

Electric current and Resistance

ELECTRIC CURRENT

Whenever there is a net flow of charge through some region, a **current** is said to exist.

Suppose that the charges are moving perpendicular to a surface of area A , The current is the rate at which charge flows through this surface.

If Q is the amount of charge that passes through this area in a time interval t , the average current I_{av} is equal to the charge that passes through A per unit time:

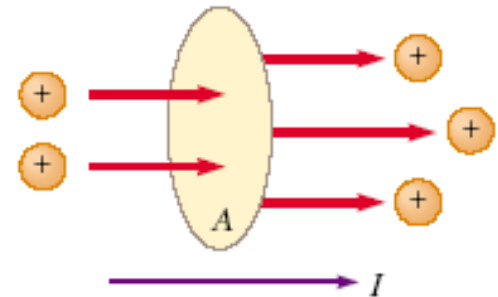
$$I_{av} = \frac{\Delta Q}{\Delta t}$$

If the rate at which charge flows varies in time, then the current varies in time; we define the **instantaneous current I** as the differential limit of average current:

$$I \equiv \frac{dQ}{dt}$$

The SI unit of current is the **ampere (A)**:

$$1 \text{ A} = \frac{1 \text{ C}}{1 \text{ s}}$$



The direction of the current

It is conventional to assign to **the current the same direction as the flow of positive charge**.

In electrical conductors, such as copper or aluminum, the current is due to the motion of negatively charged electrons. Therefore, when we speak of current in an ordinary conductor, **the direction of the current is opposite the direction of flow of electrons**.

However, if we are considering **a beam of positively** charged protons in an accelerator, the current is in the direction of motion of the protons.

In some cases—such as those involving **gases and electrolytes**, for instance—the current is the result of the flow of both positive and negative charges.

If the ends of the conducting wire are connected to a battery, all points on the loop are not at the same potential. The battery sets up a potential difference between the ends of the loop, creating an electric field within the wire. The electric field exerts forces on the conduction electrons in the wire, causing them to move around the loop and thus creating a current.

It is common to refer to a moving charge (positive or negative) as a mobile charge carrier. For example, **the mobile charge carriers in a metal are electrons**.

RESISTANCE AND OHM'S LAW

Ohm's law states that

for many materials (including most metals), the ratio of the current density to the electric field is a constant σ that is independent of the electric field producing the current.

Materials that obey Ohm's law and hence demonstrate this simple relationship between

E and J are said to be **ohmic**.

*Experimentally, it is found that not all materials have this property, however, and materials that do not obey Ohm's law are said to be **nonohmic**.*

Ohm's law is not a fundamental law of nature but rather an empirical relationship valid only for certain materials.

$$\Delta V = E\ell$$

$$J = \sigma E = \sigma \frac{\Delta V}{\ell}$$

$$\Delta V = \frac{\ell}{\sigma} J = \left(\frac{\ell}{\sigma A} \right) I$$

The quantity $\ell / \sigma A$ is called the **resistance** R of the conductor. We can define the resistance as the ratio of the potential difference across a conductor to the current through the conductor:

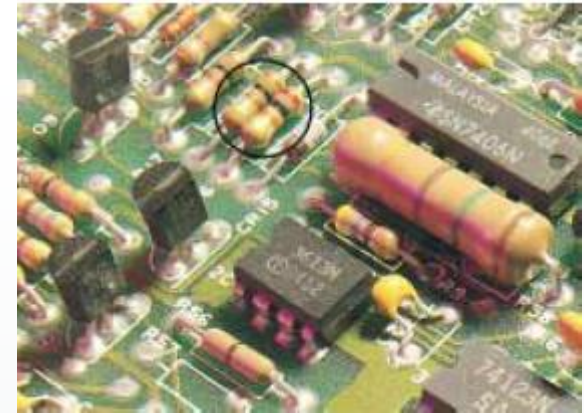
$$R \equiv \frac{\ell}{\sigma A} \equiv \frac{\Delta V}{I}$$

It determines how much current flows through it.
The inverse of conductivity is **resistivity**³ ρ :

$$\rho \equiv \frac{1}{\sigma}$$

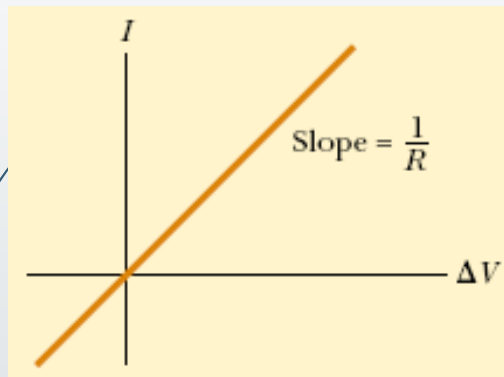
the resistance of a uniform block of material as

