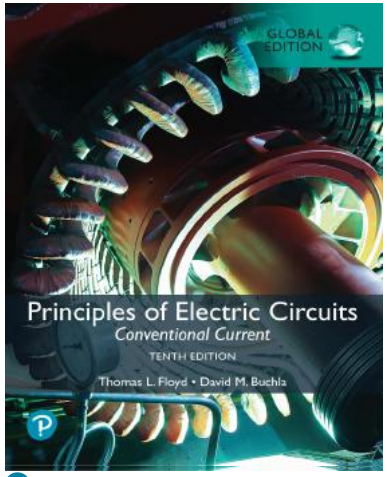
Principles of Electric Circuits: Conventional Current

Tenth Edition, Global Edition

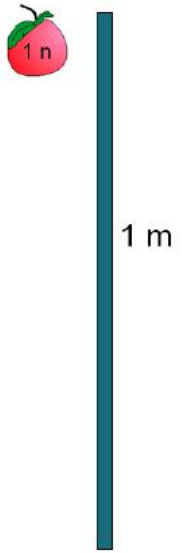


Chapter 4

Energy and Power

Summary: Energy (1 of 2)

Energy, *W*, is the ability to do work and is measured in joules. One **joule (J)** is the work done when a force of one newton is applied through a distance of one meter.



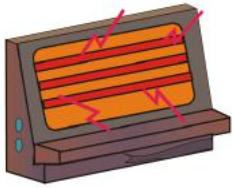
The symbol for energy, *W*, represents work, but should not be confused with the unit for power, the watt, W.

Summary: Energy (2 of 2)

The **kilowatt-hour (kWh)** is a much larger unit of energy than the joule. There are 3.6×10^6 J in one kWh. The kWh is convenient for electrical appliances and is the standard energy measurement for electrical utilities.

Question:

What is the energy used in operating a 1200 W heater for 20 minutes?



1200 W = 1.2 kW

20 min = 1/3 h

1.2 kW × 1/3 h = 0.4 kWh

Summary: Power (1 of 4)

Power is the *rate* at which energy is "used" (actually converted to heat or other form of energy). Power is measured in watts (or kilowatts). Notice that *rate* always involves *time*.

One watt = one joule/second

A large power unit in common use is the **horsepower**. Large electric motors are commonly rated in horsepower (hp) where 1 hp = 746 W.

Question:

(a) What is the power in kW of a 5.0 hp motor?

$$5.0 \text{ hp} \times \left(\frac{746 \text{ W}}{1 \text{ hp}}\right)\left(\frac{\text{kW}}{1000 \text{ W}}\right) = 3.73 \text{ kW}$$

(b) What is the energy used if the motor runs continuously for 24 h?

$$W = 3.73 \text{ kW} \times 24 \text{ h} = 89.5 \text{ kWh}$$

Summary: Power (2 of 4)

Three equations for power in circuits that are collectively known as Watt's law are:

$$P = IV \qquad P = I^2R \qquad P = \frac{V^2}{R}$$

Example-1:

What power is dissipated in a 27 Ω resistor if the current is 0.135 A?

Solution:

Given that you know the resistance and current, substitute the values into $P = I^2R$.

$$\begin{aligned} P &= I^2R \\ &= (0.135\ \text{A})^2 (27\ \Omega) \\ &= 0.49\ \text{W} \end{aligned}$$

Summary: Power (3 of 4)

Example-2:

What power is dissipated by a heater that draws 12 A of current from a 120 V supply?

Solution:

The most direct solution is to substitute into $P = IV$.

$$\begin{aligned} P &= IV \\ &= (12\ \text{A})(120\ \text{V}) \\ &= 1440\ \text{W} \end{aligned}$$

Summary: Power (4 of 4)

Example-3:

What power is dissipated in a 100 Ω resistor with 5.0 V across it?

Solution:

The most direct solution is to substitute into $P = \frac{V^2}{R}$.

$$\begin{aligned} P &= \frac{V^2}{R} \\ &= \frac{(5.0\ \text{V})^2}{100\ \Omega} = 0.25\ \text{W} \end{aligned}$$

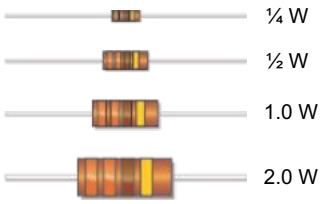
Small value resistors operating in low voltage systems need to be sized for the anticipated power.

Summary: Resistor power ratings

Resistors must dissipate heat in order to limit current. Power ratings are directly related to surface area; therefore larger resistors are rated for higher power ratings.

Question:

Which of these resistors would you choose if the voltage across it will be 15 V?



$$\begin{aligned} P &= \frac{V^2}{R} \\ &= \frac{(15\ \text{V})^2}{330\ \Omega} = 681\ \text{mW} \end{aligned}$$

Choose 1.0 W

Summary: Resistor failures (1 of 2)

The selection of the power rating for a resistor must include factors such as spacing of components (including other resistors), air flow, ambient temperature, altitude, and any heat sinks. Any of these factors can lead to failure.
Resistor failures usually are due to excessive heat. Look for discoloration (sometimes the color bands appear burned). Test with an ohmmeter by disconnecting one end from the circuit to isolate it and verify the resistance. Correct the cause of the heating problem (larger resistor?, wrong value?).

