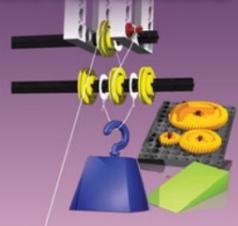


PHYSICS SIMPLE MACHINES



Instructions

Warning! — This set contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

Only for use by children 8 years of age and older. Use only under careful supervision of adults who have familiarized themselves with the kit's written safety precautions.

A Note to Parents and Supervising Adults Please stand by your child's side as they do the experiments in this kit, providing support and company to him or her as needed. Read through the instructions together before beginning the experiments, and follow them. Please be sure that no small pieces get into the hands of young children. Provide your child with any required household items that are not contained in the kit, and encourage your child to repeat an experiment if the initial results don't meet expectations.

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Water Bottle Weight

You will need to make a weight out of a water bottle. Have an adult poke two holes in the bottle cap and use it to tie on the cardboard lid and the hook with the string. Fill the bottle with about a half of a cup of water.



Introduction

Simple machines are devices that make physical work easier by changing the amount of force required to do work or changing the direction of the force required to do work. To understand this, we first need to understand what forces and work are.

For the purpose of this kit, you can think of a **force** as a push or a pull that causes an object to move, or change its speed if it is already moving. When you push on a door to open it, you are applying force to the door to move it open. Forces act on masses (objects with mass) in specific **directions**.

You may think of **work** as the chores your parents make you do or the assignments you do in school, but to a physicist, work is the amount of energy exerted when a force moves an object a certain **distance**. When you carry a box of toys up the stairs, you are doing work equal to the amount of force it takes to move that box the distance from the bottom of the stairs to the top.

So, simple machines make work easier to do by allowing you to push or pull with less force or in a more convenient direction to move an object. But, any force that is saved by using a simple machine must be accounted for in terms of distance. This is an important rule to remember about simple machines. The amount to which a simple machine makes work easier is called its **mechanical advantage**. There are six classic types of simple machines:

Lever: A lever is a rigid bar that can be pivoted on a point, called the fulcrum. Applying force to one part of the lever will cause a load (weight) somewhere else on the lever to move.

Wheel and Axle: This is a wheel with a pole through its center called the axle. It is actually a type of lever that rotates around the fulcrum.

Pulley: A pulley is a wheel and axle with a groove in its circumference. A rope or chain is run through the groove. A weight attached to one end can be moved by pulling in the opposite direction on the other end.

Inclined Plane: This is a ramp where one end is higher than the other. Moving an object up the ramp requires less force than lifting the object vertically.

Screw: A screw is an inclined plane wrapped around a pole. It converts turning force into a straight (linear) force along the length of the pole.

Wedge: A wedge is two inclined planes attached back to back. It converts a force acting on its end into two perpendicular forces acting out from the sides.

Measuring Forces

In order to be able to experiment with simple machines and see what they are doing, we need a way to measure forces. To do this, we will build a **spring scale**, which is a simple tool that uses a spring to measure forces. Most spring scales use metal coil springs, but we will build one using a rubber band which exhibits some of the same elastic properties as a metal spring.

The theory behind the way a spring scale works is that the amount of force it takes to stretch the spring is proportional to the distance the force stretches the spring. In other words, a large force will stretch the spring a lot and a small force will stretch the spring only a little. By measuring the distance a spring is stretched, we can approximate the force being exerted on the spring.



Build and Test the Spring Scale

Assemble the spring scale as shown. Use the force meter scale from the die-cut cardboard sheet. This spring scale measures forces in Newtons, which is the standard unit of force.

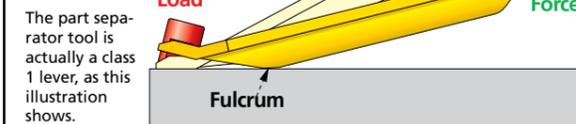
After you have built the spring scale, use it to weigh the water bottle weight. Hook the bottle weight to the washer ring and let it hang. Hold the spring scale carefully so the rubber band does not slip and snap back at you. Read the scale by looking through the washer.

How much does the water bottle weight?

