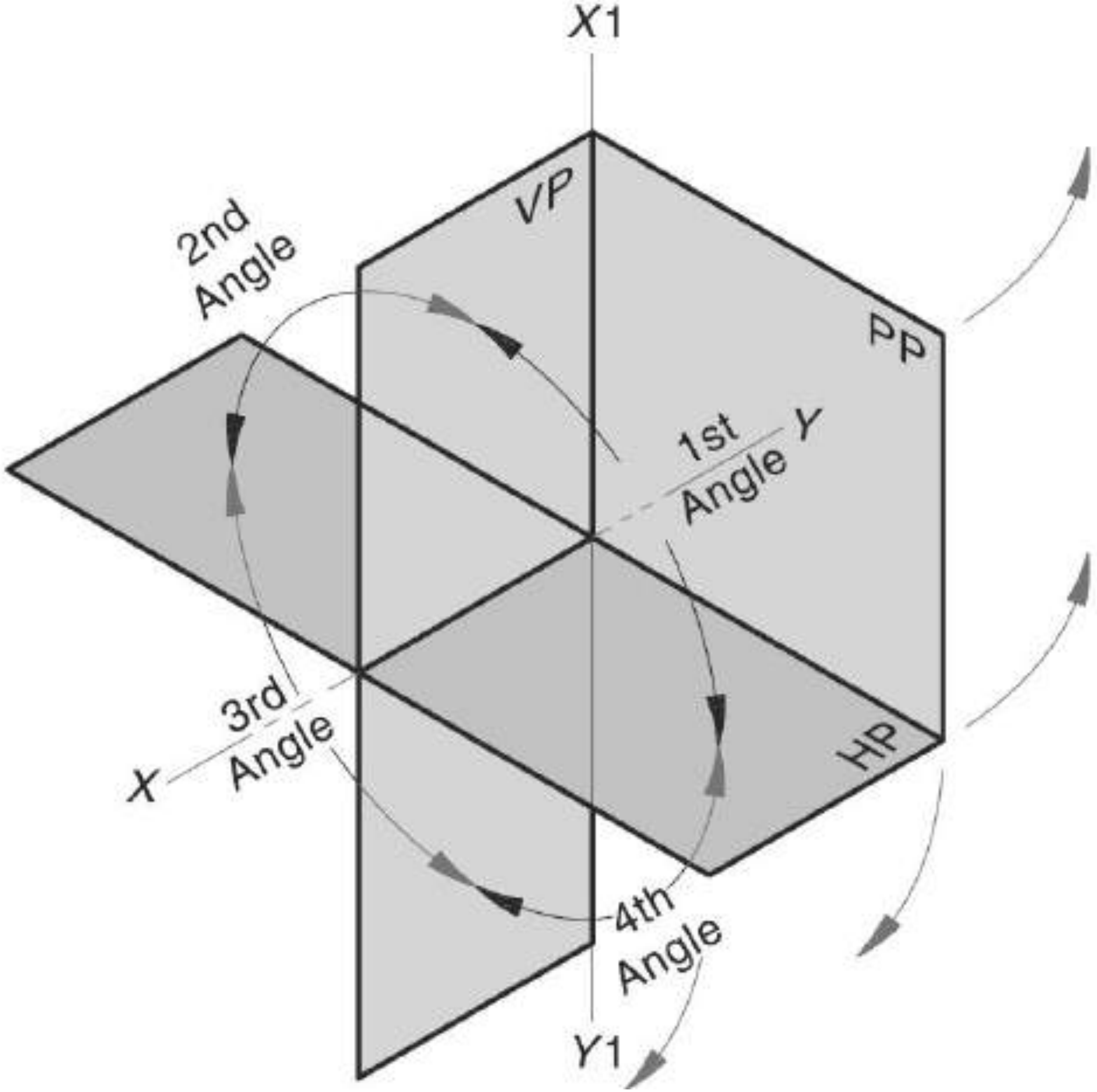
- A POP is a plane on which a particular view is projected.
- In multiview orthographic projections, we need different POPs to draw different views of an object.
- Three such planes, perpendicular to each other, are called **principal planes** or **reference planes (RP).**

