Introduction

This is a learning as well as an exam preparation video.

At the end of the video are practice assignments for you to attempt.

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Chapter 3: Current Electricity

Chapter 3: Current Electricity

Introduction

We considered all charges whether free or bound to be at rest in previous two chapters. Charges in motion constitute an electric current. Lightening is one of the natural phenomena in which charges flow from clouds to earth through the atmosphere.

In this chapter we will study some basic laws concerning steady electric current and their

applications.

Chapter 3: Current Electricity

Electric Current:

The rate of flow of electric charge through any cross-section of a conductor is known as electric current. If ΔQ amount of charge flows through any cross-section of conductor in the interval t to (t + Δt), then it is defined as

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

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Electric Current:

Direction of current is taken as direction of motion of positively charged particles and opposite to the direction of negatively charged particles. SI unit of current is ampere (A). It is a scalar quantity.

$$\vec{j} = \frac{\Delta i}{\Delta A}$$

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Electric Current:

Direction of current is taken as direction of motion of positively charged particles and opposite to the direction of negatively charged particles. SI unit of current is ampere (A). It is a scalar quantity.

The SI unit of current density is A/m2

$$\vec{j} = \frac{\Delta i}{\Delta A}$$

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Drift Speed:

Drift Velocity is defined as the average velocity with which the free electrons move towards the positive end of a conductor under the influence of an external electric field applied. It is denoted by vd.

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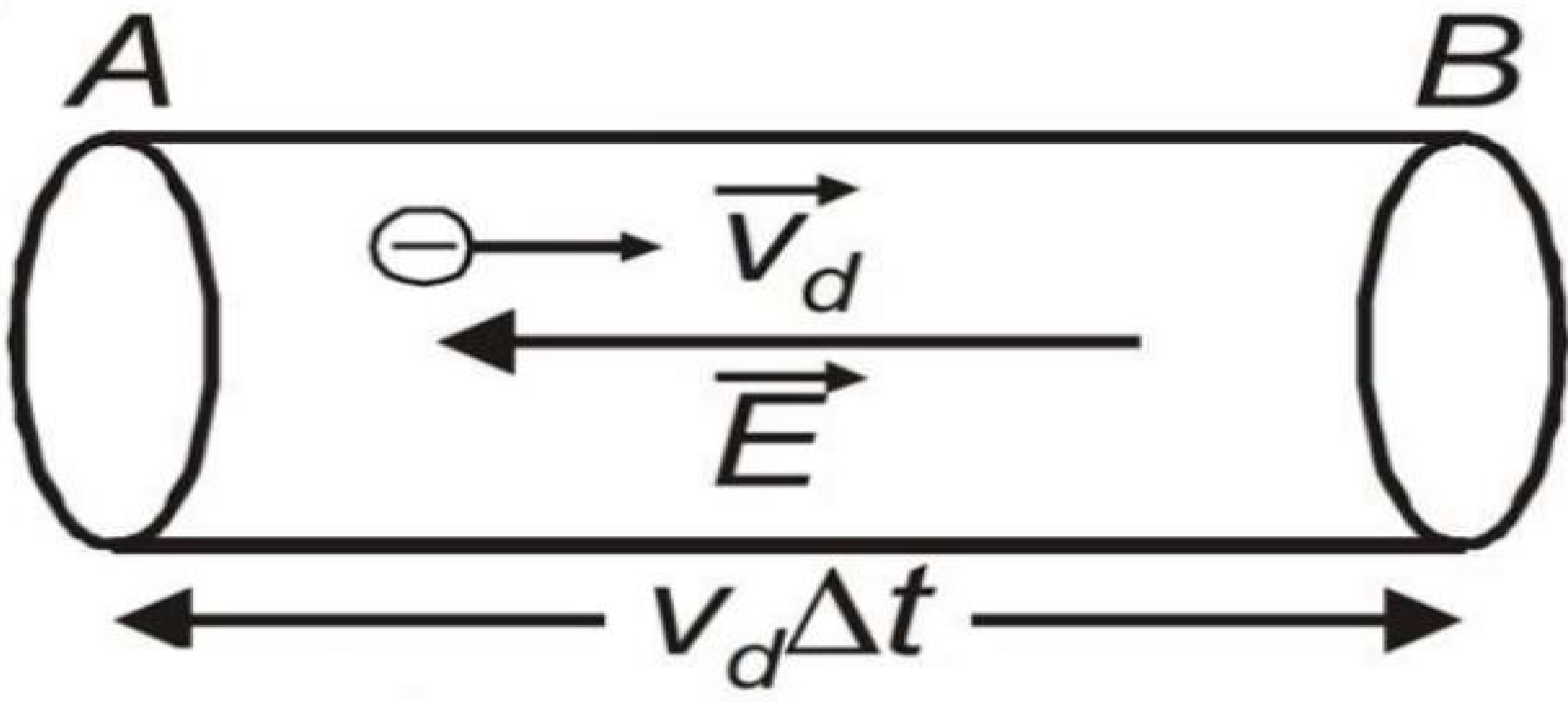
Drift Speed:



