

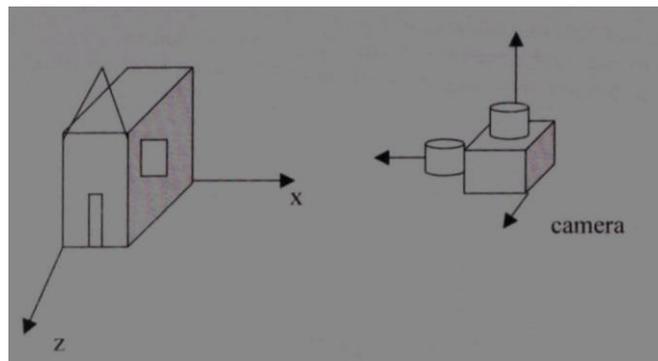
### 4.3 THREE-DIMENSIONAL VIEWING

We have seen the different methods for representing 3 dimensional objects. That is polygon surfaces. Quadric surfaces and spline curves. Suppose we have stored some 3 dimensional objects in the computer system using these representations. Now we have to find a method to display these 3 dimensional objects on the 2 dimensional view window.

We have already seen how to display a 2 dimensional picture on a view window, we have seen line clipping and polygon clipping that can be used to clip those regions of a 2 dimensional picture that are outside the window boundaries. We have seen window to view port transformation for mapping a 2 d scene to view port coordinates.

For 3 dimensional applications, display of 3 dimensional objects involves a number of steps. Here we have a number of choices. We can view the 3d object from a number of positions. (Front, back, side, top etc...). Also a 3d object must be projected on to a 2d flat surface (monitor) of the output device. Here also clipping should be done. Here clipping boundaries enclose a volume of space.

In this section, we will discuss the operations needed to produce views of a 3d scene. Generating a view of a 3d scene is similar to taking a photograph of a scene using a camera. To take a photo, first we place the camera at a particular position. Then we change the direction of the camera. We can point the camera to a particular scene and we can rotate the camera around the 3d object. Finally, when we put the switch, the scene will be adjusted to the size of the window of the camera and light from the scene will be projected on to the camera film.

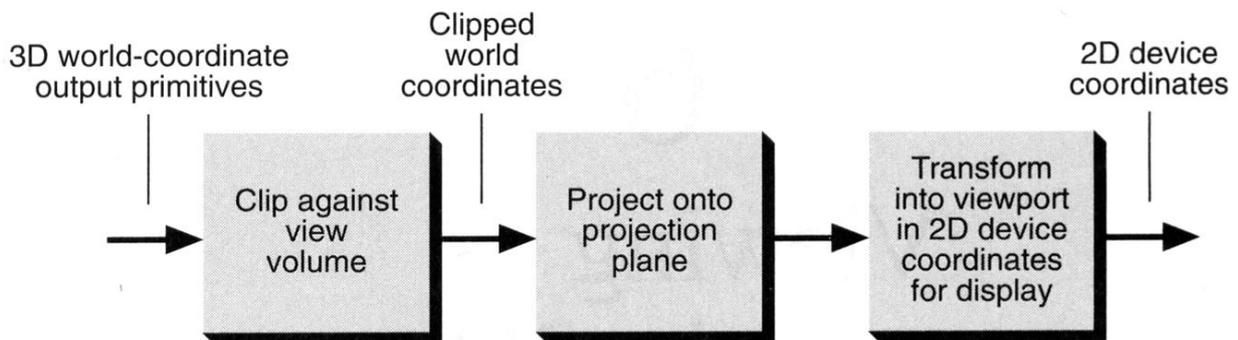


(Fig: 4.5 –Photographing a scene involves selection of a camera position and orientation)

