Engineering Graphics

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HISTORY OF ENGINEERING GRAPHICS
GEOMETRIC CONSTRUCTION & SOLID MODELING

Overview

History of Engineering Graphics: Sketching, Tools, and Mechanics

Coordinate Systems

Review specific concepts and terminology related to geometric construction and solid modeling.

Represent the use of several geometric and solid modeling tools which help in the understanding and creation of engineering drawings.

Learn the generation of solid models in CAD.

Understand how to use solid modeling in the design process.

Geometric Elements, Primitives, Solid Model Operators, Viewing Solid Models.

History of Engineering Graphics: Sketching

SKETCHING, TOOLS, AND MECHANICS

Objective

Sketching as an effective tool in the engineering design process.

Represent lines, curves, surfaces, holes, fillets, rounds, chamfers, run-outs, and ellipses in sketches.

Explain Perspective Projection and Parallel Projection

Identify normal, inclined, and oblique projections

Overview

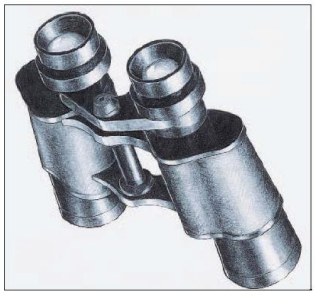


Figure 2.6 Shaded sketch

This rendered sketch is an example of the amount of detail that can be used when creating sketches. This type of sketch is more appropriate for technical illustrations than for design communications.

(Tim Brummett, Purdue University.)

Why use sketches?
- Creativity
- Communication
- Documentation

Sketching
- Definition
- Tools / Instruments

Mechanics of Sketching
- Lines and Curves
- Bounding Box

Pictorials / Projections
- Perspective
- Parallel

Sketching

Definition: A rough freehand drawing used to document, communicate, and refine ideas developed in the ideation phase of the design process

Beginners will benefit from instruments

Follows standard practices

A developed skill

Should be the first step of any CAD drawing

Technical drawings are created using freehand, mechanical, or digital means. Freehand drawings are known as sketches and are an important communication tool that engineers use frequently when designing.

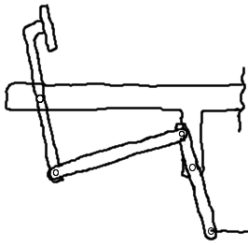
Freehand drawings are grouped by the level of detail, structure, and restrictions used to create the sketch.

Sketching: Part of the Creative Process

Quickly translate thoughts to paper

An effective means of communication

Stimulates creativity and visualization



Sketching Stimulates Creativity and Helps Visualization

The process of sketching ideas that are partially developed often aids the design process

- do not wait until you have a clear picture before you start sketching
- allow yourself the freedom to make mistakes

Visualization of the entire design is essential but often impossible without aid of sketches

Sketching: An Effective Means of Communication

Understand your audience

- Who is looking at the sketches?
- What details are they interested in?
- What type of sketch will they best understand?

Follow standard practices

- You may not always accompany your sketches
- Others may misinterpret your drawing

Sketches provide a log of ideas that were considered in a brainstorming session

Sketching : Documentation

Sketching allows for the quick translation of thoughts into paper. It allows you to commit thoughts to paper before you lose an idea!

Avoid the of use mechanical tools (drawing tools are helpful for beginners)

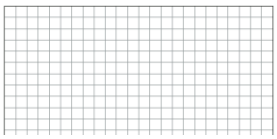
Does not need to be an exact representation

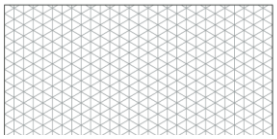
- objects may be simplified
- parts may be missing

Avoid erasing

- as new ideas are developed make new sketches
- start with light lines and then darken with darker lead or heavier strokes

Tools





Pencils
- Usual and recommended lead size is 0.5mm.
- Linetypes (construction lines) rely on different pressure

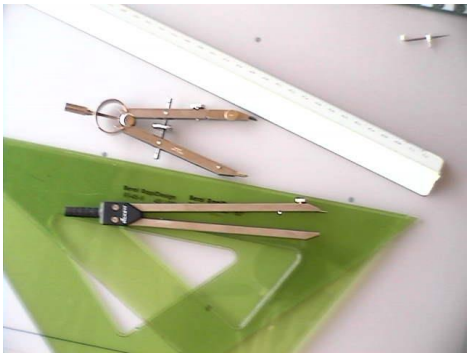
Paper
- Unlined paper is the most useful
- Square grid (isometric, square grid) and tracing paper is often useful

Eraser
- Only used for correcting lines not to make changes in design
- A good eraser is worth the investment

Tools Continued

The use of mechanical instruments is recommended only for beginners. Break away from reliance on tools that slow you down.

