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Welcome
to
PHYS 212: Physics

Chapter#26

Current and Resistance

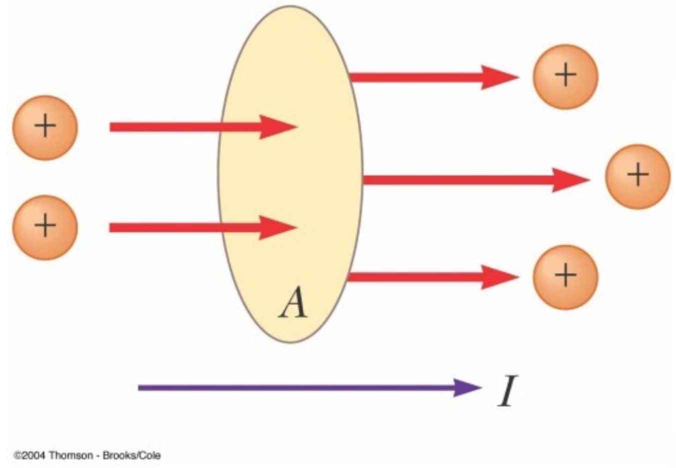
Topics

- Electric Current.
- Current Density.
- Resistance & Resistivity.
- Ohm’s Law.
- Power in Electric Circuit.

26-1 Electric Current

❖ **Electric current** is the rate of flow of charge through some region of space.

- The **IS** unit of current is the **ampere** (**A**)
- **1 A = 1 C/s**
- The symbol for electric current is I



❖ Average Electric Current

- Assume charges are moving perpendicular to a surface of area **A**
- If **ΔQ** is the amount of charge that passes through **A** in time **Δt**,
- then the **average current** is

$$I_{avg} = \frac{\Delta Q}{\Delta t}$$

Problem-1:

Module 26-1 Electric Current

•1 During the 4.0 min a 5.0 A current is set up in a wire, how many (a) coulombs and (b) electrons pass through any cross section across the wire's width?

I=q/t

Q=ne

Answer:

(a) $q = 1.2\times 10^{3}$ C.

(b) $N = 7.5 \times 10^{21}$.

Electric Current

❖ As Fig. (a), any isolated conducting loop is all at the same potential. No electric field can exist within it or along its surface.

❖ As Fig. (b), If we insert a battery in the loop, the conducting loop is no longer at a single potential.

❖ Electric fields act inside the material, exerting forces on internal charges, causing them to move and thus establishing a **current**.

❖ The diagram assumes the motion of positive charges moving clockwise.

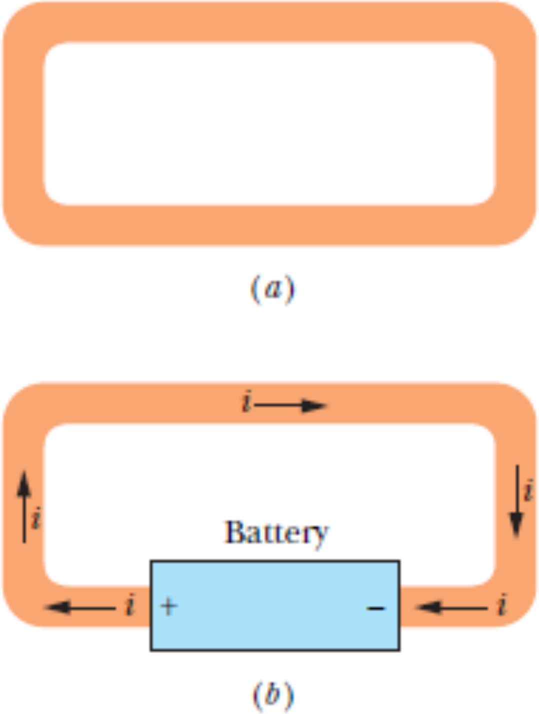
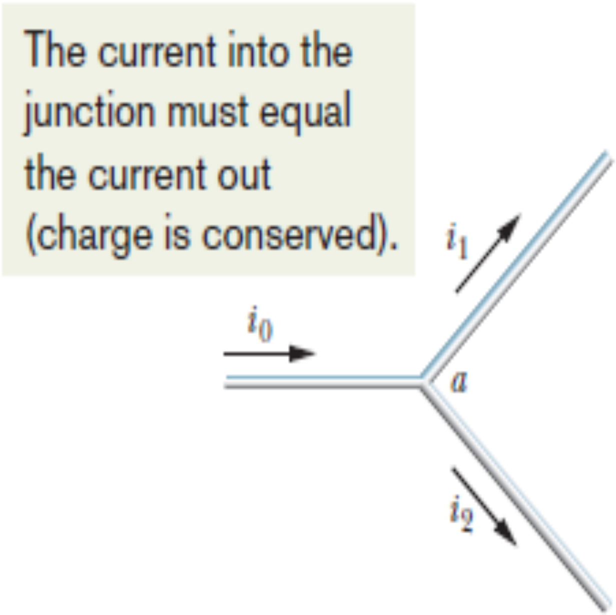


