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New York Balance Demonstration
#4-14501

Warning:

- **Not a toy; use only in a laboratory or educational setting.**
- **California Proposition 65 Warning: This product can expose you to chemicals including chromium and lead, which are known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.**

Introduction

A New York Balance Demonstration, also known as a Meter Stick Balance, is a simple device that is used to demonstrate the basics of **levers** and related concepts like **fulcrums, mechanical advantage, torque, center of gravity, equilibrium,** and more.

Levers are one of the primary examples of **simple machines**, along with wheels and axles, pulleys, inclined planes, wedges, and screws. Simple machines are basic tools that can be used to change the direction or magnitude of a force. The mathematics that describe their behavior are often attributed to the Greek mathematician Archimedes and his Law of the Lever. These laws can also be used to explore how the concept of torque applies to forces on a beam. The following pages will contain basic explanations of levers, the workings of torque on a simple beam, and simple ways to demonstrate these principles using your balance.

Components

1. Cast-iron Support Stand
2. Knife-edge Clamp and Hanger (x2)
3. Knife-edge Clamp
4. Hooked Weight (100g)
5. Hooked Weight (50g)
6. Meter Stick (50cm)

1

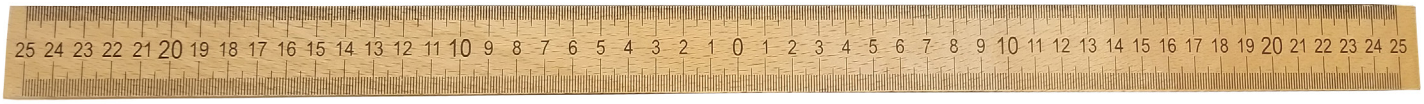
2

3

4

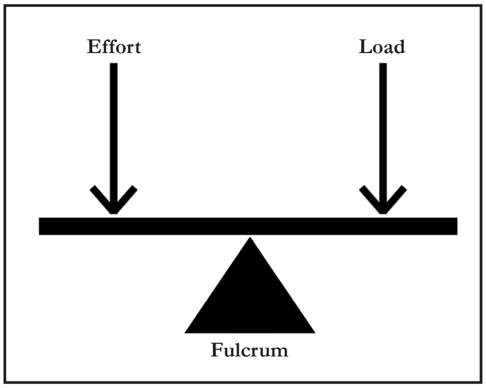
5

6

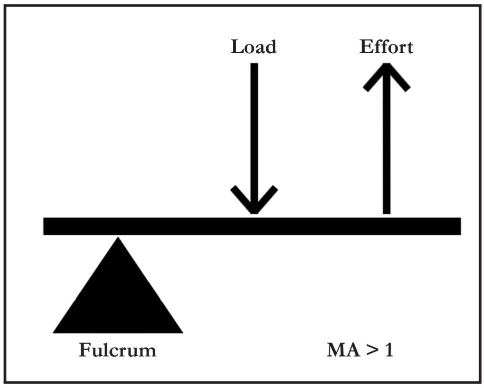


Levers

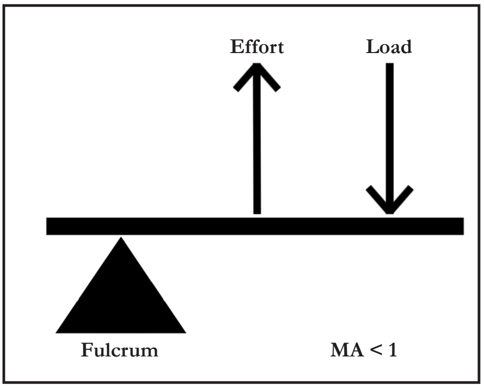
Levers are simple machines consisting of a **beam** that pivots around a fixed point known as a **fulcrum.** They are designed to amplify an input force (effort) into a greater output force (load) so that less effort is required to move something. Three classes of levers exist as defined by the relative locations of their fulcrums, efforts, and loads:



First Class Lever



Second Class Lever



Third Class Lever

This demonstration makes use of a first class lever, though the following observations of Archimedes define all three. His **Law of Levers** describes how a lever uses its fulcrum to create mechanical advantage, or **leverage.** **Mechanical advantage** is defined as the ratio of the output force created by a machine relative to the input force applied to it.

Law of Levers

$$F_i \, d_1 = F_o \, d_2$$

Mechanical Advantage Formula

$$MA = \frac{F_o}{F_i} = \frac{d_1}{d_2}$$

- **F_i = Input Force (N)**
- **F_o = Output Force (N)**
- **d_1 = Distance between F_i and Fulcrum (m)**
- **d_2 = Distance between F_o and Fulcrum (m)**
- **MA = Mechanical Advantage**

- **gf = Gram Force**
- **g = Gram**
- **N = Newton**
- **1gf = 1g • 9.8m/s^2**
- **1gf = 0.0098 N**