#### Steps involved in 3d viewing (conceptual)

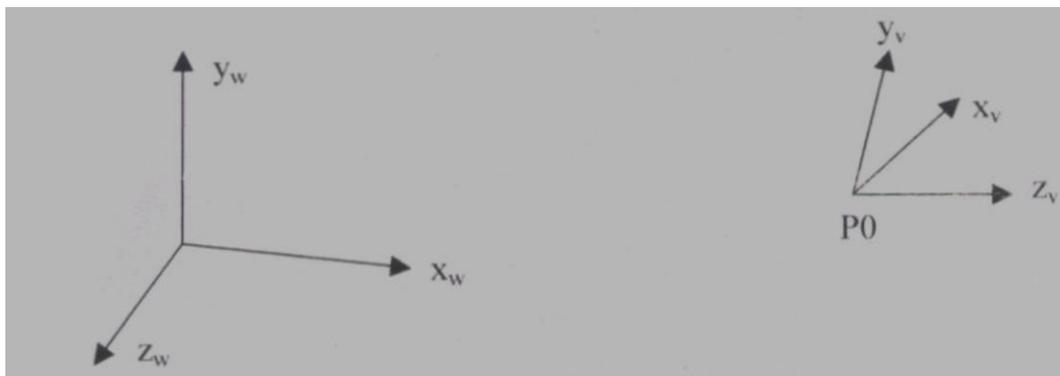
In 3 dimensional viewing, we specify a view volume. Then a projection on to a projection plane and a mapping of this projected scene on to the view surface. Objects in 3d are clipped against the view volume and are then projected on to a plane.

The contents in the projection plane are mapped (transformed) in to the view port for display.



### Viewing coordinates

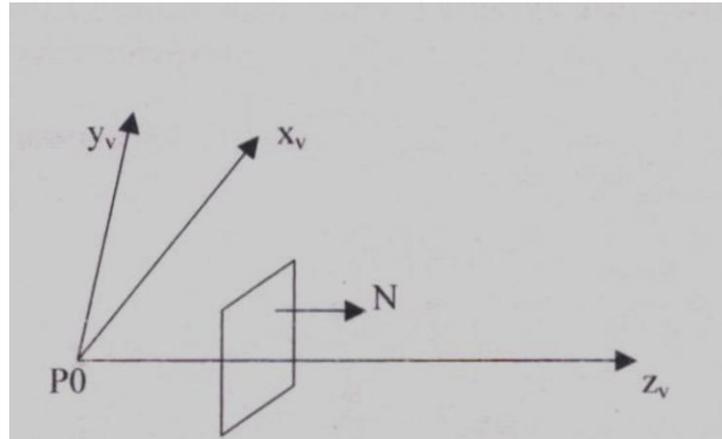
We have seen that generating the view of a 3dimensional object is similar to photographing the object. We can walk around an object. We can take its picture from any angle at various distances and we can vary the camera orientation. The size of the camera lens determines which part of the scene will appear in the final picture. Thus we have the position, orientation of the camera and aperture size of the camera lens.



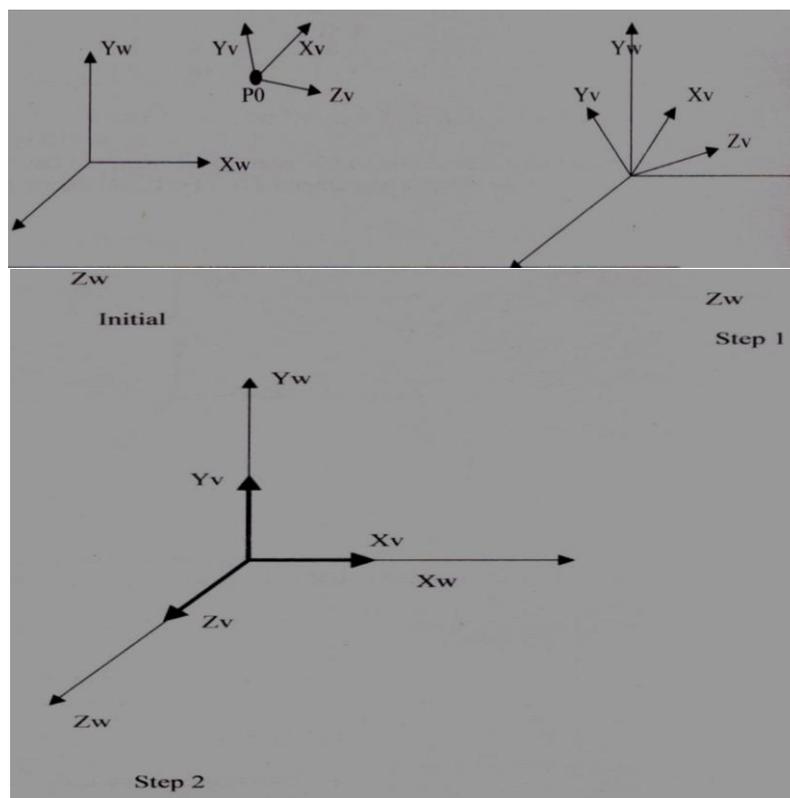
**(Fig: 4.6 - A right-handed viewing coordinate system, with axes  $x_v$ ,  $y_v$ , and  $z_v$ , relative to a world-coordinate scene).**