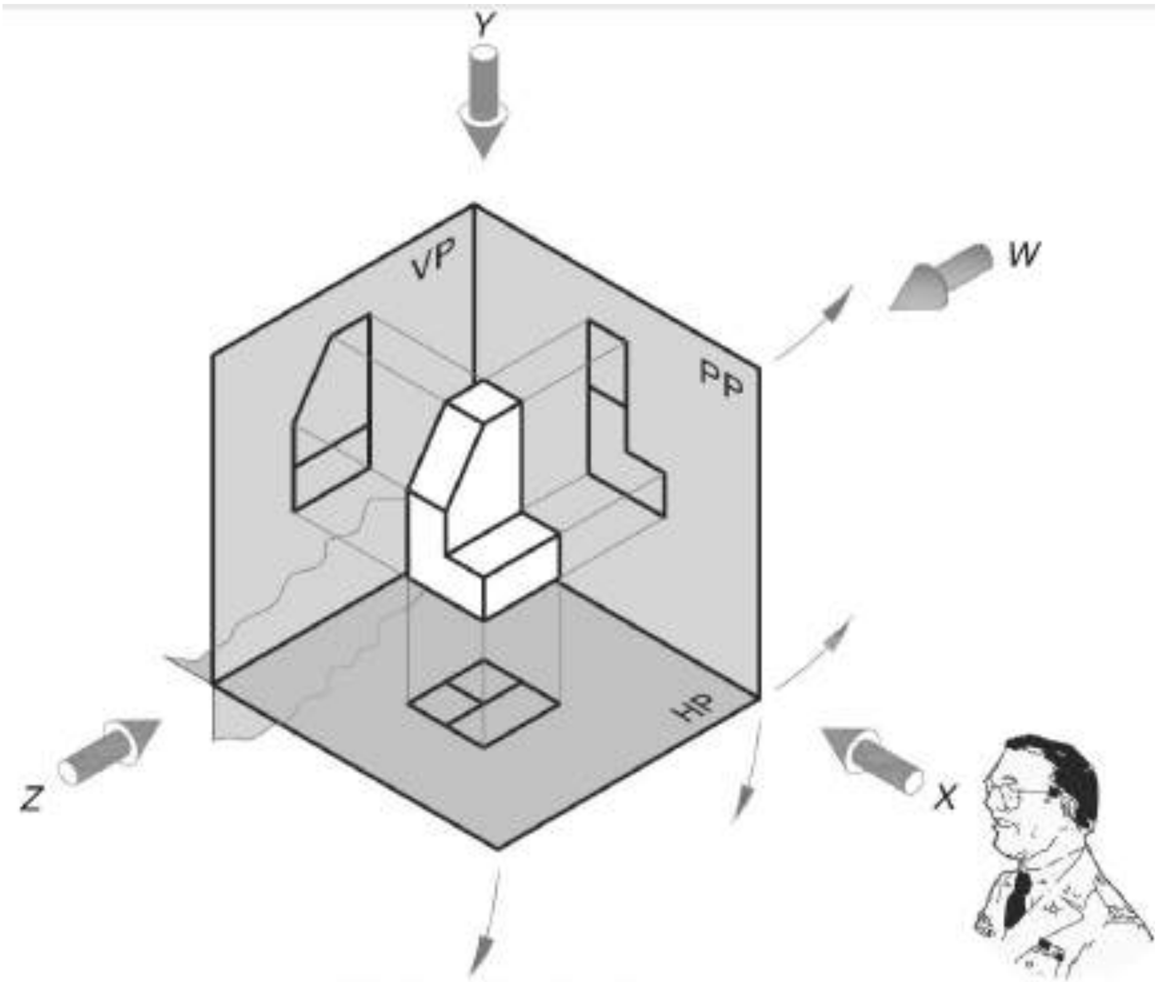
Horizontal Plane A plane parallel to the ground (or horizon) is called horizontal plane (HP) or horizontal reference plane (HRP).

Vertical Plane A plane perpendicular to the ground and intersecting the HP is called vertical plane (VP) or frontal reference plane (FRP).

Profile Plane A plane perpendicular to the HP and the VP and intersecting both of them is called profile plane (PP) or profile reference plane (PRP). It should be noted that the RPs are imaginary only. They are assumed to be transparent so that the observer can look through them.

Principal planes





(a) Object in First Angle

3D modeling structure

- A 3D model consists of entities and features like datum, solids, surfaces and so forth.
- Various operations are needed to prepare these features.
- These operations are carried out by commands available in CAD software.
- Commands are made available to the user in the forms of menus and icons.
- These icons provide maximum accessibility to the user with logical structuring.

Unit Settings

- Most CAD software contains predefined unit sets.
- Designers or CAD users should set the unit before starting any work.
- A unit system mainly consists of primary units, which are length, mass, and time. Sometimes, other primary units like temperature* that are needed in analysis may be present.
  1. SI (International System of Units)
  2. MKS (meter kilogram second)
  3. IPS (inch pound second)
  4. FPS (foot pound second)
  5. CGS (centimeter gram second)

SI base units are meter, kilogram, ampere, kelvin, mole and candela.

Sketch entities, Objects and Classification

- A 3D CAD model may consist of many entities or objects like sketches, solids, annotations, and so forth.
- **Sketches** are required to generate solid or surface models,
- **Annotations** are provided to display required process information or dimensions.
- A **CAD model** is defined as a combination of various objects.
- Objects in a CAD model facilitate applications like production drawing generation, analysis, manufacturing sequences, and so forth.
- Datums
- Sketch entities
- Solids
- Surfaces
- Annotations
- Parameters

