Work

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CHAPTER 1 Work

Lesson Objectives

- Define work, and state how to calculate it.
- Explain how power is related to work.

Lesson Vocabulary

- joule (J)
- power
- watt (W)
- work

Introduction

The teen playing tennis in **Figure** 1.1 is having fun. The other teen in the same figure is working hard studying for an exam. You can tell by their faces which teen is doing work —or can you? Would it surprise you to learn that the teen who is working is the one who is having fun playing tennis, while the teen who is studying isn't doing any work at all? The reason why has to do with how work is defined in physics.

FIGURE 1.1
Which teen is doing work and which teen isn't?

Defining and Calculating Work

Work is defined differently in physics than in everyday language. In physics, **work** means the use of force to move an object. The teen who is playing tennis in **Figure** 1.1 is using force to move her tennis racket, so she is doing work. The teen who is studying isn't moving anything, so she is not doing work.

Not all force that is used to move an object does work. For work to be done, the force must be applied in the same direction that the object moves. If a force is applied in a different direction than the object moves, no work is done.

Figure 1.2 illustrates this point. The stick person applies an upward force on the box when raising it from the ground to chest height. Work is done because the force is applied in the same direction as the box is moving. However, as the stick person walks from left to right while holding the box at chest height, no more work is done by the person's arms holding the box up. That's because the force supporting the box acts in a different direction than the box is moving. A small amount of work in the horizontal direction is performed when the person is accelerating during the first step of the walk across the room. But other than that, there is no work, because there is no net force acting on the box horizontally.

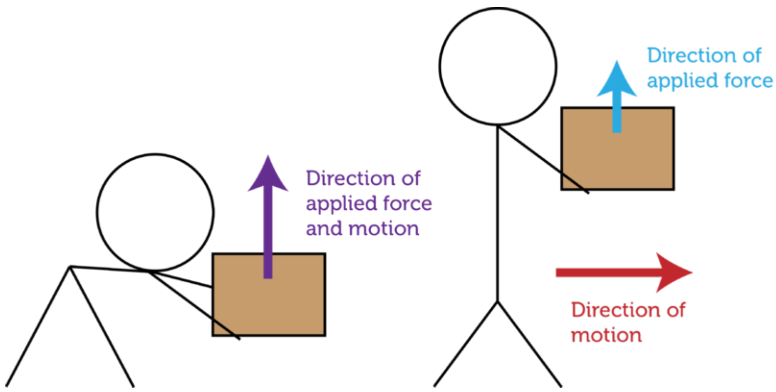

FIGURE 1.2
Carrying a box while walking does not result in work being done. Work is done only when the box is first lifted up from the ground. Can you explain why?

Work, Force, and Distance

Work is directly related to both the force applied to an object and the distance the object moves. It can be represented by the equation:

$$\text{Work} = \text{Force} \times \text{Distance}$$

This equation shows that the greater the force that is used to move an object or the farther the object is moved, the more work that is done. You can see a short video introduction to work as the product of force and distance at this link: http://www.schooltube.com/video/85de91bb7097c101fbda/Eureka-Episode-8-Work .

To see the effects of force and distance on work, compare the weight lifters in **Figure** 1.3. The two weight lifters on the left are lifting the same amount of weight, but the bottom weight lifter is lifting the weight a longer distance. Therefore, this weight lifter is doing more work. The two weight lifters on the bottom right are both lifting the weight the same distance, but the weight lifter on the left is lifting a heavier weight. Therefore, this weight lifter is doing more work.

Calculating Work

The equation for work given above can be used to calculate the amount of work that is done if force and distance are known. For example, assume that one of the weight lifters in **Figure** 1.2 lifts a weight of 400 newtons over his head to a height of 2.2 meters off the ground. The amount of work he does is:

$$\text{Work} = 400\ \text{N} \times 2.2\ \text{m} = 880\ \text{N} \cdot \text{m}$$

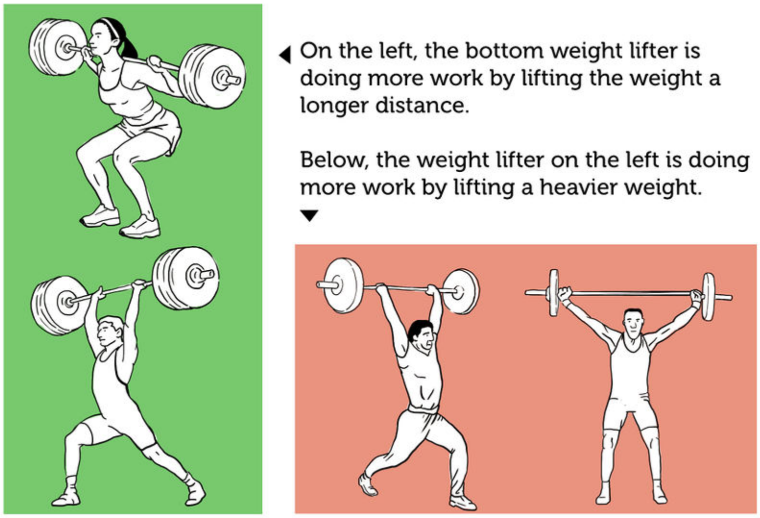

FIGURE 1.3
Weight lifters do more work when they move weights a longer distance or move heavier weights.

