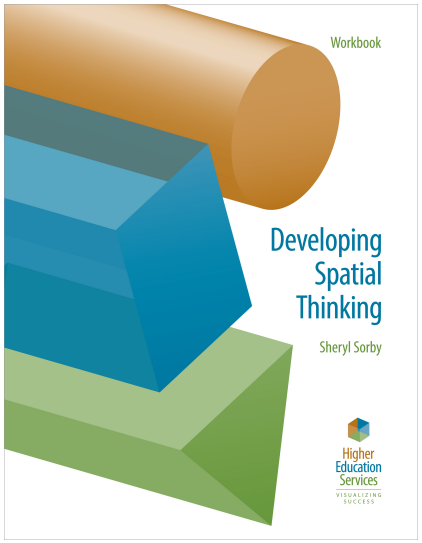
Higher Education Services
VISUALIZING SUCCESS



Presentation Slides

to be used in conjunction with the Developing Spatial Thinking Curriculum.

Module 1 – Solids of Revolution
Module 2 – Combining Solids
Module 3 – Isometric Sketching
Module 4 – Orthographic Projection
Module 5 – Incline and Curved Surfaces
Module 6 – Flat Patterns
Module 7 – Rotation of Objects about 1 Axis
Module 8 – Rotation of Objects about 2 Axes
Module 9 – Object Reflections and Symmetry
Module 10 – Cutting Planes

Accessible at
http://www.higheredservices.org/spatial-course-materials/

Surfaces and Solids of Revolution

Module 1

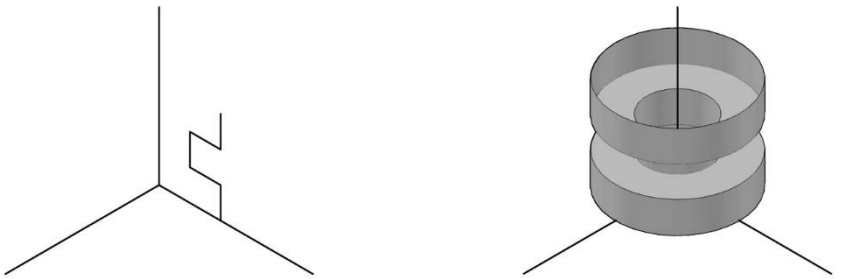
Session Topics

- Surfaces and Solids of Revolution
- Degree of Revolution
- Hollow Objects
- Visualizing Revolution

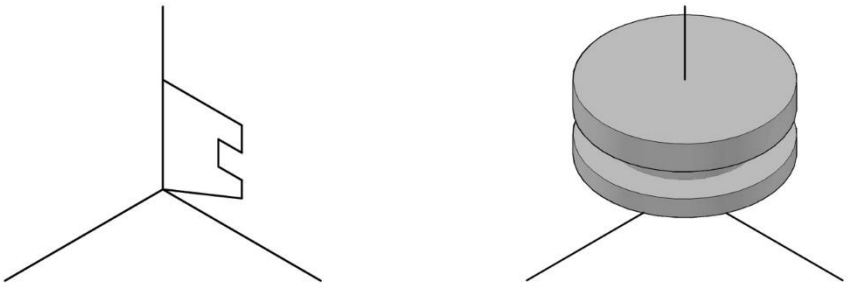
Surfaces and Solids of Revolution

Surfaces and Solids of Revolution are formed when a 2-D shape is revolved about an axis

- Surfaces result if the shape is open
- Solids result if the shape is closed



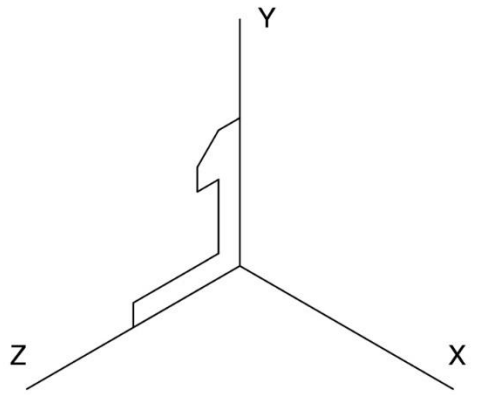
2-D Shape and Surface of Revolution



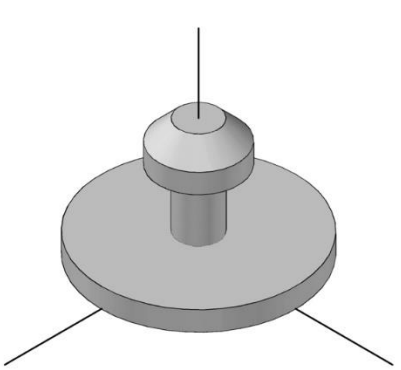
Closed 2-D Shape and Solid of Revolution

Solids of Revolution

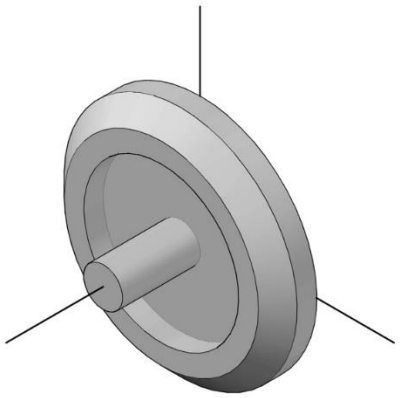
The resulting 3-D object depends on the axis about which the 2-D shape was revolved



2-D Shape



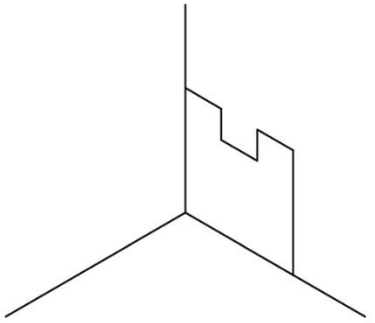
Shape Revolved About Y



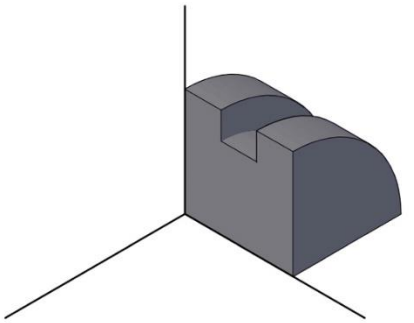
Shape Revolved About Z

Angle of Revolution

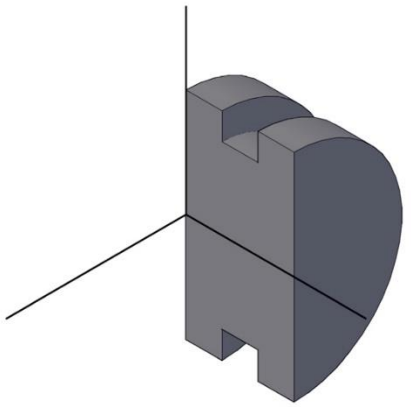
Resulting 3-D object also depends on the degree of angular revolution



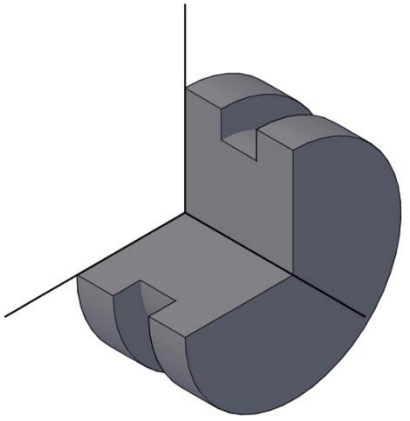
2-D Shape



Shape Revolved 90 Degrees



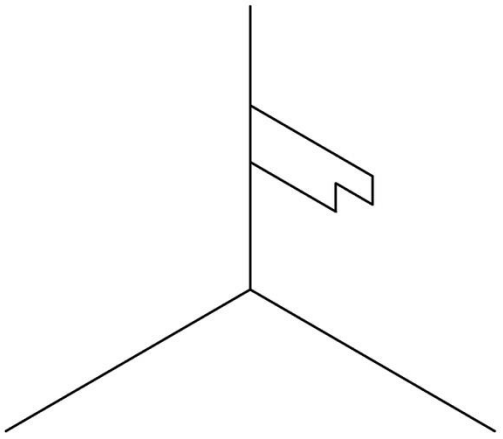
Shape Revolved 180 Degrees



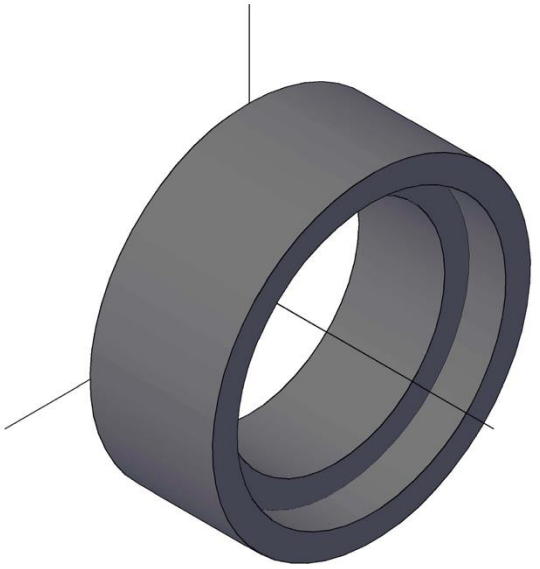
Shape Revolved 270 Degrees

Hollow Objects

If a 2-D shape is located "away from" the axis of revolution, a solid of revolution with a cylindrical hole in it will result



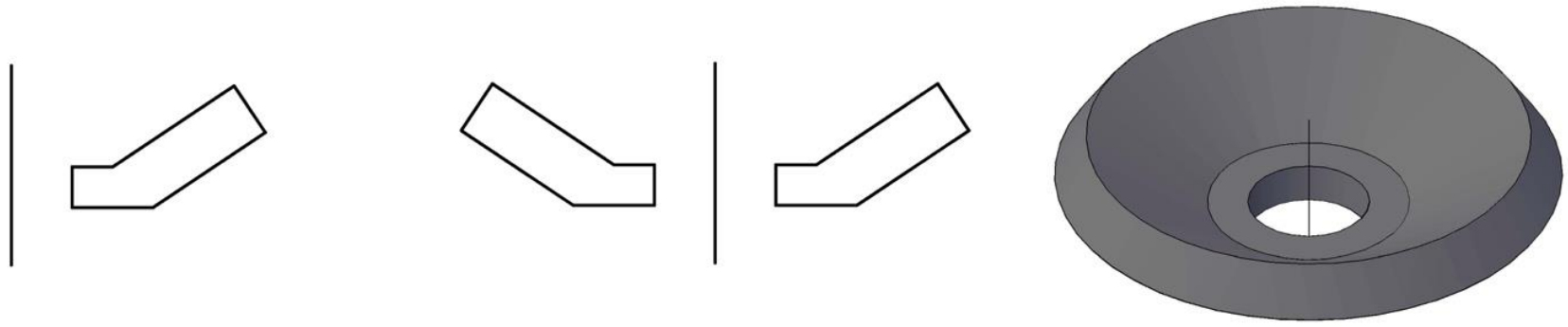
2-D Shape Located Away From Axis of Revolution



"Hollow" 3-D Part

Visualizing Revolutions

- To visualize a revolution, first think about mirroring the shape about the axis of revolution and then forming a cylindrically-shaped object from the two shapes



2-D Shape

2-D Shape Mirrored About Axis of Revolution

2-D Shape Mirrored About Axis of Revolution

Course Software...

- Work through the surfaces and solids of revolution software module

Surfaces and Solids of Revolution Homework...

- Complete the following pages in Module 1
- rev-
  - 1 - 2
  - 5 - 7
  - 9 - 11
  - 13 - 15

Combining Solids

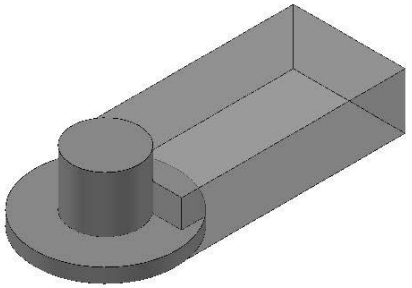
Module 2

Session Topics

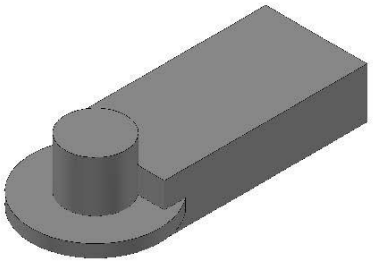
- Combining Overlapping Objects
- Volume of Interference
  - Cutting
  - Joining
  - Intersecting
- Multiple Combinations
- Visualizing Combinations

Combining Solids

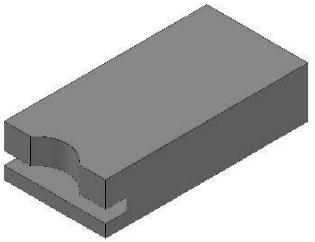
- Two overlapping objects can be combined by cutting, joining, or intersecting



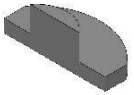
Original Two Objects



Objects Joined



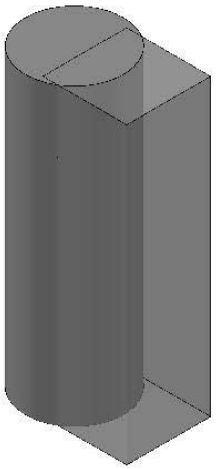
Objects Cut



Objects Intersected

Volume of Interference

- The Volume of Interference is defined as the overlapping volume between two objects

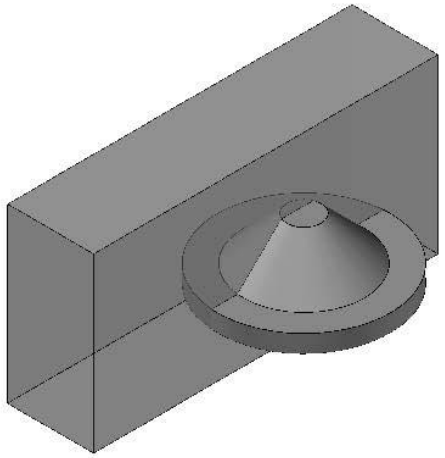


Two Overlapping Objects

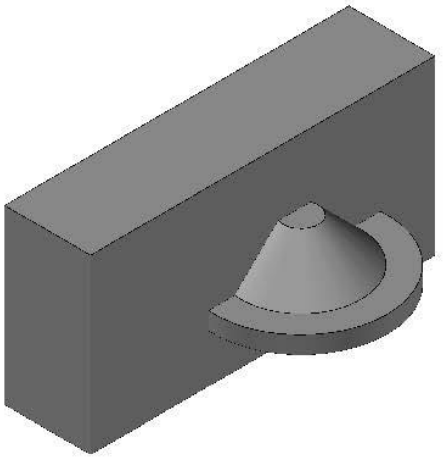
Volume of Interference

Joining Objects

- When two objects are joined, the volume of interference is absorbed into the final object



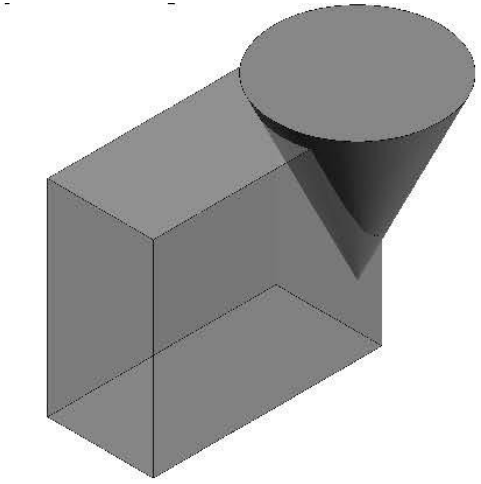
Two Overlapping Objects



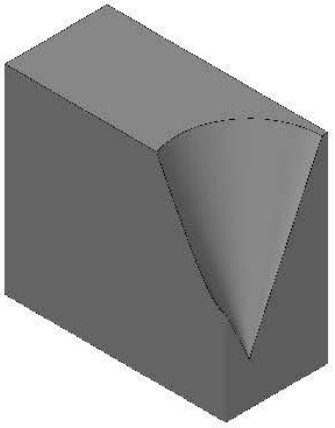
Objects Joined

Cutting Objects

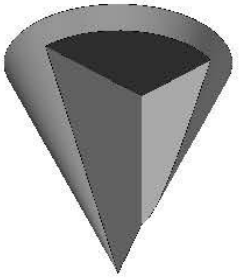
- When two objects are cut, the volume of interference is removed from the object being cut.



Overlapping Objects



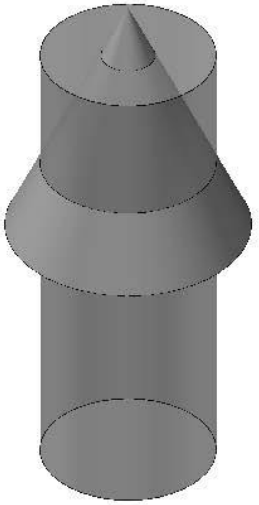
Cone Cuts Block



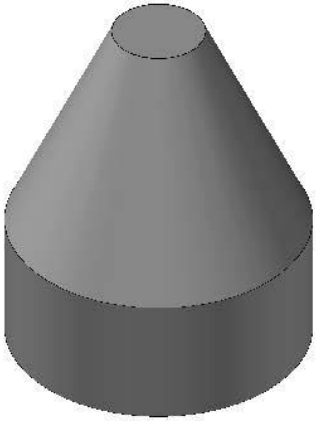
Block Cuts Cone

Intersecting Objects

- When two objects are intersected, the volume of interference becomes the new object.



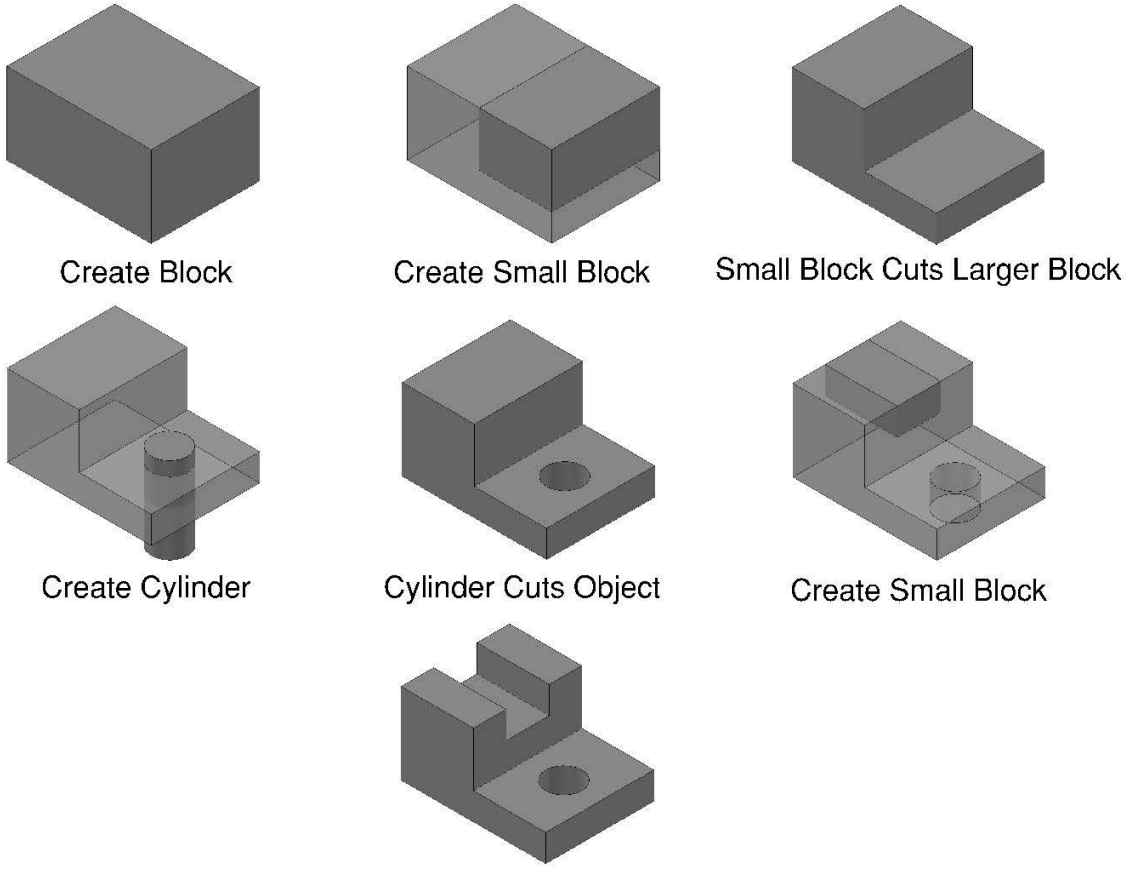
Two Overlapping Objects



Intersected Objects

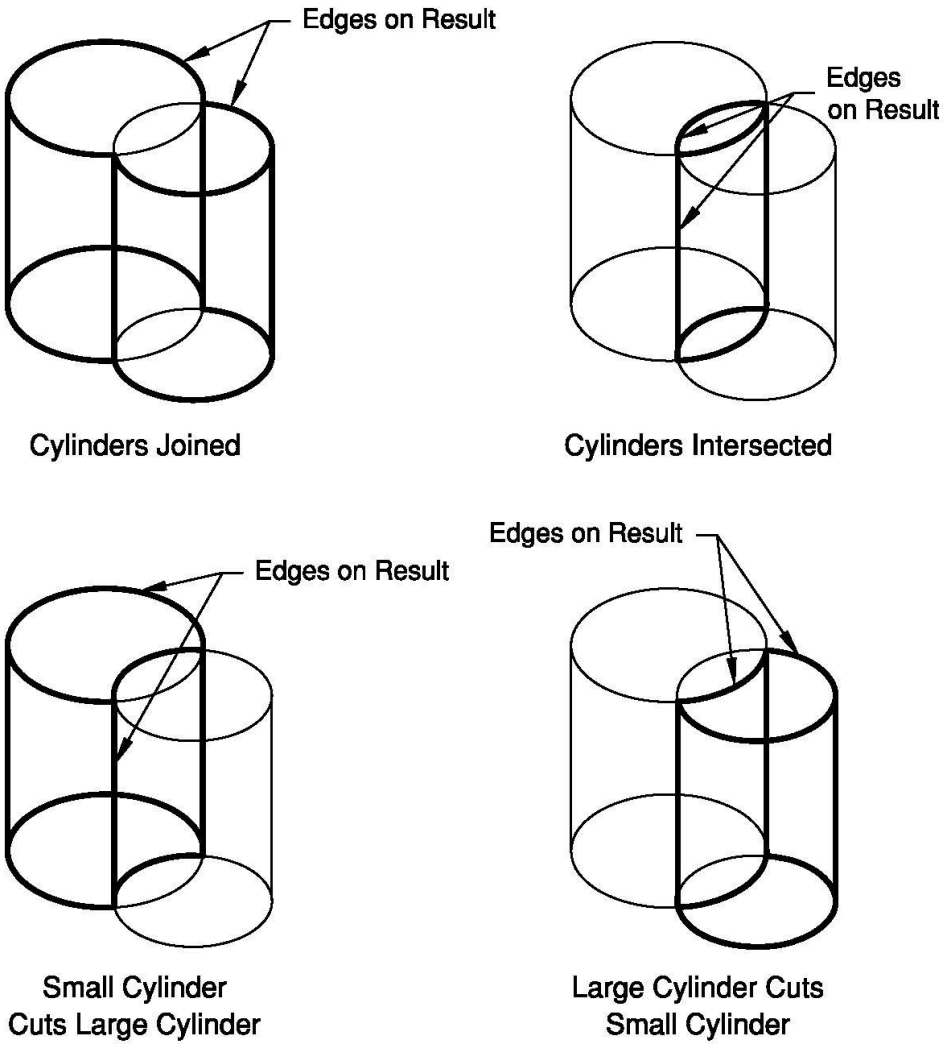
Multiple Combinations

- Complicated objects can be created through cutting, joining, or intersecting parts.