We first establish a viewing coordinate system. (Position of camera). In the above, it is  $X_v$ ,  $Y_v$  and  $Z_v$  axes. Then we set up a view plane or projection plane perpendicular to the  $z$  axis. (Camera film).

World coordinates in the scene are transformed to viewing coordinates. Then viewing coordinates are projected on to the view plane. Then we choose a view reference point, in the above, it is  $P_0$ . This is the origin of the viewing coordinate system. (Position of the camera).



Next we select the positive direction of the viewing  $z$  axis. Then we select the orientation of the viewing plane by specifying the normal vector  $N$ . Then we choose the up direction for the view by a vector,  $V$  called view up vector. Normally, the view plane or projection plane is perpendicular to  $Z_v$  axis respectively. These are shown below.



(Fig: 4.7 - Aligning a viewing system with the world coordinate axes using a sequence of translate-rotate transformations.)

## 4.4 PROJECTIONS

We have seen the method to convert world coordinate description of objects to viewing coordinates. Next we have to project 3 dimensional objects on to the 2 dimensional view planes.

Two basic projection methods are Parallel projection and Perspective projection. Key factor is the *center of projection*.

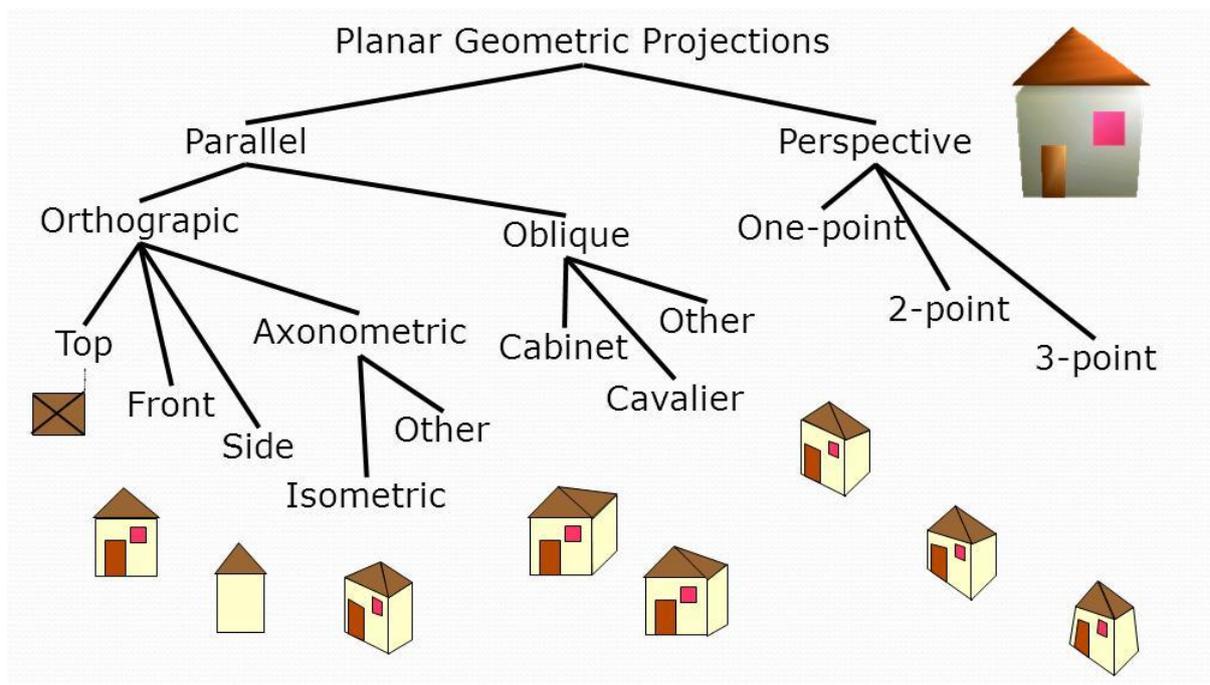
- if distance to center of projection is finite : perspective
- if infinite : parallel

