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King Saud University
College of Science
Physics & Astronomy Dept.

Phys 145 (General Physics)

Chapter 6: Direct Currents

Week n° 8

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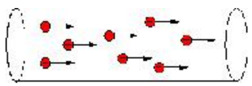
Chapter 6: Direct Currents

- **We will learn in this chapter 6:**

- Electric Current
- Resistance
- Series and Parallel Resistors; Kirchhoff's Rules
- Kirchhoff's Rules in Complex Circuits

Electric Current



- The current is the rate at which the charge moves in the wire.
- The **average current** that passes any point in a conductor during a time Δt is defined as:

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

where ΔQ is the amount of charge crosses the shaded area in a time Δt .

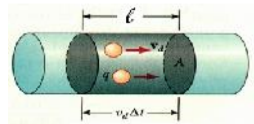
- ΔQ in Coulomb (C), Δt in seconds (s) and I in Ampere (A).

1A = 1C/s

(One Ampere of current is one Coulomb per second)

- The **instantaneous current** is: $I = \frac{dQ}{dt}$

Average Drift Velocity



- The current is the rate at which the charge moves in the wire.
- N is the total number of charge carriers in the volume (V) of the conductor.
- n is the number of mobile charge carriers per unit volume.
- We have: $n = \frac{N}{V}$
- In a time Δt, the electron moves the length ℓ with the constant velocity v_d

$$\ell = v_d \Delta t$$

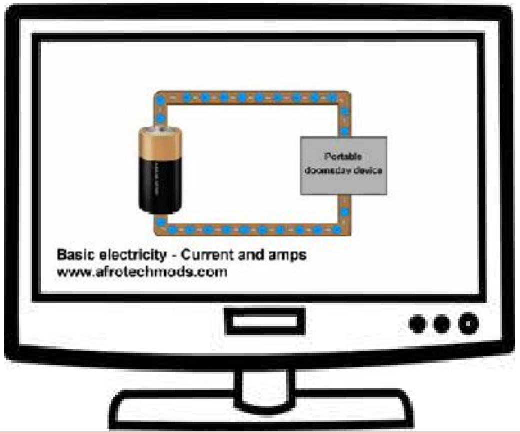
- The **charges** that passes any point in the conductor during a time Δt is:

$$\Delta Q = Ne = neV = neA\ell = neAv_d\Delta t$$

where e is the charge of an electron (e = 1.6 x 10 $^{-19}$ C).

- So: $$\bar{I} = \frac{\Delta Q}{\Delta t} = neAv_d$$

Video 01 of week 08: Basic electricity



Resistance

- Charges flow only if there is a potential difference. Something that provides a potential difference is known as a voltage source.
- The electrical resistance R of a conductor is the potential difference V between its ends divided by the current I:

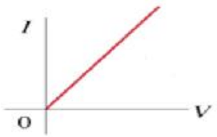
$$R = \frac{V}{I}$$

- V is in volt (V), I in Ampere (A) and R in Ohm (Ω).

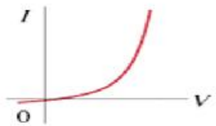
$$1\,\Omega = \frac{1\text{ V}}{1\text{ A}}.$$

- Materials with a constant resistance are said to obey **Ohm's law** and called ohmic conductors.
- Materials that do not follow Ohm's Law are called "nonohmic" materials.

Resistance



Ohmic conductor



Nonohmic conductor

Resistance

- The resistance of a conductor depends on its size, shape and composition.
- Resistance of a metal wire (R) is directly proportional to its length, (ℓ) and inversely proportional to its cross-sectional area, (A):

$$R = \rho \frac{\ell}{A}$$

- The proportionality constant ρ (rho) depends only on the properties of the material and is called the resistivity. In the S.I., ρ is in Ω.m.
- The conductivity σ (sigma) is the inverse of the resistivity ρ :

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

It is sometimes used instead of the resistivity to characterize conductors.

In the S.I., σ is in $\Omega^{-1}.m^{-1}$.

Resistivities in Ω.m at 20°C

	substance	Resistivity ρ (Ω.m)
conductors	Silver	1.47×10^{-8}
	Cooper	1.72×10^{-8}
	Aluminum	2.63×10^{-8}
semiconductors	Germanium	0.60
	Silicon	2300
Insulators	Glass	$10^{10} - 10^{14}$
	Sulfur	10^{15}
Ionic conductors	Body fluids	approx. 0.15

- **Good conductors have low resistivities.**
- **Good insulators have high resistivities.**

Series and Parallel Resistors

- Resistors in series:

$$R_{series} = R_1 + R_2 + R_3 + ----$$

- Resistors in parallel:

$$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ----$$

Video 02 of week 08: Ohm's law

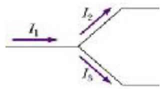
Kirchhoff's Rules

- **Junction Rule:** $\sum I = 0$

  The sum of the currents entering any point must equal the sum of the currents leaving that junction.

$$\sum I_{in} = \sum I_{out}$$

Example: $I_1 = I_2 + I_3$



- **Loop Rule:** $\sum V = 0$

  The sum of the potential changes around any closed circuit loop must be zero.