Visualizing Combinations

- When presented with two overlapping objects, try to visualize which edges will remain after a combining operation has been performed



Course software …

- Work through the combining solids software module

Combining Solid Objects Homework …

- Complete the following pages in Module 2
- ob/int-
  - 2 - 3
  - 6 - 7
  - 9 – 11
  - 13-14
  - Problem 1 on page 2 is not a typo – the resulting object is nothing
  - for pages 13 & 14 show only visible lines

Isometric Drawings & Coded Plans

Module 3

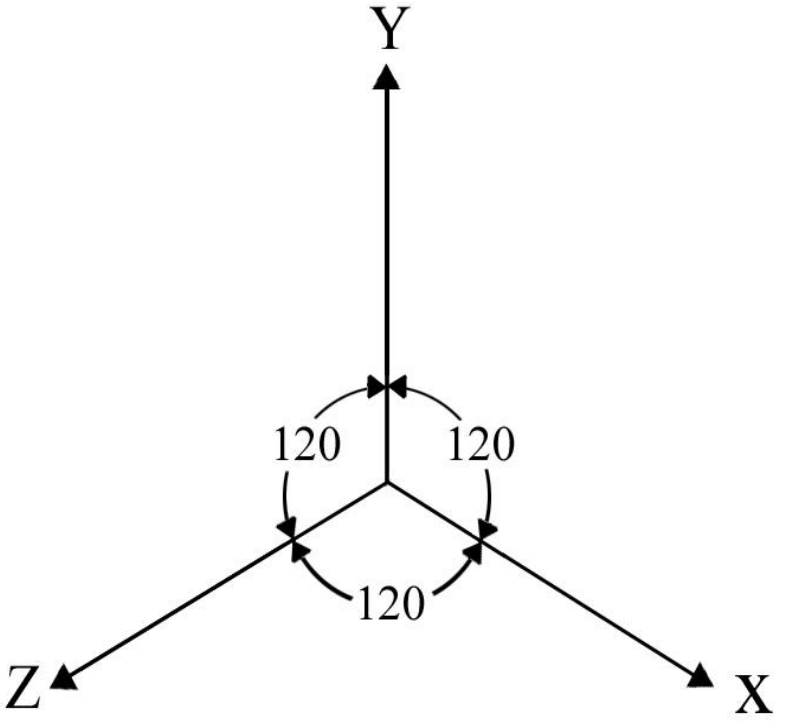
Session Topics

- Isometric Axes
- Coded Plans
- Objects from Multiple Viewpoints
- Isometric Sketching

Isometric Sketching

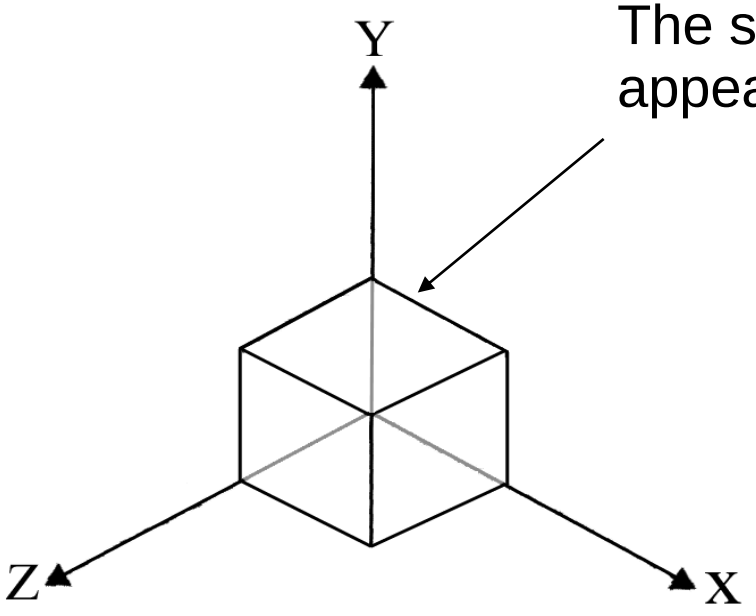
- Used to portray a 3-D object on a 2-D sheet of paper.
- The relationship between the 3-D axes appears differently when projected onto a 2-D surface, i.e., perpendicular angles no longer appear perpendicular.

Isometric Axes



Isometric Sketch of Cube

- Isometric sketches are made as if you were looking down a diagonal of a cube

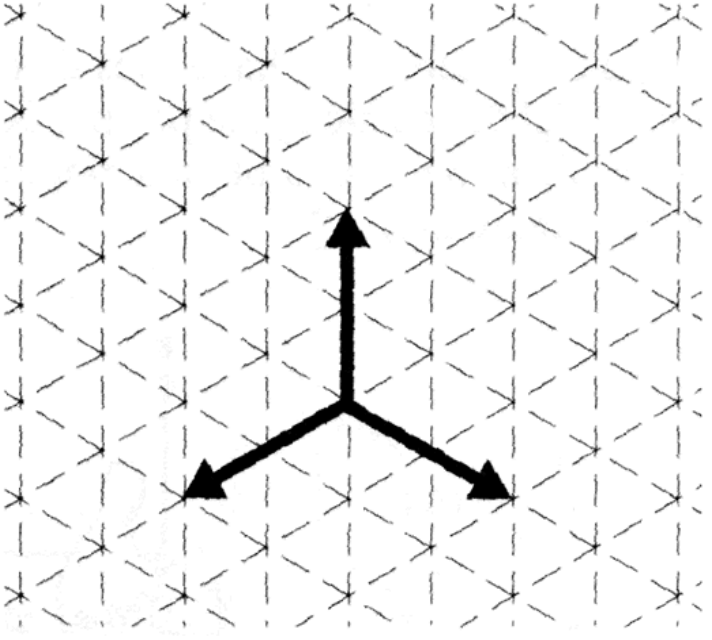


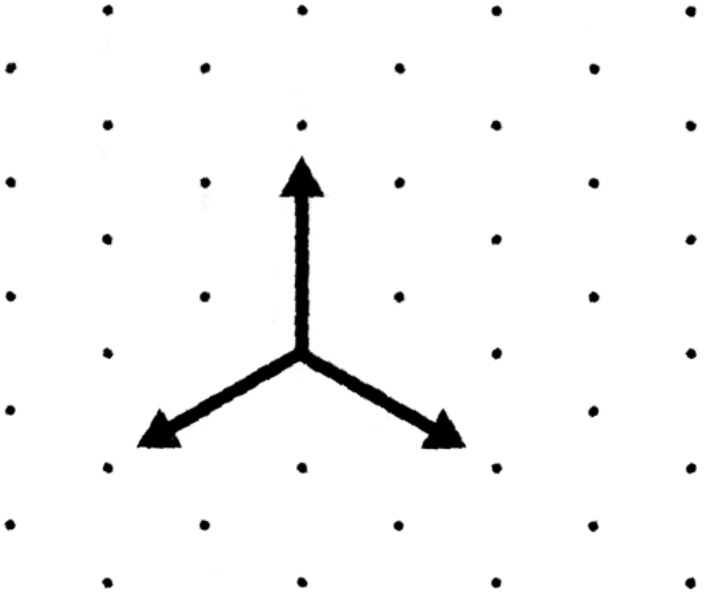
The surfaces of the cube appear to be rhomboidal

Note that all surfaces of an object sketched in isometric will appear distorted!

Isometric Axes

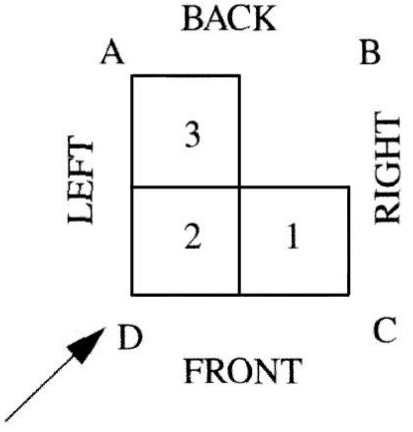
- Isometric grid paper or dot paper is a useful tool for constructing isometric drawings.



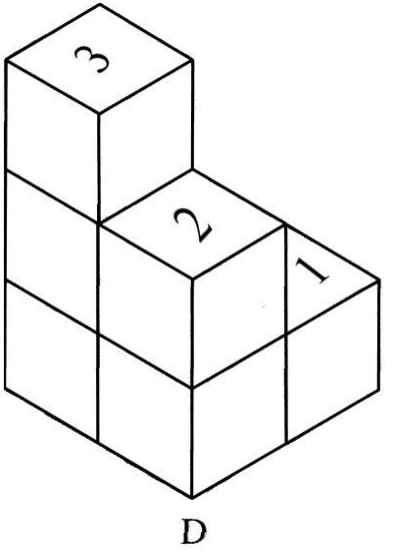


Coded Plans

- Pictorial sketches can be made from coded plans.
- Coded plans define the shape of a building made of blocks.



Coded Plan

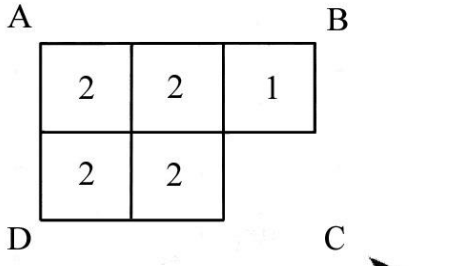


Building

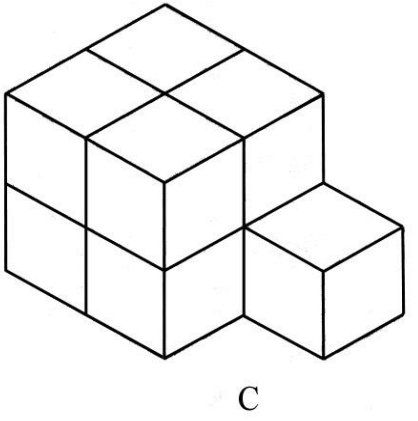
Coded Plans

- Isometric sketch from corner C.

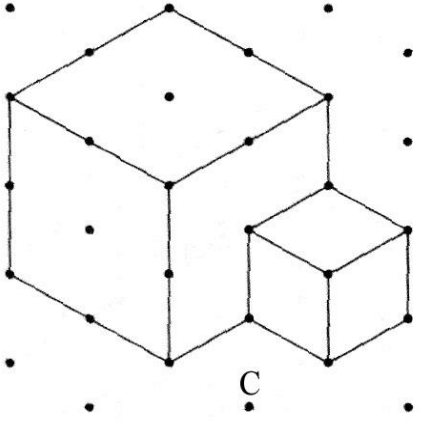
Coded Plan



Building

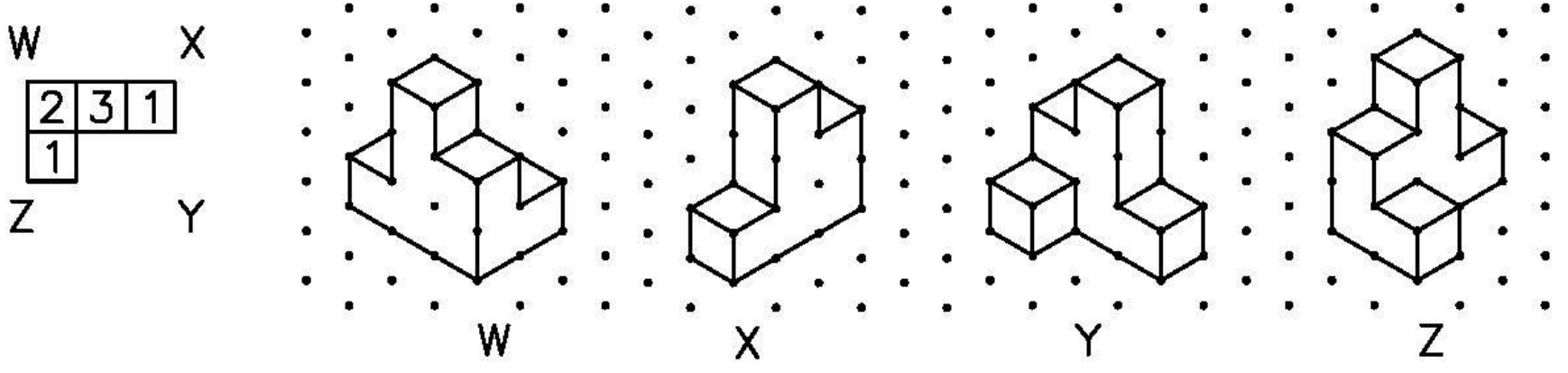


Isometric Sketch

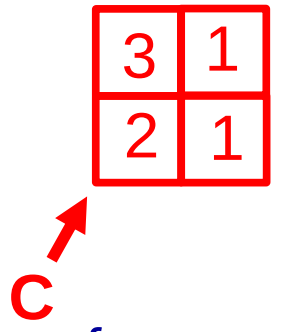


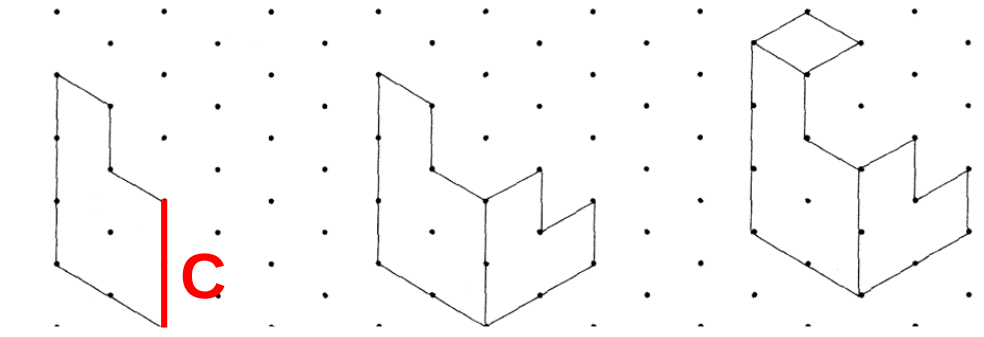
Different Viewpoints

- The object will appear differently depending on the corner you are viewing it from



Isometric Sketching

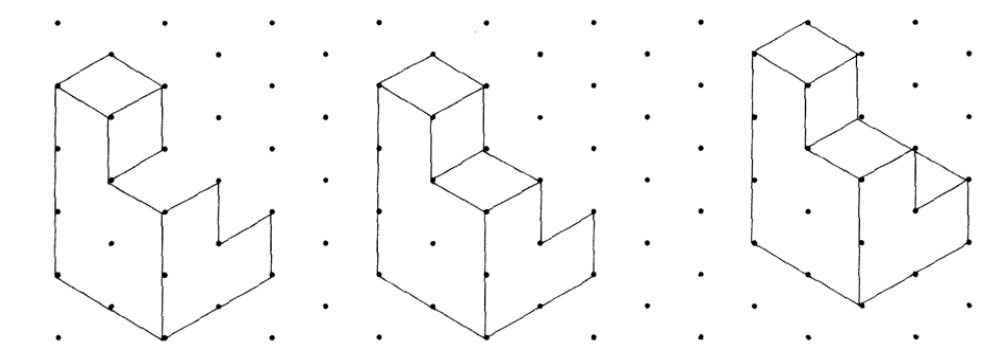




Steps 1 & 2

Step 3

Step 4 ...



Step 4 ...

Guidelines for constructing isometric drawings:

1. Draw edge "C".
2. Sketch surface to the right or left of edge “C”.
3. Draw a surface that shares an edge with the surface just drawn.
4. Continue drawing one surface at a time until the object is complete.

NOTE: Do not show the individual blocks in the building. Just show edges where surfaces intersect.

Course Software……

- Work through the Isometric Drawings and Coded Plans software module

Homework

- Complete the following pages in Module 3
- iso-
  - 1 - 5
  - 8 - 11

Orthographic Drawings

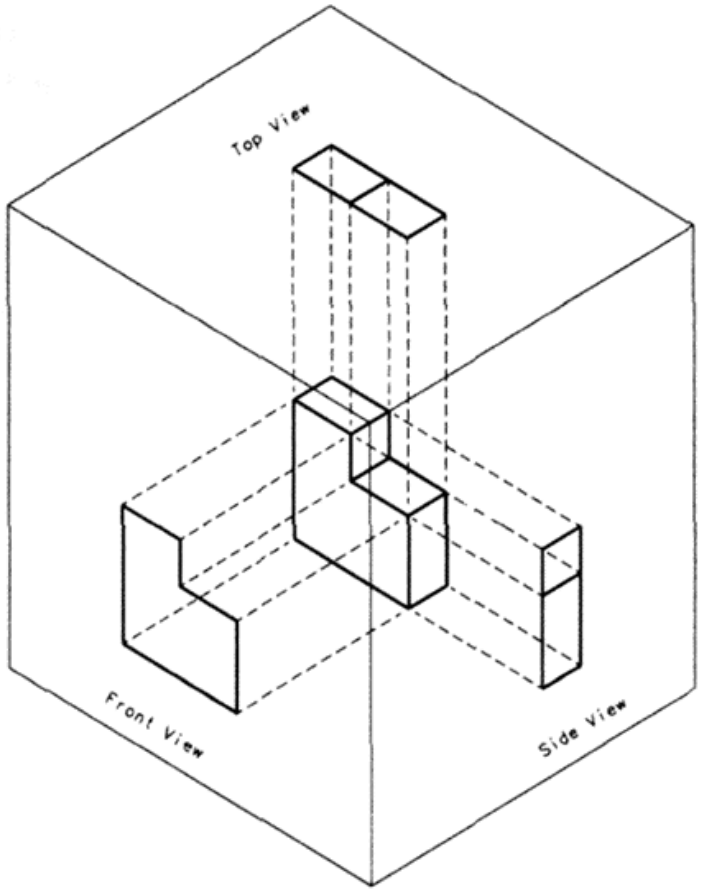
Module 4

Session Topics

- Orthographic Projection
- Normal Surfaces
- Hidden Lines
- Isometric Sketching from Orthographic Projections

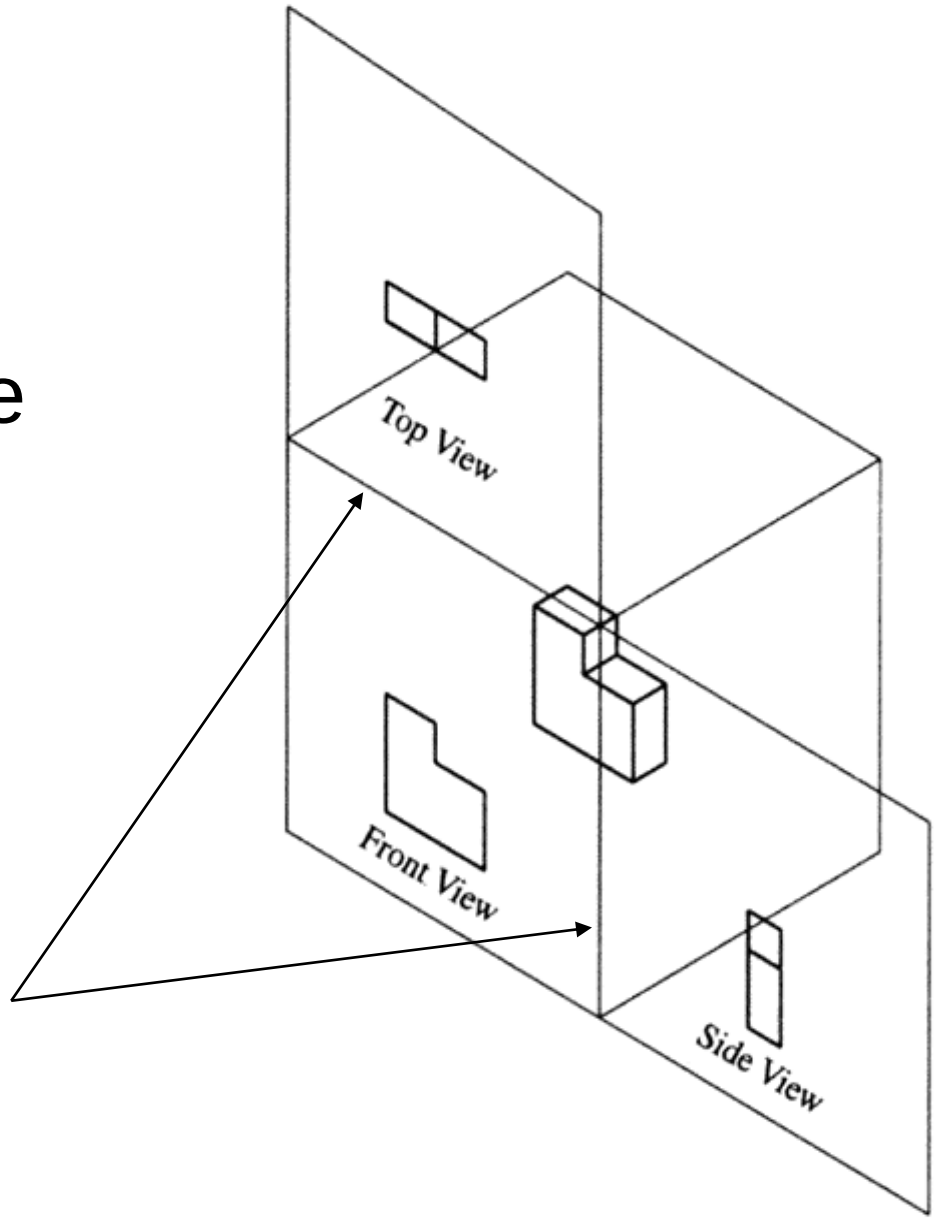
Orthographic Projection

- Imagine an object is surrounded by a glass cube.
- The object's surfaces are projected onto the faces of the glass cube.
  - The projection rays are perpendicular to the panes of glass



