Experiment P08: Equilibrium of a Rigid Body

Purpose

To use the principle of balanced torques to find the value of an unknown distance and to investigate the concept of center of gravity.

Equipment and Supplies

Meter stick
Standard masses with hook
Triple-beam balance
Fulcrum
Fulcrum holder

Discussion of equilibrium

First condition of equilibrium

An object at rest is in equilibrium (review rotational equilibrium in your text). The vector sum of all the forces exerted on the body must be equal to zero.

$$\sum \mathbf{F} = \mathbf{0}$$

Second condition of equilibrium

The resting object also shows another aspect of equilibrium. Because the object has no rotation, the sum of the *torques* exerted on it is zero.

$$\sum \boldsymbol{\tau} = \mathbf{0} \qquad \boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$$

r is position vector relative to the fulcrum

F is the force acting on the object at point, r

When a force produces a turning or rotation, a non-zero *net* torque is present.
A see-saw balances when any torque on it add up to zero. A see saw is form of lever, simple mechanical device that rotates about a pivot or fulcrum. Although the work done by a device such as a lever can never be more than the work or energy invested in it, levers make work *easier* to accomplish for a variety of tasks. Knowledge of torques can also help us to calculate the location of an object's *center of gravity*.

Earth's gravity pulls on every part of an object. It pulls more strongly on more massive parts and more weakly on less massive parts. The sum of all these pulls is the weight of the object. The average position of the weight of an object is its center of gravity, or CG.

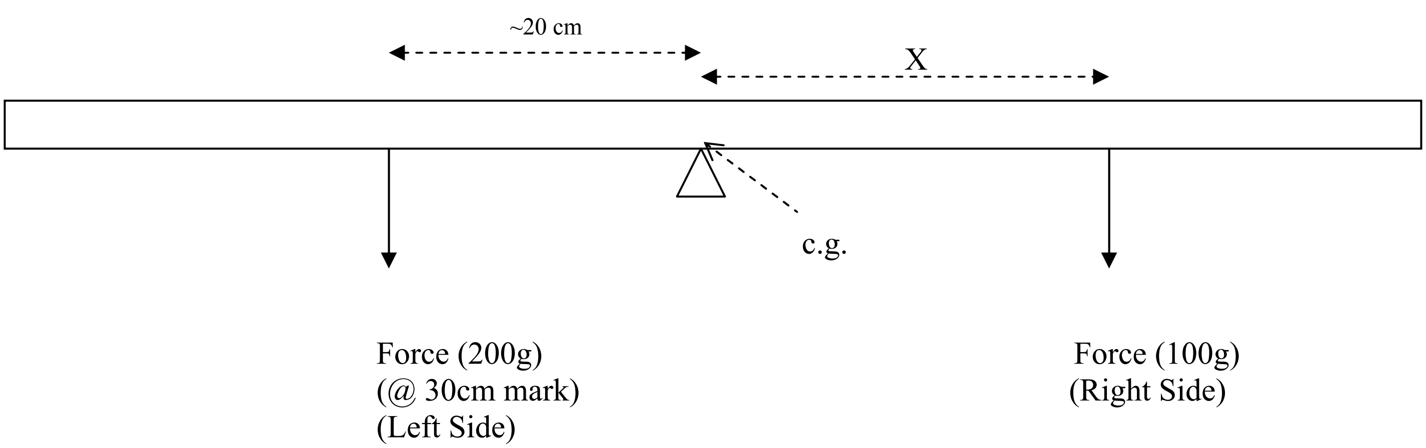
The CG of a uniform meter stick is at the 50-cm mark. In this experiment you will balance a meter stick with three known values (M_1, M_2, and X_1). You will have to compute the unknown distance of X_2.

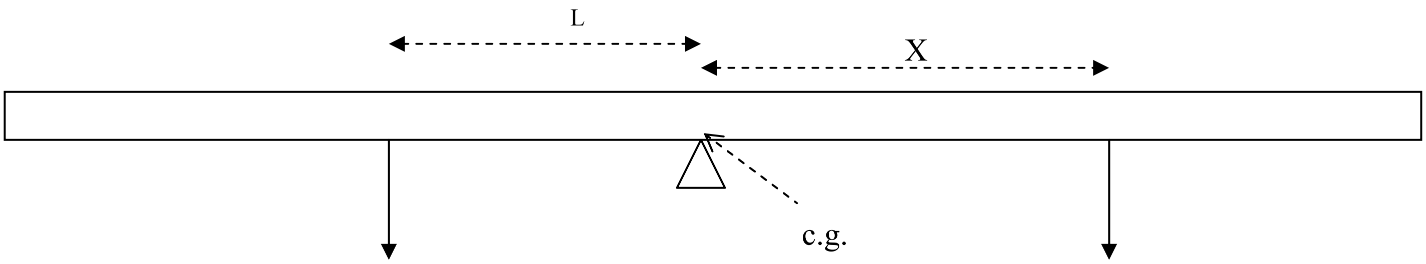
Procedure

Step 1. Measure the masses of each holder and the meter stick.
Balance the meter stick horizontally on the fulcrum with nothing hanging from it.
Record the position of the CG of the meter stick.

Step 2. Place 200-g mass on a fulcrum holder at the 30-cm mark on the meter stick. Find the position where 100-g mass will produce equilibrium.
Determine the distance X between the 100-g mass and the pivot point.

PART I: Fulcrum at Center of Gravity (c.g.)





