Lab 4 – Exploring Torque

INTRODUCTION

You might recall playing on a seesaw with a friend. If you weighed less than your friend and each of you sat on the very end of the seesaw, your end of the seesaw was lifted up in the air while your heavier friend had his feet on the ground. To compensate for the weight difference, your friend could sit closer to the center of the seesaw and balance the seesaw.

The above example demonstrates the concept of torque, which is a rotational force. A force that results in straight-line motion is a translational force. Just like the seesaw example, we will use a stick on a fulcrum, hang masses on either side, and investigate the basic principles of torque.

Torque

Torque is the rotational effect of a force. It depends on the magnitude of the force applied, the distance (from the fulcrum), and the angle at which the force is applied. The fulcrum is also referred to as the pivot point. In this lab, the orientation of the force will be such that the torque can be calculated as follows.

$$\text{Torque} = \text{lever arm} \times \text{force}$$

where the lever arm is the shortest distance from the applied force to the fulcrum or pivot or rotational axis. The units for torque is N•m when the force is in Newtons and the lever arm is in meters. In figure 1, the lever arm for F_1 is d_1.

Figure 1 shows two forces, F_1 at a distance d_1 to the left of the fulcrum, and F_2 at a distance d_2 to the right of the fulcrum. The force F_2 will produce a rotation in the clockwise direction, while the force F_1 will produce a rotation in the counter-clockwise direction. By convention, counter-clockwise torques are positive and clockwise torques are negative.

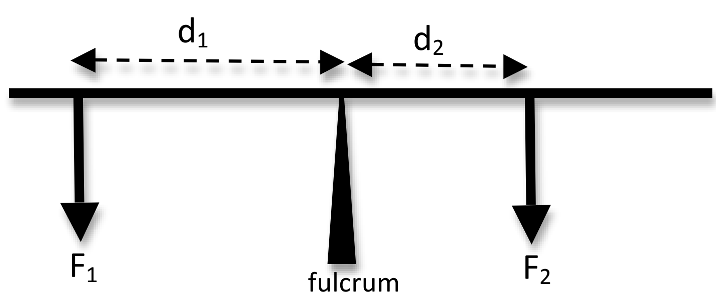

Figure 1

An object like a meter stick can be horizontally balanced at its center of mass. The center of mass of an object is the average position of the mass of the object. So we can consider the mass of an object to act at its center of mass. If the meter stick is uniform in its mass distribution, its center of mass will be at its midpoint. See figure 2.

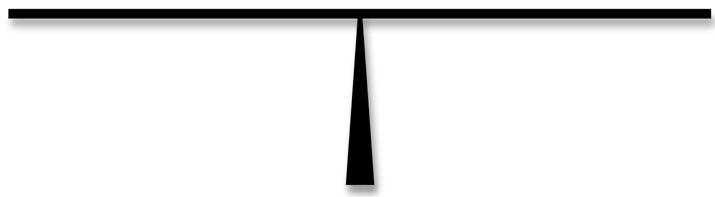

Figure 2

If the fulcrum is moved to a location other than the center of mass, the unbalanced mass of the meter stick will produce a torque and the meter stick will tilt to one side. See figure 3.

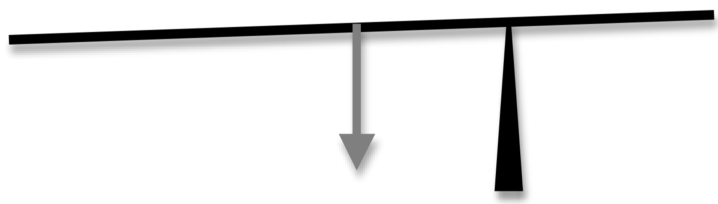

Figure 3

PROCEDURE

Note: Use g = 9.8 m/s^2 in this lab.

Part A: Two friends on the seesaw

1. You are given a meter stick, a fulcrum, and a bracket to mount the meter stick onto the fulcrum. Slide the bracket on the meter stick and hang the bracket on the fulcrum. Make sure the two hangers that protrude from the bracket are on the top part of the stick as shown in *Figure* 4. If not, turn the stick over.

Figure 4

2. Slide the meter stick in the bracket until the stick is horizontally balanced on the fulcrum. Then secure the meter stick in that position with the thumbscrew.

3. On the worksheet, record the position of the fulcrum. If it is not exactly on the 50cm mark, either the markings are not exactly centered on the meter stick or the mass is not uniformly distributed along the meter stick.

4. You are also given a set of masses of various values. Use a rubber band to hang a heavy mass on one side of the "seesaw" and a lighter mass on the other side.
5. Place the heavier mass m_1 on the left side of the fulcrum. Adjust the position of the lighter mass m_2 on the right side of the fulcrum until the meter stick is horizontal.