$$v_d = \frac{eE}{m}$$

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Relation between Current Density and Drift Speed:

Let, cross sectional area of any conductor be A, number of electrons per unit area be n, drift

velocity be vd, then number of total moving electrons in t second will be.

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Relation between Current Density and Drift Speed:

$$N = (nAv_d t)$$

So, moving charge in t second $Q = (nAv_d t).e$

Hence, electric current in t second $= \frac{Q}{t}$

$$i = \frac{nAv_d te}{t}$$

$$i = neAv_d$$

We know $J = \frac{i}{A}$

Putting $i = neAv_d$ in above equation

$$\vec{J} = nev_d$$

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Ohm’s Law:

According to this law, "At constant temperature, the potential difference V across the ends of a given metallic wire (conductor) in an circuit (electric) is directly proportional to the current flowing through it". i.e.,

$$V \propto i$$

$$V = i.R$$

where, R = resistance of conductor

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Ohm's Law:

Mobility:

Mobility is defined as the magnitude of the drift velocity per unit electric field. It is denoted by μ,

$$\mu = \frac{v_d}{E}$$

Its SI unit is $m^2V^{-1}s^{-1}$.

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Ohm's Law:

Resistance:

Resistance is the ratio of potential difference applied across the ends of conductor to the current flowing through it.

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

The SI unit of R is ohm (Ω).

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Ohm's Law:

Resistivity:

Resistivity is defined as the ratio of electric field applied at conductor to current density of conductor. It is denoted by ρ

$$\rho = \frac{E}{J} \quad \ldots (1)$$

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Ohm’s Law:

If the length of conductor be 'l', cross sectional area be 'A', potential difference at the end of

conductor be 'V' and electric current be 'i', then $\vec{E}$ and $\vec{j}$ given by.

$$\vec{E} = \frac{V}{l} \ldots (2)$$

$$\vec{j} = \frac{i}{A} \ldots (3)$$

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Ohm's Law:

Putting the value of E and J, from equation (2) and (3) into (1), we get.

The constant of proportionality ρ depends on the material of the conductor but not on its dimensions. ρ is known as resistivity or specific resistance.

$$\rho = \frac{\frac{V}{l}}{\frac{i}{A}}$$

$$\rho = \frac{V}{i} \cdot \frac{A}{l}$$

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

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Conductivity:

Conductivity is defined as the reciprocal of resistivity of a conductor. It is expressed as,

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

SI unit is mho per meter ($\Omega^{-1}\ m^{-1}$).

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Conductivity:

Superconductivity:

The resistivity of certain metal or alloy drops to zero when they are cooled below a certain temperature is called superconductivity.

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Electrical Energy:

When electric current is moved in any electric circuit, then energy of work done by taking a charge from one point to another point is called electric energy.

If a charge q at potential difference V is moved from one point to another point, then doing work

will be.

$$W = V.q \quad ..... (1)$$

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Electrical Energy:

Putting $q = i.t$ in equation (1), we get

$$W = Vit$$

Putting $V = i.R$ in equation (1), we get

$$W = i^2Rt$$

Putting $i = V/R$ in equation (1), we get

$$W = \frac{V^2}{R}t$$

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Electrical Energy:

Power: Electric power is the rate of doing work by electric charge. It is measured in watt and represented by P.

$$P = \frac{W}{t} [\because 1HP = 746 \text{ watt}]$$

Hence, $P = Vi = i2R = \frac{V^2}{R}$

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Resistor Color Codes:

Colour	Number	Multiplier	Tolerance (%)
Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
No colour			20

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Resistor Color Codes:

A carbon resistor has a set of coaxial colored rings in them, whose significance are listed in above table. First two bands formed: First two significant figures of the resistance in ohm. Third band; Decimal multiplier as shown in table. Last band; Tolerance or possible variation in percentage as

per the indicated value. For Gold ± 5%, for silver ± 10% and No color ± 20%.

