Chapter 21
Electric Current and Direct-Current Circuit

Outline

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21-2 Resistance and Ohm's Law
21-3 Energy and Power in Electric Circuit

21-4 Resistance in Series and Parallel

21-5 Kirchhoff's Rules

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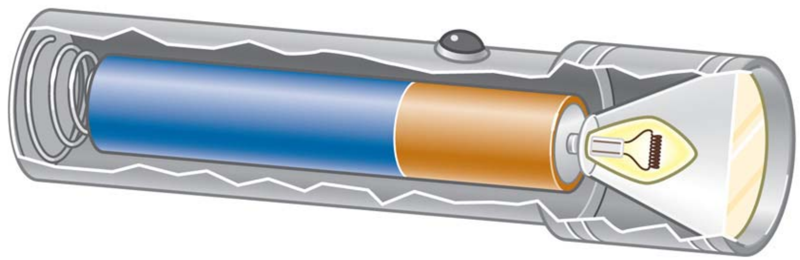
21-7 RC Circuits

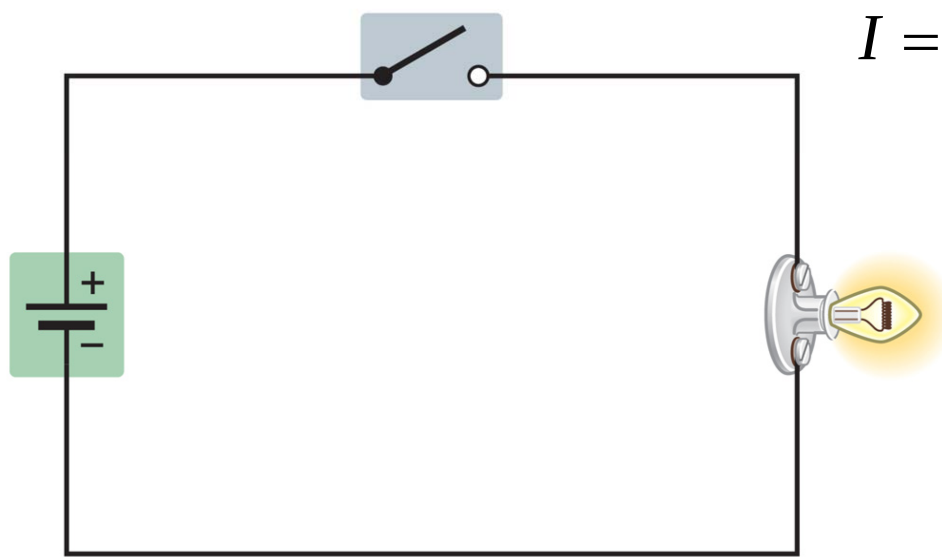
Figure 21-2
The flashlight: A simple electrical circuit



(a)

$$I = \frac{\Delta Q}{\Delta t}$$

V: potential Difference/ Voltage



R: resistance

(b)

21-1 Electric Current

Definition of Electric Current, I

$$I = \frac{\Delta Q}{\Delta t} \qquad (21-1)$$

SI unit: Coulomb per second, C/s = Ampere, A

Note:

1) Electric current I is defined in a **Circuit/wire**.

2) Electric current I is independent to the time interval.

21-5 How Many Electrons

Highly sensitive ammeters can measure currents as small as 10.0×10^{-5} A. How many electrons in 2 seconds flow through a wire with 10.0×10^{-5} A current in this case?

Batteries and Electromotive Force

Electrons will move along a metal wire only when the wire is connected with a source of electric energy, such as a battery.