6. Measure the distance from the fulcrum to the point where each mass is hanging. Be sure to use the distance **from the fulcrum** and not from the end of the stick. Record these distances (in meters) and the values of both masses (in kilograms) in the data table on the worksheet.

7. Place m_1 at a different location on the left side and repeat step 5. Record these new values in the data table on the worksheet.

8. Calculate the weight (mass x 9.8) for each mass and record the results in the same data table on the worksheet.
9. Calculate the torque (lever arm x weight) for each mass and record the results in the data table.

CHECKPOINT 1: HAVE YOUR TA CHECK YOUR WORK BEFORE PROCEEDING

Part B: Three friends on the seesaw

10. Adjust the position of the fulcrum so the meter stick is horizontal.
11. Hang a heavy mass m_1 on the left side of the "seesaw" and two lighter masses m_2 and m_3 on the right side. Do not position the two masses on the right side at the same point. Adjust the position of the masses so that the meter stick is horizontal.
12. Measure the distance from the fulcrum to the point where each mass is hanging, and record the distances and masses in the data table on the worksheet.

13. Draw a sketch of the set up. On your sketch, indicate the positions of the fulcrum, the heavy mass and the lighter masses.

14. Calculate the weight and torque for each mass. Record the values of torque, in the data table on the worksheet.

CHECKPOINT 2: HAVE YOUR TA CHECK YOUR WORK BEFORE PROCEEDING

<u>Part C:</u> Seesaw solitaire

1. Start with the meter stick horizontal. Record the position of the fulcrum on the worksheet. We will refer to this as point A.

2. Hang a single mass on one side of the meter stick and no masses on the other side. Loosen the thumbscrew on the mounting bracket and slide the meter stick in the bracket until the meter stick is horizontal.

3. Record the new position of the fulcrum on the worksheet. We will refer to this as point B.

4. Draw a sketch of the set up. On your sketch, label the points A, B, and the position of the hanging mass.

5. Measure the distance of the hanging mass from point B and record this on the worksheet.

6. Calculate the torque due to this mass and record this on the worksheet. Also indicate if this torque is clockwise or counter-clockwise on the worksheet.

7. The meter stick is horizontal. So there has to be a second torque balancing the torque due to the hanging mass. This torque is due to the weight of the meter stick acting at the point A. Measure and record the distance of point A from point B.

8. Use this to calculate the weight of the meter stick and the mass of the meter stick.

9. Use a balance to measure the mass of the meter stick and record this value on the worksheet. Compare the two values of the mass of the meter stick. Are the two values in agreement?

<u>CHECKPOINT 3</u>: HAVE YOUR TA CHECK YOUR WORK BEFORE PROCEEDING

TORQUE – WORKSHEET

Part A: Two friends on the seesaw

Position of the fulcrum: _______________ m

Mass m_1 = _________________ kg   mass m_2 = __________________ kg

Trial #	Weight W_1 (N)	Lever arm d_1 (m)	Torque 1 (N.m)	Weight W_2 (N)	Lever arm d_2 (m)	Torque 2 (N.m)
1						
2						

What is the direction of torque 1? (**CIRCLE ONE**) Clock-wise   Counter-Clockwise

What is the direction of torque 2? (**CIRCLE ONE**) Clock-wise   Counter-Clockwise

Are the magnitudes of the two torques equal in magnitude? (**CIRCLE ONE**) Yes No

CHECKPOINT 1

Part B: Three friends on the seesaw

Position of the fulcrum: _______________ cm

Sketch:

	Mass (kg)	Weight (N)	Lever arm (m)	Torque (N.m)
m_1				
m_2				
m_3				

What is the direction of torque 1? (**CIRCLE ONE**) Clock-wise Counter-Clockwise

What is the direction of torque 2? (**CIRCLE ONE**) Clock-wise Counter-Clockwise

What is the direction of torque 2? (**CIRCLE ONE**) Clock-wise Counter-Clockwise

Does the magnitude of the clockwise torque(s) equal the magnitude of the counter-clockwise torques(s)? (**CIRCLE ONE**) Yes No

CHECKPOINT 2

Part C: Seesaw solitaire

Position of the fulcrum A: _______________ m

Position of the fulcrum B: _______________ m

Sketch:

Distance of fulcrum A from fulcrum B, d_{AB} = _____________ m

Hanging mass m_h = ______________ kg   Weight W_h = _____________ N

Distance of hanging mass from fulcrum B, d_h = ______________ m

$Torque_{mass} = Torque_{meterstick}$ $W_h \times d_h = W_{meterstick} \times d_{AB}$ Substitute appropriate values and calculate $W_{meterstick}$. Show your calculations.

Use the value of $W_{meterstick}$ to calculate the mass of the meter stick.

Mass of meter stick = _______________ kg (from above calculation)

Mass of meter stick = ______________ kg (using balance)

Do the two values for the mass of the meter stick agree? (**CIRCLE ONE**) Yes No

CHECKPOINT 3