

MS 101

LECTURE 1

SKETCHING AND VISUALISATION

TEXTBOOKS REFERRED TO

MAIN BOOKS

- **Text Book 1:** Dennis K. Lieu and Sheryl Sorby, Visualization, Modeling, and Graphics for Engineering Design
- **Text Book 2:** N. D. Bhatt and V. M. Panchal, Engineering Drawing, Charotar Publishers

REFERENCE BOOKS :

- Warren J. Luzadder and Jon M. Duff, Fundamentals of Engineering Drawing, Prentice-Hall of India
- Thomas E. French, Charles J. Vierck and Robert Foster, Engineering Drawing and Graphic Technology, McGraw Hill
- Dhananjay A. Jolhe, Engineering Drawing, Tata McGraw Hill Publishing Co. Ltd.
- M. B. Shah and B. C. Rana, Engineering Drawing, Dorling Kindersley (India) Pvt. Ltd., Pearson Education

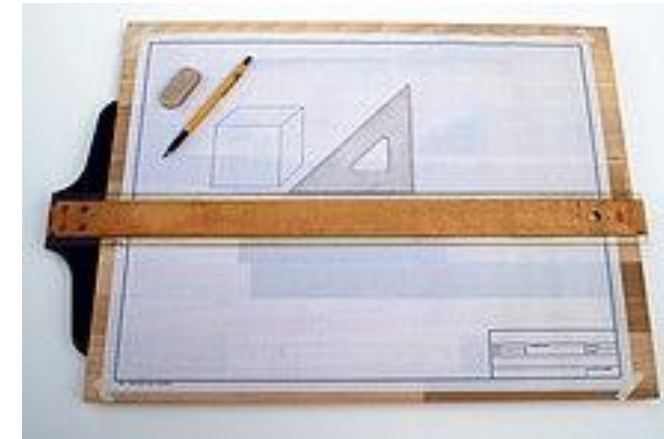
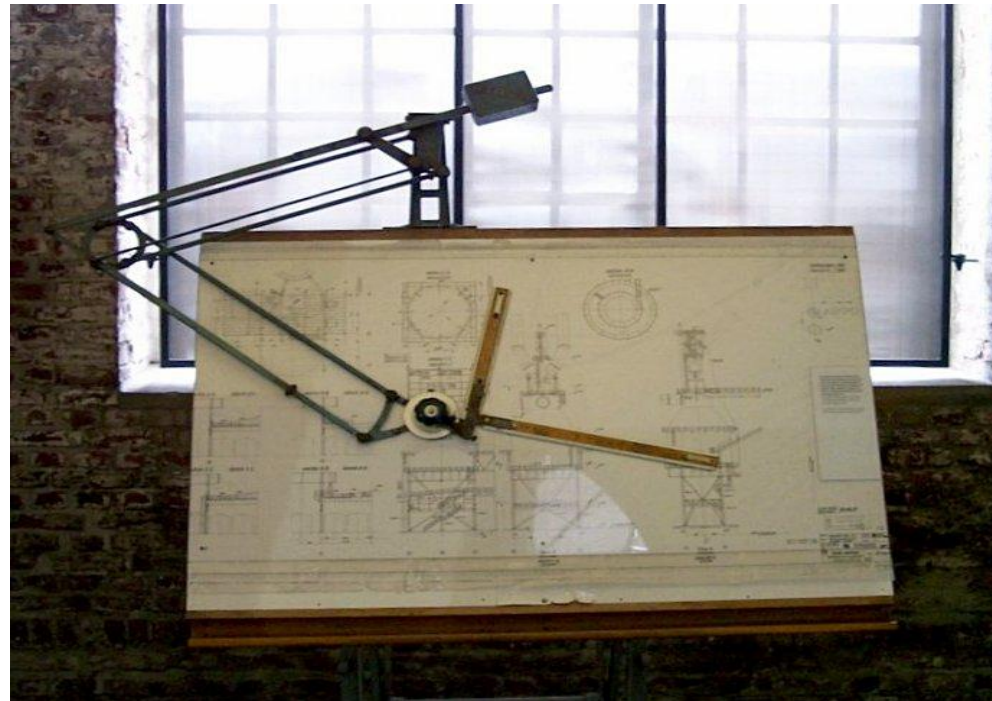
CREDITS FOR SLIDES

- Many slides are taken from Prof. Anirban Guha, ME, IITB, Prof. Amit Singh, ME, IITB
Prof. Krishna Jonnalagadda, ME, IITB

Engineering Graphics Technology

INSTRUMENT DRAWING:

Drafting board, T-square, Set-square, Scale, Compass, Protractor, French Curves, Drawing papers, Pencils, Eraser, Drawing pins, Sand paper, Duster, Drafting machine.

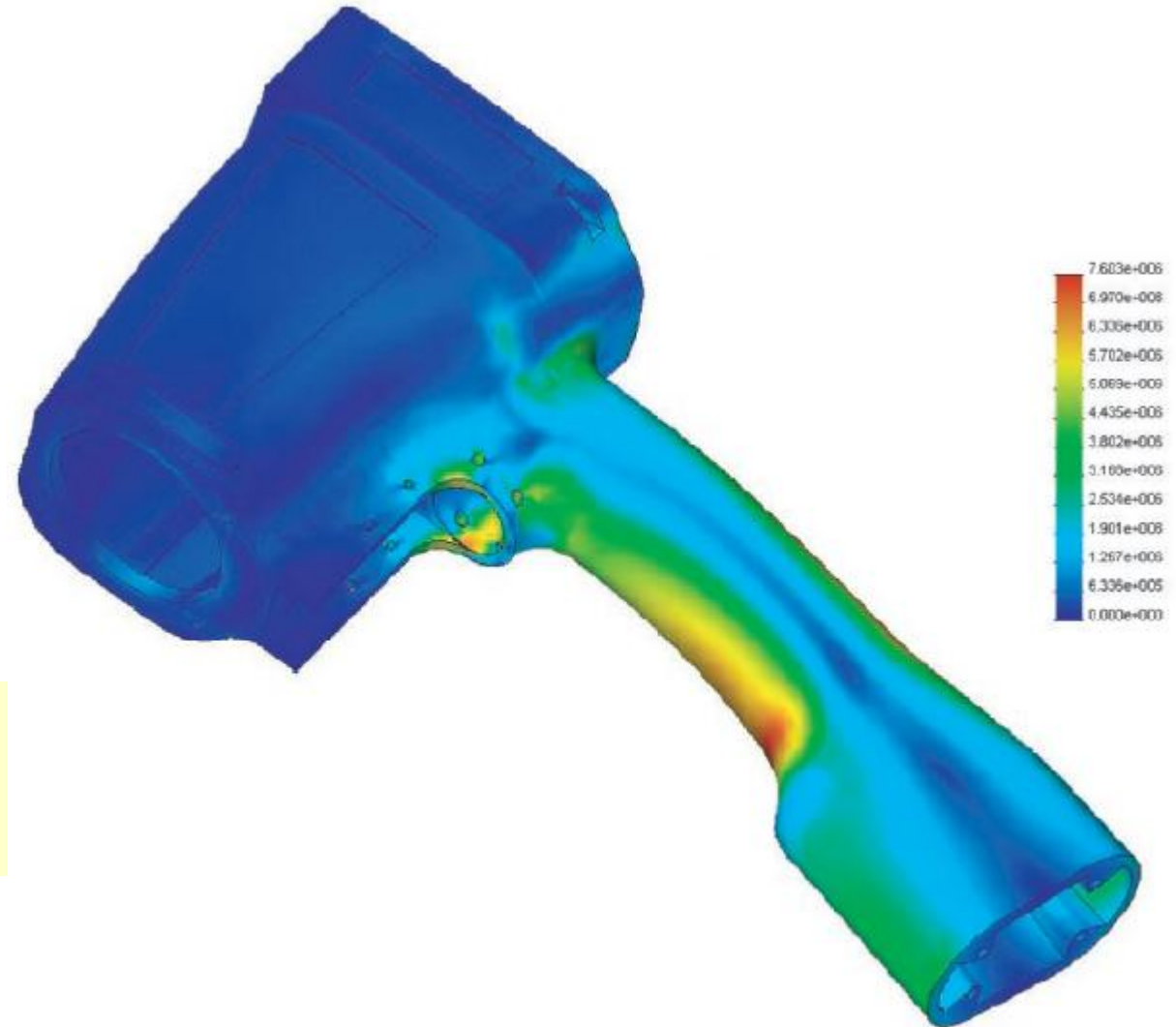


Engineering Graphics Technology

COMPUTER AIDED WITH SOFTWARE:

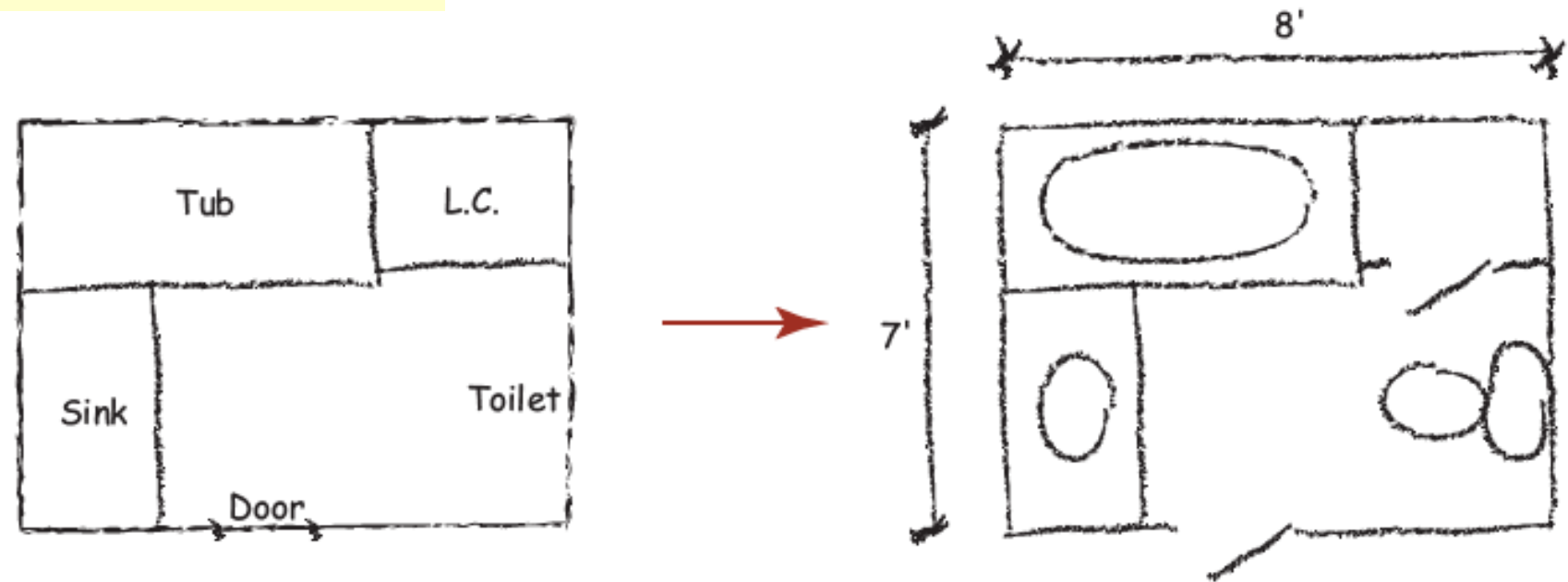


**THIS COURSE WILL ADOPT THIS
METHOD: AUTODESK FUSION 360**



SKETCHING - A drawing without the use of drawing instrument

A rough idea, e.g. sketch of a bathroom

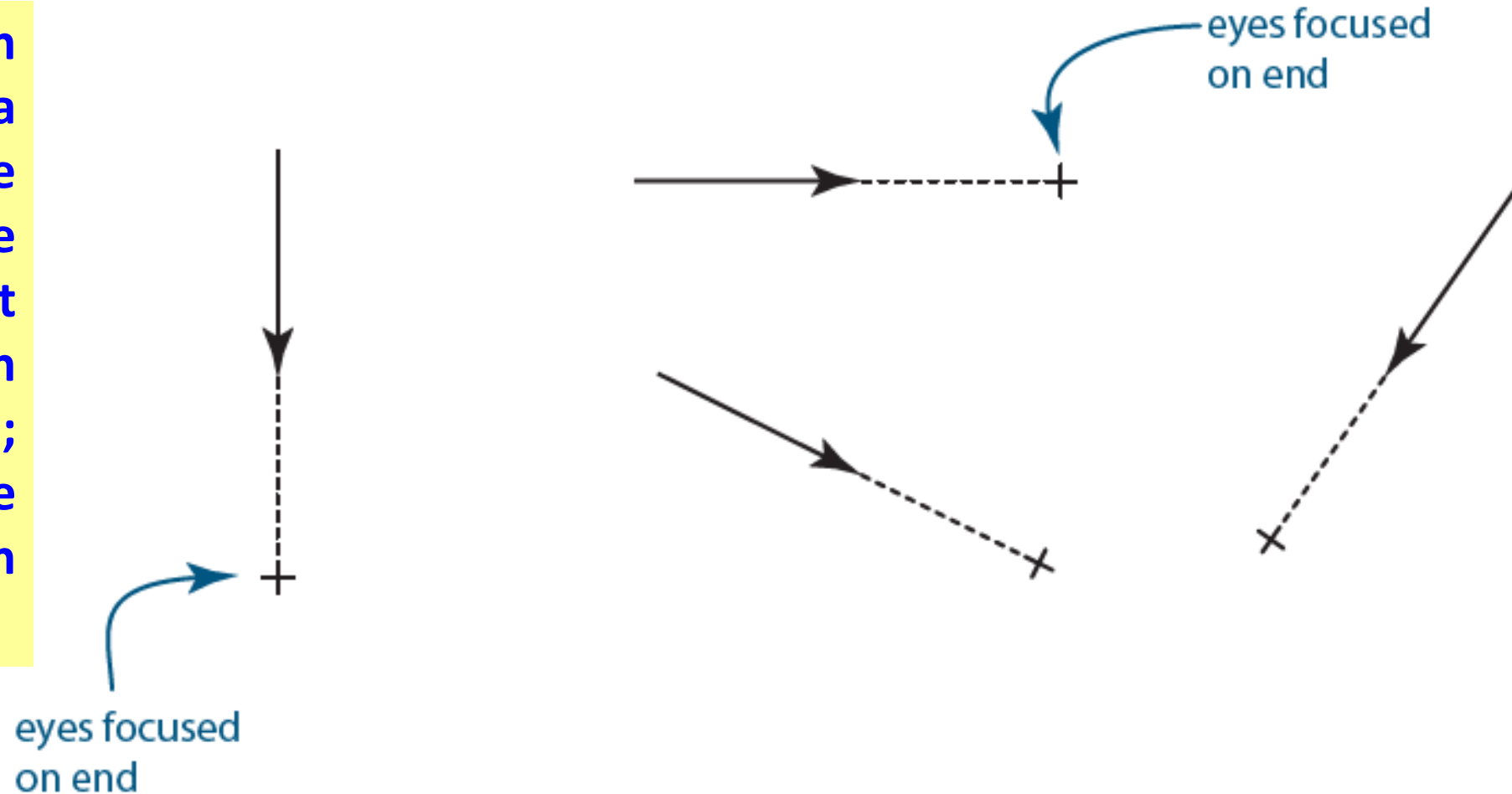


- When engineers sit down to brainstorm solutions to problems, before long, one of them usually takes out a sheet of paper and sketches an idea on it.
- The others in the discussion may add to the original sketch, or they may create sketches of their own.
- The paper-and-pencil sketches become media for the effective exchange of ideas

SKETCHING LINES

When sketching lines, the key is to make them as straight as possible. Sketch your vertical lines from top to bottom and your horizontal lines from left to right.

If you are sketching an angled line, choose a direction that matches the general inclination of the line—for angled lines that are **mostly vertical**, sketch them from **top to bottom**; for angled lines that are **mostly horizontal**, sketch them from **left to right**.



For right-handed person

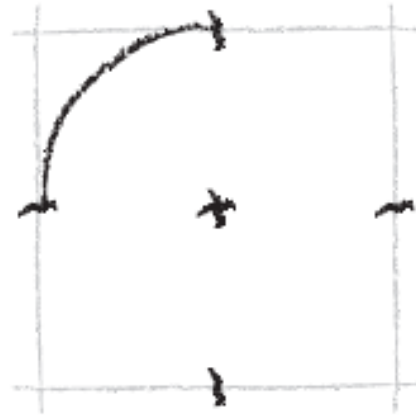
SKETCHING CURVED ENTITIES



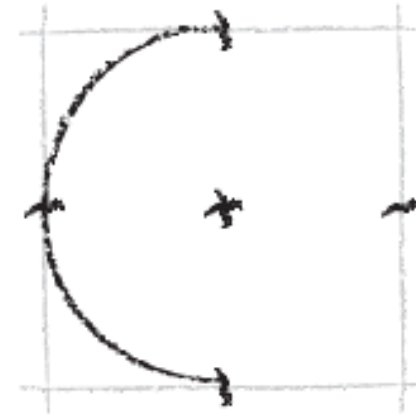
Bounding box
with circle center



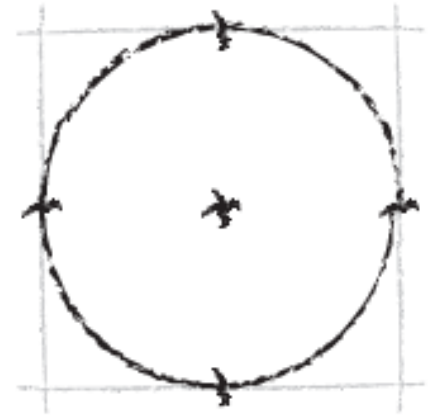
Radial tick
marks added to
boundary box



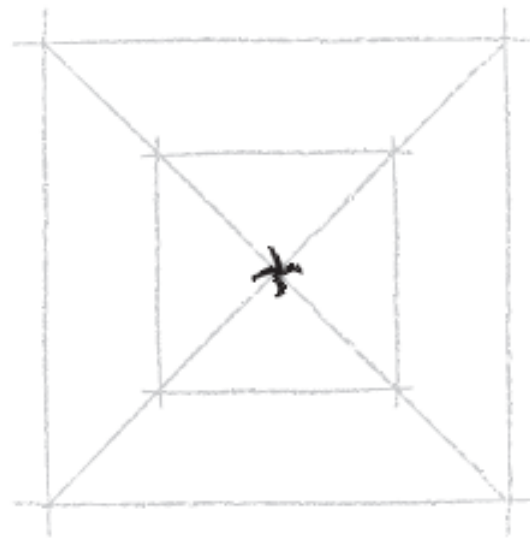
First arc drawn



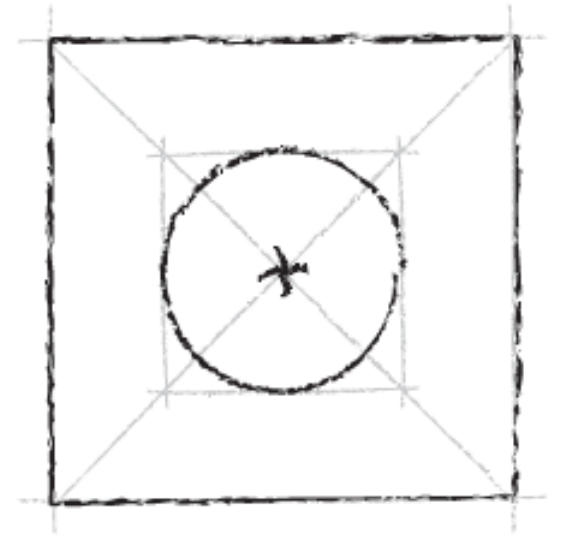
Second arc drawn



Circle complete

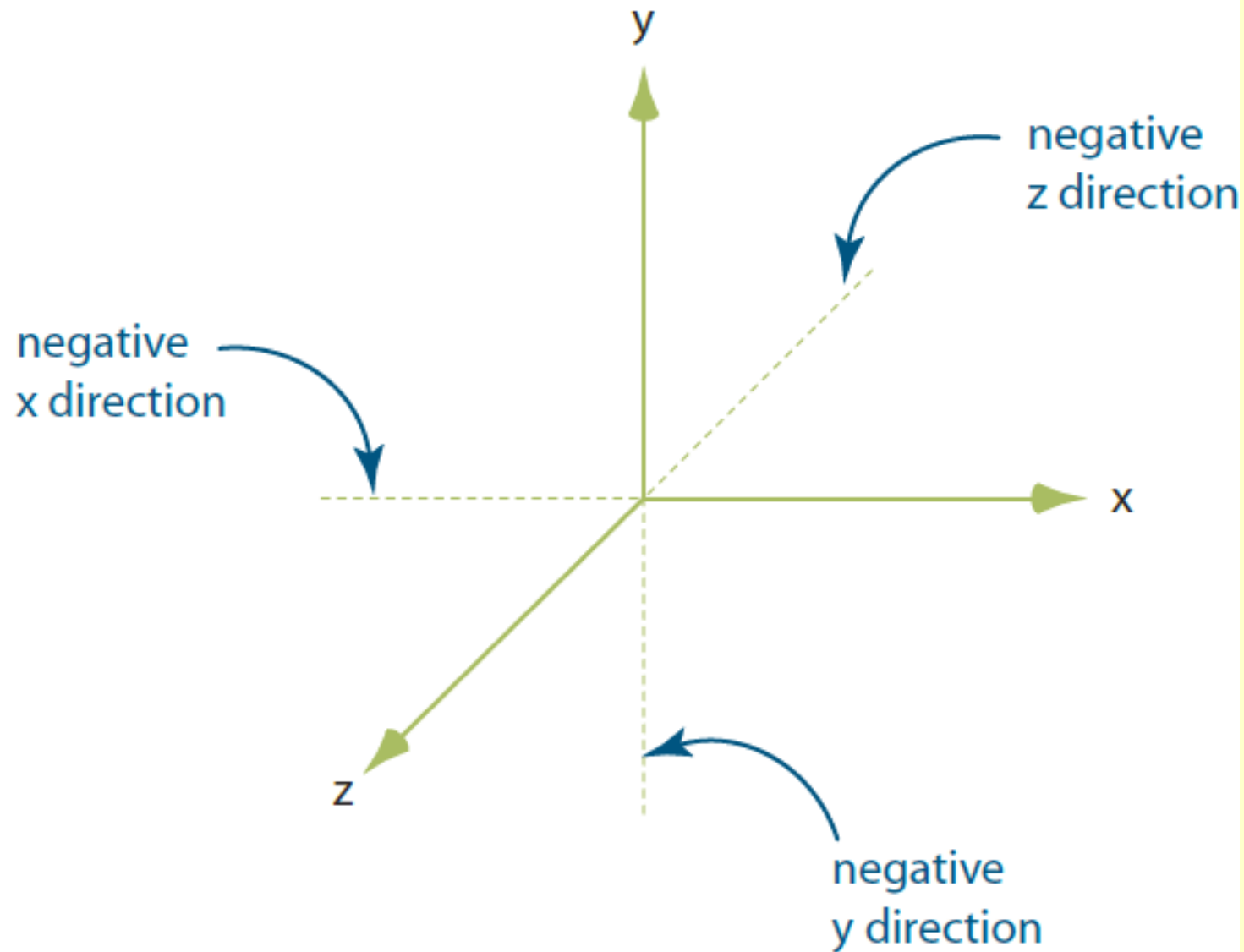


Concentric bounding boxes



Circle centered in square

COORDINATE SYSTEM - Need to portray 3-D objects on a flat 2-D sheet of paper



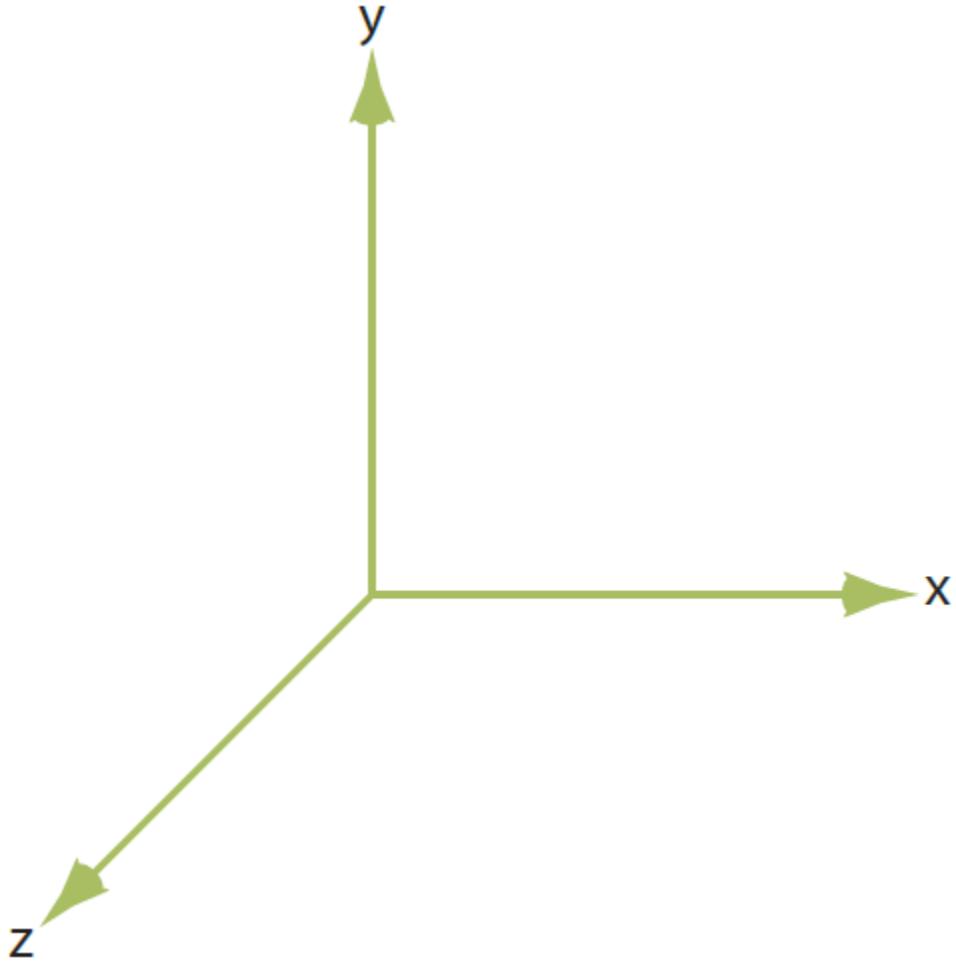
3-D COORDINATE SYSTEM

Space can be represented by three mutually perpendicular coordinate axes, typically the x-, y-, and z-axes

To visualize these three axes, look at the **bottom corner of the room**. Notice the lines that are formed by the intersection of each of the two walls with the floor and the line that is formed where the two walls intersect. we can think of **these lines of intersection** as the **x-, y-, and z-coordinate axes**.