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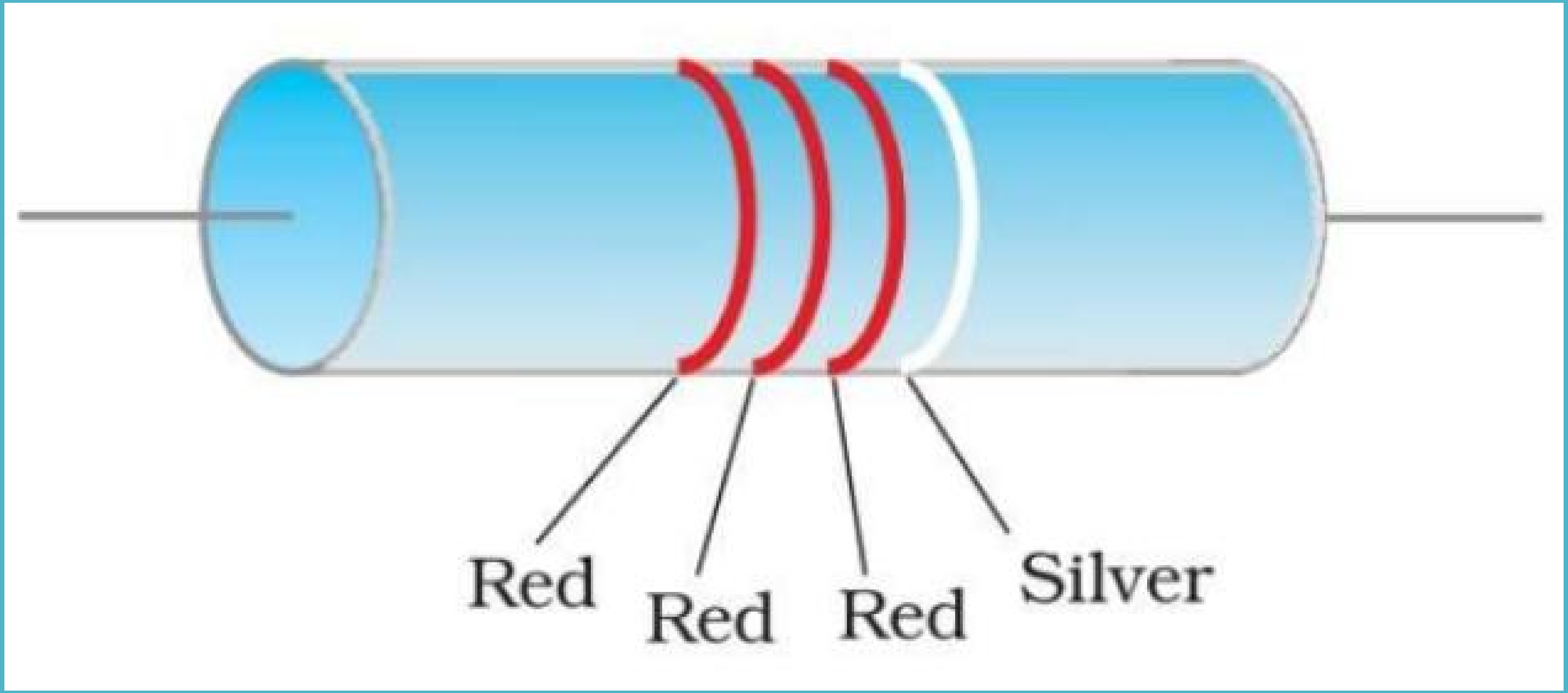
Resistor Color Codes:



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Combination of Resistors:

There are two types of resistance combinations.

