SIMPLE MACHINES : FULCRUM BALANCE

CAT NO. WDMS17

Experiment Guide

GENERAL BACKGROUND :

There are six simple machines that all other machines are made out of. Even complex machines like an automobile really consist of simple machines that all convert energy in order to do work. Machines are used to make work easier. Here work is defined as a force applied over a given distance. The force applied and the distance traveled must be in the same direction.

Simple machines can either change the direction the force is applied, or increase the mechanical advantage by doing the same amount of work over a longer distance and therefore decreasing the amount of force needed.

Mechanical advantage is a way of measuring how much easier it is to do work or how much less force is required. Written as a formula:

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}}$$

The load is the amount of force or weight that is being lifted.
The effort is the amount of force or weight being applied to the rope in order to move the load.

The six simple machines are pulleys, levers, wedges, inclined planes, screws and wheels & axles. Compound machines have two or more simple machines that when used together make work easier.

A pulley is a variation of a wheel and axle in which a rope or cord is stretched over a wheel to make it rotate as the rope is pulled. Pulleys are used to raise and lower flags, on oil derricks, to raise, lower, and adjust sails on a sailboat, and to pull open or close curtains. A single pulley can change the direction that a force is needed to be applied in order to make doing work more convenient. A combination of several pulleys can make it easier to do work, by applying a smaller force over a larger distance mechanical advantage is gained.

Levers are in use when a long stiff object, like a post or board rests on a fulcrum. The fulcrum is simply the pivot point on which the board or post rests. The pivot point does not undergo any translational motion (it doesn't move). The lever lifts a load by applying an effort force. The arrangement of the effort, load, and fulcrum determines the “class” of levers. There are three classes of levers.

In first class levers as shown in diagram 1:

- the fulcrum is positioned between the effort and the load
- the effort is smaller than the load

- the effort moves further than the load
- the lever can be considered a force magnifier

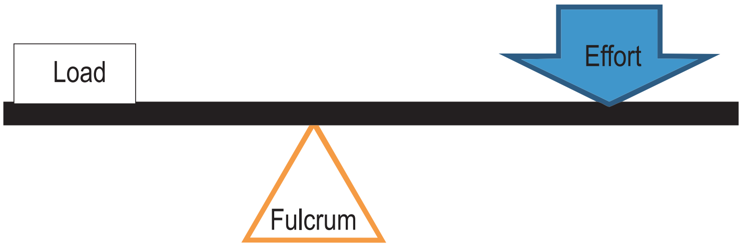

Diagram 1

Examples of class one levers are a teeter totter or see-saw, a catapult, scissors, or a crowbar.

In class two levers as shown in diagram 2:

- the effort and the load are positioned on the same side of the fulcrum but applied in opposite directions
- the load lies between the effort and the fulcrum
- the effort is smaller than the load
- the effort moves further than the load
- the lever can be considered a force magnifier

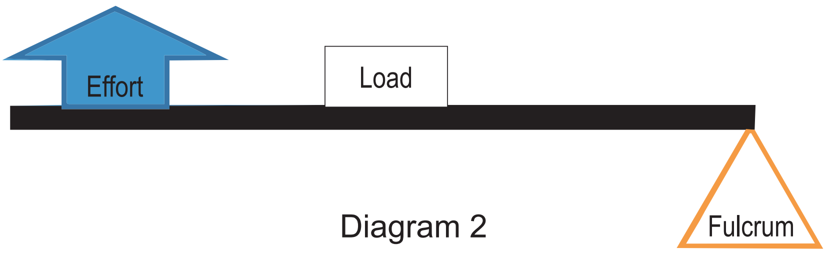

Diagram 2

Class two levers have the load in the middle and the fulcrum on the end and effort is applied on the opposite side of the fulcrum as shown in diagram 2. Examples of class two levers are wheel barrows, shovels and nutcrackers.