Orthographic Projection

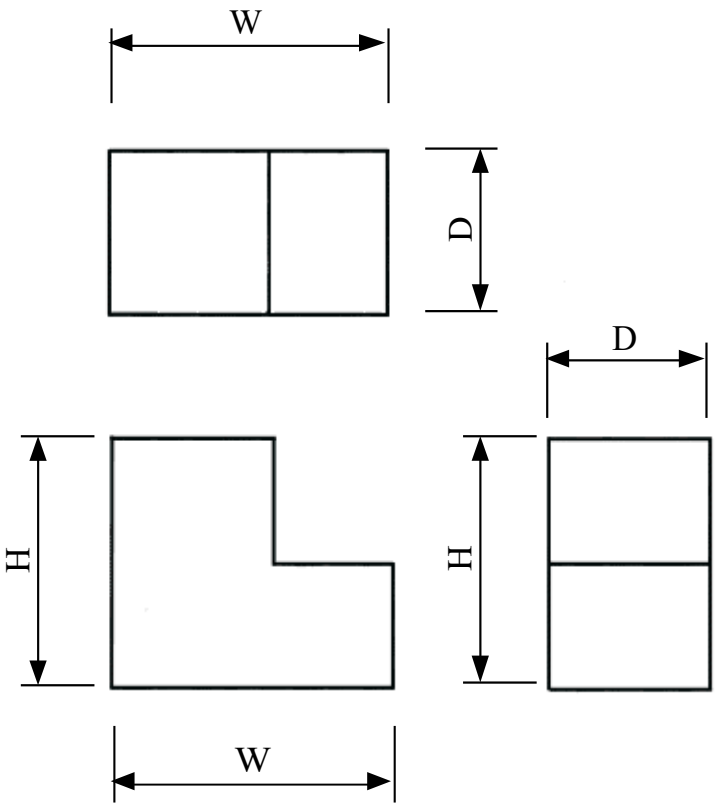
- Unfold the cube so that it lies in a single plane
- Three views of the object are now visible on the same plane in space



Orthographic Projection

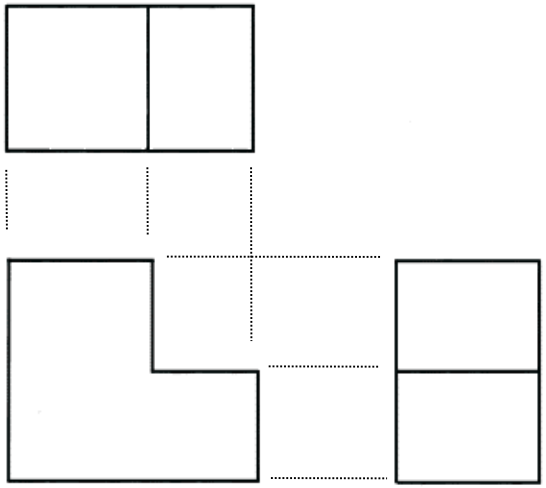
When the glass cube is unfolded each view shows two dimensions of the object:

- Front view: Height and Width
- Top view: Width and Depth
- Right view: Depth and Height

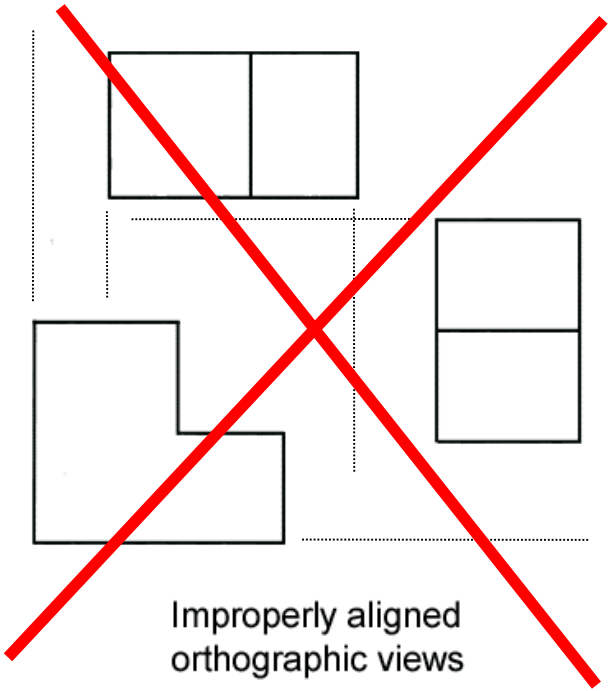


Orthographic Projection

Views are aligned with one another (features project from one view to the next)

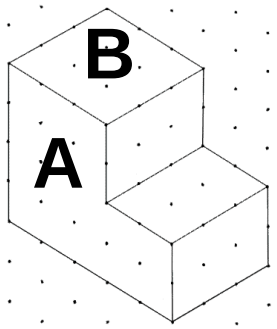


Properly aligned
orthographic views

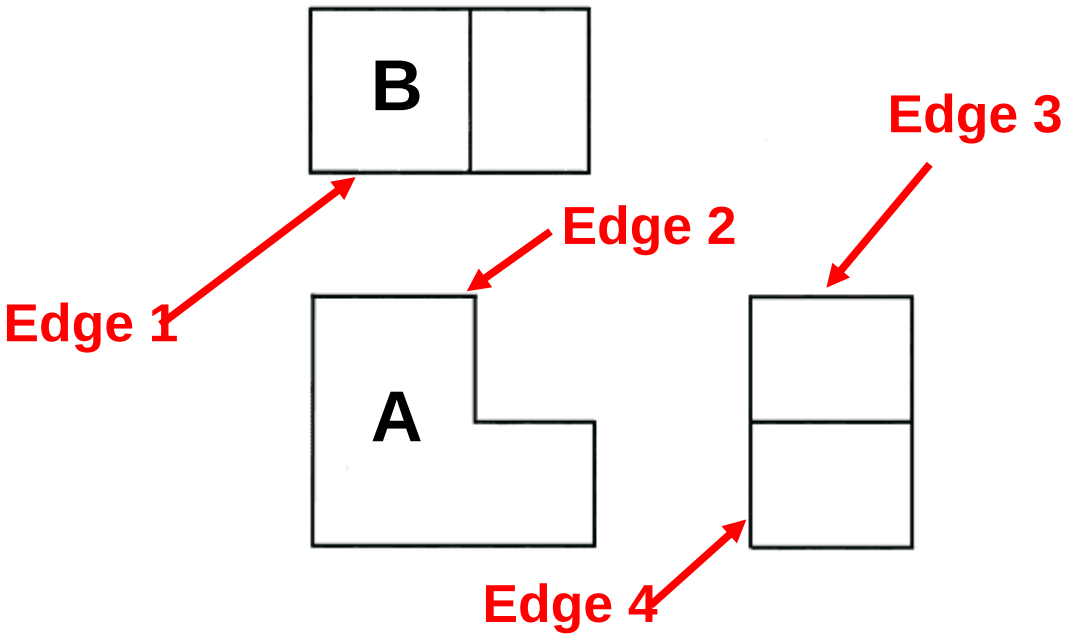


Improperly aligned
orthographic views

Normal Surfaces



- Parallel to one of the six glass panes of our transparent cube
- Perpendicular (normal) to the projectors to/from that plane



Shown true size and shape in the view that they are parallel to

Seen as edges (lines) in the other principal views

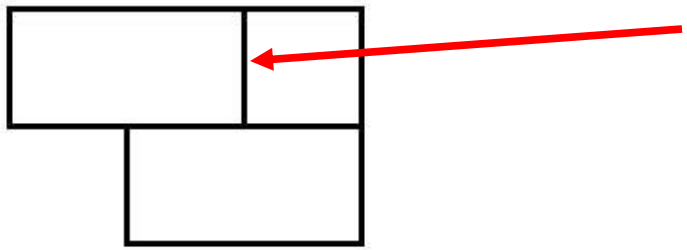
Surface A appears as edge 1 and 4 in top & right views

Surface B appears as edges 2 and 3

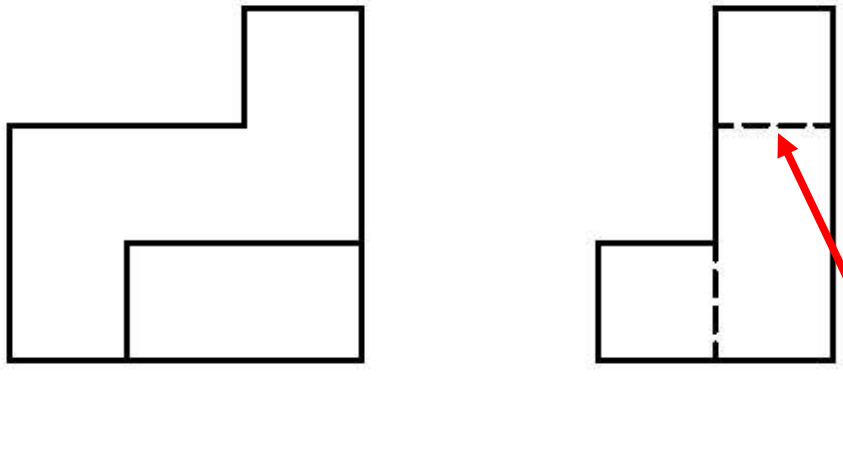
Hidden Lines

- Some object have edges which cannot be seen from certain viewing angles
- Showing these edges provides valuable graphical information
- Visible edges are continuous (solid) lines (*object lines)*
- Hidden edges are dashed lines (*hidden lines*) to avoid confusing them with visible edges

Hidden Lines



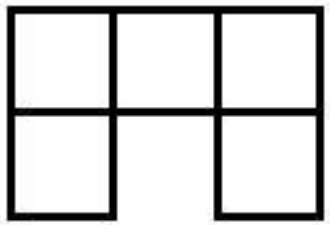
Visible Line (Solid lines, can be seen in a given view, aka: Object Lines)

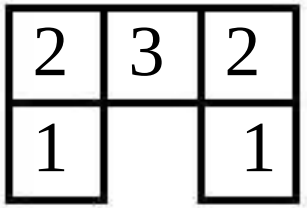


Hidden Line (Dashed lines; can't be “seen” in that view)

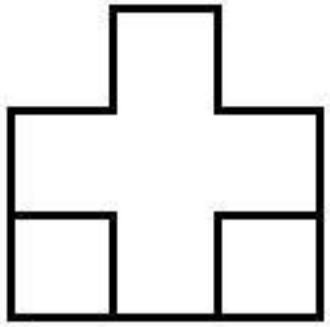
Hidden Lines and Object Lines Together

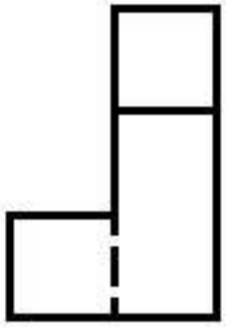
- If a solid line and a hidden line are on top of each other, show only the solid line





Coded Plan



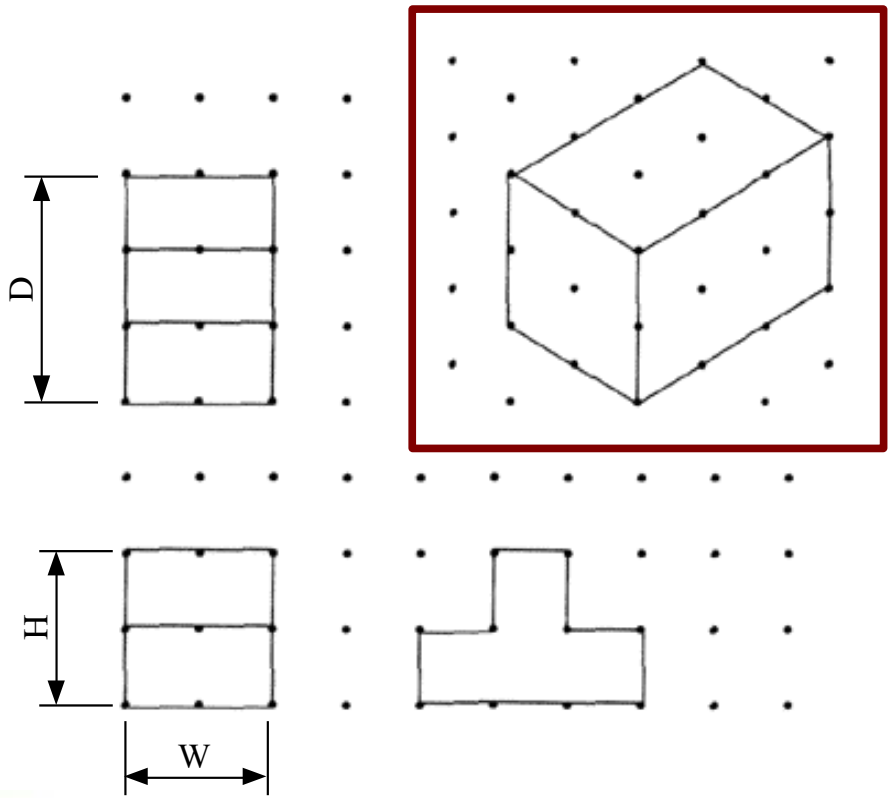


Isometric Sketches from Orthographic Views

- Sometimes you are asked to construct Isometric sketches from Orthographic views to develop visualization skills.
  - The box method is one way to do this.
  - For some problems, the box method may not be very helpful.

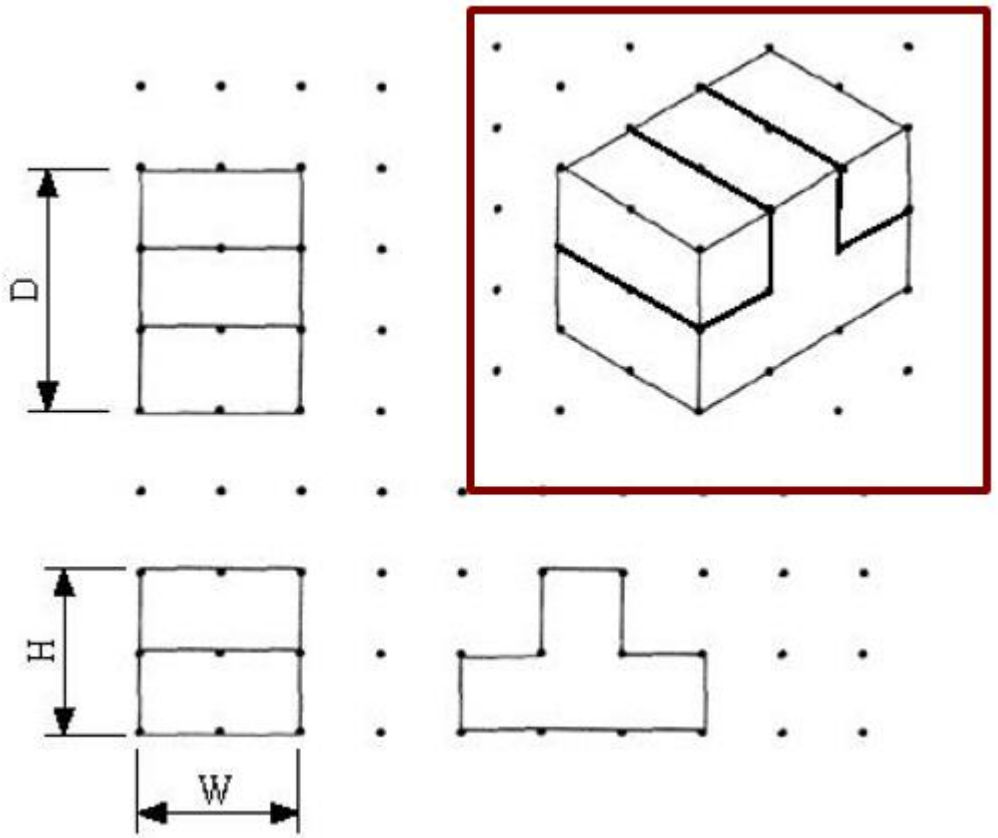
Isometric Sketches from Orthographic Views

1. Find the object's overall dimensions from the orthographic views and sketch that size box on isometric dot paper.



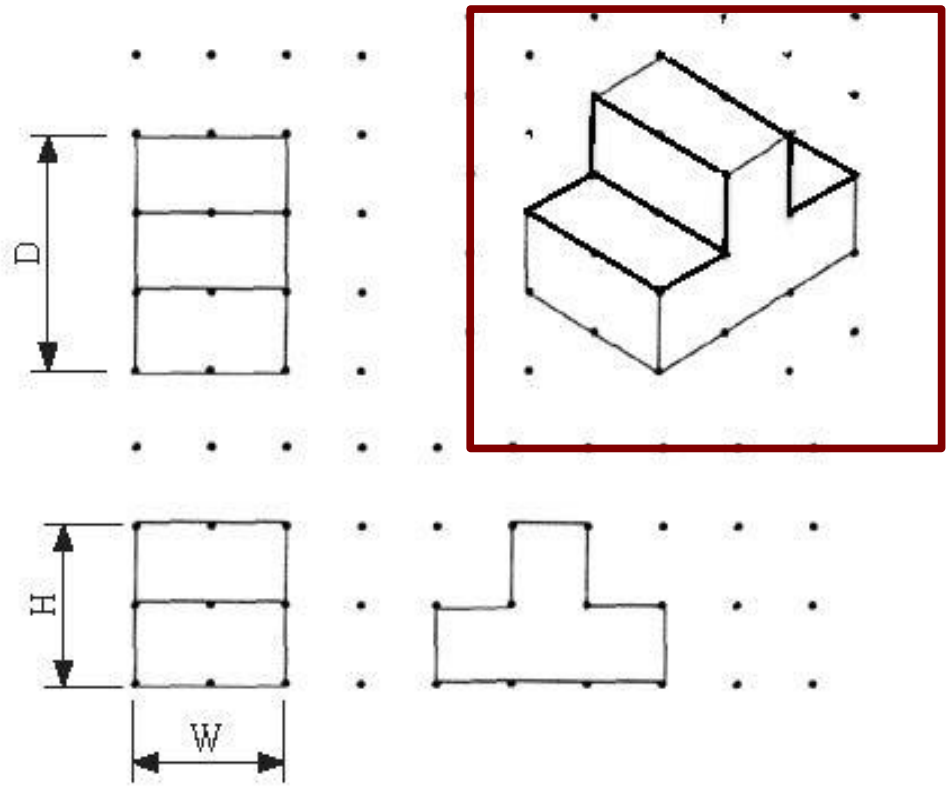
Isometric Sketches from Orthographic Views

2. Sketch the top, front, and right side views in their appropriate locations on the box.



Isometric Sketches from Orthographic Views

3. Add/remove lines until the view is complete.



Course Software…..

