DEMONSTRATION BALANCE
STUDY GUIDE

INTRODUCTION

A **lever** is a board or bar that turns on a fixed support called a **fulcrum**. Levers are simple machines used to reduce the amount of force and change the direction of force needed to do work. The force used to work a simple machine is called the **effort force**.

Levers allow you to move a load as you apply an effort force to some part of the lever. In a **first class lever**, the fulcrum is located between the load and effort. When you push down on a first class lever, it reverses the direction of your effort to lift the load up. Work is done by lifting the load. Reducing the distance between the fulcrum and the load or increasing the distance between the fulcrum and the effort both increase the mechanical advantage of a first class lever. This allows work to be done with less effort force.

A **balance** is a first-class lever that is used to determine when two forces are balanced. Two forces balance when they are equal in strength but opposite in direction (the force pushing down equals the force pushing up). The **law of moments** applies to balanced levers. It states that the load force times its lever arm (distance from the fulcrum) is the same as the effort force times its lever arm, or:

$$F_{load} \text{ x lever arm}_{load} = F_{effort} \text{ x lever arm}_{effort}$$

$$F_l \text{ x } l_l = F_e \text{ x } l_e$$

This **demonstration balance** is a flexible tool to measure the effect of different forces and leverage. It can also serve as a simple double pan balance that is suitable for many needs in grades K-12.

ASSEMBLY

Your demonstration balance includes the following items:

Metal base & upright
3 knife-edge clamps
1/2 meter stick

In addition to these items you will want to obtain several small paper clips, some small weights and paper cups (see experiments and ideas for further study given below).

1. Remove the wire loop from one of the knife-edge clamps by spreading the ends of the loop.
2. Slide this knife-edge clamp over the 1/2 meter stick so that the knurled knob is pointing down when the centimeter markings on the meter stick are pointing up.
3. Position the center of the clamp over the 25-cm mark (you will see the 25-cm line right next to the edge of the window cut into the clamp) and tighten the knurled knob. The pivot points of this knife-edge clamp acts as the fulcrum.

4. Rest the beam on the support and make sure the center knife-edge clamp pivot points rest in the support v-notch as illustrated.

5. Attach the remaining knife-edge clamps to each end of the beam. These will be used to hang weights or dishes to be used as weighing pans. Their use is described in more detail in Experiment 2.

ZERO THE BALANCE

The balance you have just assembled is very sensitive. In fact, it is probably not in the balanced horizontal position at this point due to the slight variations in the density of the wooden beam. Your first task is to zero the balance by equalizing the forces on both ends of the beam.

1. If the knife-edged clamps are on the beam, remove them.
2. Take a paperclip, open it up, and wrap it around the lightest end of the beam (the end that is highest up in the air).
3. Carefully slide the paperclip along the beam until the beam is in the horizontal position. To balance properly, let the beam rock back and forth until it comes to a stop. Don't use your hand to stop the beam from rocking.
4. Once the beam is balanced, make sure the paper clip fits snugly and won't slide off.

FORCE AND LEVERAGE - PAPERCLIPS

Experiment 1

You can study the effects of force and leverage using the balance and the law of moments equation given above.

1. Open up a paperclip into an S shape. Hook the large end of the S tightly around the 1-cm mark on the beam.
2. Open a second paperclip and hook the large end of the S tightly around the 49-cm marking on the beam.
3. The balance should be close to the balanced position with the hooks of both paperclips exactly 24 cm from the fulcrum. If not, zero the balance at this point.
4. Add four paperclips to each of the paperclip hooks. The balance will be in the balanced position with a total of five paperclips on each side (four paperclips and a paperclip hook.)
5. Each of the paperclips has a mass of about 0.5 g and a weight of 0.005 newtons. Use the law of moments to calculate where you would place a 10-paperclip force to balance a 5-paperclip force located 24 cm from the fulcrum.

   F_1 (5 clips) x l_1 (24 cm) = F_2 (10 clips) x l_2

   l_2 = (5 clips) x (24 cm) / (10 clips) = 12 cm
6. Move one of the paperclip hooks with nine paperclips on it to that distance from the fulcrum. ***Do the forces balance?*** If not, adjust the position of the 10-paperclip force until the forces balance. Record the distance of the 10-paperclip force from the fulcrum.
7. Repeat steps 4-5, but this time calculate the amount of force needed at 6 cm from the fulcrum to balance the 5-paperclip force located at 24 cm from the fulcrum. Move the paperclip hook to 6 cm from the fulcrum and add the additional paperclips needed to reach your calculated number. ***Do the forces balance? If not, how many paperclips at this location are required to balance the 5-paperclip force at 24 cm?*** Record your results.
8. Place the 5-paperclip force at 4-5 other locations on the balance and calculate the position of 10 and 20 paperclip forces to balance it. Record your results.
9. Analyze your results. ***Can the law of moments be used to determine the size and location of balancing forces? What variables may have given you results slightly different than the ideal results from the law of moments?*** Record your conclusions.

Your results should have been very close to the law of moments. Any variations should have been very slight.

FORCE AND LEVERAGE - MASSES

Experiment 2

The balance can be used as above to demonstrate the law of moments using the knife-edged clamps and weights instead of paper clips.

1. Attach the knife-edged clamps to either end of the beam. The center of the clamps should be positioned on the 1-cm and 49-cm marks.
2. Hang a known weight (e.g. 100 g) on one clamp and then hang a second, heavier weight (e.g. 200 g) on the other clamp.
3. Change the position of the second clamp until the beam is balanced.
4. Read the position of the second weight.
5. Each clamp weighs approximately 16 g. Add this amount to the known weights and use the law of moments to calculate the positions of the weights.
6. ***How do the final positions of the clamps compare with that calculated using the law of moments?***

You can expand your experimentation with a spring scale and unknown weights. The spring scale can be used to measure the force at different positions along one side of the beam while you place an unknown weight at different positions on the other side of the beam. Use the law of moments to calculate the force (weight) of the unknown weight.

TEACHING TIPS FOR YOUNG CHILDREN

Let your younger children watch the above experiments and ask them to identify the fulcrum and lever arms. Demonstrate that balancing forces on the lever arms result in the balance beam being horizontal.

Explain how the distance from the fulcrum affects the force needed to lift an object. This balance is very similar to a seesaw and children can make comparisons between the two. What happens when one person moves closer to the center of a seesaw? Is it more difficult or easier to lift the person if you are on the other end? You can discuss other types of first-class levers including scissors, crowbars and catapults. Can you or your children think of other examples of levers?

FURTHER STUDY

You can attach two pans, one on either end of your balance, for a simple double-pan balance. Use small aluminum pie-pans, styrofoam bowls or paper or plastic cups. Use three pieces of string to hang each pan from a knife-edge clamp. Adjust the position of the knife-edge clamps to balance the beam in the horizontal position. Measure the mass or weight of objects by putting them in one pan and balancing them with known masses or weights in the other pan.