Introduction

Early man had to depend on his own body to do any form of work. If he wanted to move something, he had to push or pull it himself. Man searched for ways to make work easier. Ancient Egyptians were able to build huge stone pyramids without modern **machines**. How did they move and lift the giant stones? They probably used simple machines. They used the principles of these machines to do work that may have seemed impossible. Simple and compound machines will be introduced in this unit.

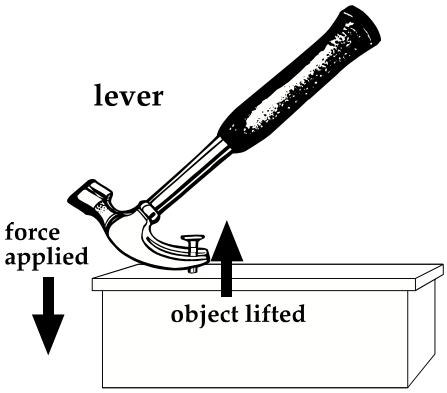
Simple Machines

A *machine* is something that makes work easier and more efficient. A machine can change the size of a force, direction of a force, or the distance a force moves. Sometimes it may seem that a machine can create energy. This is not true. A machine cannot increase the amount of energy, it can only transfer energy.

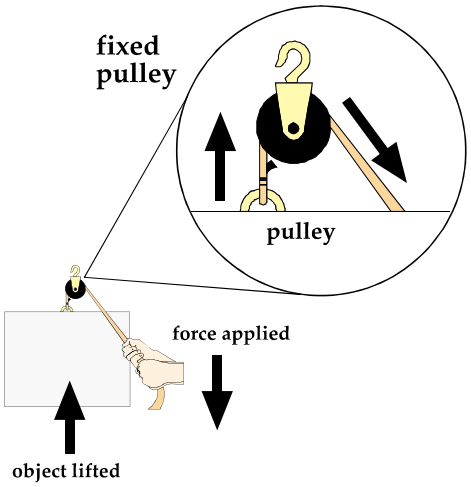
There are six kinds of simple machines. Each one has a special way of making a force stronger. The six simple machines are as follows:

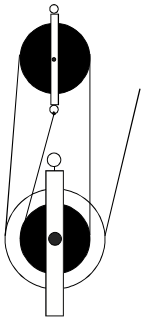
Six Kinds of Simple Machines
• lever • pulley • inclined planes • wedge • screw • wheel and axle

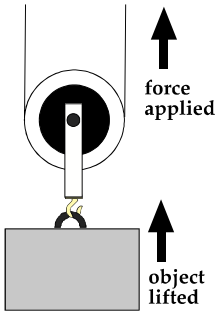
Have you ever used a crowbar or a shovel or used the claw end of a hammer? They are examples of levers. A **lever** is a stiff bar that turns on a fixed point. It is used to change the direction of a force. It may also increase the size of the force. Suppose you wanted to move a large rock. You could not do it alone. Now, put a lever under the rock and push down. The rock will move. The lever transferred your force. It did not create new energy. No machine can ever put out more energy than what was put into it.



A **pulley** is a very common simple machine. It changes the direction of the force used. It also can increase the force. It is actually a kind of lever. A **fixed pulley** does not move. It does not multiply force. It only changes the direction of the force. When you pull down on a rope around a fixed pulley, the force will go up.




block and tackle

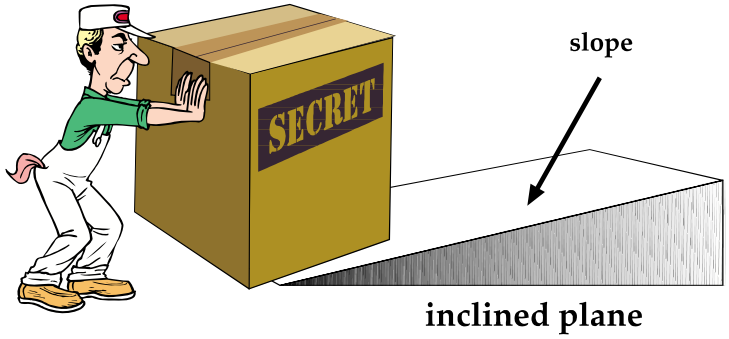


movable pulley

A **movable pulley** moves. It can increase force. When the rope is pulled, both sides of the rope apply force. The force is multiplied.

