Teacher Tune-up

Quick Content Refresher for Busy Professionals

How is the word "work" used in the sciences?

The word **work** has a narrower meaning in physics than it does in everyday speech. That narrowness makes it a useful term for describing many physical situations. Scientists and engineers use the term work to describe the amount of energy used to move an object to a different position.

In this sense, work is done only when a pushed or pulled object actually changes position. A person may feel that straining to lift an immovable weight is hard "work" (and indeed, physical work is being done within the body as muscles contract and shake). But if the weight doesn't move, then no work is done *on the weight*.

Scientists measure work as the net **force** applied to an object **multiplied by** the **distance** the object is moved in the direction of that force.

Work = force × distance, *or just* **W = Fd**

Scientists and engineers typically measure work in positive numerical values, but negative values may be appropriate in some situations, as in the case of comparing positive and negative values for an object that is first raised and then lowered.

Keep in mind that the distance used in computing work is the distance an object moves *in the direction of the force that is being applied to it*. So if you're trying to find out how much work is done in *lifting* an object, you compute the work to overcome gravity based on how much *higher* it ends up, ignoring any sideways motion.

If an object is pushed up a ramp, the work to overcome *friction* would be based on the length along the ramp while the work to overcome *gravity* would depend only on the ramp's height; these would be computed separately and added.

Real-world problems can get messy fast. When the directions of force and displacement differ, the cosine of the angle between them factors into the calculation of work. Furthermore, forces are seldom constant, more than one form of work may occur at once, and paths of travel may be crooked. Engineers launching a rocket into space need to consider that gravity grows weaker with altitude and a rocket grows lighter as it consumes fuel. But an introductory physics textbook may reasonably idealize problems, since the goal is to clarify basic concepts.

Some examples of work calculations:

- A 5-pound book is lifted from the floor to the top of a 4-foot shelf. The amount of work done is 20 foot-pounds, abbreviated as "20 ft-lb." In SI units, this would be about 27 joules (27 J). If the book is brought back down to its starting place, the work of lowering it is -20 ft-lb (or -27 J).

- Using an average force of 6 pounds to compress a spring by 6 inches (½ foot) requires 3 ft-lb of work (or about 4 J).

- If it takes a 10-pound force to slide an object along the floor, then sliding it 9 feet will require 90 ft-lb of work (or 122 J). This horizontal work overcomes the opposing horizontal force of friction.

- A baseball pitcher applies an average force of 12 pounds over a distance of 7 feet. The pitcher has done 84 ft-lb (or 114 J) of work on the ball.

Note: In the SI system, work is measured in **joules**. One joule (1 J) is a newton-meter (N·m), meaning it is the work done when a force of one newton is exerted over a distance of one meter. Since each meter is about 3.28 feet of distance and a newton is about 0.225 pounds of force, each joule equals about 0.738 foot-pounds.

Where does energy go when work is done?

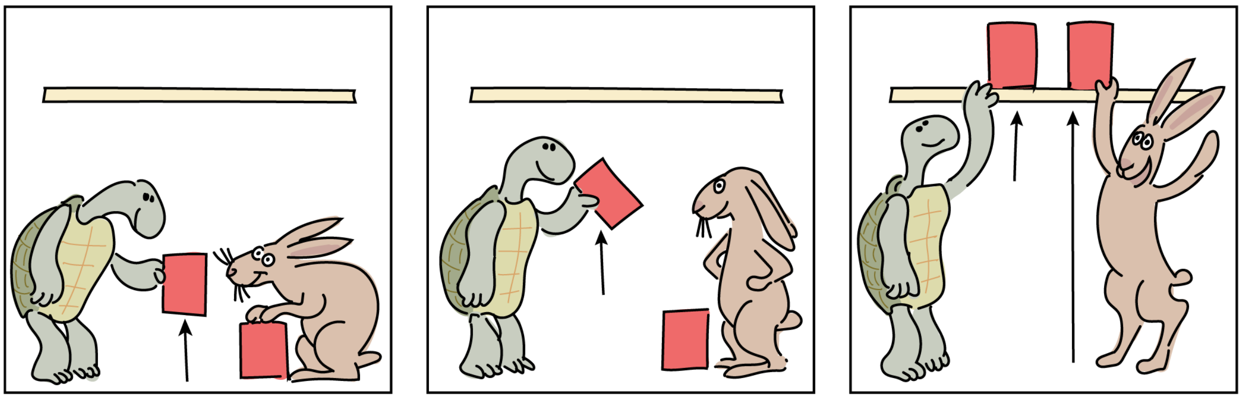
Although energy and work are closely related concepts, they are not the same thing. Energy is a property of objects and systems, and is often defined as the capacity to do work. Things *have* energy and *do* work. Work can be positive or negative, while energy cannot be negative. Since total energy is conserved, work always involves transferring energy from object to object and/or transforming energy from one form to another.

The baseball pitcher's work is mainly converted into the ball's energy of motion as it leaves his or her hand—this is an example of *kinetic* energy. A compressed spring or lifted weight has *potential* energy that can later be used to move some other object. When an object is dragged with friction along a level floor, that work is converted into *acoustic* energy (sound, an orderly vibration of particles) and *thermal* energy (the random, disordered vibration of particles). Thermal energy may in turn be converted to *radiant* energy such as infrared light.

At the fine-grained level of chemical reactions, work is done to break apart and/or form bonds between atoms. Different chemical bonds store different amounts of chemical potential energy. Dramatic reactions like combustion can turn chemical energy back into the more easily visualized work of moving trains, planes, and automobiles.

Does the speed at which work is done affect how we calculate work?

No. For example, to elevate an object of a certain weight to a certain height takes a certain amount of work, however quickly or slowly it is done.



Total work done by tortoise: (1 N x 1/3 m/s) x 3 seconds = 1 N·m = 1 joule

Total work done by hare: (1 N · 1 m/s) x 1 second = 1 N·m = 1 joule

In the cartoon, the tortoise and the hare do the same amount of work. However, the hare does the work in a shorter time with greater **power.** Power is the time rate of work. The hare lifts the object with a power of one joule per second (1 J/s, also known as one watt). The tortoise spreads the same work over a longer time, lifting with a power of 0.333 J/s (or 0.333 watt).