- Complete the software module on Orthographic Projections

Orthographic Drawings Homework …

- Complete the following pages in Module 4
- ortho-
  - 1 - 2
  - 5 - 8
  - 11 - 12
  - 15 - 18
  - 23 - 24

HigherEducationServices
VISUALIZING SUCCESS

Inclined and Curved Surfaces

Module 5

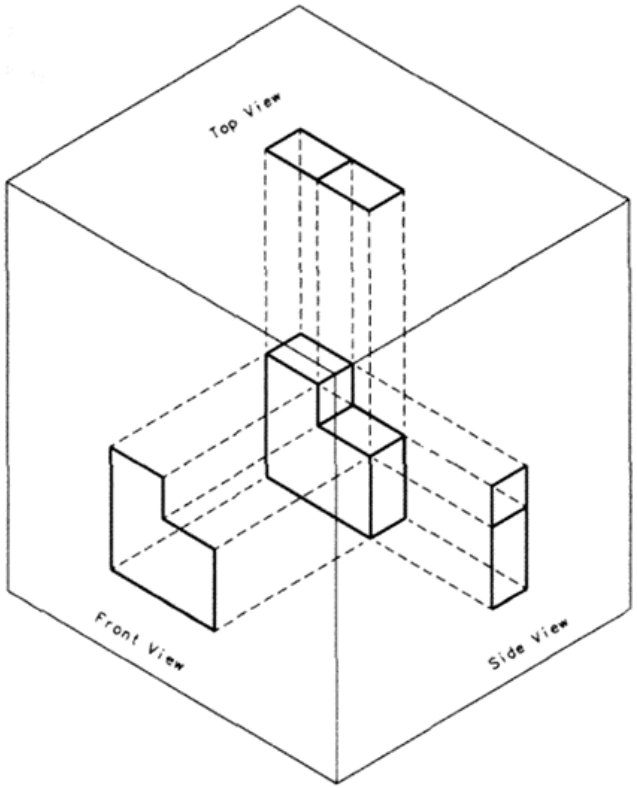
Session Topics

- Orthographic projections of inclined and single-curved surfaces
- Drawing isometric sketches from orthographic views of objects with inclined and single-curved surfaces

Review:

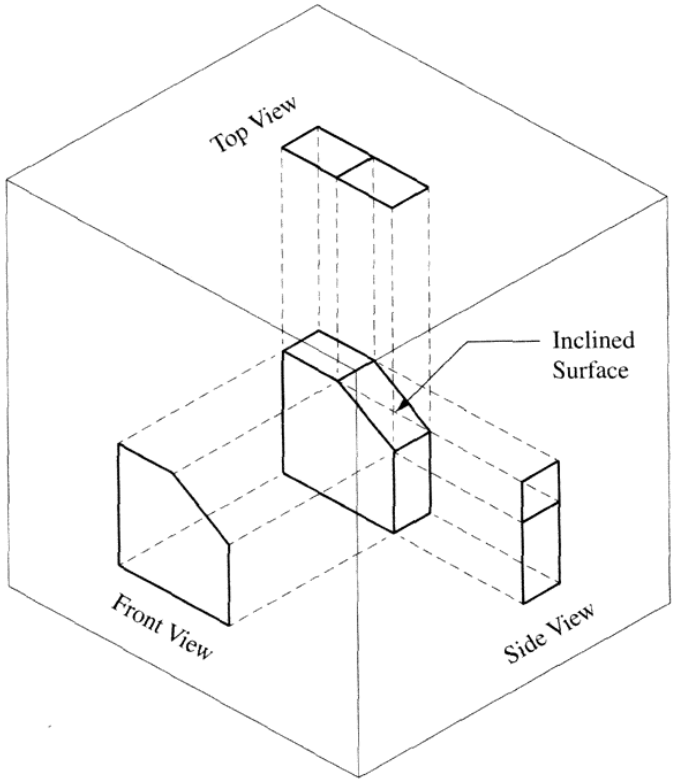
Orthographic Projection: Normal Surfaces

- Normal surfaces appear as a surface in one view, an edge in the other two views.
- Normal surfaces are shown true size and shape in the view they are parallel to.



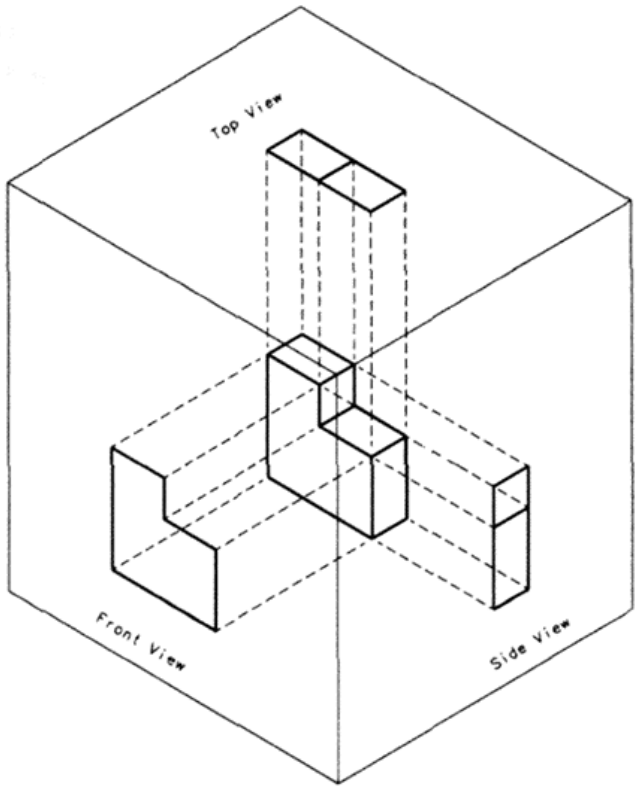
Inclined Surfaces

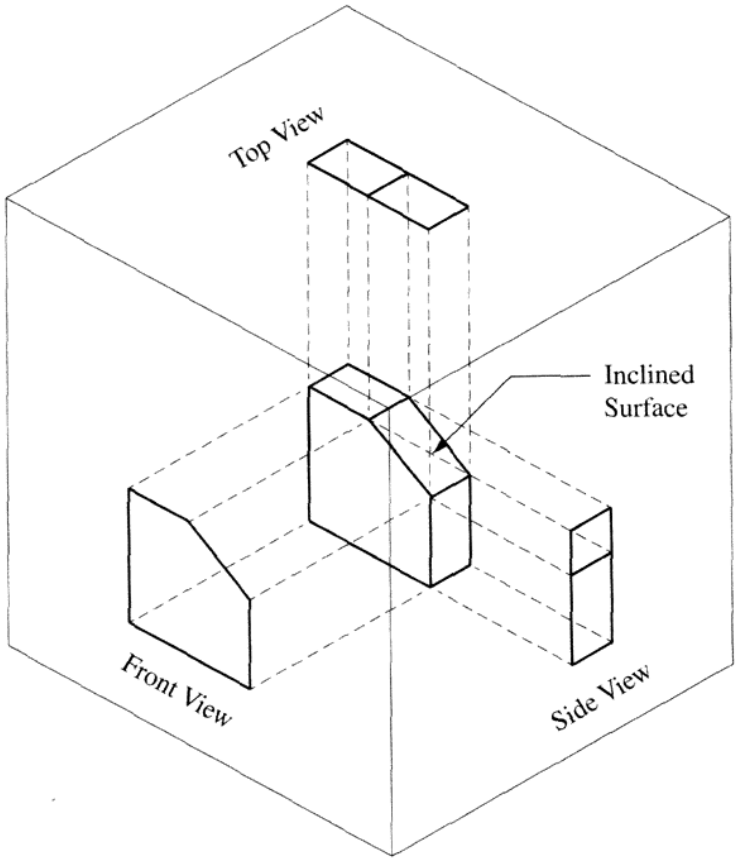
- Are not parallel to any of the principal views
- Are perpendicular to one of the three views
- Appear as an area in two views, as an edge in the third view



- Area views are *foreshortened*
- Basic shape is maintained in area views

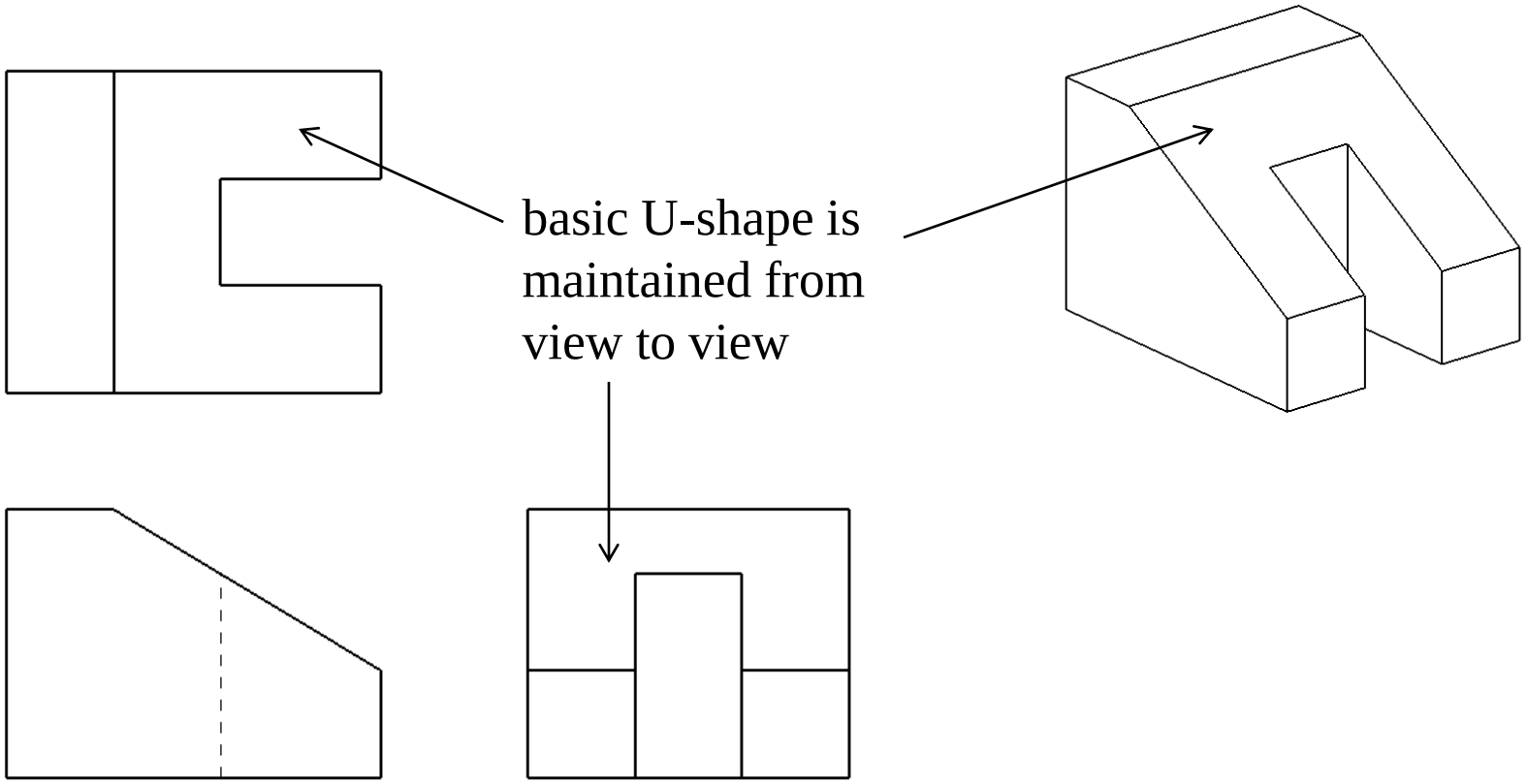
Normal versus Inclined Surfaces





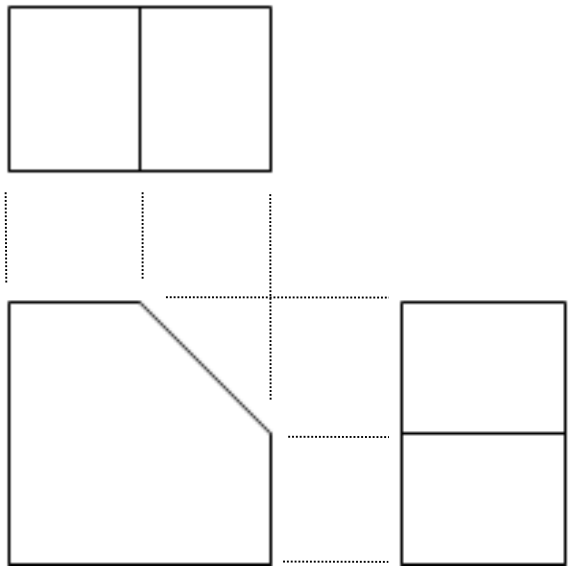
Inclined Surfaces

- An inclined surface maintains its basic shape from view to view

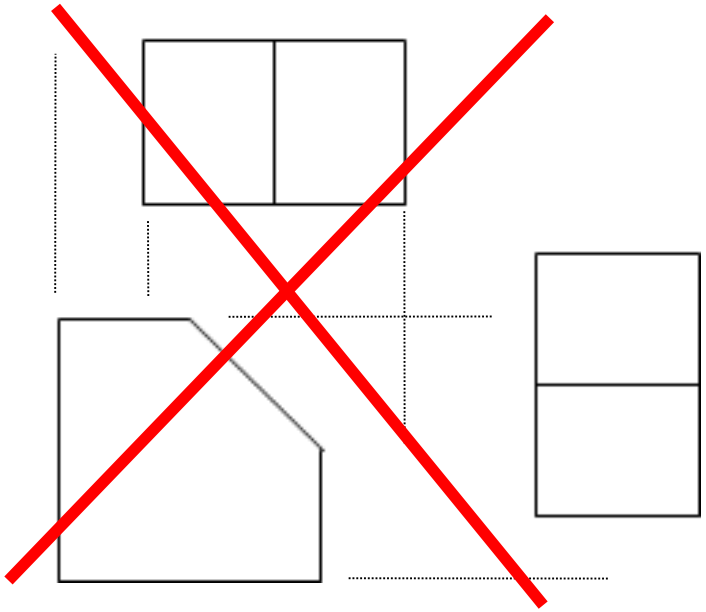


Orthographic Projection

Recall: Align views with each other (features project from one view to the next)



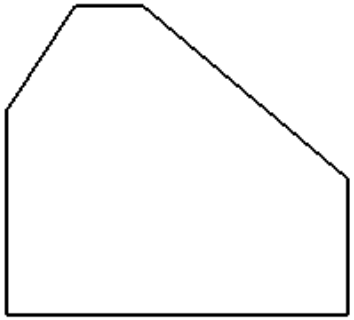
Properly aligned orthographic views

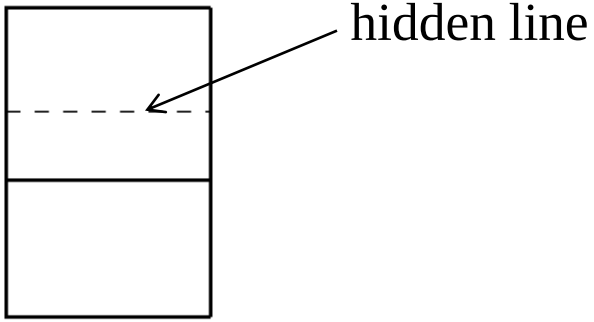


Improperly aligned orthographic views

Orthographic Projection

Recall: Use hidden (dashed) lines to show edges of an object that are hidden from a given viewpoint.

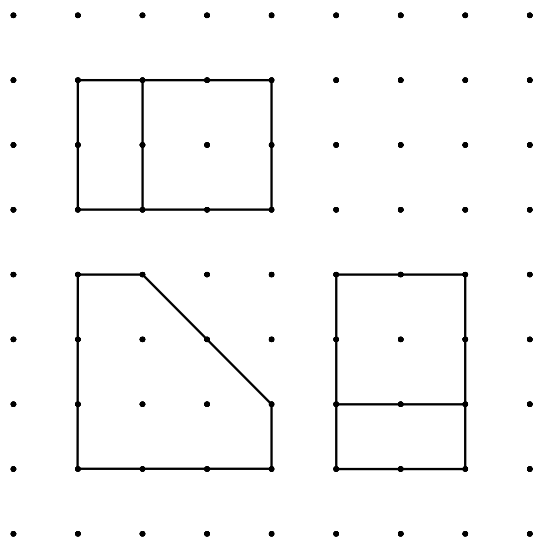




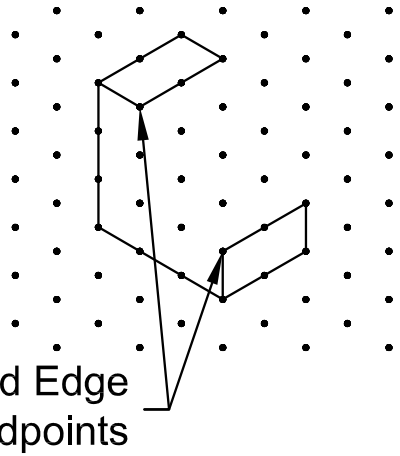
Inclined Surfaces in Isometric

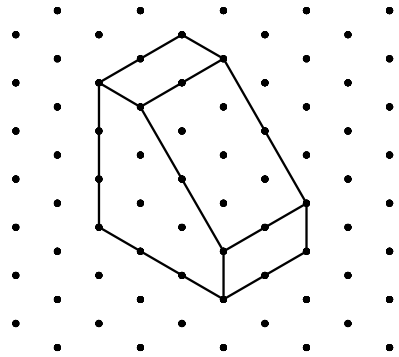
Constructing an isometric view of an inclined surface:

1. Locate the endpoints of each inclined edge
2. Draw a straight line between them



Orthographic Views

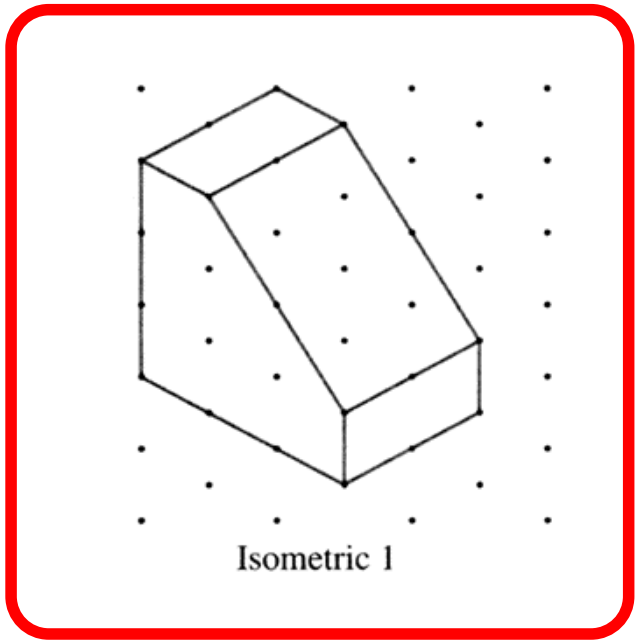




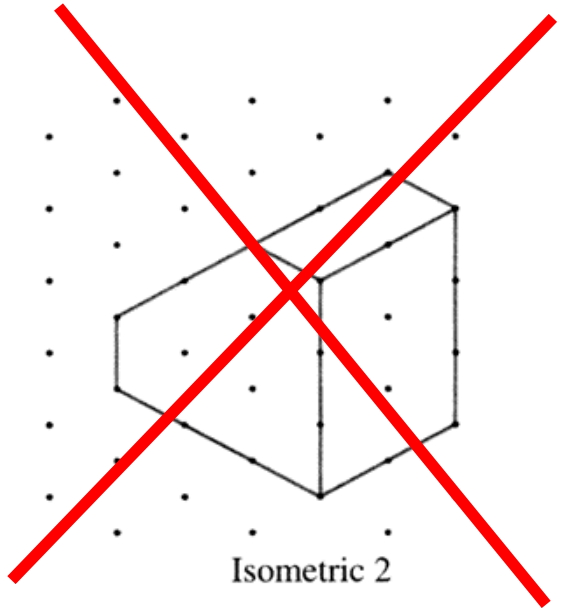
Final Isometric View

Inclined Surfaces: Constructing Isometric Views

Select an orientation that makes the inclined surface appear as a visible area (whenever feasible)