Normal Overheated

Summary: Resistor failures (2 of 2)

Use a DMM or an analog multimeter (VOM) to verify the resistance.

The DMM shown is an autoranging meter; the VOM is not. On the VOM, you choose the range and the scale. Read the scale and multiply by the range setting.

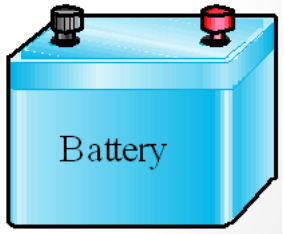
DMM Analog VOM

Summary: Ampere-hour rating of batteries

Expected battery life of batteries is given as the ampere-hours specification. Various factors affect this, so it is an approximation. (Factors include rate of discharge rate, age of battery, temperature, etc.)

Question:

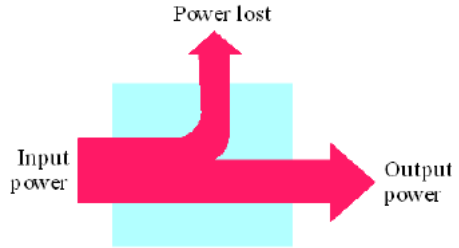
How many hours can you expect to have a battery deliver 0.5 A if it is rated at 10 Ah? 20 h



Summary: Power supply efficiency

Efficiency of a power supply is a measure of how well it converts ac to dc. For all power supplies, some of the input power is wasted in the form of heat. As an equation,

$$\text{Efficiency} = \frac{P_{\text{OUT}}}{P_{\text{IN}}} \times 100\%$$



Question:

What is the efficiency of a power supply that converts 20 W of input power to 17 W of output power? 85%

Selected Key Terms (1 of 2)

Ampere-hour rating A number determined by multiplying the current (A) times the length of time (h) that a battery can deliver that current to a load.

Efficiency The ratio of output power to input power of a circuit, usually expressed as a percent.

Energy The ability to do work.

Joule The SI unit of energy.

Selected Key Terms (2 of 2)

Kilowatt-hour (kWh) A large unit of energy used mainly by utility companies.

Power The rate of energy usage

Watt The SI unit of power.

Quiz (1 of 11)

1. A unit of power is the
   a. joule
   b. kilowatt-hour
   c. both of the above
   d. none of the above

Quiz (2 of 11)

2. The SI unit of energy is the
   a. volt
   b. joule
   c. watt
   d. kilowatt-hour

Quiz (3 of 11)

3. If the voltage for a resistive circuit doubles, the power will be
   a. halved
   b. unchanged
   c. doubled
   d. quadrupled

Quiz (4 of 11)

4. The smallest power rating you should use for a 330 Ω resistor with 12 V across it is
   a. ¼ W
   b. ½ W
   c. 1 W
   d. 2 W

Quiz (5 of 11)

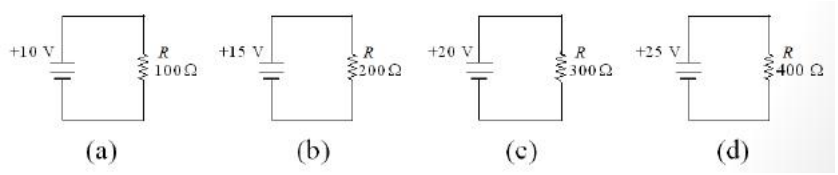
5. The power dissipated by a light operating on 12 V that has 3.0 A of current is
   a. 4.0 W
   b. 12 W
   c. 36 W
   d. 48 W

Quiz (6 of 11)

6. The power rating of a resistor is determined mainly by
   a. surface area
   b. length
   c. body color
   d. applied voltage

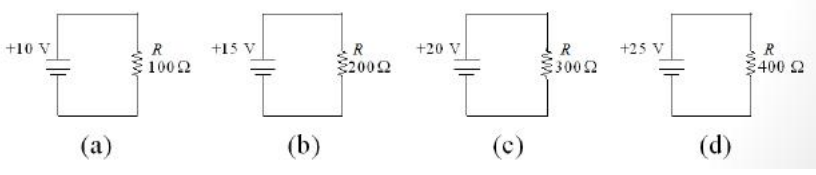
Quiz (7 of 11)

7. The circuit with the largest power dissipation is
   a. (a)
   b. (b)
   c. (c)
   d. (d)



Quiz (8 of 11)

8. The circuit with the smallest power dissipation is
   a. (a)
   b. (b)
   c. (c)
   d. (d)



Quiz (9 of 11)

9. A battery rated for 20 Ah can supply 2.0 A for a minimum of
   a. 0.1 h
   b. 2.0 h
   c. 10 h
   d. 40 h

Quiz (10 of 11)

10. The efficiency of a power supply is determined by
    a. Dividing the output power by the input power.
    b. Dividing the output voltage by the input voltage.
    c. Dividing the input power by the output power.
    d. Dividing the input voltage by the output voltage.

Quiz (11 of 11)

Answers:

1. d
2. b
3. d
4. b
5. c
6. a
7. d
8. a
9. c
10. a

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