Torque

Introduction: Forces acting through the center of mass of an object cause acceleration; forces acting at some other location on an object cause rotation and are called torques.

Theory: The mathematical definition of torque is:

$$\vec{\tau} = \vec{r} \; X \; \vec{F}$$

Equation 1

where the torque vector is projected into the plane described by *r* and *F* in a right-handed coordinate system. Of course, this reduces to:

$$\tau = rF \sin\theta$$

Equation 2

Just because a system isn't apparently rotating doesn't mean that there are no torques are present; it may be that all the torques are in equilibrium about a point. A typical case is a beam of length *L* supported by a wire or cable:

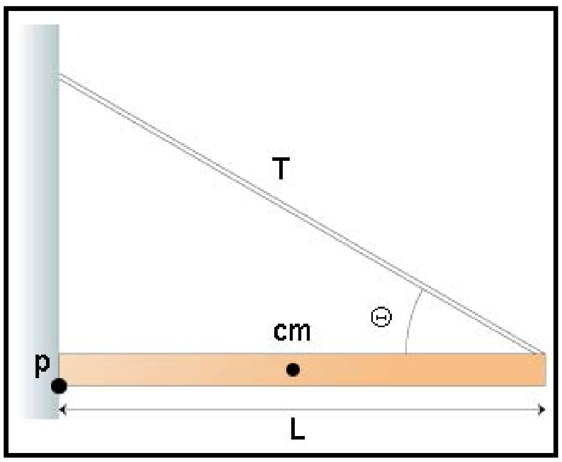

Figure 1

The tension *T* in the cable prevents the beam from rotating clockwise about the pivot *p*. What are the torques? The weight of the (uniform) beam acts at the center of mass (*cm)* halfway along the length *L*, so the clockwise torque is *mg L*/2. The y-component of the tension acting at the right end of the beam provides the counterclockwise torque; setting the torques equal to each other (the equilibrium condition) yields:

$$m_{beam} g \frac{L}{2} = \mathrm{T\,L} \sin\theta$$

Equation 3

This is fine as long as the beam is the only weight is the beam, but suppose there is another weight in addition to the beam?

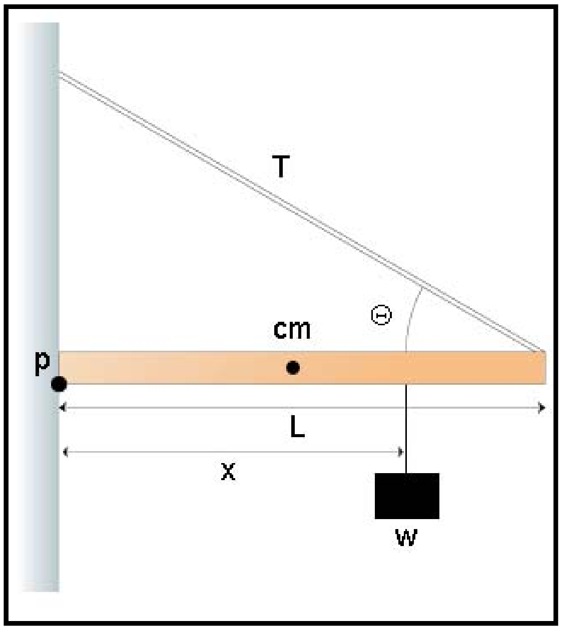

Figure 2

Weight *w* is a distance *x* from pivot *p*; therefore it adds a torque to our system and gives us a lab to do.

Task:

Explore how a hanging weight impacts the tension in a cable / beam system.

Equipment:

- Pasco Capstone Interface
- Economy Force Sensor
- beam apparatus
- level
- hanging masses

Procedure:

1. Mass the horizontal beam, m_{beam}.
    a. There is a wooden square dowel inside the metal beam and 18 little attachments, but since these additions are symmetric about the center only the total mass is needed.
2. Assemble this system; be sure that the beam is horizontal, that the sensor is high enough up on the pole to use most of the chain (record the distance from the axle), and note that the axle for the beam is underneath the sensor:

Figure 3

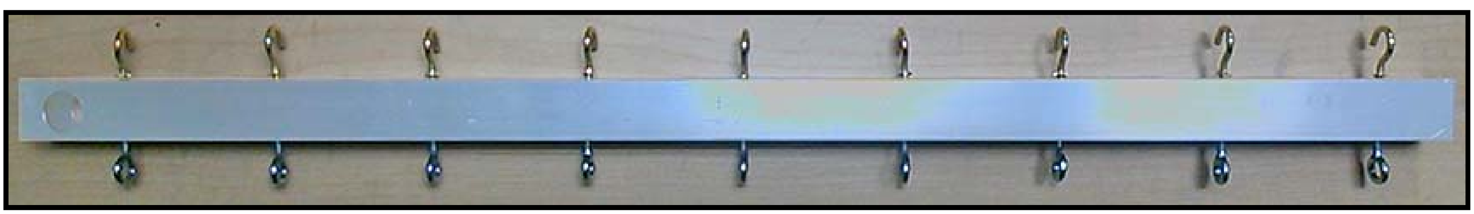

Figure 4

   a. Excess chain should be hung on the clamp so that it doesn't affect the sensor readings.
   b. The short rod that holds the sensor should be on the opposite side of the vertical pole as the short rod that is the axle of the beam. This allows maximum flexibility of the sensor position.
   c. You will have **nine** runs.
3. Open up the PCI and for Hardware choose the Bluetooth Force Sensor.
   a. Since you need only force values, no time data, you can use a table or meter display.
   b. You'll probably want to start and stop the PCI while you make adjustments.
4. Place the mass hanger with an additional 150g on it on the eye close to the end of the beam as in Figure 3.
5. Use the level to adjust the beam's horizontal position.
6. For the horizontal run, use the nine equally spaced eyes (see Figure 4) for the mass hanger under the length of the beam from one end to the other and record the force sensor reading at each position, as well as that position (distance measured from the axle).

7. For the chain measure the distance from the end of the bar to the location where the chain is hooked.

Calculations:

1. For the horizontal run modify Equation 3 to include the mass hanger with its **additional 150g**; your equation will have T(x) where *x* is the distance from the vertical bar.
2. Make a column of theoretical tensions and place it next to the column of recorded tensions.
3. Plot your equation and your results from 6) on the same graph **(use markers only)**.
4. **Does the mass of the chain introduce a significant error?** Justify your answer. **Type your answer in the excel file.**
5. Include the percent different between the measured and calculated tensions in another column.
6. **You do not need to calculate uncertainties or worry about significant figures.**