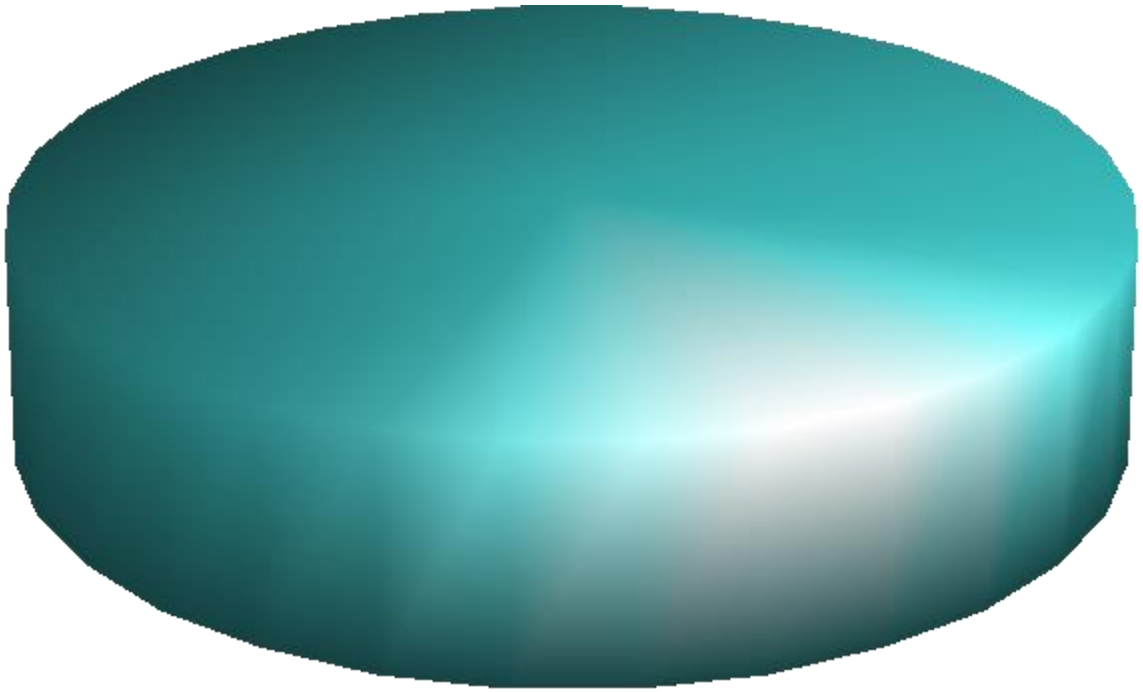


Correct



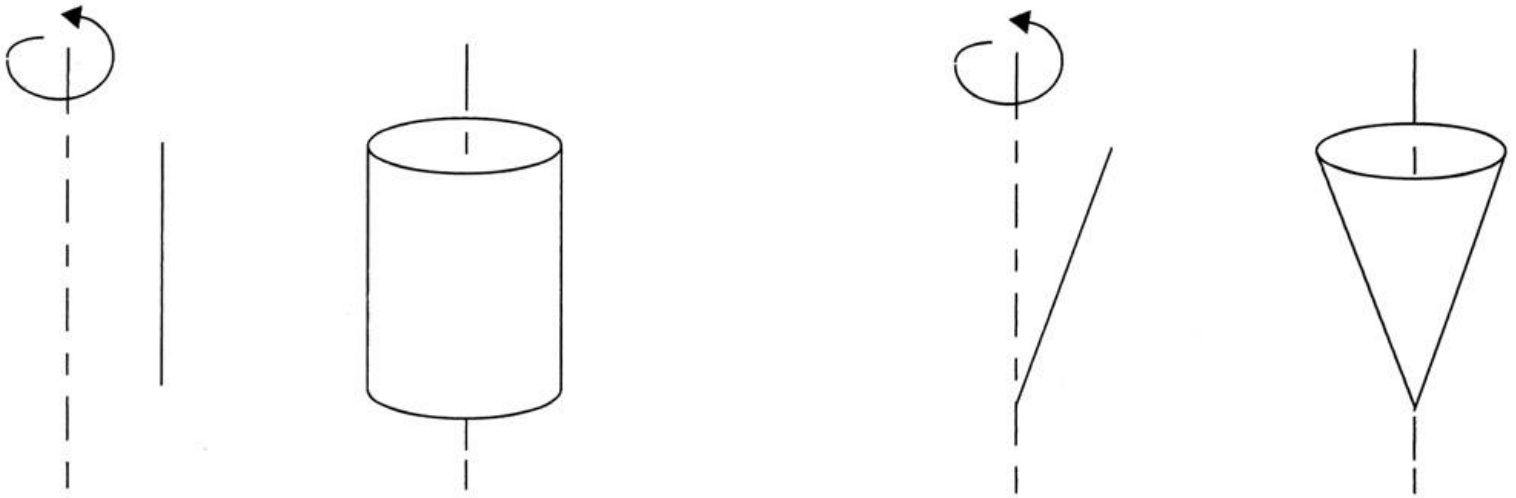
Incorrect

Single Curved Surfaces



Single Curved Surfaces

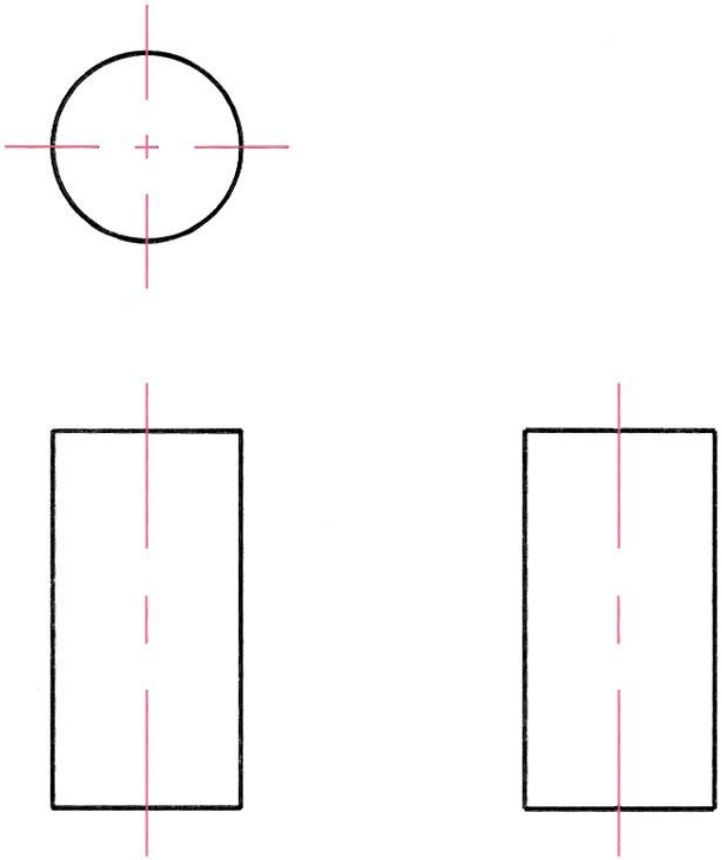
- Surfaces having a curvature about one axis.
- Generated by revolving a line about an axis.



Single Curved Surfaces

Consider a cylinder:

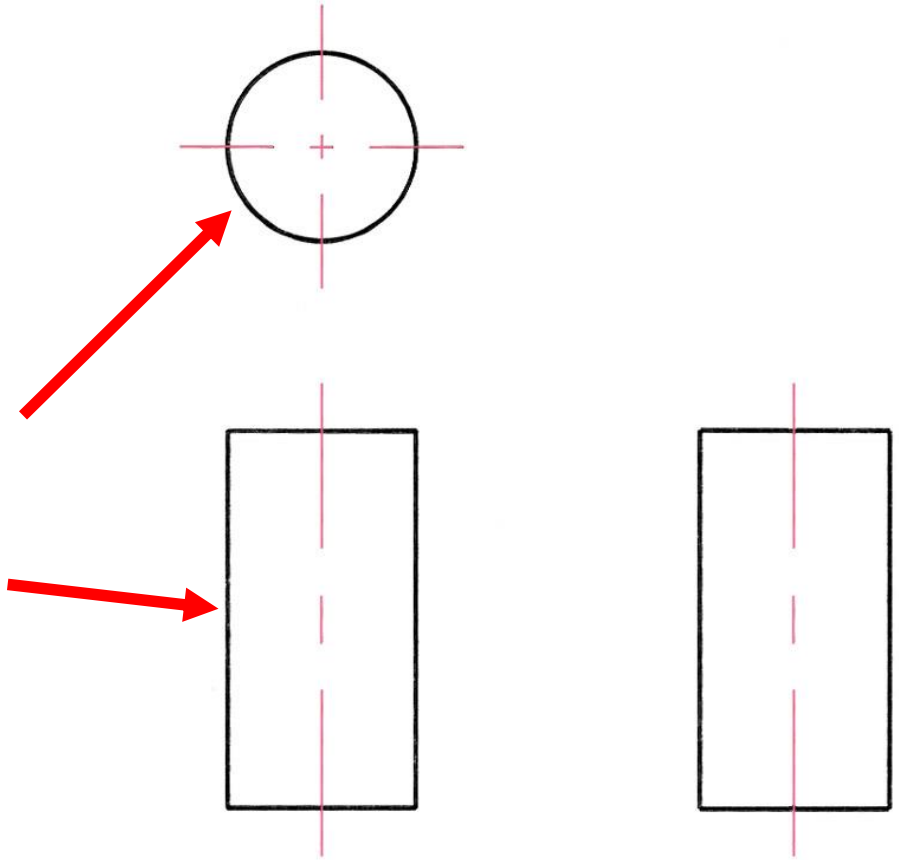
- Shown as a circle in one orthographic view
- Other orthographic views are rectangular
  - Rectangle width is equal to the cylinder diameter and represents the cylindrical boundary or visible extents of the surface



Single Curved Surfaces

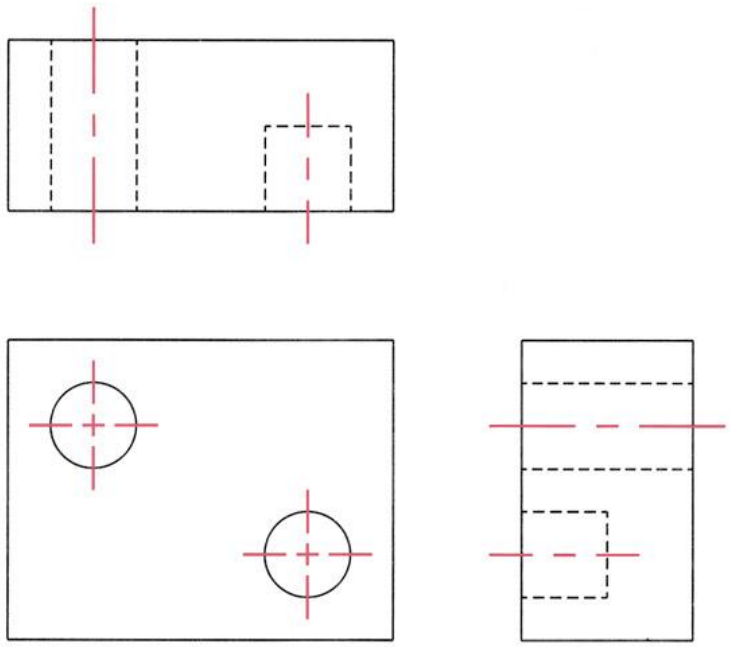
Because a curved surface is rectangular in two views, you MUST indicate the radial center with centerlines.

- Crossing centerlines are used in the circular view.
- A single centerline is shown in each “rectangular” view.



Single Curved Surfaces-Holes

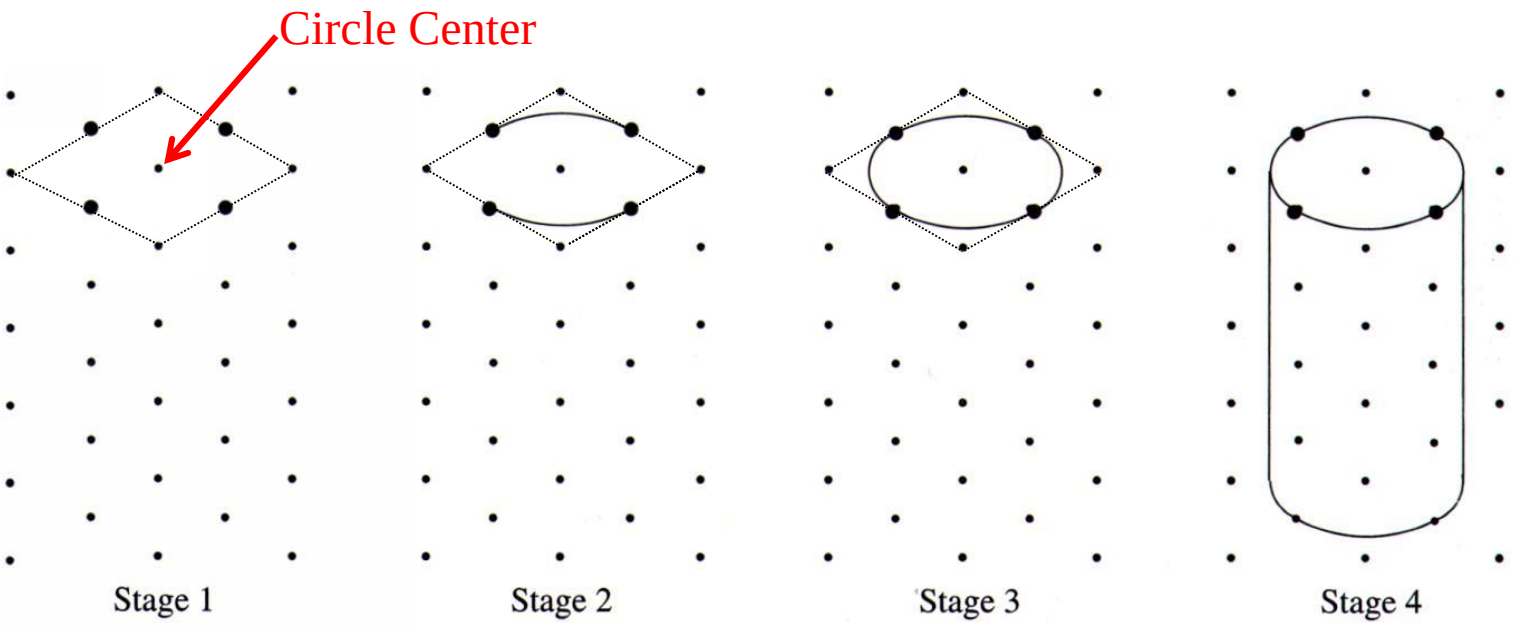
Holes follow the same rules as external curved surfaces, except the cylindrical boundaries are shown as hidden lines.



Drawing Single Curved Surfaces in Isometric

A circle appears as an ellipse in an isometric view

1. Locate the center of the circle
2. Locate the radial points
3. Sketch the "bounding box" for the ellipse
4. Sketch the four arcs of the ellipse tangent to the box edges
5. Complete the rest of the object



Course Software…..

- Work through the Inclined and Curved Surfaces Software Module

Orthographic Projection of Inclined & Curved Surfaces Homework …

- Complete the following pages in Module 5 inc/crv-
  - 1 - 2
  - 4 - 5
  - 7 - 9
  - 11 - 13
  - 15 - 16

Flat Patterns

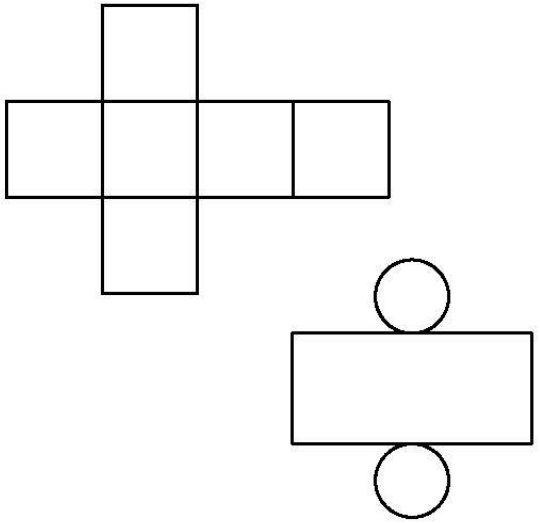
Module 6

Session Topics

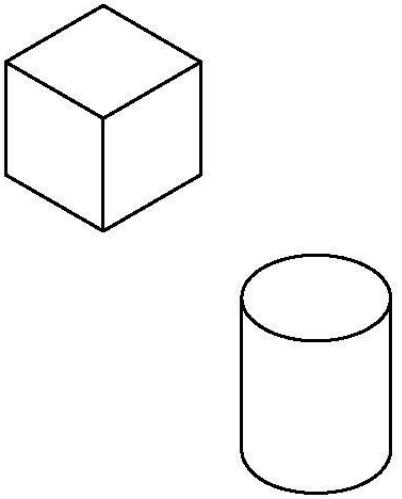
- Flat Patterns
- Fold Lines
- Multiple Patterns
- Open Surfaces
- Closed Surfaces
- Patterns with markings

Flat Patterns

- Sometimes it is important to visualize how a flat pattern can be folded up to obtain a 3-D object



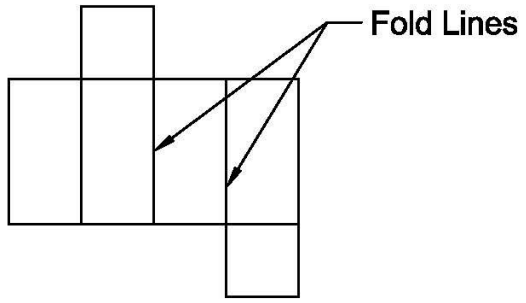
2-D Patterns



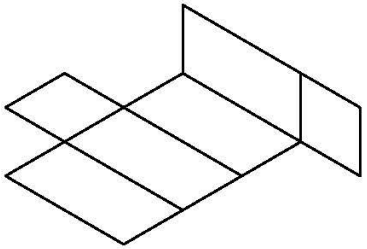
3-D Objects

Fold Lines

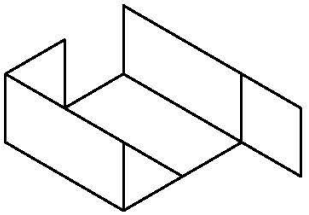
- The solid lines on a flat pattern are *fold lines*
  - When visualizing creating a 3-D object from a flat pattern, think about folding it at the fold lines



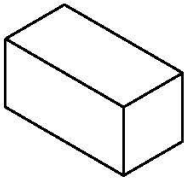
Flat Pattern



Fold 1



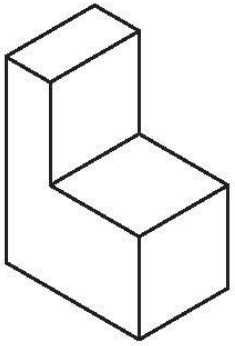
Fold 2



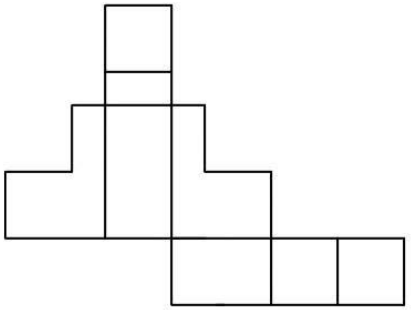
Fold 3

Multiple Patterns

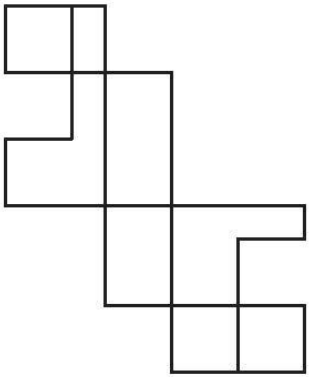
- Most objects have more than one pattern that could be folded to form it



3-D Object



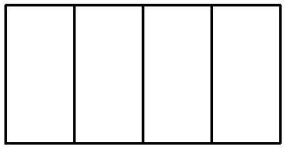
Pattern 1



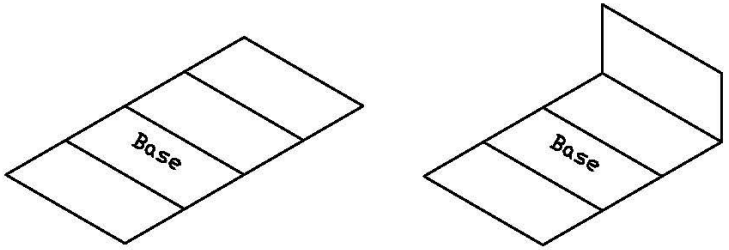
Pattern 2

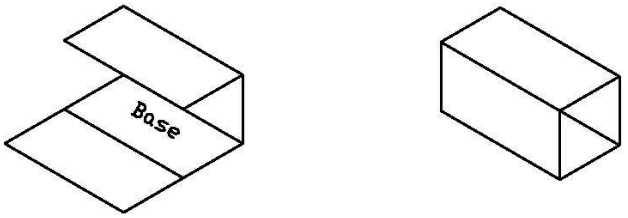
Open Objects from Patterns

- No "ends" are included in the pattern, so it is folded up and an open object results
  - Tube from paper towels



Pattern for Hollow Object

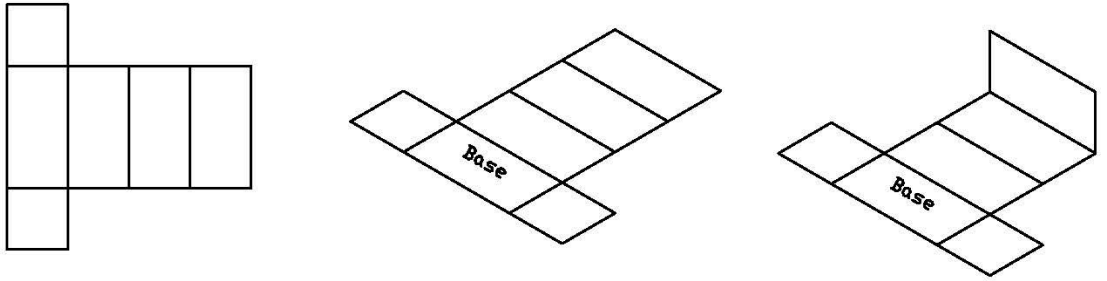




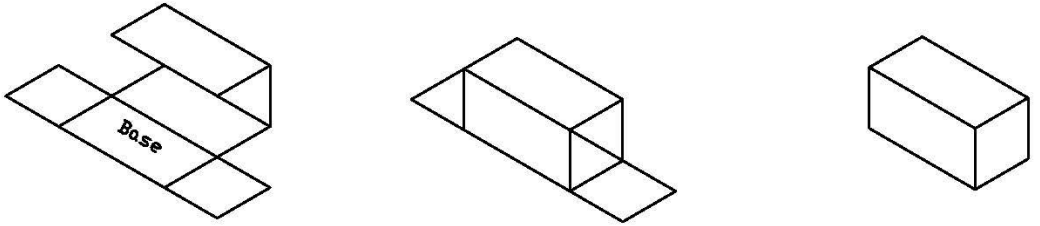
Pattern Folder to Form Hollow Object

Closed Objects from Flat Patterns

- When the pattern includes "ends" a closed surface (object) results



Pattern for Object with Closed Ends

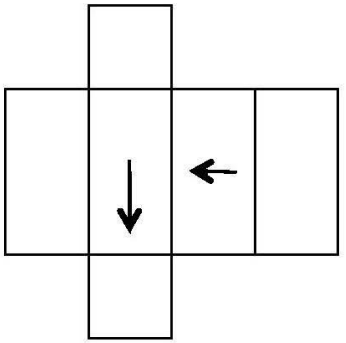


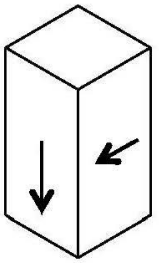
Pattern Folded to Form Closed Object

Markings on Patterns

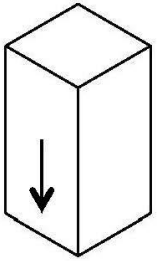
- When there are markings on a pattern that are on adjacent sides
  - Markings must end up adjacent to one another on the object
  - Markings must end up in the same orientation on the object

Markings on Patterns (continued)

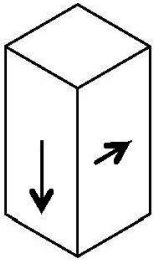




Correct 3-D Object



Markings not on Adjacent Surfaces



Markings on Adjacent Surfaces in Wrong Orientation

Course Software…

- Work through the Flat Patterns software module

Flat Patterns Homework …

- Complete the following pages in Module 6
- fp-
  - 1 - 2
  - 5 - 6
  - 9 - 12
  - 17 - 22

Rotation of Objects about a Single Axis

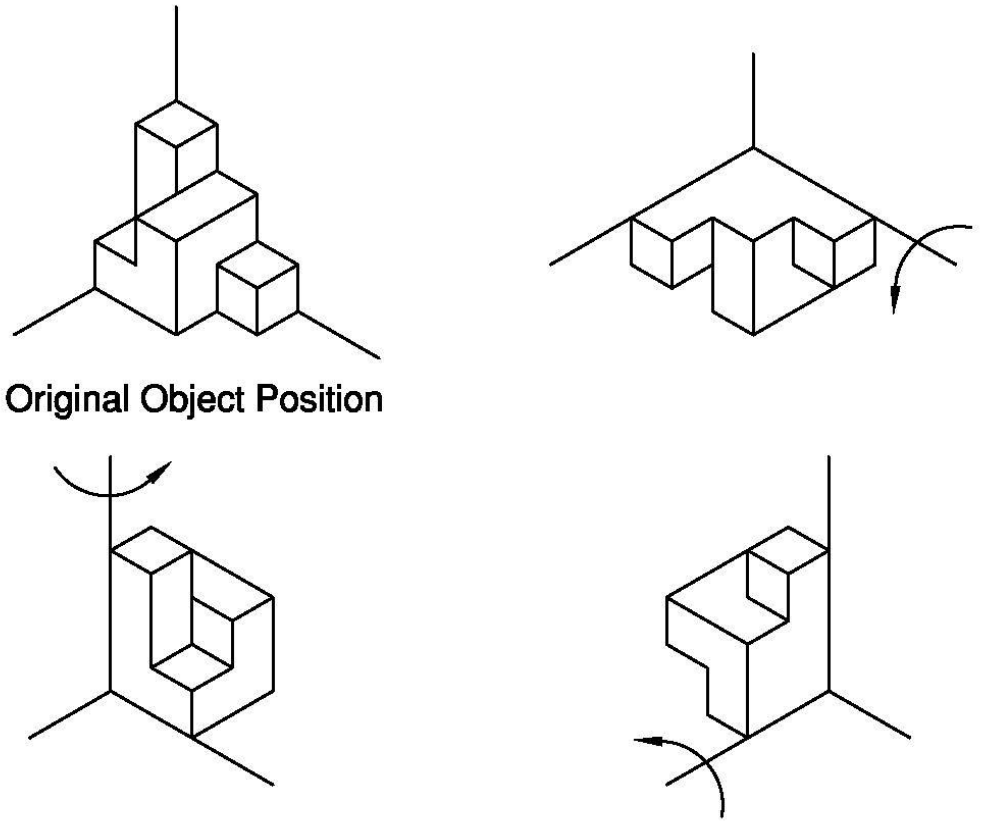
Module 7

Session Topics

- Object Rotations
- Right Hand Rule
- Rotation Notation
- Single Rotation
- Multiple Rotations
- Equivalent Rotations
- Computer Module

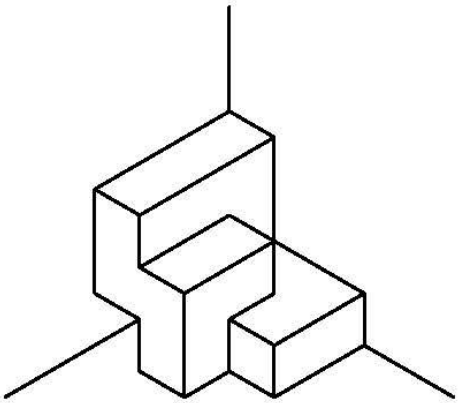
Object Rotation

- A rotation is a turning of an object about a straight line known as the axis of rotation.

