Lab Torque

Introduction:
In today’s lab you will be investigating several conditions of balance. A balanced system is in equilibrium both translationally and rotationally. We are investigating rotational equilibrium.

The seesaw is a simple device that is free to rotate about a pivot or fulcrum. Consider a large person (M=100kg) sitting on a seesaw at 2.00m from the fulcrum. On the opposite side is a child (m=20.0kg). To balance the seesaw, how far from the fulcrum must the child sit? Our lab will investigate situations similar to this. This may be an unrealistic seesaw.

We will use meter stick seesaws to learn about torque and rotation. We will discover how to describe forces and torques mathematically and solve the problem posted in the previous paragraph.

Exercise I. Learning about torque

1. Balance the meter stick on the knife-edge in the pivot and holder system given to you. The location at which the stick balances is the center of mass of the meter stick. Since your stick may have rough or rounded edges or not completely uniform wood, the center of mass may not be exactly where you expect it to be. Balance your stick and record the center of mass position. Note that it is OK if your stick is not perfectly level, but try to get reasonably close.

   \[ x_{cm} = \text{______} \pm \text{______} \text{m} \]

2. With the meterstick slider clamped at the center of mass position and balanced on the pivot holder, you will add two masses. You will hang the masses using a piece of string with a loop. You will suspend a mass a 200g mass 10cm from the fulcrum (pivot position). Now suspend a 100g mass on the opposite side of the fulcrum at the point that re-establishes balance. Record the masses and distances from the fulcrum. Consider: How is it that a lighter mass can balance out a heavier one? Your goal is to develop a relationship between the masses and the distance from the fulcrum (pivot point).

3. Make four or five more trials to fill in the table below. You can either change the positions or the masses. Be careful to keep things simple. That means don’t change too many things all at once. You should use masses that are not too small and you should not have the masses located very close to the fulcrum (hard to measure and balance).

<table>
<thead>
<tr>
<th>Small Mass (g) ( m_1 )</th>
<th>Distance from Fulcrum (cm) ( r_1 )</th>
<th>Large Mass (g) ( m_2 )</th>
<th>Distance from Fulcrum (cm) ( r_2 )</th>
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4. Looking at the measurements you have made you should be able to determine a mathematical equation involving products of the quantities involved. This equation is valid for conditions of balance. Write your equation involving the symbols \( m_1 \), \( m_2 \), \( r_1 \) and don’t forget \( r_2 \).

Math Equation Here: ________________________________

5. Now solve the problem/situation in the introduction (where is the child)?

6. Instructional side note. While your expression involves mass and distance from the fulcrum, a full definition of torque (\( \tau \)) is force times lever arm and in today’s example the forces are “mg”, but g cancels out. The sin of the angle also cancels out from all terms.

Exercise 2: Measuring the mass of a meter stick
1. You can use the method of torques as a replacement for a commercial balance scale. Here you will determine the mass of your meter stick. **Place the fulcrum at the 85.0\text{cm}** mark. You will notice that the meter stick is no longer in equilibrium. The unbalanced force is the weight of the meter stick acting at its center of mass. **Note THE ENTIRE MASS OF THE STICK ACTS AS IF IT WERE LOCATED AT THE STICKS CENTER OF MASS POSITION YOU FOUND EARLY IN EXERCISE 1.**

2. You will hang a mass at about 95.0\text{cm} (measure where you put it), and try a mass of between 200 and 500 grams to balance against the meter stick mass.

\[ x_{\text{mass}} = \text{___________} \pm \text{___________} \text{m} \]

3. Draw a diagram of this situation. Label the fulcrum and the two masses producing the torques. One mass is the known mass—what is the other mass? Where is that other mass located?

4. Use your torque relation to determine the mass of the meter stick.

\[ m_{\text{stick torques}} = \text{___________} \pm \text{___________} \text{kg} \]

5. Place the meter stick on the commercial balance (scale) to verify your determination.

\[ m_{\text{stick scale}} = \text{___________} \pm \text{___________} \text{kg} \]
6. If your results don’t agree, go back and think about what you did in step 3.

**Exercise 3: Direct measurements of Torque**

1. Set your meter stick up with the pivot point at the center of mass of the meterstick.
2. Next place 200 grams at 30.0 cm from the pivot on one side, and 400 grams at 40.0 cm on the other side of the pivot point. The system is not balanced.
3. Which side of the system must you pull upward on in order to balance the system (to make the stick level)?
4. It is now time to place a picture of a wrench on your system (use tape). The business end of the wrench goes where the pivot point is located. The far end (handle) end of the wrench is where you will tie a string and pull upward. Record where you tie the string to the meterstick, and how far that position is from the pivot point.
5. Predict how hard you will need to pull upward on the wrench handle using the string and force sensor at the location at the end of the wrench. Predict means that you should use method of torques to determine the quantity (show your work when you hand in).
6. Try this out and see if your prediction works well. What do you notice about the direction of pulling? Does the angle matter?
7. Now pretend you have a longer wrench and tie your string on at twice the distance from the pivot as in the last steps. What do you notice about the force required to balance the system now that your “wrench handle” is longer?