Lesson

16

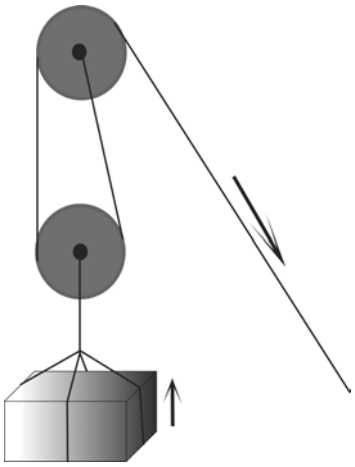
Pulleys

Wheels with ropes

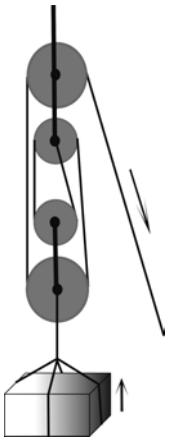
Supply list:

- Broom
- Rope
- 1 gallon jug filled with water

Have you ever used a pulley? A pulley is another modification of the lever. The pulley is a grooved wheel that serves as the fulcrum of the lever. A rope is passed over the wheel. A resistance is attached to one end of the rope and an effort is applied to the other end of the rope. If the pulley is attached to the ceiling or some other immovable surface, the effort pulling down on the rope will move an equal weight in an upward direction. This may not seem like a useful machine because there is no mechanical advantage; however, because of the design of the human body, it is often easier to pull down than up, so even though the mechanical advantage of a single pulley is 1, it often seems easier to lift something with a pulley.



With a single fixed pulley the distance that the effort moves the rope downward is equal to the distance that the resistance is moved upward. But more than one pulley can be used to improve the mechanical advantage. If a second pulley is added to the system, as shown here, the rope being pulled down moves twice as far as the weight moving upward. This gives the person pulling down on the rope a mechanical advantage of 2. A combination of fixed and moveable pulleys is called a block and tackle. The mechanical advantage of a block and tackle system is equal to the number of pulleys in the system. For example, if there are four pulleys in the system, the



mechanical advantage is 4. Keep in mind that the person pulling the rope must pull it four times further than the height he wants to lift the weight.

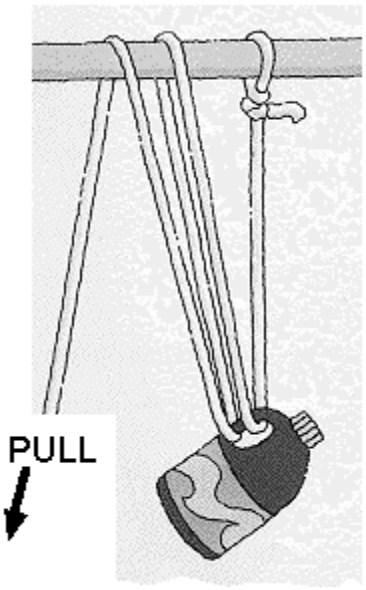
Pulley systems are used in many machines today. A modern crane is an important use of a pulley system. Cranes allow us to lift very heavy objects, such as steel I-beams, into place on skyscrapers. Pulley systems also are used in elevators to lift the car up and down. And block and tackle systems have played a very important role on sailing ships for thousands of years.

As you can see, the use of simple machines such as inclined planes including screws and wedges, as well as levers in their many forms, including wheels, gears, and pulleys, make modern day machines possible. Obviously there are other technologies at work in many modern machines, including computer controls, but the mechanical movement of all complex machines is due to the use of simple machines.

Experimenting with Pulleys:

Compliments of NASA

You can feel the difference that pulleys make by making your own simple pulleys. You can use a rope moving over a broom handle as a single pulley.



Experiment 1: 1 fixed pulley

Attach one end of a rope to the handle of a 1 gallon jug of water. Have someone hold a broom out horizontally. Loop the rope over the broom handle and pull down on the rope to lift the jug. How much effort is required to lift the jug with the rope by pulling down compared to lifting it vertically with the rope without using the broom? (It should feel about the same. It may actually feel slightly more because of the friction between the rope and the broom.)