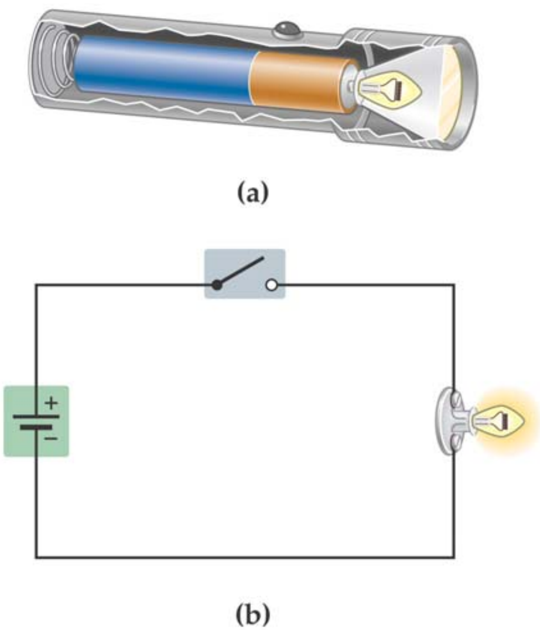


Figure 21-2
The Flashlight: A Simple Electrical Circuit

The function of a battery is to provide an electric potential difference, so that the electric current (+ charges) can move in the wire.

The electric potential difference between its two terminals of the battery is referred as Electromotive Force, or emf (ε). The magnitude of the work done by a battery of emf ε as a charge ΔQ moves from one terminal to the other is given by Eq (20-2),

$$\varepsilon = \frac{W}{\Delta Q}$$

ε Unit: volt, V

Active Example 21-1 **Operating a Flashlight**

A battery with an emf of 1.5 V delivers a current of 0.44 A to a bulb for 64 s (see Fig 21-2). Find **(a)** the charge that passes through the circuit and **(b)** the work done by the battery.

The direction of the current in a circuit

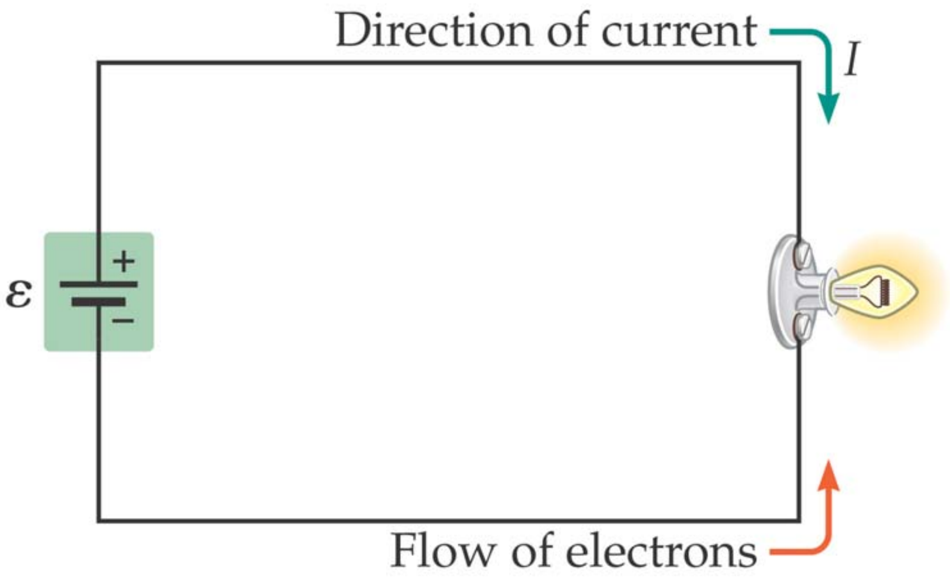


Figure 21-4
Direction of Current and Electron Flow

The direction of the current in an electrical circuit is the direction of the positive charge flowing.

21-2 Resistance and Ohm's Law

In order to cause electrons to move again the resistance of a wire, one must apply a potential difference between its two end. Assume R is the resistance, V is the potential difference, and the current is I,

Ohm's Law

$V = IR$

SI unit: volt, V

Solving for resistance:

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

SI unit: Ω, 1Ω = 1 V / A

21-8 Resistance

When a potential difference of 18 V is applied to a given wire, it conducts 0.35 A of current. What is the resistance of the wire?