Helpful tools for beginners
- Compass
- Triangles
- Dividers
- Ruler

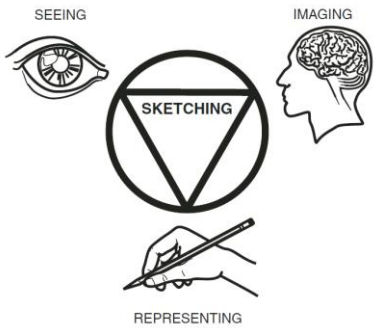


Sketching Process

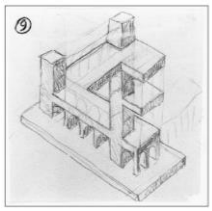
Seeing: Primary sensory channel. Empowers us to sketch

Imagining: the process used by the mind that takes the visual data received by our eyes to form some structure and meaning.

Representing: the process of creating sketches of what our minds see.



Mechanics of Sketching



M.C. Escher Waterfall October 1961

Mechanics: Straight Lines

- ✓Orient the paper to a comfortable position.
- ✓Mark endpoints of lines to be sketched.
- ✓Break long lines into short line segments by marking the midpoint.
- ✓Use a loose comfortable grip.
- ✓Reorient the paper to your convenience
  - ✓test your skill with different orientations
  - ✓an awkward orientation may occasionally produce positive results
- ✓Use an edge of a paper as a guide.
- ✓Start with a light pass if necessary and then darken

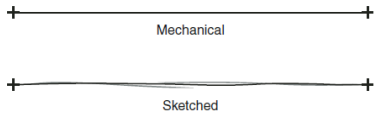


Figure 2.19 **A comparison of mechanically drawn and sketched lines**

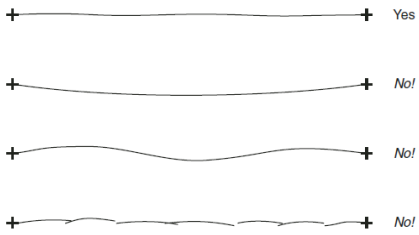


Figure 2.20 **Examples of good and bad straight-line technique**

Sketched lines should be straight and dark, and they should have a consistent thickness.

Mechanics: Curved Lines

Break large arcs/circles into small segments

Make guide marks for each segment

Circles and Ellipses

- Sketch a light square/rectangle
- Lightly sketch in diagonals
- Mark contact points on square/rectangle
- Rotate the paper for each segment

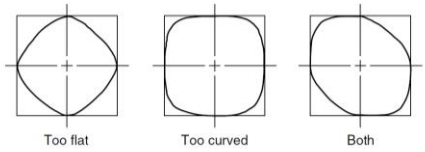
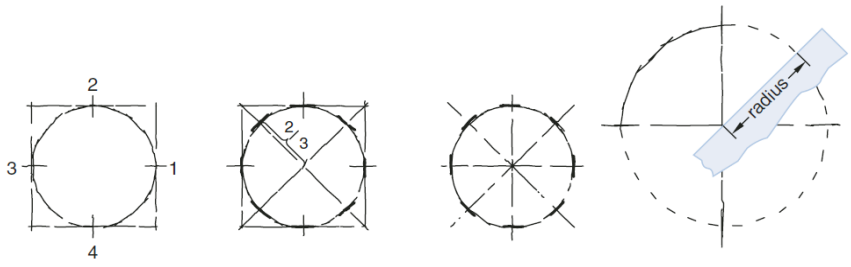
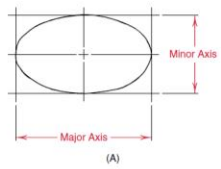
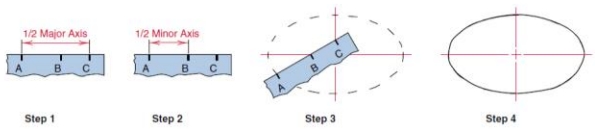


