Comparing the Mechanical Advantage of Levers

Background Information

A **lever** consists of a rigid bar that is free to rotate around a fixed point. The fixed point on the bar rotates around the **fulcrum.** Like all machines, a lever changes the size of a force that is applied to it, the direction of a force applied to it, or both. The force exerted on a lever is the **input force.** The distance between the fulcrum and the point where the input force acts is the **input arm.** The force that the lever exerts on the load is the **output force.** The distance between the fulcrum and the output force is the **output arm.** Note that the output force may be larger or smaller than the input force, depending on the type of lever.

There are three types of levers, called first-class, second-class, and third-class levers. The three classes differ in the relative positions of the fulcrum and the input and output forces. A first-class lever, such as a seesaw, has its fulcrum between the input and output forces. In a second-class lever, such as a wheelbarrow, the output force, is between the input force and the fulcrum. A third-class lever, such as a broom, has its input force between the fulcrum and the output force.

The **mechanical advantage** of any machine is the number of times that the machine multiplies the input force. The **actual mechanical advantage** (AMA) of a lever is equal to the output force divided by the input force.

$$\text{AMA} = \frac{\text{Output force}}{\text{Input force}}$$

In this investigation, you will determine and compare the actual mechanical advantage of first-class and second-class levers. Then, you will design and carry out an investigation to determine the mechanical advantage of a third-class lever.

Problem

How do the mechanical advantages of first-class, second-class, and third-class levers differ?

Procedure

Part A: Determining the AMA of First-Class Levers

1. Work with a classmate. Hang the 500-g mass from the spring scale. Read the weight of the mass on the spring scale. Record this weight as the output force in each row of Data Table 1.
2. To make a first-class lever, place the wedge-shaped block of wood on the table to serve as a fulcrum. Place the 50-cm mark of the meter stick on the fulcrum so that the 100-cm end of the meter stick extends beyond the edge of the table, as shown in Figure 1. Use string to tie the 500-g mass to the meter stick at the 10-cm mark. This mass serves as the load that the lever will lift.
3. Place the wire loop around the meter stick at the 90-cm mark, 40 cm away from the fulcrum. Hang the spring scale from the wire loop.

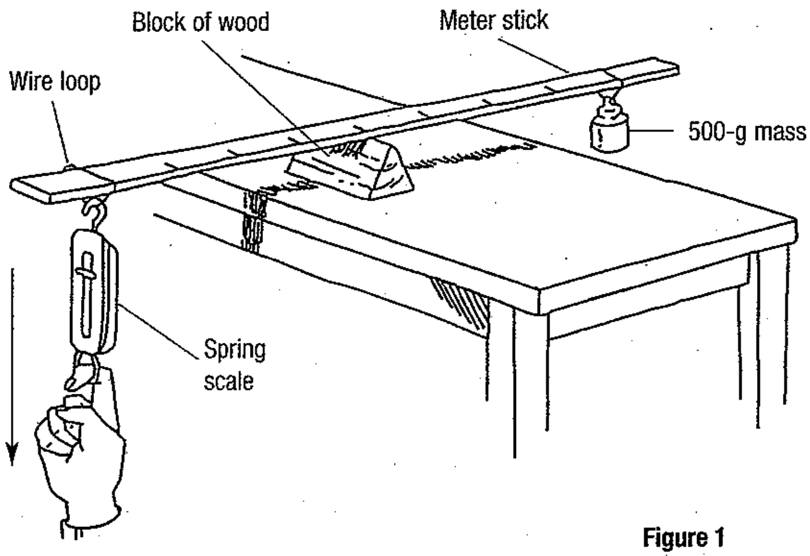

Figure 1

4. In the first row of Data Table 1, record the distance from the fulcrum to the spring scale as the input arm. Record the distance from the fulcrum to the mass as the output arm.
5. Pull the spring scale down slowly and steadily to lift the mass. When the meter stick is horizontal, read the input force on the spring scale. Record this value in Data Table 1.
6. Leaving the mass and the spring scale at the same positions, move the fulcrum to the 30-cm mark. Record the lengths of the new input and output arms in Data Table 1.
7. Repeat Step 5.
8. Repeat Steps 6 and 7, but this time, move the fulcrum to the 20-cm mark.
9. Calculate the mechanical advantage of the first-class lever in all the positions you tested. Record these values in Data Table 1.

