27-2 **Resistance**

 I- Current density:

If a wire is connected across the terminals of a battery, the conductor is not in static equilibrium. In this case, the conductor has a nonzero electric field, and a current exists in the wire.

Current density (J) is to study the flow of charge through a cross-section of the conductor at a particular point.

$$J = \frac{I}{A}$$

(27-4)

The current density J in the conductor is defined as the current per unit area.

Since: $$I = nev_d A$$

Then, $$J = nev_d$$

II- Conductivity (α) vs. Resistivity (ρ)

A current density J and an electric field E are established in a conductor whenever a potential difference is maintained across the conductor. If the potential difference is constant, then the current also is constant. In some materials, the current density is proportional to the electric field:

$$\mathbf{J} \propto \mathbf{E}$$
$$\mathbf{J} = \sigma\ \mathbf{E}$$

(27-5)

Where the constant of proportionality σ is called the **conductivity** ($\sigma = \frac{1}{\rho}, where\ \rho\ is\ called\ reistivity$) of the conductor. Materials that obey Equation (27-5) are said to follow Ohm's law.

More specifically, **Ohm's law states that**;

Ohm's law states that for many materials, including most metals, the ratio of current density to the electric field remains constant (denoted as σ) and is independent of the electric field generating the current, depending on the material's properties.

Materials that obey Ohm's law and hence demonstrate this simple relationship between E and J are said to be ohmic, while materials that do not obey Ohm's law are said to be non-ohmic.

III- Resistance

Now, let's explore practical situations where Ohm's law is not a fundamental law of nature but rather an empirical relationship that holds true only under specific conditions.

Consider a segment of straight wire of uniform cross-sectional area *A and* length *l*
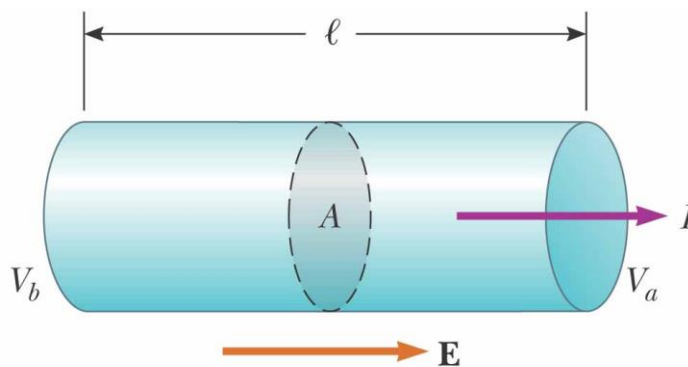
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If the field is assumed to be uniform, the potential difference is related to the field through the relationship,

$$\Delta V = E \, l$$

$$\because J = \sigma\ E$$

$$J = \sigma\ \frac{V}{l}$$

$$\because J = \frac{I}{A}$$

$$\therefore \frac{I}{A} = \sigma\ \frac{V}{l}$$

$$V = I(\frac{l}{\sigma\ A})$$

$$V = IR$$

V=IR

(27-6)

Simulations to Ohm's Law:

https://phet.colorado.edu/en/simulations/ohms-law

R is the resistance of the conductor.

The resistance is defined as the ratio of the potential difference across a conductor to the current in the conductor.

Unit for R: ohm (Ω).

$$\rho\,(\text{resistivity}) = \frac{1}{\sigma}$$

$$R \equiv \frac{\ell}{\sigma A} \equiv \rho\frac{\ell}{A} \equiv \frac{\Delta V}{I}$$

(27-7)

Comments:

- ➤ Resistors are used in electric circuits to control the current in the various parts of the circuit.
- ➤ The resistance of a sample of the material depends on the geometry of the sample and the resistivity of the material.
  See the simulation:
  https://phet.colorado.edu/en/simulations/resistance-in-a-wire

➢ More precisely, the resistance of a given cylindrical conductor such as a wire is proportional to its length and inversely proportional to its cross-sectional area. If the length of a wire is doubled, its resistance doubles. If its cross-sectional area is doubled, its resistance decreases by one-half.

➢ Ohmic materials and devices have a linear current–potential difference relationship over a broad range of applied potential differences (see Figure). The slope of the *I*-versus-D*V* curve in the linear region yields a value of 1/*R*. Nonohmic materials have a nonlinear current–potential difference relationship.

➢ Resistors come in various types, categorized based on their construction, material, and functionality. some common types are:
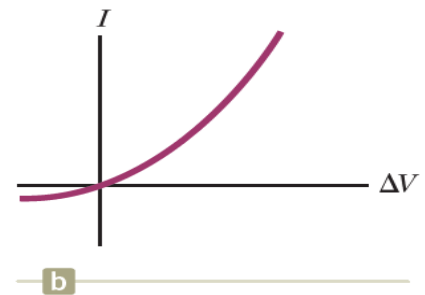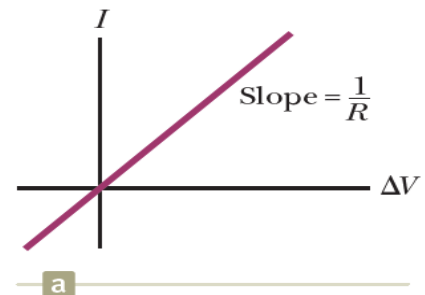
Carbon Composition Resistors: Made from a mixture of carbon and a binder. They are inexpensive but have high noise levels.

Metal Film Resistors: High precision and low noise are commonly used in circuits requiring accuracy.

Wire-Wound Resistors: Made by winding metal wire around an insulating core. They are used in high-power applications.

Thick and Thin Film Resistors: These are used in surface-mount devices (SMD) and offer better stability.

➢ **Values of resistors** in ohms are typically indicated by color coding.

The colored bands on this resistor are yellow, violet, black, and gold.
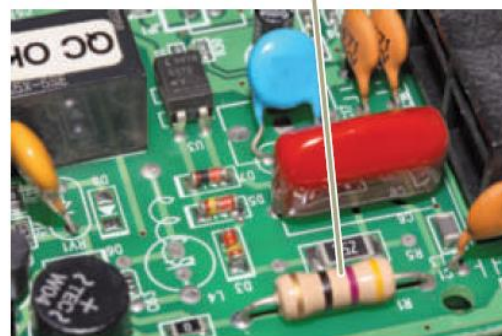
Example-1

Calculate the resistance of an aluminum cylinder that is 10.0 cm long and has a cross-sectional area of 2.0×10^{-4} m^2. Repeat the calculation for a cylinder of the same dimensions and made of glass having a resistivity of 3×10^{10} Ω. $\rho(Aluminum)=2.82 \times 10^{-8}$ (Ω.m)

Example-2

(a) Calculate the resistance per unit length of a 22-gauge Nichrome wire, which has a radius of 0.321 mm. $\rho(Nichrome)=1 \times 10^{-6}$ (Ω.m)
(b) If a potential difference of 10 V is maintained across a 1.0-m length of the Nichrome wire, what is the current in the wire?

Example-3

A 0.900 V potential difference is maintained across a 1.50 m length of tungsten wire with a cross-sectional area of 0.600 mm^2. What is the current in the wire? (resistivity of tungsten is 5.60×10^{-8} Ω . m).

Example-4

A conductor of uniform radius 1.20 cm carries a current of 3.00 A produced by an electric field of 120 V/m. What is the resistivity of the material?