I. Objectives

1. Investigate the basic principles of equilibrium, force and torque in a non-rotating system.
2. Given the location of a mass, determine the position of the other required to maintain the system in equilibrium.

II. Introduction

This lab utilizes masses. You must wear closed-toed shoes during this entire lab.

In order for the system, consisting of a rotatable object, like the beam and any added masses, to be in equilibrium, meaning that it is not rotating, the sum of all the forces must be zero and the sum of all the torques must be zero. We will also assume that the 50-cm long beam is uniform, so its center-of-gravity is at the center of the beam.

III. Calculations

We need to define some symbols to represent the situation, and will assume that the origin of our coordinate system is at the left end of the beam:

m_L = 500 g, mass to the left of the fulcrum

m_R = 1,000 g, mass to the right of the fulcrum

d_L = location of 500 g mass from the left end of the beam

d_R = location of 1,000 g mass from the left end of the beam

ℓ_L = distance of m_L from the fulcrum = 25 cm - d_L

ℓ_R = distance of m_R from the fulcrum = d_R – 25 cm

F_L = downward force exerted by m_L

F_R = downward force exerted by m_R

τ_{CC} = counterclockwise torque produced by 500 g mass

τ_C = clockwise torque produced by 1,000 g mass

The counterclockwise torque is:

$$\tau_{CC} = F_L(25\,cm - d_L)$$

$$\tau_{CC} = F_L \ell_L$$

The clockwise torque is:

$$\tau_C = F_R \ell_R$$

$$\tau_C = F_R (d_R - 25\ cm)$$

In order for the system to be in equilibrium, meaning that it is not rotating, theoretically:

$$\tau_{CC} = \tau_C$$

and by substitution:

$$F_L (25\ cm - d_L) = F_R (d_R - 25\ cm)$$

We can then calculate d_R:

$$F_R (d_R - 25\ cm) = F_L (25\ cm - d_L)$$

$$d_R - 25\ cm = \frac{F_L (25\ cm - d_L)}{F_R}$$

$$d_R = \frac{F_L (25\ cm - d_L)}{F_R} + 25\ cm$$

and ℓ_R:

$$\ell_R = d_R - 25\ cm$$

IV. Equipment and Materials

New York balance, 500 g mass, 1,000 g mass, level, calculator

V. Procedure

1. Complete Table 1. Note that the values of F_L and F_R will not change.

2. **Be careful with the equipment! It is fragile!**

3. Adjust the beam so that it balances on the fulcrum at exactly the 25 cm mark. Be sure that once it stops moving, it is level. If not, rotate the screws at the ends of the beam until it is level.

4. Place the 500 g mass at the location d_L indicated in Table 1 for Trial 1. **Do not allow the mass to drop before you have placed the 1,000 g in approximately the correct location.**

5. Adjust the location of the 1,000 g mass and record its location in Column B of Table 2.

6. Repeat the two previous steps for the remaining 4 trials.

7. Complete Table 2.

VI. Data

Table 1 Calculated Torques and 1,000 Gram Mass Location

A	B	C = 25 - B	D	E	F	G	H = G - 25
Trial	d_L in cm	ℓ_L in cm	F_L in dynes	Calculated $\tau_{CC} = \tau_C$ in dyne cm	F_R in dynes	Calculated d_R in cm	Calculated ℓ_R in cm
1	5.0						
2	10.0						
3	12.5						
4	15.0						
5	17.5						

Table 2 Actual 1,000 Gram Mass Location

A	B	C = B - 25	D	E	F	G = | E – F |	H
Trial	Experi-mental d_R in cm	Experi-mental ℓ_R in cm	F_R in dynes, from Table 1, Column F	Experi-mental τ_C in dyne cm	Calculated τ_C in dyne cm from Table 1, Column E	Difference between experi-mental and calculated τ_C in dyne cm	Difference between experi-mental and calculated τ_C in N m
1							
2							
3							
4							
5							

VII. Discussion Questions

1. What conversion factor and calculations are required to calculate the force in dynes for a corresponding mass in grams?

2. What is the conversion required to convert centimeters to meters?

3. Show the calculations necessary to convert 1,000,000 dyne cm to N m

4. Assuming that the beam is massless, how much *weight* (not mass) in dynes is the beam supporting?

5. Other than mathematical errors, what could account for the differences between the calculated and experimental values of τ_C ?