Solid Modeling Module: Basic Shapes

A. Type of activity/investigation: This module teaches the basic concepts of solid modeling or creating 3-D objects by performing elementary operations on 2D sketches. Basic then more complex 3-D shapes are created using SolidWorks solid modeling software.

B. Engineering concept investigated: Solid modeling has become an essential design tool for engineers. Until recently, most engineering designs were detailed on 2-D drawings. A few industries that produced very complex machines, such as automobiles and aircraft, began using 3-D software in the late 1980's. The software and the computer hardware required to run it were very expensive, and so the widespread use of solid modeling did not occur until the dramatic drop in the cost of computing power in the 1990's. The advantages of using solid modeling are numerous. The visualization of complex parts and assemblies from 2-D drawings can be difficult and, mistakes in interpretation are common. More importantly, the solid model can be directly used in other engineering functions, such as making rapid prototyped parts, performing stress and flow analyses, and programming automated machining centers. These functions were previously done one at a time. Now, they can be done simultaneously in the process known as *concurrent engineering*, which has led to faster development times and lower costs to bring a product to market.

C. Mathematics concepts investigated/needed: Definition of 2-D and 3-D geometric shapes such as lines, line segments, arcs, circles, squares, rectangles, triangles, spheres, cones, cylinders, cubes, and rectangular prisms. Calculation of volumes and surface areas.

D. Science concepts investigated/needed: None

E. Materials needed for the module: Solidworks

F. Estimated time needed for the entire module? 3 hours

G. Educational Outcomes: The student will be able to:

1. Create basic 3D objects by performing operations on 2D sketches
2. Explain the concepts of extrude, extrude cut, and revolve
3. Change the dimensions of an object by controlling the dimensional parameters

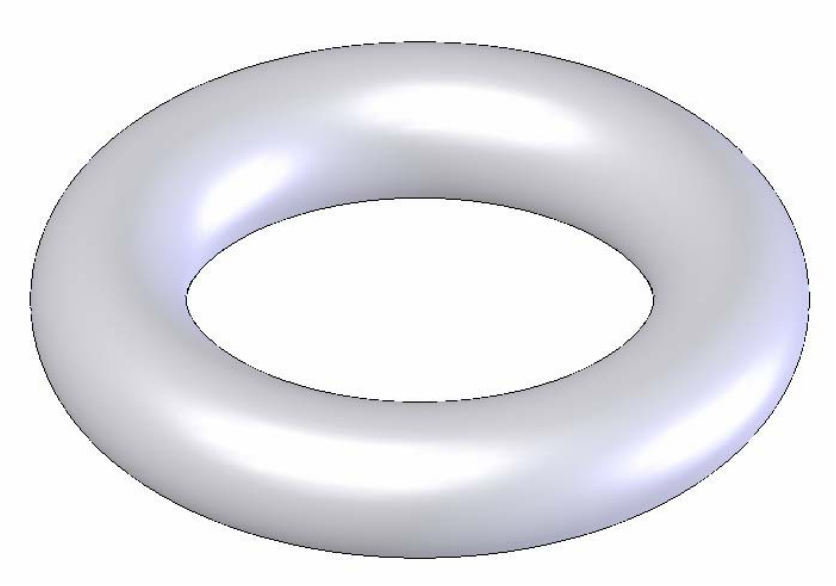
H. Techniques for instructional differentiation.