Fixed and movable pulleys can be used together. This type of arrangement is called a **block and tackle**. A block and tackle can be used to lift very heavy objects. A mechanic may use a block and tackle to lift an engine out of a car. A block and tackle can multiply force many times.

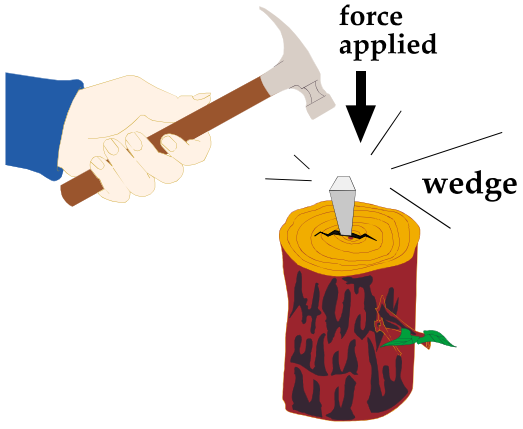
An **inclined plane** is a flat surface that has been raised at one end. An inclined plane does not move. A ramp is an inclined plane. How does an inclined plane make work easier? It redirects and multiplies force. It is much easier to push a box up an inclined plane than to carry it up a ladder. The height and length of the plane determine how much a force is multiplied. Work is easier on a gentle **slope**.



inclined plane

A **gentle slope** has an upward or downward slant with a gradual rise. A *steep slope* has an upward or downward slant with a sharp rise.

A **wedge** is a type of inclined plane. It has sloping sides. A wedge moves. It multiplies force. Suppose you want to split a log. Place a pointed wedge on the log. Hit the wedge with a hammer. The downward force of the hammer will hit against the wedge. The wedge will move downward, and the log's sides will move outward. The log will split.



Wedges do more than multiply force. A wedge slid under a door will stop movement. A chisel, a knife, and a hatchet are kinds of wedges. Wedges make work easier.

A **screw** is another form of an inclined plane. A screw is a simple machine with an inclined plane that winds around a center. It looks a little like a spiral staircase.

screw

The inclined plane on a screw is called a *thread*. Screws multiply force. However, they also multiply distance. If you look closely at the screw, you will see that the threads form a tiny ramp that runs around the screw from its tip to near its top. Think about putting a screw into wood. You have to turn the screw a lot in order to move it a short distance into the wood. Screws hold things together very tightly.

A screw can also be used to raise objects or hold objects. A vise is a type of screw. Some stools are raised or lowered by turning screws. Large jackscrews can lift sides of buildings.

A **wheel and axle** also make work easier. A wheel and axle is a form of lever. A wheel turns through a larger diameter than the axle. The diameter of a wheel is measured from the center to the outside. A gear is a wheel with teeth.

wheel and axle

The difference in size between the wheel and axle increases force. However, the distance that the force must move increases. When the axle turns a few times, the wheel will turn a greater distance. Bicycles, cars, eggbeaters, and doorknobs all have wheels and axles.

All simple machines have some things in common. They make work easier. They make force stronger. Anything that makes force stronger is called a machine.

Compound Machines

Some machines are built by putting together two or more simple machines. These machines are called **compound machines**. For example, sewing machines have wheels, axles, wedges, and levers. Can openers, bicycles, washing machines, and engines are examples of compound machines. The purpose of a compound machine is to make work easier.