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

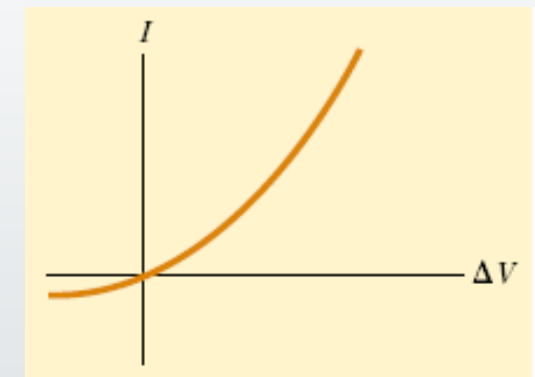


Most electric circuits use devices called **resistors** to control the current level

(a) Ohmic
(Conductors)



(b) Non ohmic
Semiconductors



(a) The current–potential difference curve for an ohmic material. The curve is linear, and the slope is equal to the inverse of the resistance of the conductor. (b) A nonlinear current–potential difference curve for a semiconducting diode. This device does not obey Ohm's law.

RESISTANCE AND TEMPERATURE

$$\rho = \rho_0[1 + \alpha(T - T_0)]$$

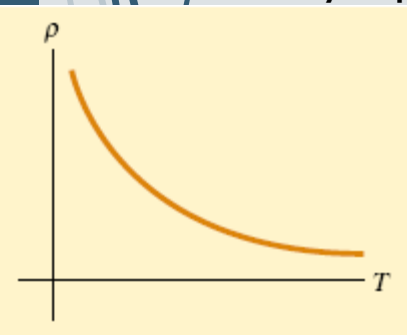
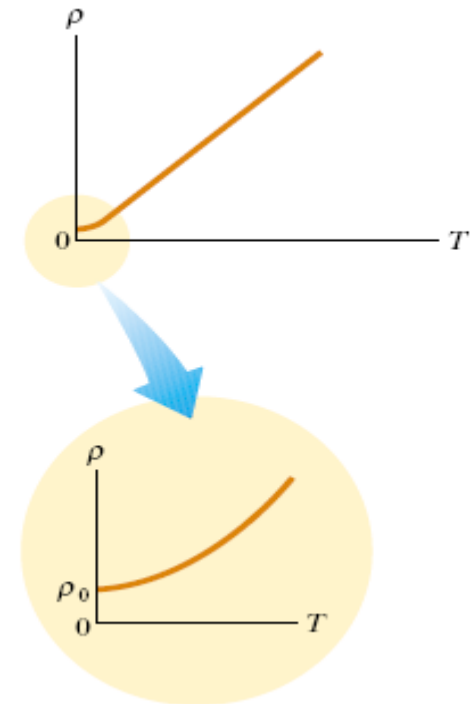
where ρ is the resistivity at some temperature T (in degrees Celsius), ρ_0 is the resistivity at some reference temperature T_0 (usually taken to be 20°C), and α is the **temperature coefficient of resistivity**.

$$\alpha = \frac{1}{\rho_0} \frac{\Delta\rho}{\Delta T}$$

Because resistance is proportional to resistivity we can write the variation of resistance as

$$R = R_0[1 + \alpha(T - T_0)]$$

Resistivity versus temperature for a metal such as copper. The curve is linear over a wide range of temperatures, and increases with increasing temperature. As T approaches absolute zero (inset), the resistivity approaches a finite value 0.



Resistivity versus temperature for a pure semiconductor, such as silicon or germanium.

Current and Resistance

Q.1: Suppose that the material composing a fuse melts once the current density rises to 440A/cm^2 . What diameter of cylinder wire should be used for the fuse to limit the current to 0.552A ?

Q.2: How long does it take electrons to get from a car battery to the starting motor? Assume that the current is 115A and the electrons travel through copper wire with cross-sectional area 31.2mm^2 and length 85.5cm . ($n = 8.49 \times 10^{28} \text{ m}^{-3}$)

Q.3: A fluid with resistivity $9.4 \Omega \text{ m}$ seeps into the space between the plates of a 110pF parallel plate air capacitor. When the space is completely filled, what is the resistance between the plates? ($\epsilon_0 = 8.85 \text{ pF/m}$)

Q.4: For a hypothetical electronic device, the potential difference V in volts, measured across the device, is related to the current " i " in mA by $V = 3.55i^2$. (a) find the resistance when current is 2.4mA. (b) At what value of the current is the resistance equal to $16\ \Omega$?

Q.5: A student's 9V, 7.5 W portable radio was left on from 9:00p.m until 3:00 am .How much charge passed through the wires?