Figure 2.24 Poorly drawn circles will have flat areas and sharp curves







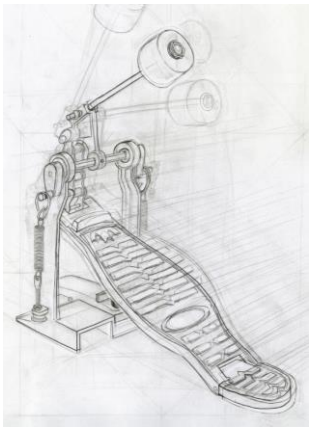
Mechanics: Construction Lines

Plan your sketch:

- Create bounding boxes for each object. (No crowding of sketch)
- Use light lines to as construction lines.
- Choose proper scale and orientation

Draw boundary lines of internal features starting with the largest features

Sketch dark object lines using light boundary lines as a guide



Geometric Construction

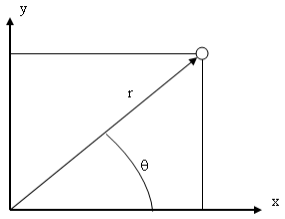
COORDINATE SYSTEMS

Coordinate Systems

Origin (reference point)

2-Dimensional Coordinate System
- Cartesian (x,y)
- Polar (r,q)

3-Dimensional Coordinate System
- Cartesian (x,y,z)
- Cylindrical (z,r,q)
- Spherical (r,q,f)

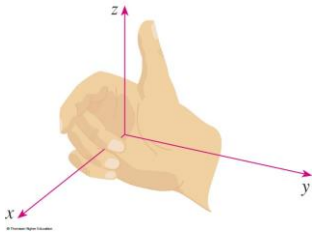


Coordinate Axes: Right Hand Rule

The direction of the z-axis is determined by the right-hand rule, illustrated as follows.

Curl the fingers of your right hand around the z-axis in the direction of a 90° counterclockwise rotation from the positive x-axis to the positive y-axis.

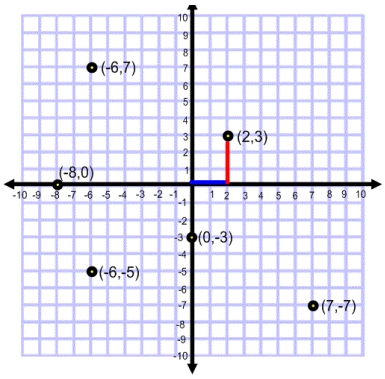
Then, your thumb points in the positive direction of the z-axis.



2-D Coordinate Systems

To locate the point (2,3), we can start at the origin O and proceed as follows:

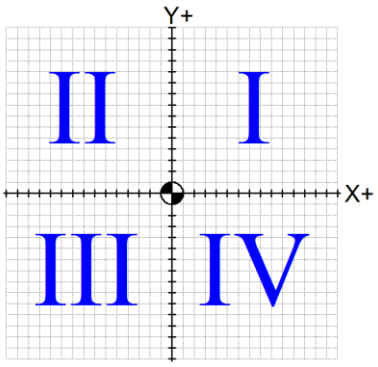
- First, move 2 units along the x-axis.
- Then, move 3 units parallel to the y-axis.



http://www.algebra-class.com/image-files/graphing-equations-3.gif

Quadrants

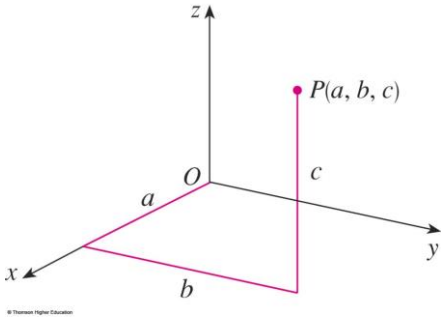
- Any of the four parts into which a plane is divided by rectangular coordinate axes lying in that plane
- Starting with the most positive, moving counter-clockwise to the most negative.
- Examples Questions:



3-D Coordinate Systems

Thus, to locate the point (a, b, c), we can start at the origin O and proceed as follows:

- First, move a units along the x-axis.
- Then, move b units parallel to the y-axis.
- Finally, move c units parallel to the z-axis.