Classification of projections. Based on:

- ▶ **Centre of projection: infinity (parallel) or a point (perspective)**
- ▶ **Projection lines wrt. projection plane: orthogonal (orthographic), another angle (oblique)**

**Projections: key terms...**

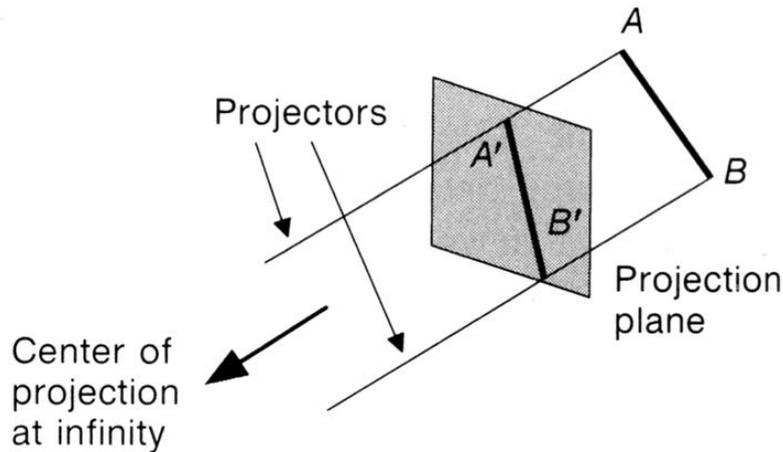
- ❖ **Projection** from 3D to 2D is defined by straight *projection rays* (*projectors*) emanating from the '*center of projection*', passing through each point of the object, and intersecting the '*projection plane*' to form a projection.



(Fig: 4.8 – Types of projections)

#### 4.4.1 PARALLEL PROJECTION

In a parallel projection, coordinate positions are transformed to the view plane along parallel lines.



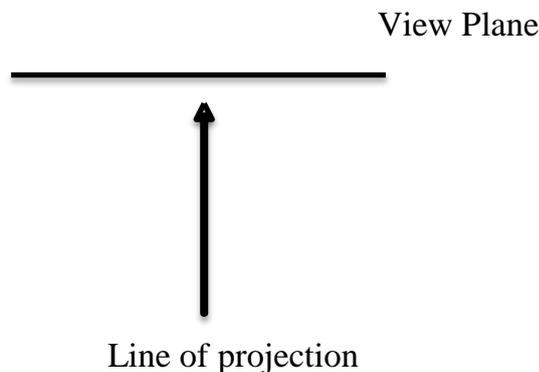
(Fig: 4.9 - Parallel projection of an object to the view plane)

A parallel projection preserves relative proportions of objects. Accurate views of the various sides of an object are obtained using parallel projection. But we will not get a realistic representation of the object.

- ❖ less realistic view because of no foreshortening
- ❖ However, parallel lines remain parallel.

#### A) Orthographic parallel projection

When the projection is perpendicular to the view plane, we have an orthographic parallel projection.

