Experiment 8: Torques and Rotational Motion

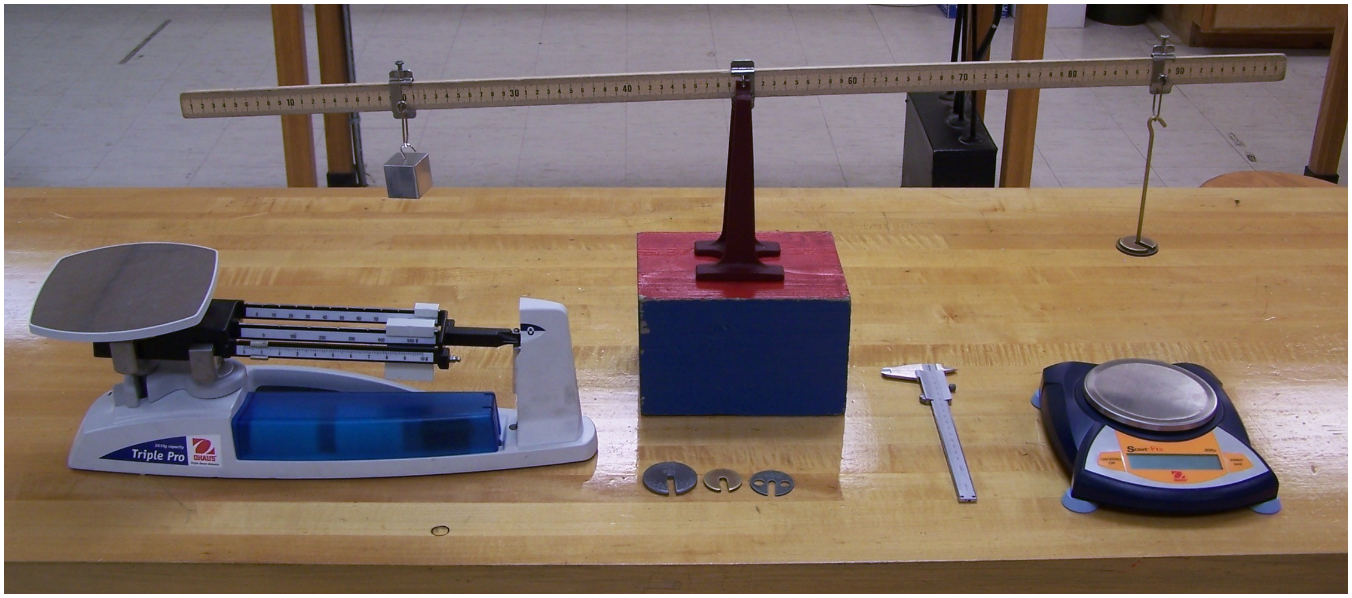

Figure 8.1: The wood block provides necessary height for the hangers to not touch the table.

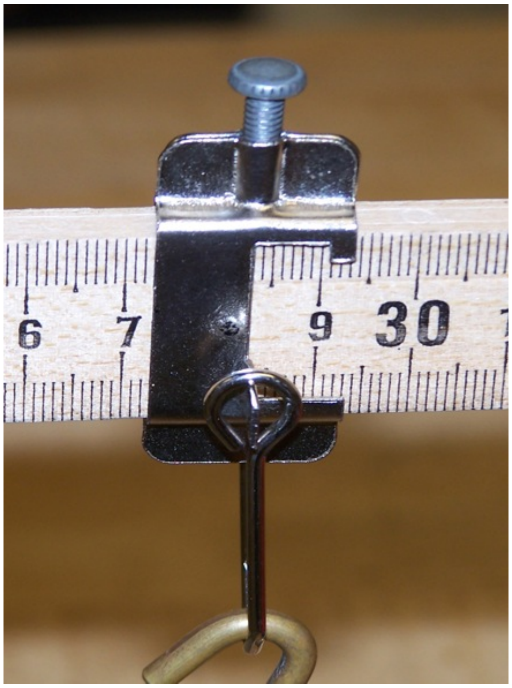

Figure 8.2: Clamp - *The arrow indicates the correct edge for position measurement.*