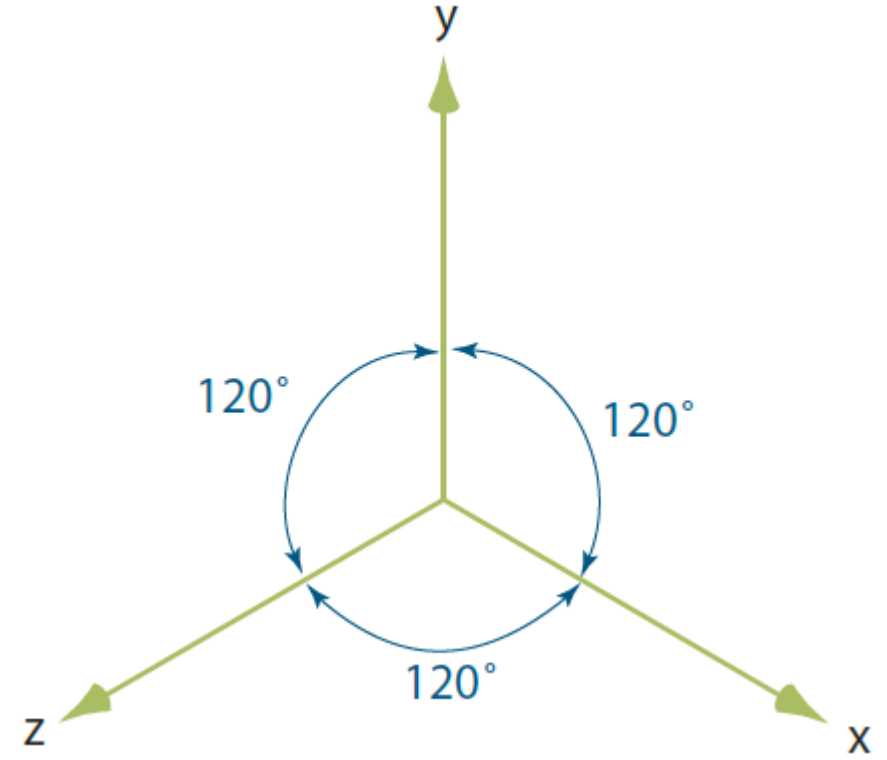
We can define all locations in the room with respect to this corner, just as all points in 3-D space can be defined from an origin where the three axes intersect.

OBLIQUE AXIS REPRESENTATION



Two axes perpendicular, third at an angle of 45 degrees to both axes

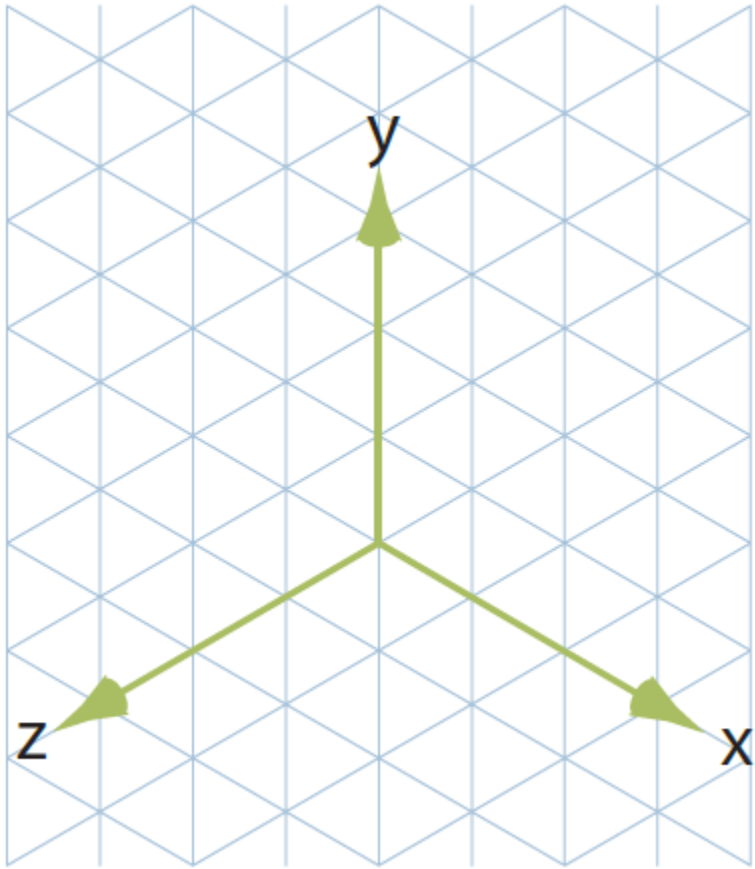
ISOMETRIC REPRESENTATION



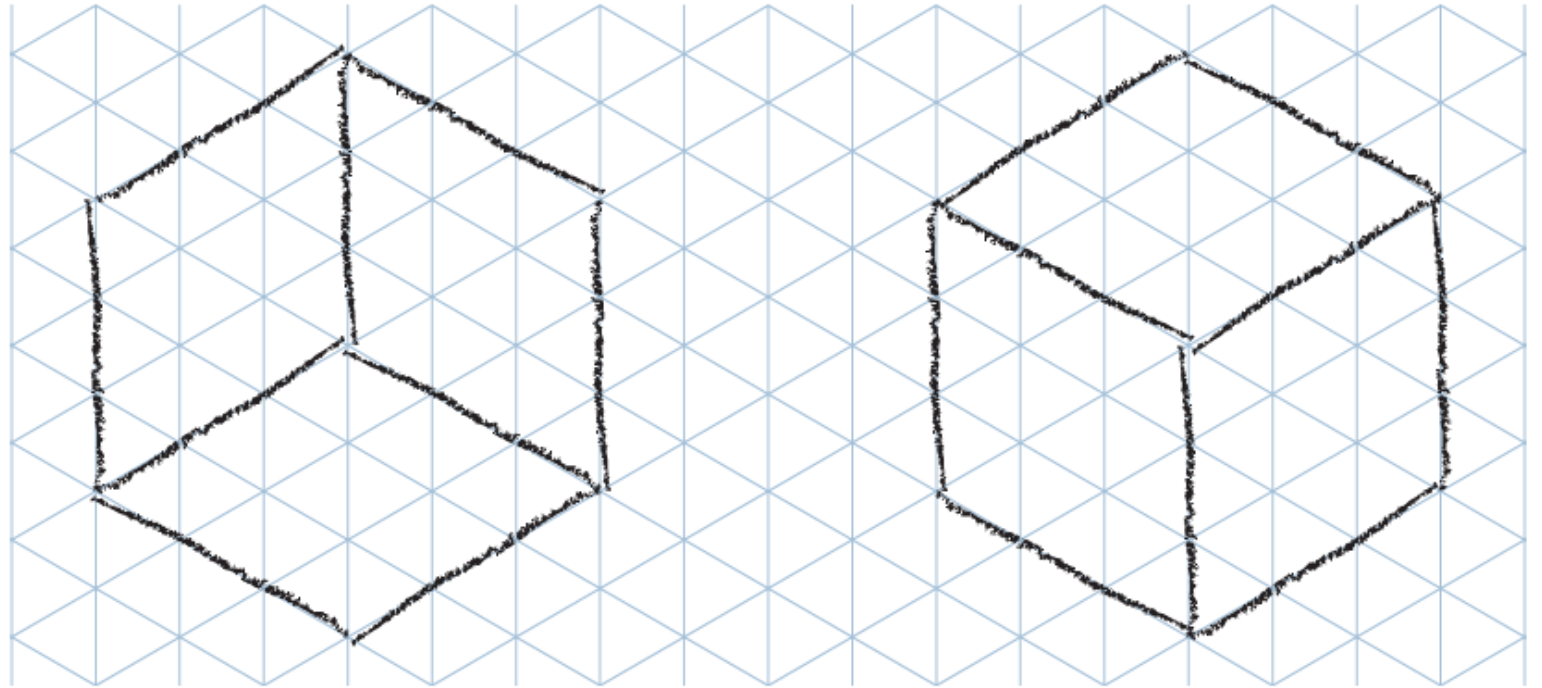
Axes projection as if looking down diagonal of the cube. 120 degrees all axes

ISOMETRIC SKETCHES

ISOMETRIC GRID : Lines are drawn are oriented in such a manner that standard 120 degree coordinate axes are obtained.

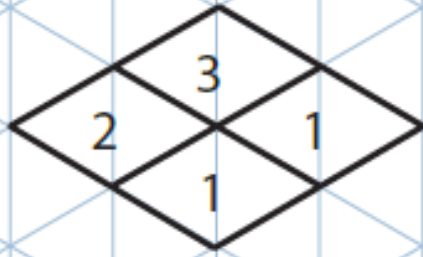


USING ISOMETRIC GRID PAPER TO SKETCH A BLOCK

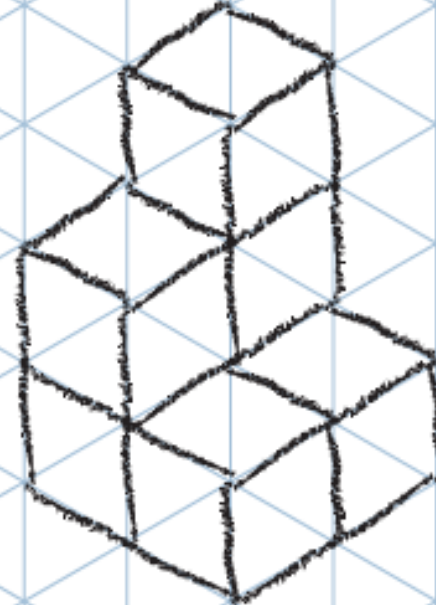


ISOMETRIC SKETCHES

Coded plans: Lines appear only when two surfaces intersect



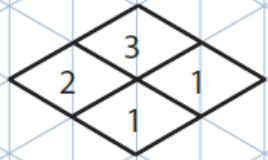
CODED PLAN



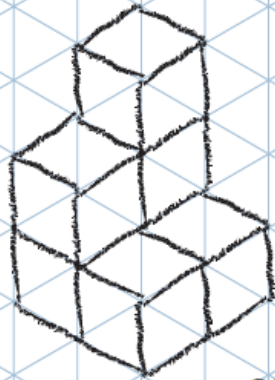
OBJECT CREATED
WITH BLOCKS

ISOMETRIC SKETCHES

A coded plan and the resulting object

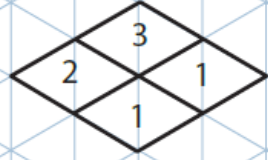


CODED PLAN

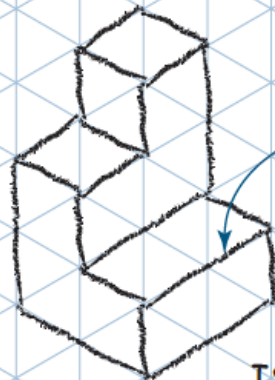


OBJECT CREATED
WITH BLOCKS

A properly drawn isometric sketch of the object from the coded plan

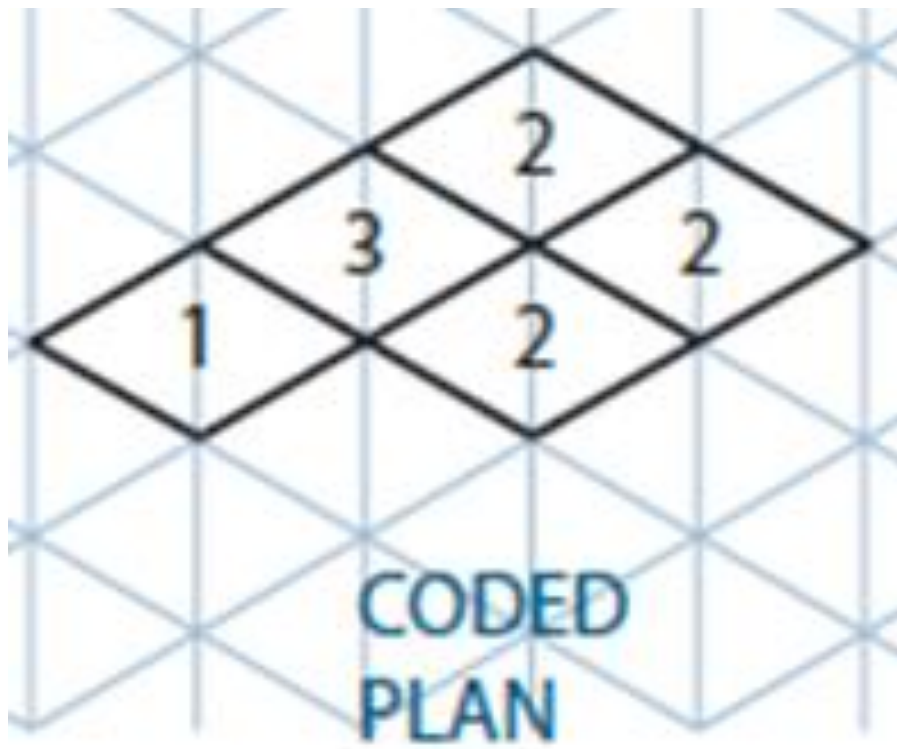
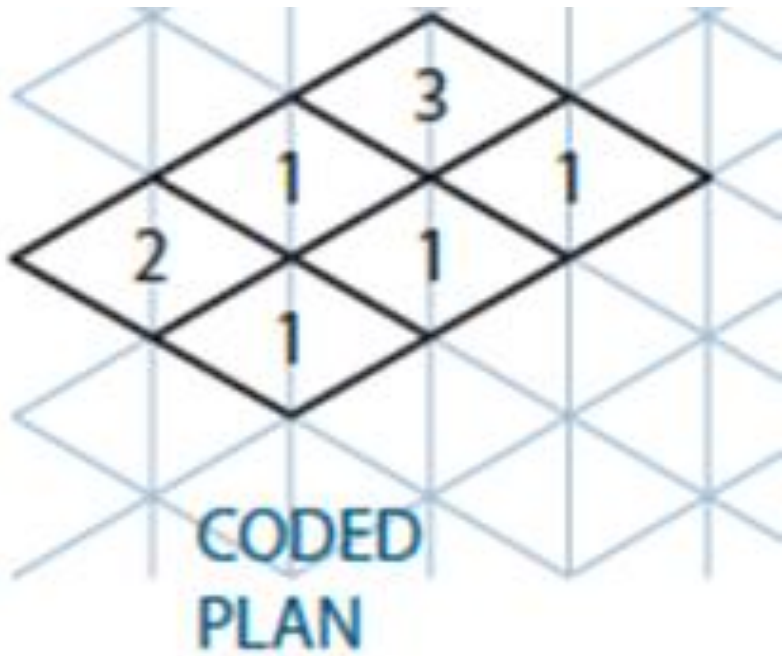
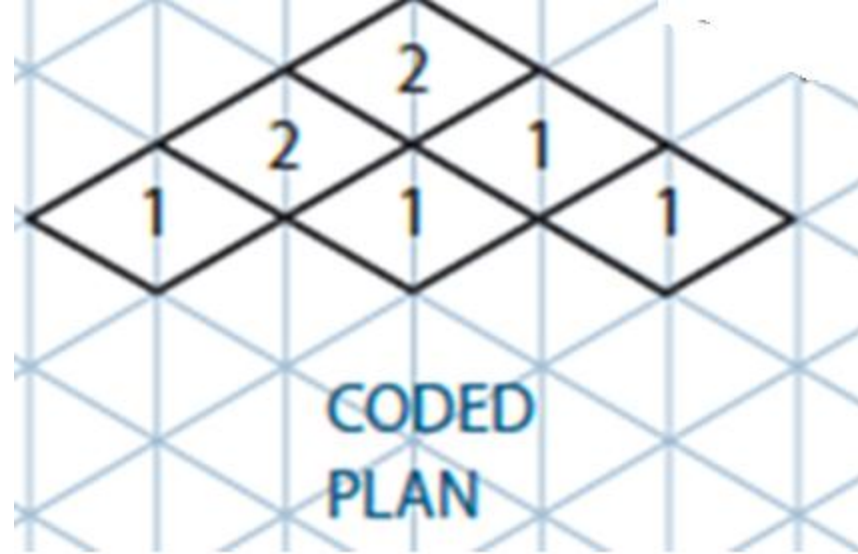
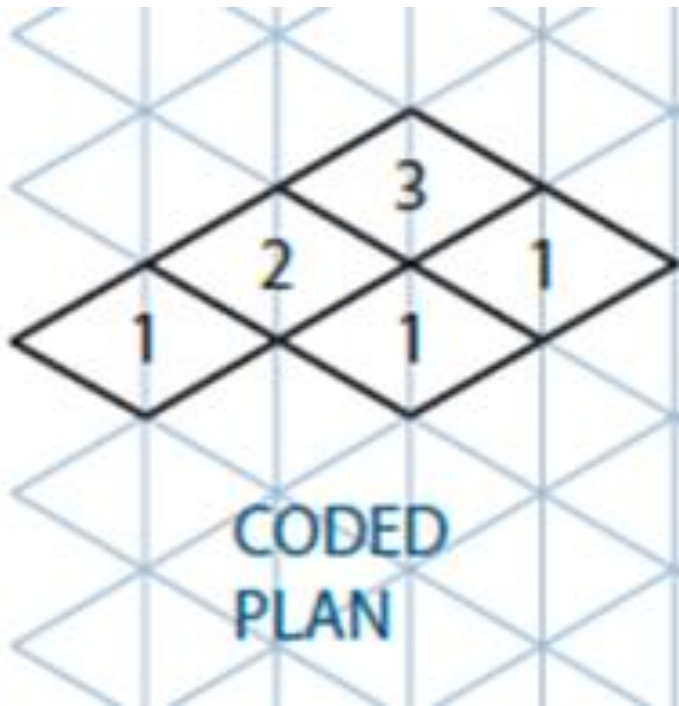


CODED PLAN

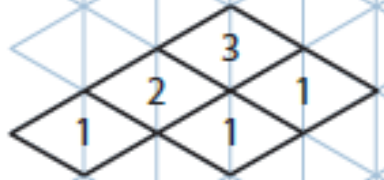


ISOMETRIC
SKETCH

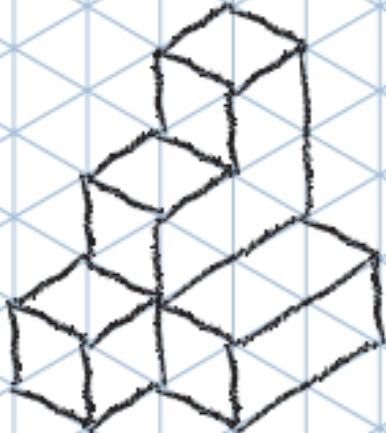
Edge where two
surfaces intersect



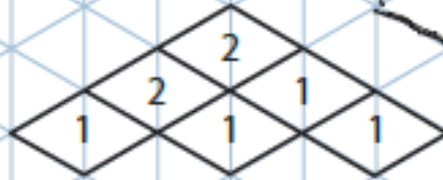
ISOMETRIC SKETCHES



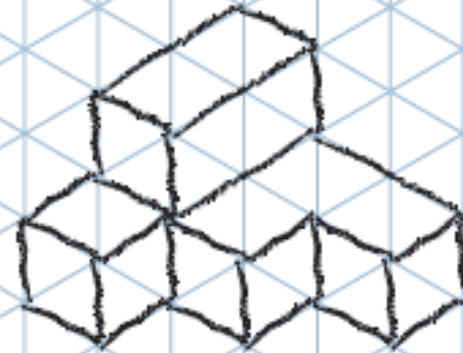
CODED
PLAN



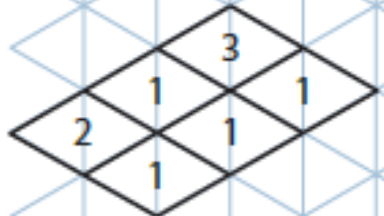
RESULTING
SKETCH



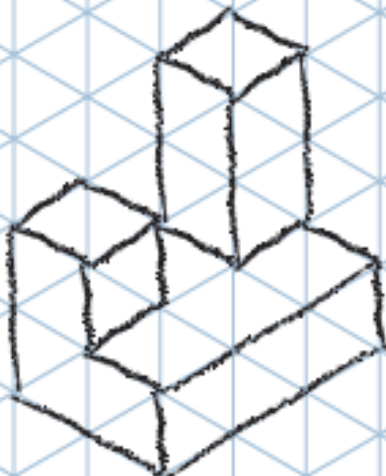
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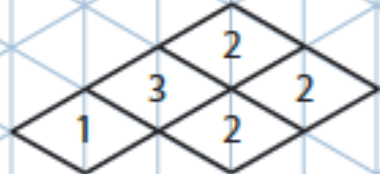
RESULTING
SKETCH



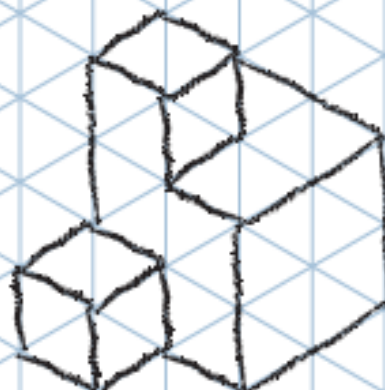
CODED
PLAN



RESULTING
SKETCH

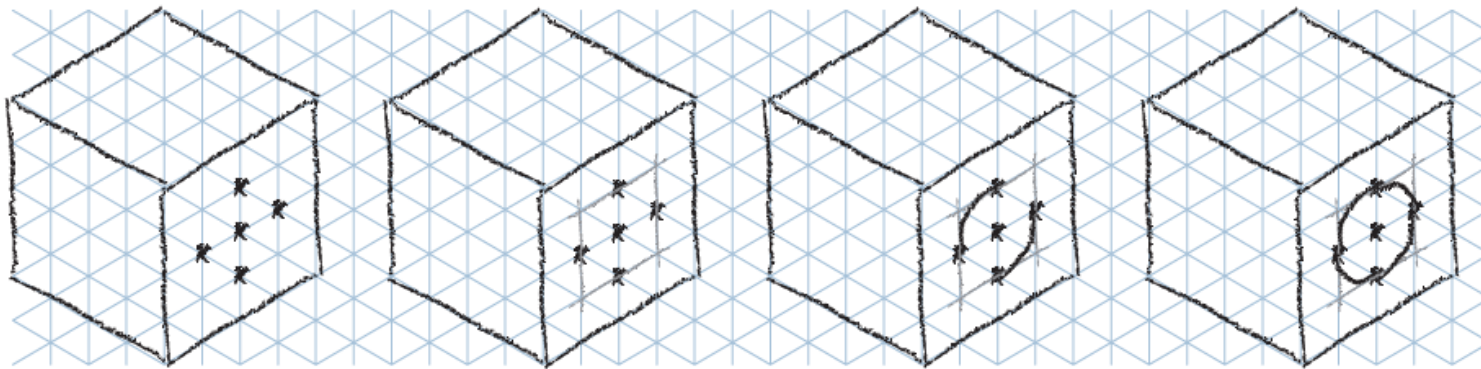
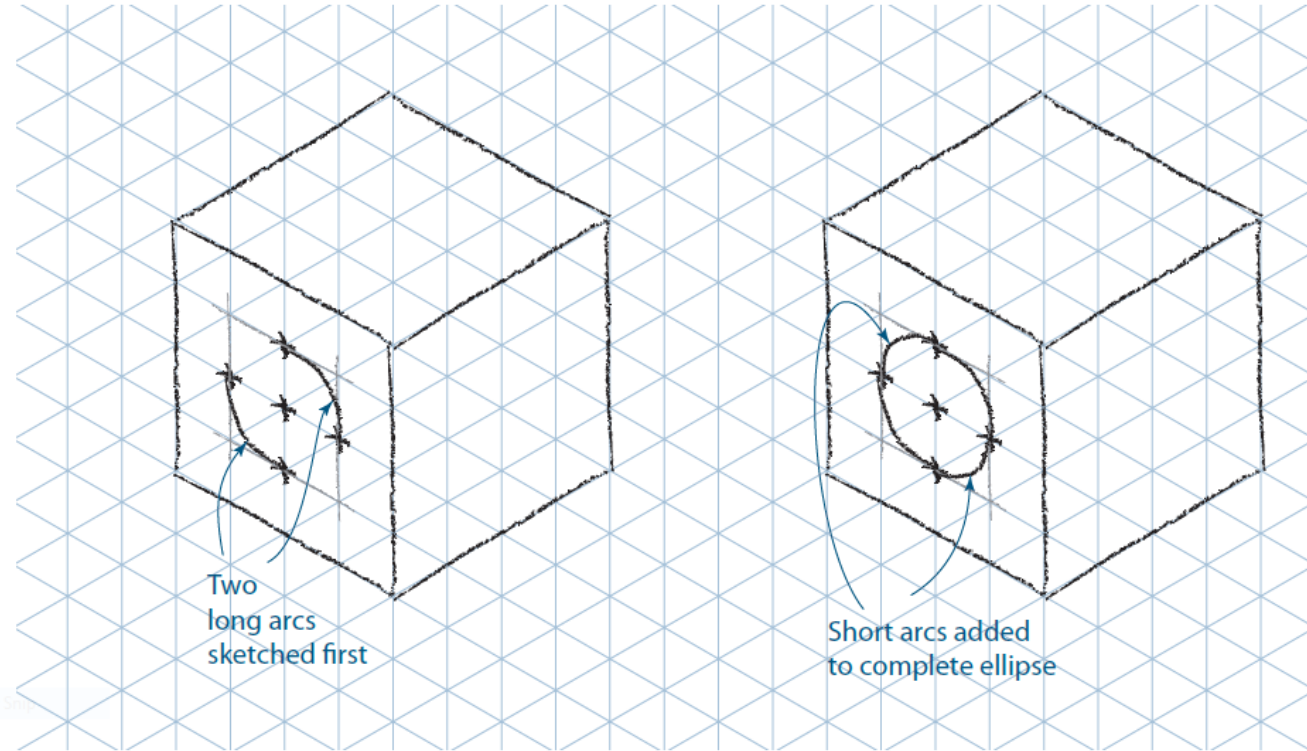
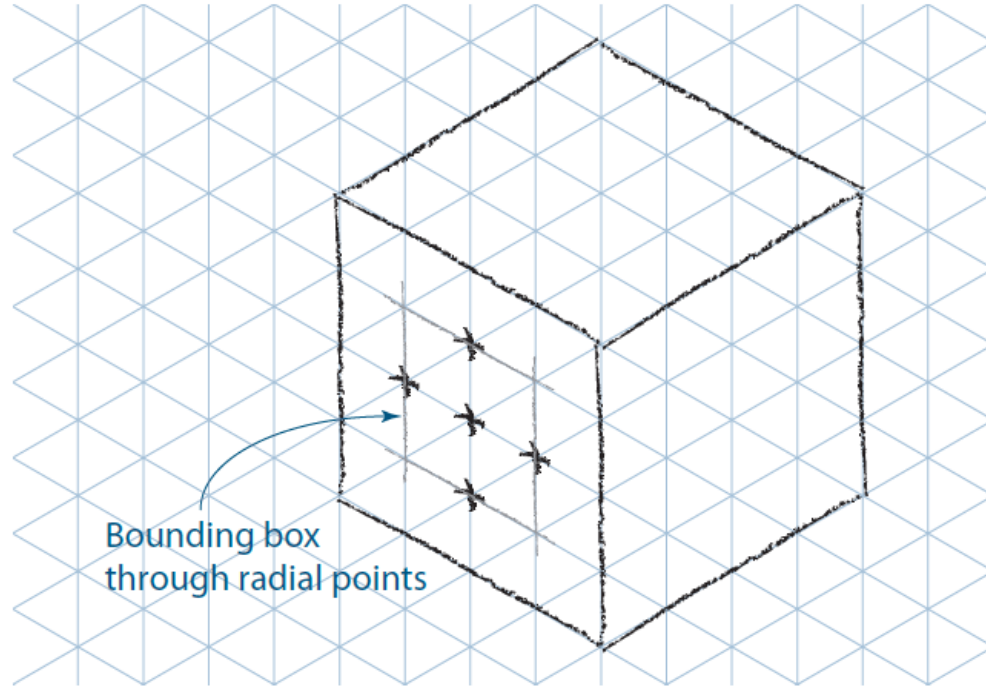


