Center of Gravity

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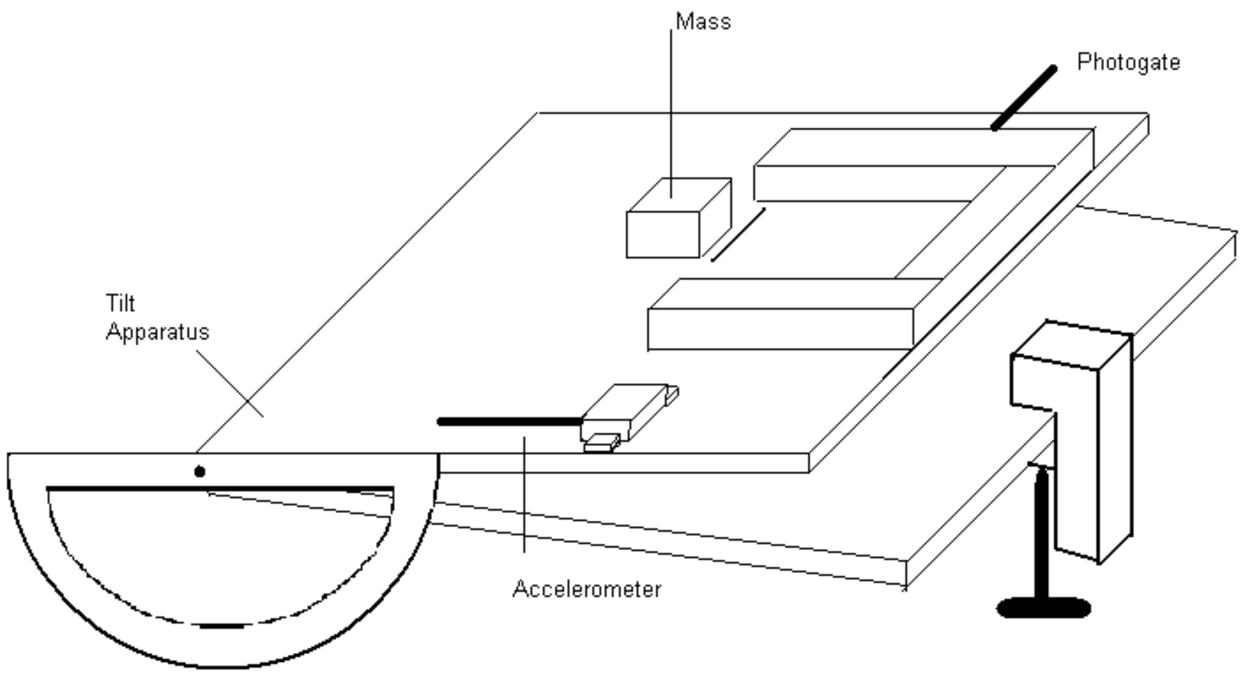
Introduction:

The weight of a body, although distributed throughout the object, can be said to be focused at a single point. This point is called the center of gravity. The ability to locate the center of gravity can be seen from a variety of common actions, such as balancing a ruler at a single point or balancing a baseball bat atop a single finger. It is understandable therefore that the entire body can be balanced, controlled, and simulated through that single point.

In this experiment, we are going to perform a toppling experiment. We will use an enhanced version of a tilt apparatus to see how different masses with varying heights and density distribution affect the angle at which the object will topple. After the data is going to be acquired, it will be left up to the students to infer where the C.G. (Center of Gravity) of the object is located.



Background:

1. The center of gravity is defined as the average point on a body in which the average location of the weight of that object lies. The C.G. is a geometric point and hence a geometrical property and therefore can be understood through physical experimentation such as the balancing of a body at different points.

2. As formulated the general expression for the center of gravity involves a mathematical formulation of an average calculation, except in this case instead of taking an average of actual numbers, we will take it of the average mass.

I. $C.G. = \frac{\text{Sum of the product of the infitesimal weight and the displacement from the origin to that weight}}{\text{Total Weight}}$

II. $C.G. = \frac{\sum w \bullet \Delta d}{W}$

3. With the definition of the center of gravity known, it is useful to know the importance of this concept. We can completely describe the motion of any object through space in terms of the translation of the center of gravity of the object from one place to another and the rotation of the object about its center of gravity if it is free to rotate. If the object is confined to rotate about some other point, like a hinge, we can still describe its motion.[i]

4. In this experiment, we will place a mass on the tilt apparatus and constantly change the angle of the tilt apparatus using spring like motion. Once the center of gravity of the object exceeds its stability margin it will tip or begin sliding. Once the object moves from its original position the photogate will detect its motion and record it in the software as a gatestate change, marked by a 0 or 1, after which the angle at which it tipped can be recorded by taking the angle right before the state change.