In class 3 levers as shown in diagram 3:

- the effort lies between the load and the fulcrum
- the effort is greater than the load
- the load moves further than the effort
- the lever can be considered a distance magnifier

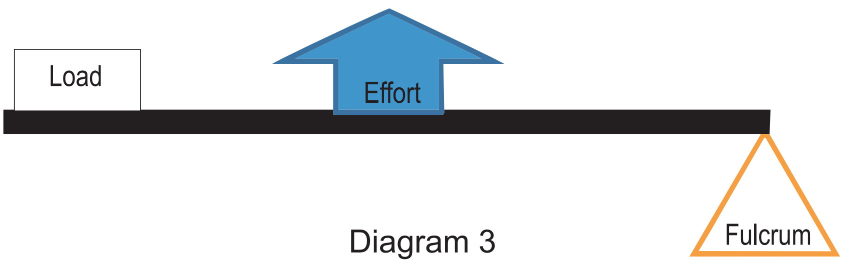

Diagram 3

Class three levers have the load on one end of the post, the fulcrum on the opposite end, and the effort is applied to the middle as shown in diagram 3. A fishing pole, tweezers and your forearm are good examples of class three levers.

The effort force applied to a lever can be calculated by a simple formula:

[Force applied or weight of the load] [Distance from the center of the load to the fulcrum] = [Force applied by the effort] [Distance from the center of the effort to the fulcrum]

$$F_l \times d_l = F_e \times d_e$$

$F_l \times d_l$ is also called the torque. Torque is the force applied to an object to get it to undergo rotational motion.

If we rearrange this equation we get:

$$\frac{F_l}{F_e} = \frac{d_e}{d_l}$$

This means that if the distance between the effort and the fulcrum is smaller than the distance between the load and the fulcrum, we will be able to apply less force to lift a heavier object. This is true in class 1 and class 2 levers.

A wedge is a simple machine that changes the direction of a force. The force applied is usually perpendicular to the force acting on the object. Examples of wedges are door stops, nails, axes, teeth (incisors, not molars), pins, a chisel.

Wheels and axles increase mechanical advantage, and by covering a longer distance using less force. The larger the wheel the greater the mechanical advantage. As a wheel turns the distance traveled by the one rotation of the wheel is directly proportional to the diameter of the wheel. For the penny farthing bike one rotation of the pedal equals one rotation of the bike's wheel. However the distance covered by the person's foot is much smaller than the distance covered by the bikes wheel. Examples of wheels and axles include bike tires, car tyres, windmills and steering wheels.

Inclined planes also increase mechanical advantage by increasing the distance traveled and decreasing the amount of force applied. Examples of inclined planes include ramps, hills, ladders, stairs and the backs of dump trucks.

Screws are really just inclined planes wrapped around a post as shown in diagram 4. Examples of common screws are screw top jar lids, drill bits, meat grinders, corkscrews, swivel stools, and of course, screws.

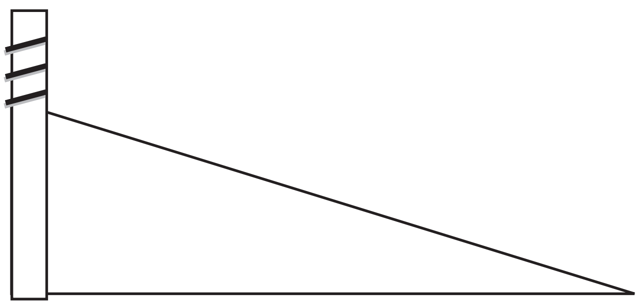

Diagram 4

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Fulcrum balance base	1
Lever arm with three notches	1
Platform for adding mass	2
Small brass dowel	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Masses of known weight	6
Ruler	1

SET UP OF APPARATUS:

There are three notches and three holes drilled in the top of the lever arm for the fulcrum balance. The three notches allow the lever arm to change positions and can be used similar to Activity 1 in WDMS 18: Levers. For all experiments in this manual, only the center notch and hole should be used. Set up and balance apparatus as shown in diagram 5.

