# Rotational Mechanics

By:
Dane Kurian and Arsen Zavlyanov

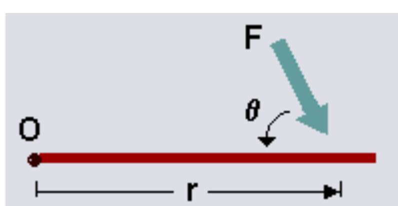
**Introduction:**

The modern day concepts of torque that we utilize today were first recorded by Archimedes during his work with levers. A lever is a simple machine much like a wedge, pulley, gears, inclined plane, and a wheel and axel. A simple machine is a mechanism that makes work for humans much easier that it would be to do without using them. Think about it, would you rather push a heavy box up a ramp, or would you rather pick the box up and carry it up a flight of stairs. Obviously you would rather push the box up a ramp and save your self a lot of effort. The way these machines work is by taking advantages of the laws of physics in our favor. The mechanical advantages of a lever in lifting heavy objects will be shown in this laboratory experiment.

**Background:**

1. The easiest way to understand rotational mechanics is to adapt its usages analogously to translational mechanics such as velocity, acceleration, and force with angular velocity, angular acceleration and torque.
   - In the most abstract manner translational motion transforms into rotational motion with a factor of the displacement between the rotation point and the measured value.

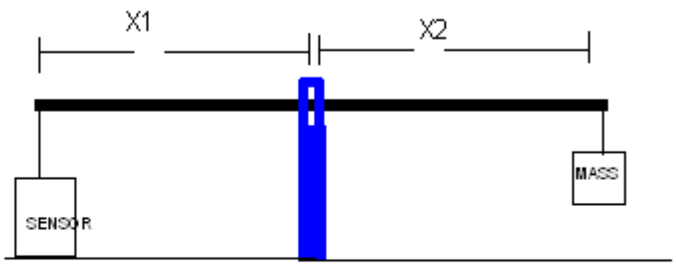
2. Torque is a measure of how much force acting on an object causes that object to rotate. Torque is a vector quantity; therefore it is both a measure of magnitude and direction. The object rotates about an axis, which we will call the pivot point, and will label 'O'. We will call the force 'F'. The distance from the pivot point to the point where the force acts is called the moment arm, and is denoted by 'r'. Note that this distance, 'r', is also a vector, and points from the axis of rotation to the point where the force acts.[i]




   - By definition torque is the product of the moment arm and the normal force component that is perpendicular to the moment arm.

$$\tau = r \cdot F \sin\theta = rF_{normal}$$

3. In this experiment we are going determine through empirical evidence how the force is related to the moment arm ‘r’, by varying the center point and hence changing the orientation.




In order for equilibrium to exist the following formula must be satisfied:

$$F_{Sensor} = \frac{X_2}{X_1} F_{weight-of-mass}$$

If equilibrium is to be valid, then theoretically the force measured by the sensor will equal to the product of the ratio between the two displacements and the weight of the mass.

**Equipment List**

- Power Macintosh or Windows PC
- Logger Pro
- Measuring device
- Fulcrum
- Scale
- LabPro or Universal Lab Interface
- cantilever beam
- Bi-Directional Force Sensor
- Load (it can be anything)

**Procedure**

**Part I Preliminary Experiments**

1. Connect the Bi-Directional force sensor to the LabPro in CH4 of the Universal Lab Interface. Then set the sensor to zero. (this reading can be seen at the upper right hand corner of the interface)

2. Place the weighted fulcrum on the table. Make sure that it is in some what of a clear area so that the experiment procedures will not be disturbed while you are performing the experiment

3. Balance the bar over the fulcrum with no weights attached so that it balances perfectly and the beam does not tip and stays still.

4. Connect the force sensor to the longer loop and take the reading; it should remain zero because there is no force being applied.

5. Now hang a mass on the opposite side of the beam, the measurement of the force sensor will be the force that the sensor has to exert in order to keep the mass from making the beam tilt (which is the weight of the mass)

6. Click the Collect button and the computer will record at least 10 values once you have enough values click stop. The average value is then calculated and record this value in the appropriate row in the “force final” column.

**Part II As the Fulcrum Moves Away From the Mass**

7. Move the fulcrum closer to the force sensor and away from the mass.

8. By clicking [Collect] record the force that is being applied on the force sensor and then record 10 appropriate values. Measure the distance from the mass to the fulcrum and then measure the distance from the force sensor to the fulcrum, record both values.
9. Repeat steps 7 and 8 five more times, each time moving the fulcrum farther away from the mass, make sure you record the data.

**Part III Fulcrum Moves Closer to the Mass**

13. Move the fulcrum back to the center point so that the force sensor detects the weight of the mass only
14. Move the fulcrum closer to the mass and away from the force sensor.
15. By clicking [Collect] record the force that is being applied in the force sensor and then record 10 appropriate values. Measure the distance from the mass to the fulcrum and then measure the distance from the force sensor to the fulcrum, record both values.
16. Repeat steps 14 and 15 five more times, each time moving the fulcrum closer to the mass, make sure you record the data each time.
17. You will have 12 sets of values.

**Results:**

| Position | X1, [cm] | X2, [cm] | Weight, [N] | Sensor Reading, [N] |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**Analysis:**

1. Explain in your own words why the force values on the sensor changes when the pivot point has been moved to a different location?

2. What kind of relationship is there between the ratio of the displacements and the force measured?

3. Find the theoretical sensor measurement through the formula provided, and compare those values with the experimentally measured ones?

4. Are there any discrepancies, why?

**References:**

[i] http://www.physics.uoguelph.ca/tutorials/torque/Q.torque.intro.html