Pulleys

Well, I hope you used the lever lesson to get some "leverage" on this work, energy and simple machines concept. This lesson we're going to "pulley" ourselves up by our bootstraps and play with these concepts just a little more.

When we played with levers we could see that, by using a simple machine, we were able to use less force to move a heavy object than we would have had to use if we didn't use a simple machine. We also saw that with that lessening of force came an increase in distance. Obviously, you can only make a lever so long. After a while it gets kind of ridiculous. Imagine lifting a concrete block or a car with a lever. That's a big lever and you probably still wouldn't be able to lift the car very high. This is where pulleys come in. By the use of a pulley (otherwise known as a block and tackle), car mechanics lift 600 lb car engines with one hand! Cranes that lift steel girders and thousand pound air conditioning units are basically pulleys! (By the way, Archimedes is credited for inventing the crane. He actually used a crane as a weapon to defend Syracuse from Rome. When the Roman ships got close to the Syracuse walls, Archimedes' crane would grab them and turn them over! Go science!)

So, you ready to do some weight lifting? Let's go! By the way, there's a movie of the next three experiments at www.bitesizephysics.com/physicsmovies.html.

Experiment 1

The Lone Pulley

You need:

One pulley (You can use a spool and a straw but I would recommend buying some pulleys at a hardware store. Get small ones that spin as freely as possible. You'll need three single pulleys or if you can find one get a double pulley to make experiment 3 easier.)

About four feet of string

2 paper cups

many little masses (about 50 marbles, pennies, washers etc.)

Yardstick or measuring tape

A scale (optional)

2 paper clips

Nail or some sort of sharp pokey thing

Table

1. Take a look at the picture to see how to make your "mass carriers" Use the nail to poke a hole in both sides of the cup. Be careful to poke the cup...not your finger! Thread about 4 inches of string or a pipe cleaner through both holes. Make sure the string is a little loose. Make two of these mass carriers. One is going to be your load (what you lift) and the other is going to be your effort (the force that does the lifting).

2. Dangle the pulley from the table (check out the picture).

3. Bend your two paper clips into hooks.

4. Take about three feet of string and tie your paper clip hooks to both ends.

5. Thread your string through the pulley and let the ends dangle.

6. Put 40 masses (coins or whatever you're using) into one of the mass carriers. Attach it to one of the strings and put it on the floor. This is your load.

7. Attach the other mass carrier to the other end of the string (which should be dangling a foot or less from the pulley). This is your effort.

8. Drop masses into the effort cup. Continue dropping until the effort can lift the load.

9. Once your effort lifts the load, you can collect some data. First allow the effort to lift the load about one foot (30 cm) into the air. This is best done if you manually

pull the effort until the load is one foot off the ground. Measure how far the effort has to move to lift the load one foot.

10. When you have that measurement, you can either count the number of masses in the load and the effort cup or if you have a scale, you can get the mass of the load and the effort.

11. Write your data into your pulley data table. There's an example of one at the end of this lesson.

Experiment 2

A Pair of Pulleys

Now that you did one pulley, let's see what happens with two.

You need:

Same stuff you needed in Experiment 1, except that now you need two pulleys.

1. Attach the string to the hook that's on the bottom of your top pulley.

2. Thread the string through the bottom pulley.

3. Thread the string up and through the top pulley.

4. Attach the string to the effort.

5. Attach the load to the bottom pulley.

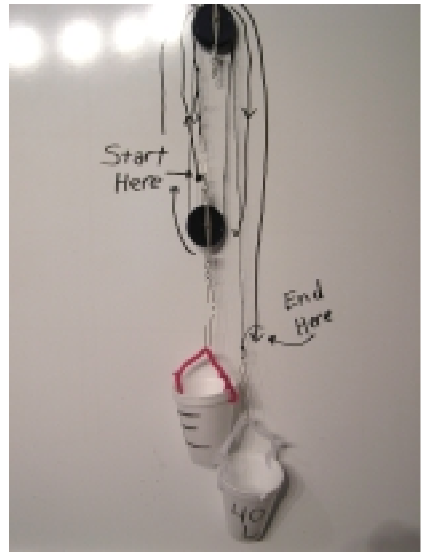
6. Once you get it all together, do the same thing as before. Put 40 masses in the load and put masses in the effort until it can lift the load.

7. When you get the load to lift, collect the data. How far does the effort have to move now in order to lift the load one foot (30 cm)? How many masses (or how much mass, if you have a scale) did it take to lift the load?

8. Enter your data into your pulley table.

Experiment 3

Triple Action

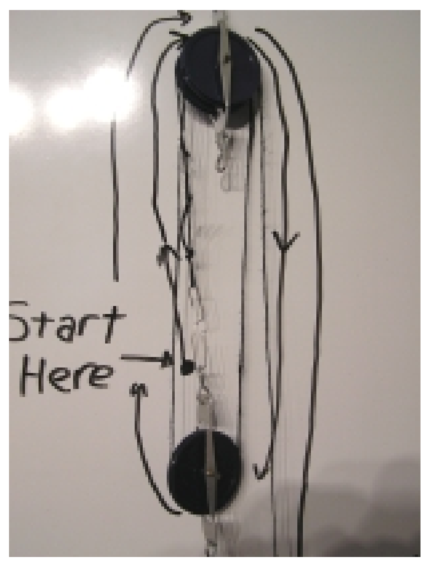


You Need

Same stuff as before

If you have a double pulley or three pulleys you can give this a shot. If not, don't worry about this experiment.