EQUIPMENT
Fulcrum
Meter Stick
Vernier Caliper
(3) Mass Hangers
Masses
(3) Hanger Clamps (Clamps)
(1) Knife-Edge Clamp
Digital Balance
Triple-Beam Balance
Block of Wood
Unknown Mass (Marble or "Silver" Cube)

TA's Table:
(1) Dial-O-Gram Balance

Advance Reading

Text: Torque, center of mass, stable and unstable equilibrium, lever arm

Lab Manual: Appendix B

Objective

To measure torques on a rigid body, to determine the conditions necessary for equilibrium to occur, to perform error analysis.

Theory

When a force F is applied to a rigid body at any point away from the center of mass, a torque is produced. Torque, τ (Greek letter, *tau*), can be defined as the tendency to cause rotation. The magnitude of the vector is:

$$\tau = rF\sin\theta \tag{8.1}$$

where r is the distance from the point of rotation to the point at which the force is being applied (*i.e., lever arm*), and $F\sin\theta$ is the component of the force perpendicular to r. Note that the unit for torque is mN (meter × newton).

In this experiment, all forces will be acting normal (perpendicular) to the meter stick: $\theta = 90°$; therefore, $\sin\theta = 1$. The equation for torque is simplified:

$$\tau = rF \tag{8.2}$$

Equilibrium, Latin for *equal forces* or *balance*, is reached when the net force and net torque on an object are zero. The first condition is that the vector sum of the forces must equal zero:

$$\Sigma\vec{\mathbf{F}} = \Sigma F_x = \Sigma F_y = \Sigma F_z = 0.0 \text{ N} \tag{8.3}$$

The second condition that must be met is that the net torques about any axis of rotation must equal zero. We will use the standard convention for summing torques. Torques that tend to cause counterclockwise rotation, τ_{cc}, will be positive torques, while torques that tend to cause clockwise rotation, τ_c, will be negative torques.

$$\Sigma\vec{\tau} = \Sigma\vec{\tau}_{\mathbf{cc}} - \Sigma\vec{\tau}_{\mathbf{c}} = 0.0 \text{ mN} \tag{8.4}$$

The system under consideration for this experiment will need to not only attain equilibrium, but also remain in equilibrium. This will require that the object be in *stable equilibrium*, meaning if a slight displacement of the system occurs, the system will return to its original position (*e.g.*, a pendulum). If the system were to move farther from its original position when given a slight displacement, it would be in *unstable equilibrium* (*e.g.*, a ball on a hill).

Once stable equilibrium has been attained for each experimental arrangement, measure the mass at each position using the appropriate balance.

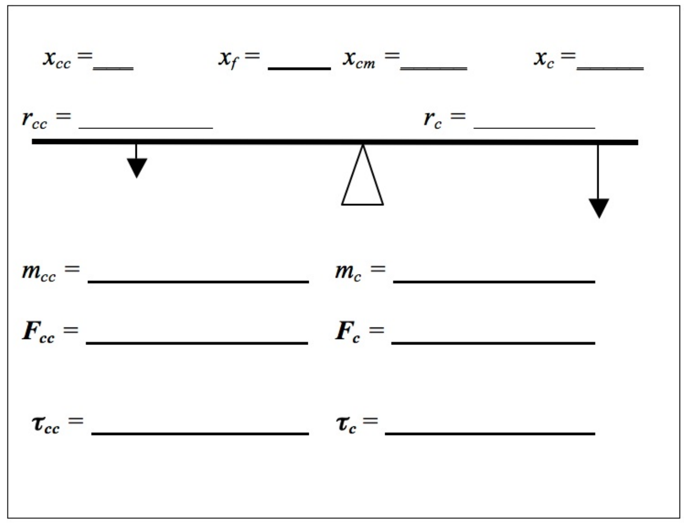

Figure 8.3: Required sketch for each experimental arrangement

Once stable equilibrium is attained, sketch each set-up:

- x: position
- F: magnitude of force
- *Arrow*: direction of force
- r: lever arm
- *cc*: counterclockwise
- *c*: clockwise
- *cm*: center of mass
- *f*: fulcrum