Polar Coordinate System

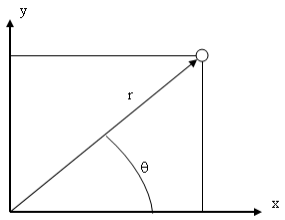
The distance from the origin to the point in the x-y plane is specified as the radius (r)

The angle measured form the positive x axis is specified as θ

Positive angles are defined according to the right hand rule

Conversion between Cartesian and Polar:

- $x = r * \cos\theta$
- y= $r * \sin\theta$
- $x^2 + x^2 = r^2$
- $\theta = tan^{-1}\left(\frac{y}{x}\right)$



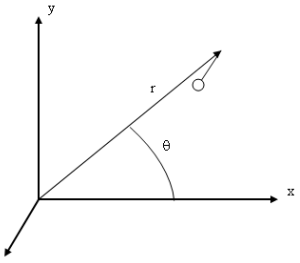
Cylindrical Coordinate System

3-D Polar Coordinates

Same as polar except a z-axis is added which is normal to the x-y plane in which angle q is measured

The direction of the positive z-axis is defined by the right hand rule

Useful for describing cylindrical features



Spherical Coordinate System

The distance from the origin is specified as the radius (r)

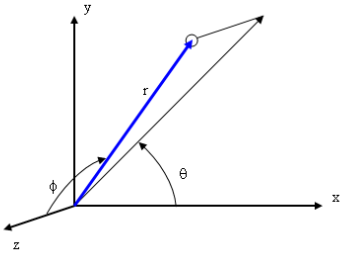
The angle between the x-axis and the projection of line r on the x-y plane is specified as θ

The angle between line r and the z-axis is specified as ϕ

Positive angles of θ are defined according to the right hand rule and the sign of f does not affect the results

Conversion between Cartesian and spherical

- $x = r * sin\phi * cos\theta$
- $y = r * sin\phi * sin\theta$
- $z = r * cos\phi$



Redefining Coordinates

Absolute coordinates
- measured relative to the origin
- LINE (1,2,1) - (4,4,7)

Relative coordinates
- measured relative to a previously specified point
- LINE (1,2,1) - @(3,2,6)

World Coordinate System
- a stationary reference

User Coordinate System (ucs)
- change the location of the origin
- change the orientation of axes

Geometric Elements

Geometric Elements used in 2-D Sketching:
Points, Lines,
Planar Geometry:
- Circles
- Polygons
- Surfaces

ENGINEERING GEOMETRY IS THE BASIC GEOMETRIC ELEMENTS AND FORMS USED IN ENGINEERING DESIGN.

A Point

Specifies an exact location in space

Dimensionless: No height, No Width, No Depth.

Some computer graphics software calls points **nodes**.

Locus represents all possible positions for a point.

Lines

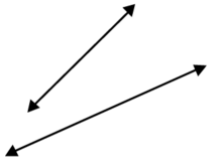
Geometric primitive that has direction but not thickness.

Lines may be straight, curved, or a combination of these.

Relationship of one line to another:

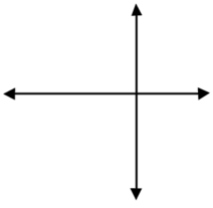
- Parallel line
- Perpendicular
- Intersecting
- Tangent

Parallel Lines

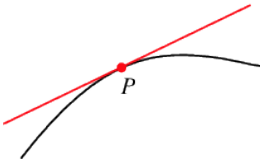


Non-Parallel Lines

Intersecting Lines



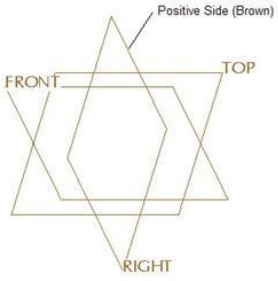
Perpendicular Lines



Tangent Lines

Some Graphics Software will refer to planes as DATUMS

Appears as a line when the direction of view is parallel to the plane



Planar Geometry

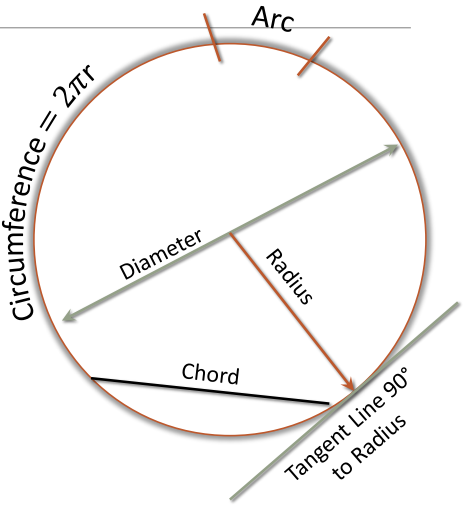
PLANE: A TWO-DIMENSIONAL SURFACE THAT WHOLLY CONTAINS EVERY STRAIGHT LINE JOINING ANY TWO POINTS LYING ON THAT SURFACE.

