EGR 110
Engineering Graphics
File: N110IL8

Inventor Lecture #8

Mass Properties of Solids

A powerful analysis feature available in Inventor is the ability to determine the mass properties of complex objects. Many engineering students will later calculate many of these properties in courses like ***Statics*** and ***Mechanics of Materials***. The calculations can become quite involved, even for fairly simple objects, so the ability of Inventor to find mass properties for complex object made of various types of materials is quite impressive.
In particular, Inventor can be used to specify the material type for each part, including the density, and then it can calculate:

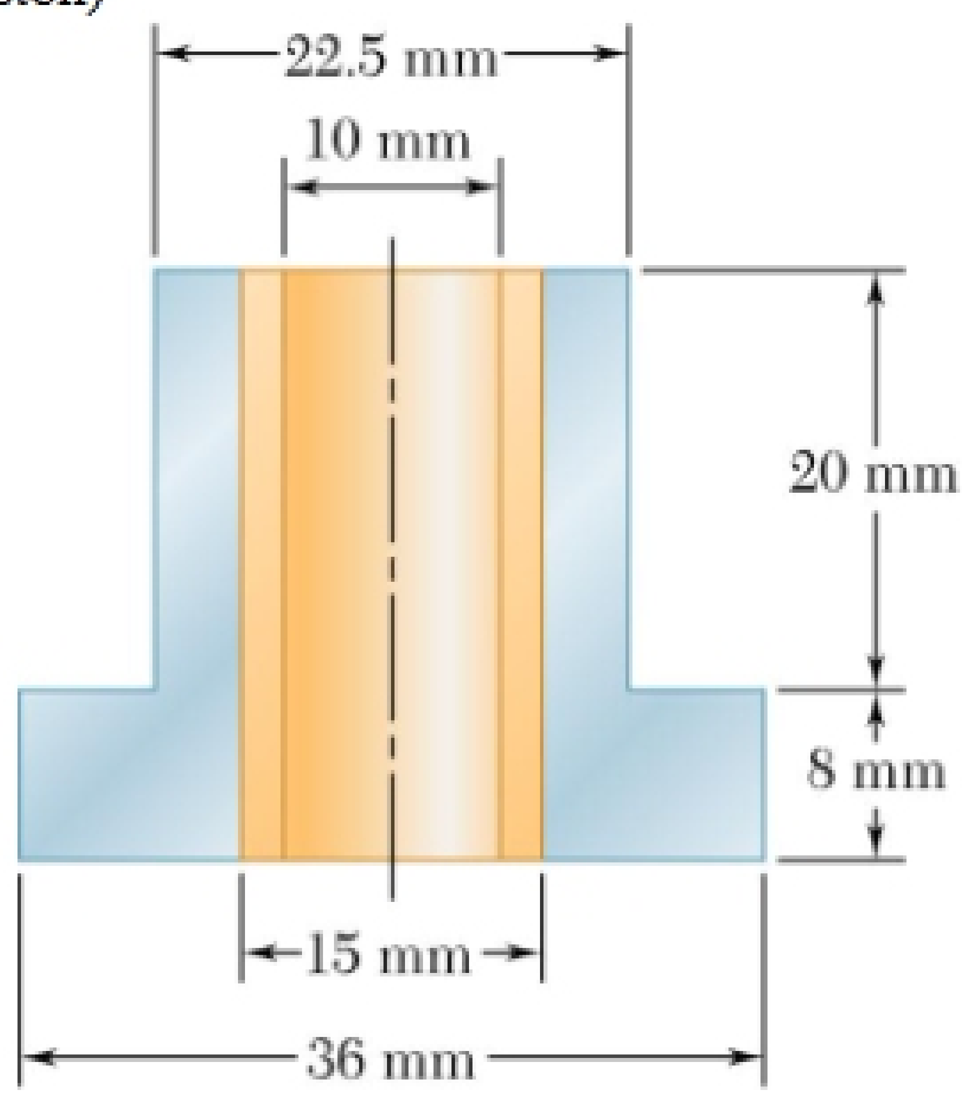
- Volume
- Mass
- Surface Area
- Center of Gravity
- Mass Moments of Inertia
- Principle Moments of Inertia

Center of Gravity

It is often important to know the center of gravity of a part in order to use it properly. The center of gravity of the boom of a crane is important in determining the max load that the crane can lift and weights are added to wheels on automobiles in order to "balance" the wheels such that their center of gravity will be in line with the axle of the wheel.