CODED
PLAN



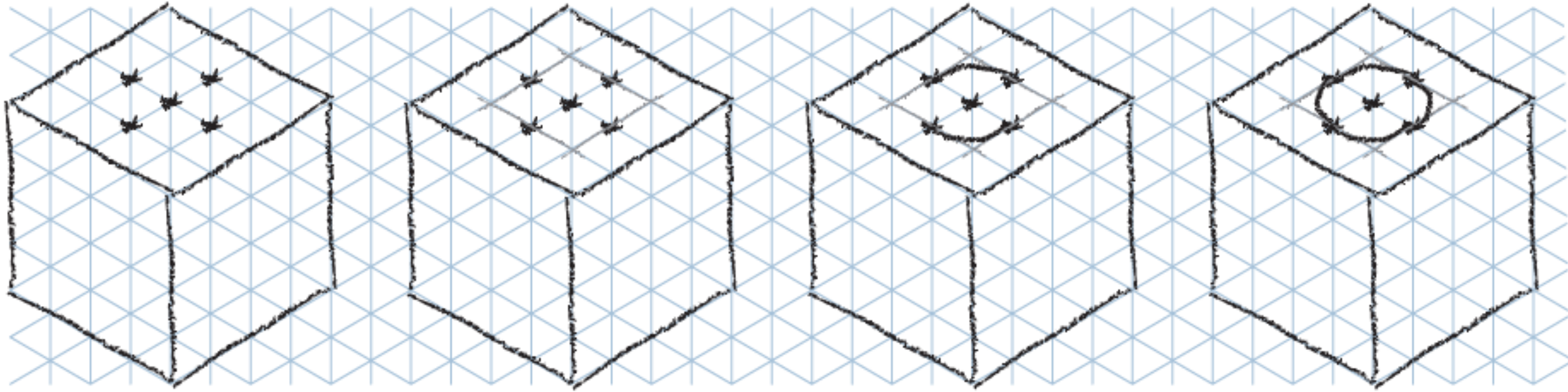
RESULTING
SKETCH

Circles and holes in isometric sketches



Sketching an ellipse on the side face of a cube

Sketching an ellipse on the top surface of a cube



Circle center
and radial
points located

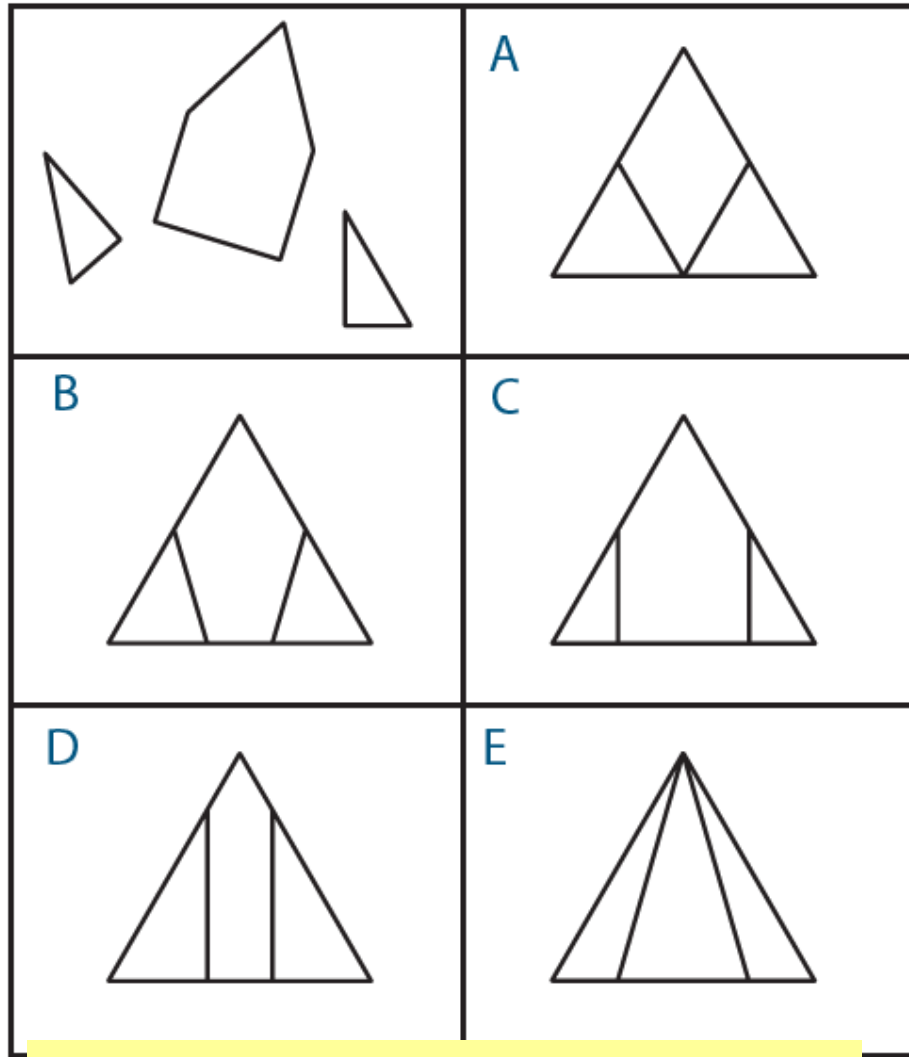
Bounding box
through radial points

Long arcs
sketched

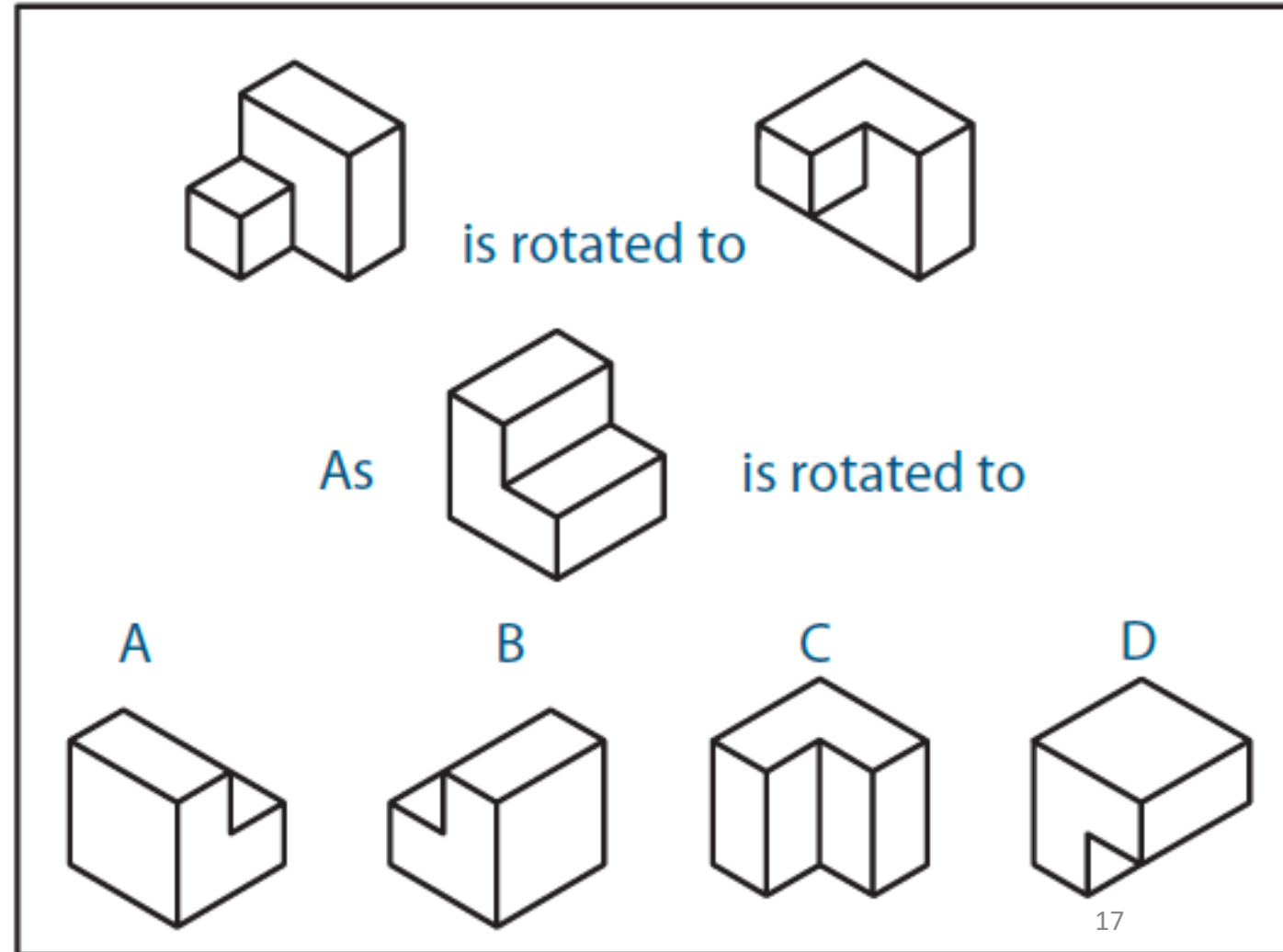
Short arcs added
to complete ellipse

VISUALISATION - Assessing spatial skills

SPATIAL ABILITY: the ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli



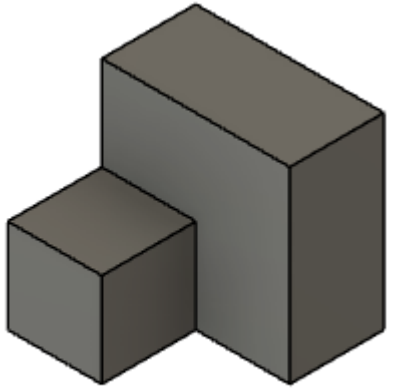
MENTAL ROTATION TEST



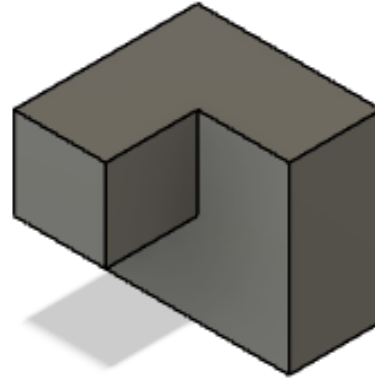
PAPER FORM BOARD TEST - C

VISUALISATION - Assessing spatial skills

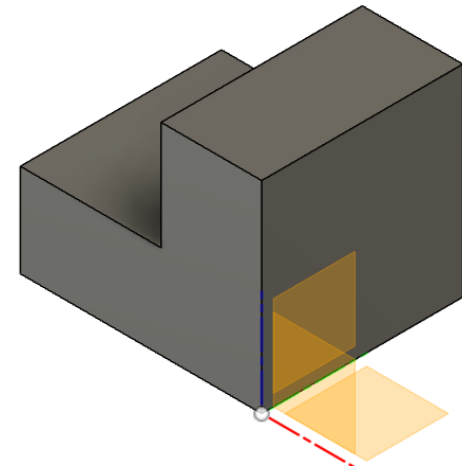
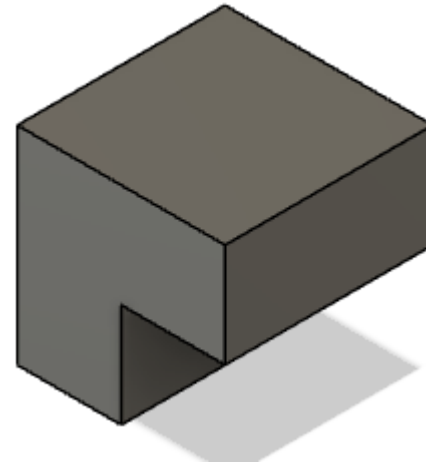
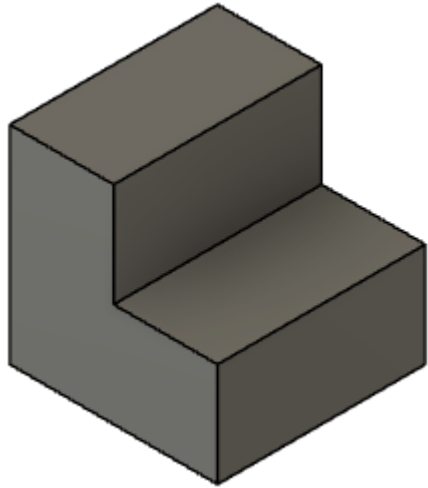
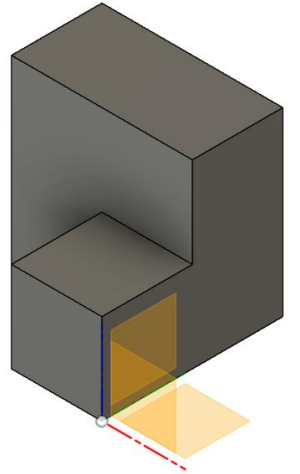
SPATIAL ABILITY: the ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli



90° rotation
about Y-axis



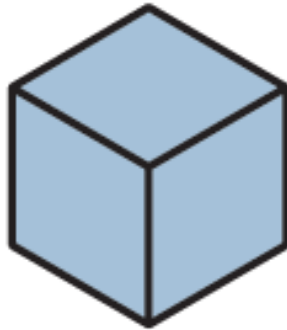
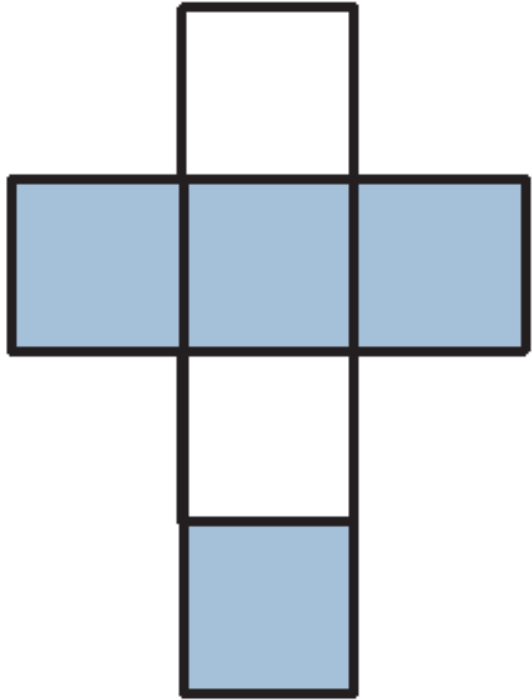
-90° rotation
about Y-axis



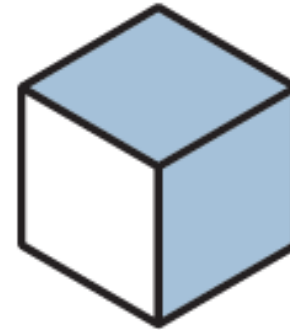
Differential Aptitude Test: Space Relations – DEVELOPMENT OF SURFACES

This test is designed to measure your ability to move from the 2-D to the 3-D world.

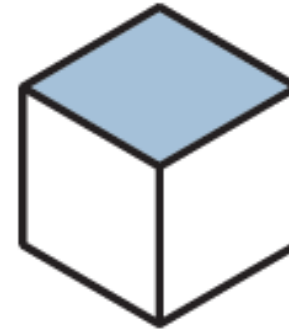
The objective is to mentally fold the 2-D pattern along the solid lines, which designate the fold lines, so the object will result in the 3-D shape



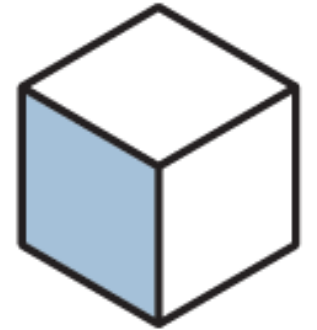
A



B



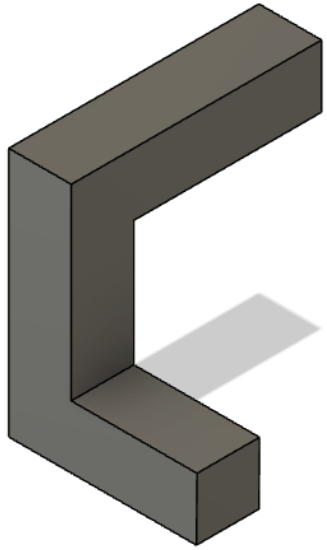
C



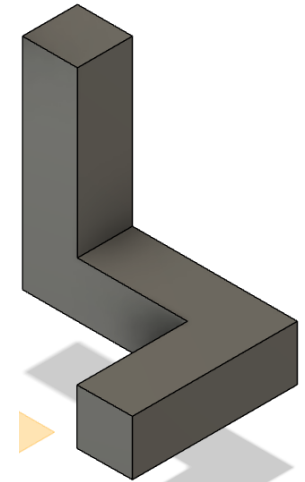
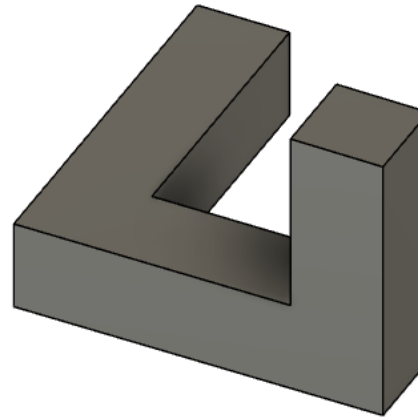
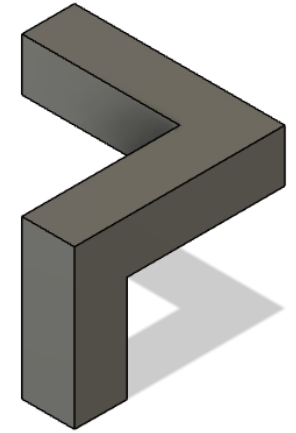
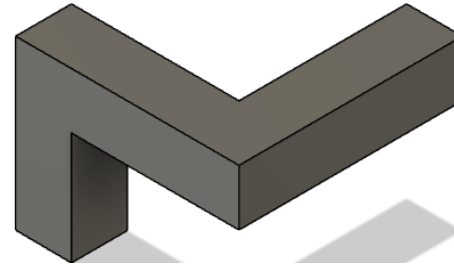
D

VISUALISATION - Assessing spatial skills

MENTAL ROTATION TEST

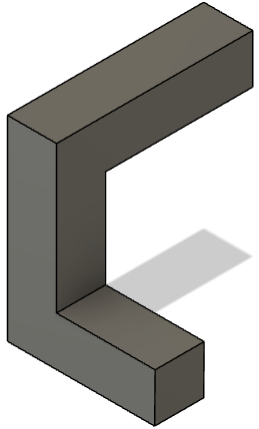


Identify the
rotation of the left
body to obtain the
right-side
configurations

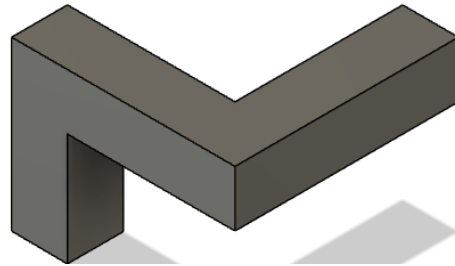


VISUALISATION - Assessing spatial skills

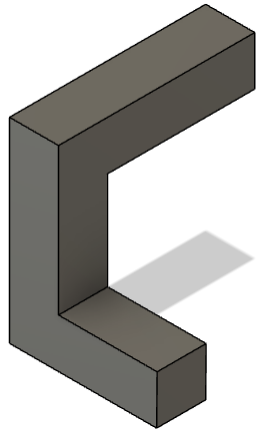
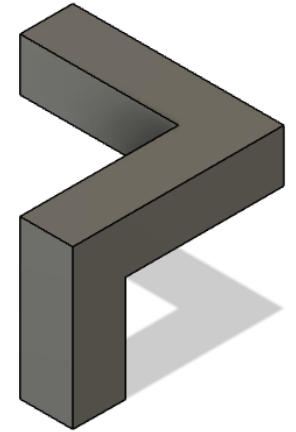
MENTAL ROTATION TEST