Circles

Circle is a single-curved-surface primitive, all points of which are equidistant from one point, the **center**.

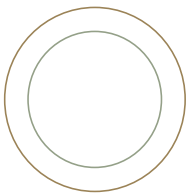
Elements of a Circle:

- Center: midpoint of Circle
- Circumference: distance around the circle → $C = 2\pi r$
- Radius (r): line from the center to the circumference
- Diameter (d): twice the radius and passes through the center
- Arc: continuous segment of a circle

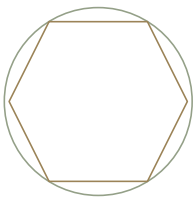


Circles

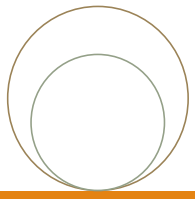
Concentric Circles



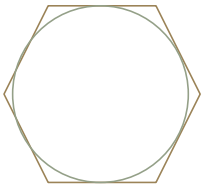
Circumscribed Circles



Eccentric Circles

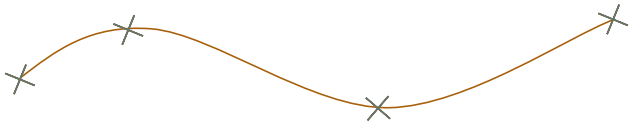


Inscribed Circles

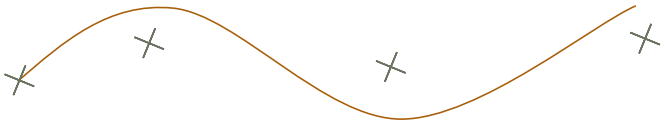


Free Form Curves

Spline Curve is a smooth, free form curve that connects a series of points.



B-Spline Curve uses a set of blending functions that have only local influence and depend only on a few neighboring control points.



Polygons

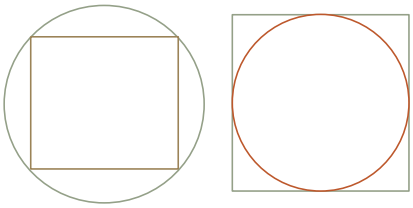
Polygons are multisided plane of number of sides. If the sides are of equal length then it is labeled as a **regular polygon**.

Regular polygons:

- 3 sides: equilateral triangle
- 4 sides: square

Triangles, Squares, Pentagons, Hexagons, Heptagons, Octagons, Nonagons, Decagons, Dodecagons.

Circumscribed or Inscribed:



Polygons Continued

Parallelograms:

- 4 sides
- Opposite sides are parallel
- Ex. square, rectangle, and rhombus

Triangles:

- Equilateral: All sides equal, 60 deg. angles
- Isosceles: two sides equal
- Right: one angle is 90 degrees

Surfaces

Surface: a finite portion of a plane or the outer face of an objected bounded by an identifiable perimeter.

No Thickness

Two Dimensional at Every Point

No Mass

No Volume

Used to define the boundary of a 3-D Object.

Solid Modeling

CONSISTS OF VOLUMETRIC INFORMATION, THAT IS, WHAT IS ON THE INSIDE OF THE 3-D MODEL, AS WELL AS INFORMATION ABOUT THE SURFACE OF THE OBJECT.