A half cup of water weighs about 1 N (Newton).

Levers

Levers are rigid bars that pivot on a point called the fulcrum. A weight (or load) at one point on the bar can be moved by applying a force to another point on the bar. If the distance from the fulcrum to the force (the **force arm**) is greater than the distance from the fulcrum to the load (the **load arm**), then a smaller force can move a larger load. This is how the lever makes work easier. There are three types of levers: **Class 1, 2, and 3**. The class depends on where the load and force are positioned relative to the fulcrum.



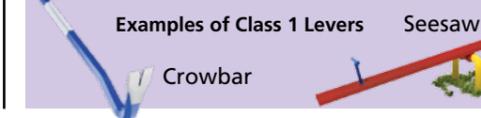
01 Experiment

Class 1 Lever

Assemble the parts as shown. The long rod should pivot on the axle. This pivot point is the fulcrum.

Now we will test it. You will need a helper to hold the base plate firmly in place. Hook the water bottle weight (the load) to one side and use a joint pin to attach the spring scale washer to the other side.

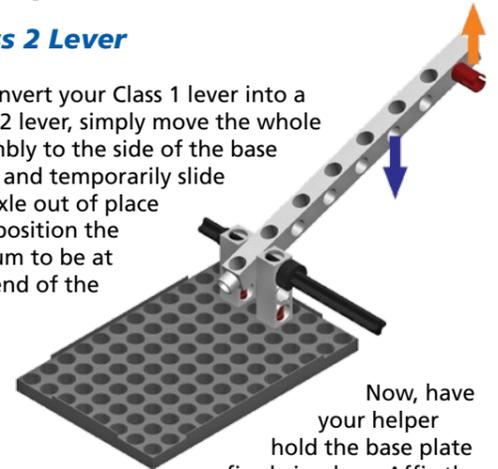
A downward force on the load side is counteracted by a downward force on the other side. How much force does it take to lift the water bottle weight?



02 Experiment

Class 2 Lever

To convert your Class 1 lever into a Class 2 lever, simply move the whole assembly to the side of the base plate and temporarily slide the axle out of place to reposition the fulcrum to be at one end of the lever.



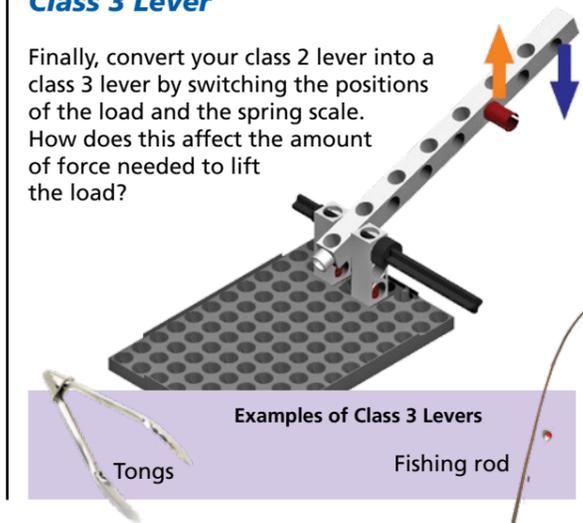
Now, have your helper hold the base plate firmly in place. Affix the bottle weight to the spot where the blue arrow is and hook the spring scale on the joint pin. Now, a downward load is counteracted by an upward force. How much force does it take to lift the bottle now? If you move the load to a hole closer to the fulcrum, how does it change the force required to lift it?



03 Experiment

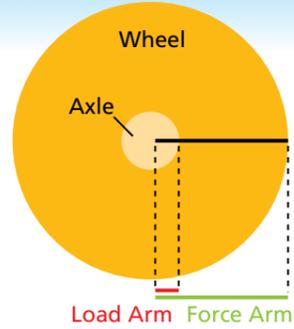
Class 3 Lever

Finally, convert your class 2 lever into a class 3 lever by switching the positions of the load and the spring scale. How does this affect the amount of force needed to lift the load?



