Key Term

power

Rate of Energy Transfer

The rate at which work is done is called power. More generally, power is the rate of energy transfer by any method. Like the concepts of energy and work, power has a specific meaning in science that differs from its everyday meaning.

Imagine you are producing a play and you need to raise and lower the curtain between scenes in a specific amount of time. You decide to use a motor that will pull on a rope connected to the top of the curtain rod. Your assistant finds three motors but doesn’t know which one to use. One way to decide is to consider the power output of each motor.

If the work done on an object is \( W \) in a time interval \( \Delta t \), then the average power delivered to the object over this time interval is written as follows:

\[
\text{Power } P = \frac{W}{\Delta t}
\]

power = work ÷ time interval

It is sometimes useful to rewrite this equation in an alternative form by substituting the definition of work into the definition of power.

\[
W = Fd
\]

\[
P = \frac{W}{\Delta t} = \frac{F \cdot d}{\Delta t}
\]

The distance moved per unit time is just the speed of the object.

Conceptual Challenge

1. Assuming mechanical energy is conserved, the same amount of energy is needed to reach the top in both cases. Because the same amount of work must be done, the path with the longer distance takes more time and requires less power.

2. Light bulbs don’t have energy stored within them; energy is transferred to them in the form of electricity at a rate of 60 J/s.
Power (Alternative Form)

\[ P = Fv \]

Power = force \times speed

The SI unit of power is the watt, W, which is defined to be one joule per second. The horsepower, hp, is another unit of power that is sometimes used. One horsepower is equal to 746 watts.

The watt is perhaps most familiar to you from your everyday experience with light bulbs (see Figure 4.1). A dim light bulb uses about 40 W of power, while a bright bulb can use up to 500 W. Decorative lights use about 0.7 W each for indoor lights and 7.0 W each for outdoor lights.

In Sample Problem F, the three motors would lift the curtain at different rates because the power output for each motor is different. So each motor would do work on the curtain at different rates and would thus transfer energy to the curtain at different rates.

**Problem Solving**

**ALTERNATIVE APPROACHES**

Show students that they can solve Sample Problem F in another way by calculating the time it would take each motor to do the work:

\[ W = Fd = mgd = 14 \times 10^3 \text{ J} \]

\[ t = \frac{W}{P} \]

- \( t_1 = 14 \times 10^3 \text{ J} / 1.0 \times 10^3 \text{ W} = 14 \text{ s} \)
- \( t_2 = 14 \times 10^3 \text{ J} / 3.5 \times 10^3 \text{ W} = 4.0 \text{ s} \)
- \( t_3 = 14 \times 10^3 \text{ J} / 5.5 \times 10^3 \text{ W} = 2.5 \text{ s} \)

This approach shows that the second motor comes closest to 5.0 s and is therefore the best motor to use.
Reviewing Main Ideas

1. A 50.0 kg student climbs up a 5.00 m rope at a constant speed. The student has a power output of 200.0 W. How long does it take the student to climb the rope? How much work does the student do?

2. A motor-driven winch pulls the 50.0 kg student from the previous problem up the 5.00 m rope at a constant speed of 1.25 m/s. How much power does the motor use in raising the student? How much work does the motor do on the student?

Critical Thinking

3. How are energy, time, and power related?

4. People often use the word powerful to describe the engines in some automobiles. In this context, how does the word relate to the definition of power? How does this word relate to the alternative definition of power?

Answers to Section Assessment

1. 12.3 s; 2.45 × 10³ J
2. 613 W; 2.45 × 10³ J
3. Power equals energy transferred divided by time of transfer.
4. A powerful engine is capable of doing more work in a given time. The force and speed delivered by a powerful engine is large relative to less powerful engines.

Answers

Practice F

1. 66 kW
2. 2.38 × 10⁴ W (23.8 kW)
3. 2.61 × 10⁸ s (8.27 years)
4. 3.6 × 10¹ s (1.0 h)
5. a. 7.50 × 10⁴ J
    b. 2.50 × 10⁴ W

PROBLEM GUIDE E

Use this guide to assign problems.
SE = Student Edition Textbook
PW = Sample Problem Set I (online)
PB = Sample Problem Set II (online)

Solving for:

\[ P \]
SE Sample, 1–2, 5; Ch. Rvw. 36
PW 5–6
PB 8–10

\[ \Delta t \]
SE 3–4; Ch. Rvw. 35
PW 3–4
PB Sample, 1–3

\[ W \]
SE 5
PW Sample, 1–2
PB 4–7

*Challenging Problem

Assess and Reteach ▼

Assess Use the Formative Assessment on this page to evaluate student mastery of the section.

Reteach For students who need additional instruction, download the Section Study Guide.

Response to Intervention To reassess students’ mastery, use the Section Quiz, available to print or to take directly online at HMDScience.com.