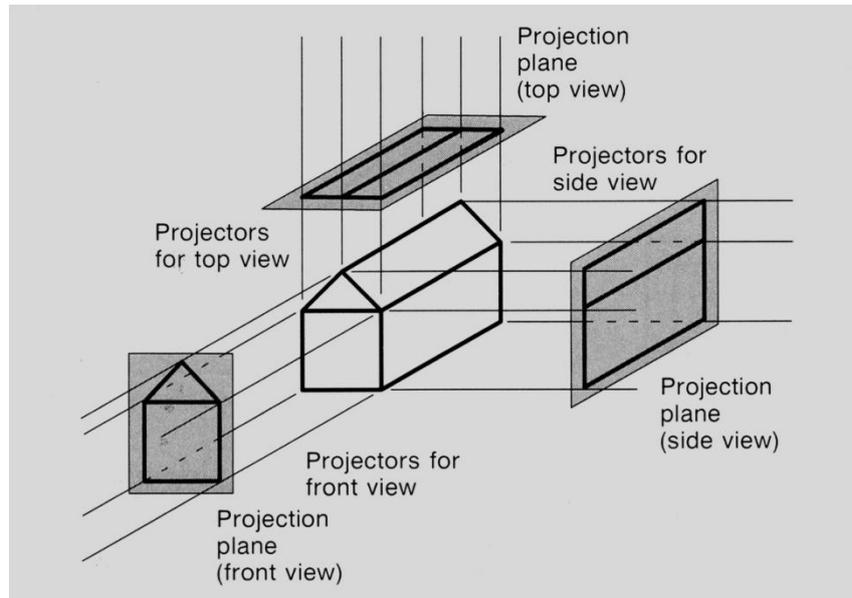


Orthographic projections are often used to obtain the front, side and top views of an object.

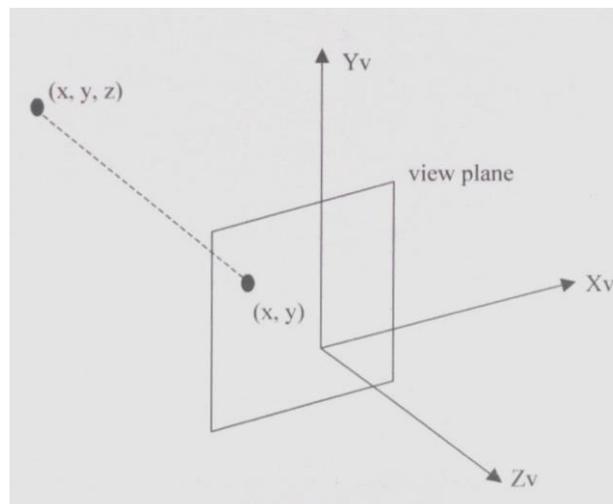
Transformation equations for orthographic parallel projection are simple. Suppose the view plane is perpendicular to  $Z_v$  axis and along  $X_v$ ,  $Y_v$  plane, then any point  $(x, y, z)$  on the object projected on to the view plane is  $x_p = x$ ,  $y_p = y$

- ❖ Orthographic projections are most often used to produce the front, side, and top **views** of an object.

- ❖ Front, side, and rear orthographic projections of an object are called *elevations*; and a top orthographic projection is called a plan view.
- ❖ Engineering and architectural drawings commonly employ these orthographic projections, because lengths and angles are accurately depicted, and can be measured from the drawings.



(Fig: 4.10 – Orthographic projection of an object)



(Fig: 4.11 - Orthographic projection of a point onto a viewing plane.)

We can also form orthographic projections that display more than one face of an object. Such views are called axonometric orthographic projections. The most commonly used axonometric projection is the isometric projection.

We generate an isometric projection by aligning the projection plane so that it intersects each coordinate axis in which object is defined (called the *principal axes*) at the same distance from the origin

## B) Oblique parallel projection

An oblique projection is obtained by projecting points along parallel lines that are not perpendicular to the projection plane.