Do the same thing you did in experiments 1 and 2 but just use 3 pulleys. It's pretty tricky to rig up 3 pulleys so look carefully at the pictures. The top pulley in the picture is a double pulley.



1. Attach the string to the bottom pulley. The bottom pulley is the single pulley.
2. Thread the string up and through one of the pulleys in the top pulley. The top pulley is the double pulley.
3. Take the string and thread it through the bottom pulley.
4. Now keep going around and thread it again through the other pulley in the top (double) pulley.
5. Almost there. Attach the load to the bottom pulley.
6. Last, attach the effort to the string.
7. Phew, that's it. Now play with it!

Take a look at the table and compare your data. If you have decent pulleys, you should get some nice results. For one pulley, you should have found that the amount of mass it takes to lift the load is about the same as the amount of mass of the load. Also, the distance the load moves is about the same as the distance the effort moves. All you're really doing with one pulley, is changing the direction of the force. The effort force is down but the load moves up. Now, however, take a look at two pulleys. The mass needed to lift the load is now about half the force of the load itself! The distance changed too. Now the distance you needed to move the effort, is about twice the distance that the load moves. When you do a little math, you notice that, as always, work in equals work out (it won't be exactly but it should be pretty close if your pulleys have low friction). What happened with three pulleys? You needed about 1/3 the mass and 3 times the distance right? With a long enough rope, and enough pulleys you can lift anything! Just like with the lever, the pulley, like all simple machines, does a force and distance switcheroo. The more distance the string has to move through the pulleys, the less force is needed to lift the object. The work in, is equal to the work out (allowing for loss of work due to friction) but the force needed is much less.

Mechanical Advantage

One more thing I'd like to add here, is the concept of mechanical advantage. The definition of mechanical advantage is that it is the factor by which a mechanism multiplies the force put into it. The whole idea behind simple machines is that they give you an advantage. In other words, they help you do things more easily. The nice thing about pulleys is that it is very easy to see the mechanical advantage. You noticed when you used one pulley that it took about the same amount of effort to lift the load. That would be a mechanical advantage of one. However, when you used two pulleys, half the effort lifted the load. You only had to pull half as hard to lift the load. The pulleys doubled your strength. In this case, the mechanical advantage is two. Can you guess what the mechanical advantage was of three pulleys? Yup, three. The pulleys tripled your strength. Who needs exercise when you have pulleys!

	Effort Side			Load Side		
	Force Number of Weights or Mass of Weights	Distance Distance the Mass Carrier Moved Down	Work In Multiply Force x Distance on Effort Side	Force Number of Weights or Mass of Weights	Distance Distance the Mass Carrier Moved Down	Work Out Multiply Force x Distance on Load Side
1 Pulley						
2 Pulleys						
3 Pulleys						

If you used a scale to get the masses you can find out how much work you did. Remember that work=force x distance. The table will tell you how to find work for the effort side (work in) and for the load side (work out). You can multiply what you have or if you'd like to convert to Joules, which is a unit of work, feel free to convert your distance measurements to meters and your mass measurements to Newtons. Then you can multiply meters times Newtons and get Joules.

Conversion Chart

1 inch = .025 meters

1 cm = .01 meter

1 ounce =0.278 Newtons

1 gram = 0.0098 Newtons

In a Nutshell

-The pulley is a very powerful simple machine.

- A major job of simple machines is to decrease the force needed to move something.

- Flag poles, fishing rods, cranes, window blinds, and wishing wells all have pulleys.

- The more pulleys that are rigged together, the more effective a pulley system can be.

- Pulleys, like all simple machines, sacrifice distance for force. The more distance the effort moves, the less force is needed to lift the load.

- Simple machines give you mechanical advantage.

-Mechanical advantage is simply how many times easier it is to lift an object using a simple machine. Officially, mechanical advantage is the factor by which a mechanism multiplies the force put into it. A simple machine with a mechanical advantage of 100 could lift a 100 pound load with the effort of one pound.

Did You Get It

1. If I'm talking about simple machines, what does load mean?
2. So what does effort mean when it comes to simple machines?
3. With the pulleys, as your effort got less and less, what happened to the amount of string you had to pull?
4. What is mechanical advantage?

Warning: the following questions are "mathy". Don't worry about these if it gets in the way of your enjoyment or understanding of the lesson.

5. If a lever had a mechanical advantage of 10 and you wanted to lift a 50 pound watermelon, how many pounds of force would you have to use for the effort?
6. If a pulley had a mechanical advantage of 500 and you wanted to lift a 2000 pound hippo, how many pounds of force would you have to use for the effort?
7. Same hippo different units. Newtons are the official unit of force. So to do this officially, a 2000 pound hippo would take about 9000 Newtons to lift. If you lift that hippo 2 meters, how much work did you do? Remember, work is force x distance.
8. One last question. This one's a little tricky. So if you lifted the hippo 2 meters, how much chain (because string's not going to cut it) did you pull?

Answers

1. The load is what you are lifting or moving.

2. Effort is the force needed to lift the load.

3. As the effort got less, the amount of string (distance) got greater and greater.

4. Mechanical advantage is the factor by which a mechanism multiplies the force put into it.

5. 5 pounds. The lever has a mechanical advantage of 10 so it multiplies the force by 10. So 5 x 10 = 50. (By the way, when you cut up that watermelon invite me over!)

6. 4 pounds. 4 x 500 = 2000

7. 18,000 Joules of work. 9000 Newtons x 2 meters = 18,000 Joules.

8. 1000 meters (3280 ft) of chain!!! Since the mechanical advantage is 500 you would multiply 2 meters by 500 which gives you 1000 meters.