Fig. 26-1 (*a*) A loop of copper in electrostatic equilibrium. The entire loop is at a single potential, and the electric field is zero at all points inside the copper. (*b*) Adding a battery imposes an electric potential difference between the ends of the loop that are connected to the terminals of the battery. The battery thus produces an electric field within the loop, from terminal to terminal, and the field causes charges to move around the loop. This movement of charges is a current *i*.

Electric Current

❖ Figure shows a conductor with current i_0 splitting at a junction into two branches.

❖ Because charge is conserved, the magnitudes of the currents in the branches must add to yield the magnitude of the current in the original conductor, so that



$$i_0 = i_1 + i_2.$$

Electric Current

❖The Directions of Currents

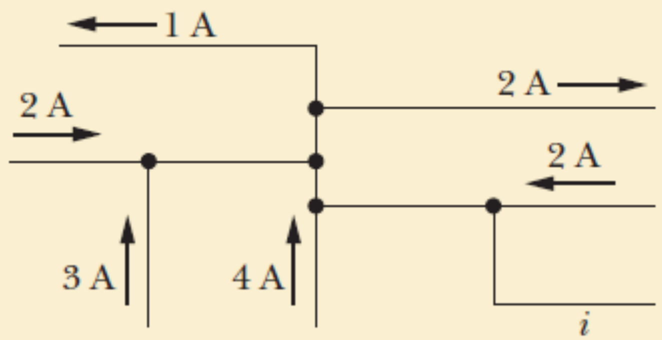
A current arrow is drawn in the direction in which positive charge carriers would move, even if the actual charge carriers are negative and move in the opposite direction.

- The charges passing through the area could be positive or negative or both.
- It is common to refer to any moving charge as a charge carrier.
- It is conventional to assign to the current the same direction as the flow of positive charges.
- The direction of current flow is opposite the direction of the flow of electrons.

Electric Current

Checkpoint 1

The figure here shows a portion of a circuit. What are the magnitude and direction of the current i in the lower right-hand wire?