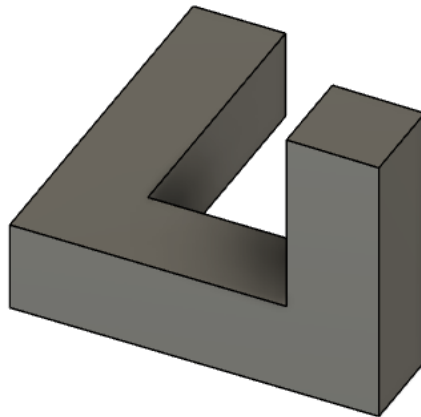
**90° rotation
about Y-axis**



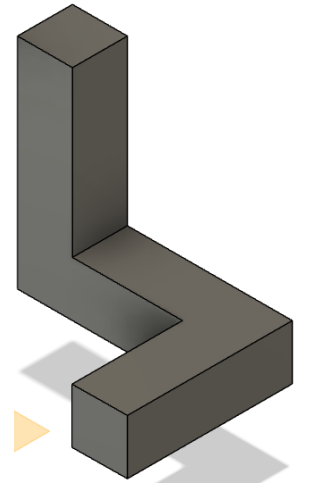
**90° rotation
about Z-axis**



**-90° rotation
about Y-axis**



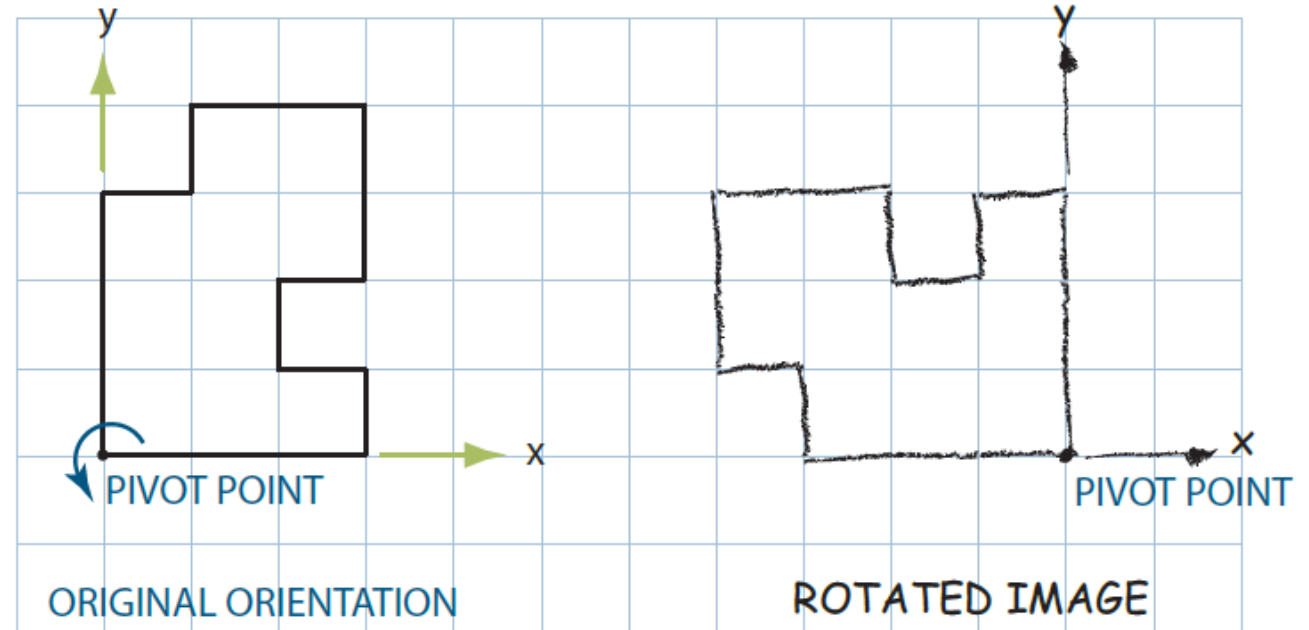
**90° rotation
about X-axis**



OBJECT ROTATIONS ABOUT A SINGLE AXIS

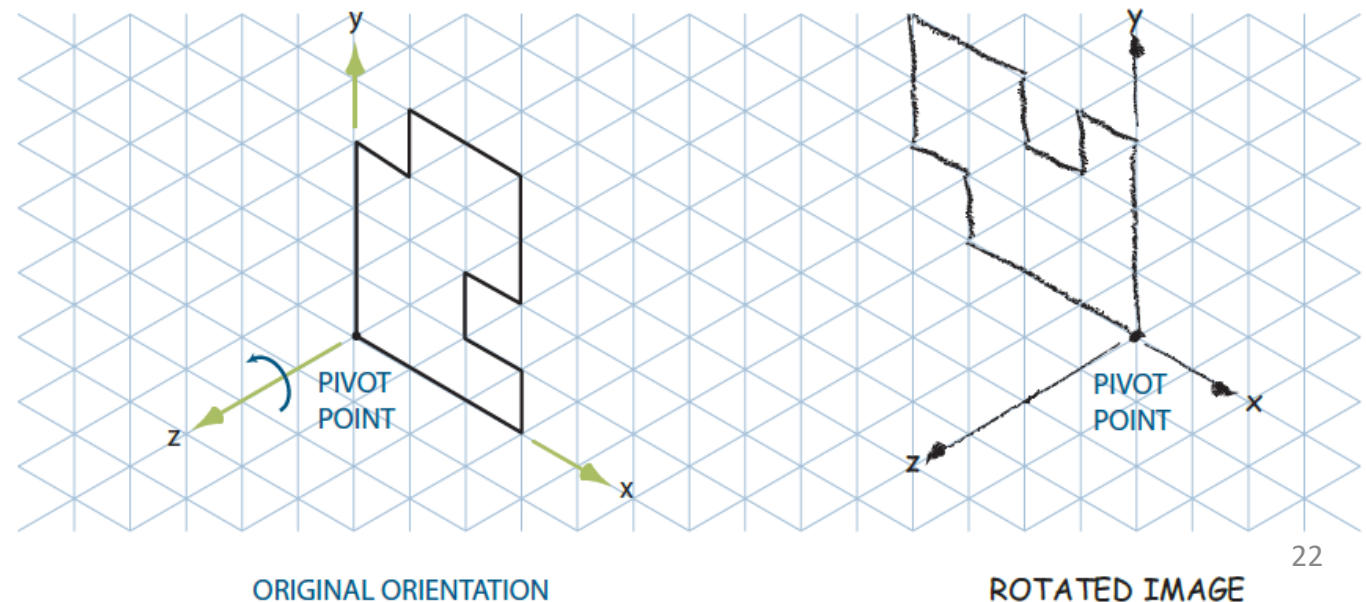
A shape rotated about a pivot point in 2-D space

A 2-D object rotated 90 degrees counterclockwise (CCW) about the pivot point



A 2-D shape rotated in 3-D space

A 2-D object rotated 90 degrees counterclockwise (CCW) about the z-axis



OBJECT ROTATIONS ABOUT A SINGLE AXIS

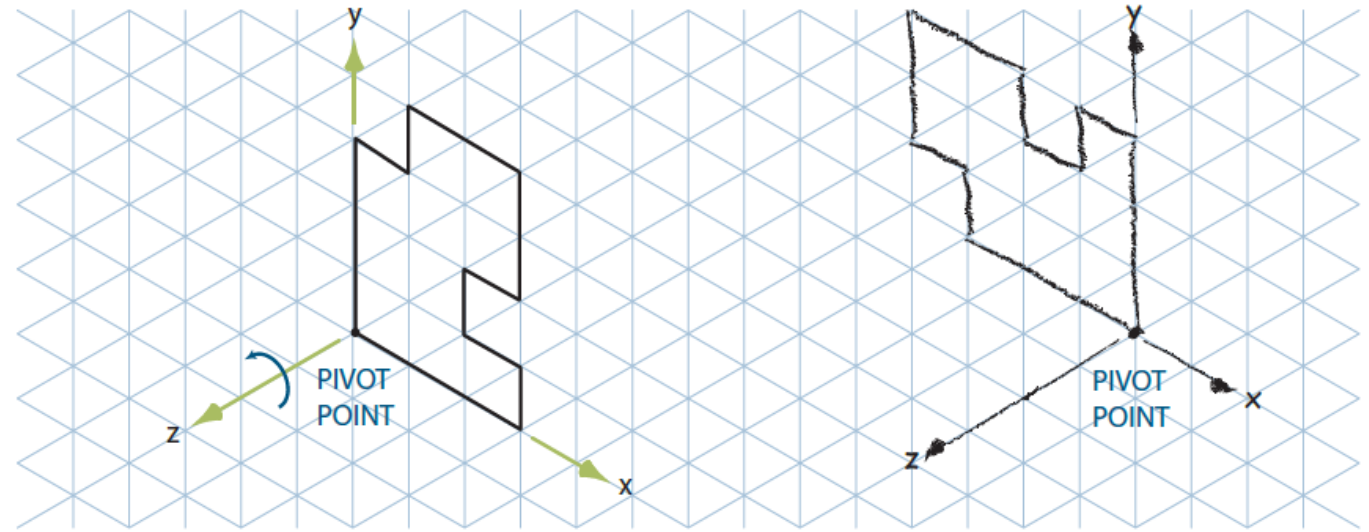
A 2-D shape rotated in 3-D space

A 2-D object rotated 90 degrees counterclockwise (CCW) about the z-axis

If you point the thumb of your right hand in the positive direction of the z-axis and curl your fingers, you will see that the 90-degree CCW rotation mimics the direction that your fingers curl as in Figure.

This **CCW rotation** of the 2-D shape represents a **positive 90-degree** rotation about the **z-axis**.

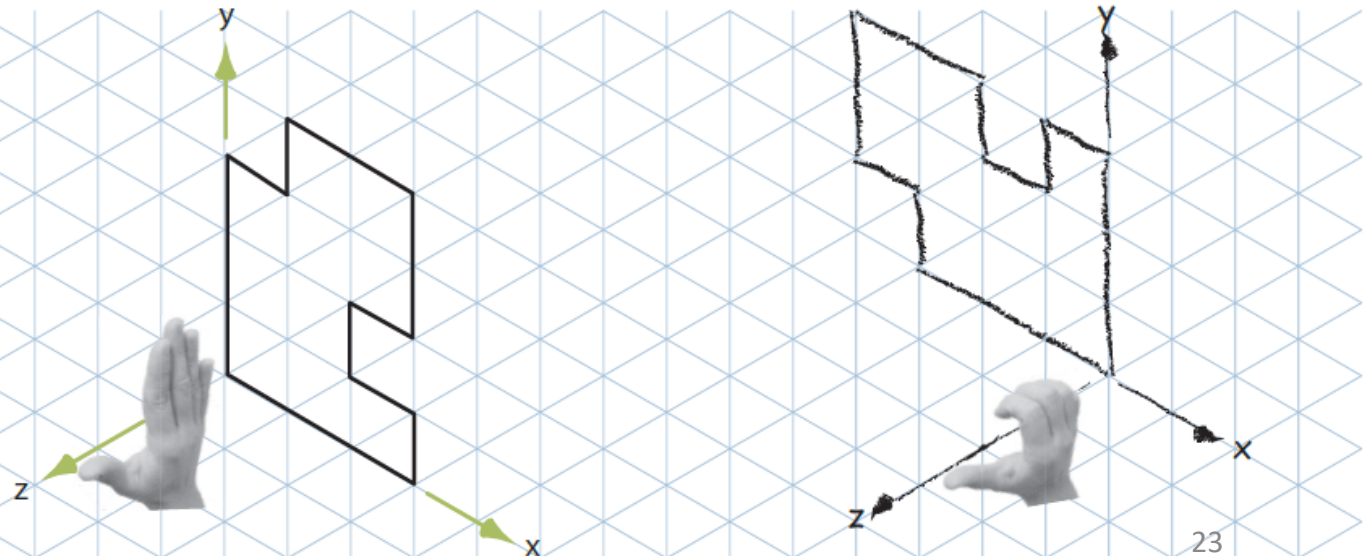
The CCW rotation is positive because the **thumb** of your **right hand** was **pointing** in the **positive direction** of the z-axis as the shape was rotated.



ORIGINAL ORIENTATION

ROTATED IMAGE

Positive rotation of a 2-D shape about the z-axis

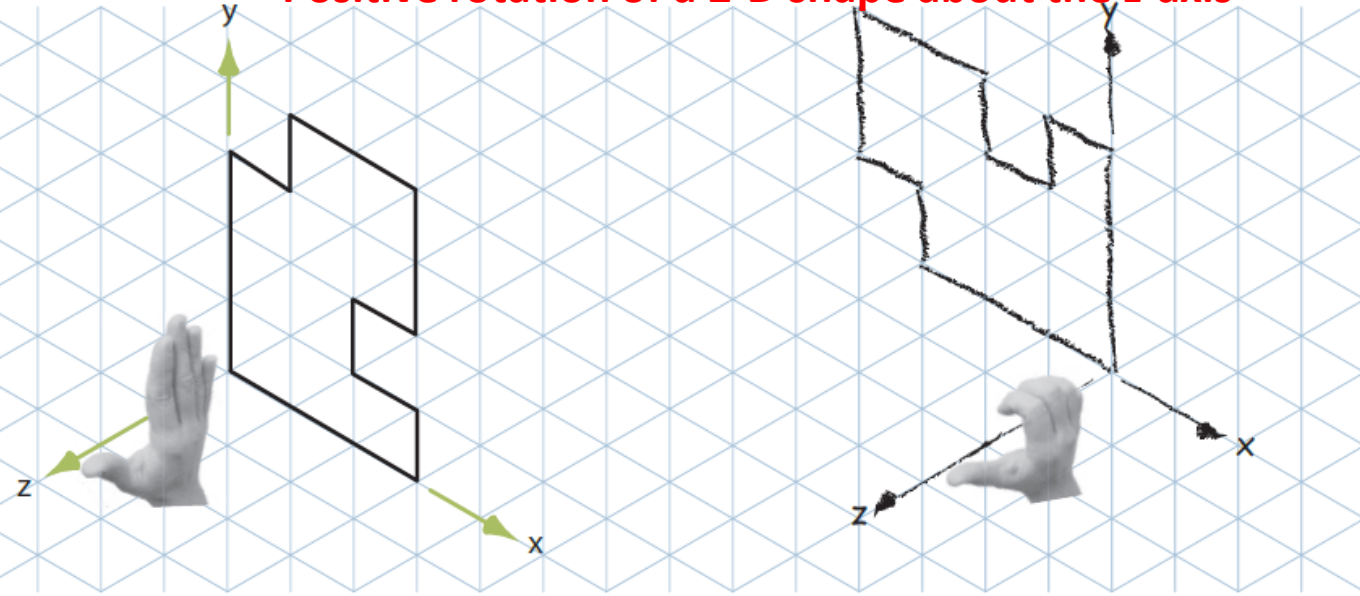


OBJECT ROTATIONS ABOUT A SINGLE AXIS

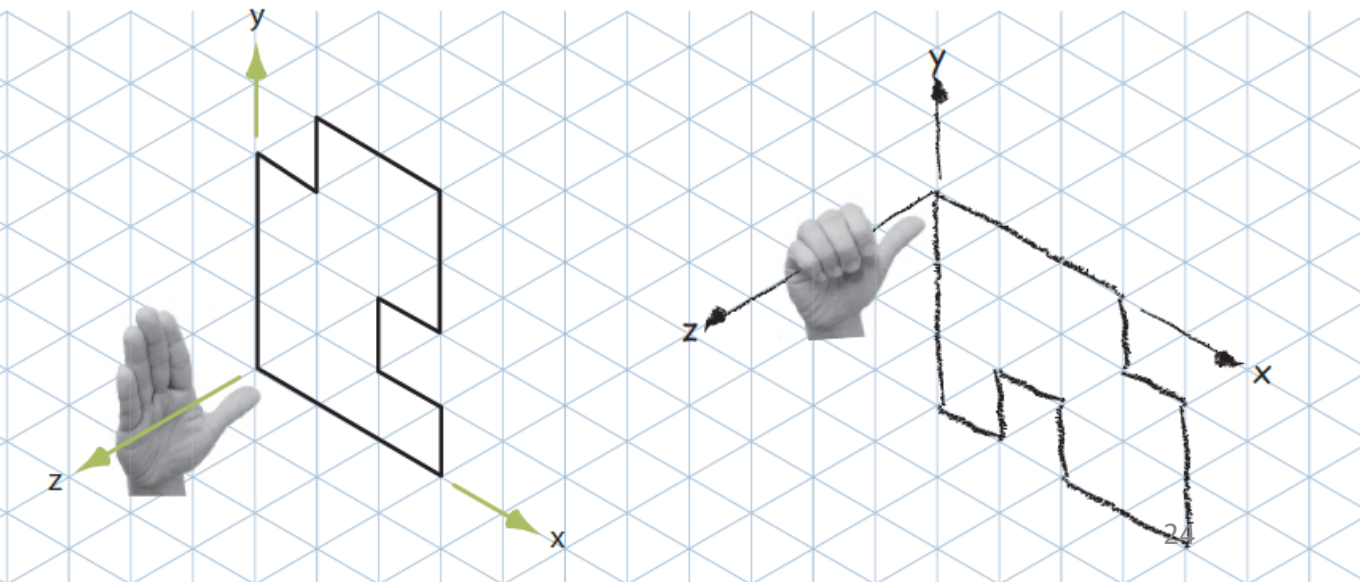
A 2-D object rotated 90 degrees counterclockwise (CCW) about the z-axis

If you point the thumb of your right hand in the negative direction of the z-axis and the shape is rotated in the direction the fingers of your right hand curl, your fingers indicate a **clockwise (CW)** rotation of the shape about the z-axis, as in Figure. A **CW rotation** about an axis is defined as a **negative rotation**. Remember that the thumb of your right hand is pointing in the **negative z-direction**.

Positive rotation of a 2-D shape about the z-axis



Negative rotation of a 2-D shape about the z-axis



OBJECT ROTATIONS ABOUT A SINGLE AXIS

A 2-D shape rotated in 3-D space

Counter
Clockwise(CCW)
X-axis

Clockwise(CW)
X-axis

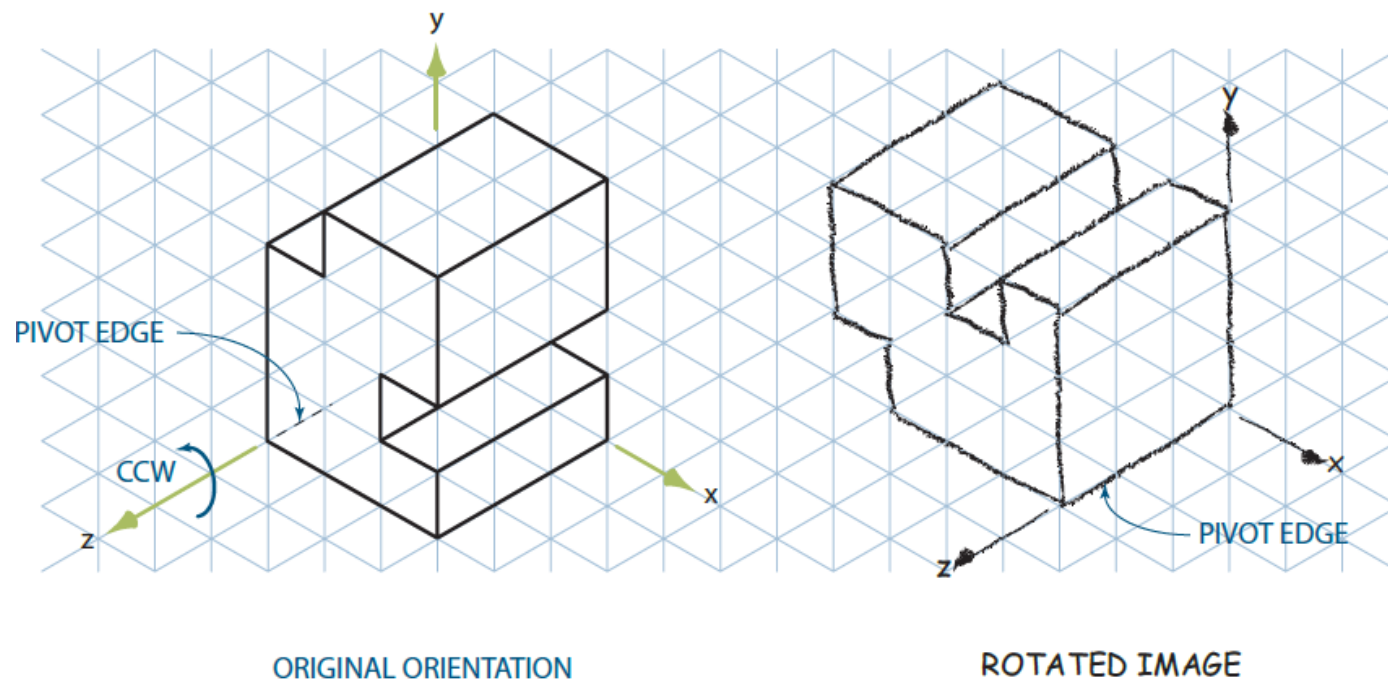
Counter
Clockwise(CCW)
Y-axis

Clockwise(CW)
Y-axis

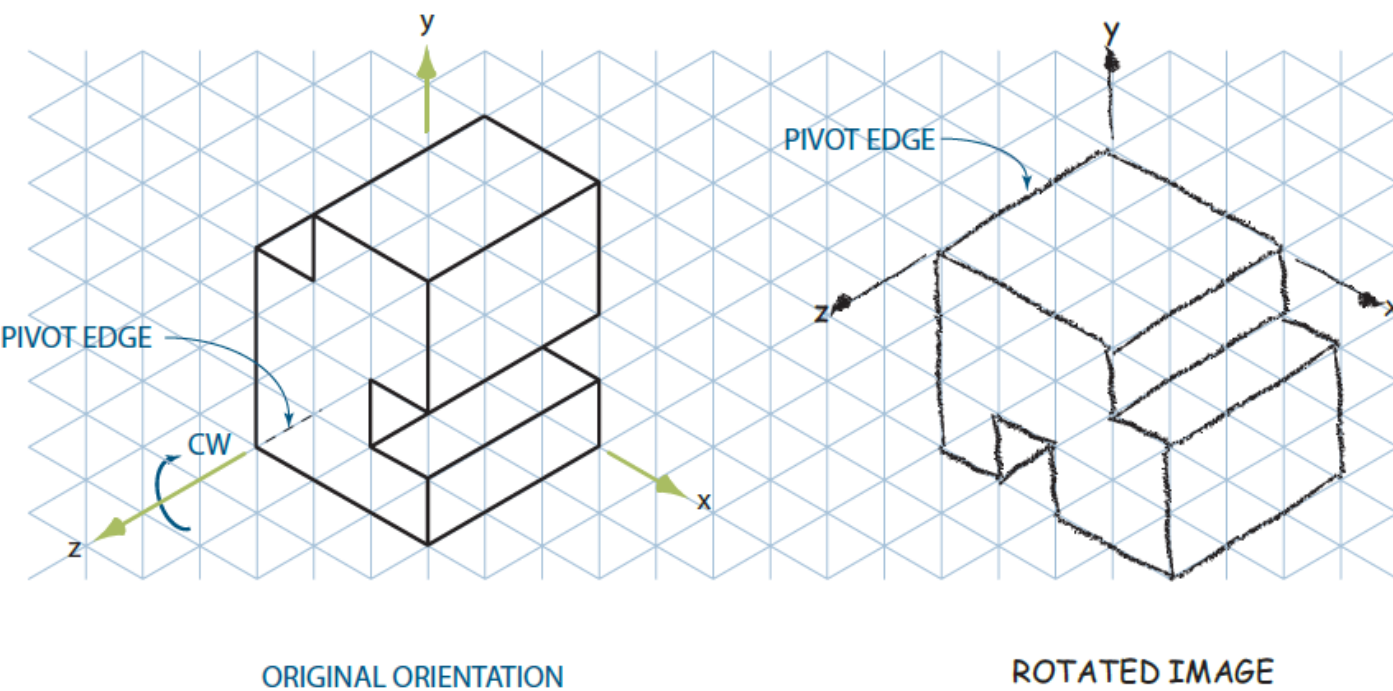
Counter
Clockwise
(CCW)
Z-axis

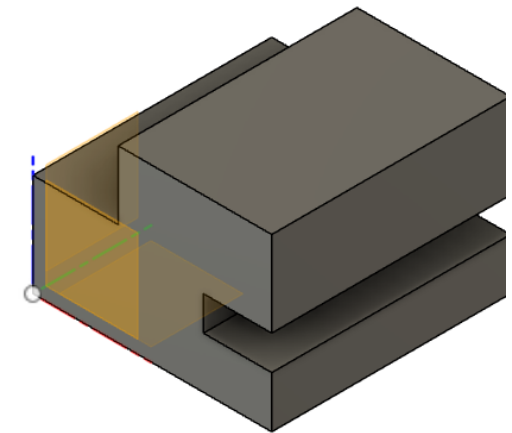
Clockwise(CW)
Z-axis

A 3-D object rotated 90 degrees counterclockwise about the z-axis

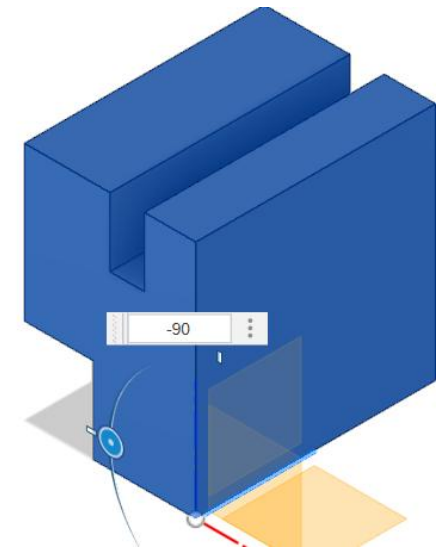


A 3-D object rotated 90 degrees clockwise about the z-axis.