1. Series Combination
2. Parallel Combination

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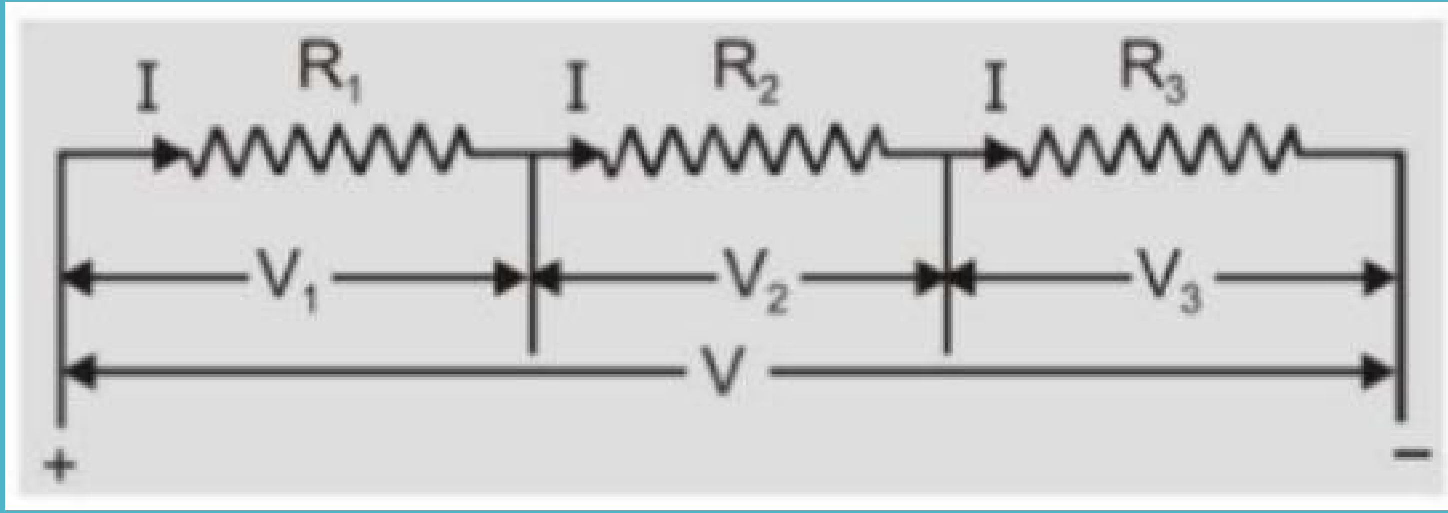
Combination of Resistors: Series Combination



In Series Combination, different resistances are connected end to end. Equivalent resistance can be obtained as the formula,

$$R = R1 + R2 + R3$$

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Combination of Resistors: Series Combination

NOTE: The total resistance in the series combination is more than the greatest resistance in the circuit.

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Combination of Resistors: Series Combination

NOTE: The total resistance in the series combination is more than the greatest resistance in the circuit.

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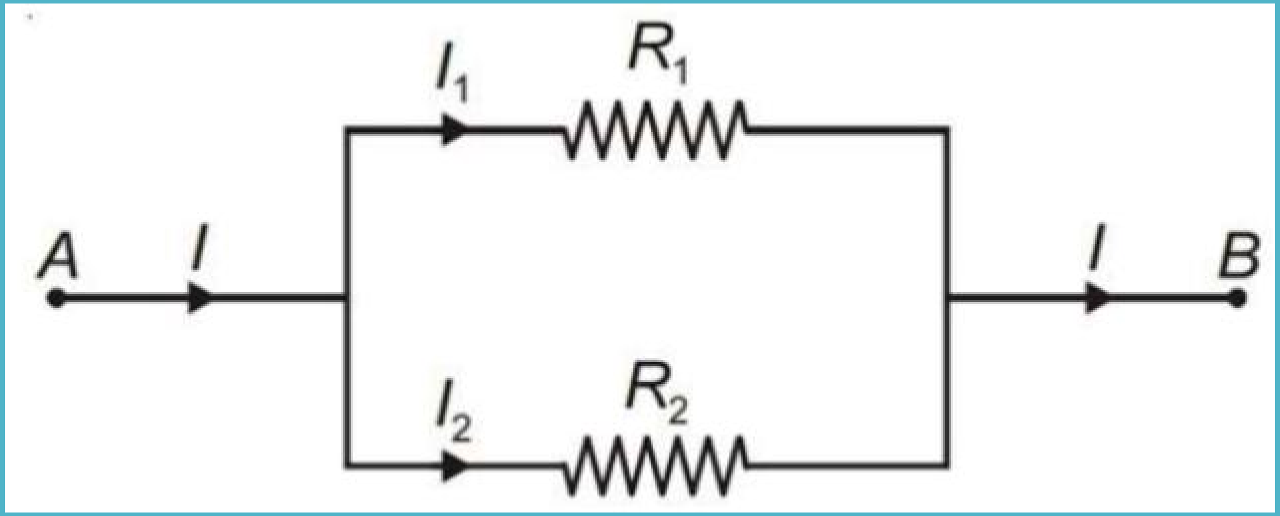
Combination of Resistors: Parallel Combination



In Parallel combination, first end of all the resistances are connected to one point and last end of all the resistances are connected to other point. Equivalent resistance can be obtained by the formula.