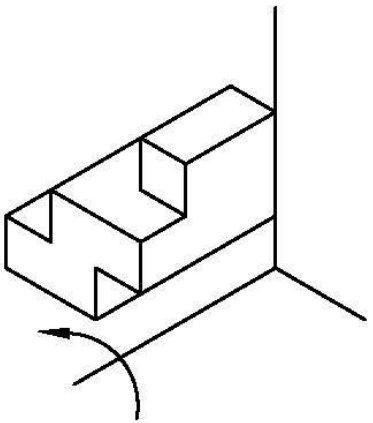


Direction of Rotation

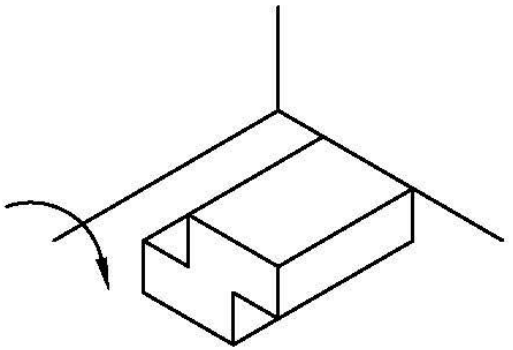
- A rotation about an axis can be either positive (counterclockwise) or negative (clockwise)



Original Object Position



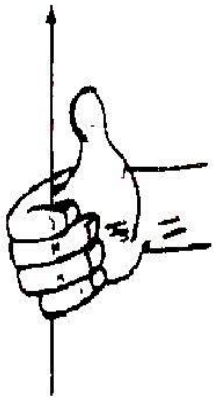
Positive Rotation



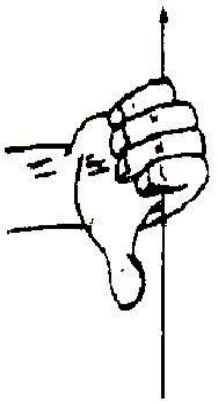
Negative Rotation

Right Hand Rule

- If you place the thumb of your *right hand* down the axis of rotation, your fingers will curl in the direction of the rotation



Positive Rotation



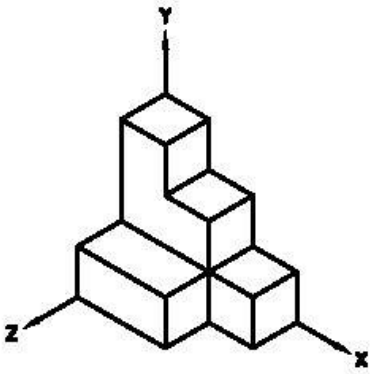
Negative Rotation

Arrow Coding

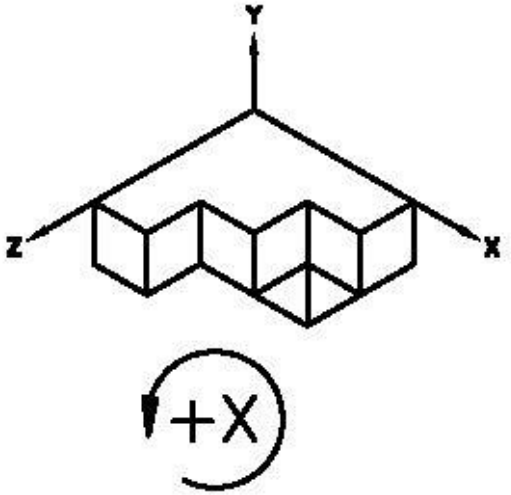
- Object Rotations can be designated by arrow coding
  - A curved counterclockwise arrow is a positive rotation

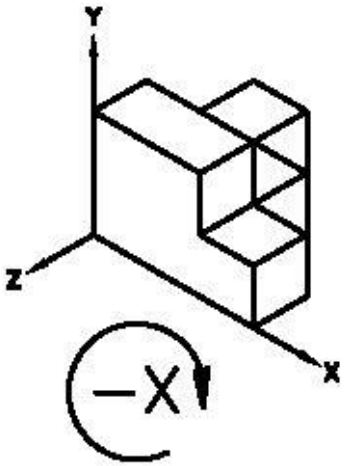
  - A curved clockwise arrow is a negative rotation

  - The axis for the rotation is included within the notation
  - The increment for the rotation is always 90^{o}

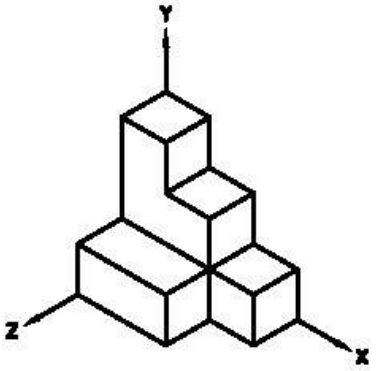


Original Object Position

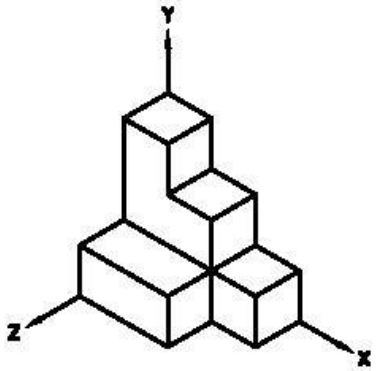




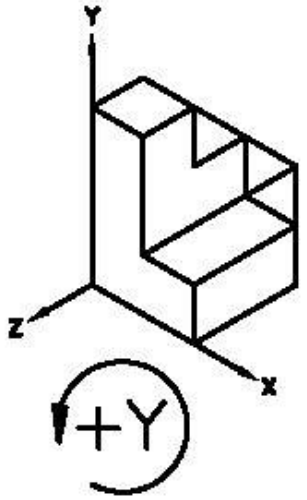
For each of the following slides, try to visualize the rotation

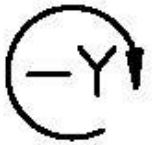


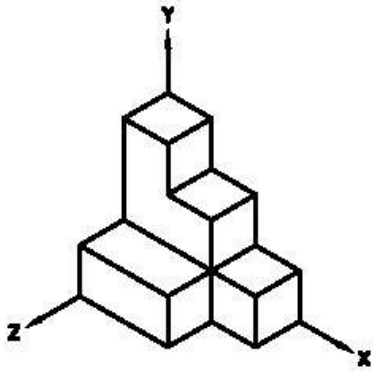
Original Object Position



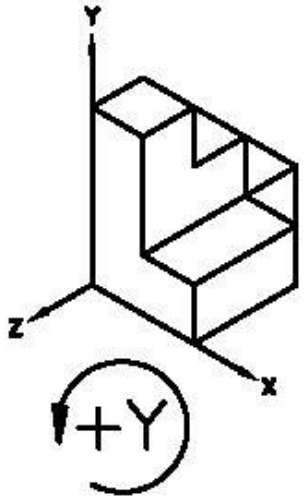
Original Object Position

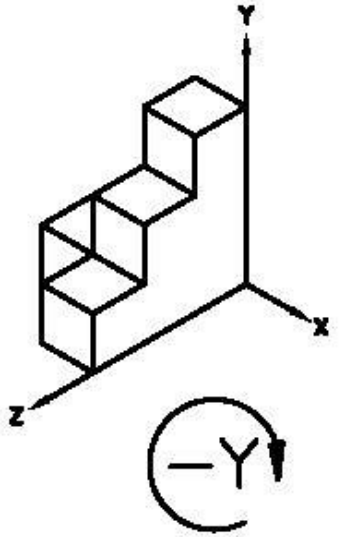


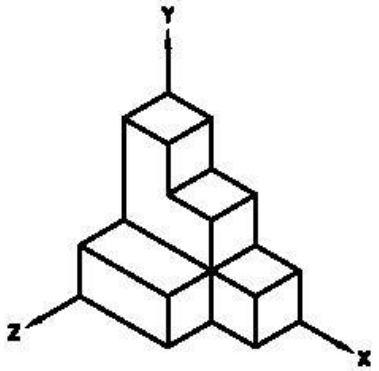




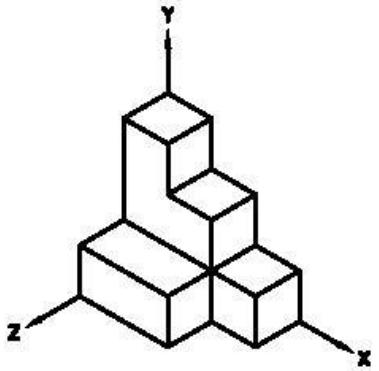
Original Object Position



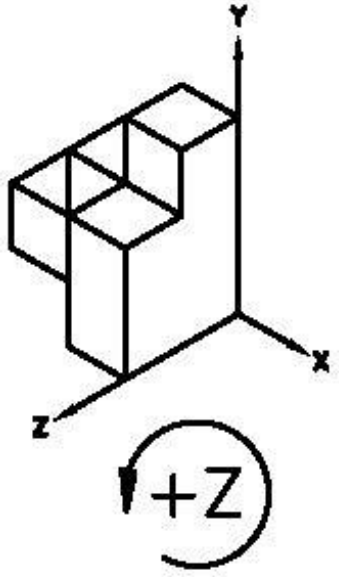


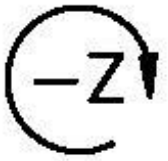


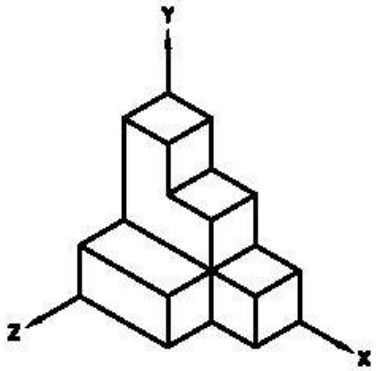
Original Object Position



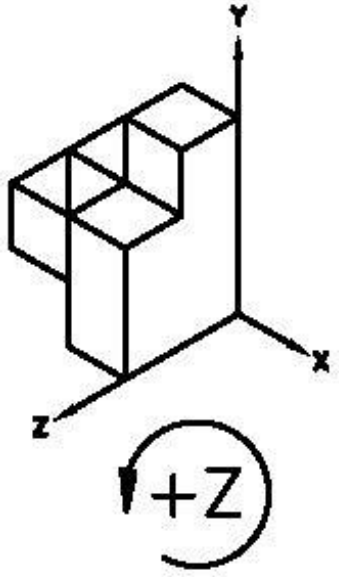
Original Object Position

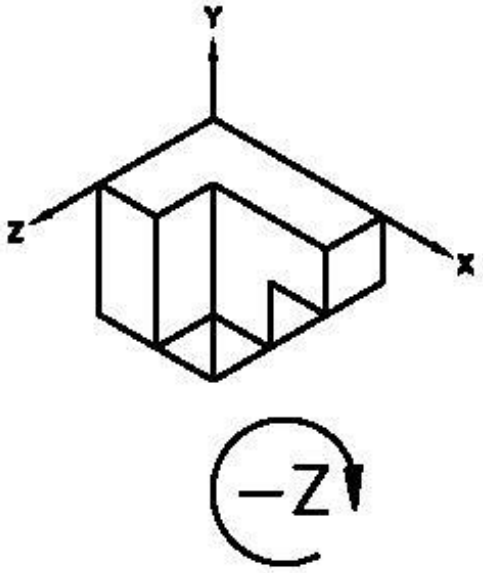






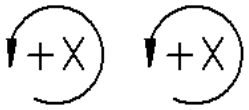
Original Object Position





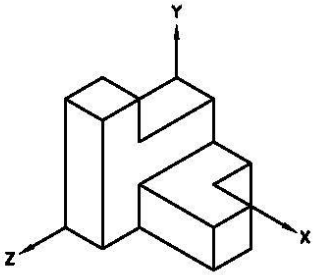
Multiple Rotations

- For multiple rotations about the same axis, use an arrow for *each* rotation of 90º.

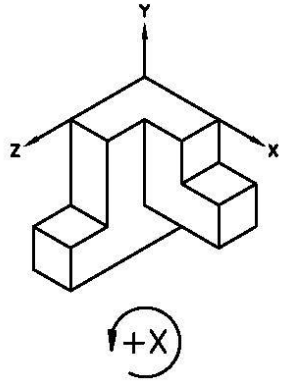


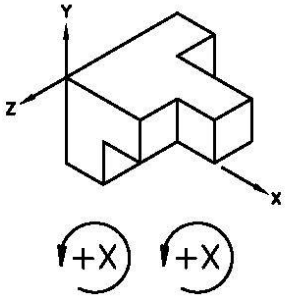
Positive 180˚ rotation about the x-axis

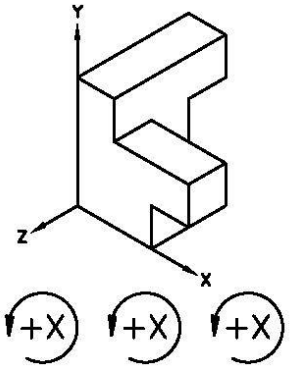
Negative 270˚ rotation about the y-axis

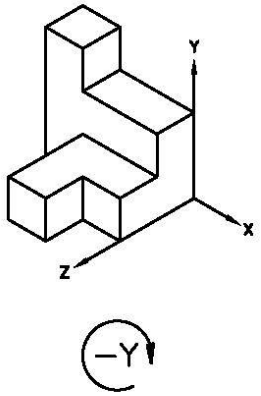


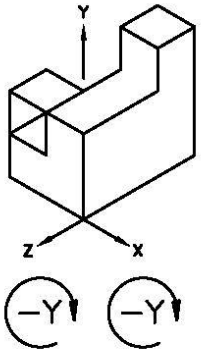
Original Object Position

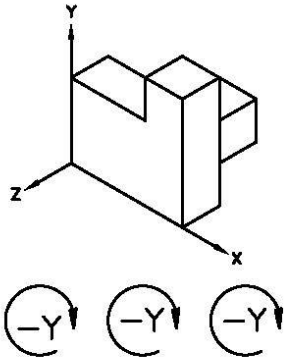






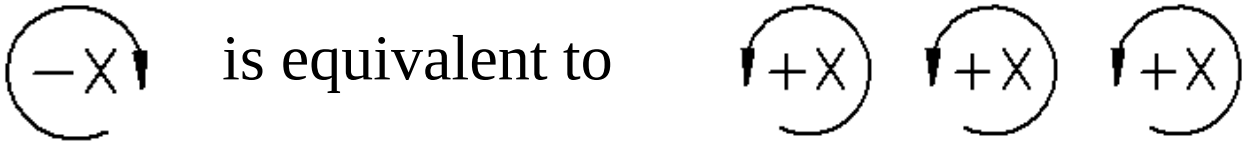


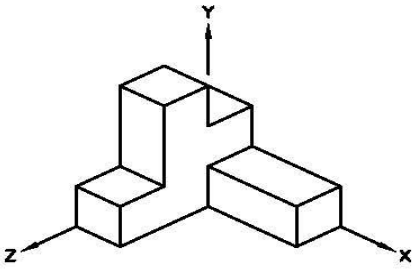




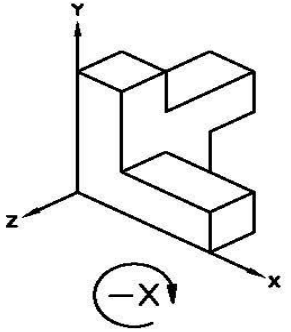
Equivalent Rotations

- Sometimes one set of rotations can be replaced by a simpler set.





Original Object Position



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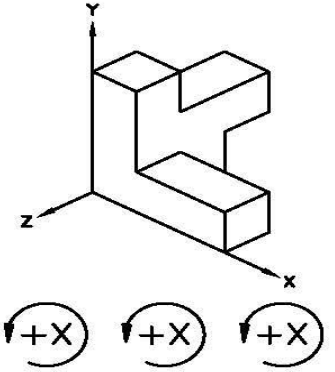

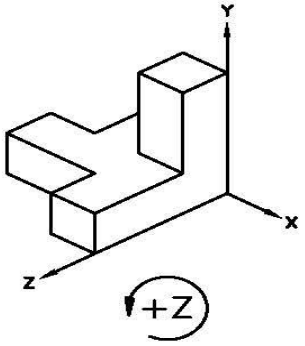

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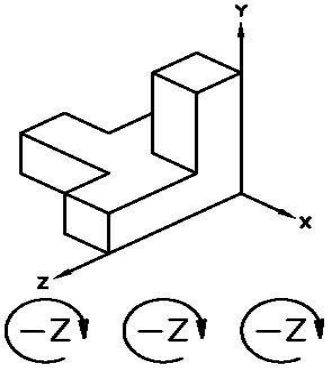

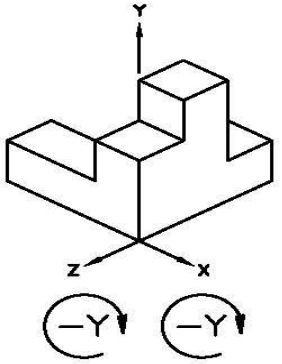

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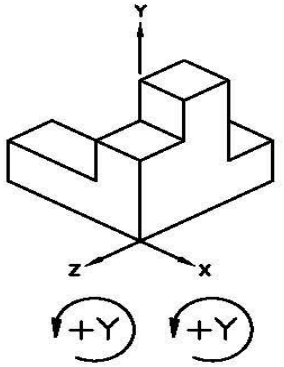
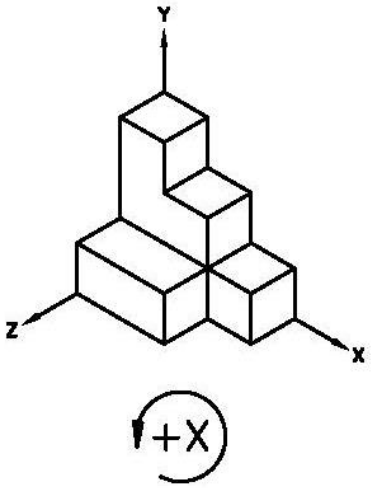
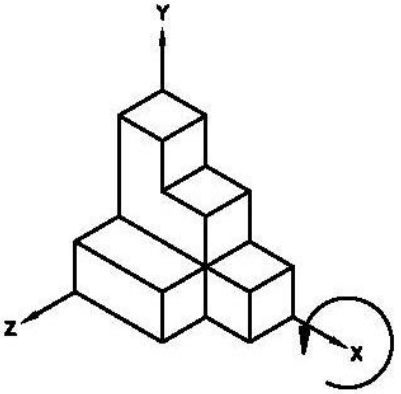
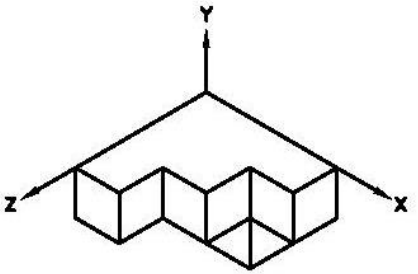
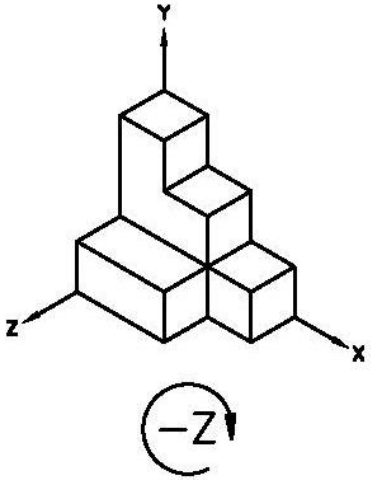