Experiment 2: 2 pulleys

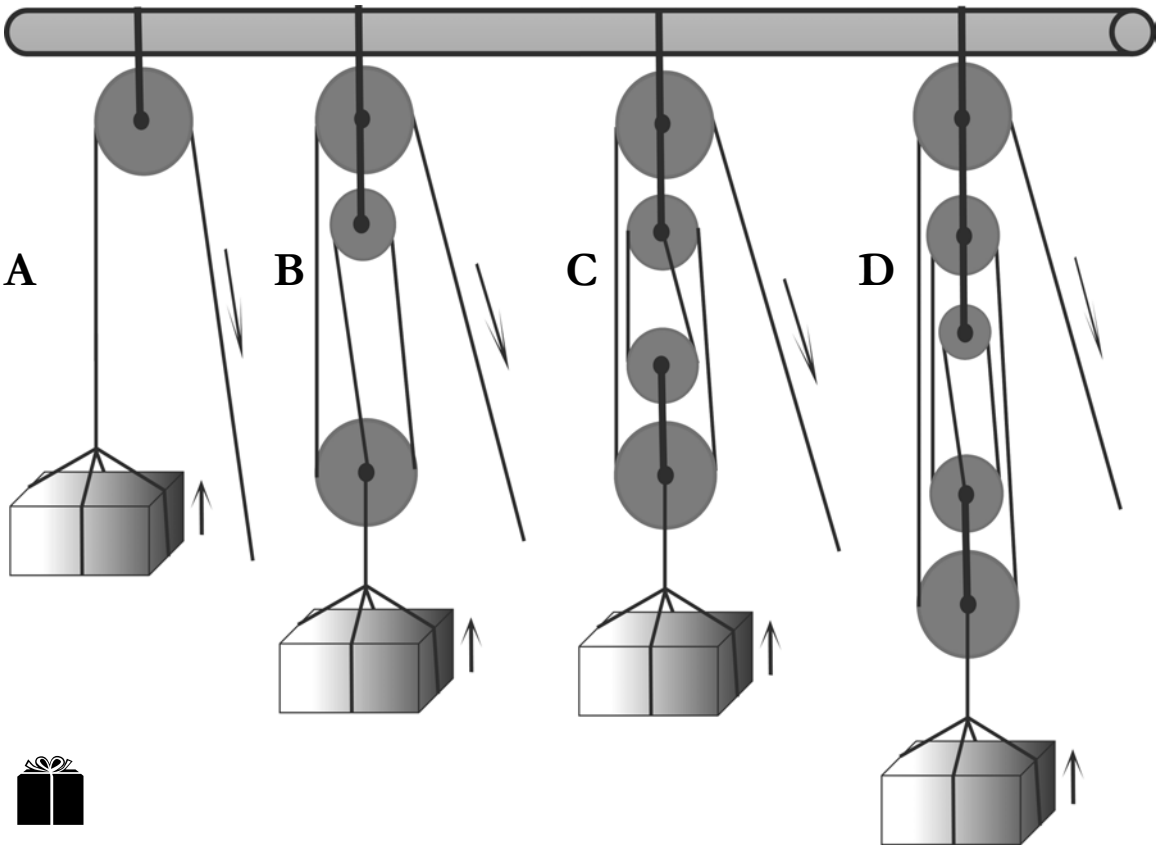
Untie the rope from the handle of the jug and instead loop it through the handle and tie it to the broom. Next, take the other end of the rope and loop it over the broom handle. Pull down on the rope to lift the jug. How much effort is required to lift the jug compared to experiment 1? It should be less. How do you pay for this reduced effort? (By having to pull the rope down twice as far as the distance the jug moves up.)

Experiment 3: 4 pulleys

This time thread the rope through the handle of the jug, and over the broom handle a second time like shown in the picture above. Again pull on the rope to lift the jug. Does it feel easier than

just lifting the jug alone? (It should feel a lot easier.) How far do you have to pull on the rope to lift the jug 1 foot off the ground? (You should have to pull the rope about 4 feet.) What is the mechanical advantage of this system? (4)

The mechanical advantage of a pulley system can be determined by the number of ropes that are supporting the weight of the object being lifted. A single fixed pulley has a mechanical advantage of 1. Examine the pictures below. For each pulley system, determine the mechanical advantage.



What did we learn?

What is a pulley? (A grooved wheel over which a rope can move.)

What type of simple machine does a pulley represent? (A lever)

How does a pulley system provide a mechanical advantage? (It allows you to pull a rope through a longer distance so the effort required is less.)

Taking it further

If someone wants to lift an object that is five times heavier than the person, what is the minimum number of pulleys needed in order for the person to be able to lift the object? (Theoretically the person would need five pulleys; however, in reality the loss of effort due to friction would require at least six pulleys.)

How might a pulley system have been used in medieval warfare? (Pulleys were used to pull back catapult systems as well as crossbows.)

In lesson 9 you were asked to identify simple machines around you. Now that you have learned more about simple machines, go back and look at the same objects and see if you can identify more simple machines.

FUN FACT

Archimedes was one of the greatest inventors of the Greek world. According to legend, the king of Syracuse challenged Archimedes to drag a ship up the beach by himself. Supposedly, Archimedes developed a system of ropes and pulleys that magnified his effort enough to allow him to drag the ship across the beach single-handedly.