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Combination of Resistors: Parallel Combination

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

NOTE: The total resistance in parallel combination is less than the least resistance of the circuit.

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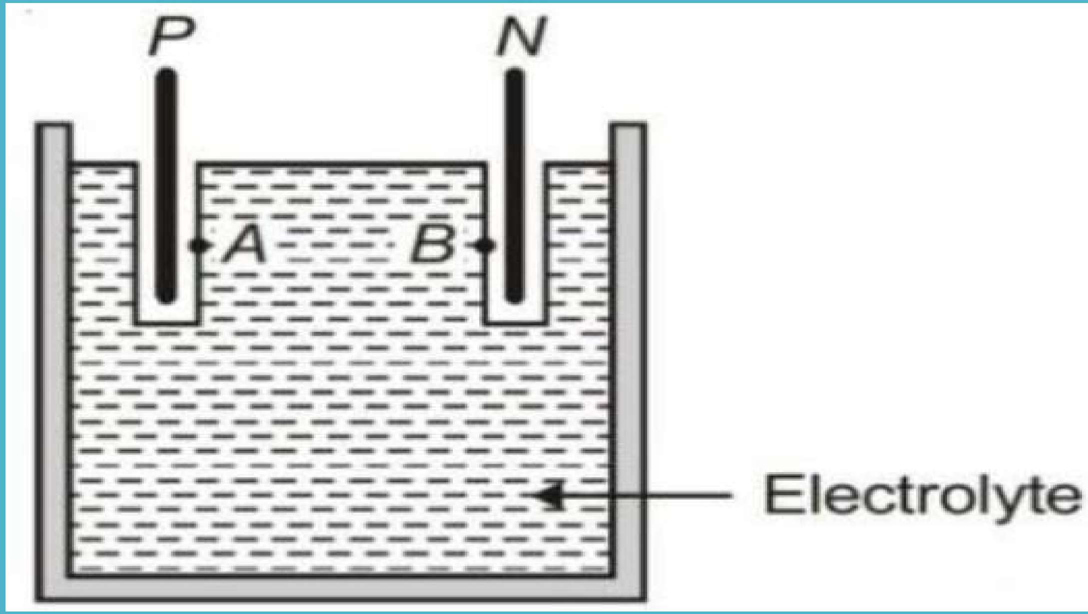
Cells, EMF, Internal Resistance:

Cells: An electrolytic cell consisting of two electrodes, called positive (P) and negative (N) immersed in an electrolytic solution as shown in figure.



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Cells, EMF, Internal Resistance:

Electrodes exchange charges with the electrolyte. Positive electrode P has a potential difference V+ between itself and electrolyte solution A immediately adjacent to it. Negative electrode N has a potential difference (V–) relative to electrolyte B adjacent to it.

$$\varepsilon = V_+ - V_-$$

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Cells, EMF, Internal Resistance:

EMF: It is the difference of chemical potentials of electrodes used. It is also defined as the difference of potential across the electrodes of cell, when the electrodes are in open loop.

$$\varepsilon = V_+ - V_-$$

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Cells, EMF, Internal Resistance:

Internal Resistance: It is the opposition offered by the electrolyte of the cell to the flow of current

through itself. It is represented by r and given by.

$$r = \frac{V}{i}$$

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Kirchhoff's Laws:

Kirchhoff's two rules are used for analyzing electric circuits consisting of a number of resistors and cells interconnected in a complicated way.

Kirchhoff's first rule: Junction rule

At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction.