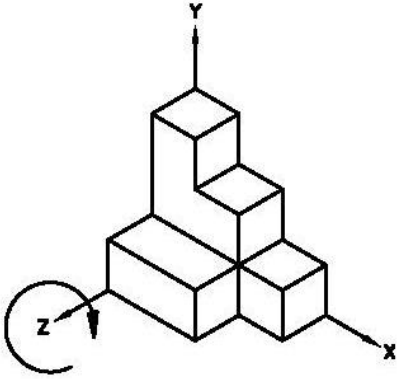
To visualize a rotation, think about moving the notation to the *positive* end of the axis—the arrow will show you the direction of the rotation

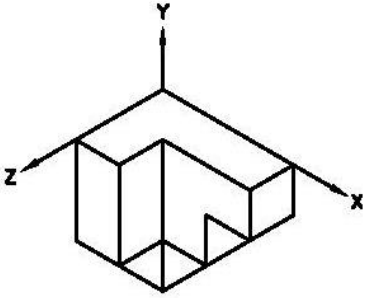












Course Software…

- Work through the Rotation of Objects About a Single Axis computer module

Rotation of Objects about a Single Axis Homework …

- Complete the following pages in Module 7
- rot1-
  - 1 - 3
  - 5 - 6
  - 9 - 10
  - 13 - 14
  - 16 - 18

Rotation of Objects about Two or More Axes

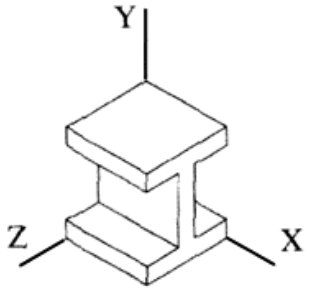
Module 8

Session Topics

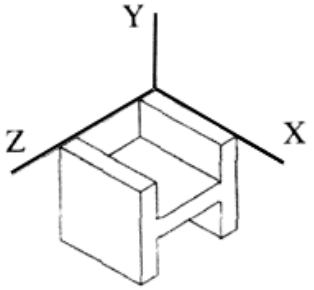
- Rotations about Two Axes
- Order of Rotations
- Equivalent Rotations
- Computer Module

Review: Rotation of Objects

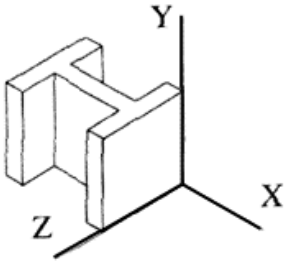
- Rotation: turning an object about a straight line (axis of rotation)



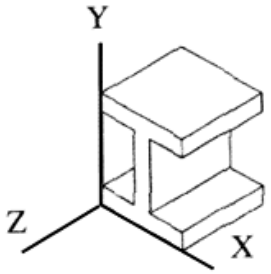
Original Position



Positive X-axis Rotation



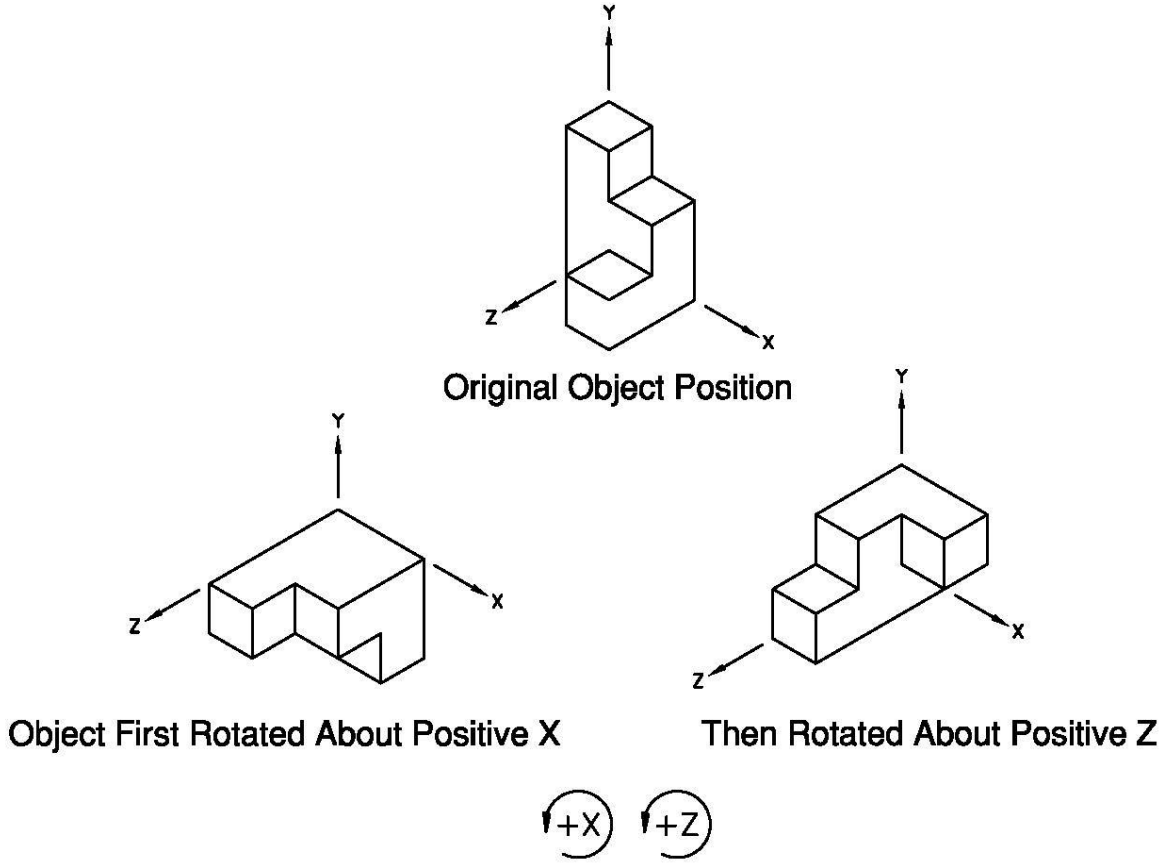
Positive Z-axis Rotation



Positive Y-axis Rotation

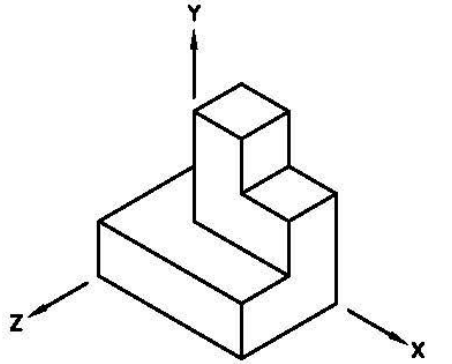
Rotation About Two Axes

- Objects can be rotated about two or more axes the same way they were rotated about a single axis

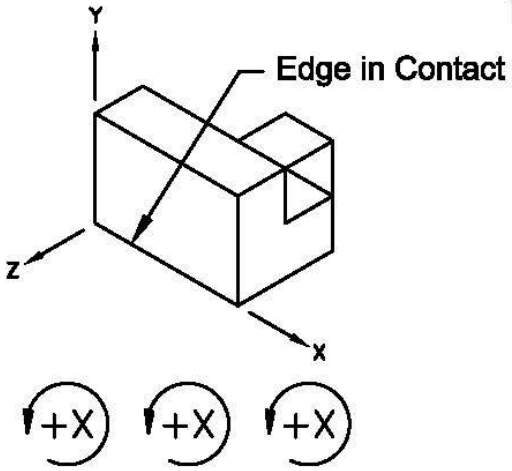


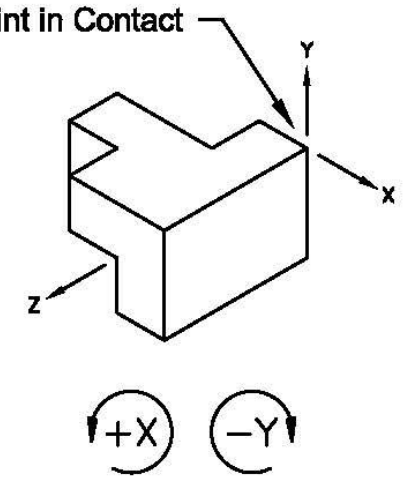
Rotation Origin

- When objects are rotated about two or more axes, only a single point remains in its original position



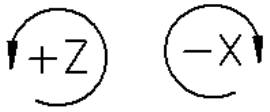
Original Object Position





Arrow Coding in Multiple-Axes Rotations

- Arrows are placed in the order in which the rotations are performed

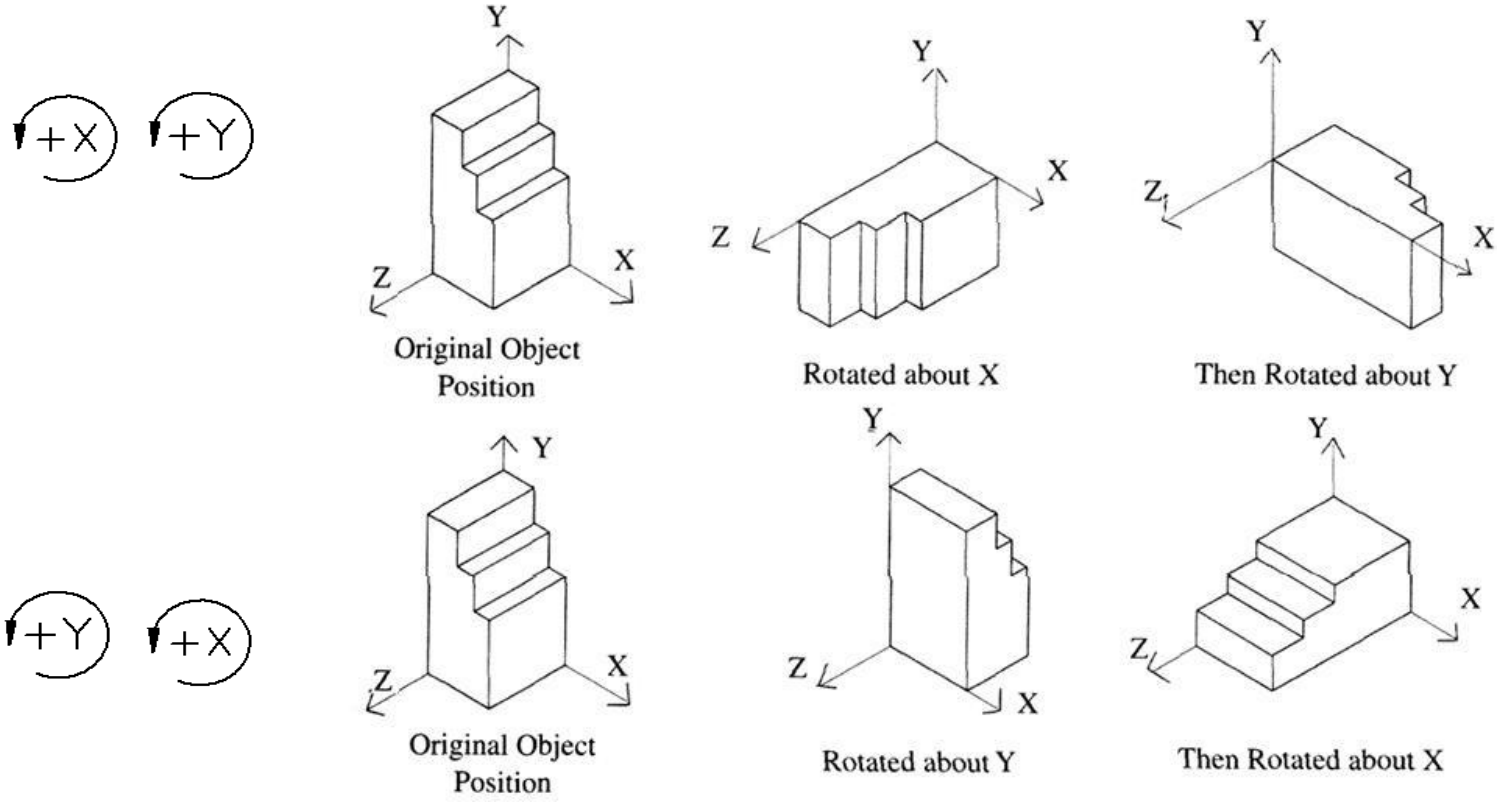


Positive 90° rotation about the z-axis followed by a negative 90° rotation about the x-axis.

Positive 90° rotation about the y-axis followed by a positive 90° rotation about the x-axis followed by a negative 90° rotation about the x-axis.

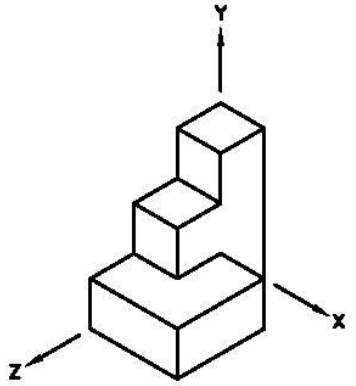
Order of Rotations

- Final orientation of the object depends on the order in which the rotations were performed.

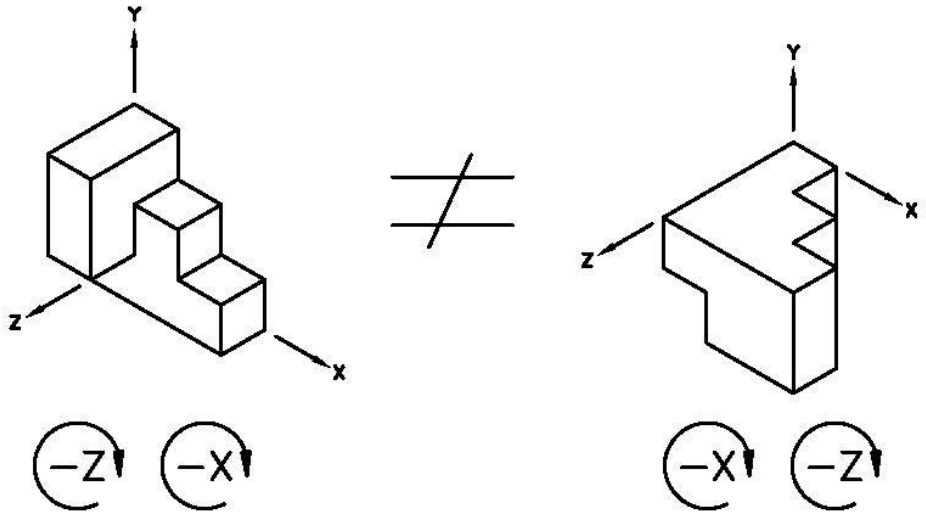


Order of Rotations

- Object rotations about two or more axes are not commutative!

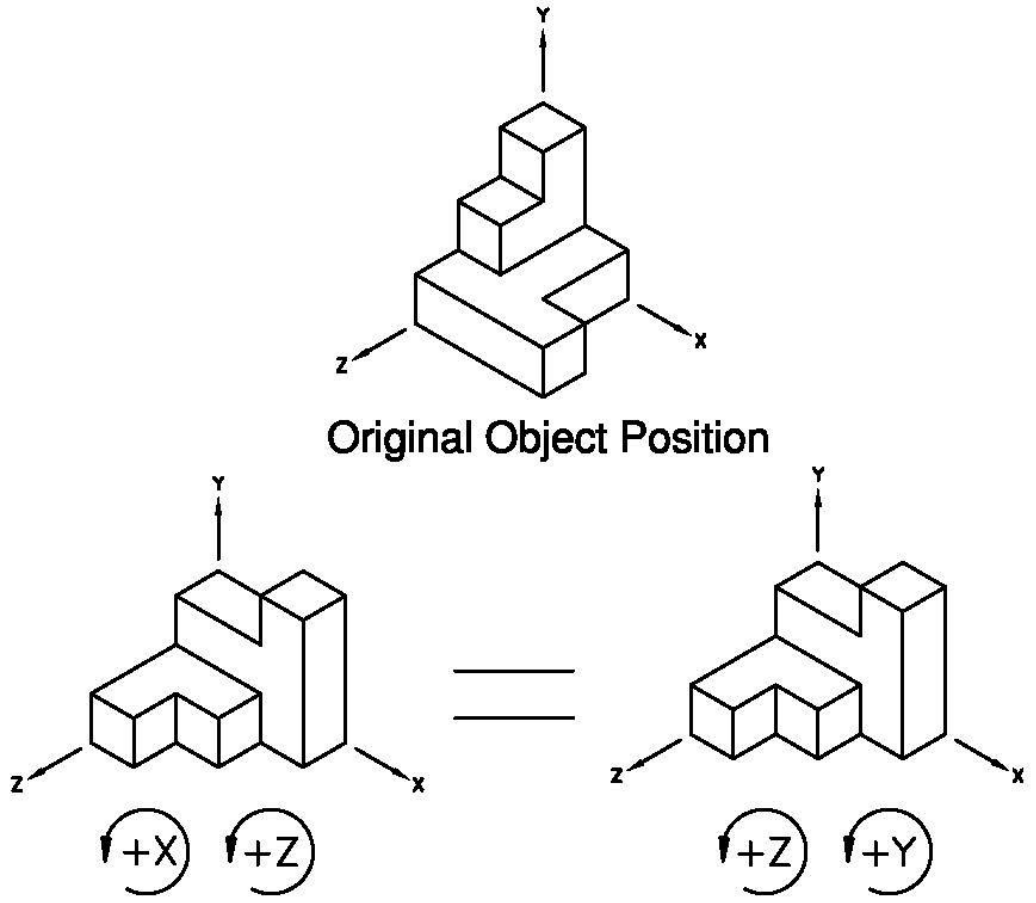


Original Object Position



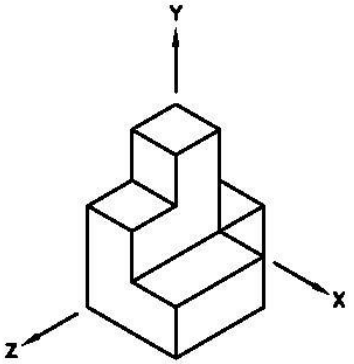
Equivalent Rotations

- Two sets of rotations can result in the same final orientation of the object

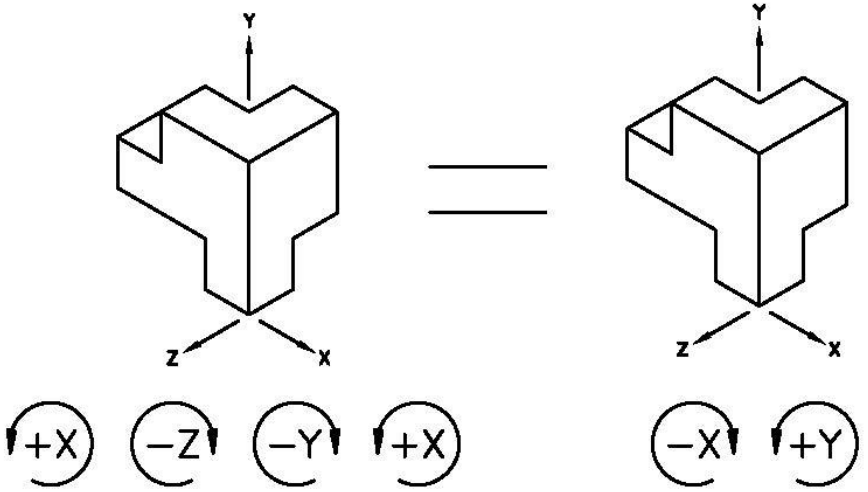


Equivalent Rotations

- Sometimes one set of rotations can be replaced by a simpler set.



Original Object Position



Course Software…..