Solution

With Ohm's law, one has

$$R = \frac{V}{I} = \frac{18 \text{ V}}{0.35 \text{ A}} = \boxed{51 \, \Omega}$$

Resistivity

Suppose a piece of wire has length L and cross-section area A. The resistance of a material is determined by its resistivity ρ,

Definition of Resistivity, ρ

$$R = \rho\left(\frac{L}{A}\right) \qquad (21-3)$$

Unit: Ω·m

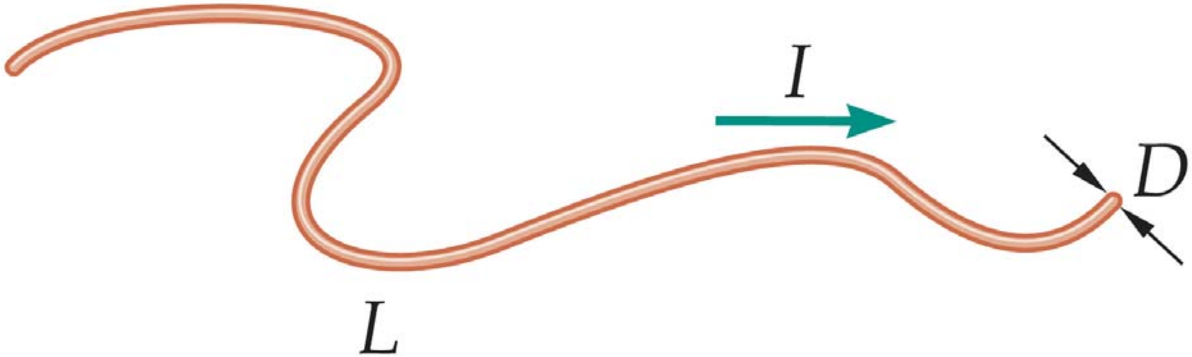


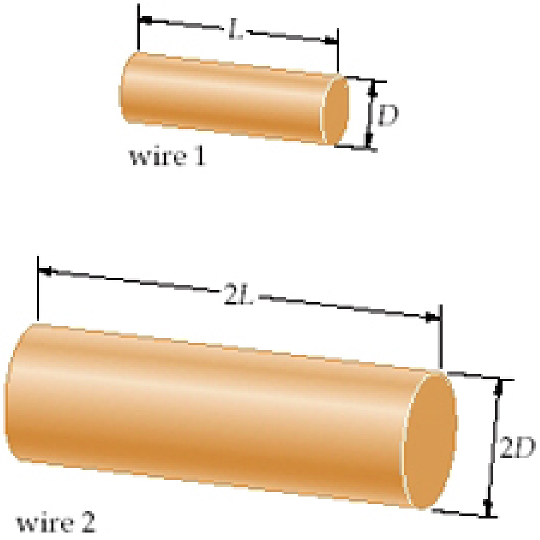
Table 21-1
Resistivities

Substance	Resistivity, ρ ($\Omega \cdot m$)
Insulators	
Quartz (fused)	7.5×10^{17}
Rubber	$1 \text{ to } 100 \times 10^{13}$
Glass	$1 \text{ to } 10{,}000 \times 10^{9}$
Semiconductors	
Silicon*	0.10 to 60
Germanium*	0.001 to 0.5
Conductors	
Lead	22×10^{-8}
Iron	9.71×10^{-8}
Tungsten	5.6×10^{-8}
Aluminum	2.65×10^{-8}
Gold	2.20×10^{-8}
Copper	1.68×10^{-8}
Silver	1.59×10^{-8}

*The resistivity of a semiconductor varies greatly with the type and amount of impurities it contains. This property makes it particularly useful in electronic applications.

CONCEPTUAL CHECKPOINT 21–1

Wire 1 has a length L and a circular cross section of diameter D. Wire 2 is constructed from the same material as wire 1 and has the same shape, but its length is $2L$, and its diameter is $2D$. Is the resistance of wire 2 **(a)** the same as that of wire 1, **(b)** twice that of wire 1, or **(c)** half that of wire 1?



