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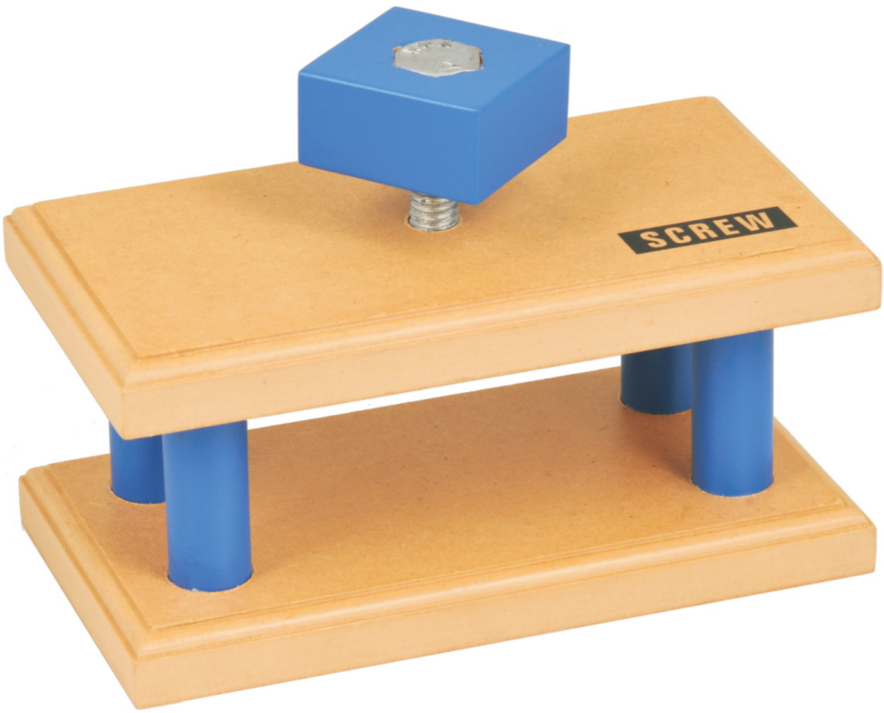
SIMPLE MACHINES : SCREW

CAT NO. WDMS20



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 axel 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 rest 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.

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First class levers as shown in diagram 1:

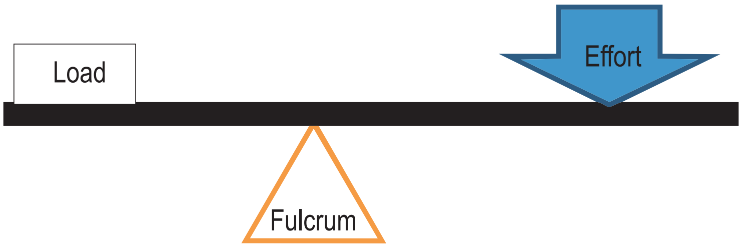

Diagram 1

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

Class two levers as shown in diagram 2:

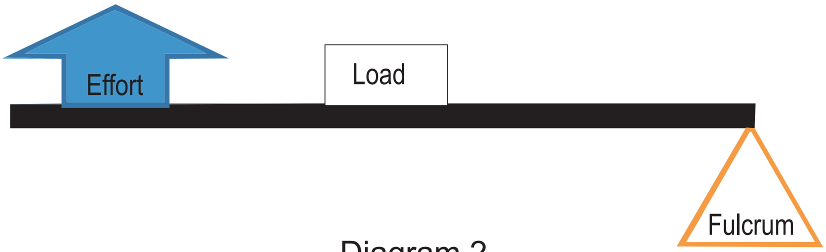

Diagram 2

Examples of class two levers are wheel barrows, shovels, and nutcrackers.

Class 3 levers as shown in diagram 3:

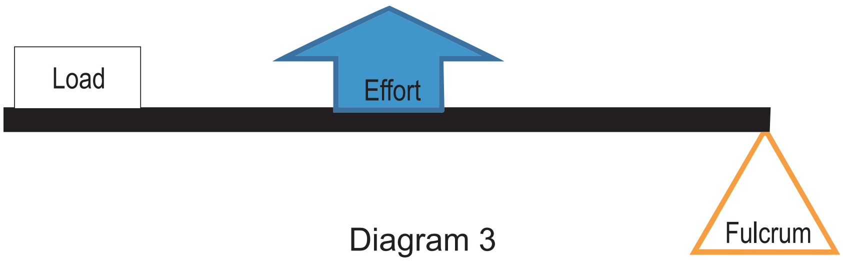

Diagram 3

A fishing pole, tweezers, and your forearm are good examples of class three levers.

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 by covering a longer distance using less force. The larger the wheel the greater the mechanical advantage of that wheel. As a wheel turns the distance traveled by the one rotations 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 bike's wheel. Examples of

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wheels and axels include bike tires, car tires, 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.