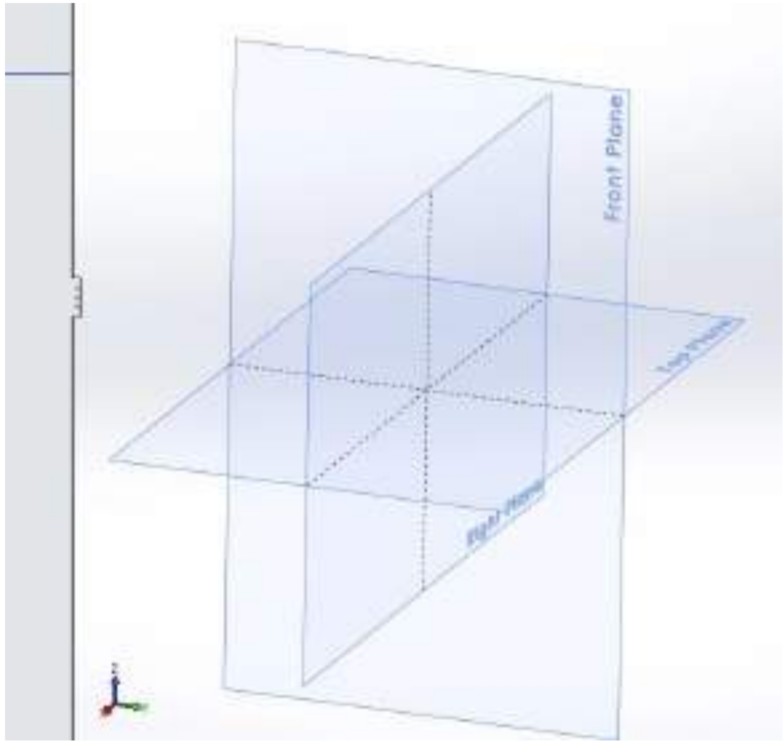
Objects in a CAD model

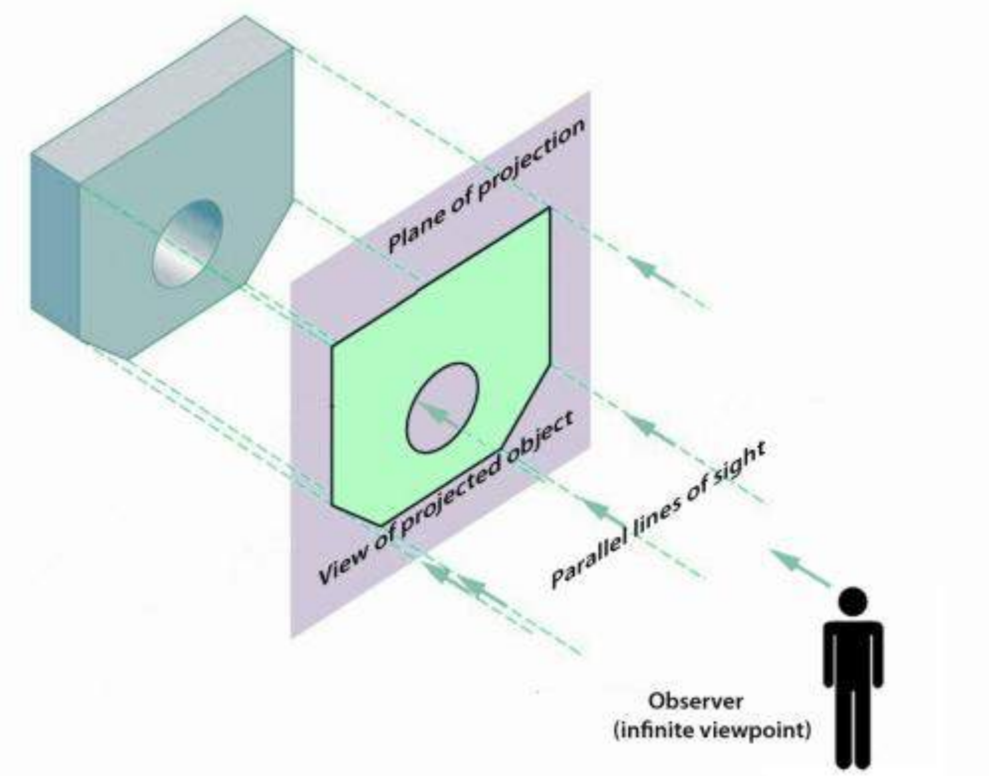
Datum

- Datum entities are those that do not have any physical existence or mass properties.
- However, they have an important function in creation of sketches or solids or in other applications like analysis, automation, and so forth.
- A parametric sketch can be best drawn on a flat plane; however, when starting the creation of a model, there would not be any flat surface on which sketches can be made.
- Planes are necessary to fulfill this need.
- Datum – plane, axis, point

Plane

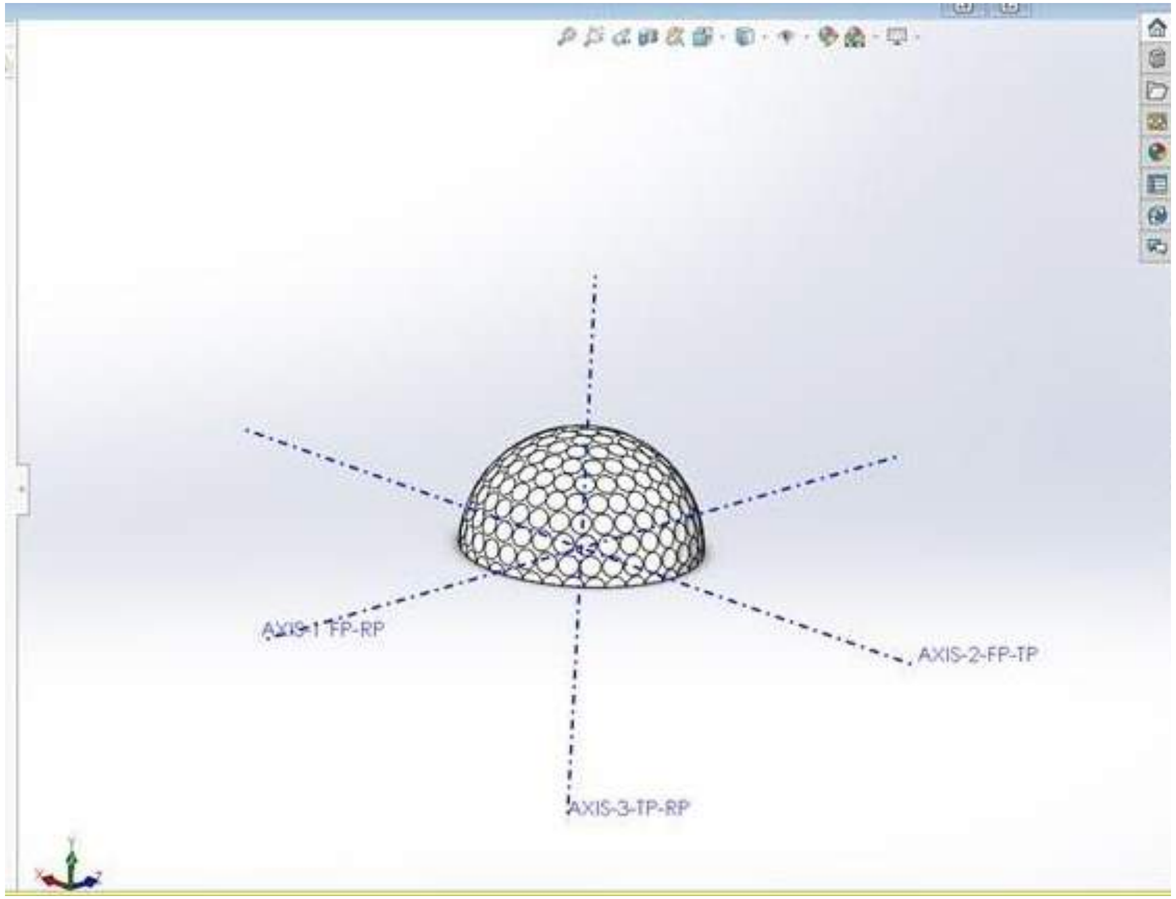
- A plane is an imaginary or real surface such that when end points of a straight line lie on the plane, every point that lies on the line also lies on the plane.
- Planes are mostly used as sketch planes.
- Planes are also being used as a reference element for measuring distance or for orientation and view creation.
- Normally, software provides three planes and a coordinate system by default to start with.