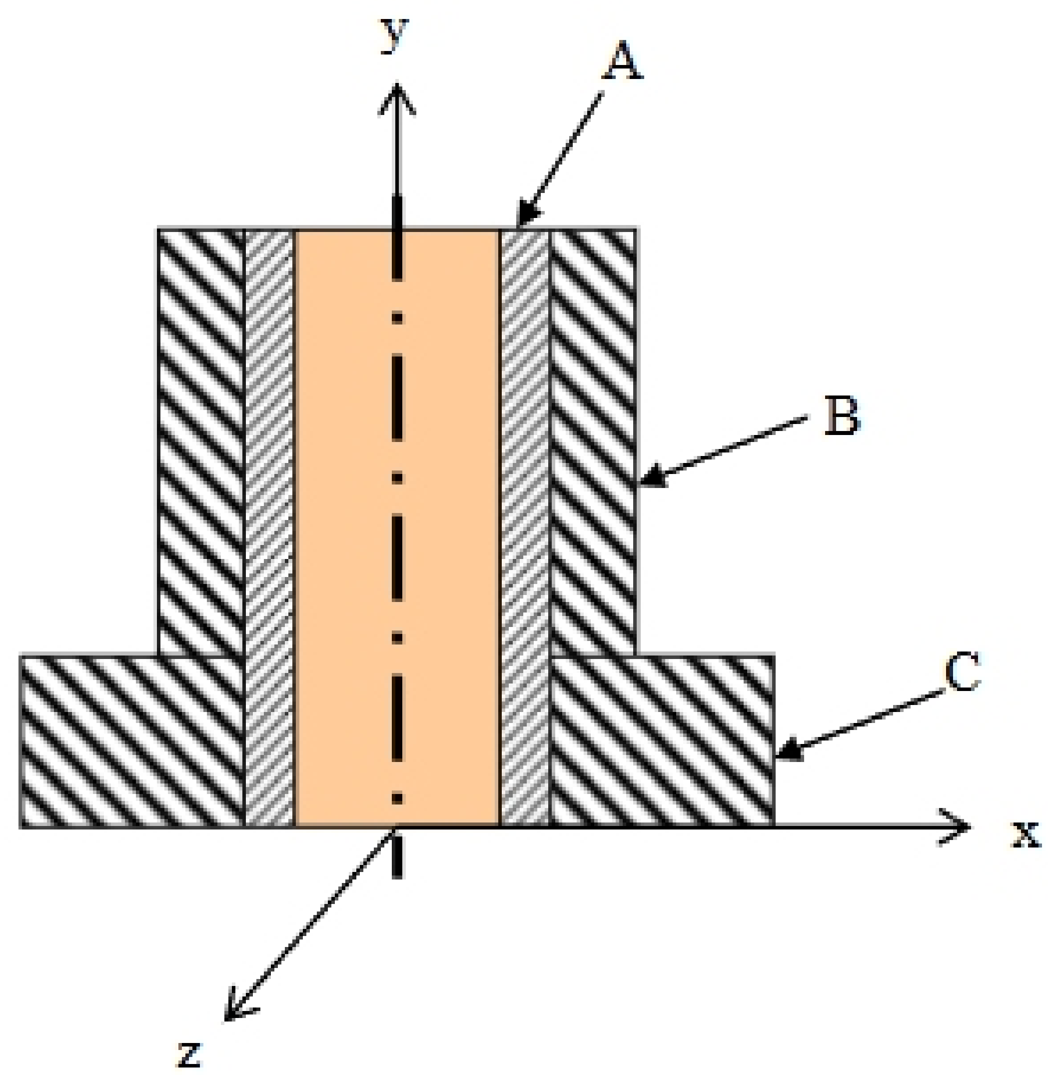
Example: Students taking EGR 140 - Statics will learn to calculate the center of gravity for various types of objects. Shown below is a problem from a Statics text used recently in EGR 140. The solution is also shown. You do not need to understand the solution at this point, but it will be nice to see that we can build the part in Inventor and achieve the same result.

Problem 5-113 (Statics, 7th Edition, by Beer & Johnston)
A bronze bushing is mounted inside a steel sleeve. Knowing that the density of bronze is 8800 kg/m^3 and steel is 7860 kg/m^3, determine the center of gravity of the assembly.