Wheels and Axles

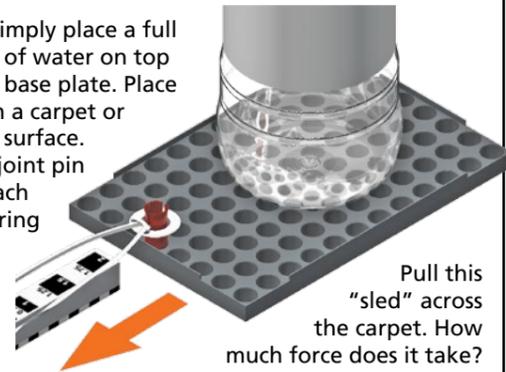
A wheel and axle together form a simple machine that is basically just a lever rotated around a center axis, or fulcrum. In this case, the force arm is the distance from the fulcrum to the edge of the wheel, while the load arm is the distance from the fulcrum to the edge of the axle. A small force applied to the edge of the wheel will result in a large force at the edge of the axle. Alternatively, a slow turning of the axle will yield a faster turning of the outer edge of the wheel, if speed is what you are after.



04 Experiment

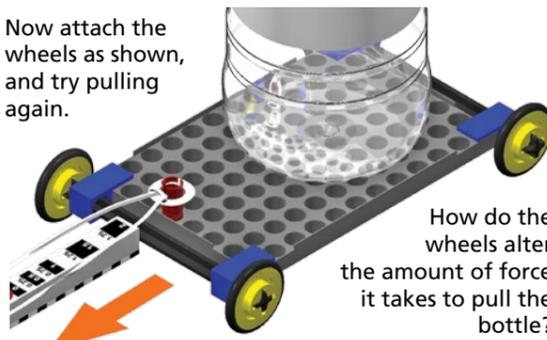
With and Without Wheels

First, simply place a full bottle of water on top of the base plate. Place this on a carpet or rough surface. Use a joint pin to attach the spring scale.



Pull this "sled" across the carpet. How much force does it take?

Now attach the wheels as shown, and try pulling again.

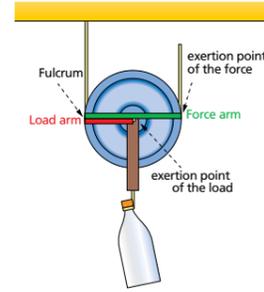
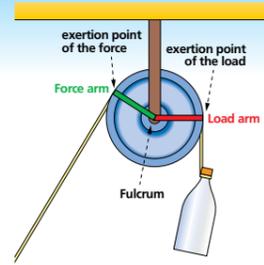


How do the wheels alter the amount of force it takes to pull the bottle?



Pulleys

Pulleys are wheels and axles with ropes or chains running over them. There are three types of pulleys: **fixed**, **movable**, and **compound**. A fixed pulley is an equal-armed, two-sided lever that rotates around a fulcrum. The force and load arms are equal in length, so it does not actually reduce the amount of force needed to move the load, but it does change the direction of the force, allowing the user to pull in a more convenient direction.

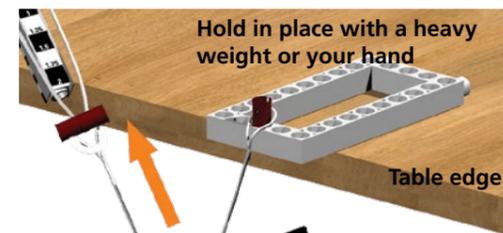


A moveable pulley reduces the amount of force needed to lift the load, but at the cost of increasing the distance over which the rope has to move. The suspended load is divided between two ropes, cutting the force in half but doubling the distance.

05 Experiment

Moveable Pulley

Construct this pulley assembly. Tie string to two washers to make a loop where the water bottle weight can be hooked on.

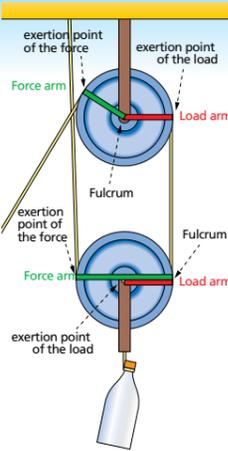


Hold in place with a heavy weight or your hand

Table edge

Set up the pulley system like this. Tie one end of a piece of string to the frame held in place with a heavy weight or your hand, run the string under the middle pulley wheel, and attach the other end of the string to the spring scale to read the force.