Solid Primitives

Prisms: Box (Parallelepiped)

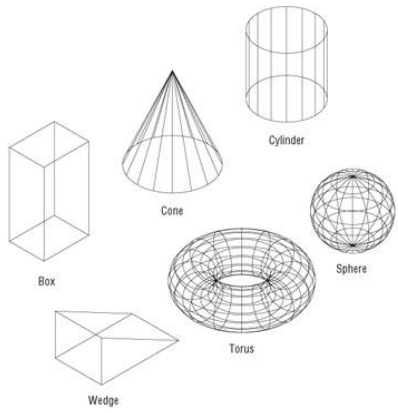
Cylinder

Cone

Sphere

Wedge

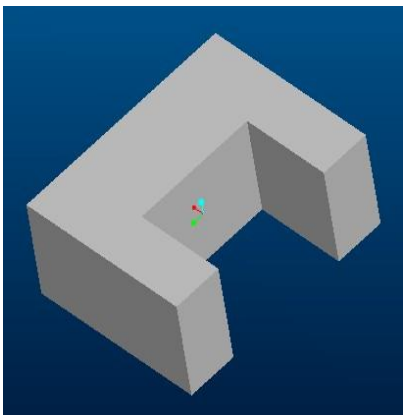
Torus



From Sketch to Object

3-D MODELING ELEMENTS

EXTRUDE



Cross Sectional 2-D Sketch is given height to make it a 3-D object.

The direction of the extrusion is typically normal to the sketch.

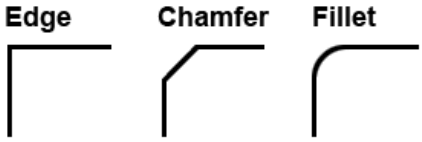
The height of extrusion is specified.

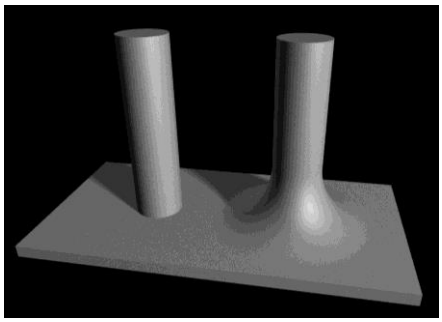
It gives 3-D effects to 2-D objects

Rounding

Fillet: a rounding of an exterior or interior corner of a part of a design.

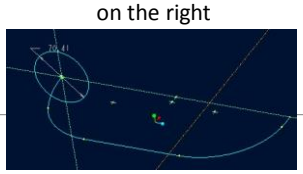
Chamfer: an exterior corner with an angle or type of bevel.

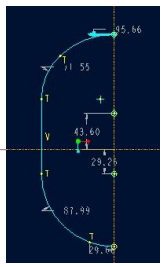




Sweep

Trajectory of the sweep shown on the right

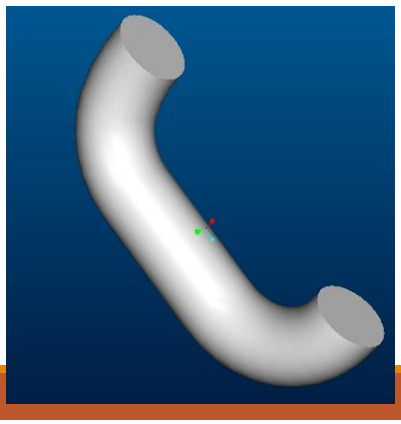




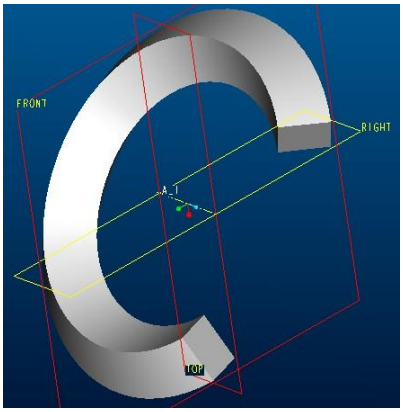
Modeling technique that allows you to define surfaces by moving a 2-D closed sketch in a trajectory.

Trajectory is the path the 2-D cross-section must travel.

The cross section stays normal (perpendicular) to the path

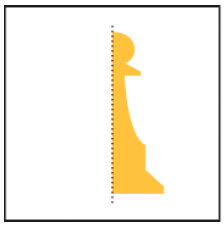


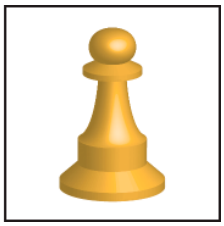
REVOLVE



Modeling Technique that involves revolving a 2-D cross-section about an axis.

Angle of Revolution must be defined.



