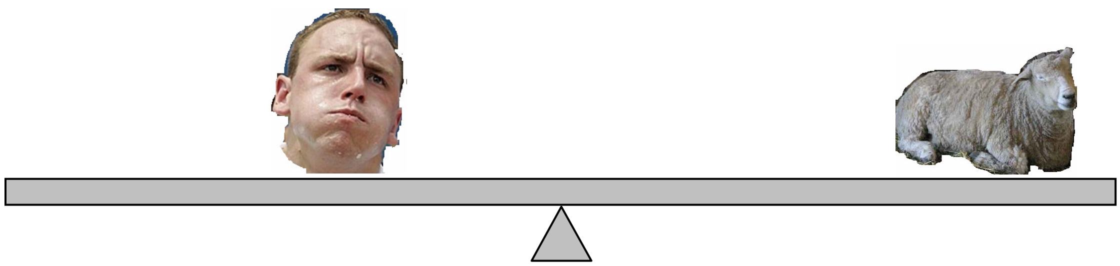
Experiment: Torque & Rotation

Objectives

- To compare the rotational motion of objects rolling down an incline
- Calculate the moment of inertia for various objects
- To apply the concept of torque and mechanical equilibrium to a balanced meter stick
- Calculate the mass of a meter stick knowing the conditions of equilibrium of a rigid body

Preliminary Questions:

Joey and a sheep are sitting on a teeter-totter. Ignore the effects of friction and mass of their mutual attraction as well as that of the teeter-totter.



a) Joey (with a mass of 60 kg) sits 2.0 m from the fulcrum. What is the torque exerted by Joey on the teeter-totter?

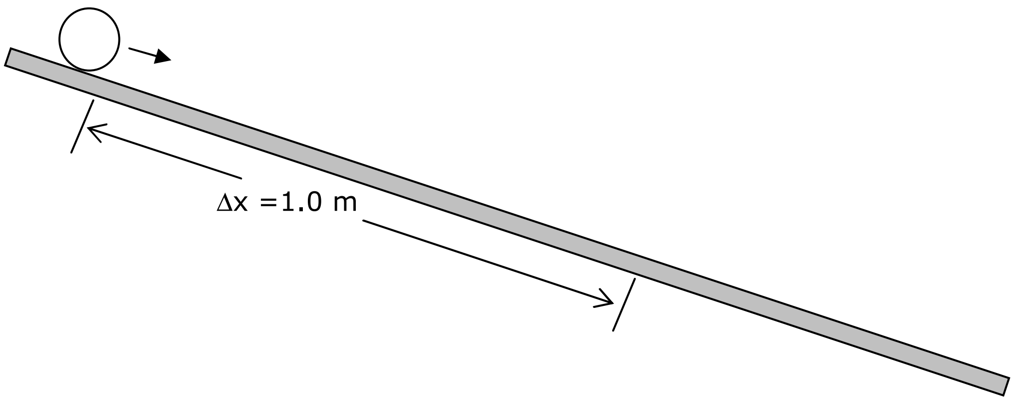
b) For the teeter-totter to balance with the sheep sitting on the opposing end, how much torque must she exert on the teeter-totter?

c) Draw a free-body vector diagram for the teeter-totter.

d) If sheep has a mass of 40 kg, how far from the fulcrum must she sit so that the teeter-totter balances?

A) Rotational Inertia

1) Obtain a hollow cylinder (a tin can with both ends cut out), a solid can (a full can of "ravioli" ought to do the trick), a solid (steel bearing) and a hollow sphere (racquetball).
2) Using a collision track, set-up a ramp at a slight incline.



3) Measure a 1.0 m distance along the incline. Use tape to mark the beginning and end points.
4) Using a stop watch, measure the time it takes for the hollow cylinder to roll 1.0 m down the ramp. Record the distance and time in the data table below.
5) Repeat for each object.

Object	$\Delta x_{along\ ramp}$ (m)	Δt (s)	Average Acceleration (m/s^2)

Question: Which object reached the bottom in the shortest amount of time? Arrange the objects in order time (shortest to longest).

6) Calculate the average acceleration of each object. Use the following equation from kinematics:

$$a_{average} = 2 \cdot \Delta x / t^2$$

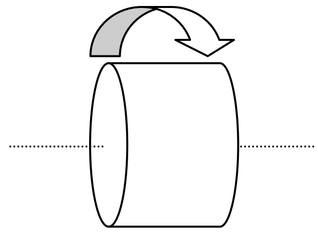
Record the acceleration values in the table above.

Question: Arrange the objects in order of average acceleration (highest to lowest).