A compound pulley is a combination of a fixed and a moveable pulley. This allows for both a convenient pulling direction as well as a reduction in the amount of force needed to lift the load. Many compound pulleys can be put together in a row to make a device called a **block and tackle**, which increases the mechanical advantage.



06 Experiment

Compound Pulley

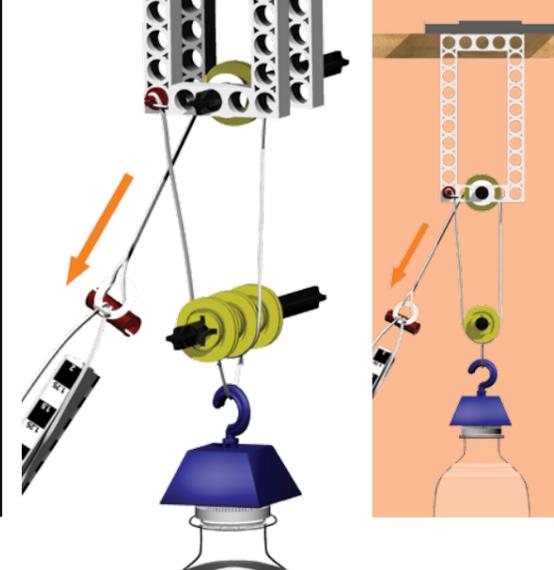
Now set up this pulley system. This time, the string is looped over a second, fixed pulley as well as the moveable pulley. Again use a heavy weight or your hand to hold the frame in place at the edge of the table. Attach the free end of the string to the spring scale and read the force. Has it changed?

Hold in place with a heavy weight or your hand



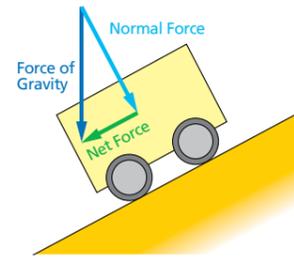
Table edge

View from the side



Inclined Planes

An inclined plane is a surface where one side is higher than the other. When an object is moved upward along an inclined plane, less force is needed than when the object is moved straight up the same vertical distance. The expense is that the object has to travel a longer distance when it moves up the ramp. The diagram shows how forces act on an object on an inclined plane. The net force, the force required to move the object up the ramp, is less than the force of gravity, the force required to lift the object straight up in the air.



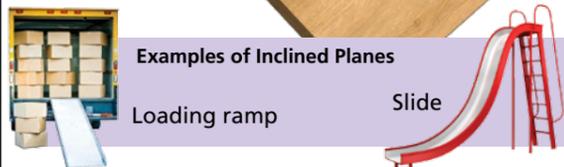
07 Experiment

Ramping Up

Position a board so that one side is higher than the other. (If you have a ramp in your home or school, you can use that.) First, use the spring scale to measure how much the water bottle weighs when you lift it straight off the ground.



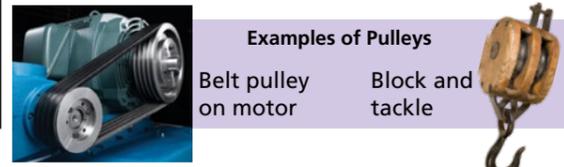
Then, place the bottle at the bottom of the ramp and pull it up the ramp with the spring scale. How much force does it take to slide the bottle up the ramp?



Examples of Inclined Planes

Loading ramp

Slide



Examples of Pulleys

Belt pulley on motor

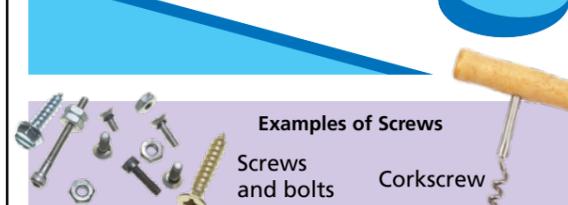
Block and tackle

Screws

A screw is an inclined plane wrapped around a cylinder. When a screw is turned, the turning force is converted into a linear force along the length of the screw. A metal woodworking screw makes it easier to bore itself into a block of wood because with each rotation of the screw, the threads move a lot farther than the tip of the screw that is being driven into the wood. Again, the force is reduced but the distance is increased.