Notice that the unit for work is the newton · meter. This is the SI unit for work, also called the **joule (J)**. One joule equals the amount of work that is done when 1 newton of force moves an object over a distance of 1 meter.

Problem Solving

Problem: Todd pushed a 500 N box 4 meters across the floor. How much work did he do?

Solution: Use the equation Work = Force × Distance.

$$\text{Work} = 500\ \text{N} \times 4\ \text{m} = 2000\ \text{N} \cdot \text{m, or } 2000\ \text{J}$$

You Try It!

Problem: Lara lifted a 100 N box 1.5 meters above the floor. How much work did she do?

Work and Power

Did you ever rake leaves, like the woman in **Figure** 1.4? It can take a long time to do all that work. But if you use an electric leaf blower, like the man in the figure, the job gets done much sooner. Both the leaf blower and the rake do the work of removing leaves from the yard, but the leaf blower has more power. That's why it can do the same amount of work in less time.

What Is Power?

Power is a measure of the amount of work that can be done in a given amount of time. Power can be represented by the equation:

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

FIGURE 1.4
Which way of removing leaves would take less effort on your part?

In this equation, work is measured in joules and time is measured in seconds, so power is expressed in joules per second (J/s). This is the SI unit for work, also known as the **watt (W)**. A watt equals 1 joule of work per second. The watt is named for James Watt, a Scottish inventor you will read about below.

You may already be familiar with watts. That's because light bulbs and small appliances such as hair dryers are labeled with the watts of power they provide. For example, the hair dryer in **Figure** 1.5 is labeled "2000 watts." This amount of power could also be expressed kilowatts. A kilowatt equals 1000 watts, so the 2000-watt hair dryer produces 2 kilowatts of power.

FIGURE 1.5
Hair dryers vary in power. How do you think this affects drying time?

Compared with a less powerful device, a more powerful device can either do more work in the same time or do the same work in less time. For example, compared with a low-power microwave, a high-power microwave can cook more food in the same time or the same amount of food in less time.

Calculating Power or Work

Power can be calculated using the formula above, if the amount of work and time are known. For example, assume that a small engine does 3000 joules of work in 2 seconds. Then the power of the motor is:

$$\text{Power} = \frac{3000\ \text{J}}{2\ \text{s}} = 1500\ \text{J/s, or } 1500\ \text{W}$$

You can also calculate work if you know power and time by rewriting the power equation above as:

$$\text{Work} = \text{Power} \times \text{Time}$$

For example, if you use a 2000-watt hair dryer for 30 seconds, how much work is done? First express 2000 watts in J/s and then substitute this value for power in the work equation:

$$\text{Work} = 2000 \text{ J/s} \times 30 \text{ s} = 60,000 \text{ J}$$

For a video presentation on calculating power and work, go to this link: http://www.brightstorm.com/science/physics/energy-and-momentum/power/ .

Problem Solving

Problem: An electric mixer does 2500 joules of work in 5 seconds. What is its power?

Solution: Use the equation: $\text{Power} = \frac{\text{Work}}{\text{Time}}$.

$$\text{Power} = \frac{2500 \text{ J}}{5 \text{ s}} = 500 \text{ J/s, or } 500 \text{ W}$$

You Try It!

Problem: How much work can be done in 30 seconds by a 1000-watt microwave?

Horsepower

Sometimes power is measured in a unit called the horsepower. One horsepower is the amount of work a horse can do in 1 minute. It equals 745 watts of power. The horsepower was introduced by James Watt, who invented the first powerful steam engine in the 1770s. Watt's steam engine led to a revolution in industry and agriculture because of its power. Watt wanted to impress people with the power of his steam engine, so he compared it with something familiar to people of his time: the power of workhorses, like those pictured in **Figure** 1.6. Watt said his steam engine could produce the power of 20 horses, or 20 horsepower. The most powerful engines today may produce more than 100,000 horsepower! How many watts of power is that?

FIGURE 1.6
The horses and the tractor are both pulling a plow. The horses provide less horsepower than the tractor. Which do you think will get the job done faster?

Lesson Summary

- Work is the use of force to move an object. It can be calculated as the product of force and distance. The SI unit for work is the joule (J).

- Power is a measure of the amount of work that can be done in a given amount of time. The SI unit for power is the watt (W).

Lesson Review Questions

Recall

1. How is work defined in physics?
2. What does power measure?
3. Identify the SI units for work and power.

Apply Concepts

4. Jana lifted a 200-newton weight over her head to a distance of 2 meters above the ground. How much work did she do?
5. Pieter picked up a 20-newton book from the floor. Then he passed it to Ahmad, who carried it for 20 meters. How much work did Ahmad do?
6. If an electric mixer does 10,000 joules of work in 10 seconds, what is its power?

Think Critically

7. Explain how power is related to work.

Points to Consider

Machines such as the tractor and leaf blower you read about in this lesson help people do work.

- What are other examples of machines?
- What do all these machines have in common?

References

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