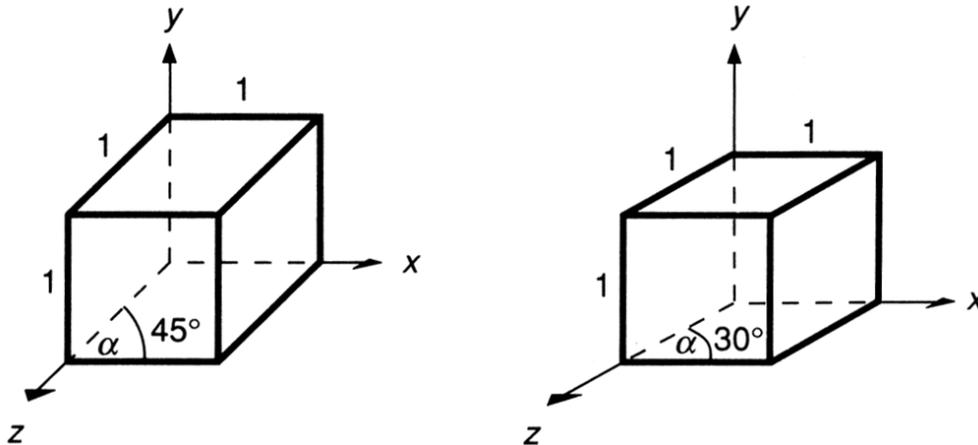
- ❖ Objects can be visualized better than with orthographic projections
- ❖ Can measure distances, but not angles\*

\* Can only measure angles for faces of objects parallel to the plane

2 common oblique parallel projections: *Cavalier* and *Cabinet*

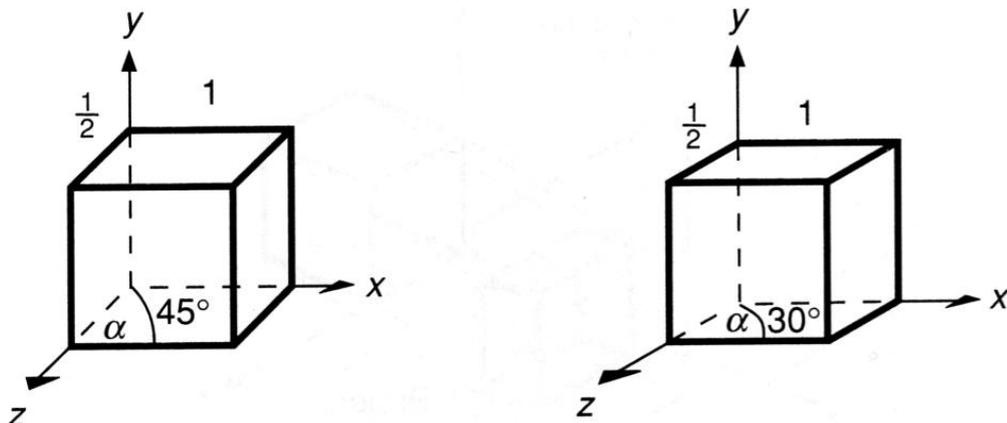
### Cavalier:

Common choices for angle  $\theta$  are 30 and 45 degree, which display a combination view of the front, side, and top (or front, side, and bottom) of an object. Two commonly used values for  $\alpha$  are those for which  $\tan \alpha = 1$  and  $\tan \alpha = 2$ . For the first case,  $\alpha = 45^\circ$  and the views obtained are called cavalier projections. All lines perpendicular to the projection plane are projected with no change in length.



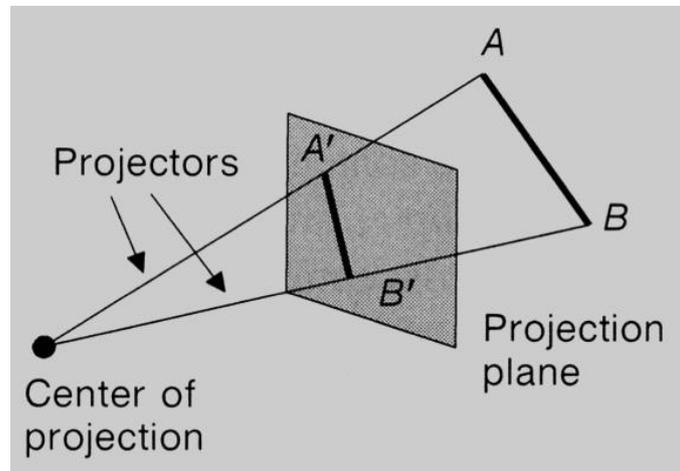
### Cabinet:

The direction of the projection makes a 63.4 degree angle with the projection plane. This results in foreshortening of the z axis, and provides a more “realistic” view.