Solution:
The centroid or center of gravity of the referred to as $(\bar{x}, \bar{y}, \bar{z})$

Note that symmetry implies that $\bar{x} = \bar{z} = 0$
so we only need to find $\bar{y}$.
Divide the object into three parts as shown:
A – Bronze bushing
B – Upper part of steel sleeve
C - Lower part of steel sleeve



Note that the volume of a cylinder is:

$$V = \pi \cdot R^2 \cdot H = \pi \cdot \left(\frac{D}{2}\right)^2 \cdot H = \frac{\pi}{4} \cdot D^2 \cdot H$$

and the volume of a hollow cylinder is :

$$V = \frac{\pi}{4} \cdot \left[(D_{outer})^2 - (D_{inner})^2\right] \cdot H$$

so (using values in meters)

$$V_A = \frac{\pi}{4} \cdot \left[(0.036)^2 - (0.015)^2\right] \cdot (0.008) = 6.7293 \times 10^{-6}\ m^3$$

$$V_B = \frac{\pi}{4} \cdot \left[(0.0225)^2 - (0.015)^2\right] \cdot (0.020) = 4.4179 \times 10^{-6}\ m^3$$

$$V_C = \frac{\pi}{4} \cdot \left[(0.015)^2 - (0.010)^2\right] \cdot (0.028) = 2.7489 \times 10^{-6}\ m^3$$

Also note that :

$m = \rho V$ or mass = (mass density)(volume)

and

$W = mg$ or Weight = (mass)(acceleration due to gravity)

and $g = 9.81\ m/s^2$

Part	Material	Volume (m^3)	Mass Density (kg/m^3)	Mass (kg)	Weight (N)	$\bar{y}$ (mm)
A	Bronze	2.749E-06	8874	0.0244	0.2393	14
B	Steel	4.418E-06	7860	0.0347	0.3406	18
C	Steel	6.729E-06	7860	0.0529	0.5189	4
B and C	Steel	1.115E-05	- - -	0.0876	0.8595	9.55
A, B, and C	- - -	1.390E-05	- - -	0.1120	0.8595	10.52

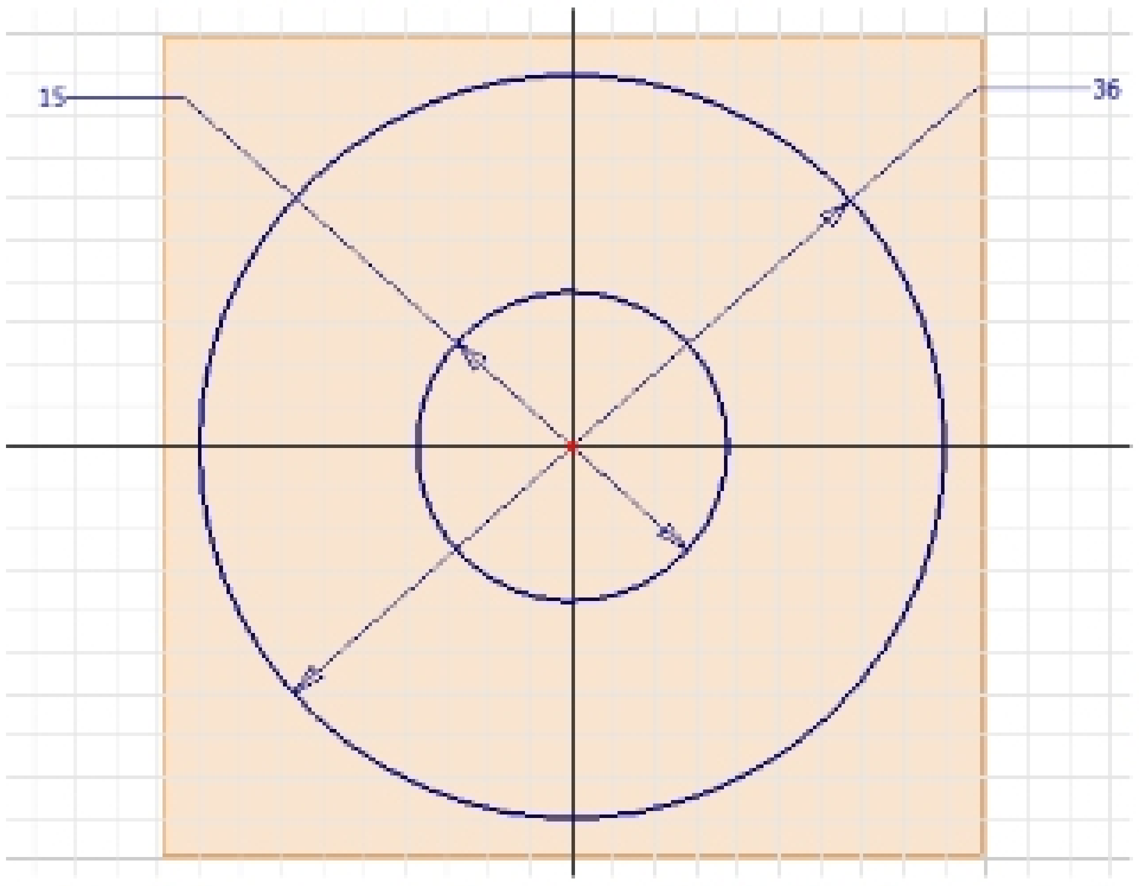
The centroid is calculated using a weighted average of the centroids of each part, so

