NDA-CDS 1 2025

GS LIVE

PHYSICS

ELECTRICITY

CLASS 2

ELECTRICITY - II

(Current Electricity)

(charges are in motion)

SSBCrack EXAMS

WHAT WILL WE STUDY ?

- Electric Current
- Ohm's Law
- Resistance and Resistivity
- Combination of Resistors
- Kirchoff's Laws
- Cells and Internal Resistance
- Combination of Cells
- Electrical Energy and Power ✓
- Heating Effect of Electric Current ✓
- Domestic Electric Circuit

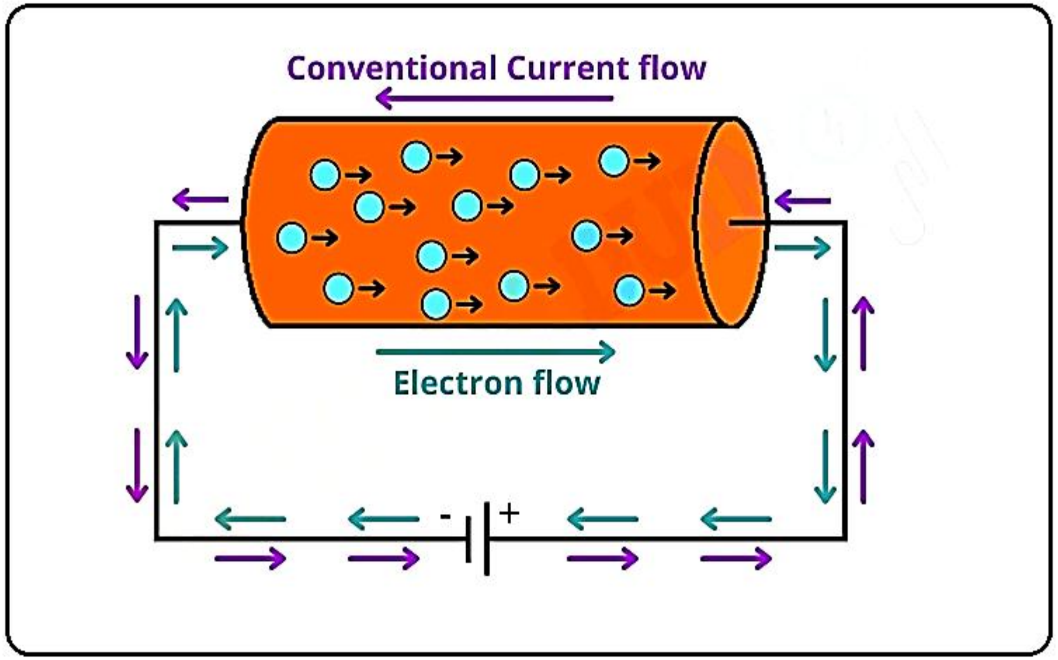
ELECTRIC CURRENT

$$I = \frac{\text{Charge} \rightarrow (C)}{\text{Time} \rightarrow (s)}$$

Unit → Coulomb sec^{-1}

or Amperes (A)

- The conventional direction of electric current is opposite to the direction of motion of electrons.