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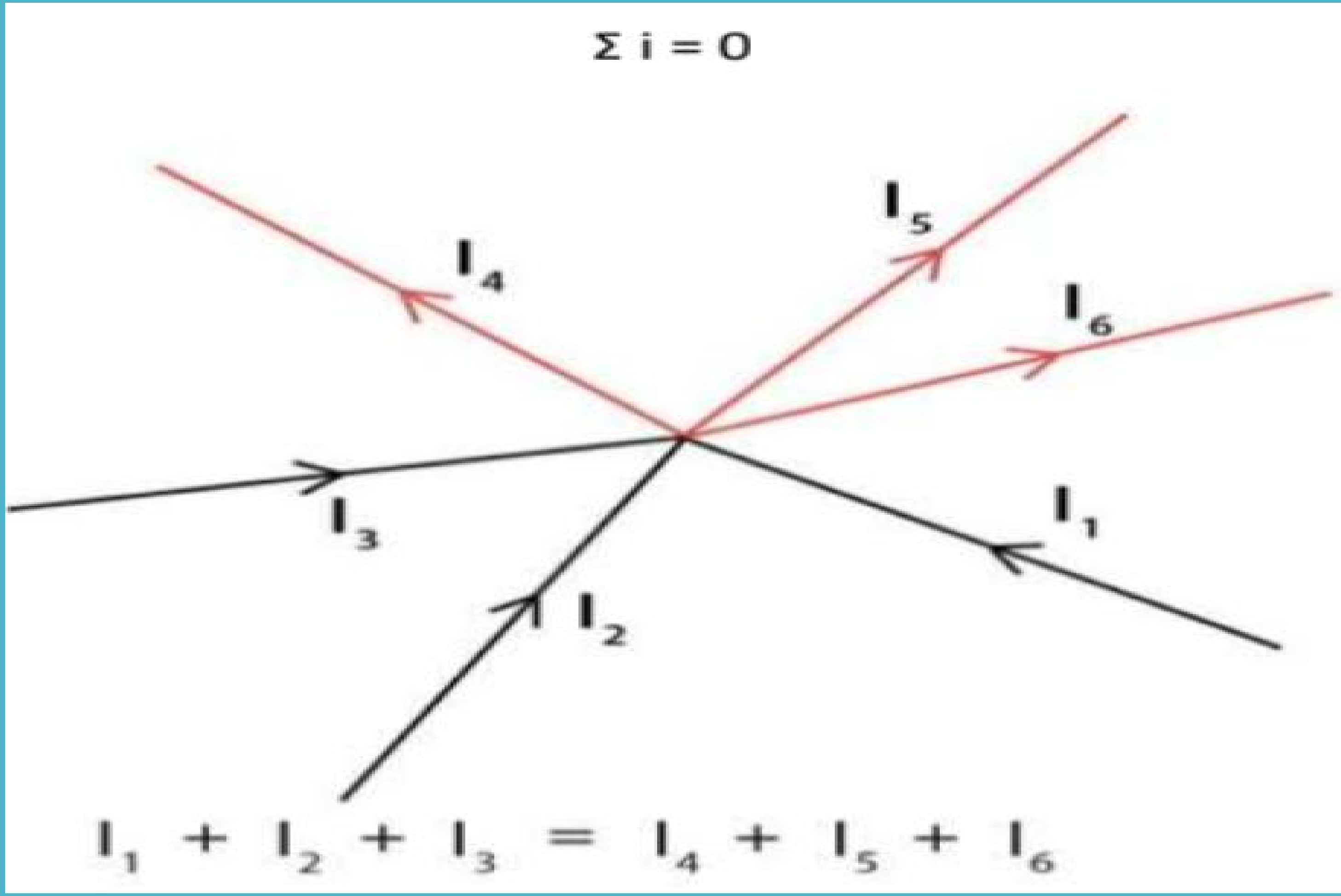
Kirchhoff's Laws:



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Kirchhoff's Laws:

Kirchhoff's second rule: Loop rule

The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero.

$$\Sigma\, iR = \Sigma E$$

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Wheatstone Bridge:

It is an application of Kirchhoff's rules. The bridge is consisting of four resistances R1, R2, R3 and R4 as four sides of a square ABCD as shown in figure.