Torque

Torque (τ), or **moment,** occurs when a force is applied to an object that has been confined to an axis. It is a rotational vector quantity made up of the product of the force, the length of the **moment arm** (the distance between the fulcrum and the weight, in our case), and the sine of the angle between the force and the arm. Due to the nature of this demonstration, we will assume the angle between the force and the arm is 90°, and, because the sine of 90° equals 1, we can safely think of torque with the following, simplified formula:

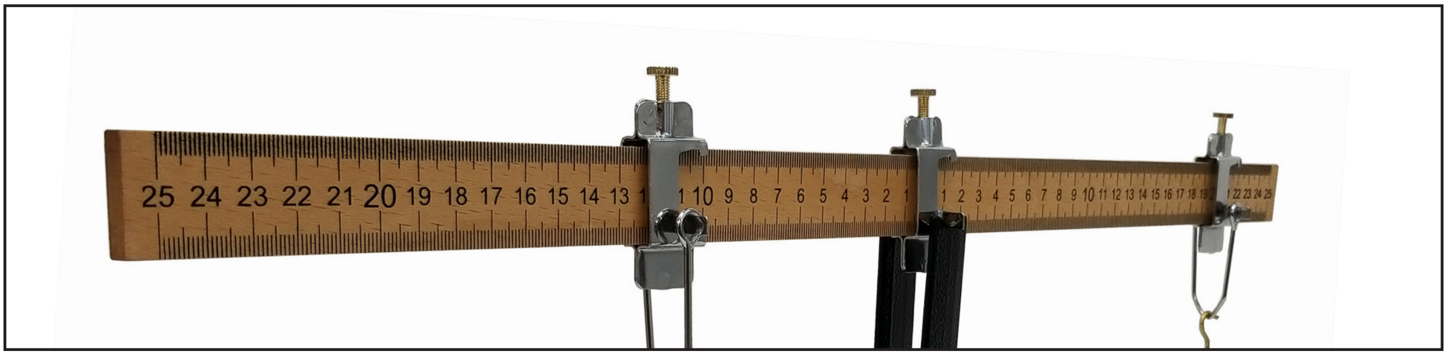
$$\boxed{\tau = F\ d}$$

Two important concepts to this demonstration are that of static equilibrium and center of gravity. The term **static equilibrium** is used to describe a system that is experiencing no rotational or linear acceleration. With the first class lever system we are using for this demonstration, the system experiences torque on each side of the fulcrum. Therefore, torque and static equilibrium in our system can be expressed as follows:

$$\boxed{\tau_1 = \tau_2}$$

- $\tau_1 = F_i \cdot d_1$
- $\tau_2 = F_o \cdot d_2$

Center of gravity, as mentioned earlier, is a related concept referring to the average location of weight in an object. If an object were to be placed in a gravity-free vacuum and were given torque and rotational acceleration, it would rotate around its center of gravity. Similarly, the torque on all sides of the point of the center of gravity would need to equal net zero for the object to rest still in static equilibrium.



Now that you have a better grasp on the concepts of levers and torque, the experiments on the following page will allow you see them in action.

How to Use

Follow the instructions below to explore the concepts described earlier in these instructions.

Finding the Center of Gravity

1. Pick up your ruler.
2. Make two fists with your hands with your pointer fingers sticking out.
3. Balance the ruler so that it is suspended between your two fingers with one finger on each end.
4. Slowly, bring your hands together until they are touching. Make sure the ruler stays balanced and doesn't fall. The place on the ruler below where your fingers are touching is the **center of gravity.**
5. Attach a knife edge clamp with a hanger to each end of the ruler and hang your 100g weight on one side and your 50g weight on the other.
6. Repeat step 4. Your hands will not meet in the middle this time. In order to keep your balance from falling from your fingers, one hand will need to move farther than the other. You will notice that the center of gravity has moved closer to the side where the 100g weight is hanging.

Setting Up Your Balance

1. Place your cast-iron base on a table so that the fulcrum arms are upright.
2. Gather your knife-edge clamp without a hanger.
3. Insert your ruler through the clamp, and tighten the clamp over the mid-point on the ruler.
4. Place the arms of your knife-edge clamp into the fulcrum base. It should now be resting in equilibrium with the ruler perpendicular to the base. If this is not the case, you may need to loosen your clamp and make tiny adjustments in your ruler's side-to-side position until it balances steady on your base.

Using Your Balance

1. Set up your balance.
2. Observe that the ruler is in **static equilibrium.**
3. Attach a single knife-edge clamp with hanger to either side of the balance. Observe that by attaching the weight and increasing the torque on one side of the balance, it moves out of its state of equilibrium.
4. Place one knife-edge clamp with hanger 10cm to the left of the fulcrum, and place the other knife-edge clamp with hanger 20cm to the right of the fulcrum.
5. In the hanger 10cm to the left of the fulcrum, hang your 100g weight, and in the hanger 20cm to the right of the fulcrum, hang your 50g weight. Observe that the balance stays in equilibrium even though unequal weights are being suspended from its arms.
6. Verify this observation using the Law of Levers.
7. Experiment with different distances to see which ones allow your balance to remain in equilibrium. Verify these distance combinations with the Law of Levers as well.