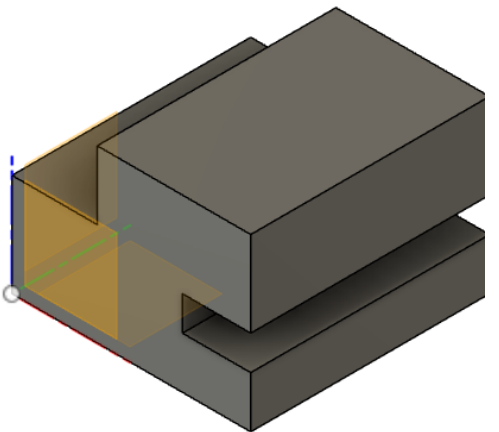
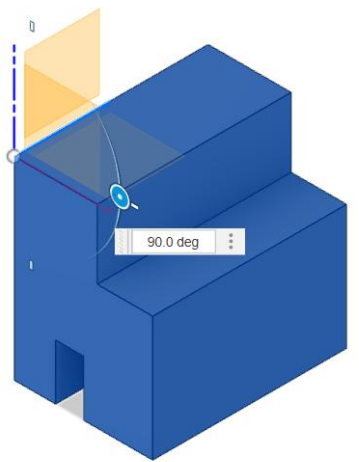




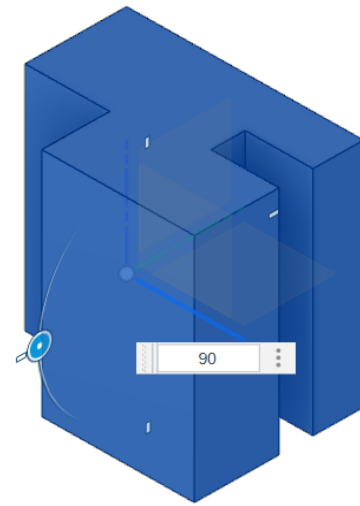
(-90°): CW: Y-axis



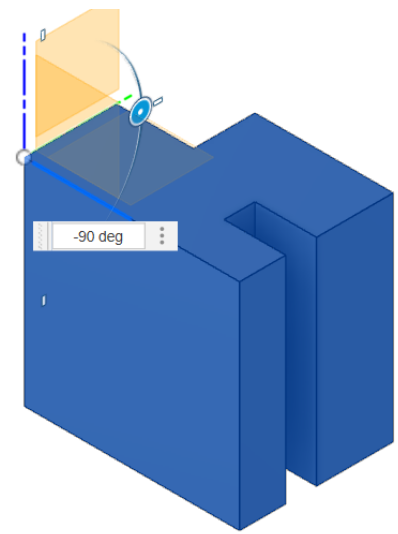
(90°): CCW: Y-axis



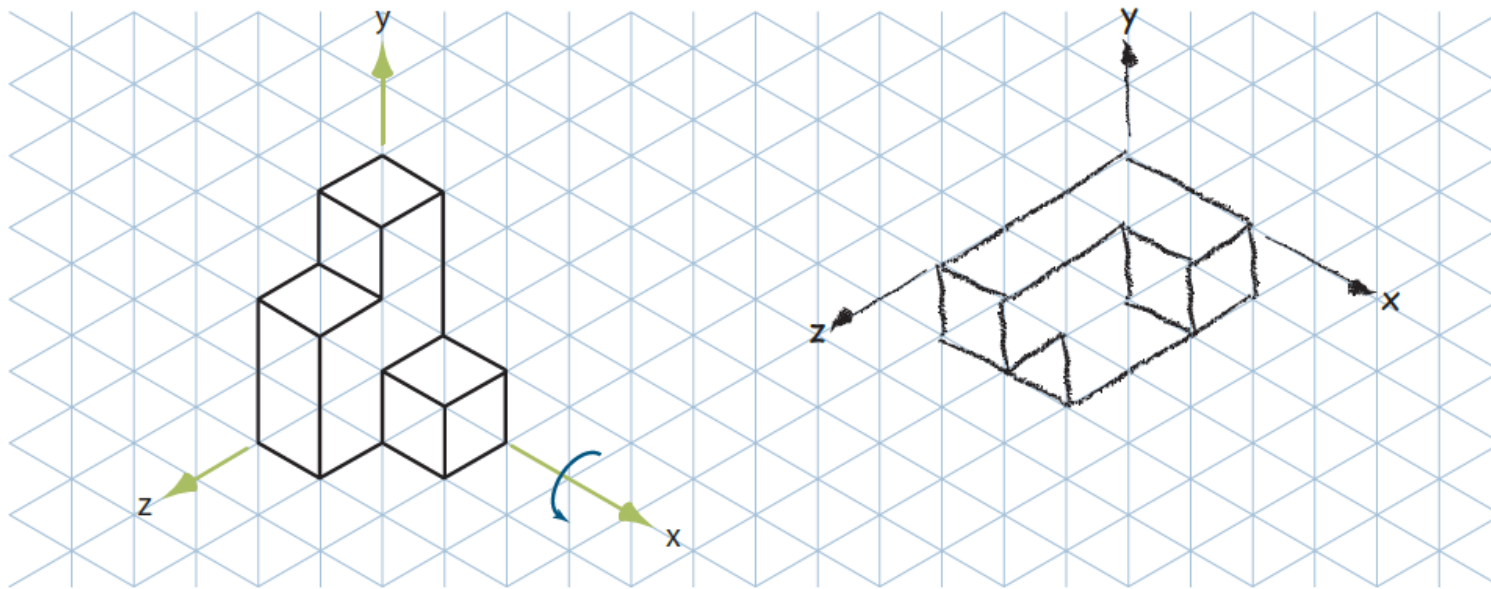
(90°): CCW: X-axis



(-90°): CW: X-axis



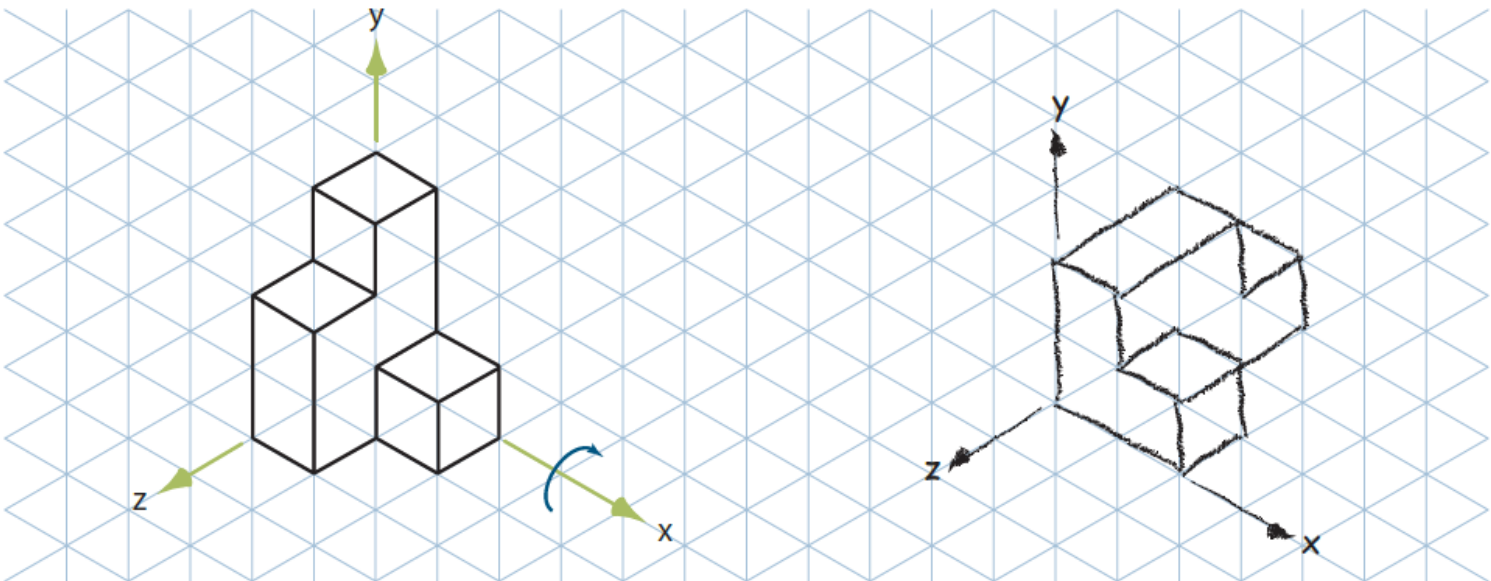
Positive rotation about the x-axis



POSITIVE x-ROTATION

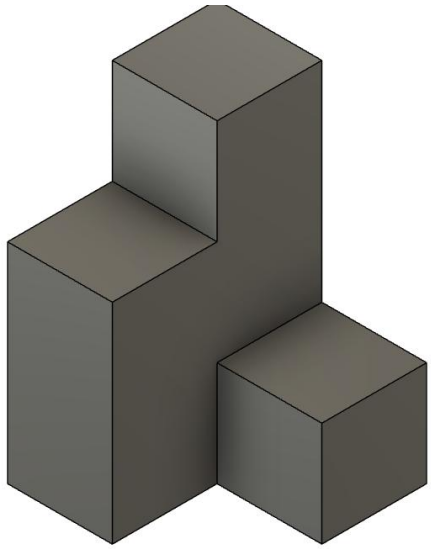
ROTATED IMAGE

Negative rotation about the x-axis

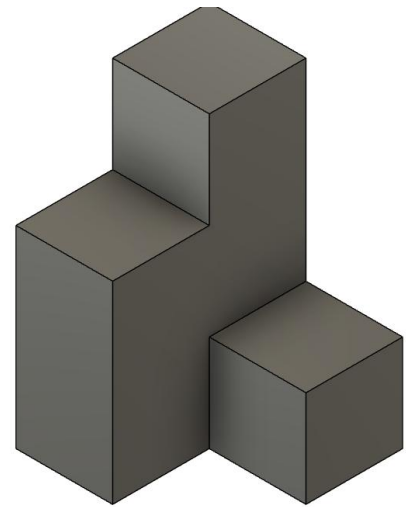
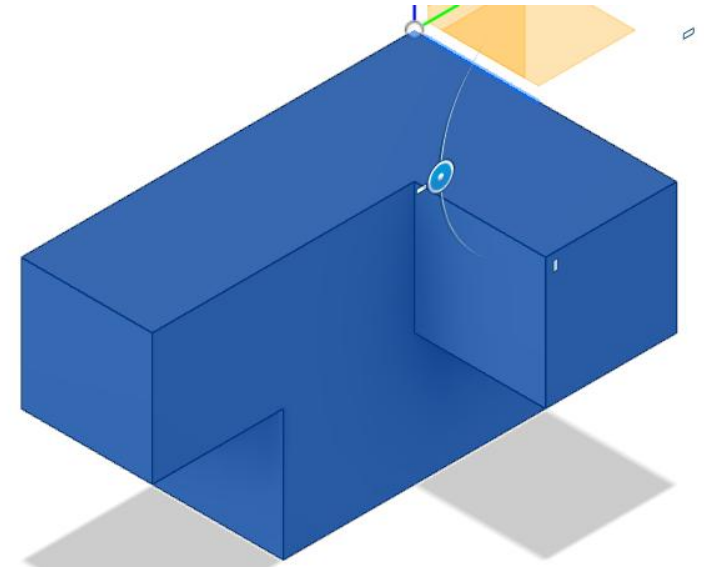


NEGATIVE x-ROTATION

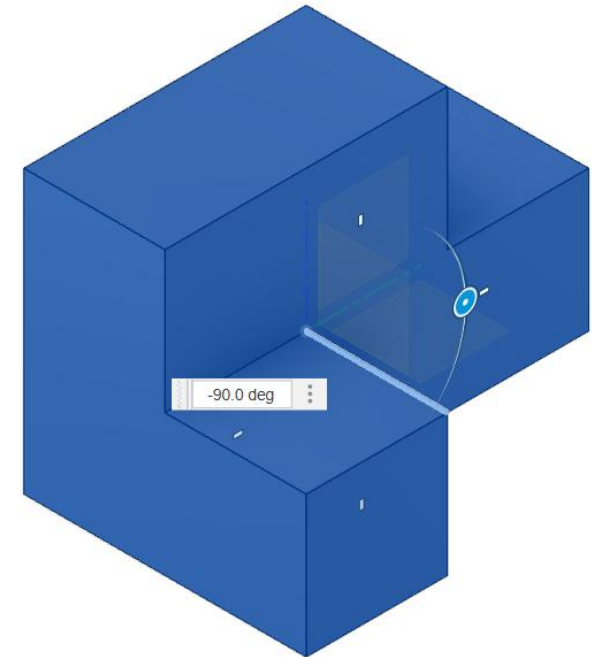
ROTATED IMAGE



+ve rotation: x-axis

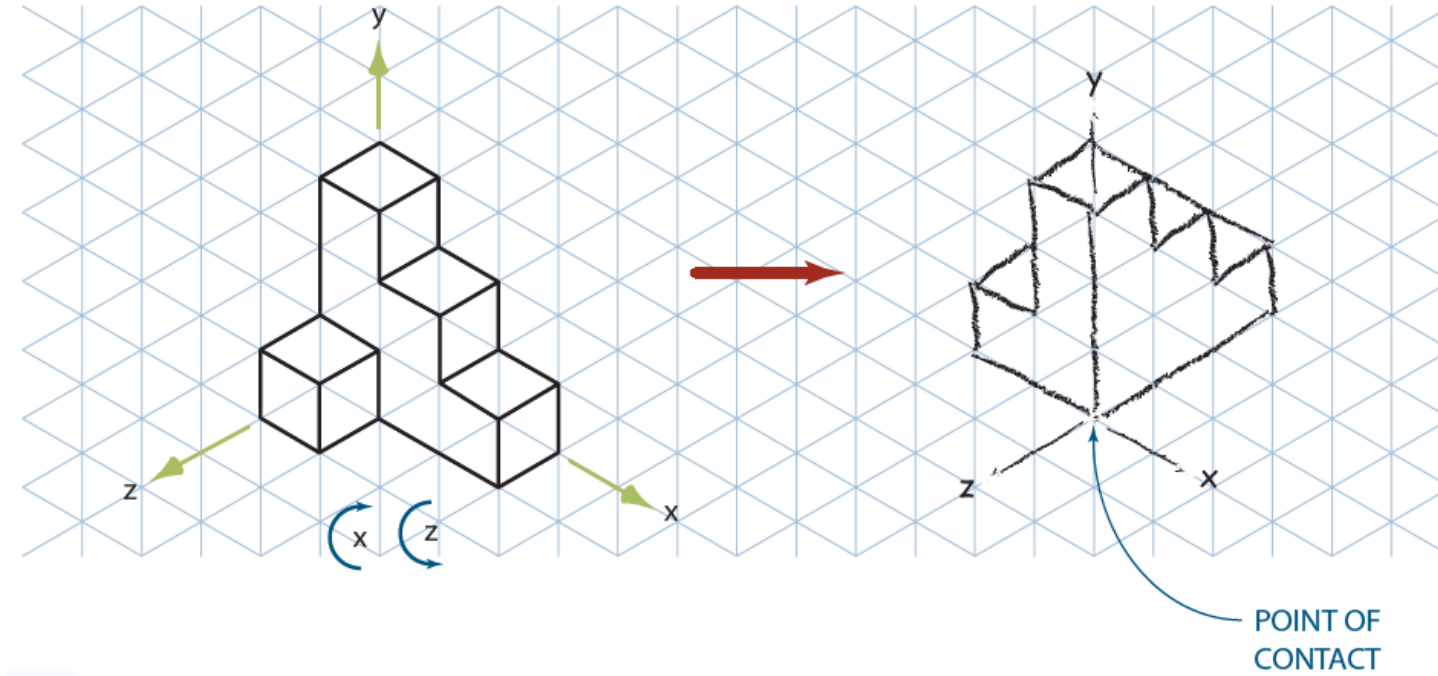


-ve rotation: x-axis

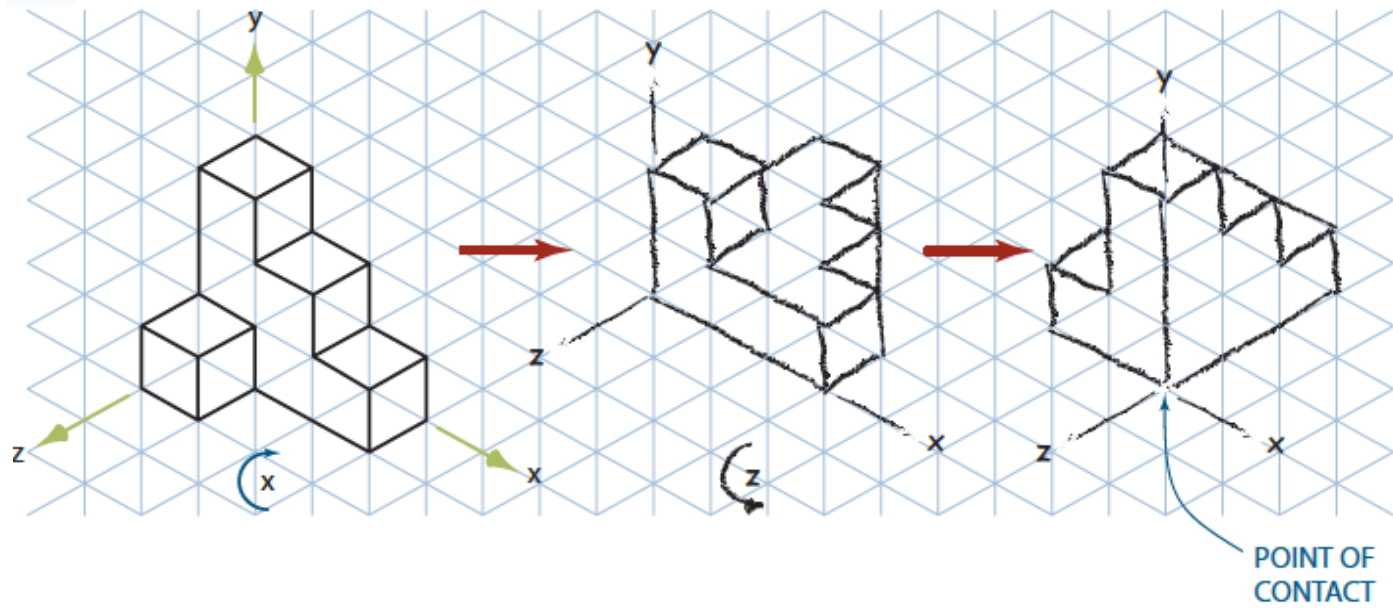


ROTATION ABOUT TWO OR MORE AXES

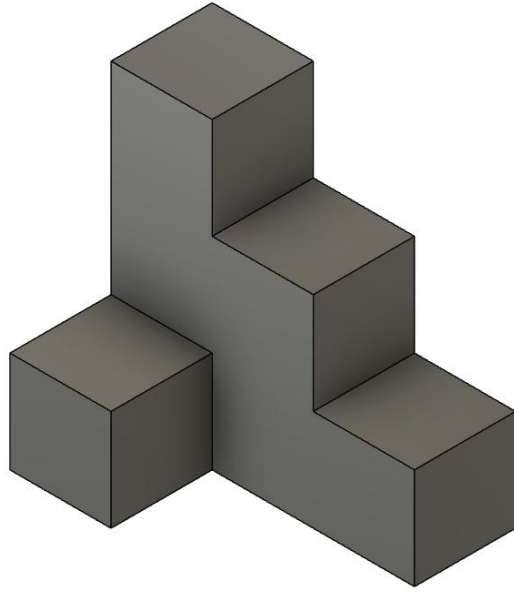
An object rotated about two axes



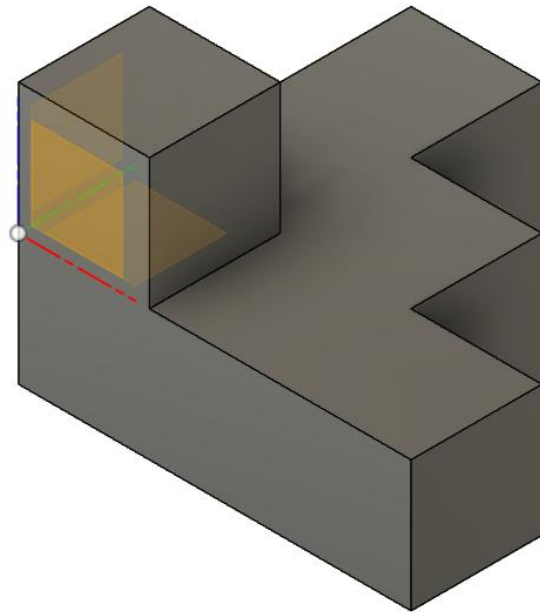
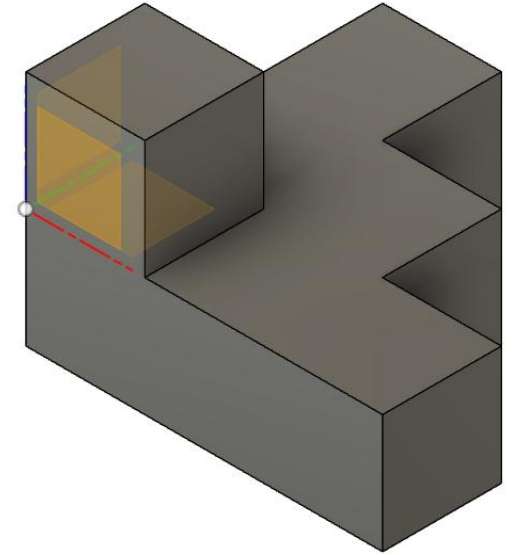
An object rotated in two steps



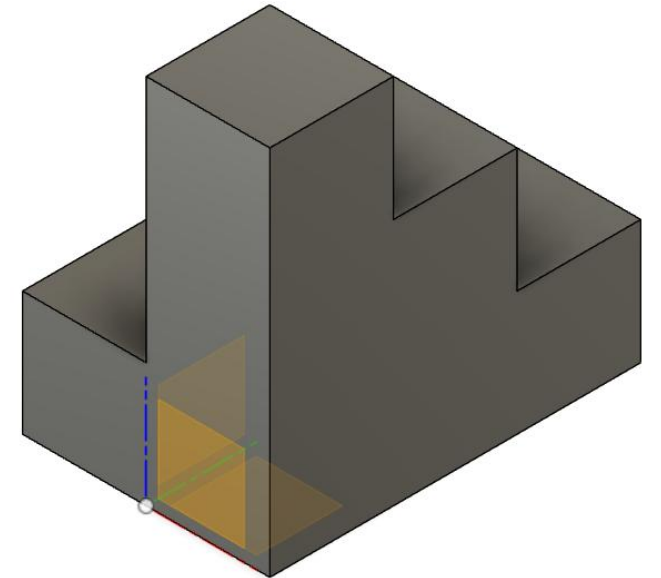
ROTATION ABOUT TWO OR MORE AXES



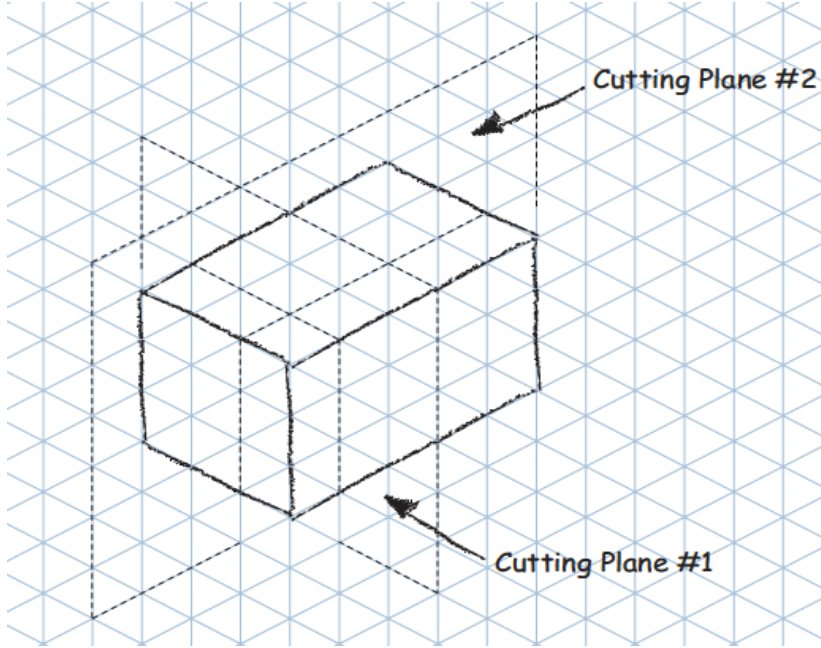
CW rotation: X-axis
-ve rotation: X-axis



CW rotation: Y-axis
-ve rotation: Y-axis



CROSS SECTIONS OF SOLIDS



Cross Section #1



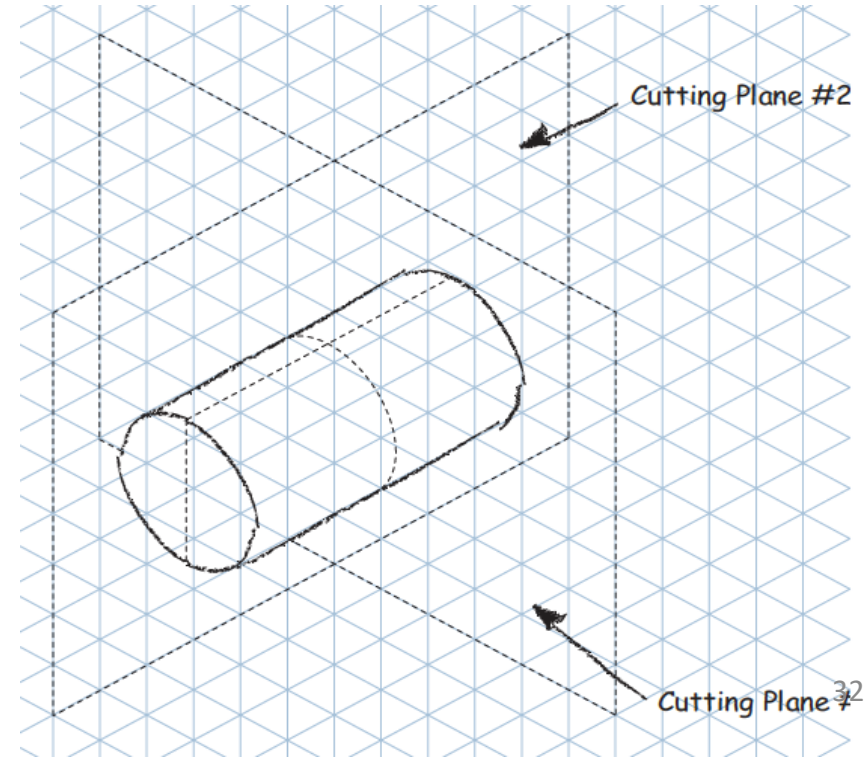
Cross Section #2



Cross Section #1

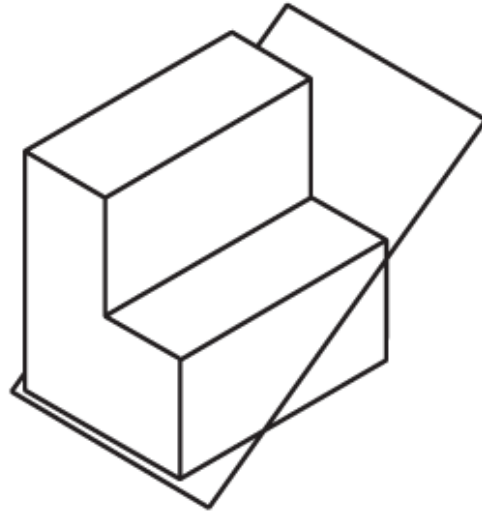


Cross Section #2



VISUALISATION - Assessing spatial skills

MENTAL CUTTING TEST



A



B



C

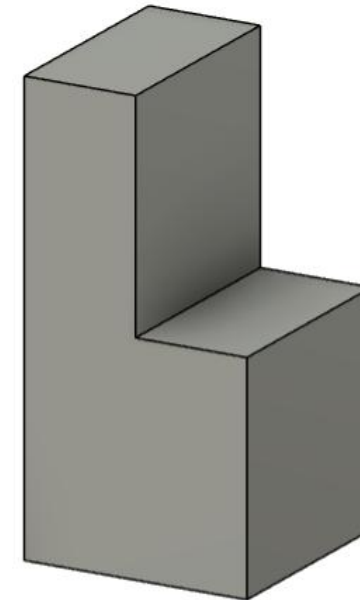
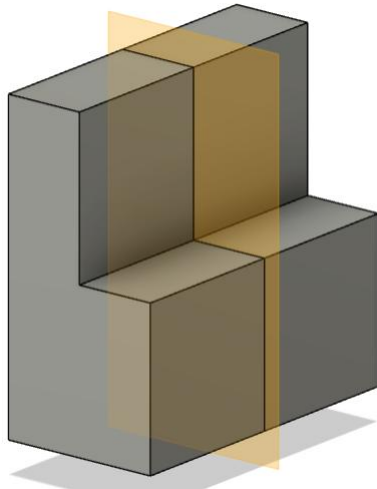
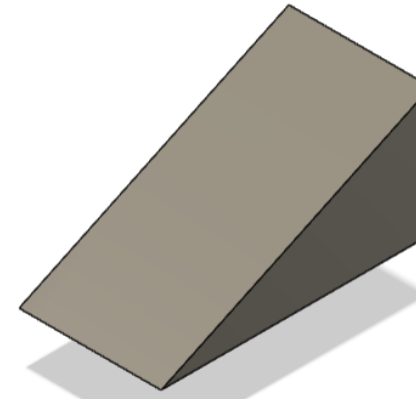
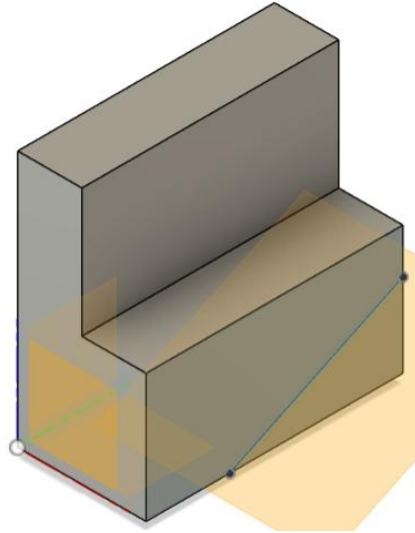