### 4.4.2 PERSPECTIVE:

- ❖ Visual effect is similar to human visual system.
- ❖ Has 'perspective foreshortening'.
- ❖ Size of object varies inversely with distance from the center of projection.



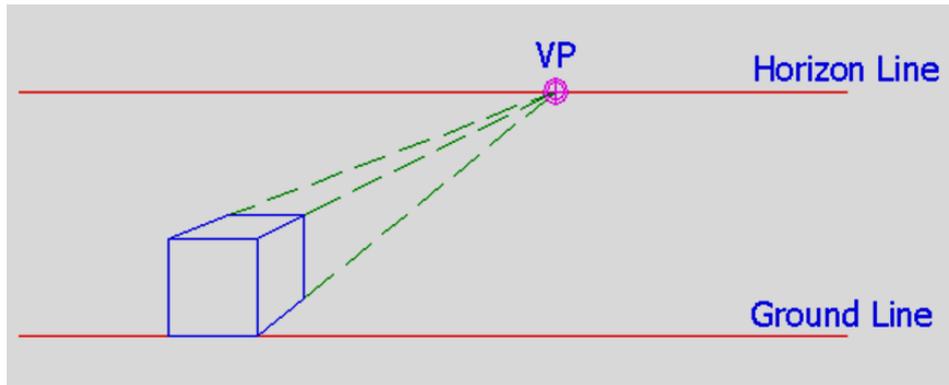
- ❖ Single point centre of projection (i.e. projection lines converge at a point).
- ❖ Shapes are projected smaller as their distances to the view plane increase.
- ❖ More realistic (human eye is a perspective projector).
- ❖ Depending on number of principal axes intersecting the viewing plane: 1, 2 or 3 vanishing points.

#### Perspective Projection Characteristics

- Center of Projection (CP) is a finite distance from object
- Projectors are rays (i.e., non-parallel)
- *Vanishing points*
- Objects appear smaller as distance from CP (eye of observer) increases
- Difficult to determine exact size and shape of object
- Most realistic, difficult to execute