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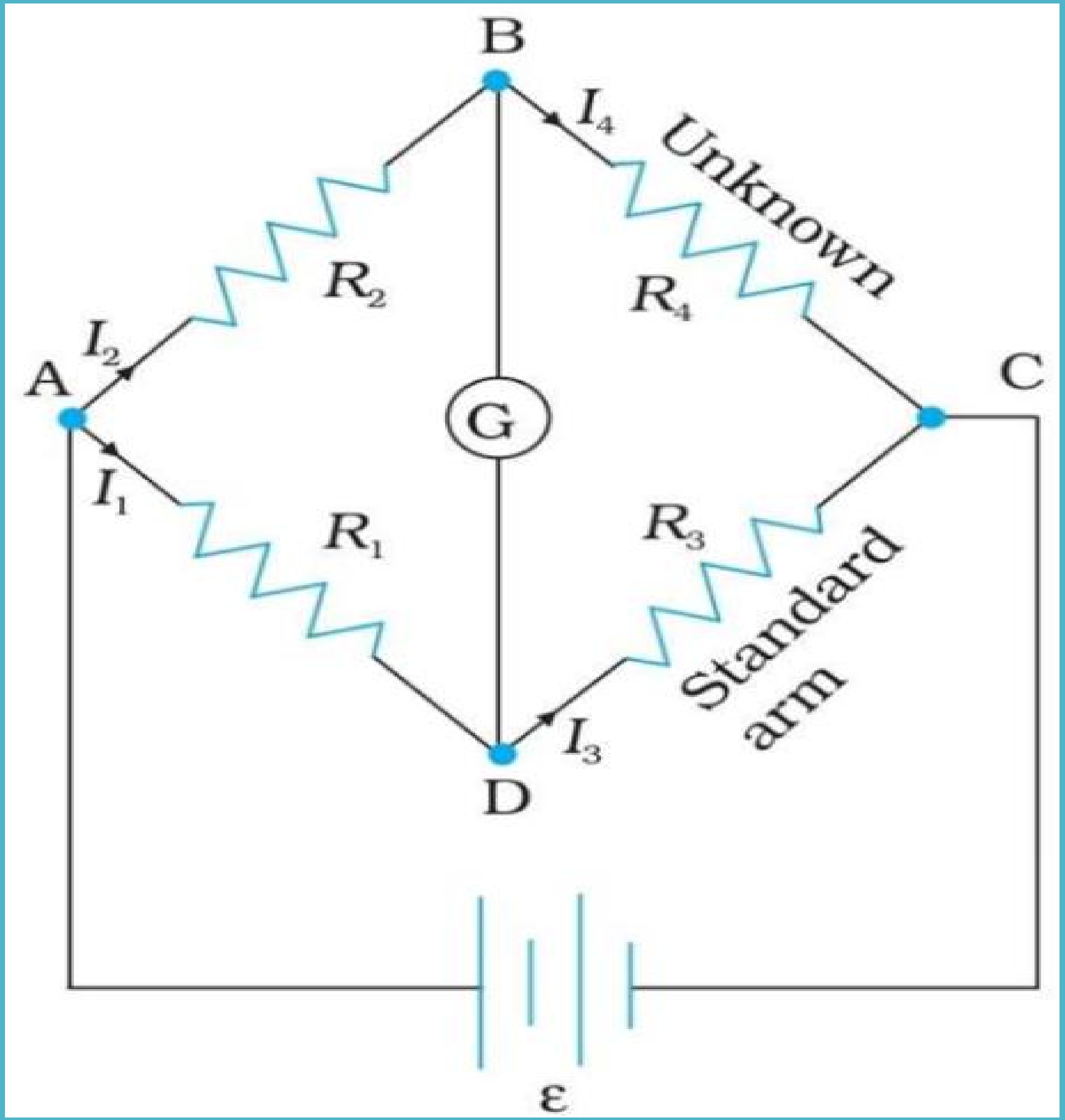
Wheatstone Bridge:



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Wheatstone Bridge:

Across the diagonally opposite points between A and C, battery E is connected. This is called battery arm. To remaining two diagonally opposite points B and D, a galvanometer G is connected to detect current. This line is known as galvanometer arm.