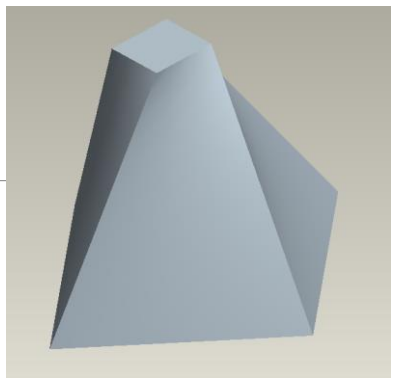


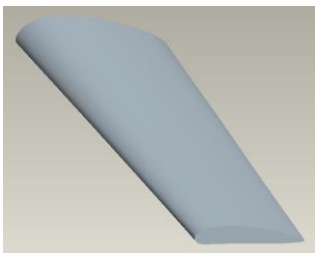
BLEND

Smooth transition can be made between two closed shapes with similar geometry (i.e. equal number of vertices)

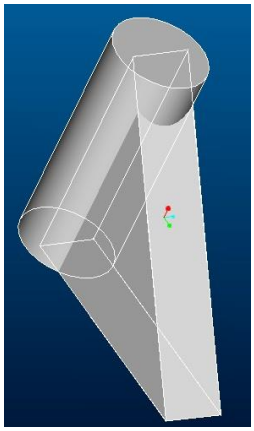
The distance between sections must be defined