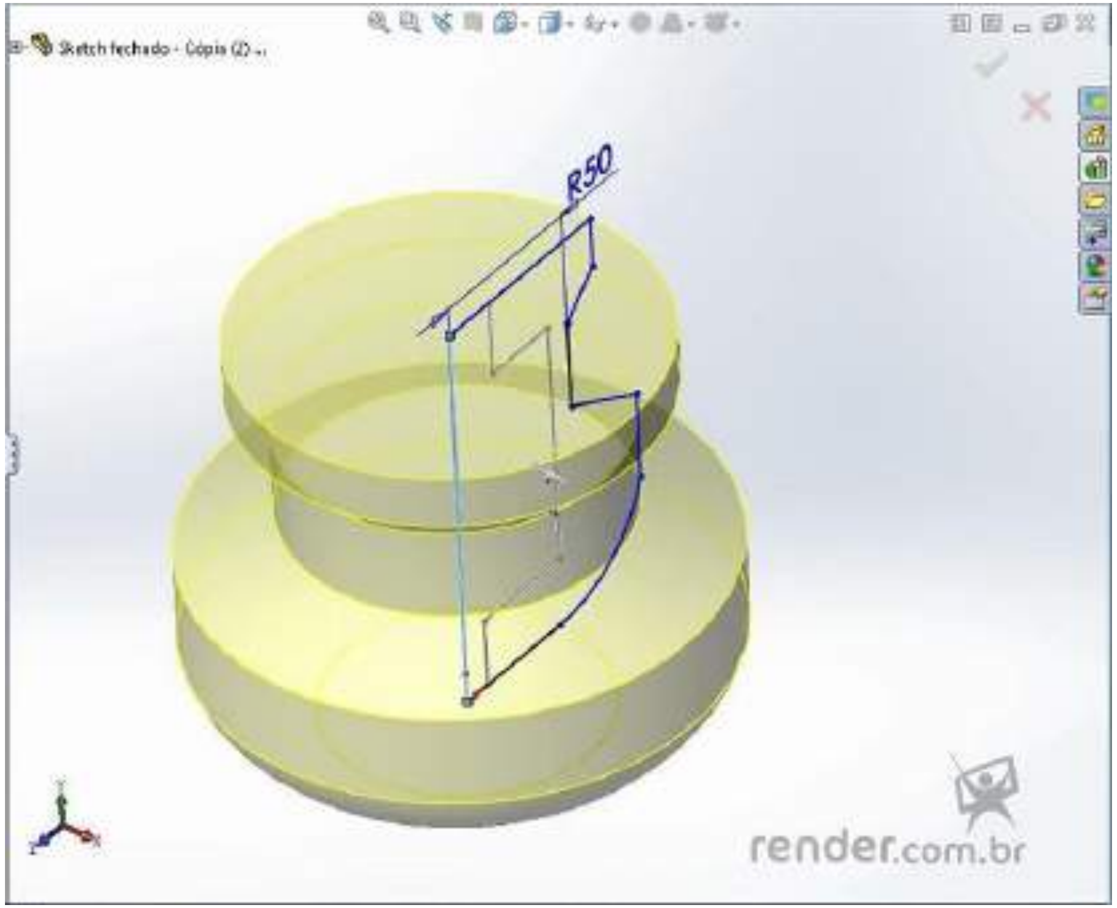




Axis

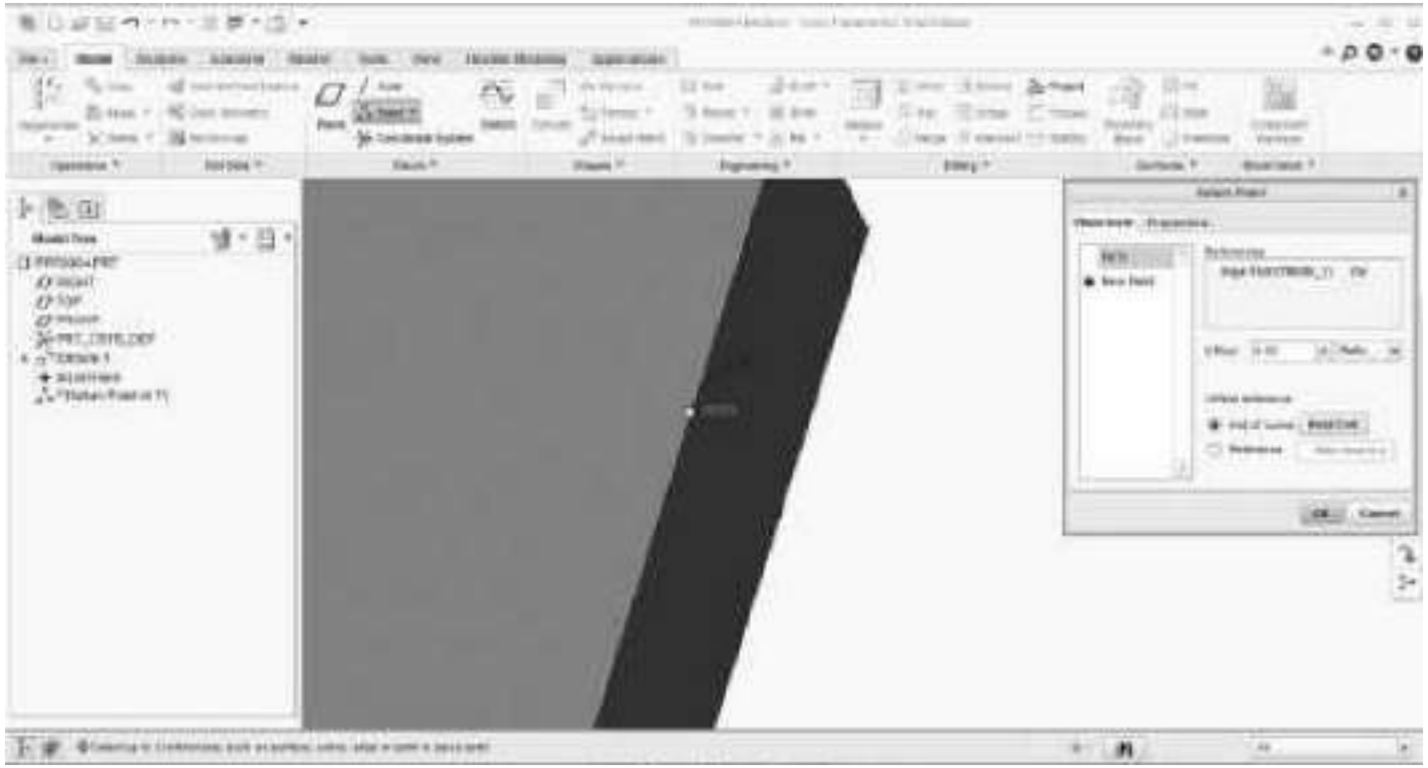
- An Axis is basically an imaginary infinite straight line in space.
- Axes are also used as reference geometry for sketching or locating or being an axis of rotation.