- Work through the Rotation of Objects about Two or More Axes software module

Rotation of Objects about Two or More Axes Homework …

- Complete the following pages in Module 8
- rot2-
  - 1 - 2
  - 5 – 8
  - 11 – 12
  - 15 - 16

Object Reflections and Symmetry

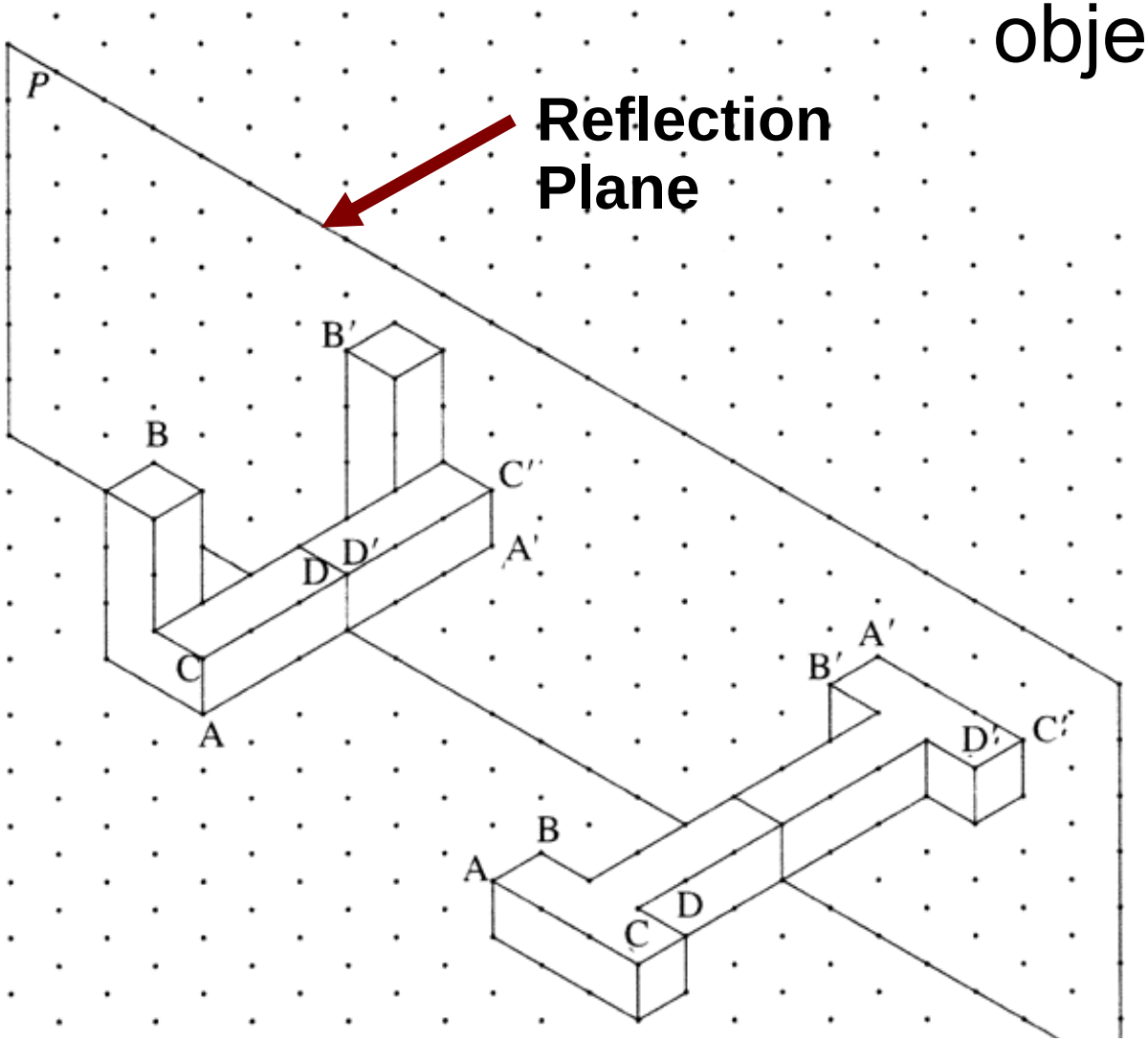
Module 9

Session Topics

- Reflection of an object
- Planes of symmetry
- Reflections through rotations

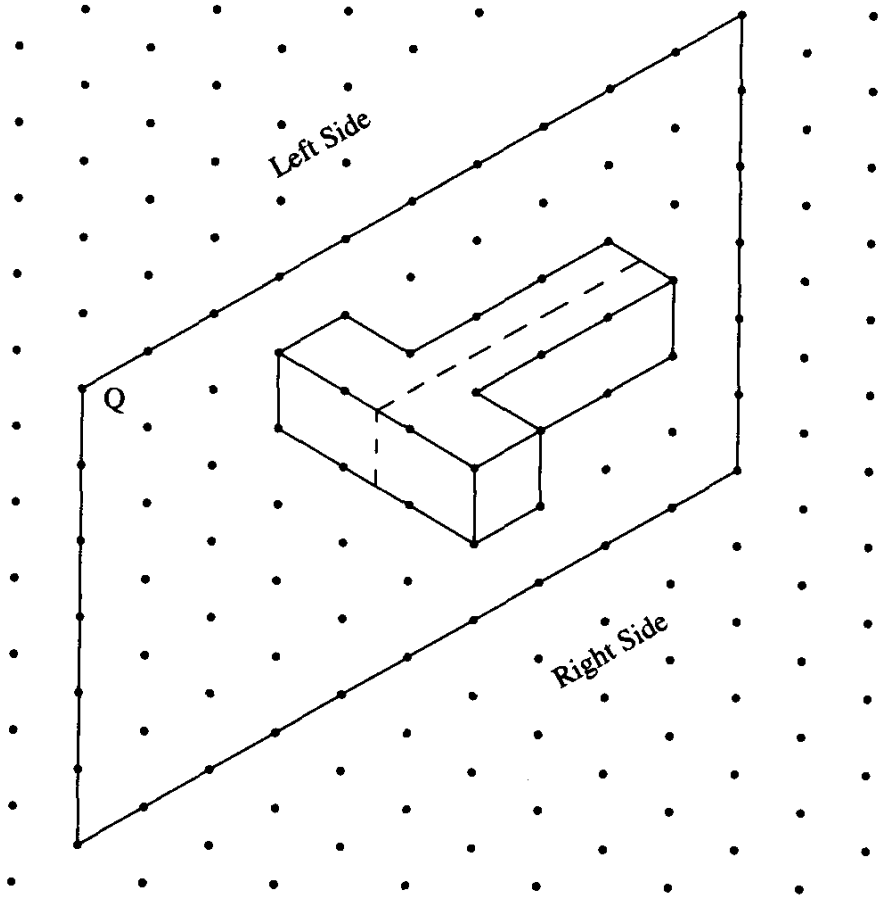
Reflection

A reflection across a plane displays the object's mirror image.



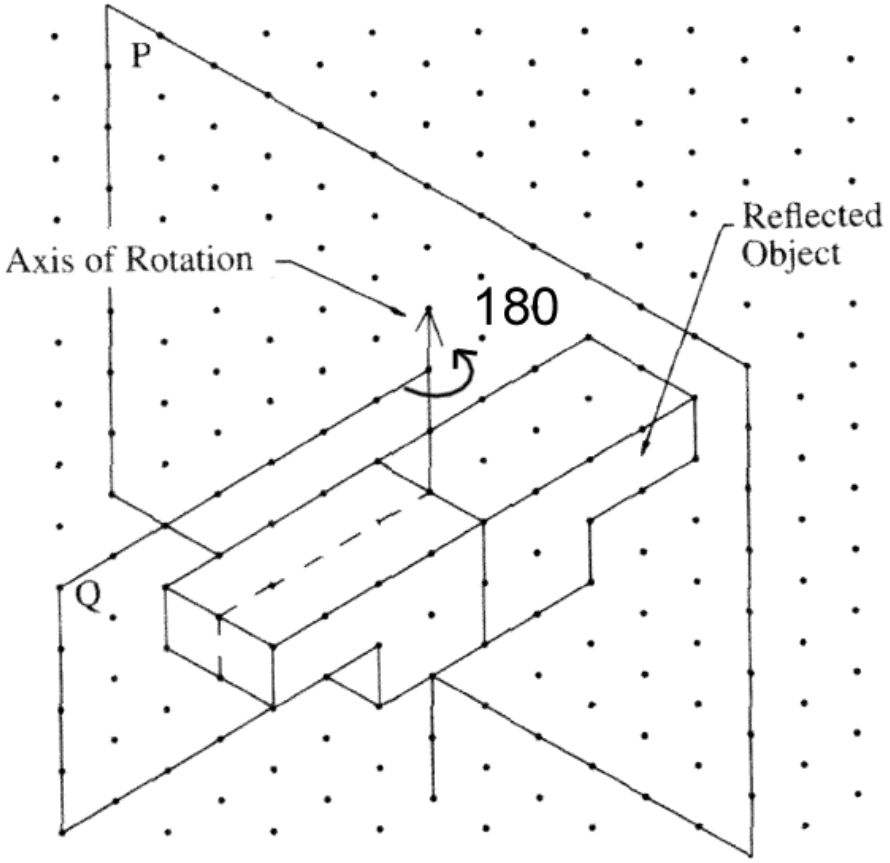
Each point, A, is associated with an image point, A', such that the plane, P, is a perpendicular bisector of the line segment AA'.

Plane of Symmetry



Plane of symmetry occurs if the parts of the object on both sides of the plane are mirror images of each other.

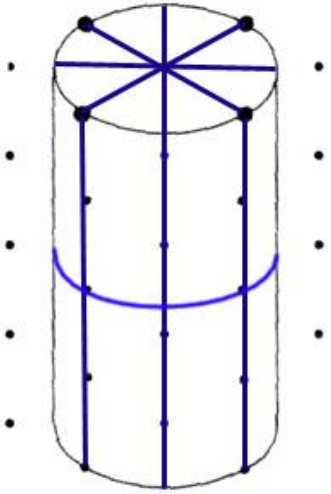
Reflection through Rotation



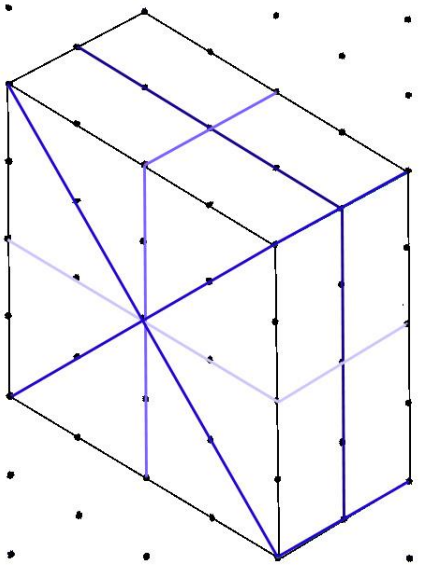
For a symmetric object, the mirror image can occur by rotating one side of the object 180° about an axis of rotation that's in the plane of symmetry.

Multiple Planes of Symmetry

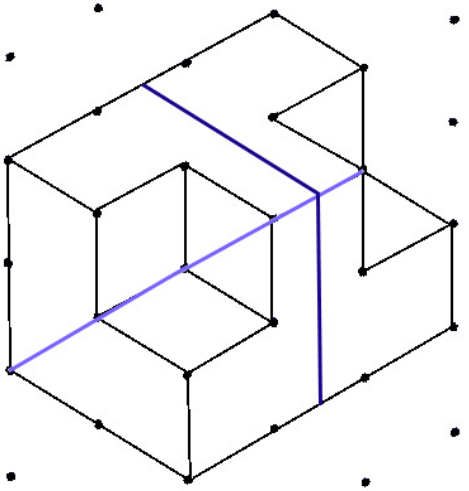
Many objects have multiple planes of symmetry



Infinite



5



2

Course Software…..

- Work through the Reflections and Symmetry software module

Object Reflections and Symmetry Homework …

- Complete the following pages in Module 9
- reflx/sym-
  - 2 - 5
  - 8 - 9
  - 12 - 15

Cutting Planes and Cross Sections

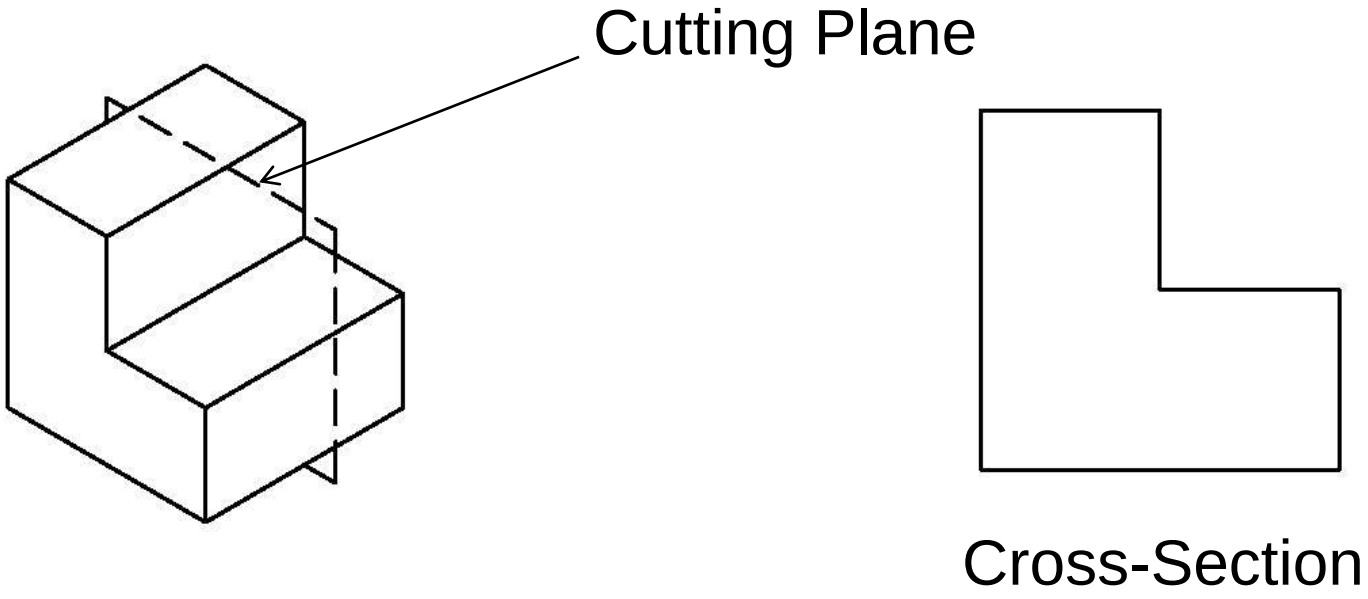
Module 10

Session topics

- Cutting planes
- Cross Sections
- Multiple Cross Sections

Cutting Planes

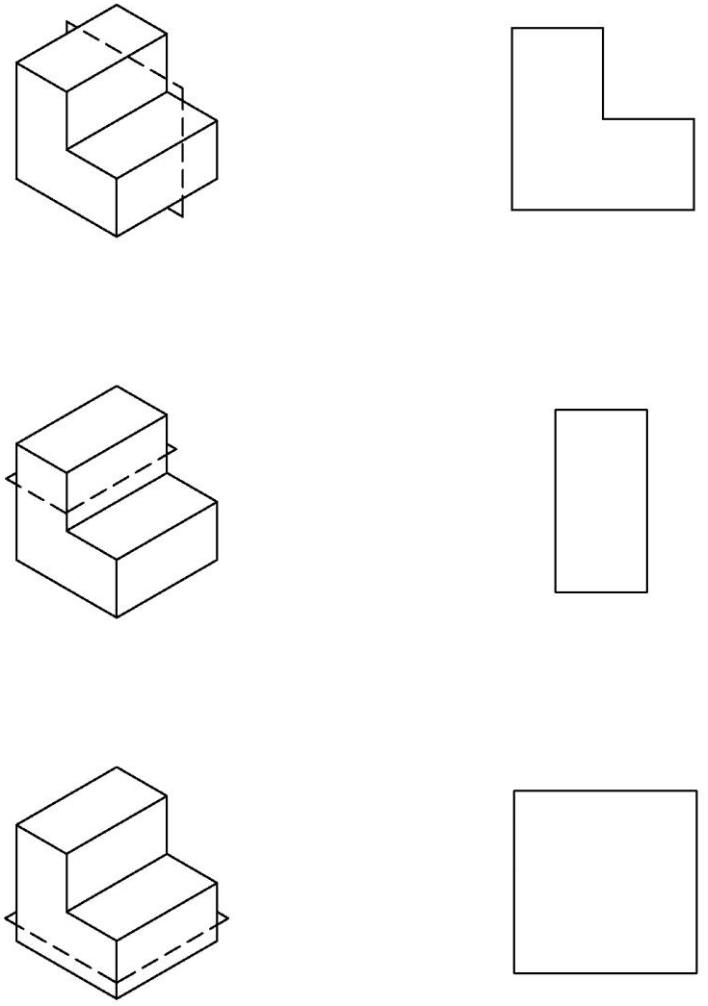
- A cutting plane is an imaginary plane that slices through an object



Cutting Planes and Cross Sections

A cross section is the intersection of a cutting plane with a solid object.

- The result is a 2-D shape defined by the boundaries of the original object

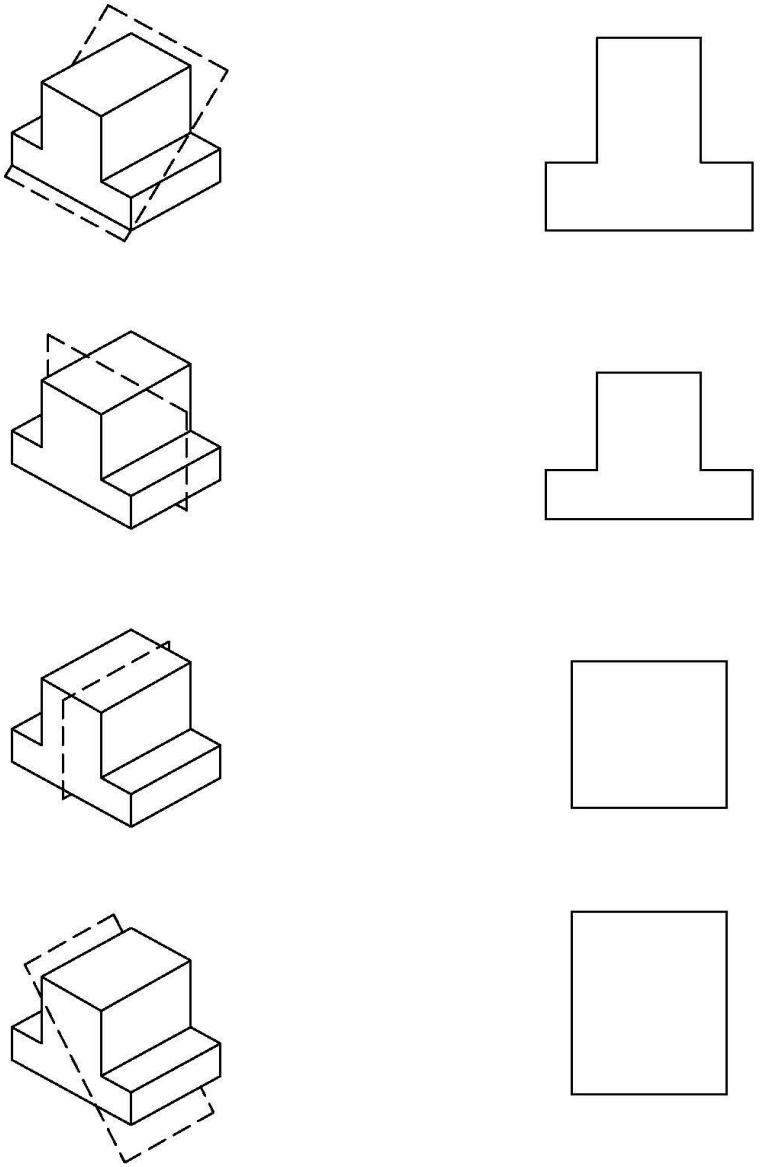


Object and Cutting Plane

Resulting Cross Section

Cross Sections

The shape of the resulting cross section depends on the orientation of the cutting plane with respect to the object

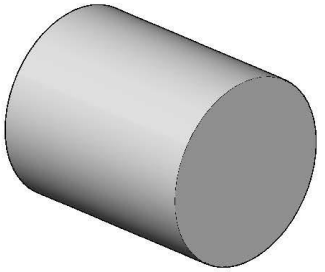


Object and Cutting Plane

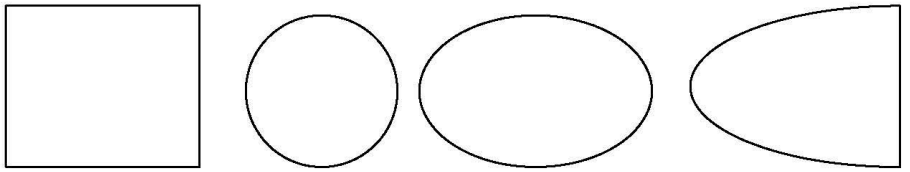
Resulting Cross Section

Multiple Cross Sections

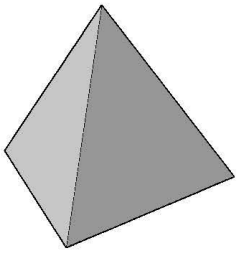
Objects can produce several cross sections



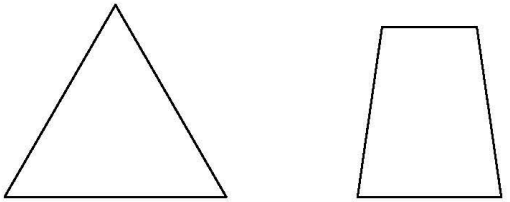
Object



Possible Cross Sections



Object

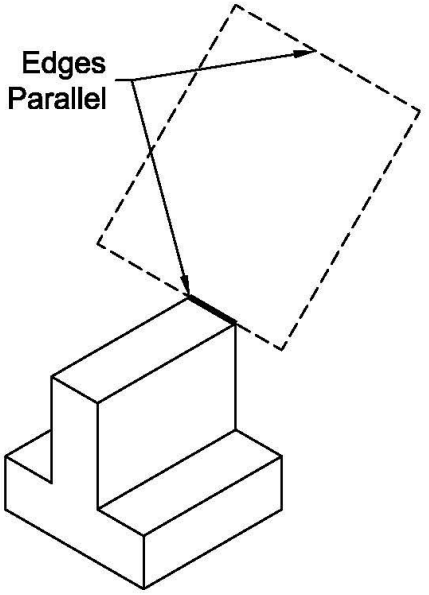


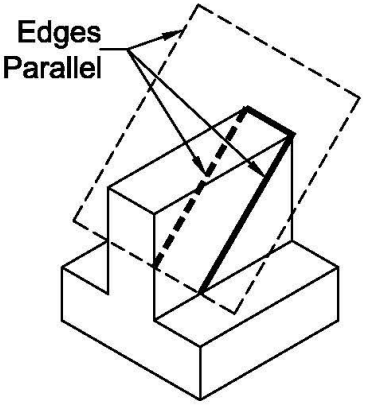
Possible Cross Sections

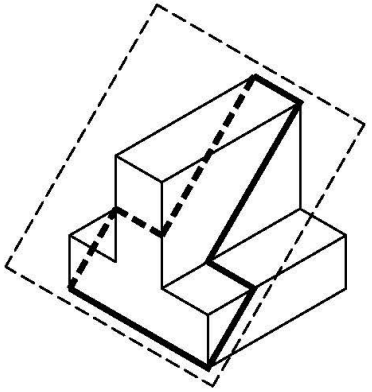
Cutting Planes

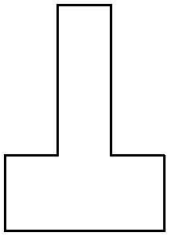
As a plane cuts an object, the boundary edges on the cross section that results will be parallel to the edges of the cutting plane itself

- Rotate the plane into position to view it "straight on"









Cross Section Rotated to Viewing Plane

Course Software...

- Work through the Cutting Planes and Cross Sections software module

Cutting Planes and Cross Sections Homework …

- Complete the following pages in Module 10
- cp/cs-
  - 1 - 2
  - 5 - 6
  - 9 - 10
  - 13 - 16
  - Hint: for pages 14 and 16 all problems have at least two correct answers