The mechanical advantage of a screw depends on the pitch of the threads. The **pitch** is the angle of the inclined plane relative to the cylinder.

Let's make a simple model of a screw. Take the die-cut cardboard piece and wrap it around a pen or pencil into a spiral as shown, and tape it together. This clearly shows how a screw is just a rotated inclined plane.



Examples of Screws

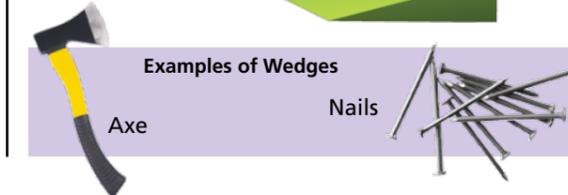
Screws and bolts

Corkscrew

Wedges

A wedge is made when two inclined planes are attached back to back. The wedge converts force applied to its blunt side into two outward forces from its longer sides.

Make a simple model of a wedge by folding the two inclined planes from the cardboard sheet and taping them together.



Examples of Wedges

Axe

Nails

Gears

Gears are not considered one of the six classic simple machines, but they are often included in lists with the simple machines because they are so widely used. Gears are actually versions of wheels and axles with teeth that allow them to mesh together and turn each other.

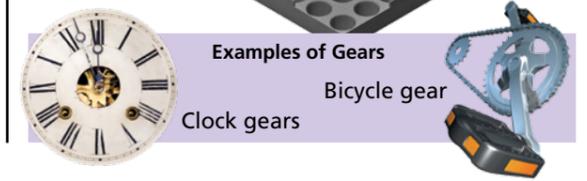
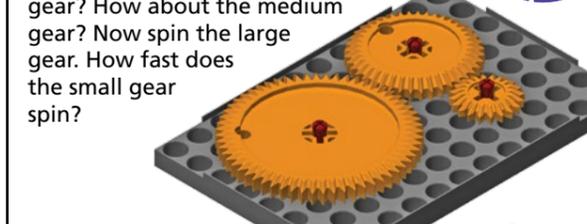
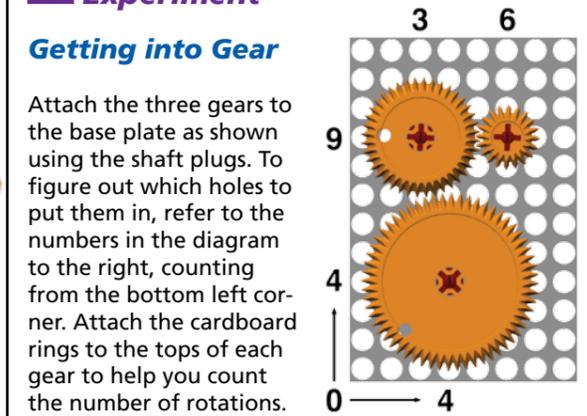
The mechanical advantage of a gear is evident when a large gear meshes with a small gear. One full turn of the large gear will produce, say, three full turns of the small gear. Because of this, the smaller gear always turns faster than the larger. On the other hand, the larger gear turns with greater force than the smaller. So, in this way, gears can be used to make slow turning motion into rapid turning motion, or to convert small forces into large forces. Now try this yourself.

08 Experiment

Getting into Gear

Attach the three gears to the base plate as shown using the shaft plugs. To figure out which holes to put them in, refer to the numbers in the diagram to the right, counting from the bottom left corner. Attach the cardboard rings to the tops of each gear to help you count the number of rotations.

Now, turn the large gear one full rotation and watch the small gear. How many times does the small gear turn completely for each turn of the large gear? How about the medium gear? Now spin the large gear. How fast does the small gear spin?



Examples of Gears

Clock gears

Bicycle gear