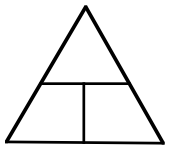
Simple Machines and Mechanical Advantage

Machines are devices that make work easier. How they do this varies from one machine to another. For much of human history, machines were powered by either human or animal muscle power. Today most machines are powered by electricity as in an electric drill, or by some type of engine that burns a fuel, like a gas powered lawn mower.

The two main types of machines are simple and compound. Simple machines are those able to do work ($w = f \cdot d$) with just one movement of the machine. Compound machines require more than one movement to do work.



Our focus will be the simple machines, of which there are six basic types. They can be grouped into the following categories:

lever family- the lever, wheel and axle, and pulley

inclined plane family- inclined plane, screw and wedge

The ways a machine makes work easier is by changing the direction and/or the size of the force put into the machine. The amount of force you put into a machine is called the effort force (F_e), while the amount of force the machine needs to move something to do work is called the resistance force (F_r).

Speaking of work, when a machine is being used, you must do work on the machine, called the input work (W_{in}), while the machine itself does work, called the output work (W_{out}).

The work input can be determined using the formula $W_{in} = F_e \times d_e$, where d_e is the distance the effort force has to move. The work output is determined in a similar fashion, where $W_{out} = F_r \times d_r$ with d_r being the distance the resistance force has to move.

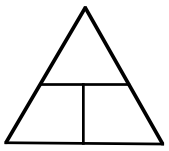
Since a machine has parts that are in contact with other things, friction is produced. So in the real world, the work input can never be equal to the work output. However, engineers and designers of machines like to

imagine their machines as having no friction. These ideal machines would have the work input equal to the work output, or $W_{in} = W_{out}$.

Since machines can't produce more work than the work put into them, there has to be a trade off. For example, to lift a 10 Newton weight straight up a distance of 2 meters, requires 20 Joules of work ($w = f \cdot d$). If the same 10 Newton weight is pulled along an inclined plane it might only need 2 Newtons of force to pull it, but you would have to pull it for a distance of 10 meters.

The amount that a machine is able to multiply the effort force put into it is called the mechanical advantage (MA). This can be calculated by the following:

$$MA = \frac{\text{resistance force}}{\text{effort force}} = \frac{F_r}{F_e}$$



For ideal machines (which only exist in the minds of engineers and designers) that ignore friction, there is a term called the Ideal Mechanical Advantage (IMA). Depending on the type of machine being used, there are different ways the IMA can be determined. As you learn more about specific kinds of simple machines, you'll also learn how to calculate their IMA.