Part B: Determining the AMA of Second-Class Levers

10. To make a second-class lever, place the 10-cm mark of the meter stick on the fulcrum as shown in Figure 2. Tie the mass to the meter stick at the 50-cm mark.

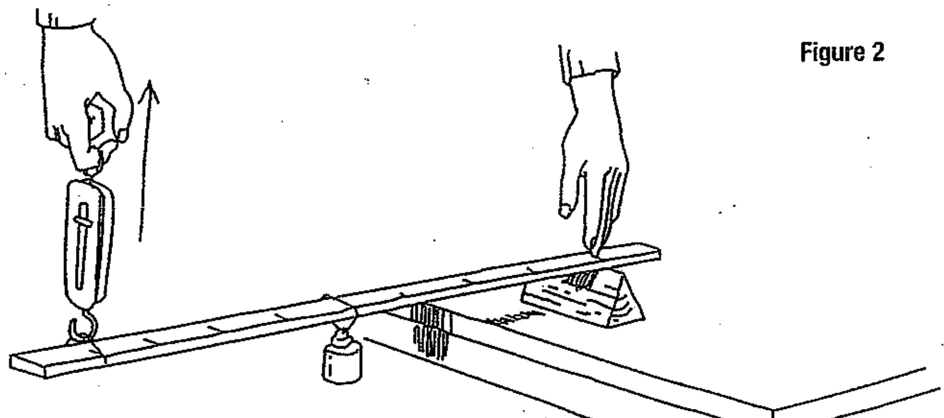

Figure 2

11. Place the wire loop around the meter stick at the 90-cm mark, 80 cm away from the fulcrum. Attach the spring scale to the wire loop.
12. In Data Table 1, record the distance from the fulcrum to the spring scale as the input arm. Record the distance from the fulcrum to the mass as the output arm.
13. Have your partner hold the meter stick down on the fulcrum so that the meter stick does not slide or rise up off of the fulcrum. Pull the spring scale up slowly and steadily to lift the mass. When the meter stick is horizontal, read the input force on the spring scale. Record this value in Data Table 1.
14. Leaving the fulcrum and the spring scale at the same positions, move the mass to the 30-cm mark. Record the lengths of the new input and output arms in Data Table 1.
15. Repeat Step 13.
16. Repeat Steps 14 and 15, but this time, move the mass to the 20-cm mark.
17. Calculate the actual mechanical advantage of the second-class lever in all the positions you tested. Record these values in Data Table 1.

DATA TABLE 1: Parts A and B

Fulcrum Position (cm)	Output Arm (cm)	Input Arm (cm)	Output Force (N)	Input Force (N)	Actual Mechanical Advantage
First-Class Lever					
50					
30					
20					
Second-Class Lever					
10					
10					
10					

* Please add to the first class lever experiment, data for placing the fulcrum as the 40 cm and the 60 cm mark.*

Analysis:

1. Draw a first class lever and a second class lever and label for each:
    a. fulcrum
    b. input force and output force
    c. input distance and output distance

2. Can a first class lever have a mechanical advantage less than 1?_______ under what conditions? ____

3. Can a first class lever have a mechanical advantage greater than 1? ___________ under what conditions?____

4. Does a second class lever have a mechanical advantage less than, greater than, or equal to zero? ________________ explain why

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5. What is an example of a first class lever?_______________

6. What is an example of a second class lever?_____________________

7. What do you do to increase the mechanical advantage of any lever?

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