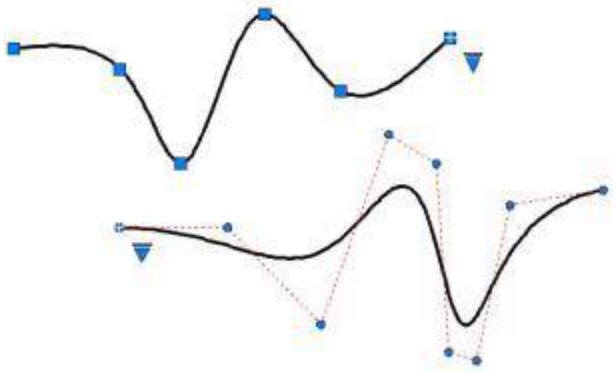
Point

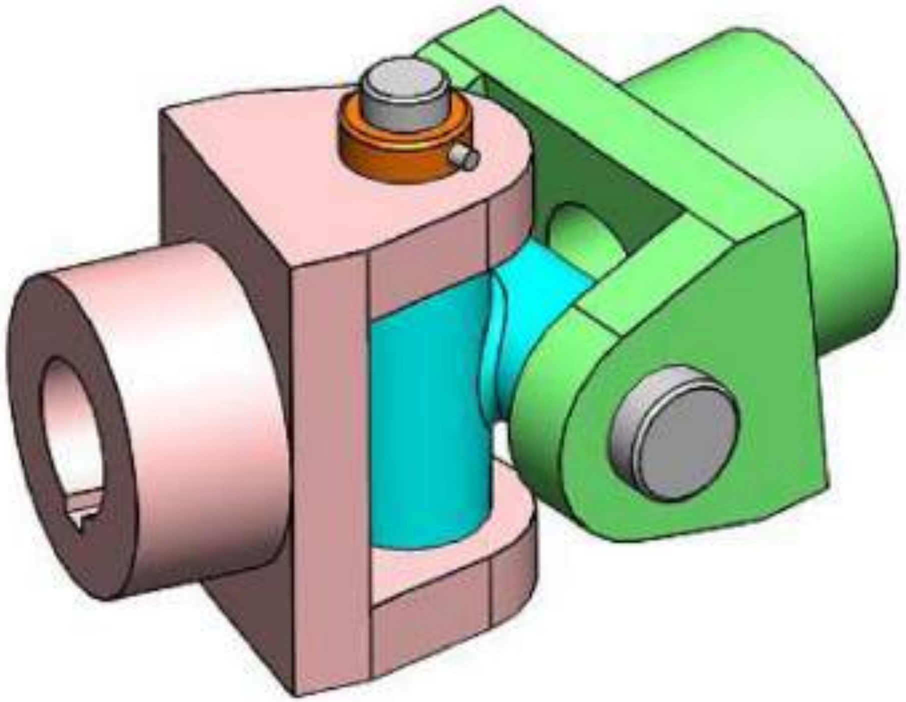
- Points can be created in a sketch or directly in 3-D space.
- Points are used to create various geometries or to facilitate measurement and dimensioning.