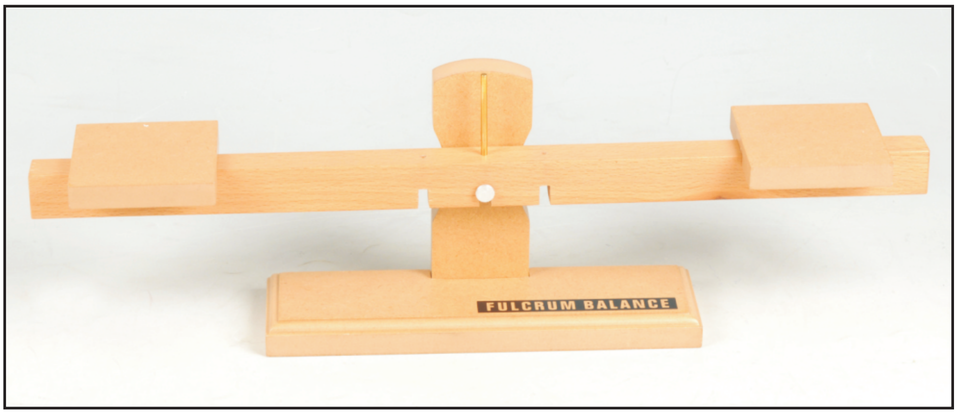

Diagram 5

It will make it easier for students to keep their data in order and to find the center of the platforms if you draw lines to help them find the center of each platform. Each platform is 7cm square, so find 3.5 cm from the edge and draw two lines as shown in diagram 6. It may also be helpful to label the platforms 1 & 2.

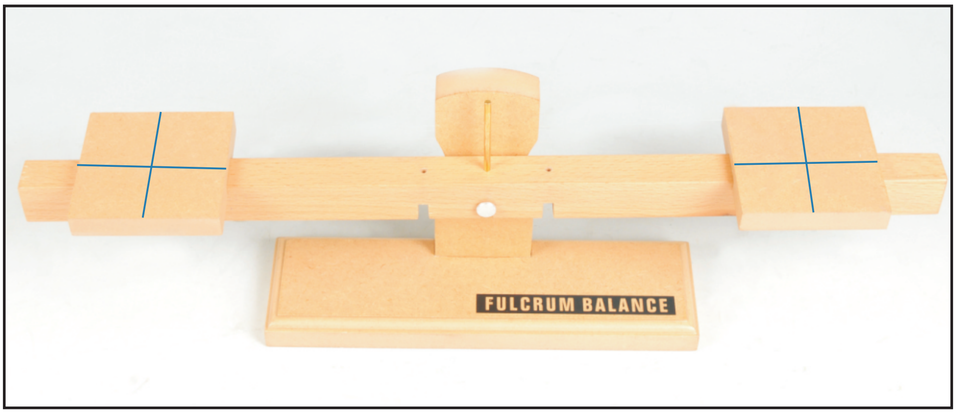

Diagram 6

ACTIVITY 1: SEE SAW (TEACHER'S ANSWERS)

Torque is the amount of force applied to rotate an object times the distance that object is from the pivot point (in this case the fulcrum.)

PRE-LAB QUESTIONS:

1. What class lever is the fulcrum balance?

   (A first class lever)

2. If a balance is in equilibrium, this means that the lever arm is parallel to the table and neither end is being held up. Adjust your fulcrum balance so that it balances with no weight on it.

3. The amount of torque applied by the platform on the left side of the fulcrum balance is equal to the amount of torque acting on the other end of the fulcrum balance. Therefore if a big force is being applied over a little distance on one side of the fulcrum balance then a little force is being applied over bigger distance on the other side of the lever can balance out. Write an equation using "F" as the big force and "f" as the little force, "D" is the bigger distance and "d" is the smaller distance where the left hand side of the equation represents the torque applied by a small force and the right hand side of the equation represents the torque applied by a larger force while the balance is in equilibrium.

   $$f \times D = F \times d$$

4. Have your teacher check your answers and see that your fulcrum balance is in equilibrium. If everything is correct you may now begin your investigation.

PROCEDURE:

1. Take two objects of different mass and place each one in the center of a platform on opposite sides of the fulcrum balance as shown in diagram 7.