Kirchhoff's Rules

The voltage across a battery is taken to be positive (a voltage rise) if traversed from – to + and negative if traversed in the opposite direction.

Kirchhoff's Rules

- The voltage across a resistor is taken to be negative (a drop) if the loop is traversed in the direction of the assigned current and positive if traversed in the opposite direction.

$V_{ab} = V_b - V_a = RI$

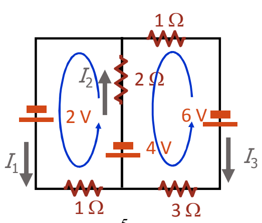
$V_{ab} = V_b - V_a = -RI$

Kirchhoff's Rules in Complex Circuits

- For any loop, we chose a direction, (in blue in the figure).
- We put + the potential (V) if we enter by the positive pole and – the potential (-V) if we enter by the negative pole.
- We put + RI if we are in the same direction than the current and – RI in the opposite case.
- In the left loop:

  $-2 + I_1 + 4 + 2I_2 = 0$
- In the right loop:

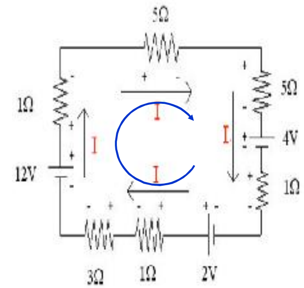
  $-I_3 - 2I_2 - 4 - 3I_3 + 6 = 0$
- The junction rule gives: $I_1 + I_3 = I_2$
- Solving the 3 equations, we obtain:



$I_1 = -\frac{8}{7}A \approx -1.14A;\ I_2 = -\frac{3}{7}A \approx -0.43A;\ I_3 = \frac{5}{7}A \approx 0.71A$

- The negative sign means that the current is the opposite to the direction.

Kirchhoff's Rules in Complex Circuits



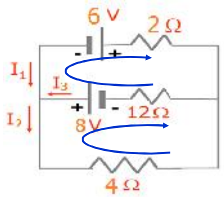
$$5I + 5I + 4 + I - 2 + I + 3I - 12 + I = 0$$

$$16I - 10 = 0$$

$$I = \frac{10}{16} = \frac{5}{8} \approx 0.625A$$

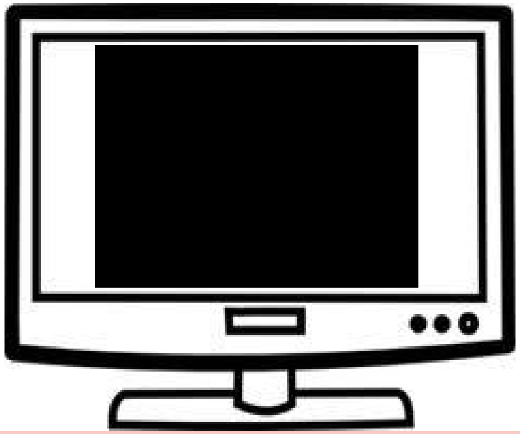
Kirchhoff's Rules in Complex Circuits

$$-6 - 2I_1 + 12I_3 - 8 = 0$$
$$+8 - 12I_3 - 4I_2 = 0$$
$$I_1 + I_3 = I_2$$



$$I_1 = -\frac{8}{5}A \approx -1.6\,A;\; I_2 = -\frac{7}{10}A \approx -0.7\,A;\; I_3 = \frac{9}{10}A \approx 0.9\,A$$

Video 03 of week 08: Kirchhoff's rules



Summary of week 08

Average current $\bar{I} = \frac{\Delta Q}{\Delta t}$ Instantaneous current $I = \frac{dQ}{dt}$

Magnitude of the current $I_{av} = nev_d A$

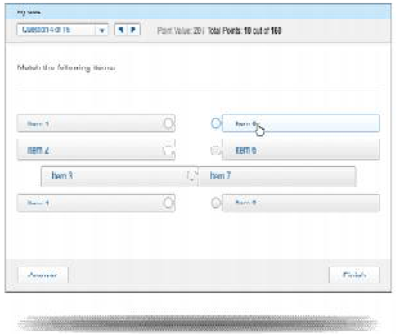
Resistance of a conductor $R = \frac{V}{I}$

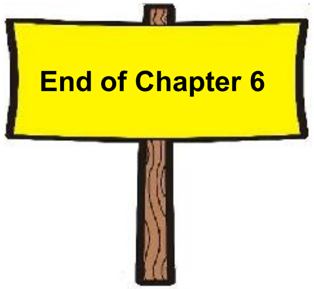
Resistance is determined by the geometry and by the resistivity of the material $R = \rho \frac{L}{A}$

$$R_{series} = R_1 + R_2 + R_3 + ----\quad \frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ----$$

Kirchhoff's Rules
- Junction Rule $\sum I_{in} = \sum I_{out}$
- Loop Rule $\sum V_i = 0$

Quiz for week 08




End of Chapter 6