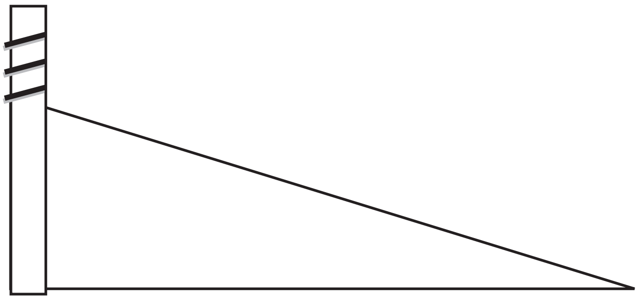
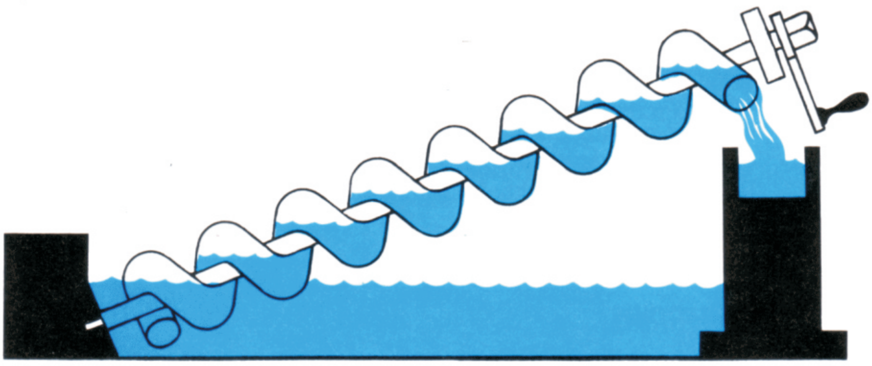


Diagram 4

Archimedes screws were some of the first kinds of screws known to be used around 250 BC, although there is some debate as to whether Archimedes himself invented the screw or just improved upon an earlier design.



These screws were used in irrigation and to pump water out of boats. The water was scooped up from the stream or boat and forced upwards as the screw turned. Because of the mechanical advantage of the screws horses could turn the screw and were able to carry much more water than if they were to pull the water up with buckets.

Screws were also used to help press fruit such as grapes to make wine and olives to make olive oil. The mechanical advantage of the screws allowed much more juice/oil to be extracted from their crop.

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Diagram 6

Notice the screw and the lever used to maximize the mechanical advantage of this olive press. Before presses were made using screws, a large force was applied to the olives using a very heavy stone as shown in diagram 7.

Diagram 7

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Screw	1
Screw base	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Egg	1
Dish that fits under the screw	1
Wooden block	1
Metal bar or post	1
Ruler	1
Bleach solution to clean up broken egg mess	

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ACTIVITY 1: HOW MUCH MECHANICAL ADVANTAGE? (TEACHER ANSWERS)

PROCEDURE:

1. Turn the screw one complete rotation (one time around), what shape path does the corner of the screw take? Is it a square or a circle? *(A circle)*

2. What mathematical formula can you use to find the distance around the outside of this shape? *(Circumference =   x Diameter)*

3. Measure the diameter of the widest part of the top of the screw with a ruler and give that value in centimeters to the nearest tenth of a centimeter.
   6.9 cm

4. What is the distance traveled by your hand (which is applying the effort force) for one complete rotation of the screw? Show all work including formula and substitution with units.
   Circumference =   x Diameter = 3.14 x 6.9 cm = 21.7 cm

5. Screw the screw into the holder and continue turning until the screw head is completely flush with the bottom of the platform holding the screw.

6. Screw the screw completely into the platform and count the number of rotations. How many times could you turn the screw? Estimate to the nearest ¼ turn and record this value below.
   7.5 turns

7. What is the total distance your hand applies a force while screwing the screw into the top platform? Show all work.
   Distance for one turn is 21.7 cm x 7.5 turns = 162 cm or 1.62 m

8. Measure the distance the end of screw moves down during this rotation to the nearest tenth of a centimeter and record this value in the space provided below.
   1.5 cm

9. Use the formula for mechanical advantage to calculate the mechanical advantage of the screw.

$$\frac{F_l}{F_e} = \frac{d_e}{d_l} = \frac{\text{mechanical}}{\text{advantage}} = \frac{162\text{ cm}}{1.5\text{cm}} = 108$$

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EXTENSION:

Lets say you want to use a wrench to tighten your screw. Use the same equation above but instead using the diameter you used in your original calculations, make the diameter bigger to assume you are using a wrench. What is your mechanical advantage now?

(If the diameter is increased to just 10 cm, then the mechanical advantage is 157)

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NAME:____ DATE:_______________

ACTIVITY 1: HOW MUCH MECHANICAL ADVANTAGE?

Mechanical advantage is a way we describe how much easier work is to do. It is the ratio of the amount of force the person (or animal) doing the work applies (called the effort) compared to the amount of force the object being worked on feels (called the load).