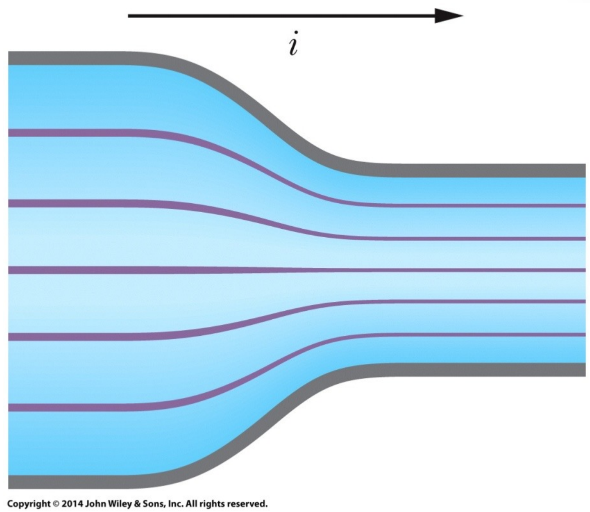
Answer: 8A with arrow pointing right

26-2 Current Density

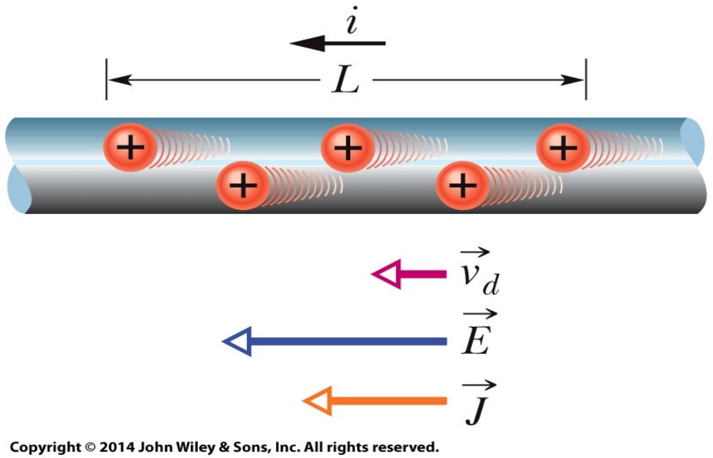
❖ Current ***i*** (a scalar quantity) is related to **current density *J*** (a vector quantity) by

$$i = \int \vec{J} \cdot d\vec{A}.$$

where $\vec{J}$ is a vector perpendicular to a surface element of area ***dA***.



❖ The **current density *J*** has the same direction as the velocity of the moving charges if they are positive charges and the opposite direction if the moving charges are negative.



Current Density

- ***J*** is the **current density** of a conductor. It is defined as the current per unit area.

$$J = I / A = (nq)v_d$$

where

  - v_d is the drift velocity.
  - ***nq*** is the carrier charge density and **SI** unit is (**C/m³**)

- This expression is valid only if the current density is uniform and A is perpendicular to the direction of the current.
- ***J*** has **SI** units of **A/m²**
- The current density is in the direction of the positive charge carriers.

Sample Problem 26.02 Current density, uniform and nonuniform

(a) The current density in a cylindrical wire of radius R = 2.0 mm is uniform across a cross section of the wire and is $J = 2.0 \times 10^5$ A/m^2. What is the current through the outer portion of the wire between radial distances $R/2$ and R (Fig. 26-6*a*)?

KEY IDEA

Because the current density is uniform across the cross section, the current density J, the current i, and the cross-sectional area A are related by Eq. 26-5 ($J = i/A$).

Calculations: We want only the current through a reduced cross-sectional area A' of the wire (rather than the entire area), where

$$A' = \pi R^2 - \pi\left(\frac{R}{2}\right)^2 = \pi\left(\frac{3R^2}{4}\right)$$

$$= \frac{3\pi}{4}(0.0020\ \text{m})^2 = 9.424 \times 10^{-6}\ \text{m}^2.$$

So, we rewrite Eq. 26-5 as

$$i = JA'$$

and then substitute the data to find

$$i = (2.0 \times 10^5\ \text{A/m}^2)(9.424 \times 10^{-6}\ \text{m}^2)$$

$$= 1.9\ \text{A}. \qquad \text{(Answer)}$$

26-3 Resistance & Resistivity

❖ If we apply the same potential difference between the ends of geometrically similar rods of copper and of glass, very different currents result. The characteristic of the conductor that enters here is its **electrical resistance**. The resistance *R* of a conductor is defined as

$$R = \frac{V}{i} \quad \text{(definition of } R\text{).}$$

where ***V*** is the potential difference across the conductor and ***i*** is the current through the conductor.