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Wheatstone Bridge:

Currents through all resistances and galvanometer are as shown in figure. In balanced

Wheatstone bridge we consider the special case $I_g = 0$. Applying junction rule to junction B and D, we have

$$I_2 = I_4 \text{ and } I_1 = I_3$$

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Wheatstone Bridge:

Applying loop rule to loop ABDA

$$I_2R_2 + 0 - I_1R_1 = 0$$

$$\frac{I_1}{I_2} = \frac{R_2}{R_1} \ldots\ldots (i)$$

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Wheatstone Bridge:

Applying loop rule to loop BCDB

$$I_4R_4 - I_3R_3 + 0 = 0$$

$$I_2R_4 - I_1R_3 = 0 \text{ (Using } I_4 = I_2 \text{ and } I_3 = I_1)$$

$$\frac{I_1}{I_2} = \frac{R_4}{R_3} \ldots\ldots \text{(ii)}$$

The equation (iii) relating the four resistor is called the balance condition for the galvanometer to give zero or null deflection.

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Potentiometer:

It is a versatile instrument consisting of a long piece of uniform wire AC across which a standard cell B is connected.

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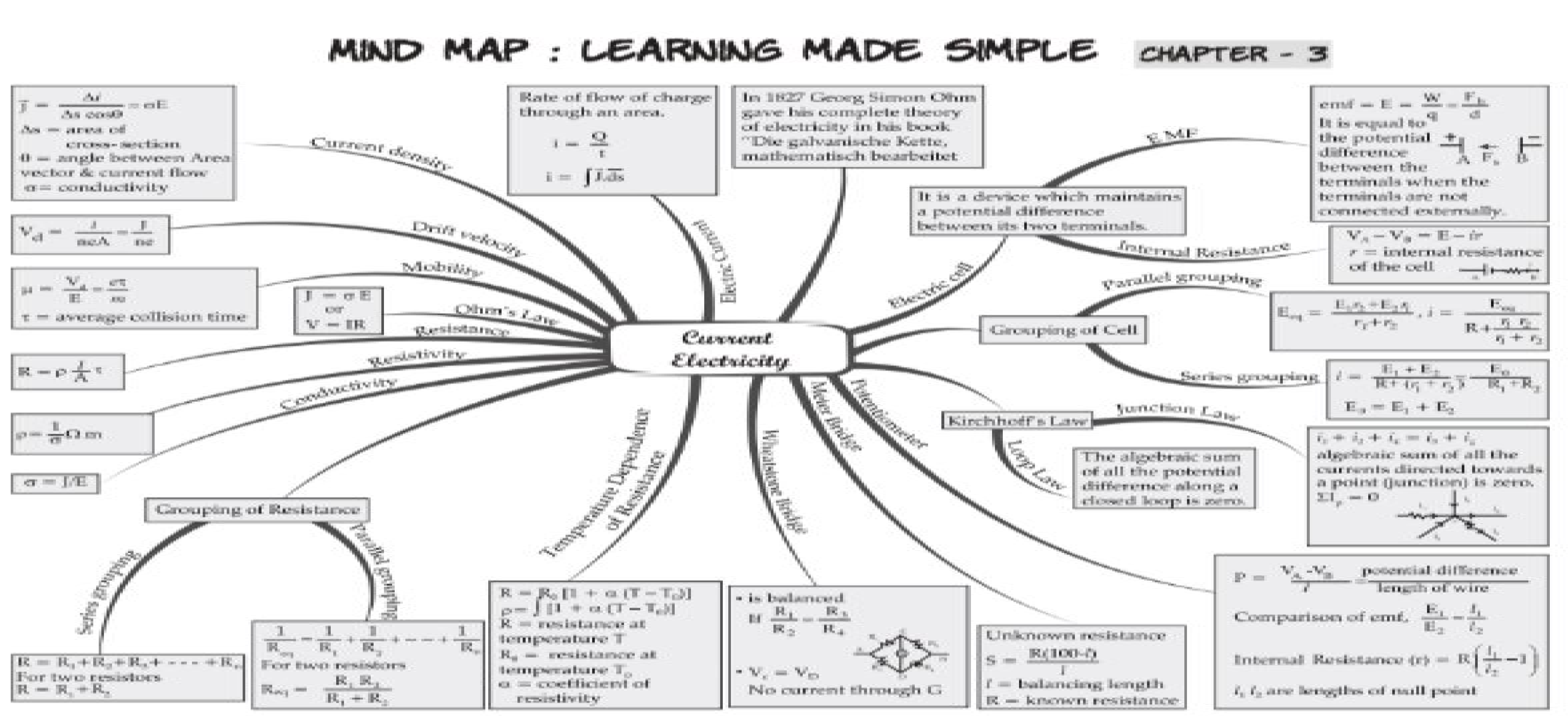

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