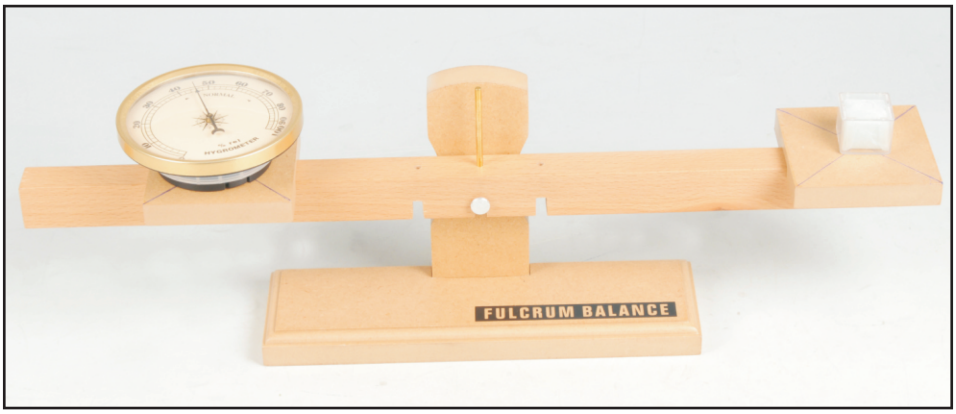

Diagram 7

2. Slide the platforms until the fulcrum balance is in equilibrium.

3. Which object has the most mass?
   (Depending on what you give the students to use, any answer should be ok here as long as the student identifies the more massive object.)

4. Which object is closer to the fulcrum?
   (The more massive object is closer to the fulcrum.)

5. Move your more massive object closer to the fulcrum and rebalance your fulcrum balance.

6. As the more massive object moves closer to the fulcrum, did you need to move your less massive object closer or farther away from the fulcrum to reach equilibrium?
   (The less massive object also had to move closer to the fulcrum.)

7. Move your more massive object farther away from the fulcrum and rebalance your fulcrum balance.

8. As the more massive object moves farther the fulcrum, did you need to move your less massive object closer or farther away from the fulcrum to reach equilibrium?
   (The less massive object also had to move farther from the fulcrum.)

9. When using a seesaw to balance two people, who has to be closer to the middle of the seesaw to get the seesaw to balance, the larger kid or the smaller kid?
   (The larger kid)

NAME:____ DATE:_______________

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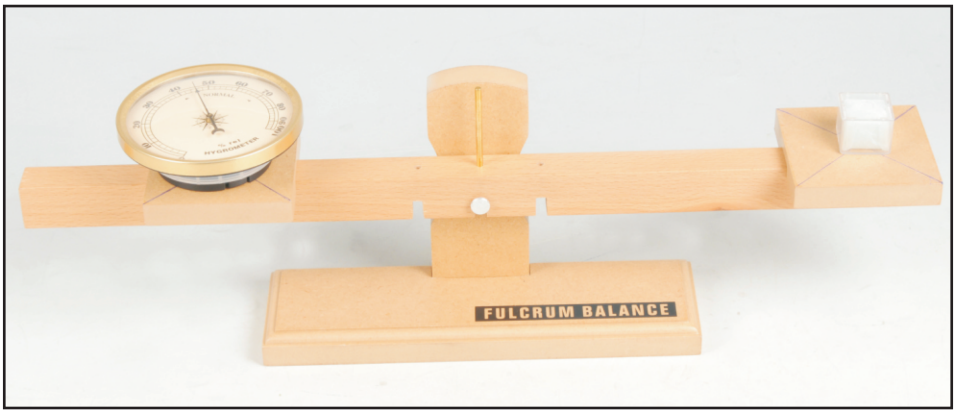

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ACTIVITY 2: SIMPLE MATH TO MAKE PREDICTIONS (TEACHER'S ANSWERS)

Here students will be using the fulcrum balance and two objects of known and unknown mass to determine first the ratio of the masses of the two objects and then to estimate where object two will reach equilibrium if object one is placed a given distance away from the fulcrum. A teacher can adjust the difficulty of the math in this activity by using masses that are in different ratios to one another. The simplest ratio is 2:1, however a ratio of 4:1 or even 3:2 could be used for students needing an additional challenge.