Equipment List:

1. Tilt apparatus.
2. Protractor.
3. 3 different uniform masses.
4. 3 different non-uniform masses with different density distribution.
5. Computer with Logger Pro software
6. Vernier LabPro
7. Vernier Low-G Accelerometer
8. Table Clamp
9. Beaker

Experimental Procedure:

Part I. – Center of gravity with uniform densities.

1. Adjust the tilting apparatus so that the initial angle is at its minimum.
2. Weight the first mass and record it in the first part of the results section.
3. Place the mass on the apparatus and press the collect button while simultaneously lifting the apparatus to an increasing angle until it topples.
4. Once the mass topples over the computer will record the information in the "Gatestate" column.
5. The angle at which the object topples can be found by the point previous to the "Gatestate" state change in the "Angle" column.

6. Record the true angle at which it toppled over in part one, in the results section of the lab by taking the difference from the initial angle.
   III. $\theta_{true} = \theta_{measured} - \theta_{\text{initial}}$
7. Measure the volume of the mass by taking a marked beaker filled with some water.
8. Place the mass inside the beaker and take the difference in the volume measurement to get the true volume of the mass.
   IV. $V_{true} = V_{measured} - V_{\text{initial}}$
9. Repeat procedures 1 through 7 for the same mass, to see if you get a variation in the measurements.
10. Repeat procedures 1 through 8 with the remaining two masses.

Part II. – Center of gravity with non-uniform densities.

1. As in part I of the experiment you will precede with the same method except the three objects that you are working with have different materials molded together.
2. Repeat procedures 1 through 8 of part I of the experiment and record this information in part II of the results section, with an additional column for the object number.

Results:

Part I. – Center of gravity with uniform masses.

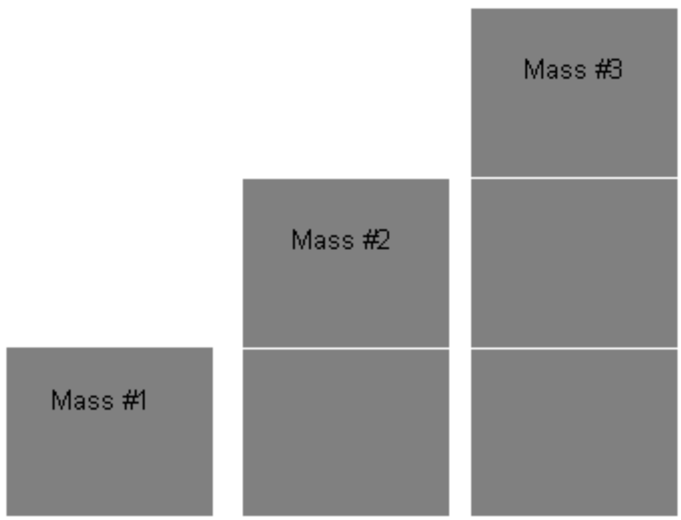
Trials	Weight, [g]	Angle, [deg]	Volume, [cm^3]
1			
2			
3			
1			
2			
3			
1			
2			
3			

Part II. – Center of gravity with non-uniform masses.

Trials	Object, [#]	Weight, [g]	Angle, [deg]	Volume, [cm^3]
1				
2				
3				
1				
2				
3				
1				
2				
3				

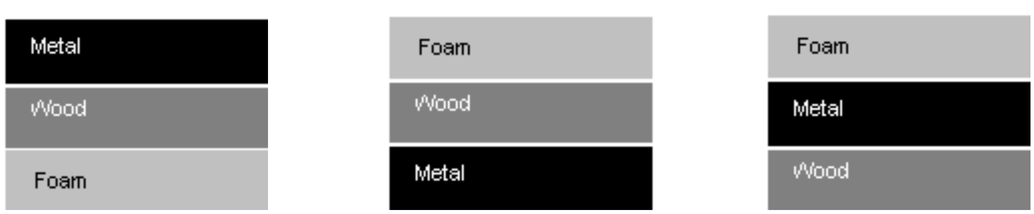
Analysis:

1. Calculate the average values for the masses in both parts of the experiment
2. Calculate the average densities for the objects in part II.
3. Based on the angle measurements, approximate where the center of gravity is located for each object.
4. What inferences can you make based on the location and the tip angle of the objects.
5. In part I of the experiment masses 1, 2, and 3 have the same shape and size but their masses varied, also it is known that their densities are uniformly distributed throughout the volume of the object.



Explain, why based on the data and the statement that if the object has both a uniform density distribution and a uniform shape, then the center of mass is located in the average geometrical point on the object is true.

6. In part II of the experiment object 1, 2 and 3 have the same materials fixed together except their arrangements are different.



Explain in your words why different arrangements of the same materials will affect the center of gravity for these objects.

References:

[i] wright.nasa.gov/ airplane/cg.html