The SI unit of resistance is volt per ampere (V/A) or **ohm (Ω)**

26-3 Resistance & Resistivity

Instead of the **resistance R** of an object, we may deal with the **resistivity** ***ρ*** of the material:

$$\rho = \frac{E}{J} \quad \text{(definition of } \rho\text{).}$$

If we combine the SI units of *E* and *J* according to above equation, we get, for the unit of ***ρ***, the ohm-meter (m):

$$\frac{\text{unit } (E)}{\text{unit } (J)} = \frac{\text{V/m}}{\text{A/m}^2} = \frac{\text{V}}{\text{A}}\text{m} = \Omega \cdot \text{m}.$$

We often speak of the conductivity **σ** of a material. This is simply the reciprocal of its resistivity:

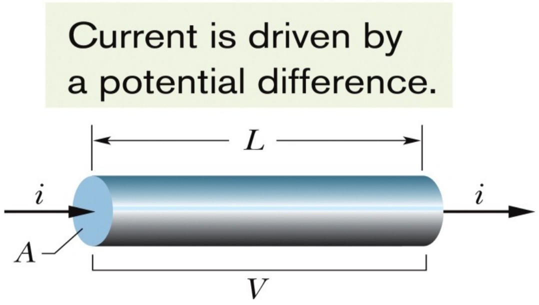
$$\sigma = \frac{1}{\rho} \quad \text{(definition of } \sigma\text{).}$$

Resistance & Resistivity

Resistance is a property of an object. Resistivity is a property of a material.

❖ The resistance ***R*** of a conducting wire of length ***L*** and uniform cross section is

$$R = \rho \frac{L}{A}.$$

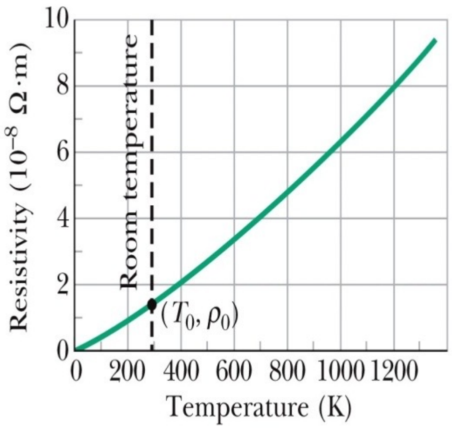


Here ***A*** is the cross-sectional area.

❖ The resistivity ***ρ*** for most materials changes with temperature.

❖ For many materials, including metals, the relation between ***ρ*** and temperature ***T*** is approximated by the equation

$$\rho - \rho_0 = \rho_0 \alpha (T - T_0).$$



❖ Here ***T_0*** is a reference temperature, ***ρ_0*** is the resistivity at ***T_0***, and ***α*** is the temperature coefficient of resistivity for the material.

Problem-3:

(A) Calculate the resistance per unit length of 22-gauge Nichrome wire, which has a radius of 0.321 mm. [use resistivity of Nichrome 1.5 x 10^{-6} Ω.m]

(B) If the potential difference of 10 V is maintained across a 1.0 m length of the Nichrome wire, what is the current in the wire?

Answer:

(A) $\frac{R}{\ell} = \boxed{4.6\ \Omega/\mathrm{m}}$

(B) $I = \boxed{2.2\ \mathrm{A}}$

I= V/R R= roh l/A

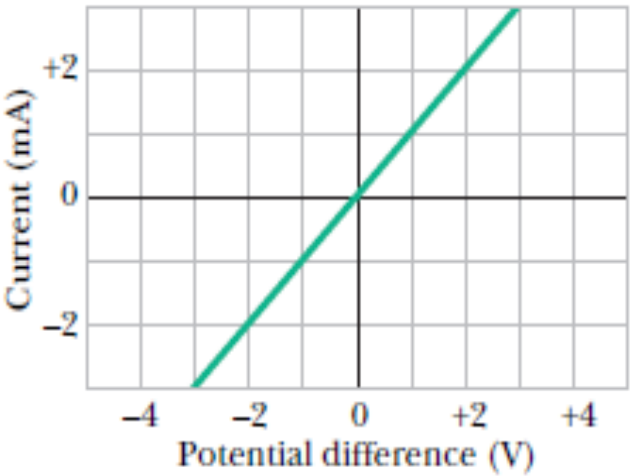
26-4 Ohm's Law

Ohm's law states electric current(**I**) is directly proportional to voltage(**V**) and inversely proportional to resistance(**R**).

