5 Energy and Machines

5-1 Work and Power

Vocabulary **Work:** The product of the component of the force exerted on an object in the direction of displacement and the magnitude of the displacement.

work = (force)(displacement) or $W = F\Delta d$

The SI unit for work is the **joule (J),** which equals one **newton·meter (N·m).**

For maximum work to be done, the object *must* move in the direction of the force. If the object is moving at an angle to the force, determine the component of the force in the direction of motion. Remember, if the object does not move, or moves perpendicular to the direction of the force, no work has been done.

Vocabulary **Power:** The rate at which work is done.

$$\textbf{power} = \frac{\textbf{work}}{\textbf{elapsed time}} \quad \textbf{or} \quad P = \frac{W}{\Delta t}$$

The SI unit for power is the **watt (W),** which equals one **joule per second (J/s).** One person is more powerful than another if he or she can do more work in a given amount of time, or can do the same amount of work in less time.

Solved Examples

Example 1: Bud, a very large man of mass 130 kg, stands on a pogo stick. How much work is done as Bud compresses the spring of the pogo stick 0.50 m?

Solution: First, find Bud's weight, which is the force with which he compresses the pogo stick spring.

Given: $m = 130$ kg
$g = 10.0\ \text{m/s}^2$

Unknown: $w = ?$
Original equation: $w = mg$

Solve: $w = mg = (130\ \text{kg})(10.0\ \text{m/s}^2) = 1300\ \text{N}$

Now use this weight to solve for the work done to compress the spring.

Given: $F = 1300\ \text{N}$
$\Delta d = 0.050\ \text{m}$

Unknown: $W = ?$
Original equation: $W = F\Delta d$

Solve: $W = F\Delta d = (1300\ \text{N})(0.050\ \text{m}) = \mathbf{65\ J}$

Don't get confused here by the two *W*'s you see in this example. The *w* in $w = mg$ means *weight* while the *W* in $W = F\Delta d$ means *work.* There are many ways to tell them apart, the most important of which is to understand how they are used in the context of the exercise. Also, the units used for each are quite different: weight is measured in newtons, and work is measured in joules. Last of all, weight is a vector and work is a scalar.

Example 2: After finishing her physics homework, Sherita pulls her 50.0-kg body out of the living room chair and climbs up the 5.0-m-high flight of stairs to her bedroom. How much work does Sherita do in ascending the stairs?

Solution: First find Sherita's weight. Her muscles exert a force to carry her weight up the stairs.

Given: $m = 50.0\ \text{kg}$
$g = 10.0\ \text{m/s}^2$

Unknown: $w = ?$
Original equation: $w = mg$

Solve: $w = mg = (50.0\text{kg})(10.0\ \text{m/s}^2) = 500.\ \text{N}$

Now use Sherita's weight (or force) to determine the amount of work done. It is important to note that when you are solving for the work done, you need know only the displacement of the body moved. The number of stairs climbed or their steepness is irrelevant. All that is important is the *change* in position.

Given: $F = 500.\ \text{N}$
$\Delta d = 5.0\ \text{m}$

Unknown: $W = ?$
Original equation: $W = F\Delta d$

Solve: $W = F\Delta d = (500.\ \text{N})(5.0\ \text{m}) = \mathbf{2500\ J}$

Example 3: In the previous example, Sherita slowly ascends the stairs, taking 10.0 s to go from bottom to top. The next evening, in a rush to catch her favorite TV show, she runs up the stairs in 3.0 s. a) On which night does Sherita do more work? b) On which night does Sherita generate more power?

a) Sherita does the same amount of work on both nights because the force she exerts and her displacement are the same each time.

b) Sherita's power output varies because the time taken to do the same amount of work varies.

First night:

Given: $W = 2500\ \text{J}$
$\Delta t = 10.0\ \text{s}$

Unknown: $P = ?$
Original equation: $P = \dfrac{W}{\Delta t}$

Solve: $P = \frac{W}{\Delta t} = \frac{2500\text{ J}}{10.0\text{ s}} = \mathbf{250\ W}$

Second night:

Given: $W = 2500$ J
$\Delta t = 3.0$ s

Unknown: $P = ?$
Original equation: $P = \frac{W}{\Delta t}$

Solve: $P = \frac{W}{\Delta t} = \frac{2500\text{ J}}{3.0\text{ s}} = \mathbf{830\ W}$

Sherita generates more power on the second night.

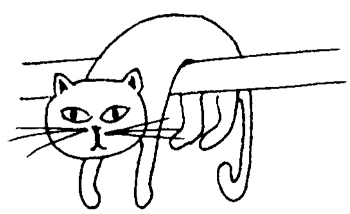
Practice Exercises

Exercise 1: On his way off to college, Russell drags his suitcase 15.0 m from the door of his house to the car at a constant speed with a horizontal force of 95.0 N. a) How much work does Russell do to overcome the force of friction? b) If the floor has just been waxed, does he have to do more work or less work to move the suitcase? Explain.

Answer: **a.** ________________________

Answer: **b.** ________________________

Exercise 2: Katie, a 30.0-kg child, climbs a tree to rescue her cat who is afraid to jump 8.0 m to the ground. How much work does Katie do in order to reach the cat?



Answer: ________________________

Exercise 3: Marissa does 3.2 J of work to lower the window shade in her bedroom a distance of 0.8 m. How much force must Marrisa exert on the window shade?

Answer: ____________________

Exercise 4: Atlas and Hercules, two carnival sideshow strong men, each lift 200.-kg barbells 2.00 m off the ground. Atlas lifts his barbells in 1.00 s and Hercules lifts his in 3.00 s. a) Which strong man does more work? b) Calculate which man is more powerful.

Answer: **a.** ____________________

Answer: **b.** ____________________

1. a) 1430 J
3. 4 N