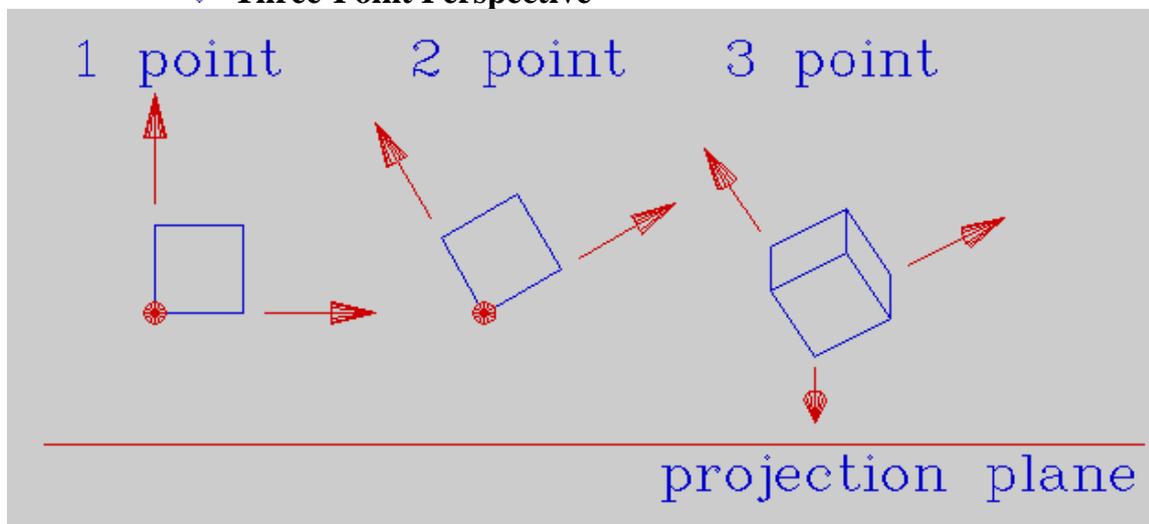
#### Perspective Sketch

- ◆ Horizon – observer's eye level.
- ◆ Ground Line – plane on which object rests.
- ◆ Vanishing point – position on horizon where depth projectors converge.
- ◆ Projection plane – plane upon which object is projected.



### Classes of Perspective Projection

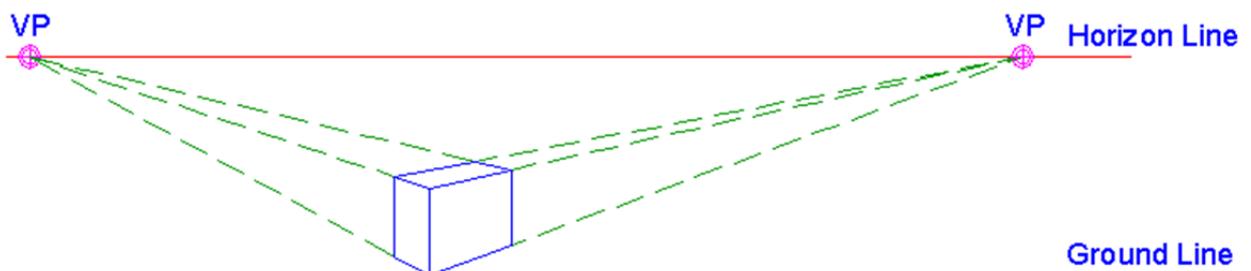
- ◆ One-Point Perspective
- ◆ Two-Point Perspective
- ◆ Three-Point Perspective



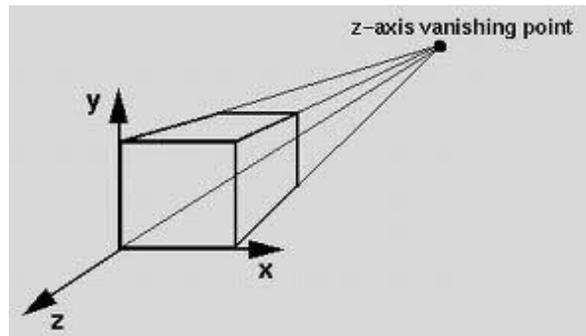
View from Above

### Vanishing Points

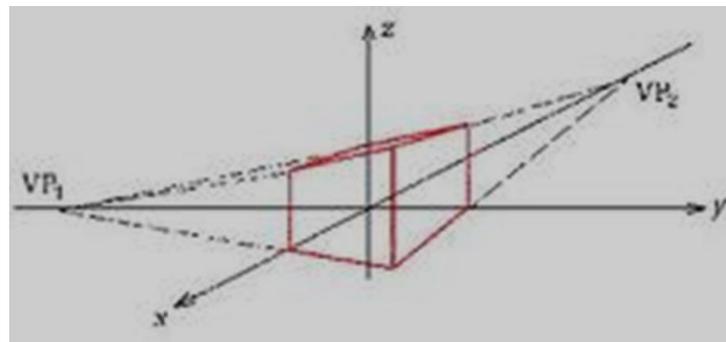
- ◆ Object edges parallel to projection plane remain parallel in a perspective projection
- ◆ Object edges not parallel to projection plane converge to a single point in a perspective projection → *vanishing point (vp)*
- ◆ Vanishing point of a principal axis → *principal vanishing point (pvp)*



## One-Point Perspective



## Two-Point Perspective



## Three-Point Perspective