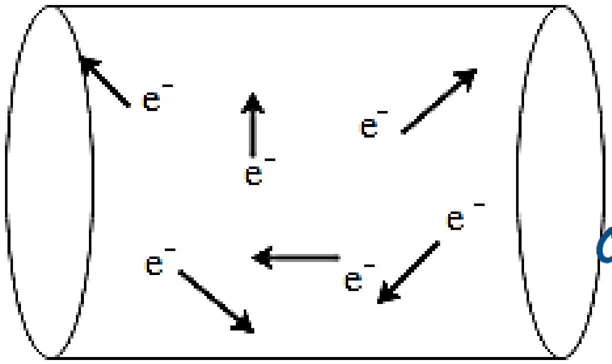


DRIFT VELOCITY

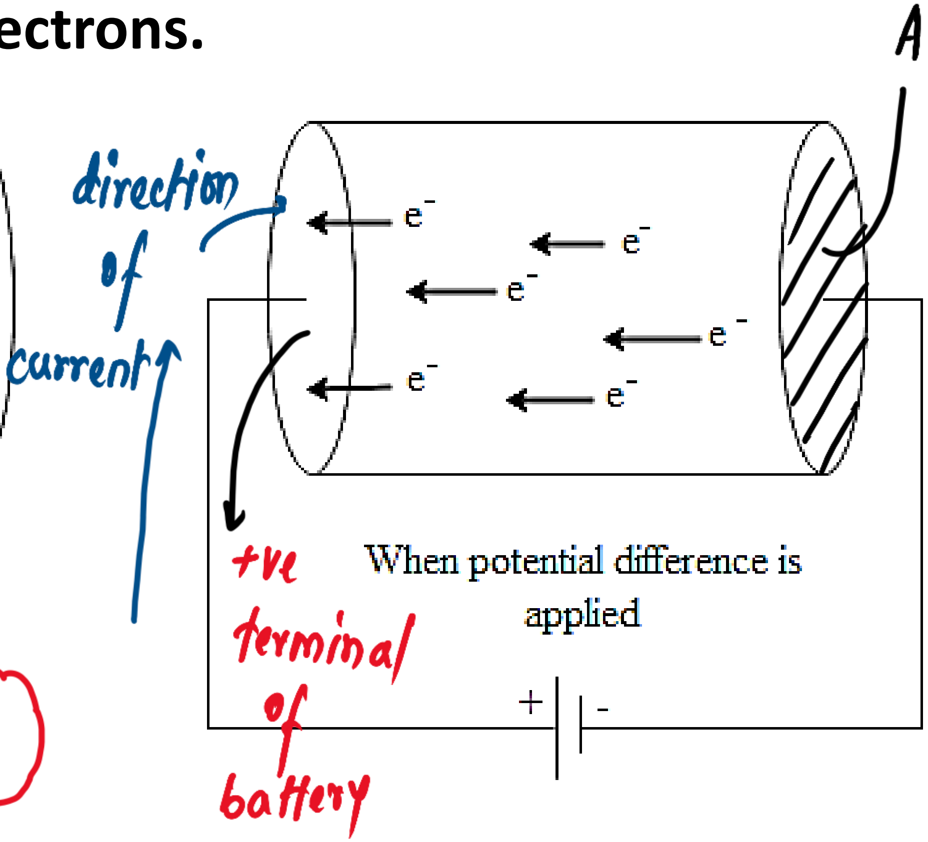
When a potential difference is applied across the ends of a conductor, the free electrons in it move with an average velocity opposite to the direction of electric field, which is called drift velocity of free electrons.

$$v_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$$

$V = E \cdot l$ (E → Electric field, l → length)



When no potential difference is applied



When potential difference is applied

$I = neAv_d$ (n → number of electrons per unit volume)

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

$e \longrightarrow$ charge on an electron

$E \longrightarrow$ Electric field

$\tau \longrightarrow$ average relaxation time $\longrightarrow$ $\tau \propto \frac{1}{\text{Temperature}}$

$m \longrightarrow$ mass of an electron

$$v_d = e\left(\frac{V}{l}\right) \times \frac{\tau}{m} = \frac{eV\tau}{ml}$$

l - length of conductor

OHM's LAW

- **If physical conditions of a conductor such as temperature remains unchanged, then the electric current (I) flowing through the conductor is directly proportional to the potential difference (V) applied across its ends.**

$$I \propto V \quad \text{or} \quad V = IR$$

Unit = ohms (Ω)

where, R is the electrical resistance of the conductor and $R = \dfrac{ml}{Ane^2\tau}$