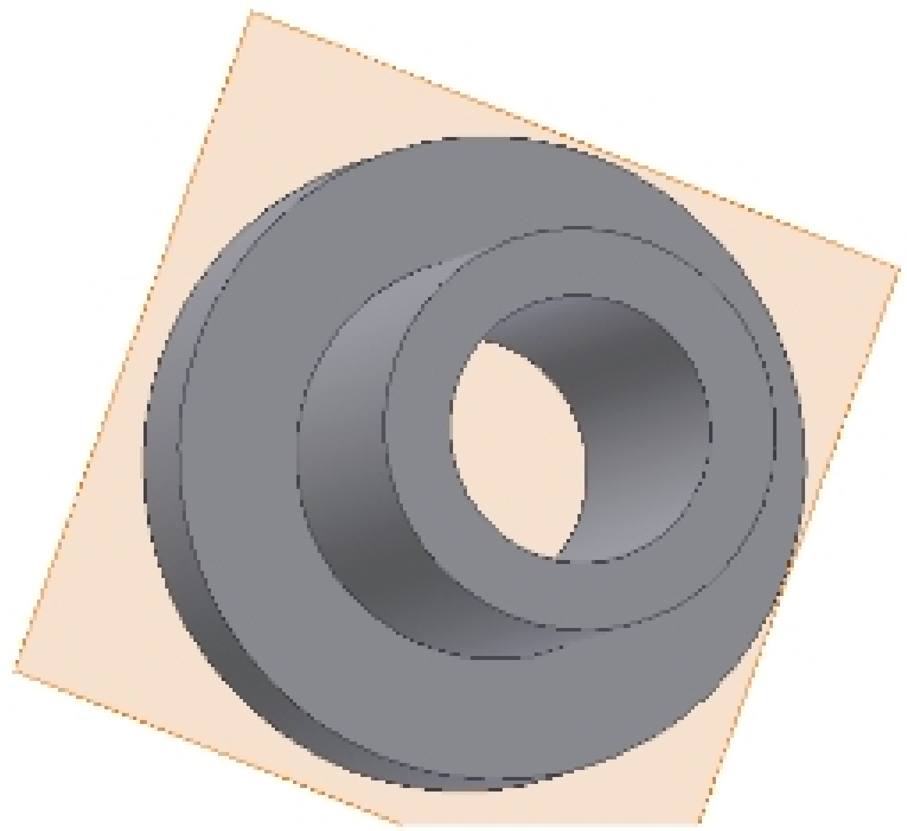
$$\bar{y}_{ABC} = \frac{\sum \bar{y}W}{\sum W} = \frac{y_A W_A + y_B W_B + y_C W_C}{W_A + W_B + W_C} = \frac{14(0.2393) + 18(0.3406) + 4(0.5189)}{1.0988} = 10.52 \text{ mm (entire assembly)}$$

$$\bar{y}_{BC} = \frac{\sum \bar{y}W}{\sum W} = \frac{y_B W_B + y_C W_C}{W_B + W_C} = \frac{18(0.3406) + 4(0.5189)}{0.8595} = 9.55 \text{ mm (entire steel portion)}$$