21-13 How long the wire is?

A current of 0.76 A flows through a copper wire 0.44 mm in diameter when it is connected to a potential difference of 15 V. How long is the wire?

Summary

1) Definition of Electric Current, I

$$I = \frac{\Delta Q}{\Delta t} \qquad (21-1)$$

2) Ohm's Law

$$V = IR, \qquad I = V / R$$

3) Definition of Resistivity, ρ

$$R = \rho\left(\frac{L}{A}\right) \qquad (21-3)$$

Example 21-1 **Mega Blaster**

The disk drive in a portable CD player is connected to a battery that supplies it with a current of 0.22 A. How many electrons pass through the drive in 4.5 s ?

Solution

1) Find the charge ΔQ, according to the definition I

$$\Delta Q = I \times \Delta t = (0.22A)(4.5s) = 0.99C$$

2) Then find the number of electrons in charge ΔQ,

$$N = \frac{\Delta Q}{e} = \frac{0.99C}{1.60 \times 10^{-19} C / electron}$$

$$= 6.2 \times 10^{18} \quad electrons$$

Exercise 21-1

A potential difference of 24 V is applied to 150 Ω resistor. How much current flows through the resistance?

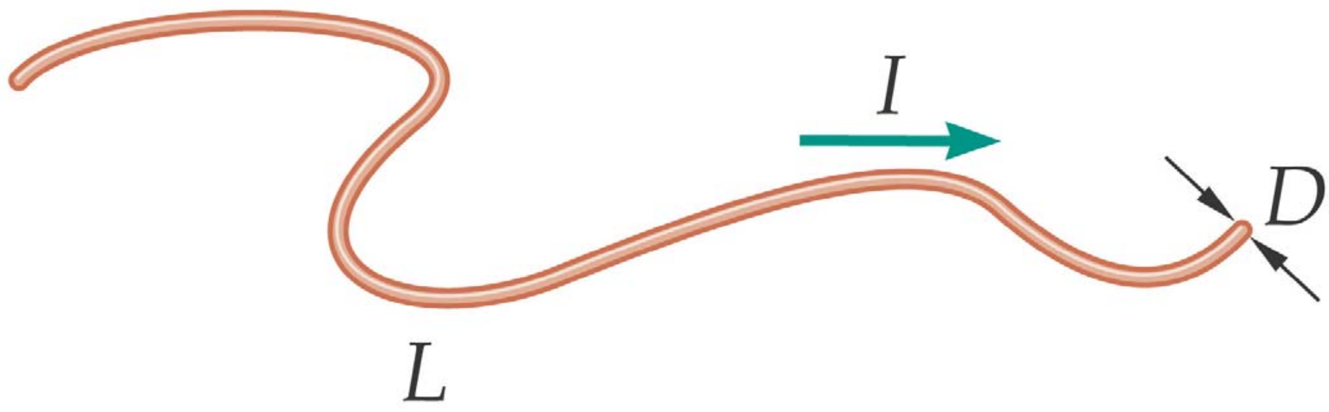
Solution

With Ohm's law, one has

$$I = \frac{V}{R} = \frac{24V}{150\Omega} = 0.16 \quad A$$

Examples 21-2 **A current-Carrying Wire**

A current of 1.82 A flows through a copper wire 1.75m long and 1.10 mm diameter. Find the potential difference between the ends of the wire. (the value ρ for copper is $1.68\text{x}10^{-8}$ Ω·m).



Example 21-2
A Current-Carrying Wire

Solution

1) Find the resistance of the wire

$$R = \rho\left(\frac{L}{A}\right) = (1.68\times10^{-8}\Omega\cdot m)[\frac{1.75m}{\pi(0.00110m)^2/4}]$$

$$= 0.0309 \quad \Omega$$

2) Find the potential difference, according to Ohm's law

V = IR = (1.82 A) (0.0309 Ω) = 0.0562 V