PhyzGuide: Work

We now have several quantities that we can use to describe the behavior of a body. Our understanding and application of kinematics and dynamics (Newton's laws of motion) can take us a long way in our understanding of nature.

Another useful way of describing and understanding nature is in terms of **energy**. The use of energy concepts to describe nature is helpful, but is not a new or independent way of analyzing the universe. Energy considerations are simply Newton's laws expressed in different terms. Just as "hola" has the same fundamental meaning as "hello," but in a different language.

The first energy-related concept we must understand is *work*. We all have a colloquial understanding of "work," and in some ways it is similar to the physical definition of mechanical work.

Work is done on an object when a force acts on the object and produces a displacement *in the direction of force*. Work is the scalar product of that force and distance. Work is a scalar quantity.

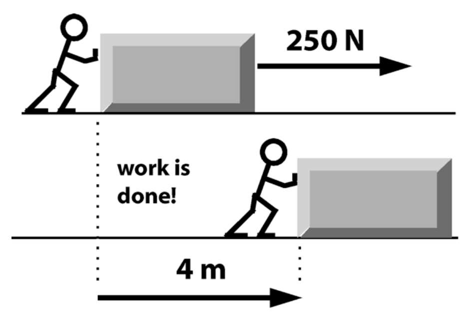
$$W = \mathbf{F} \cdot \mathbf{d} = Fd\cos\phi$$

The SI units of work are N·m = J (joule)

F is the force exerted
d is the distance moved
ϕ is the angle between force and displacement vectors

IMPORTANT: For work to be done, the *force* (or a component of force) must act in the *direction* of motion.

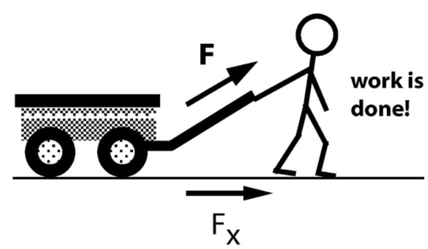
For instance, suppose you push a heavy crate across the floor ($\mu \neq 0$). You exerted a force in the horizontal direction which moved the crate in the horizontal direction. If you had exerted a force of 250 N and moved the crate 4 m, the work you did on the crate would be



$W = 250\ \text{N} \cdot 4\ \text{m} = 1000\ \text{J}$

(The "cosϕ" is left out because the direction of force and direction of motion are the same.)

Consider, however, a child pulling a wagon as shown. The child exerts a force at an angle to the motion. Only F_x, the component of force in the direction of motion, "counts" for doing work. The force component in the *y*-direction produces *no displacement*; it therefore does *no work*.

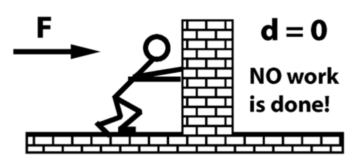


If the child exerts a force of 25 N on the wagon at an angle of 30° and moves the wagon 4 m, the work done is

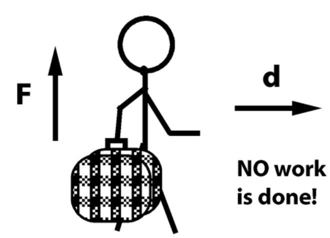
$W = 25\ \text{N} \cdot 4\ \text{m} \cdot \cos(30°) = 87\ \text{J}$

Lastly, consider two cases in which *no* work is done.

First, a person exerts a great force against a wall. Although the *force* is great, the *displacement* is zero.



Second, a heavy suitcase is carried a distance horizontally. "But wait!" you say, "a force is acting (to hold up the suitcase) over a distance, surely work is being done!" If this evil thought were running through your mind, re-read the definition of work. It is *very* important that you understand that information!



PhyzGuide: Simple Machines

YOU CAN'T GET SOMETHIN' FOR NOTHIN'!

Simple machines are used to change the *size* or *direction* of force. Usually, the advantage of a simple machine is that it allows a user to exert a small force to accomplish a task that would normally require a large force.

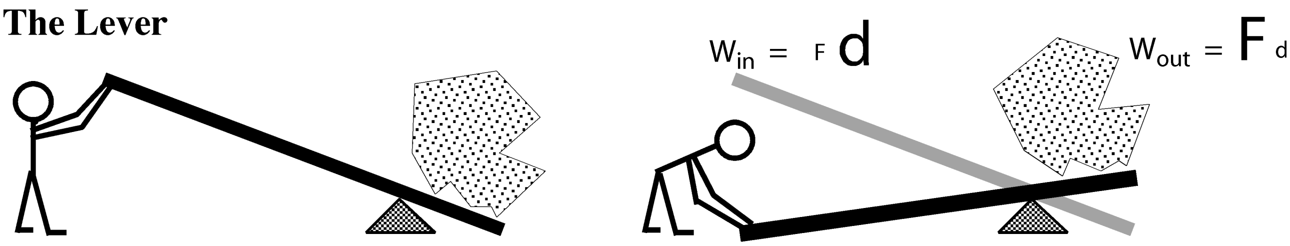
For example, a person of ordinary strength is able to lift a car with the help of a hydraulic press.

It is important to note that while a simple machine may “multiply your force,” you are *not* getting something for nothing. The *work output* of a simple machine is equal to the *work input*. In fact, real output under non-ideal conditions is *less* than input: the ratio of work output to work input is called “efficiency.”

$$\varepsilon = W_{out} / W_{in}$$

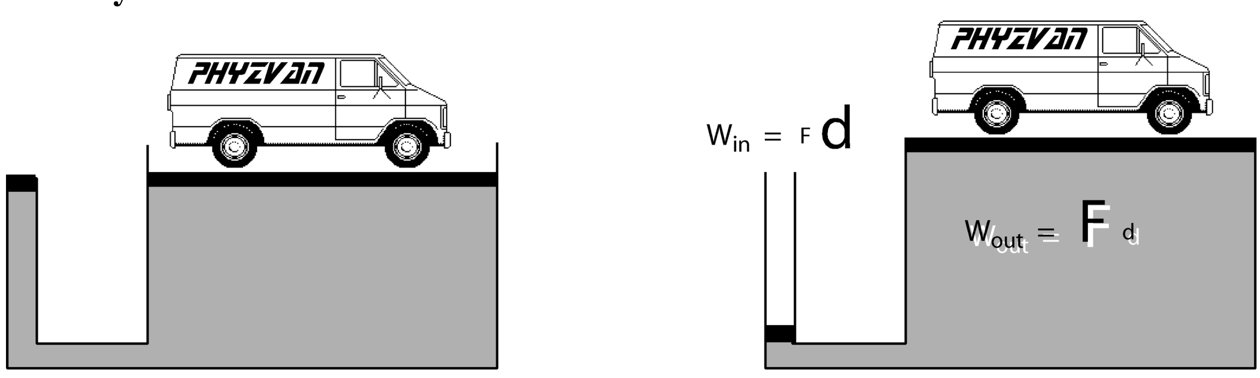
Consider the following simple machines:

The Lever



A big force is needed to lift the rock. The person exerts a small force over a large distance to produce a large force acting on the rock. The force acting on the rock, however, acts over a small distance.

The Hydraulic Press



A big force is needed to lift the auto. A person exerts a small force over a large distance via the small piston on the left to produce a large force lifting the auto. The force acting on the auto, however, acts over a small distance.