I α V

I α 1/R

I = V/R



- Most metals obey Ohm's law
- Materials that obey Ohm's law are said to be Ohmic.

Checkpoint 4

The following table gives the current i (in amperes) through two devices for several values of potential difference V (in volts). From these data, determine which device does not obey Ohm's law.

Device 1		Device 2	
V	i	V	i
2.00	4.50	2.00	1.50
3.00	6.75	3.00	2.20
4.00	9.00	4.00	2.80

Problem-3:

Module 26-3 Resistance and Resistivity

•**14** A human being can be electrocuted if a current as small as 50 mA passes near the heart. An electrician working with sweaty hands makes good contact with the two conductors he is holding, one in each hand. If his resistance is 2000 Ω, what might the fatal voltage be?

Answer:

$V = 100$ V.

Problem-4:

•19 SSM What is the resistivity of a wire of 1.0 mm diameter, 2.0 m length, and 50 mΩ resistance?

Answer:

$\rho = 2.0 \times 10^{-8}\,\Omega \cdot \text{m}.$

R=d/2 R= roh l/A A=pixr^2

Problem-5:

••23 When 115 V is applied across a wire that is 10 m long and has a 0.30 mm radius, the magnitude of the current density is $1.4 \times 10^{8}\ \text{A/m}^2$. Find the resistivity of the wire.

Answer:

$$\rho = \frac{V}{LJ} = 8.2 \times 10^{-8}\,\Omega \cdot \text{m}.$$

26-5 Power in Electric Circuit

❖ The power ***P***, or rate of energy transfer, in an electrical device across which a potential difference ***V*** is maintained is

$$P = iV \quad \text{(rate of electrical energy transfer).}$$

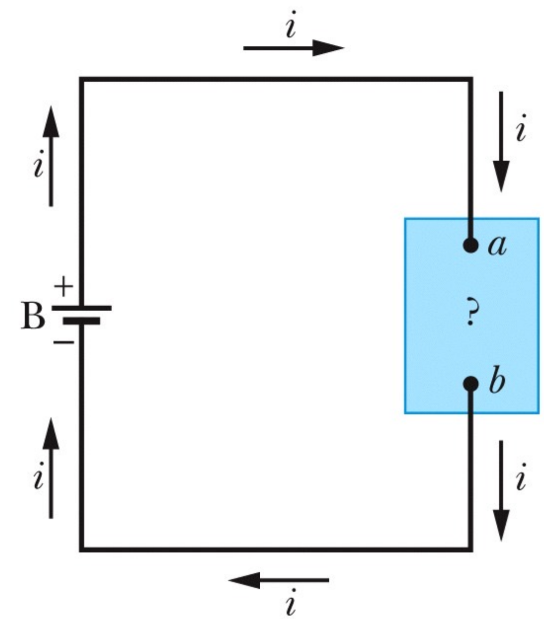
If the device is a resistor, the power can also be written as

$$P = i^2R \quad \text{(resistive dissipation)}$$

or,

$$P = \frac{V^2}{R} \quad \text{(resistive dissipation).}$$

The battery at the left supplies energy to the conduction electrons that form the current.



Problem-6:

•40 Thermal energy is produced in a resistor at a rate of 100 W when the current is 3.00 A. What is the resistance?

Answer:

The resistance is $R = 11.1\ \Omega$.

Problem-7:

An electric heater is constructed by applying a potential difference of 120 V to a Nichrome wire that has a total resistance of 8.00 Ω. Find the current carried by the wire and the power rating of the heater.

Answer:

$I = \boxed{15.0\ \text{A}}$ $\quad \mathcal{P} = \boxed{1.80\ \text{kW}}$

Problem-7:

•43 ILW An unknown resistor is connected between the terminals of a 3.00 V battery. Energy is dissipated in the resistor at the rate of 0.540 W. The same resistor is then connected between the terminals of a 1.50 V battery. At what rate is energy now dissipated?

Answer:

$P = 0.135$ W.