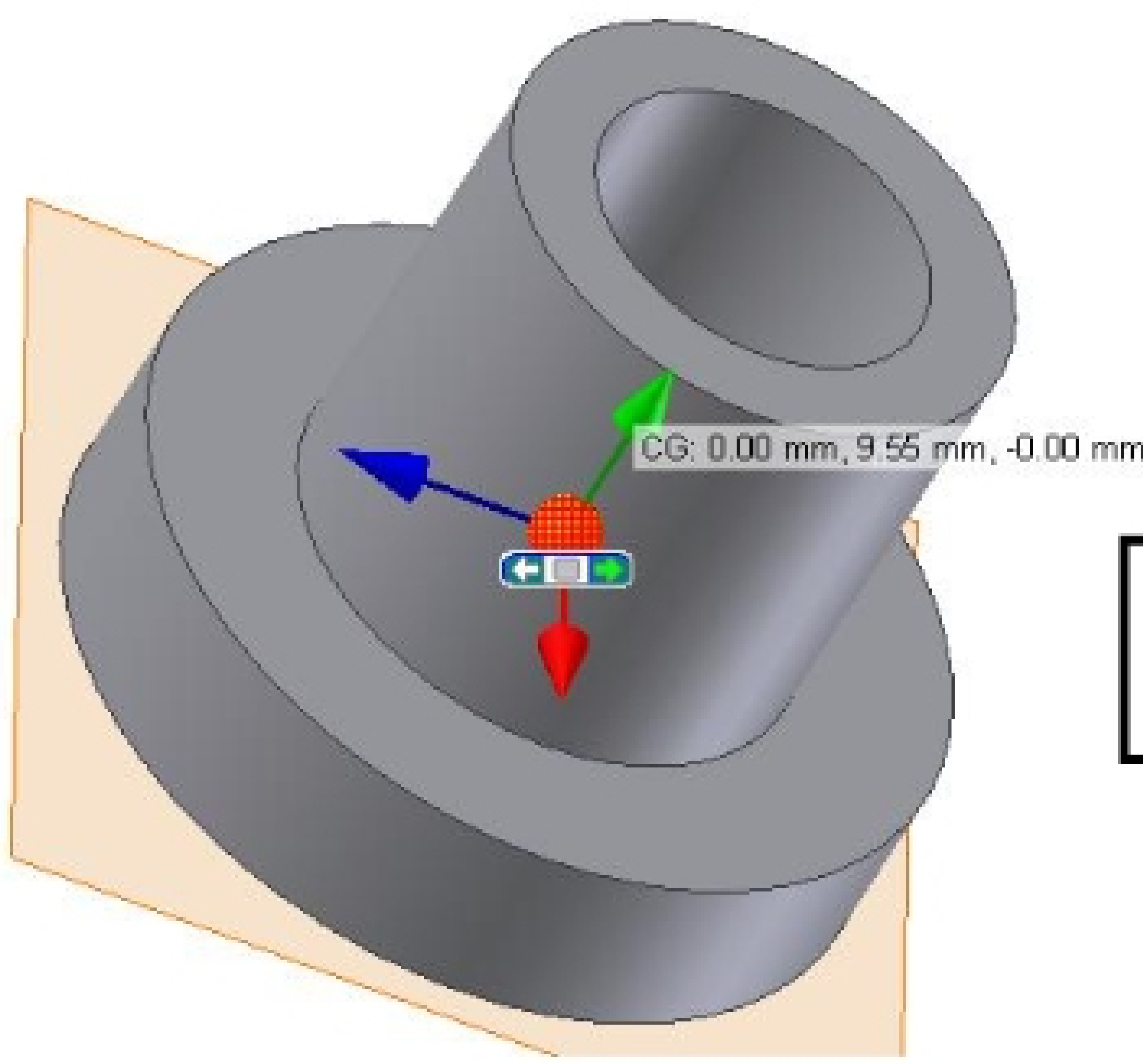
Example: Build of model of Problem 5-113 above and use the mass properties of Inventor to find the center of gravity.

1. Create a metric part for the **steel sleeve**
   - Since the solution above has the axis of the assembly along the y-axis, begin the part by:
     - Selecting on the **xz plane**
     - Making the xz plane **visible**
     - Adding a Sketch Plane to the xz plane
   - It is important that the position of the object is known precisely with respect to the origin, so select **Project Geometry** from the 2D Sketch Panel and then pick **Center Point** under the browser. The Center Point should be clearly seen as a dot on the sketch plane.
   - Note that two extrusions are required for the part. Only the sketch plane for the first extrusion is shown below.





2. Find the center of gravity (CG) for the steel sleeve just created. To do this:
   - Select **View – Center of Gravity** from the main menu. The center of gravity axes icon should appear. Note that the origin of this icon is located at the CG.
   - Pause the mouse over the center of gravity symbol until the select tool appears. Click on one of the arrows until the coordinates for the CG appear. Note that the axes are color coded as follows:



x-axis: Red
y-axis: Green
z-axis: Blue