WARNING: Heavier objects will slide off the fulcrum balance very easily. Make sure that students are carefully releasing the masses and keeping their hands under either end of the balance to make sure it doesn't tip and the masses don't fall off. It may be wise to have a mat or pad under the fulcrum balance so that falling objects don't dent your table.

PROCEDURE:

1. Bring your platforms as close to the fulcrum as possible and balance them so they reach equilibrium.
2. Measure the distance from the center of platform 1 to fulcrum and the center of platform two to the fulcrum and record this value in your data table.
3. Move platform 1 about two centimeters away from its original position and then adjust platform 2 again so that the fulcrum balance is in equilibrium.
4. Measure the distance from the fulcrum to the center of platform 1 and 2 again and record this in your data table.
5. Repeat steps 3 & 4 two more times.

DATA TABLE:

Distance from fulcrum to center of platform 1 (cm) D1	***Distance from fulcrum to center of platform 2 (cm) D2***	***Ratio of distances***
6.1	6.4	1
8.4	8.5	1
10.5	10.7	1
14.3	14.3	1

The ratio of distance should have been around 1 if you divide D1/D2

QUESTIONS:

1. What is the ratio of D1:D2? *(1:1)*
2. Rearrange the equation F1 x D1 = F2 x D2, where F1 is the mass of platform 1 and D2 is the mass of platform 2, so that the equation is written as D1/D2 =

$$\frac{D1}{D2} = \frac{F2}{F1}$$

3. Using the equation above we can say that the force applied by platform 1 is how many times bigger than the force applied by platform 2?
   (The force applied by platform 1 is exactly the same as the force applied by platform 2.)

Now we wish to find the mass of an unknown object by using the same procedure as above and an object of known mass. Note that the masses need to be fairly heavy compared to the mass of the platforms for this to work. I would suggest around 500 grams to 1000 grams of mass. Another option is to make the mass on platform one a ratio of the mass of platform 2. This will make the ratio appear a little more even. There will be some variation even if you take into account the mass of the platform because the mass of the lever itself isn't really negligible.

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5. Repeat steps 3 & 4 two more times.

DATA TABLE:

Distance from fulcrum to center of platform 1 (cm) D1	***Distance from fulcrum to center of platform 2 (cm) D2***	***Ratio of distances***
6.1	3.2	2
8.4	4.3	2
10.5	5.4	2
14.3	7.2	2

The ratio of distance should have been around 2 if you divide D1/D2

QUESTIONS:

1. What is average ratio of distance between D1 and D2?
   (D1 is twice as far from the fulcrum as D2, the ratio is 2:1)

2. What can you say about the force on platform 1 compared to the force on platform 2 based on the ratio between your distances?
   (The force on platform 1 is one half that of the force on platform 2.)

3. Measure the mass of the object on platform 1 (in this case 500g) and use the ratio of the force on platform one to the force on platform 2 to estimate the mass on platform two. Explain how you got your answer.
   (Since the ratio of force1 to force 2 is 1:2, the mass on platform two is twice that of platform 1, so the mass would be 1000g.)

4. If platform 1 was moved 18cm away from the fulcrum, then where should the center of platform 2 be placed to reach equilibrium? Show how you got your answer.
   (Graphing the data and picking a point would be acceptable, or simply dividing 18cm by 2 to get 9 cm would work as well. If the ratio for the students was not as simple as 2:1, using the formula F1 x D1 = F2 x D2 would work as well to come up with desired answer.)

NAME:____ DATE:_______________

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The ratio of distance should have been around 1 if you divide D1/D2

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3. Measure the mass of the object on platform 1 and use the ratio of the force on platform one to the force on platform 2 to estimate the mass on platform two. Explain how you got your answer.

4. If platform 1 was moved 18cm away from the fulcrum, then where should the center of platform 2 be placed to reach equilibrium? Show how you got your answer.

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