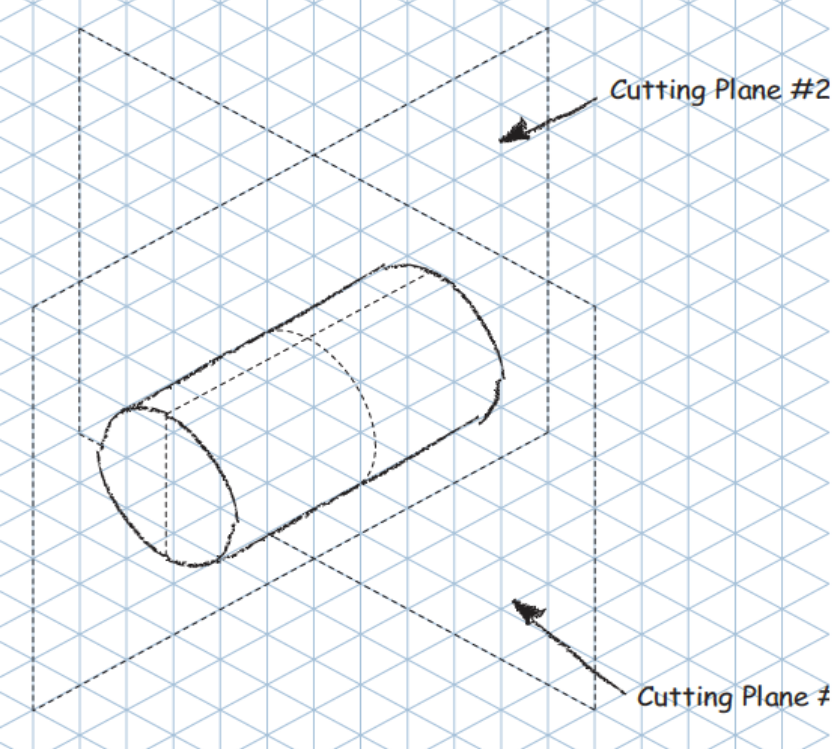
D



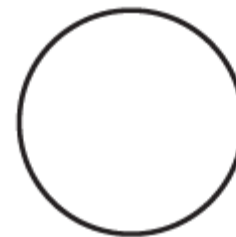
VISUALISATION - Assessing spatial skills

MENTAL CUTTING TEST

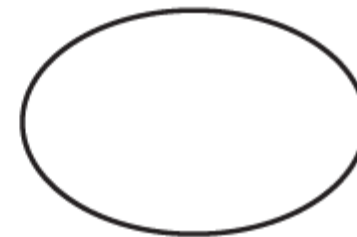




2



1

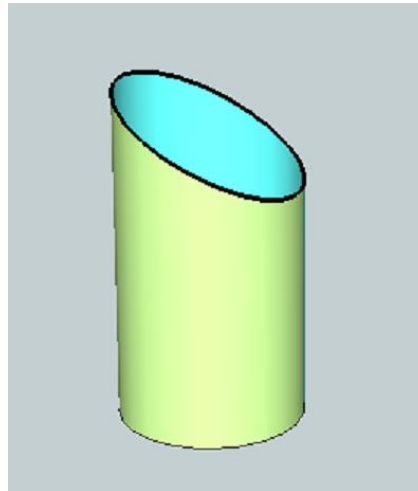


3

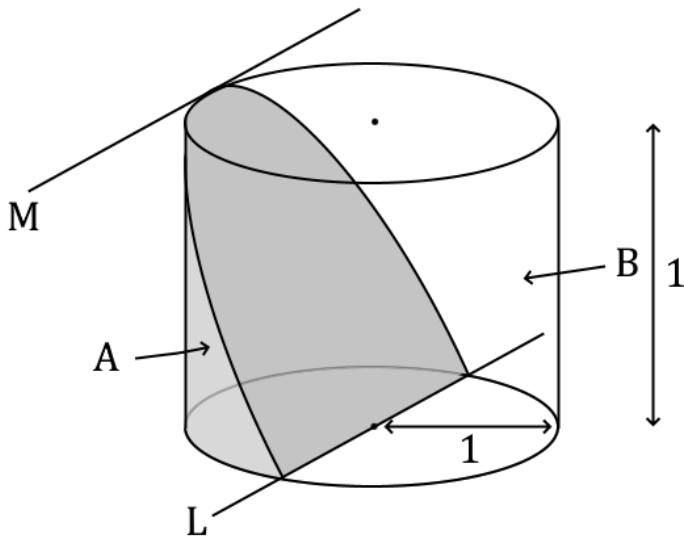


4

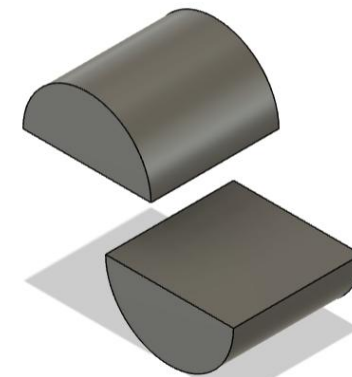
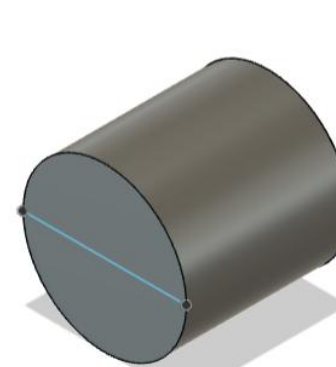
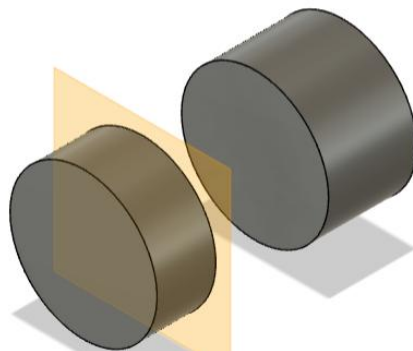
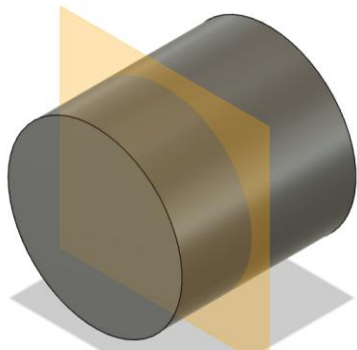
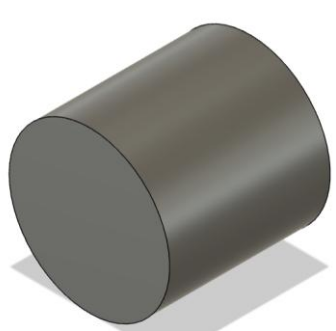
SEVERAL CROSS SECTIONS OF A CYLINDER



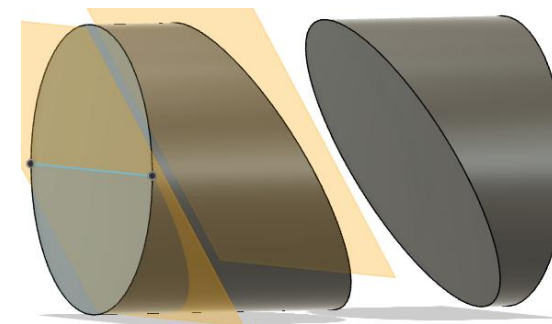
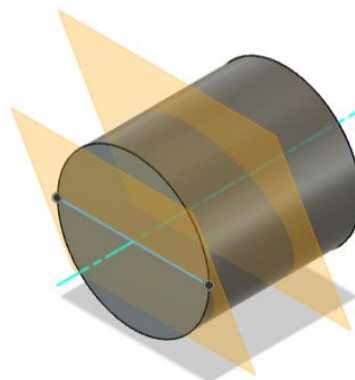
Third cross section - obtained by orienting the cutting plane at an angle with respect to the axis of the cylinder



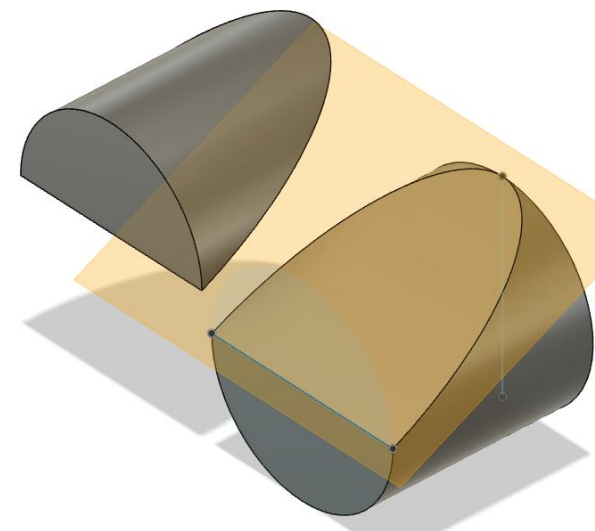
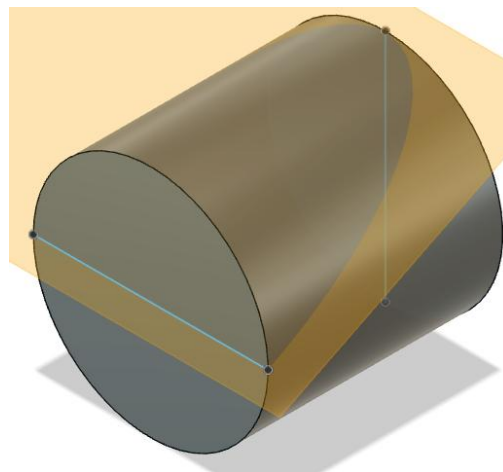
Fourth cross section - obtained by angling the cutting plane with respect to the cylinder axis, but the angle was such that a portion of the cutting plane went through the flat circular end surface of the cylinder



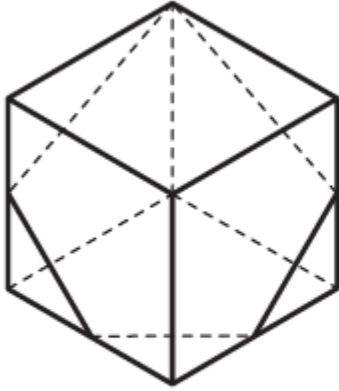
Construct plane angle to diameter
Construct offset plane



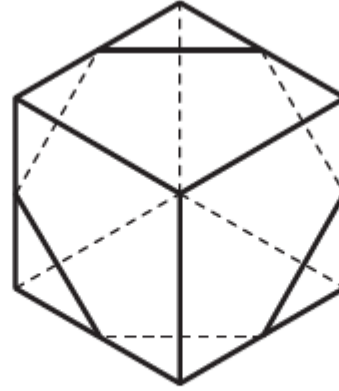
Construct plane
through 3 points



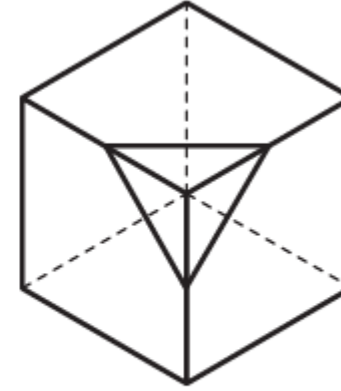
SEVERAL CROSS SECTIONS OBTAINED BY SLICING A CUBE WITH CUTTING PLANES AT DIFFERENT ORIENTATIONS



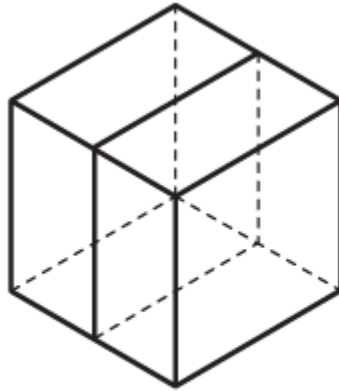
Pentagon



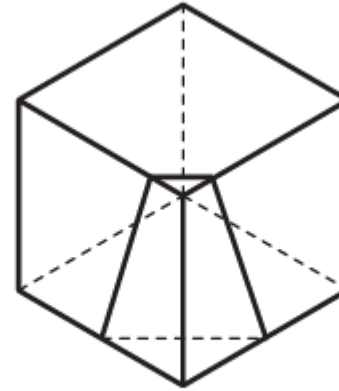
Hexagon



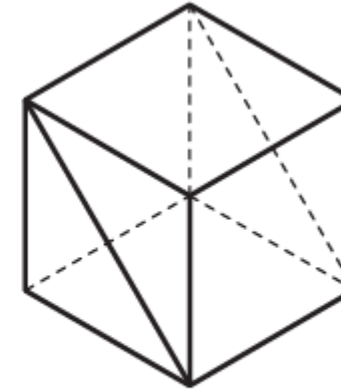
Triangle



Square

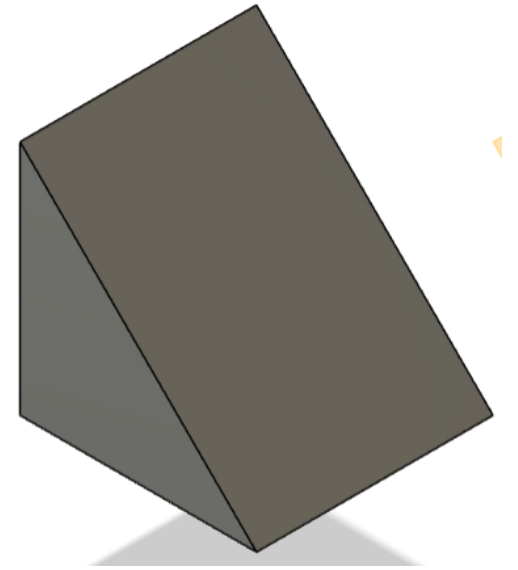
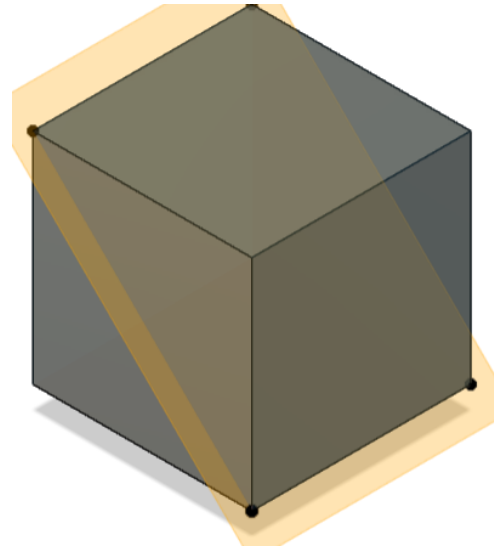
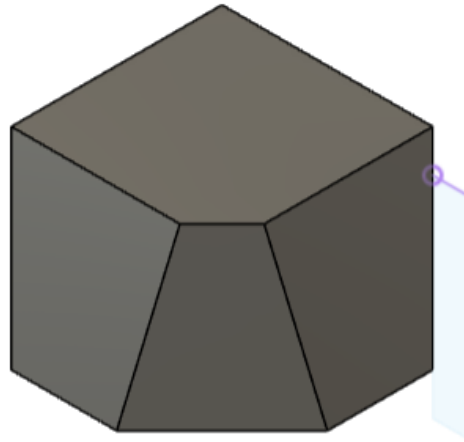
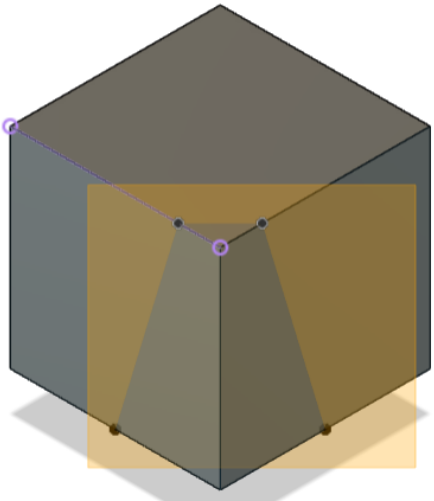
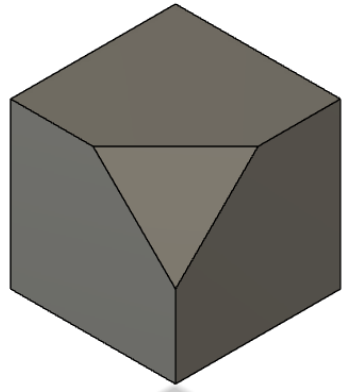
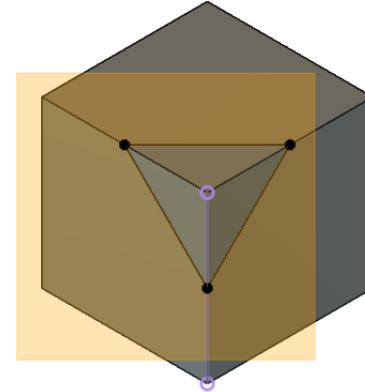
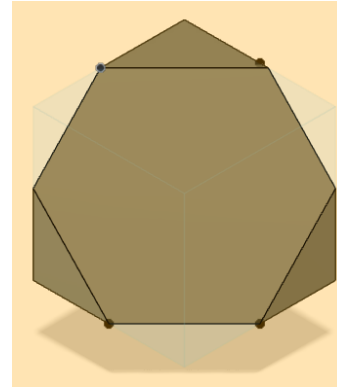
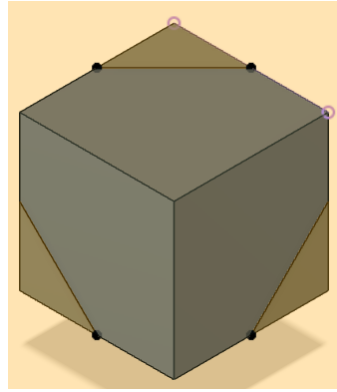
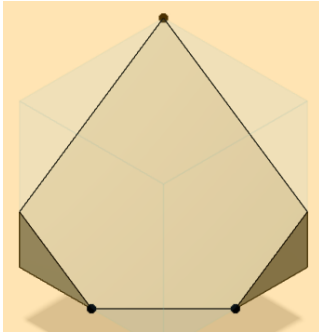
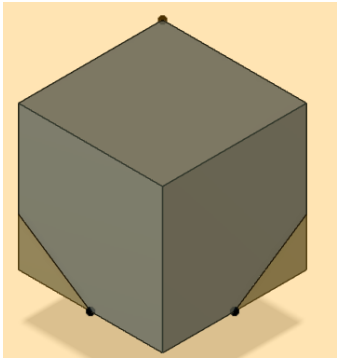


Trapezoid



Rectangle

SEVERAL CROSS SECTIONS OBTAINED BY SLICING A CUBE WITH CUTTING PLANES AT DIFFERENT ORIENTATIONS



COMBINING SOLIDS

The ability to visualize combining solids will be helpful as you learn how to use solid modeling software.

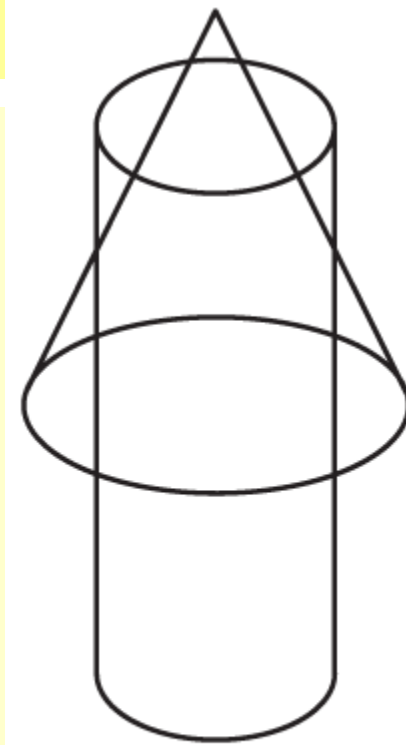
In early versions of 3-D CAD software, commands used to combine solids were sometimes known as Boolean operations.

Two overlapping objects can be combined to form a third object with characteristics of each original object apparent in the final result.

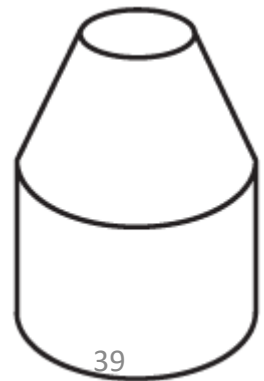
To perform any Cut, Join, or Intersect operation to combine objects, the objects must be overlapping initially.

OVERLAPPING – objects share a common volume in 3-D space—called the **VOLUME OF INTERFERENCE**

Volume of interference takes shape and size characteristics from each of the two initial objects.

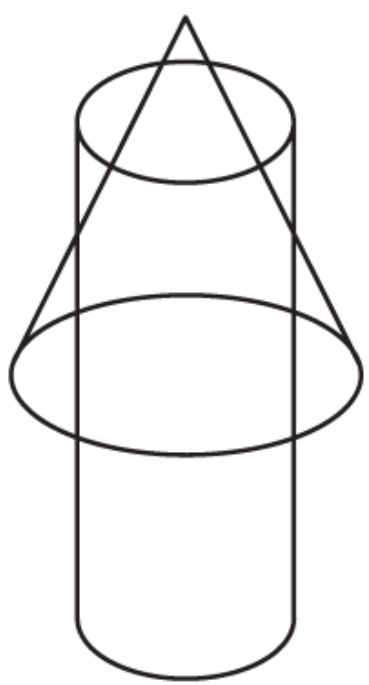


Overlapping
Objects



Volume of interference

COMBINING SOLIDS



Overlapping
Objects



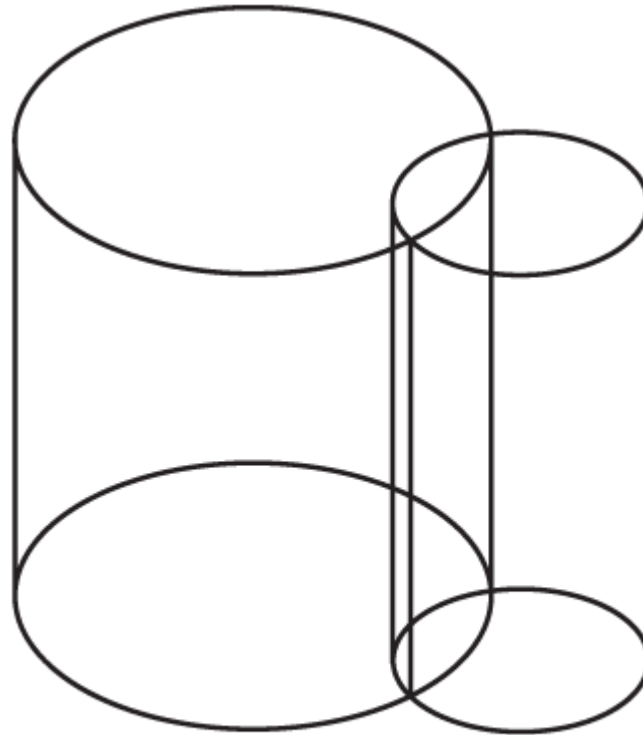
Volume of
interference

Volume of interference takes shape and size characteristics from each of the two initial objects.

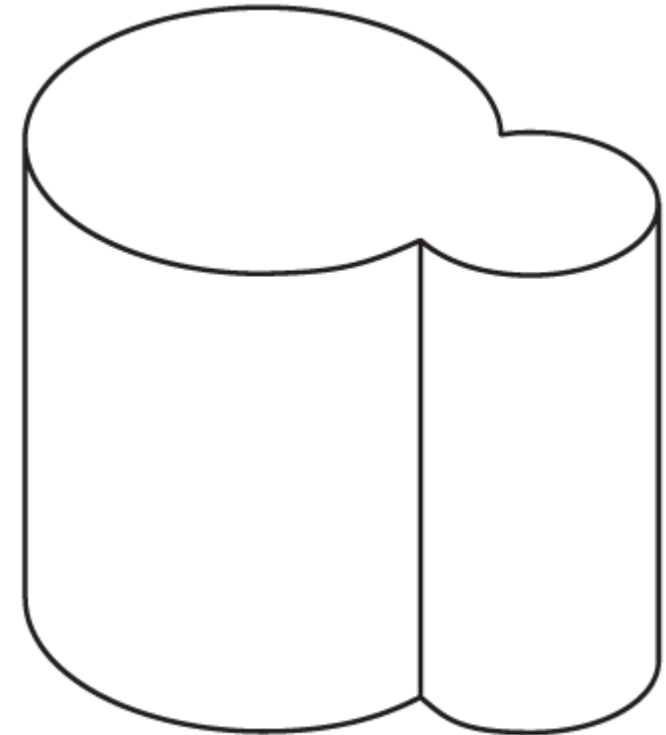
THE BOOLEAN JOIN OPERATION

When two objects are joined, the volume of interference is absorbed into the combined object.

