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Electric Power

Sample Problem

An alarm clock uses 5.0 W of electric power. If the clock is plugged into a 120 V outlet, what electric current is in the clock's circuit?

1. List the given and unknown values.

   Given: *voltage*, $V = 120\text{ V}$

   power, $P = 5.0\text{ W}$

   Unknown: *current*, $I = ?\text{ A}$

2. Write the equation for power, and rearrange it to put current by itself on the left side of the equation.

   $$P = VI \qquad VI = P \qquad I = \frac{P}{V}$$

3. Insert the known values into the equation, and solve.

   $$I = \frac{5.0\text{ W}}{120\text{ V}}$$

   $$I = 4.2 \times 10^{-2}\text{ A}$$

Your Turn to Think

1. The headlights of an automobile have two power ratings: 45 W for the low beam and 65 W for the high beam. How much is the current in the headlight filament of a headlight bulb for both of these settings when 12 V is provided by the car battery?

   $I = \frac{P}{V}$ $\quad \frac{45}{12} = 3.75\text{ A}$

   $\frac{65}{12} = 5.42\text{ A}$

2. The heating coils of an electric stove are made of a high-resistance material so that the electricity that passes through the coils causes them to become red hot within a minute. The smaller coil draws 1250 W of power, while the larger coil draws 2100 W. The voltage provided across each coil is 240 V. What is the current in each coil?

   $I = \frac{P}{V}$ $\quad \frac{1250}{240} = 5.2\text{ A}$ $\quad \frac{2100}{240} = 8.75\text{ A}$

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3. An electric mixer draws 200.0 W of power. If the mixer is plugged into an outlet across a voltage of 115 V, what current is in the mixer's circuit?

$$I = \frac{P}{V} = \frac{200}{115} = 1.74\ A$$

4. A bus built in 1905 used electricity produced by a gasoline-powered generator. The generator provided 33.6 kW of power to the bus. If the voltage across the electric motor was 440 V, what was the current in the motor?

$$I = \frac{P}{V} = \frac{33600}{440} = 76.36\ A$$

5. Alternating current is used today because its voltage can be easily changed by a device called a *transformer*. Transformers are used both to increase the voltage of electricity, so that it can travel long distances, and to decrease the voltage, so that the electricity can be used in your house with relative safety. If the voltage across two wires is raised to 2.5×10^5 V, what is its current if 1.0×10^5 W of power is provided?

$$I = \frac{P}{V} = \frac{1 \times 10^5}{2.5 \times 10^5} = 0.4\ A$$

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Electric Power *continued*

Sample Problem

A high-intensity portable lantern is powered by several batteries that are connected in series. The lantern's bulb uses 96 W of power, while the current in the lantern is 4.0 A. Assuming that there is no power loss in the circuit, what is the total voltage of the batteries?

1. List the given and unknown values.

   Given: *power,* $P = 96$ W

   current, $I = 4.0$ A

   Unknown: *voltage,* $V = ?$ V

2. Write the equation for power, and rearrange it to solve for voltage.

   $$P = VI \qquad VI = P \qquad V = \frac{P}{I}$$

3. Insert the known values into the equation and solve.

   $$V = \frac{96\ \text{W}}{4.0\ \text{A}}$$

   $$V = 24\ \text{V}$$

Your Turn to Think

6. A nightlight uses 4.00 W of power when plugged into an outlet. Assume that the only resistance in the circuit is provided by the light bulb's filament. The current in the circuit is 3.40×10^{-2} A. What is the voltage across the filament?

   $$V = \frac{P}{I} = \frac{4}{3.4 \times 10^{-2}} = 117.6\ V$$

7. A portable power source is available for travelers who need electricity for appliances. The power source provides 54 W of power to operate an air compressor for inflating tires. This compressor draws 4.5 A of current when connected to the power supply. What is the voltage across the compressor?

   $$V = \frac{P}{I} = \frac{54}{4.5} = 12\ V$$

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8. A certain high-speed train is powered by 64 electric motors—one motor for each axle of each car. The power output of each motor is 185 kW. The current provided to each motor from overhead power lines is 7.4 A. What is the voltage across each motor?

$$V = \frac{P}{I} = \frac{185000}{7.4} = 25\ kV$$

9. A particular laser developed in 1995 at the University of Rochester, in New York, produced a beam of light that lasted for about one-billionth of a second. The power output of this beam was 6.0×10^{13} W. Assume that all of the electrical power was converted into light and that 8.0×10^{6} A of current was needed to produce this beam. How large was the voltage that produced the current?

$$V = \frac{P}{I} = \frac{6 \times 10^{13}}{8 \times 10^{6}} = 7.5 \times 10^{6}\ V$$

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Electric Power *continued*

10. Fuel cells are chemical cells that combine hydrogen and oxygen gas to produce electrical energy. In recent years, a fuel cell has been developed that can generate 1.06×10^4 W of power. If this electricity has a current of 16.3 A, what is the voltage of the electricity?

$V = \frac{P}{I} = \frac{1.06 \times 10^4}{16.3} = 650.3\ V$

Sample Problem

A generator at a power plant produces electricity with a voltage of 2.5×10^4 V and a current of 20.0 A. How much power does the generator produce?