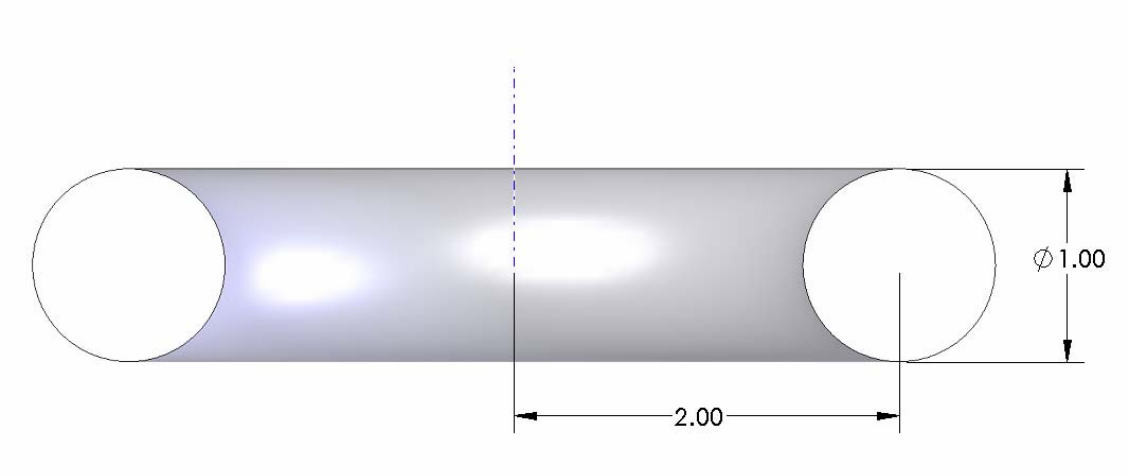
This module is written for new users of SolidWorks, with no special skills or knowledge required.

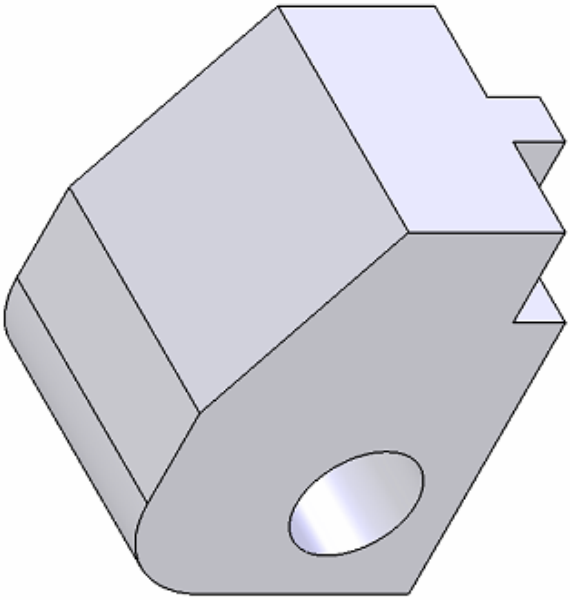
Advanced Students:

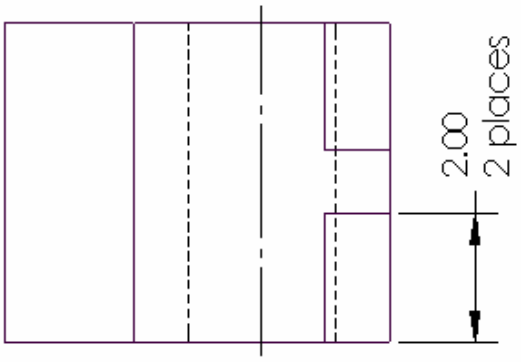
1. Challenge students to calculate all of the volumes and surface areas of the parts created (calculations attached). Calculus students can derive these equations.
2. Have students create a torus shown on page 2and find its volume and surface area.
3. Have students create the part illustrated in the multi-view drawing on page 3. This exercise challenges students to interpret a 2-D drawing.