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

We already know that work is the amount of force applied over a distance. In the case of a frictionless incline plane, the work done to lift a 100N block 1.0 meters straight in the air is 100 J. W = F x d = 100N x 1.0 M = 100 J. In instead we push the block up an incline that is 4.0 m long, we still need to do 100 J of work, but now we need to apply only 25 N of force while pushing the block up the incline. Our mechanical advantage is therefore 100N/25N = 4.

[Force applied or weight of the load] [Distance load moves] = [Force applied by the effort] [Distance effort force is applied]

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

$F_l \times d_l$ 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:

$$\frac{F_l}{F_e} = \frac{d_e}{d_l} \quad \text{Mechanical advantage}$$

Look at diagram 4 :

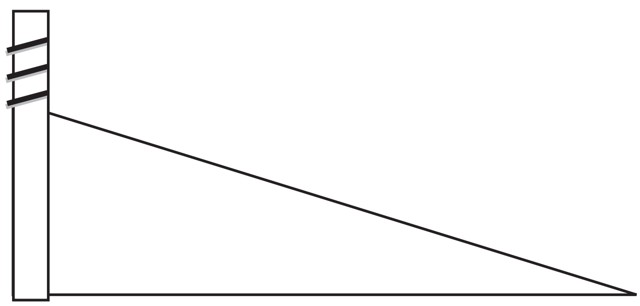

Diagram 4

A screw is really just an inclined plane wrapped around a post, so in effect it is a more compact incline plane. Just like an incline plane, if we can find the distance the screw

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moves down and the distance our hand moves applying a force to ramp, we can find the mechanical advantage of the screw. The ratio of those two distances will give us the mechanical advantage of the screw. The mechanical advantage of our screw is magnified by the fact that our screw has a very large head on it. So when we rotate the screw one time with our hand, we are applying a force over the distance of the circumference of the circle we rotate the screw with.

PROCEDURE:

1. Turn the screw one complete rotation (one time around), what shape path does the corner of the screw take? Is it a square or a circle?

   ____

2. What mathematical formula can you use to find the distance around the outside of this shape?

   ____

3. Measure the diameter of your circle with a ruler and give that value in centimeters to the nearest tenth of a centimeter.

   ________ cm

4. What is the distance traveled by your hand (which is applying the effort force) for one complete rotation of the screw? Show all work including formula and substitution with units.

5. Screw the screw into the holder and continue turning until the screw head is completely flush with the bottom of the platform holding the screw.

6. Screw the screw completely into the platform and count the number of rotations. How many times could you turn the screw? Estimate to the nearest ¼ turn and record this value below.

   ___________ cm

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7. What is the total distance your hand applies a force while screwing the screw into the top platform? Show all work.

8. Measure the distance the end of screw moves down during this rotation to the nearest tenth of a centimeter and record this value in the space provided below.

___________ cm

9. Use the formula for mechanical advantage to calculate the mechanical advantage of the screw. Include formula and substitution units.

EXTENSION:

Let's say you want to use a wrench to tighten your screw. Use the same equation above but instead using the diameter you used in your original calculations, make the diameter bigger to assume you are using a wrench. What is your mechanical advantage now?

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ACTIVITY 2: PUTTING YOUR MECHANICAL ADVANTAGE TO GOOD USE (TEACHER ANSWERS)

What could you break if you were 100 times stronger? I'm sure a lot of things come to mind . . . and it sure would be fun to test. Egg shells are fairly strong, have students try to break an egg shell by pressing on it with their finger. You might want to have students wear gloves and do this on top of something easy to clean up. If an egg does break, make sure you clean and sanitize the area where the raw egg was. Now place the egg in a dish and place the dish under the screw as shown in diagram 8.

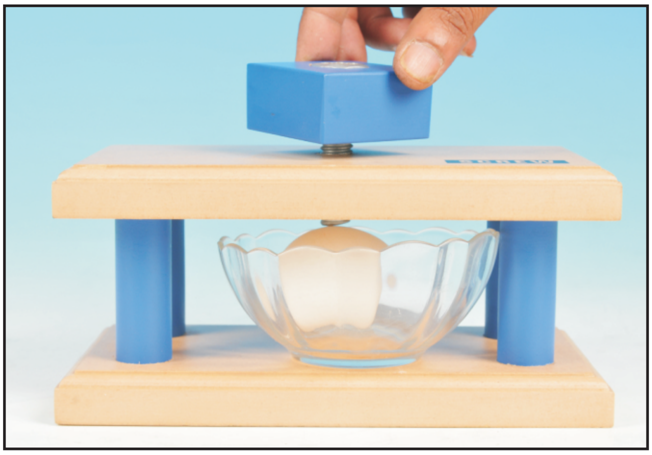

Diagram 8

Have students turn the screw until the egg breaks. They will be surprised how easy this is to do. They can also easily dent a piece of wood, or even bend metal. If you put something to strong to break in there, you can break the apparatus, but the wooden posts will pull apart before the screw will be stripped. Just another testament as to how strong screws actually are.

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