1. List the given and unknown values.

   Given: *voltage,* $V = 2.5 \times 10^4$ V

   current, $I = 20.0$ A

   Unknown: *power,* $P = ?$ W

2. Write the equation for power.

$$P = VI$$

3. Insert the known values into the equation, and solve.

   $P = (2.5 \times 10^4 \text{ V}) \times (20.0 \text{ A})$

   $P = 5.0 \times 10^5$ W

Sample Problem

A computer with a resistance of 57.5 Ω has a power input of 230.0 W. Calculate the voltage across and current in the computer, using the formulas relating power to resistance.

1. List the given and unknown values.

   Given: *power,* $P = 230.0$ W

   resistance, $R = 57.5\ \Omega$

   Unknown: *voltage,* $V = ?$ V

   current, $I = ?$ A

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Electric Power *continued*

2. Write the equations for power in terms of resistance, and rearrange them to solve for voltage and current.

$$P = VI = V \times \frac{V}{R} = \frac{V^2}{R}$$

$$V = \quad PR$$

$$P = VI = (IR) \times I = I^2R$$

$$I = \frac{P}{R}$$

3. Insert the known values into the equations, and solve.

$$V = \quad (230.0 \text{ W}) \times (57.5\ \Omega)$$

$$V = 115 \text{ V}$$

$$I = \frac{230.0 \text{ W}}{57.5\ \Omega}$$

$$I = 2.00 \text{ A}$$

Your Turn to Think

11. A current of 5.83 A is used to produce the microwave radiation in a microwave oven. If the voltage across the oven is 120 V, how much power does the oven use?

$P = VI = 120 \times 5.83 = 699.6$ W

12. A vacuum cleaner's motor has a voltage of 120 V across its terminals and a current of 12 A. How much power does the vacuum cleaneruse?

$P = VI = 120 \times 12 = 1440$ W

13. A refrigerator uses a current of 0.62 A and a voltage of 116 V. How much power does the refrigerator use?

$P = VI = 116 \times 0.62 = 71.9$ W

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14. An electric sports car was developed several years ago at Texas A & M University, in College Station, Texas. If the voltage required to operate the car was 720 V and the resistance was 0.30 Ω, how much power was needed for the car to run? (**Hint:** Express current in terms of voltage and resistance, and substitute this into the power equation.)

$$P = \frac{V^2}{R} = \frac{720^2}{0.3} = 1728 \text{ kW}$$

Mixed Review

15. Electric power is often produced by a gas-powered generator. Suppose one of these generators has a power output of about 7.50×10^4 W. If the generator produces a voltage of 114 V, how much current is in the generator?

$$I = \frac{P}{V} = \frac{7.5 \times 10^4}{114} = 657.9 \text{ A}$$

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Electric Power *continued*

16. Several appliances in a house contribute to the home's overall energy consumption. If a toaster ($R = 18.0\ \Omega$), an air conditioner ($R = 24.0\ \Omega$), and an electric lamp ($R = 192\ \Omega$) are all plugged into 120.0 V outlets, what is the power use of each appliance? What is the overall power use?

$$P_1 = \frac{V^2}{R} \quad P_1 = \frac{120^2}{18} = 800\ W \quad P_2 = \frac{120^2}{24} = 600\ W$$

$$P_3 = \frac{120^2}{192} = 75\ W \quad P = P_1 + P_2 + P_3 = 1475\ W$$

17. There are 17 generators at Hoover Dam, each of which produces electricity with a voltage of 1.65×10^4 V and a current of 7.37×10^3 A. What is each generator's power output?

$$P = VI = 1.65 \times 10^4 \times 7.37 \times 10^3$$
$$\approx 1.22 \times 10^8\ W$$

18. One of the problems with transmitting electricity is that the resistance of the wire causes some energy to be transferred away as heat. This energy loss is equal to I^2R. The loss can be reduced if the voltage can be increased so that the current decreases. Only alternating current can undergo this voltage increase, which is why AC is used for producing most electricity. Consider a power plant that produces 5.00×10^5 W of electricity. The wire has a resistance of $1.00 \times 10^5\ \Omega$. What is the power loss if the voltage is transmitted 2.50×10^2 V? at 2.50×10^5 V?

$$I = \frac{P}{V} \quad I_1 = \frac{5 \times 10^5}{2.5 \times 10^2} = 2000\ A$$

$$I_2 = \frac{5 \times 10^5}{2.5 \times 10^5} = 2\ A$$

$$P_{Loss\,1} = I_1^2 R = 2000^2 \times 1 \times 10^5 = 4 \times 10^{11}\ W$$

$$P_{Loss\,2} = I_2^2 R = 2^2 \times 1 \times 10^5 = 4 \times 10^5\ W$$

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19. Power from mechanical work is often converted into electrical energy. Suppose you have a generator connected to a waterwheel that is turned by a waterfall. The waterfall is 25 m high, with 980 kg of water falling each second onto the waterwheel. Formula to calculate gravitational potential energy is E = mgh, where m is mass, h is height and g = 9.8 m/s^2 (acceleration due to the gravity). If all of this mechanical energy is converted to electricity, how much power is generated? If the generated current is 20.0 A, what is the voltage?

$E = mgh = 980 \times 9.8 \times 25 = 240100\ J$

$P = \frac{E}{t} = \frac{240100\ J}{1\ s} = 240100\ W$

$V = \frac{P}{I} = \frac{240100}{20} = 12005\ V$