Simple Machines

When you hear the word *machine*, do you think of power tools or construction equipment, like the ones pictured above? While both of these examples are machines, you might be surprised to learn that devices as simple as hammers and screws are also machines.

Q: Why are simple tools considered to be machines?

A: Like all machines, they change forces and make work easier.

What Is a Machine?

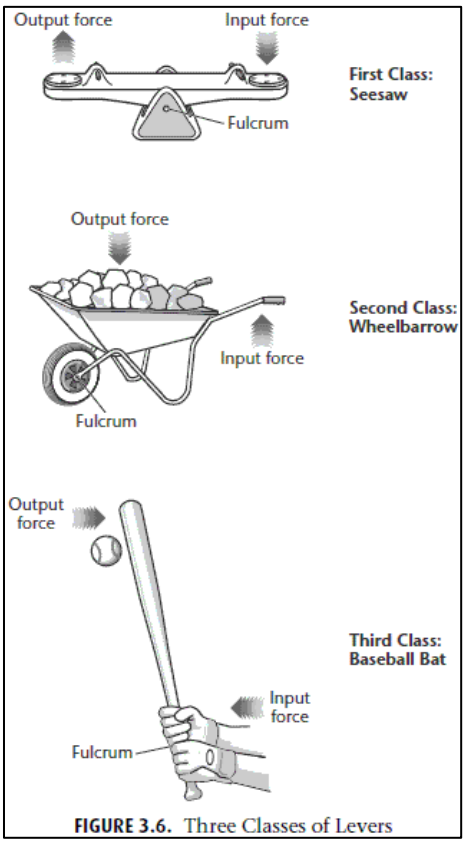


FIGURE 3.6. Three Classes of Levers

A **machine** is any device that makes work easier by changing a force. Work is done whenever a force moves an object over a distance. The amount of work done is represented by the equation:

Work = Force x Distance

When you use a machine, you apply force to the machine. This force is called the input force. The machine, in turn, applies force to an object. This force is called the output force. The output force may or may not be the same as the input force. You can see the three different types of levers at the right and where the input and output forces are at work.

The closer the output force is to the amount of the input force you use, the more efficient the machine is. **Efficiency** measures how much of your input force is used to move the load. Some of your effort is lost to friction, which reduces how efficient your machine can work. You can increase the efficiency of a machine by reducing friction in the moving parts of the machine (oiling gears, adding wheels on ramps) and reducing the amount of movable parts (using only 1 pulley instead of 2).

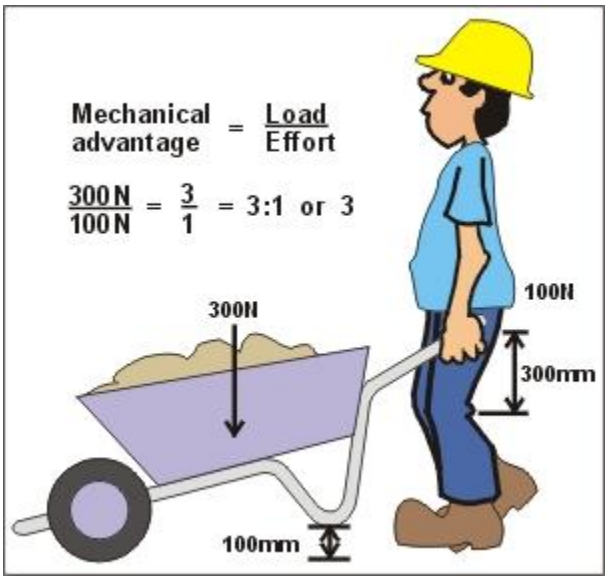
How Machines Make Work Easier

Contrary to popular belief, machines do not increase the amount of work that is done. They just change how the work is done. Machines make work easier by increasing the amount of force that is applied, increasing the distance over which the force is applied, or changing the direction in which the force is applied.

Q: If a machine increases the force applied, what does this tell you about the distance over which the force is applied by the machine:

A: The machine must apply the force over a shorter distance. That's because a machine doesn't change the amount of work and work equals force times distance. Therefore, if force increases, distance must decrease. For the same reason, if a machine increases the distance over which the force is applied, it must apply less force.

Machines that magnify the amount of force you put into them have a mechanical advantage. **Mechanical advantage** measures how many times stronger the load (object to be moved) is compared to the effort you put into a machine. Look at the example below. The boy is lifting the wheelbarrow with a force of 100N. However, the load in the wheelbarrow has a weight of 300N which is being pulled downward due to gravity. The wheelbarrow is allowing the boy to move the load that weighs three times as much force as he is using. Thus, the wheelbarrow has a mechanical advantage of 3.



Increasing Force

Examples of machines that increase force are steering wheels and pliers (See **Figure** below). Read below to find out how both of these machines work. In each case, the machine applies more force than the user applies to the machine, but the machine applies the force over a shorter distance.

When you turn a steering wheel, it causes the smaller steering column in the center of the wheel to turn. The steering column turns a shorter distance but with greater force. The force applied by the steering column is great enough to turn the wheels of the car.

When you press together the two handles of the pliers, it causes the other ends of the handles to squeeze an object, such as the cord in this photo. The squeezing ends move a shorter distance but with greater force, so the pliers squeeze the object harder than you could with your fingers alone.

Increasing Distance

Examples of machines that increase the distance over which force is applied are leaf rakes and hammers (See **Figure** below). Read below to find out how these two machines work. In each case, the machine increases the distance over which the force is applied, but it reduces the strength of the force.

When the woman applies force to the handle end of the rake, she moves it over a short distance. The other end of the rake moves over a greater distance but with less force. By covering a greater distance, the rake can do more work than the woman could do with her hands alone.

When a carpenter moves the handle of the hammer back and forth a short distance with strong force, the head of the hammer moves a greater distance back and forth against the nail but with less force. By repeatedly hitting the nail, the hammer drives the nail into the board.

Changing the Direction of Force

Some machines change the direction of the force applied by the user. They may or may not also change the strength of the force or the distance over which the force is applied. Two examples of machines that work this way are the claw ends of hammers and flagpole pulleys. You can see in the **Figure** below how each of these machines works. In both cases, the direction of the force applied by the user is reversed by the machine.

When the user of the hammer pushes down on the handle, the claw of the hammer pulls up on the nail. The hammer changes the direction of the force. It also applies greater force over a smaller distance.

The rope on a flagpole wraps around the pulley, which is a wheel with a groove in the rim. When a person pulls down on one end of the rope, the other end of the rope pulls up on the flag. However, the pulley doesn't change the strength of the force or the distance over which it is applied.

Q: If the pulley only changes the direction of the force, how does it make the work of raising the flag easier?

A: The pulley makes it easier to lift the flag because it allows a person to pull down on the rope and add his or her own weight to the effort, rather than simply lifting the load.

Summary

- A machine is any device that makes work easier by changing a force.
- Machines may increase the strength of the force, increase the distance over which the force is applied, or change the direction in which the force is applied.