Sketch Entities

- In engineering, large assemblies are mostly combinations of simple or complex individual models.
- These solid are also created from geometries.
- Most CAD software provides common geometry tools for sketching.
- Point, Line, Arc or Circle, Rectangle, Parallelogram, Polygon, Ellipse, Spline





3D Curves

- If all the points on the curve do not lie in a single plane, then the curve is called a three-dimensional curve or 3D curve.
- 3D curves can be created by one of the following methods:

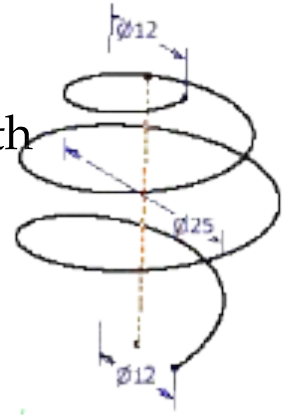
  1. By equation

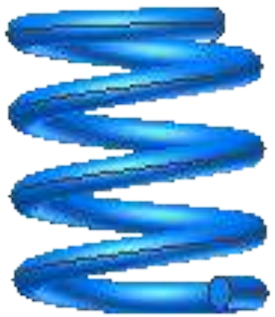
  2. By special available tools like 3D curve, helical sweep, and so forth

  3. By tracing of a point in a mechanism
- The explicit applications of 3D curves are as follows:

  1. To create an object

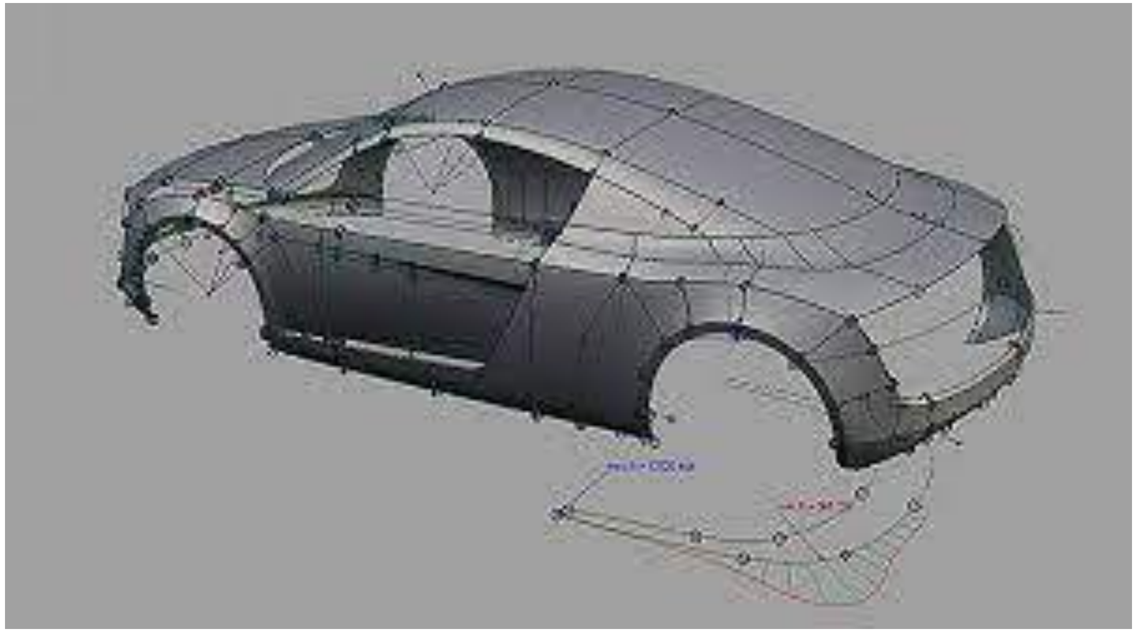
  2. To create the path of a point, which may be created from a mechanism





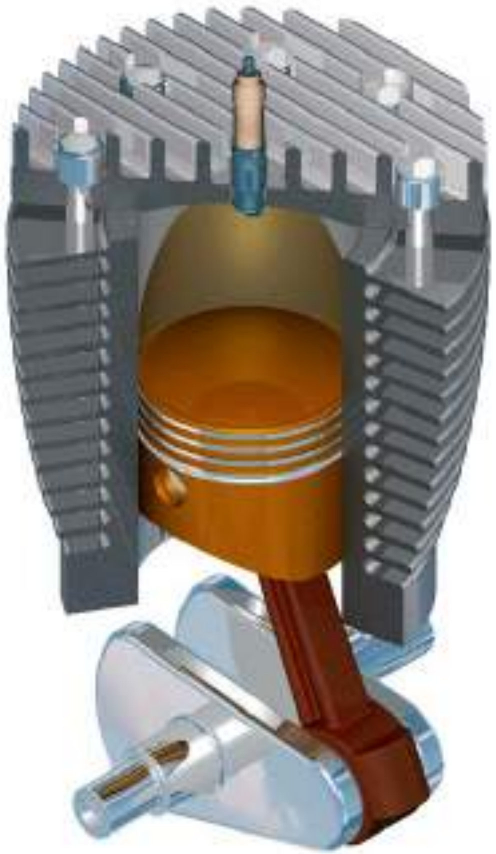
Surfaces

- A surface can be imagined as the skin of a solid.
- Widely used in designing shapes, such as vehicle's body, wings of airplanes etc.
- It's a mathematical method for displaying solid 3D objects.
- Allows users to view 3D models from different angles.



Solids

- Solids are created by operating primitives or protruding the sections in a path.
- Solids are mainly used for the following purposes:
  - To visualize component shape and size
  - To analyze a model
  - To generate a production drawing