The result is a single object that does not have “double” volume in the region of interference.



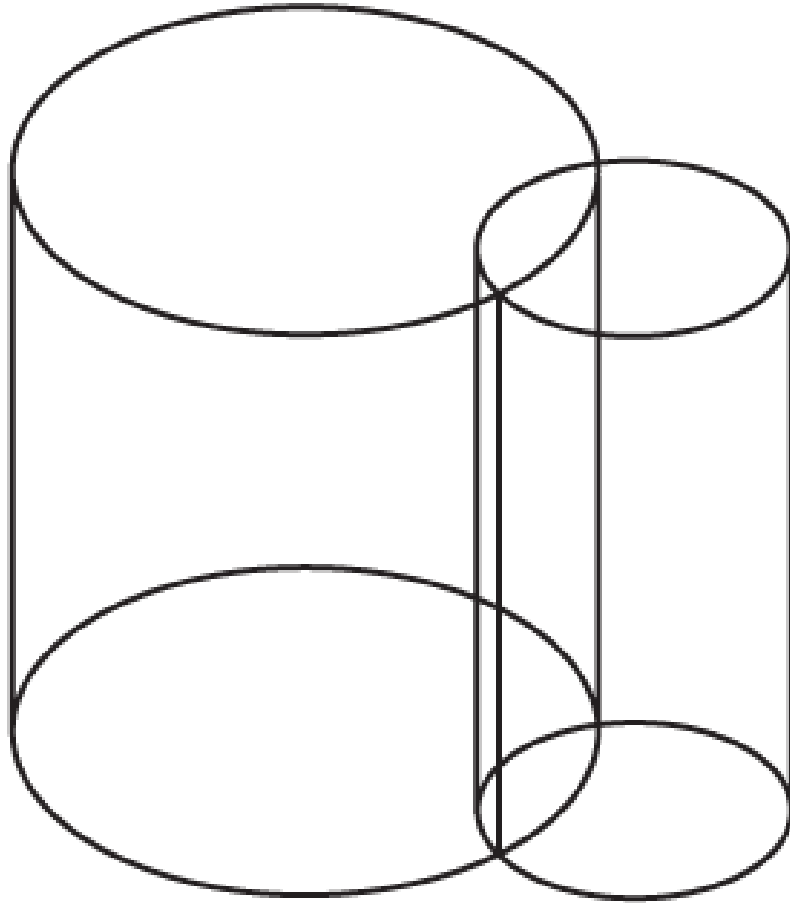
Overlapping Objects



Objects Joined

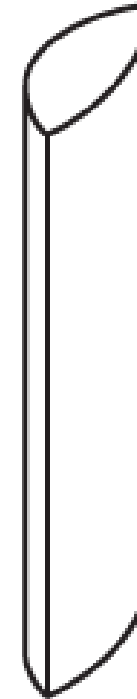
COMBINING SOLIDS

Result of two objects intersected



Overlapping Objects

When two objects are combined by intersecting, the combined object that results from the intersection is the volume of interference between them

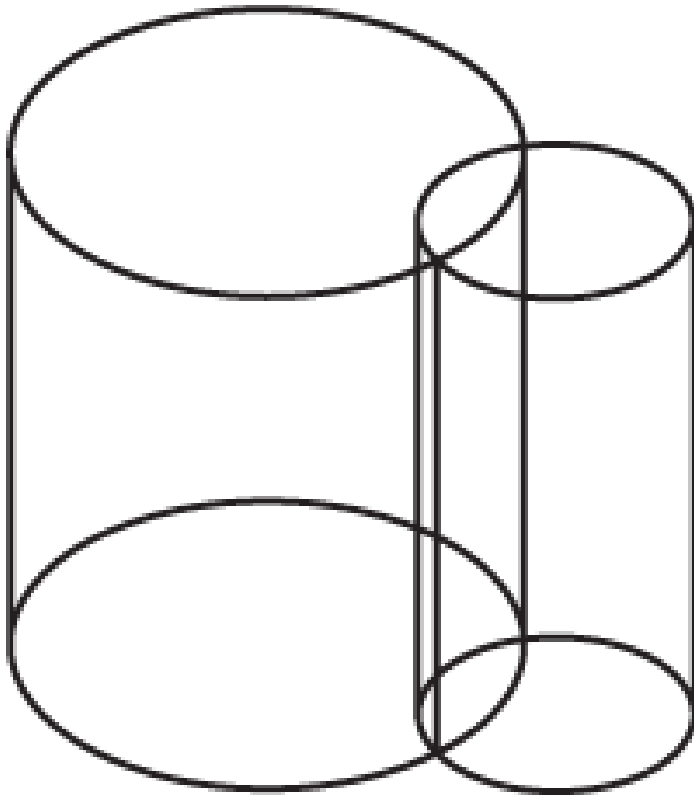


Objects Intersected

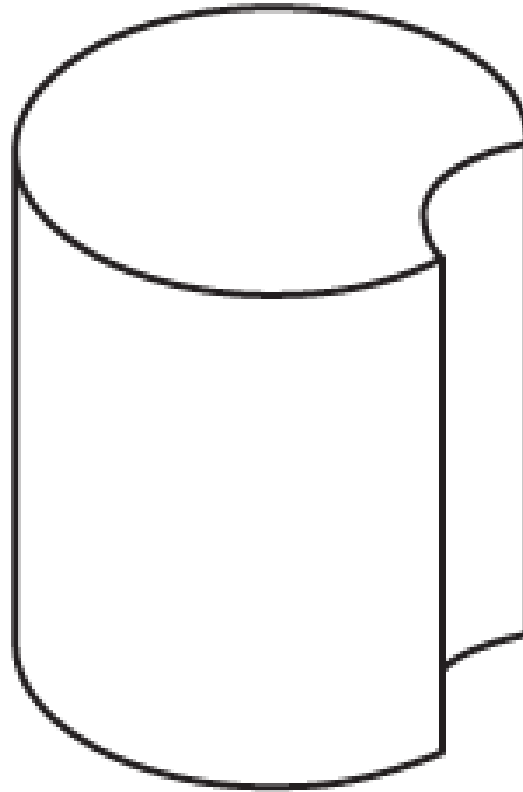
COMBINING SOLIDS

Result of two objects cutting

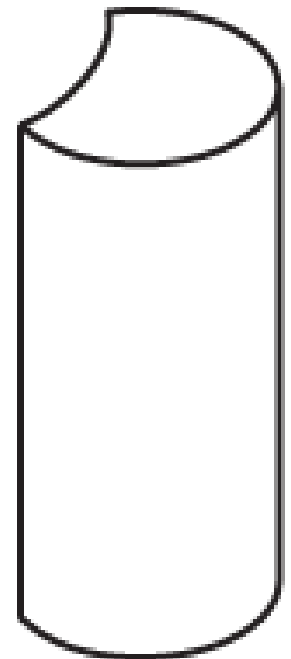
In the cutting of two objects, the combined object that results from the cutting depends on which object serves as the cutting tool and which object is cut by the other object. The result of a cutting operation is that the volume of interference is removed from the object that is cut,



Overlapping Objects



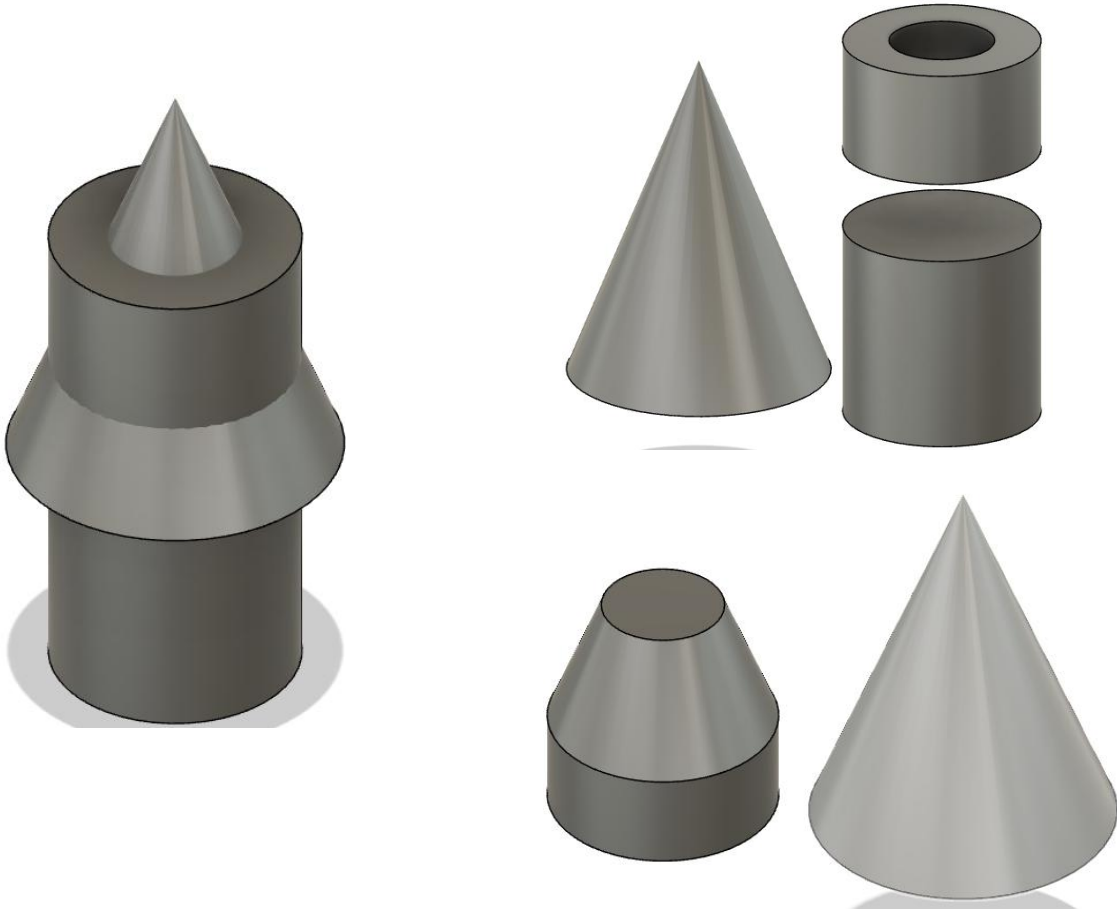
Small Cylinder Cuts
Large Cylinder



Large Cylinder Cuts
Small Cylinder

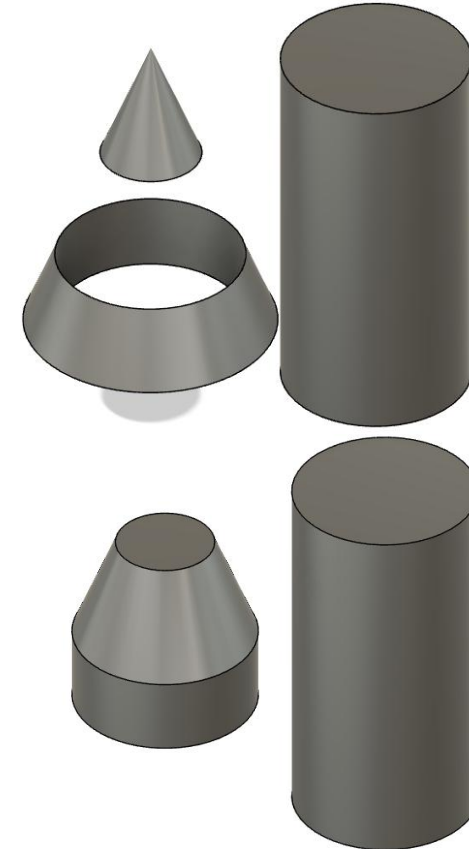
COMBINING SOLIDS

Cutting tool: cone



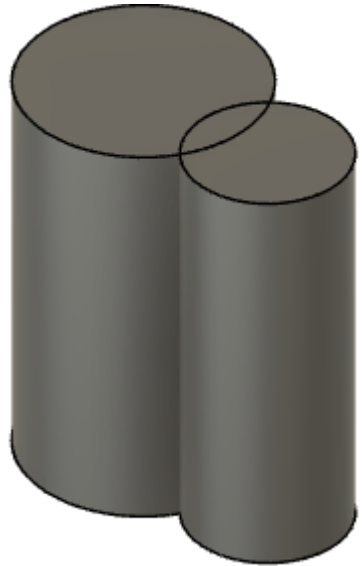
intersection: cone

Cutting tool: cylinder

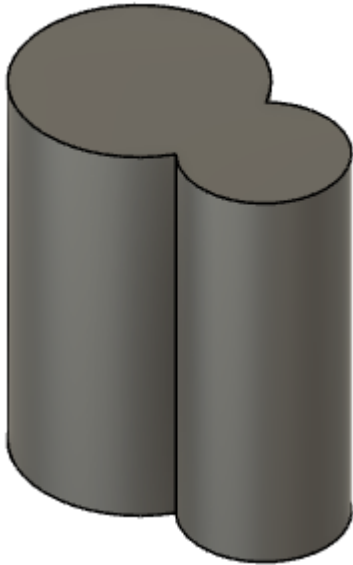


intersection: cylinder

COMBINING SOLIDS



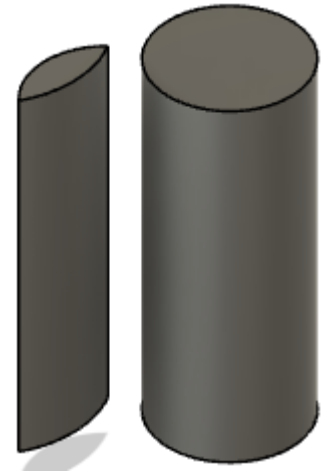
**Cutting tool:
smaller cylinder**



**Cutting tool:
bigger cylinder**



intersection



LABORATORY EXERCISE

- Already the laboratory exercise questions are kept in the moodle
- Content of the material taught (taken from Lieu or Sorby) is in moodle
- You will be given the same questions when you come over to lab, you need to solve all of them without consulting your friends or teaching assistants
- Work on lab sheets independently. **IT IS CONDUCTED LIKE A QUIZ.** Do not copy from others.
- In case, if you are stuck and cannot make headway at all, your teaching assistant will help you but few marks would be deducted

Best way is to

Study the **material** taught in the theory class – **NOTES**

Solve the laboratory **sheet before** coming to the **lab** class.

LABORATORY EXERCISE

- **Basis of evaluation of Lab submissions :**
 - **Effort**
 - **Correctness**
 - **Neatness**

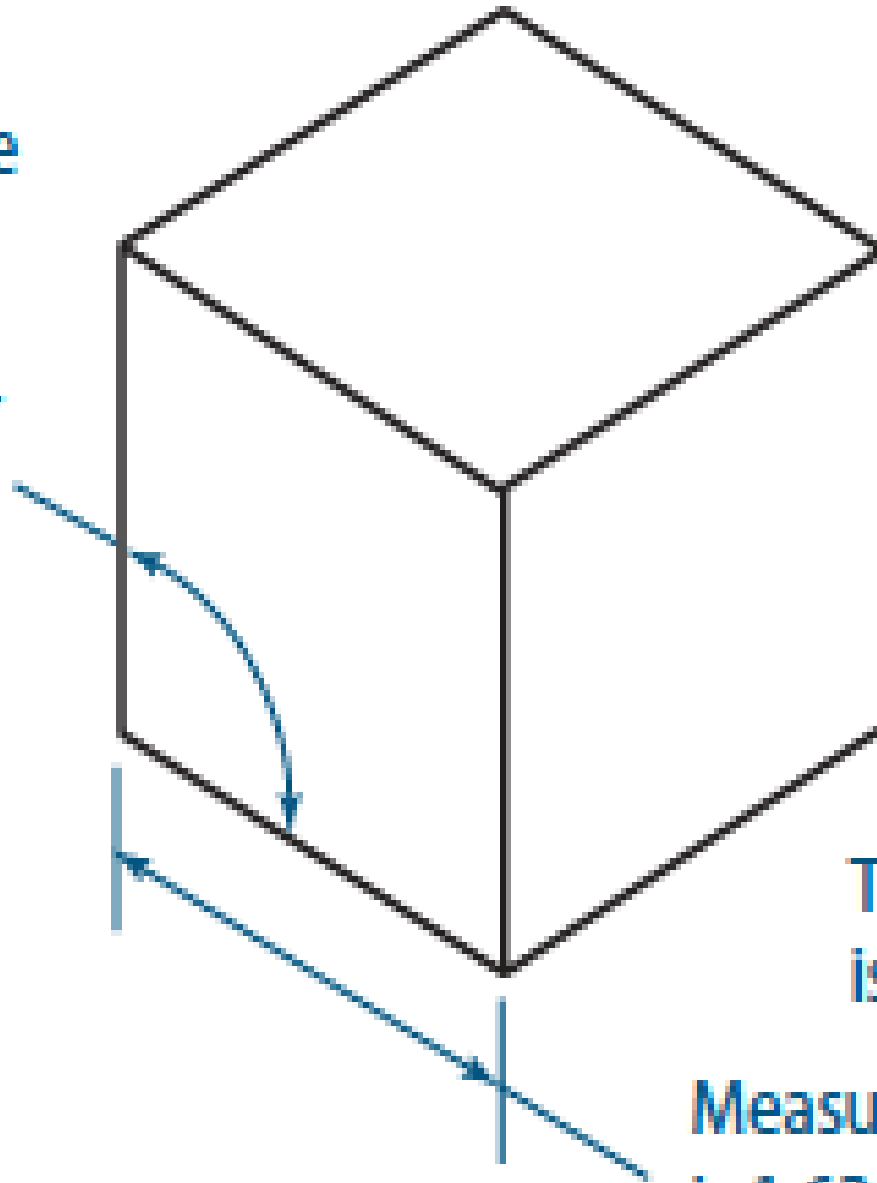
Thank you

**Extra reading on ISOMETRIC
PROJECTIONS if interested**

ISOMETRIC PROJECTION

True corner angle
is 90° for cube

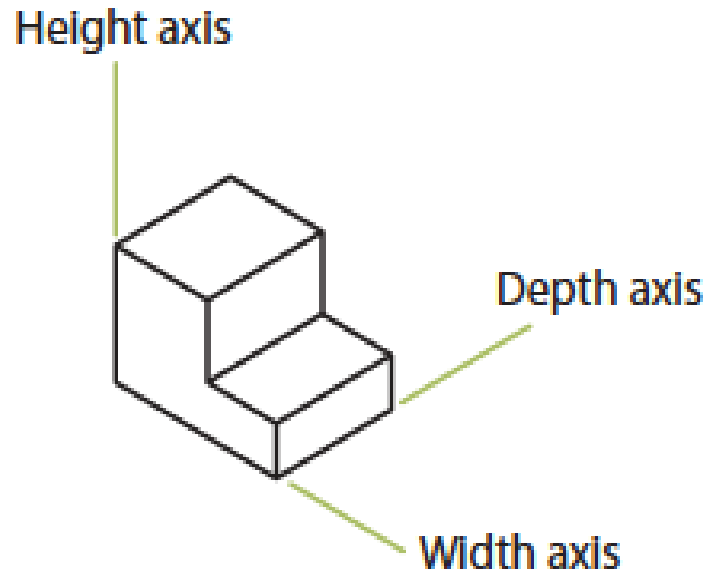
Measured corner
angle is 120°



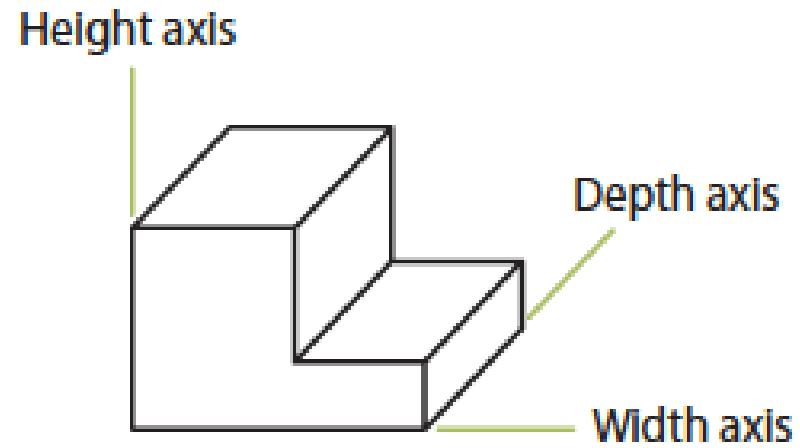
True edge length
is 2 units for this cube

Measured edge length
is 1.63 units

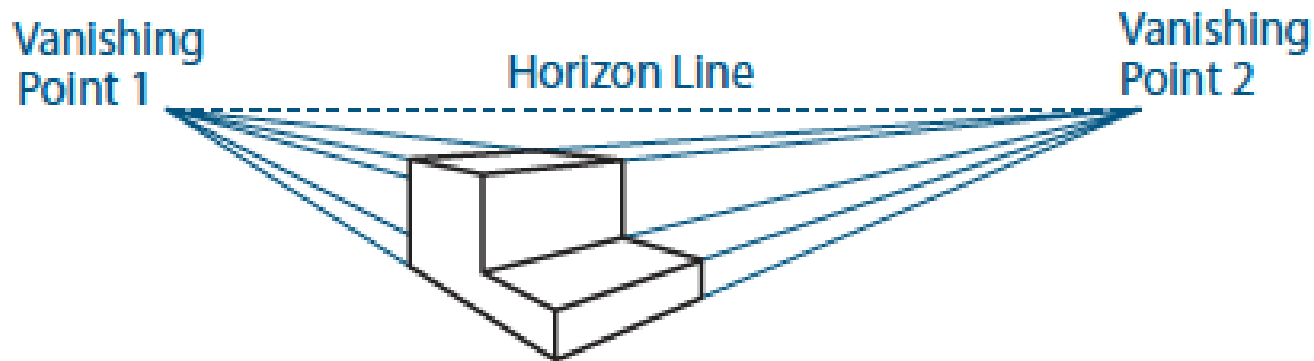
Axonometric refers to the angle that axes make with each other



AXONOMETRIC DRAWING

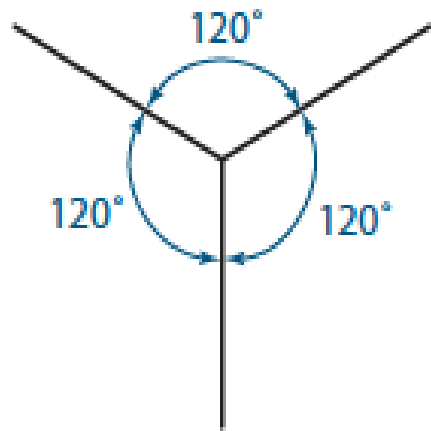


OBLIQUE DRAWING

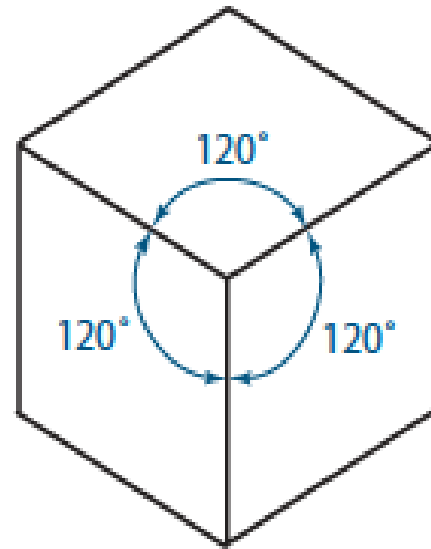


PERSPECTIVE DRAWING

All angles equal

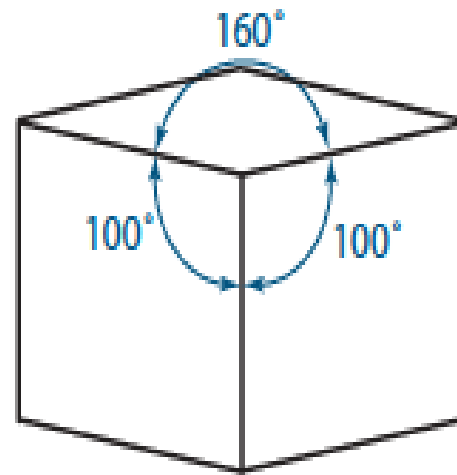
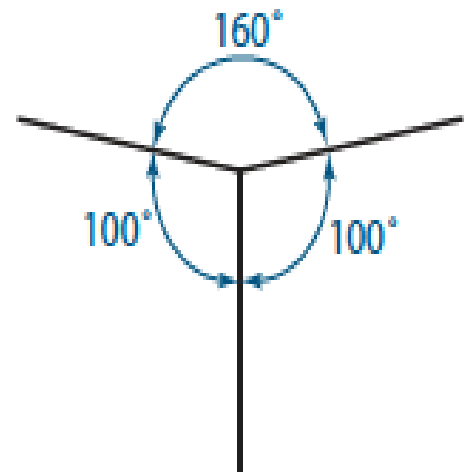