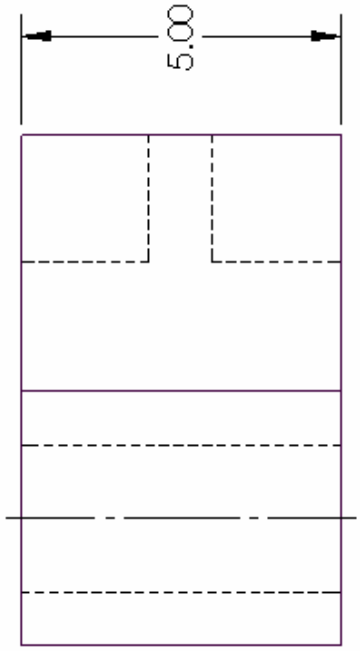
Torus Model:








2.00
2 places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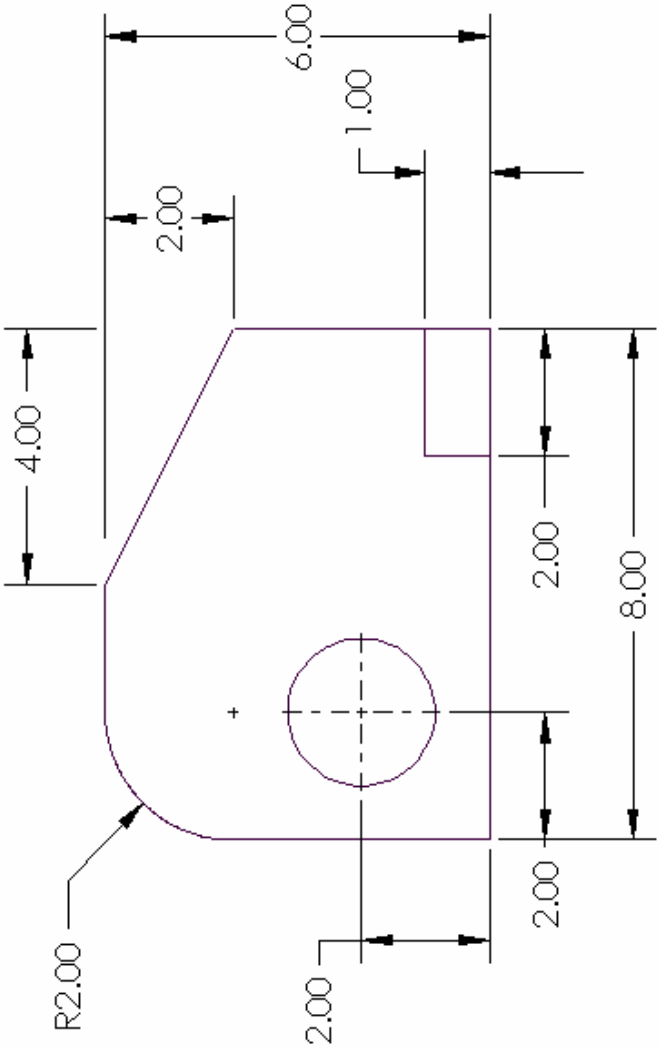
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VOLUME AND AREA CALCULATIONS

PART 1

VOLUME OF SOLID BLOCK = $(6)(4)(3) = 72\ in^3$

SURFACE AREA = $2[(6)(4)+(6)(3)+(3)(4)] = 108\ in^2$

VOLUME REMOVED BY HOLE = $\pi(1)^2(3) = 9.4248\ in^3$

FINAL VOLUME = $72 - 9.4248 = \boxed{62.575\ in^3}$

AREA ADDED BY HOLE =

$2\pi(1\ in)(3\ in)$

$= 18.8496\ in^2$

AREA REMOVED BY HOLE =

$2[\pi(1\ in)^2] = 6.2832\ in^2$

FINAL SURFACE AREA =

$108 + 18.8496 - 6.2832 = \boxed{120.566\ in^2}$

PART 2

VOLUME:

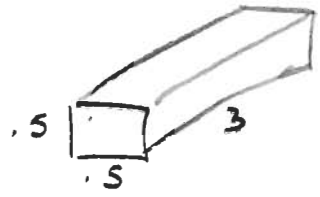
BASE BLOCK = $(5)(3)(2) = 30\ in^3$

CYLINDER = $\pi(1)^2(2) = 6.2832\ in^3$

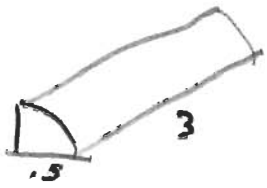
SLOT (REMOVED) = $(3)(.5)(3) = 4.5\ in^3$