Efficiency

Machines do work. However, work or energy must be put into a machine before it can do any work. **Work input** is the amount of work put into a machine. **Work output** is a measure of the amount of work done by the machine. Work input never equals work output. Why? The reason is that some of the work input will be used to overcome friction and **resistance**. Any surfaces that touch will have friction. This energy will be lost as heat. This means that you will get less work out of a machine than you put into it. The force put into the machine, though, will be less than the force put out. This means that the work will be easier.

Efficiency is the measure of work input to work output. An ideal machine would have work input equal to work output. Scientists study ways to improve the efficiency of machines. Natural resources like oil can be saved if machines become more efficient.

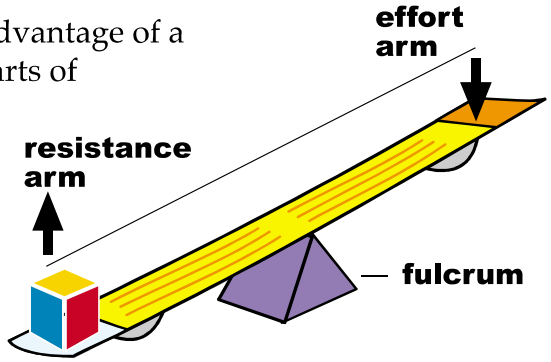
Mechanical Advantage

You have learned that a machine multiplies force, but not all machines multiply force equally. The number of times a force is multiplied is called **mechanical advantage**. There is a formula for finding the mechanical advantage. Mechanical advantage (MA) is equal to resistance (R) divided by effort (E). **Effort** is the amount of force. Resistance is the opposing force or the weight of the object that must be moved. For example, a 100-newton box must be moved. It takes a 50-newton force to move it.

$$\mathbf{MA} = \frac{\mathbf{100\ n\ \ (R)}}{\mathbf{50\ n\ \ (E)}} = \mathbf{2}$$

The mechanical advantage is 2.

It is easy to figure the mechanical advantage of a lever. First you need to know the parts of a lever. A **fulcrum** is the point about which a lever turns. Think of a seesaw. On a seesaw, the fulcrum is in the middle, but the fulcrum can be located anywhere. The **effort arm** is the part of the lever between the fulcrum and the force being applied. The **resistance arm** is the part of the lever between the fulcrum and the object to be moved (resistance).



For levers, we rewrite the equation for mechanical advantage. It looks like this:

$$\text{MA} = \frac{\text{Length of Effort Arm}}{\text{Length of Resistance Arm}}$$

If an effort arm is 40 cm and the resistance arm is 80 cm, what is the MA?

$$\text{MA} = \frac{\text{Length of Effort Arm}}{\text{Length of Resistance Arm}} \qquad \text{MA} = \frac{40\text{ cm}}{80\text{ cm}} = \frac{1}{2}$$

What happens if you increase the length of the effort arm?

Try this: The effort arm is 120 cm and the resistance arm is 60 cm.

What is the mechanical advantage?

It is 2.

$$\text{MA} = \frac{120\text{ cm}}{60\text{ cm}} = 2$$

The longer the effort arm, the greater the mechanical advantage. The longer the resistance arm, the lower the mechanical advantage.

The mechanical advantage for all simple machines can be computed. Each simple machine has its own formula for finding mechanical advantage. However, you can find the mechanical advantage of any machine if you divide the force of the resistance by the effort it takes to move it. In essence,

$$\text{MA} = \frac{\text{Resistance}}{\text{Effort}}$$

Remember that machines do not reduce the amount of work. They multiply a force. As a "price" for multiplying a force, the distance the effort force must move is also increased.

Summary

A machine changes the strength, direction, or distance of a force. Machines do not create energy. There are six types of simple machines. Two or more simple machines working together make a compound machine. The efficiency of a machine measures how well a machine uses its work input. Mechanical advantage tells how many times a machine multiplies force.