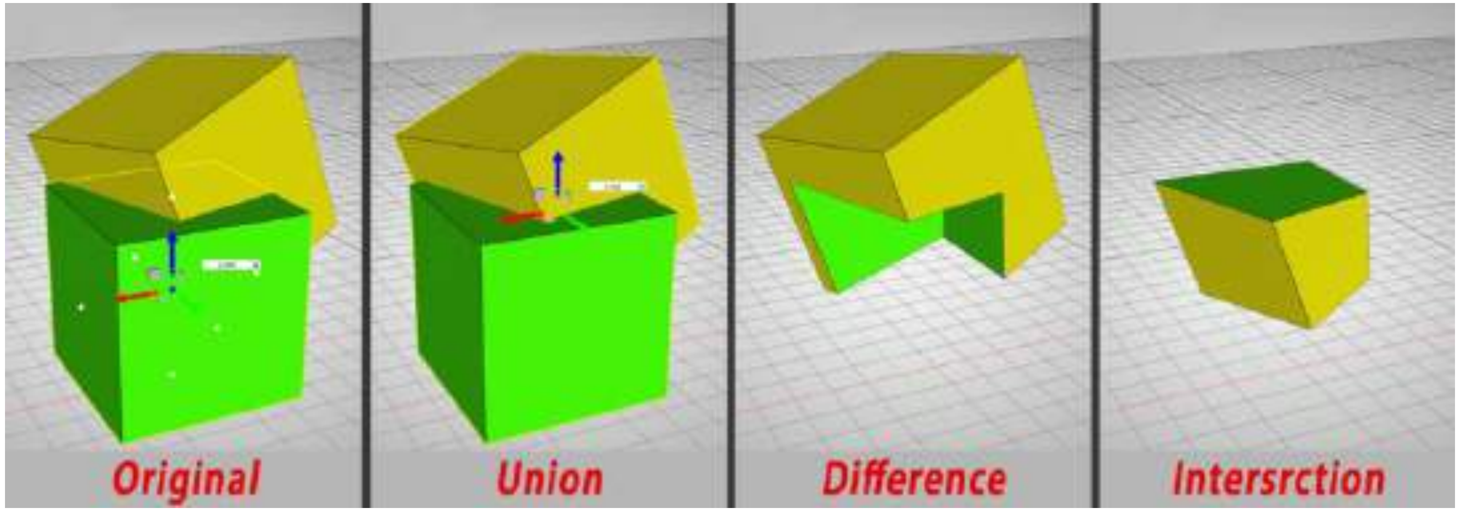
Regional Operations

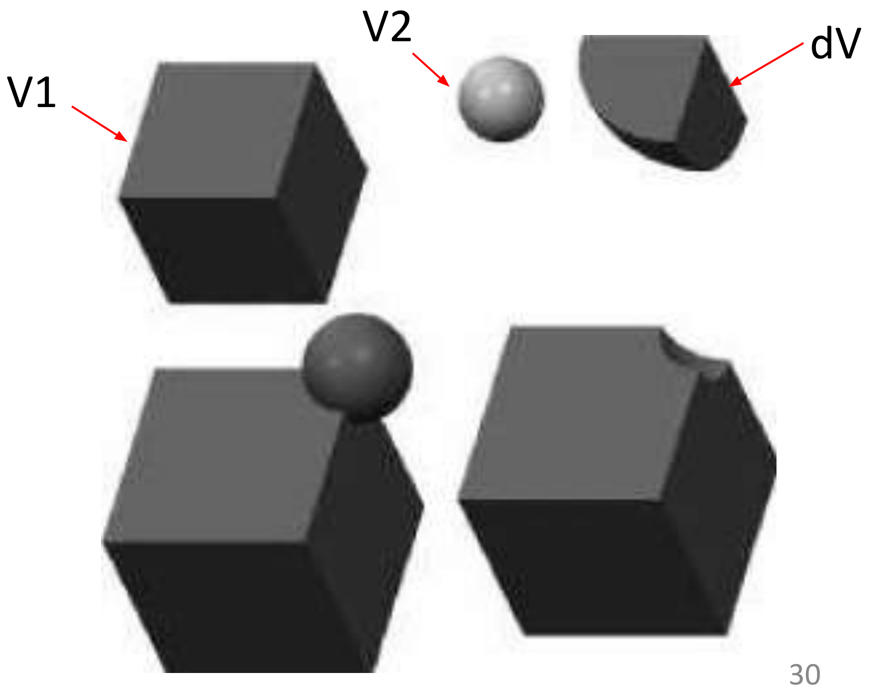
- Regional operations are mainly manipulation of regions to create a desired shape.
- A desired shape of a product may not be generated easily by single creation of any entity or object.
- Boolean operations are used for constructive solid geometry creation.
- Boolean operation in solid modeling can be broadly divided into three categories as follows:

  1. Union/addition
  2. Difference/subtraction
  3. Intersection

Regional Operations

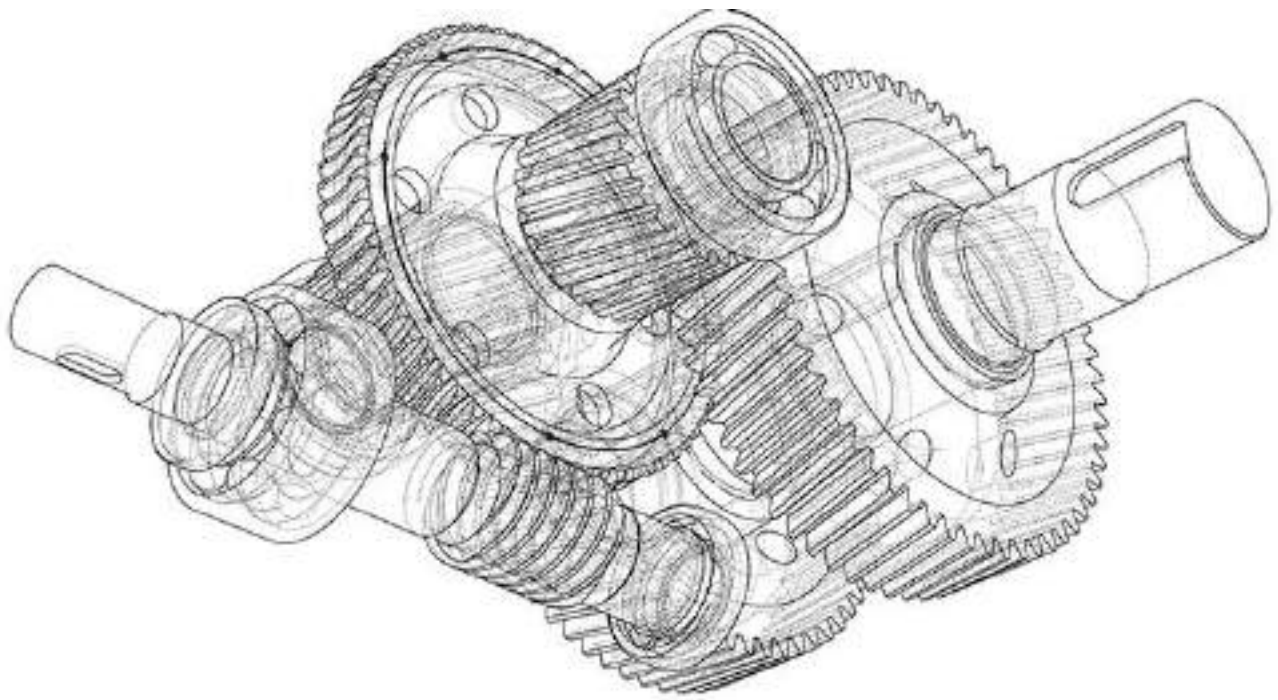
- The final volume after union operation will be $V1 + V2 - dV$.
- The final volume after subtraction will be $V1 - dV$.
- The final volume after intersection will be dV.