ROUNDS:

REMOVED:



ADDED:



$-(.5)(.5)(3) \quad + \frac{1}{4}\pi(.5)^2(3) = -.1610 \text{ in}^3$

FOR 2 ROUNDS, NET REMOVAL = 0.3220 in^3

TOTAL VOLUME = $30 + 6.2832 - 4.5 - .3220$

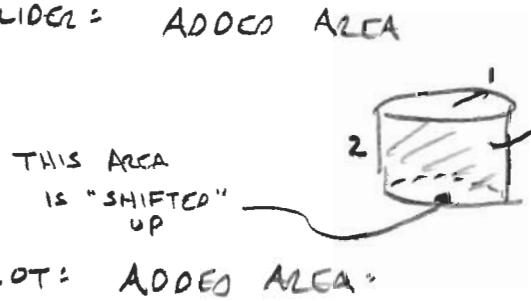
$= \boxed{31.46 \text{ in}^3}$

AREA:

BASE BLOCK = $2[(5)(3) + (5)(2) + (3)(2)]$

$= 62 \text{ in}^2$

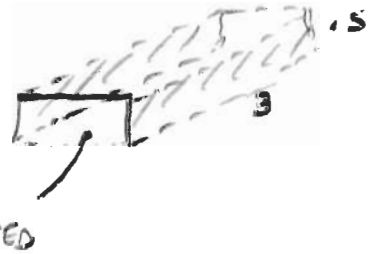
CYLIDER: ADDED AREA



$A = 2\pi(1)(2) =$

12.5664 in^2

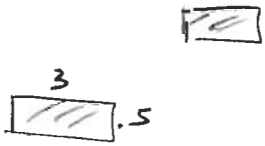
SLOT: ADDED AREA:



$A = 2(.5)(3) =$

3.0 in^2

SUBTRACTED AREA:



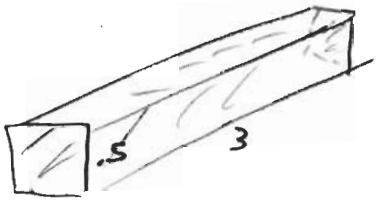
$A = 2(3)(.5) =$

3 in^2

$\therefore$ NO CHANGE

ROUNDS:

REMOVED:

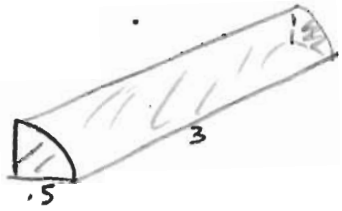


$A =$

$2(.5)(3) + 2(.5)(.5)$

$= 3.50\ in^2$

ADDED:



$A =$

$2\frac{1}{4}\pi(.5)^2$

$+ \frac{1}{4}(2\pi(.5))(3) = 2.7489\ in^2$

NET REDUCTION FOR 2 ROUNDS $= 2(3.50 - 2.7489)$

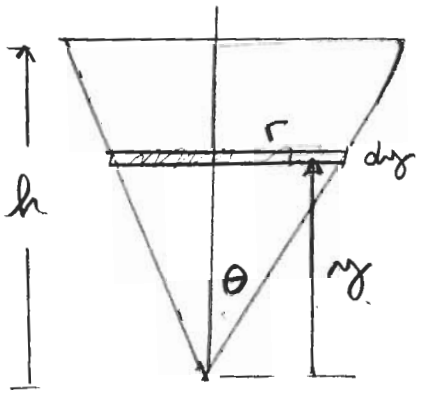
$= 1.5022\ in^2$

TOTAL AREA $= 62 + 12.5664 + 0.0 - 1.5022$

$= \boxed{73.06\ in^2}$

PART 3

VOLUME OF CONE - DERIVATION OF FORMULA:



