Resistance

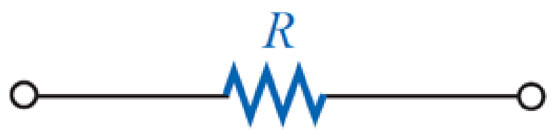
The flow of charge through any material encounters an opposing force (mechanical friction).

This is due to collision between electrons and atoms,

These collisions convert electrical energy into heat.

This opposition is called resistance of the material,

The unit of resistance is the "ohm" **Ω**



Resistance symbol and notation.

Ohm's Law, Power and Energy

4.1 OHM'S LAW

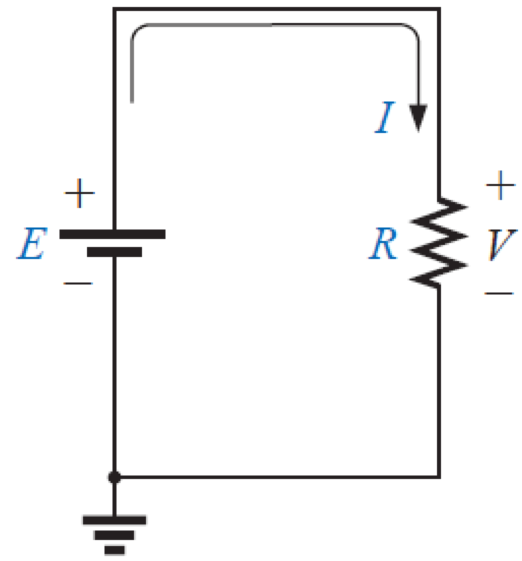
$$Effect = \frac{Cause}{Opposition}$$

Effect	≡	Current
Cause	≡	Potential difference or voltage
Opposition	≡	Resistance

$$Current = \frac{Potential\ Difference}{Resistance}$$

$I = \frac{E}{R}$ Ohm' s Law

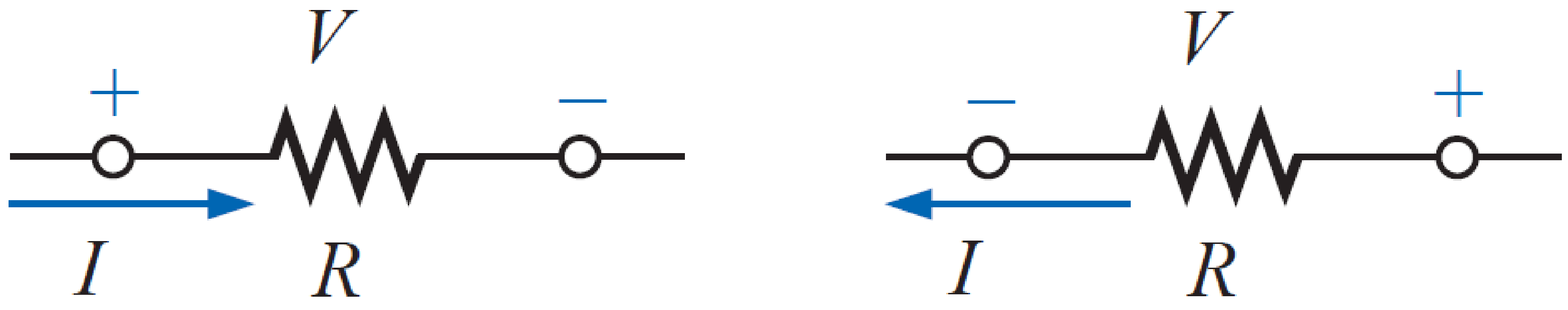
$\Longrightarrow$ $E = R.I$ $\Longrightarrow$ $R = \frac{E}{I}$



Basic circuit.

Defining the polarity:

flow of charge: from a high **(+)** to a low **(-)** potential



(a)   (b)

EXAMPLE 4.1 Determine the current resulting from the application of a 9-V battery across a network with a resistance of 2.2 Ω.

