3.2: Work- The Scientific Definition

Learning Objectives

By the end of this section, you will be able to:

- Explain how an object must be displaced for a force on it to do work.
- Explain how relative directions of force and displacement determine whether the work done is positive, negative, or zero.

What It Means to Do Work

The scientific definition of work differs in some ways from its everyday meaning. Certain things we think of as hard work, such as writing an exam or carrying a heavy load on level ground, are not work as defined by a scientist. The scientific definition of work reveals its relationship to energy—whenever work is done, energy is transferred. For work, in the scientific sense, to be done, a force must be exerted and there must be motion or displacement in the direction of the force.

Formally, the work done on a system by a constant force is defined to be *the product of the component of the force in the direction of motion times the distance through which the force acts*. For one-way motion in one dimension, this is expressed in equation form as

$$W = F\,d \tag{3.2.1}$$

where W is work, d is the displacement of the system, and F is the magnitude of the applied force. Note that when the displacement and the applied force point in opposite directions, the work done is negative, which means that energy is being transferred out of the object as it is being displaced.

To find the work done on a system that undergoes motion that is not one-way or that is in two or three dimensions, we divide the motion into one-way one-dimensional segments and add up the work done over each segment.

What is Work?

The work done on a system by a constant force is *the product of the component of the force in the direction of motion times the distance through which the force acts*. For one-way motion in one dimension, this is expressed in equation form as

$$W = F\,d \tag{3.2.2}$$

where W is work, F is the magnitude of the force on the system, d is the magnitude of the displacement of the system.

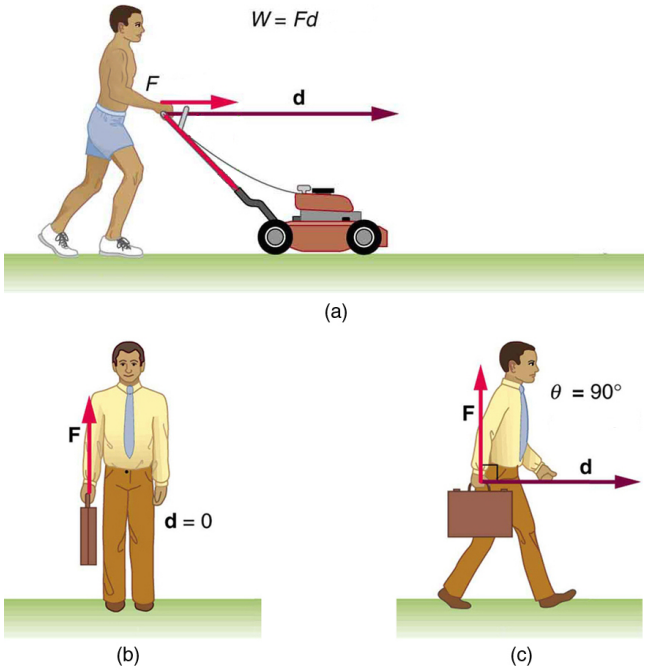

Figure 3.2.1: Examples of work. (a) The work done by the force F on this lawn mower is $Fd\cos\theta$. Note that $F\cos\theta$ is the component of the force in the direction of motion. (b) A person holding a briefcase does no work on it, because there is no motion. No energy is transferred to or from the briefcase. (c) The person moving the briefcase horizontally at a constant speed does no work on it, and transfers no energy to it. (d) Work is done on the briefcase by carrying it upstairs at constant speed, because there is necessarily a component of force F in the direction of the motion. Energy is transferred to the briefcase and could in turn be used to do work. (e) When the briefcase is lowered, energy is transferred out of the briefcase and into an electric generator. Here the work done on the briefcase by the generator is negative, removing energy from the briefcase, because F and d are in opposite directions.

To examine what the definition of work means, let us consider the other situations shown in Figure. The person holding the briefcase in Figure $3.2.1b$does no work, for example. Here $d = 0$, so $W = 0$. Why is it you get tired just holding a load? The answer is that your muscles are doing work against one another, *but they are doing no work on the system of interest* (the "briefcase-Earth system" - see Gravitational Potential Energy for more details). There must be motion for work to be done, and there must be a component of the force in the direction of the motion. For example, the person carrying the briefcase on level ground in Figure $3.2.1c$does no work on it, because the force is perpendicular to the motion.

Summary

- Work is the transfer of energy by a force acting on an object as it is displaced.
- The work W that a force F does on an object is the product of the magnitude F of the force, times the magnitude d of the displacement. In symbols,

$$W = Fd \tag{3.2.3}$$

- The SI unit for work and energy is the joule (J), where $1\ J = 1\ N \cdot m = 1\ kg\,m^2/s^2$.
- The work done by a force is zero if the displacement is either zero or perpendicular to the force.
- The work done is positive if the force and displacement have the same direction, and negative if they have opposite direction.

Glossary

energy

the ability to do work

work

the transfer of energy by a force that causes an object to be displaced; the product of the component of the force in the direction of the displacement and the magnitude of the displacement

joule

SI unit of work and energy, equal to one newton-meter

Contributors and Attributions

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