$V = \int dV$

$dV = \pi r^2 dy$

$r = y \tan\theta$

$dV = \pi \tan^2\theta\, y^2\, dy$

$V = \pi \tan^2\theta \int_0^h y^2\, dy$

$V = \pi \tan^2\theta \frac{h^3}{3}$

OR, IN TERMS OF BASE RADIUS b:

$$\tan\theta = \frac{b}{h}$$

$$V = \pi \frac{b^2}{h^2} \frac{h^3}{3} = \frac{\pi}{3} b^2 h$$

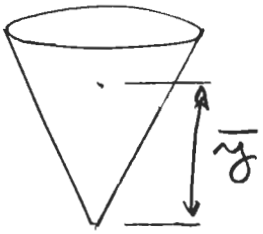
FOR EXAMPLE PART, $\theta = 30°$, $h = 6$ in

$$V = \pi (\tan 30°)^2 \left(\frac{6\text{in}^3}{3}\right) = \boxed{75.40 \text{ in}^3}$$

CENTER OF GRAVITY:

$$\bar{y} = \frac{\int y\,dV}{\int dV}$$

$$\int y\,dV =$$



$$\int (\pi \tan^2\theta\, y^2)\, y\, dy$$

$$= \pi \tan^2\theta \int_0^h y^3\, dy$$

$$= \pi \tan^2\theta \frac{h^4}{4}$$

$$\bar{y} = \frac{\pi \tan^2\theta \, h^4/4}{\pi \tan^2\theta \, h^3/3} = \frac{3h}{4} \quad (\text{OR } \frac{h}{4} \text{ FROM BASE})$$

VOLUME BY SECTION & CIRCUMFERENCE OF ROTATION CIRCLE

$$A = \frac{1}{2} bh$$

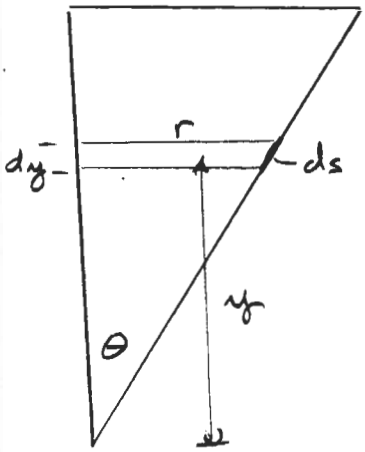
$$r = \frac{1}{3} b$$

$$\text{CIRCUM} = 2\pi\left(\frac{b}{3}\right)$$

$$V = \frac{1}{2} bh \left(2\pi \frac{b}{3}\right)$$

$$V = \frac{\pi}{3} b^2 h \;\checkmark$$

SURFACE AREA:



$r = y \tan\theta$

$$dA = 2\pi r\, ds$$

$dy \perp ds$ $\quad ds = dy/\cos\theta$

$$dA = 2\pi (y\tan\theta)\left(\frac{1}{\cos\theta}\right) dy$$

$$A = 2\pi \frac{\tan\theta}{\cos\theta} \int_0^h y\, dy$$

$$A = \pi \frac{\tan\theta}{\cos\theta} h^2$$

ADD CIRCULAR AREA OF BASE $= \pi b^2 = \pi h^2 \tan^2\theta$

TOTAL SURFACE AREA $= \pi \frac{\sin\theta}{\cos^2\theta} h^2 + \pi h^2 \tan^2\theta$

$$= \pi \frac{\sin 30}{\cos^2 30} (6\text{in})^2 + \pi (6\text{in})^2 \tan^2 30°$$

$$= 75.3982\ \text{in}^2 + 37.6991\ \text{in}^2$$

$$= \boxed{113.10\ \text{in}^2}$$