$M_{(200g)}$
$M_{(200g)} * g + M_{(LH)} * g$

M (100g)
$M_{(100g)} * g + M_{(RH)} g$

Mass of Meter Stick =______________

Mass of Left Weight Holder =____________ **Mass of Right Weight Holder =____________**

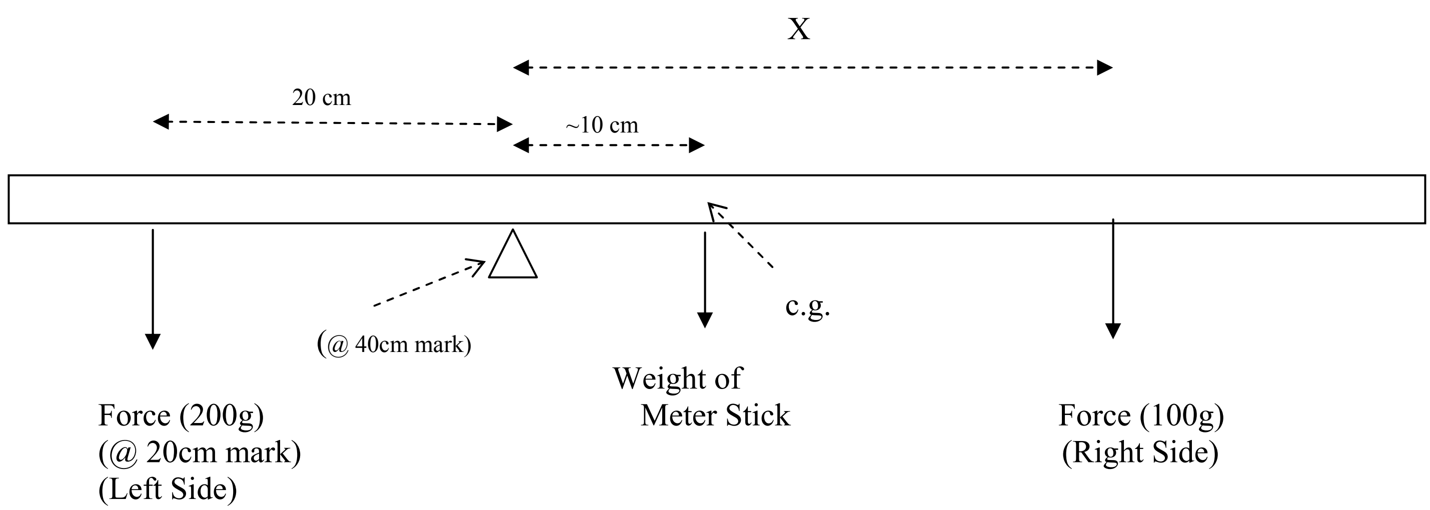
Analyzing the data

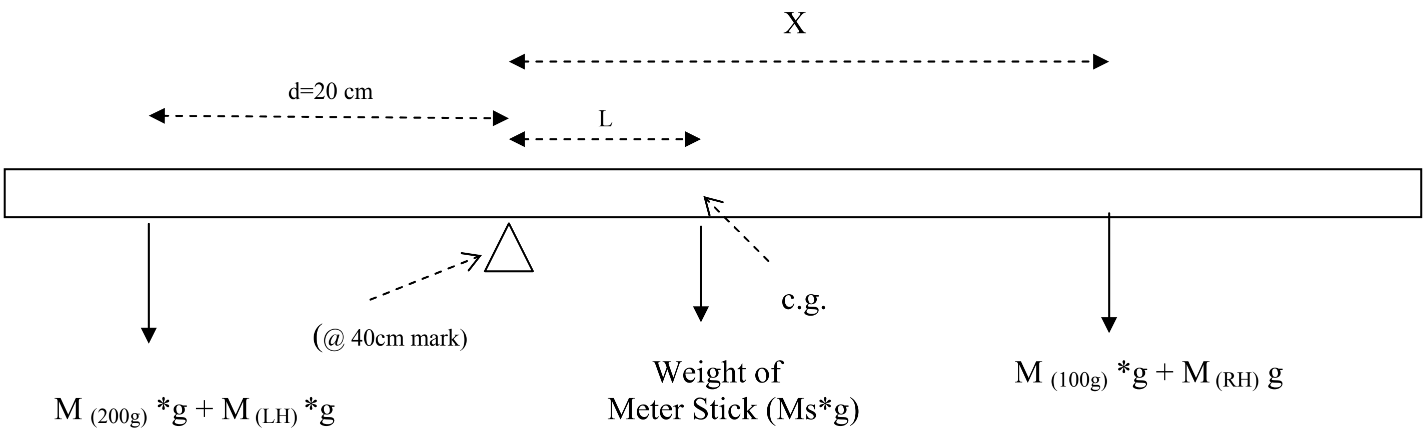
$$X_{theory} = \frac{(M_{200} + M_{LH}) * L}{(M_{100} + M_{RH})} =$$

$$\% \text{ error} = \frac{|X_{exp} - X_{theory}|}{|X_{theory}|} * 100 =$$

Step 3. Move the pivot position to a 40-cm mark on the meter stick and place 200-g mass at the 20-cm mark. Repeat *Step 2* and find the point where 100-g mass should be suspended to produce equilibrium. Determine the distance X between the 100-g mass and the pivot point.

PART II: Fulcrum at 40 cm mark (~10 cm to the left of the c.g.)





Mass of Meter Stick =______________

Mass of Left Weight Holder =____________ **Mass of Right Weight Holder =____________**

Analyzing the data

$$X_{theory} = \frac{(M_{200} + M_{LH}) * d - Ms*L}{(M_{100} + M_{RH})} =$$

$$\% \text{ error} = \frac{|X_{exp} - X_{theory}|}{|X_{theory}|} * 100 =$$

Questions

1. How well did your experiment check the two conditions of equilibrium? Explain.

2. What is the effect of each condition of equilibrium on the motion of a rigid body?