The angle of twist between sections must be specified





Solid Model Boolean Operators

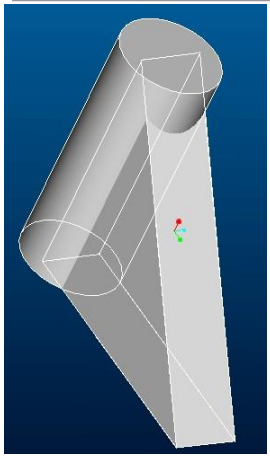


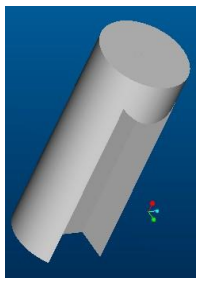
Subtract / Cut

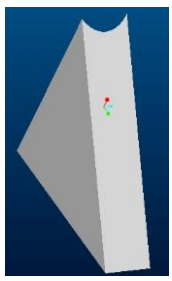
Intersection

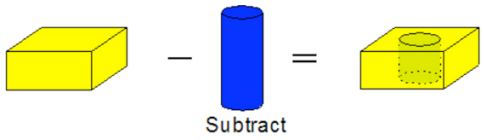
Union / Protrusion

Subtract / Cut: Subtracts or removes one solid from another

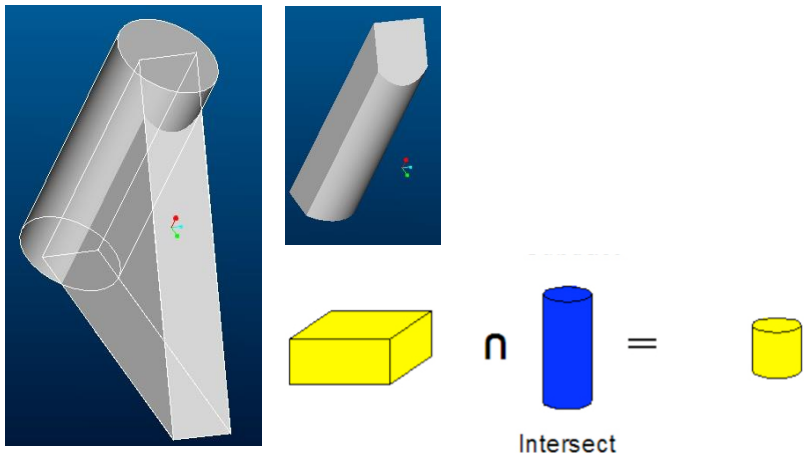




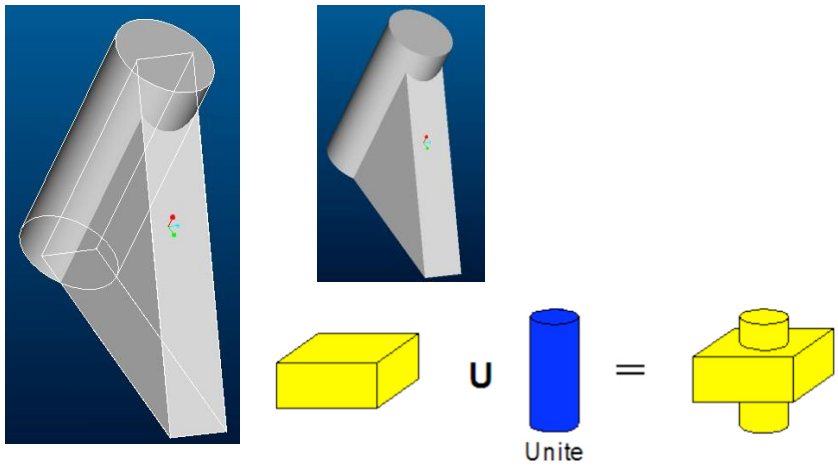




Intersection: Solid that is in common to the selected Solids



Union / Protrusion: Creates a single solid from two solids



Example: Solid Model Operators

What procedure would you follow to create the two mating parts?

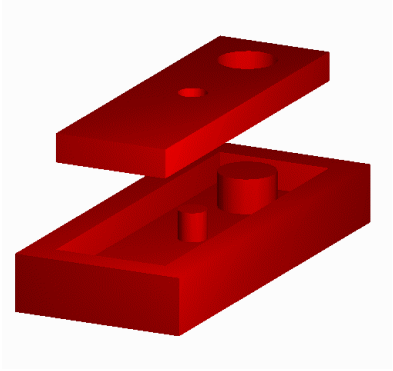
Create the bounding box for the upper part

Create the two cylinders

Subtract the cylinders from the box

Create the bounding box for the lower part

Subtract the finished upper part



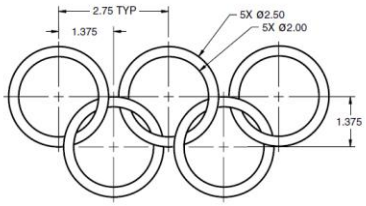
Sketching Activity

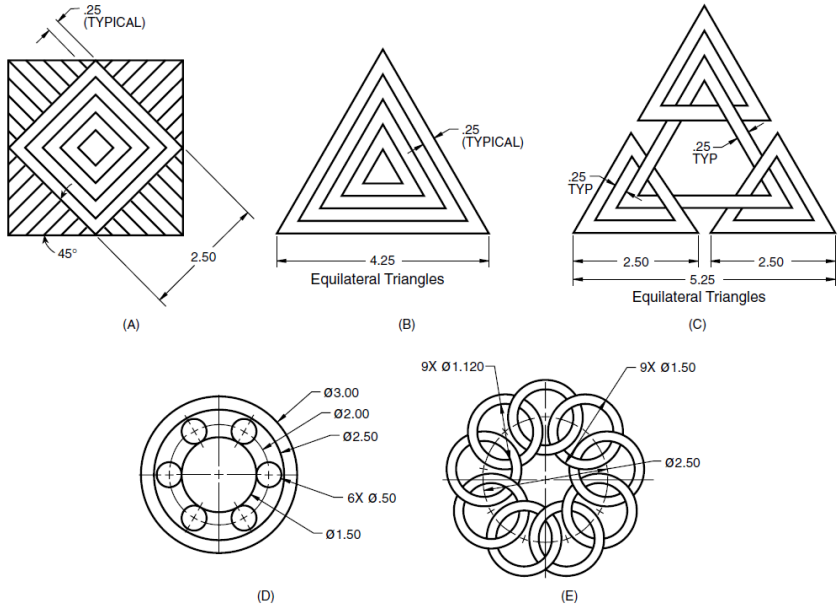
Do not Dimension.

Do not trace.

Approximate size.

Whenever you see TYPICAL or TYP on the drawings, it means that similar features are the same size, Ø means diameter of the circle.




.25
(TYPICAL)
45°
2.50
(A)
.25
(TYPICAL)
4.25
Equilateral Triangles
(B)
.25
TYP
.25
TYP
2.50
2.50
5.25
Equilateral Triangles
(C)
Ø3.00
Ø2.00
Ø2.50
6X Ø.50
Ø1.50
(D)
9X Ø1.120
9X Ø1.50
Ø2.50
(E)