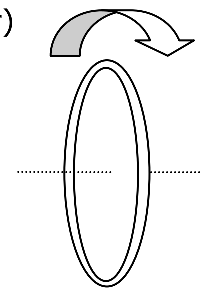
7) Using your textbook as a reference, calculate the moment of inertia for the following objects:

{For these calculations, assume that the mass (m) of each object is 0.1 kg and the radius, r, is 0.5 m}

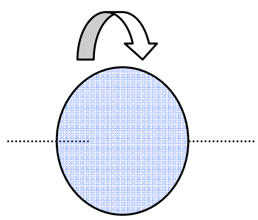
a) a solid disc



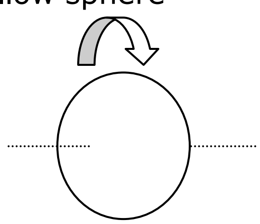
b) a ring (or hollow cylinder)



c) a solid sphere



d) a hollow sphere



Question: Which of the above objects has the smallest rotational inertia? Arrange the objects in order their rotational inertia (low to high).

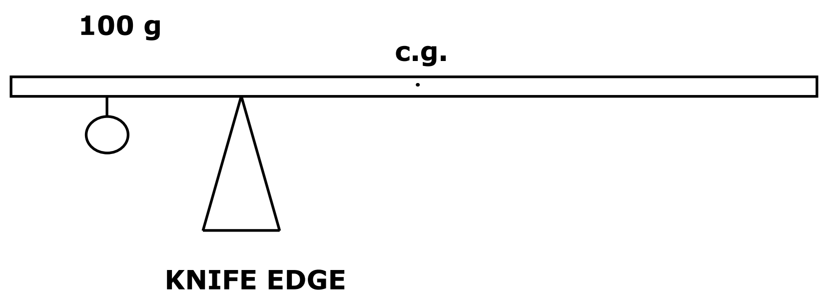
Question: How does the order of rotational inertia values compare with the order of time and acceleration values above?

B) Mechanical Equilibrium & Torque:

1) Find the position of the knife-edge that balances the meter stick (do not weigh the meter stick ahead of time). This locates the center of gravity for the meter stick.

2) Attach a 200 gram mass at the 90 cm position.

3) Re-adjust the position of the knife edge such that the meter stick is once again balanced.



4) Draw a force vector diagram for the meter stick.

5) Apply Newton's 2nd Law to the meter stick:

Force:

Torque:

6) From the conditions of equilibrium, $\Sigma F=0$ and $\Sigma\tau=0$, calculate the mass of the meter stick.

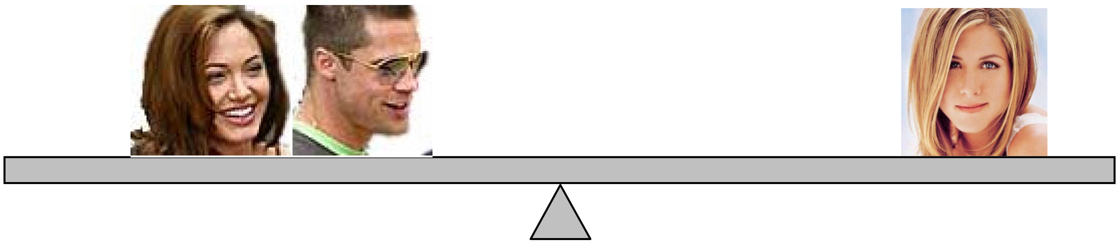
Calculated $m_{meter\ stick}$ = ______________

7) Check this value by a direct weighing of the stick. Also, calculate the % error.

Measured $m_{meter\ stick}$ = ______________

% Error = ______________

Final Question: Brad and Angelina are sitting together on one end of a teeter-totter ($m_{teeter\text{-}totter}$ = 20 kg) while Jennifer ($m_{jennifer}$ = 45 kg) is sitting on the opposite end. Brad (m_{brad} = 80 kg) sits 1.5 m from the fulcrum and Angelina ($m_{angelina}$ = 50 kg) shamelessly nudges against him sitting 1.8 m from the fulcrum.



a) Draw a simple force vector diagram of the 3-person teeter-totter system.

b) Apply Newton's 2nd Law (torque-only) to the balanced teeter-totter.

c) For the teeter-totter to balance with Jennifer on the opposing end, how much torque must she exert on the teeter-totter?

d) How far from the fulcrum must Jennifer sit so that the teeter-totter balances?

e) Apply Newton's 2nd Law (for force-only) to the balanced teeter-totter.

f) How much force does the fulcrum exert on the teeter-totter?