Solution: Eq. (4.2):

$$I = \frac{E}{R} = \frac{9\ \text{V}}{2.2\ \Omega} = \mathbf{4.09\ A}$$

EXAMPLE 4.2 Calculate the resistance of a 60-W bulb if a current of 500 mA results from an applied voltage of 120 V.

Solution: Eq. (4.4):

$$R = \frac{E}{I} = \frac{120\ \text{V}}{500 \times 10^{-3}\ \text{A}} = \mathbf{240\ \Omega}$$

EXAMPLE 4.3 Calculate the current through the 2-kΩ resistor of Fig. 4.4 if the voltage drop across it is 16 V.

Solution:

$$I = \frac{V}{R} = \frac{16\text{ V}}{2 \times 10^3\ \Omega} = \mathbf{8\ mA}$$

EXAMPLE 4.4 Calculate the voltage that must be applied across the soldering iron of Fig. 4.5 to establish a current of 1.5 A through the iron if its internal resistance is 80 Ω.

Solution:

$$E = IR = (1.5\text{ A})(80\ \Omega) = \mathbf{120\ V}$$

4.3 POWER

Power is an indication of how much work can be accomplished in a certain time

Power ≡ Rate of doing work

1 Watt (W) ≡ 1 Joule (J) / second(s) = J/s

$$P = \frac{W}{t}$$

unit of power is Watts (W) or (J/s) 1 horsepower (hp) = 746 W	$P = \frac{W}{t}$

In electrical device the power absorbed or delivered is:

$$P = \frac{W}{t} = \frac{Q \cdot V}{t} = V \cdot \frac{Q}{t} = V \cdot I$$

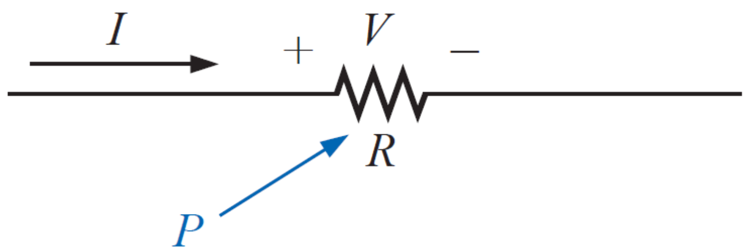
$$\boldsymbol{P = V \cdot I} \quad (W)$$

In a resistance

$$P = V \cdot I$$

$$\Rightarrow \quad P = V \cdot \frac{V}{R} = \frac{V^2}{R}$$

$$\Rightarrow \quad P = (R \cdot I) \cdot I = R \cdot I^2$$

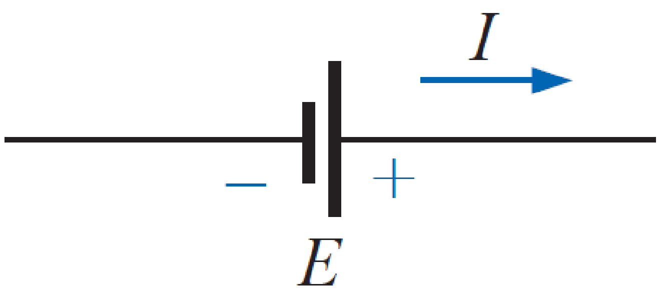


For resistive element, all the power delivered is dissipated in the form of heat.

$$P = R \cdot I^2 \quad \Rightarrow \quad I = \sqrt{P/R}$$

$$P = \frac{V^2}{R} \Rightarrow V = \sqrt{P \cdot R}$$

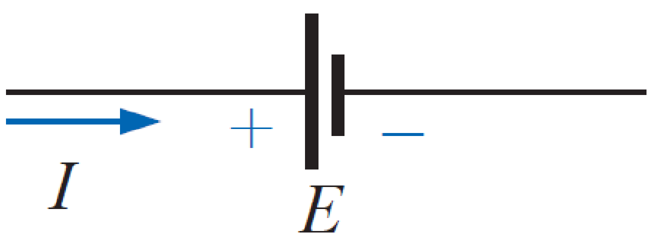
In Voltage supply (battery)



(a)

$$P = E \cdot I$$

Power is supplied by the source



(b)

$$P = E \cdot I$$

Power is absorbed by the source

EXAMPLE 4.6 Find the power delivered to the dc motor of Fig. 4.14.