Isometric projection



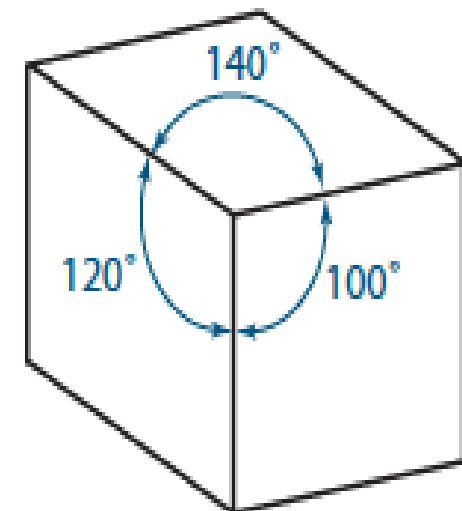
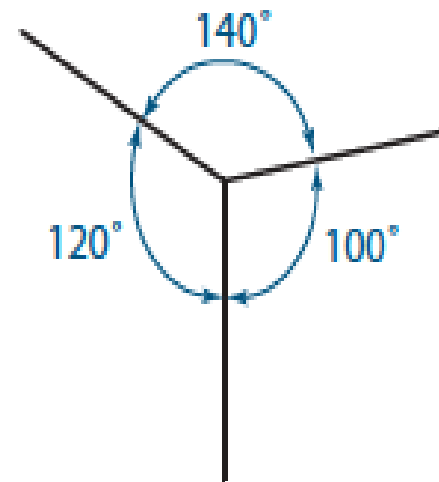
Two angles equal

Dimetric projection

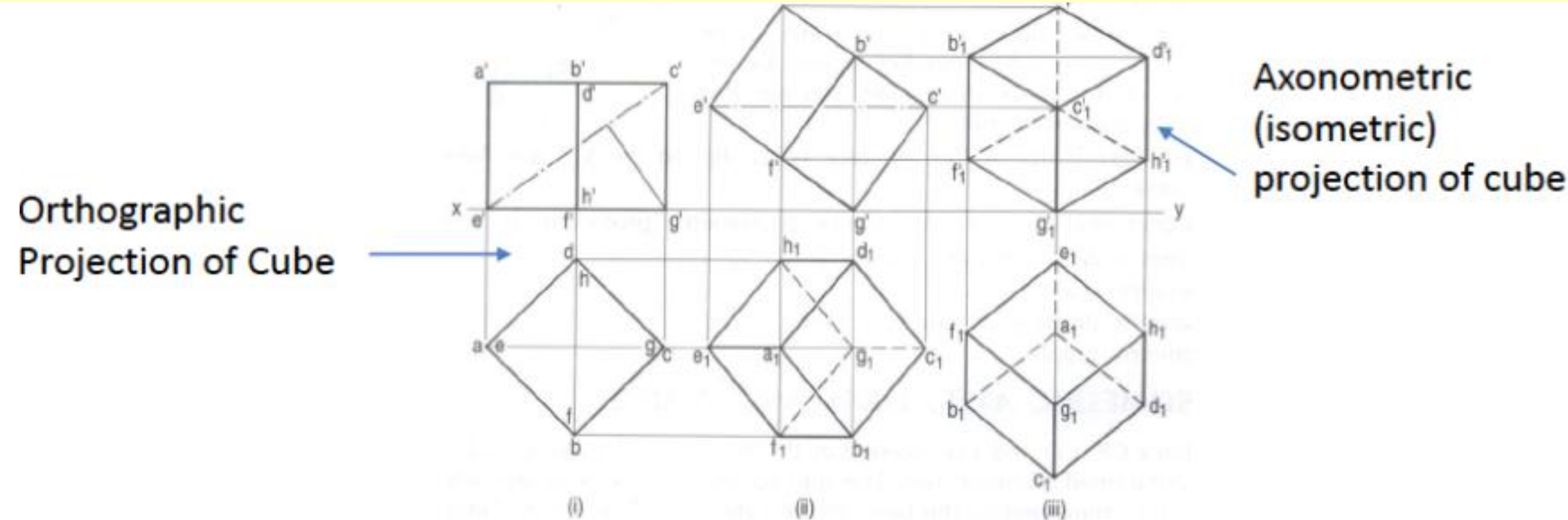


No angles equal

Trimetric projection



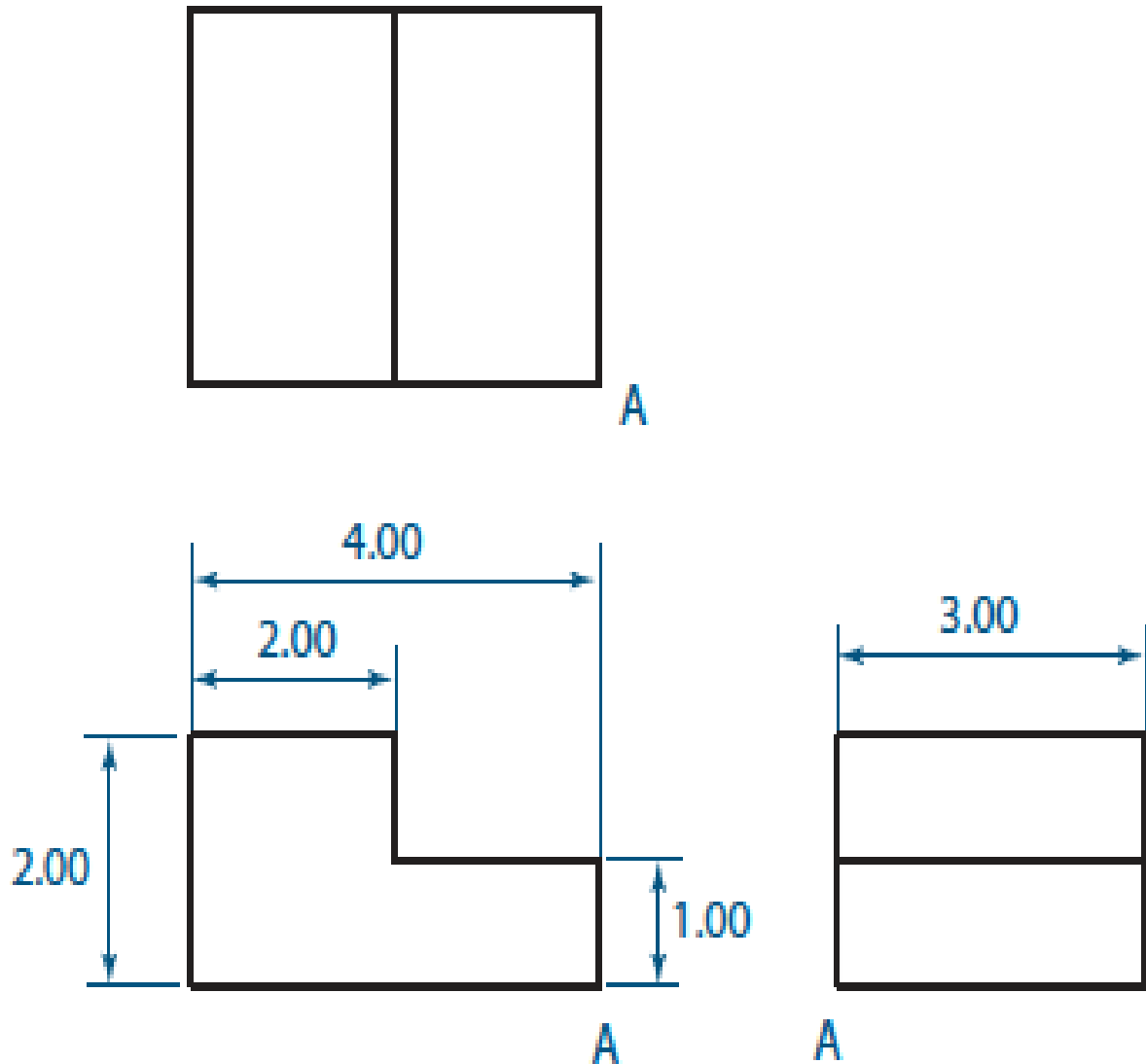
Before projecting the object onto V.P/H.P., if it is rotated about X/Y/Z axes by some arbitrary angle(s), more details of the object becomes visible as 2 or 3 faces of its bounding cube becomes visible. Such an **orthographic view** preceded by the rotation of the object is called **axonometric projection**. It is a pictorial view as it looks like a 3D view of the object



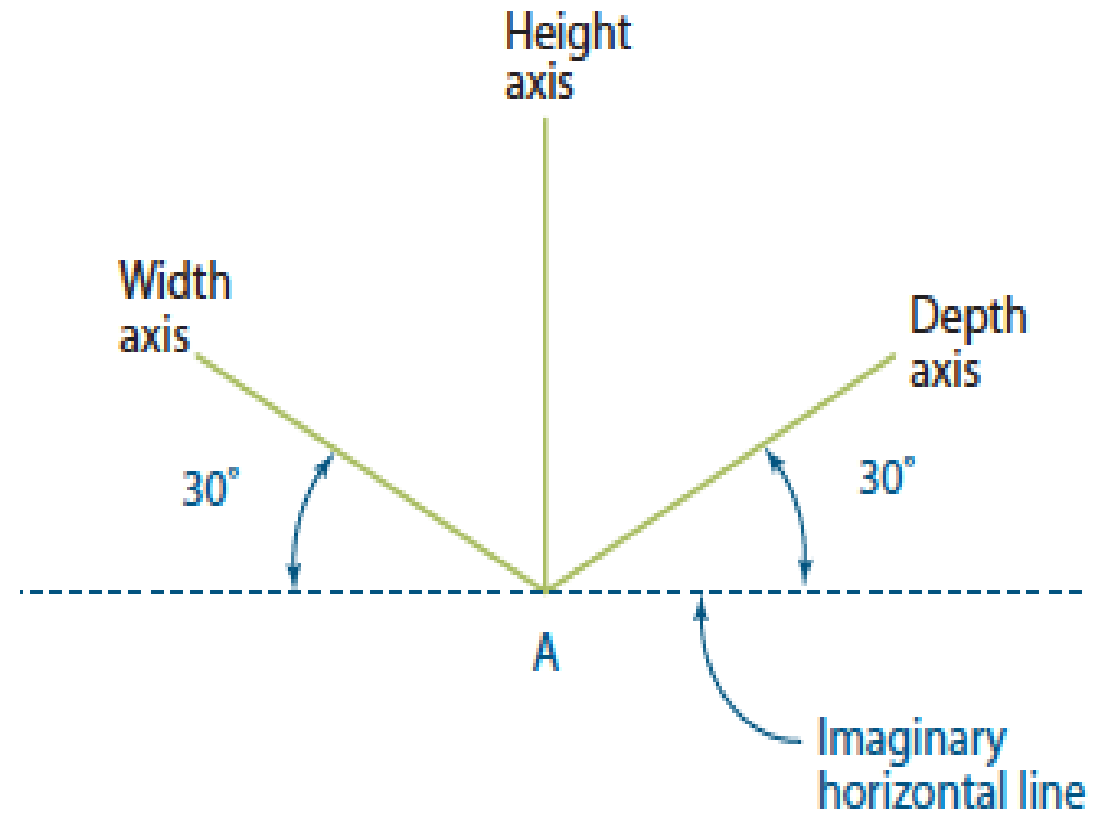
To draw the projections of a cube of 25 mm long edges resting on the ground on one of its corners with a solid diagonal perpendicular to the V.P., assume the cube to be resting on one of its faces on the ground with a solid diagonal parallel to the V.P.

Isometric drawing/view of a step block

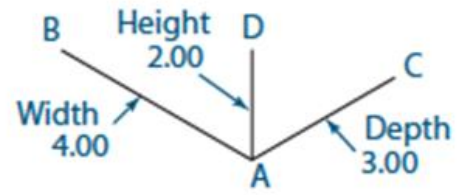
Orthographic views



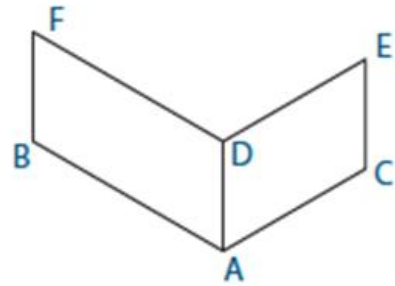
Isometric axes



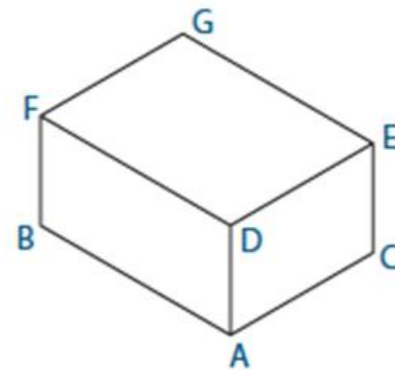
Isometric drawing of a step block



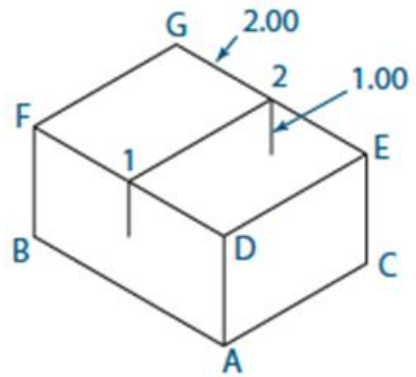
STEP 1



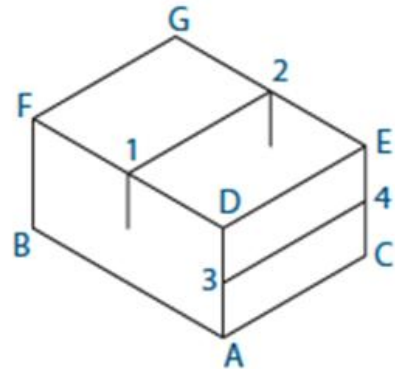
STEP 2



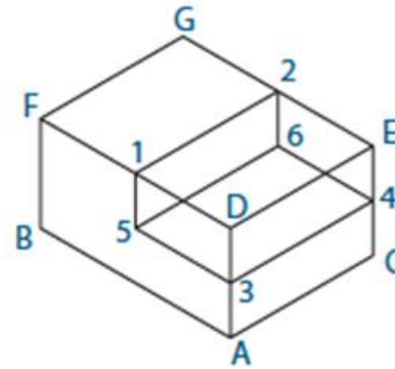
STEP 3



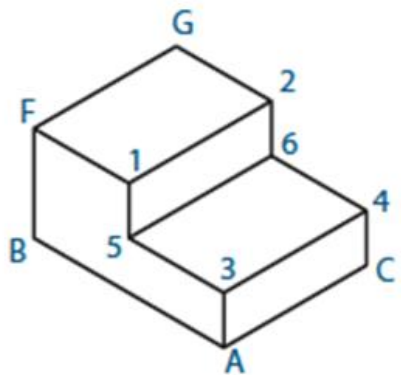
STEP 4



STEP 5



STEP 6

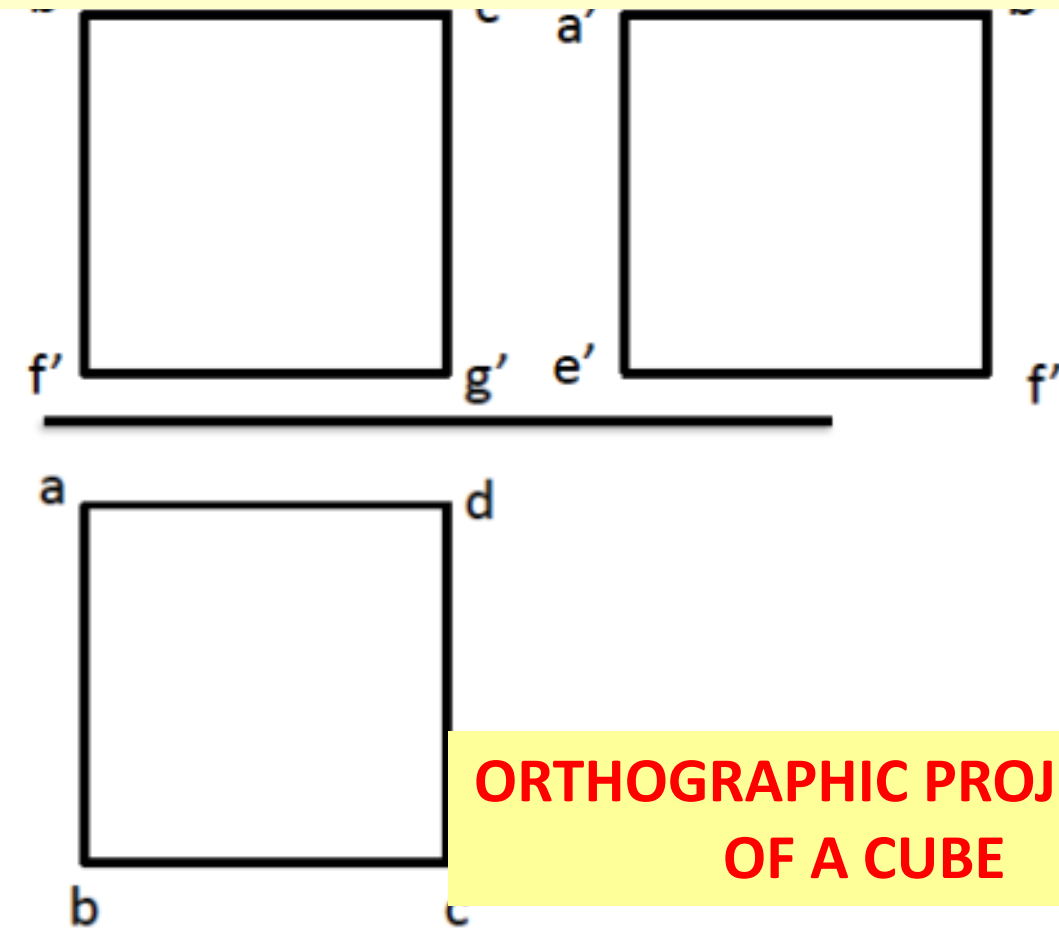


STEP 7

ISOMETRIC PROJECTION OF A CUBE

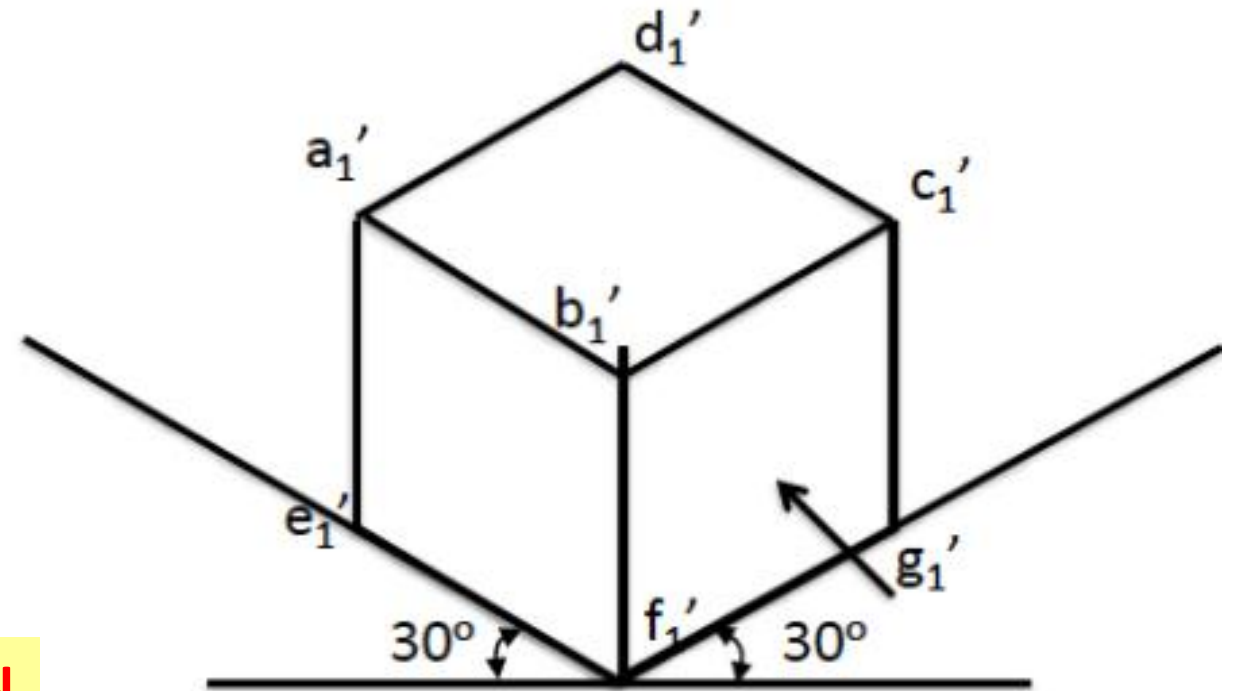
Draw the orthographic and the isometric projections of a cube with base parallel to the XY plane and the two adjacent faces parallel to the coordinate planes XZ and YZ.

The direction of viewing is normal to the XZ plane.



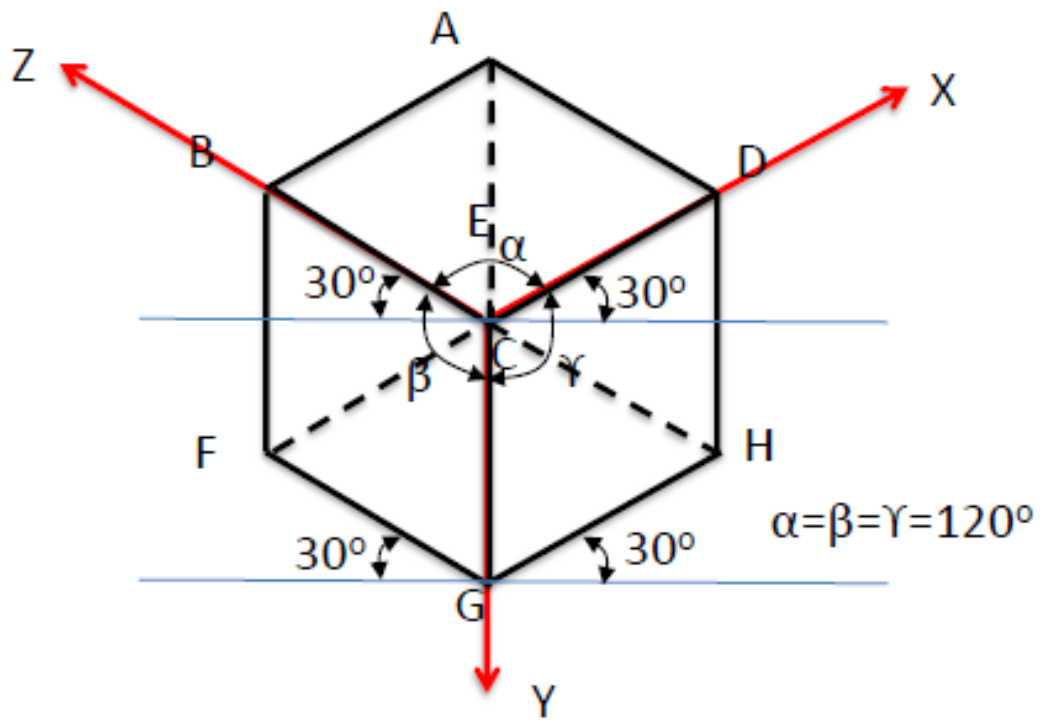
**ORTHOGRAPHIC PROJECTION
OF A CUBE**

ISOMETRIC PROJECTION OF A CUBE



The length of all the sides which were parallel to the coordinate axes has decreased (foreshortened) equally

SOME FEATURES OF ISOMETRIC PROJECTION/VIEWS



The front edges - CB, CD and CG are called isometric axes

CG is for height, CD is for length (width) and CB is for width (length)

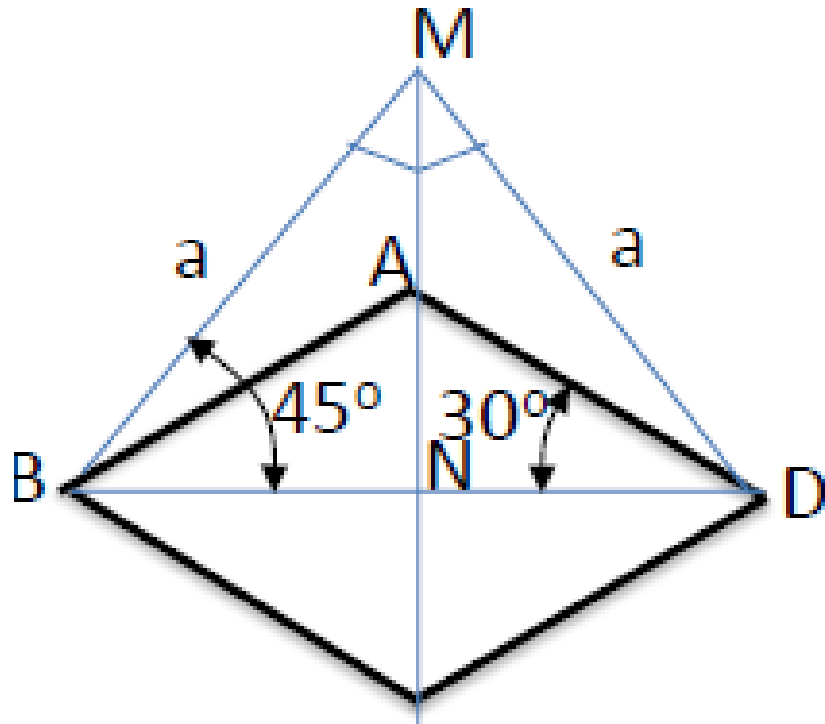
The three faces seen in the isometric projections are the same faces that will be seen in normal orthographic projections: top, front & side

Lines parallel to the isometric axes are called isometric lines

Planes representing the faces of the cube and planes parallel to them are called isometric planes

The angles between the projections of these axes is equal (hence isometric) and is 120°
 90° of the cube appear as either 60° or 120°

SOME FEATURES OF ISOMETRIC PROJECTION/VIEWS



$$\cos(45) = \frac{l(BN)}{l(BM)}$$

$$\cos(30) = \frac{l(BN)}{l(AB)}$$

$$\frac{l(AB)}{l(BM)} = \sqrt{\frac{2}{3}}$$

The projected length of an isometric line is $2/\sqrt{3}$ times the true length of the line

Lines which are not parallel to the isometric axis are called non-isometric lines

Non-isometric lines are not shortened in any fixed ratio, hence their lengths need to be found indirectly

Measurements should always be made on isometric lines and isometric axes only

Non-isometric lines are drawn by locating the position of their extremities on isometric planes and then connecting them