Wireframes

- Wireframe modeling is an approach that aims to demonstrate the basic structure of an object via lines and transparency. In other words, a 3D model wireframe is composed of lines, edges and curves, but you do not just see the front-facing side of the object, you also see its edges and structure from the back, lower side, etc.
- A wireframe object is not recognized as solid. Instead, the boundary of the object is recorded as points and their connections.



3D modeling software

- AutoCAD
- Pro-E (Pro/Engineer)
- Catia
- SolidWorks
- Blender
- Maya
- SketchUp
- 3DS Max
- Zbrush
- ArchiCAD
- Fusion 360

File types

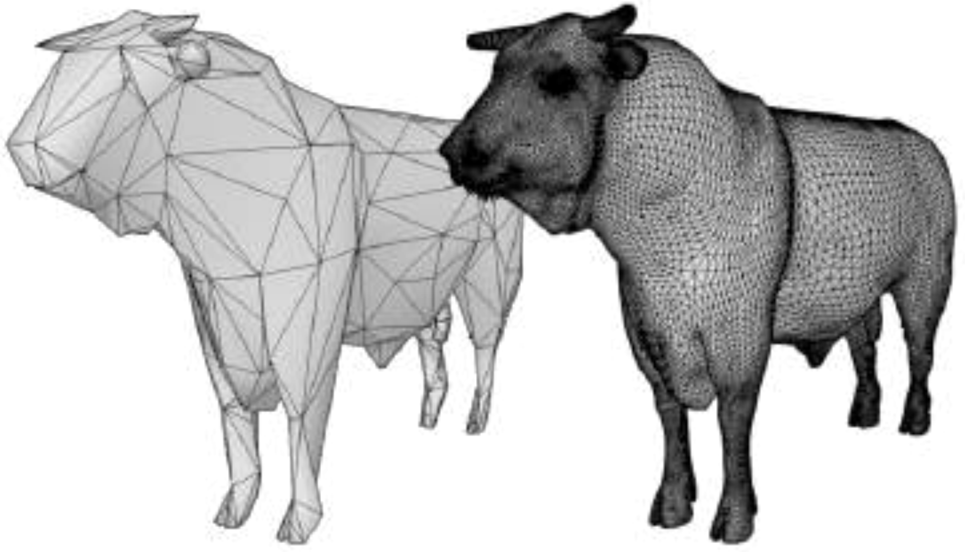
- CAD files are digital files containing 3D or 2D models of physical objects.
- Includes information such as geometric data, manufacturing data, material properties etc.
- Native and Neutral CAD formats.
- For example, *.CATPart (a CATIA format) will only work on CATIA-approved software. It will not easily be readable or editable on other CAD software like AutoDesk, Creo, NX, etc.
- Neutral file format i.e. STL

File types

- **STL:** a popular file format, widely used in 3D printing, rapid prototyping and CAM.
- **FBX:** It can store information on a model's geometry, texture, color, and other appearance-related properties. It's mostly used when working with film and video games.
- **3DS:** It also stores geometry, animation, and basic information on the appearance of the model. The 3DS format is mostly used in academic, engineering, architecture, and production domains.
- **OBJ:** This 3D file format is mainly found in 3D printing. It stores 3D objects that contain polygonal faces, texture maps, 3D coordinates, and other object information.
- **STEP:** are the most widely used and accepted neutral CAD format today, making it a standard across multiple industries. Most CAD software supports importing and exporting STEP files, allowing it to be interoperable between different systems, including CAM (computer-aided manufacturing), CAI (computer-aided inspection), and CAE (computer-aided engineering).

Low Poly and High Poly models

- This represents polygon counts of an individual 3D model.
- Number of polygons present in a model determines the smoothness and accuracy of finished objects.
- Model's weight is heavier with higher poly counts requiring longer to process, download and greater storage.



Low Poly and High Poly models

Advantages of High Poly models

- The ability to create **photorealistic 3D representations** of real-world objects.
- The geometry of high-poly models is **very complex** as it consists of many polyg
  different shapes, especially, when it comes to curved objects.
- Models can be looked at closely without dramatic loss of **image quality**.
- high-poly models take **longer to render** than low-poly models due to complex
  textures, and details. Rendering engine has to calculate the light refraction fro
  surface and all edges of the high-poly 3D object

Advantages of Low Poly models

- **Lower processing** requirements mean that Low Poly modeling can be **faster**.
- **Lower file weights** make storing a large number of Low Poly 3D models more convenient.
- Low Poly 3D models can be **manipulated in real-time** by users without lag or slow-down.
- **Ideal for use in games** where speed matters more than visual richness.
- Low Poly art generally has a much **lower price tag** than High Poly alternatives. However, that also depends on the model complexity.
- Speed and interactivity mean that Low Poly techniques **work well when VR or AR** are involved.