Solution:

$$P = VI = (120\text{ V})(5\text{ A}) = 600\text{ W} = \mathbf{0.6\ kW}$$

EXAMPLE 4.7 What is the power dissipated by a 5-Ω resistor if the current is 4 A?

Solution:

$$P = I^2R = (4\text{ A})^2(5\ \Omega) = \mathbf{80\ W}$$

EXAMPLE 4.8 The *I-V* characteristics of a light bulb are provided in Fig. 4.15. Note the nonlinearity of the curve, indicating a wide range in resistance of the bulb with applied voltage as defined by the discussion of Section 4.2. If the rated voltage is 120 V, find the wattage rating of the bulb. Also calculate the resistance of the bulb under rated conditions.

Solution: At 120 V,

$$I = 0.625\text{ A}$$

and

$$P = VI = (120\text{ V})(0.625\text{ A}) = \mathbf{75\ W}$$

At 120 V,

$$R = \frac{V}{I} = \frac{120\text{ V}}{0.625\text{ A}} = \mathbf{192\ \Omega}$$

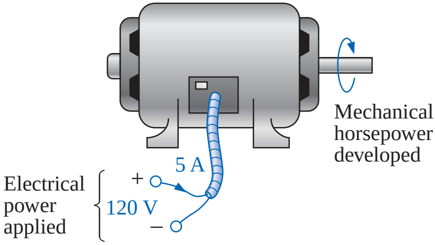


FIG. 4.14

Example 4.6.

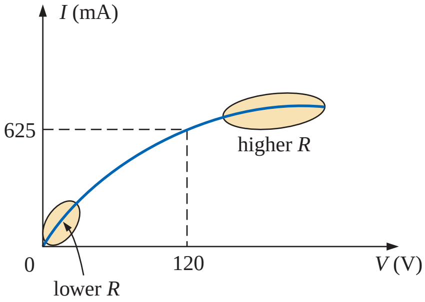
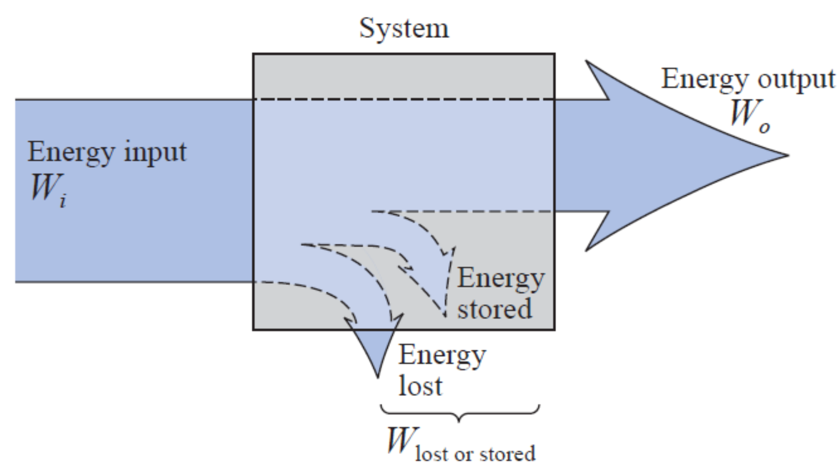


FIG. 4.15

The nonlinear I-V characteristics of a 75-W light bulb.

4.5 EFFICIENCY

Energy flow in a system that converts energy from one form to another. $W_o < W_i$ due to losses and storage $W_i = W_o + W_{lost\ or\ stored}$ $P_i = P_o + P_{lost\ or\ stored}$	

The efficiency (η) of the system is:

$$Efficiency = \frac{Power\ output}{Power\ input}$$

$$\eta = \frac{P_o}{P_i} \quad \Longrightarrow \quad \eta(\%) = \frac{P_o}{P_i} \times 100\ \%$$

η is always less than 1 (100 %)