$R \propto l$ — length of conductor

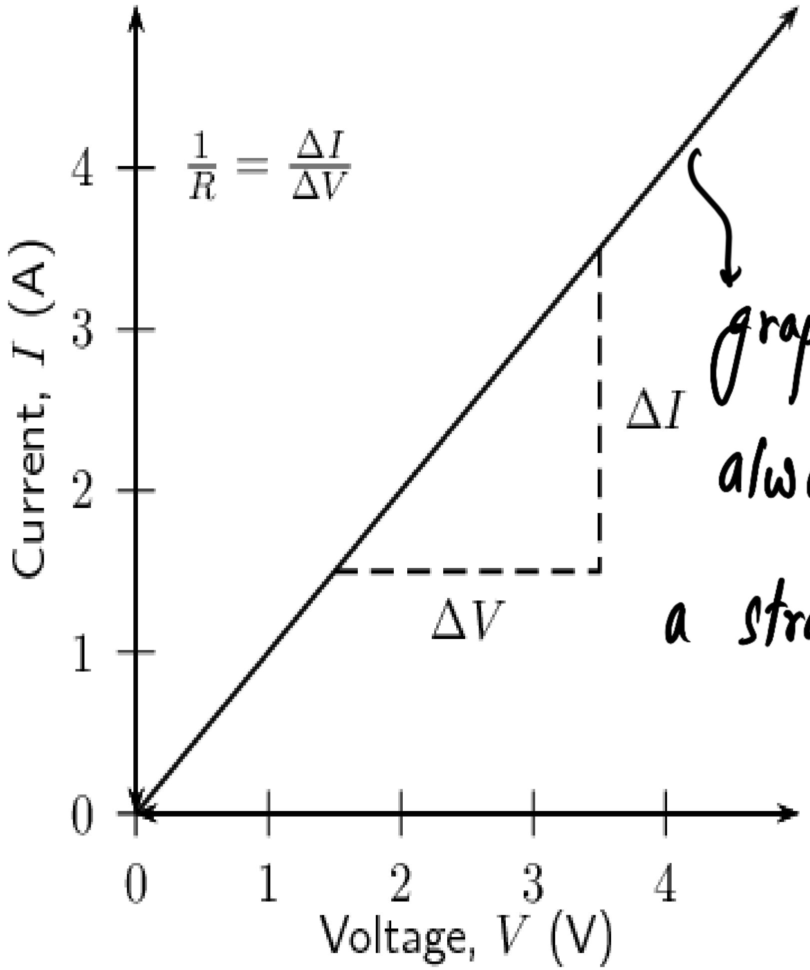
$R \propto \dfrac{1}{A}$ — Area of cross section

$R \propto \dfrac{1}{\tau}$ ($\tau \propto \dfrac{1}{\text{Temp.}}$)

⇓

$R \propto$ Temperature

OHM's LAW



graph is always a straight line,

$V = IR$

$\frac{I}{V} = \frac{1}{R}$

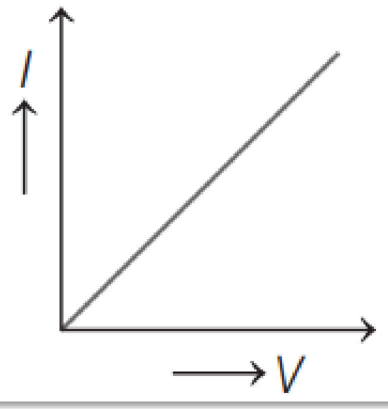
→ If the graph is V v/s I,

slope = R

OHMIC CONDUCTORS

Those conductors which obey Ohm's law, are called ohmic conductors, *e.g.* all metallic conductors are ohmic conductor.

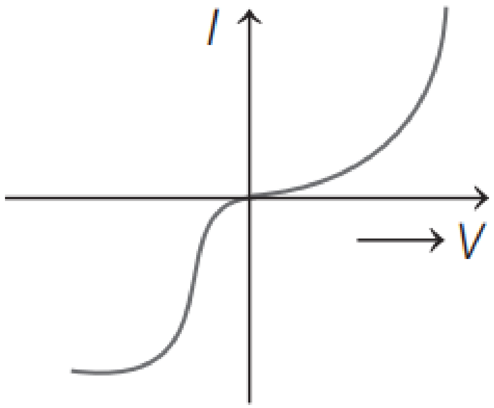
For ohmic conductors *V-I* graph is a straight line.



NON-OHMIC CONDUCTORS

Those conductors which do not obey Ohm's law, are called non-ohmic conductors, *e.g.* diode valve, triode valve, transistor , vacuum tubes etc.

For non-ohmic conductors *V*-*I* graph is not a straight line.



SSBCrack EXAMS

RESISTANCE

- **The obstruction offered by any conductor in the path of flow of current is called its electrical resistance.**

Electrical resistance of a conductor, $R = \frac{\rho l}{A}$

where, l = length of the conductor, A = cross-section area and ρ = resistivity of the material of the conductor.

Unit = ohms (Ω)

$R = \frac{ml}{Ane^2\tau}$

constant for a conductor

$\rho = \frac{m}{ne^2\tau}$

RESISTIVITY (specific Resistance)

Resistivity of a material of a conductor is given by

$$\rho = \frac{m}{ne^2\tau}$$

Resistivity is low for metals, more for semiconductors and very high for alloys like nichrome, constantan etc.

manganin

$\rho \propto \frac{1}{\tau}$ $\left(\tau \propto \frac{1}{Temp.}\right)$ $\Rightarrow$ $\rho \propto$ Temperature

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

$\rho \rightarrow$ nature of material

Unit $\rightarrow \frac{\Omega\ m^2}{m}$ $= \Omega\ m$ (ohm - m)

$\rho = \frac{RA}{l}$

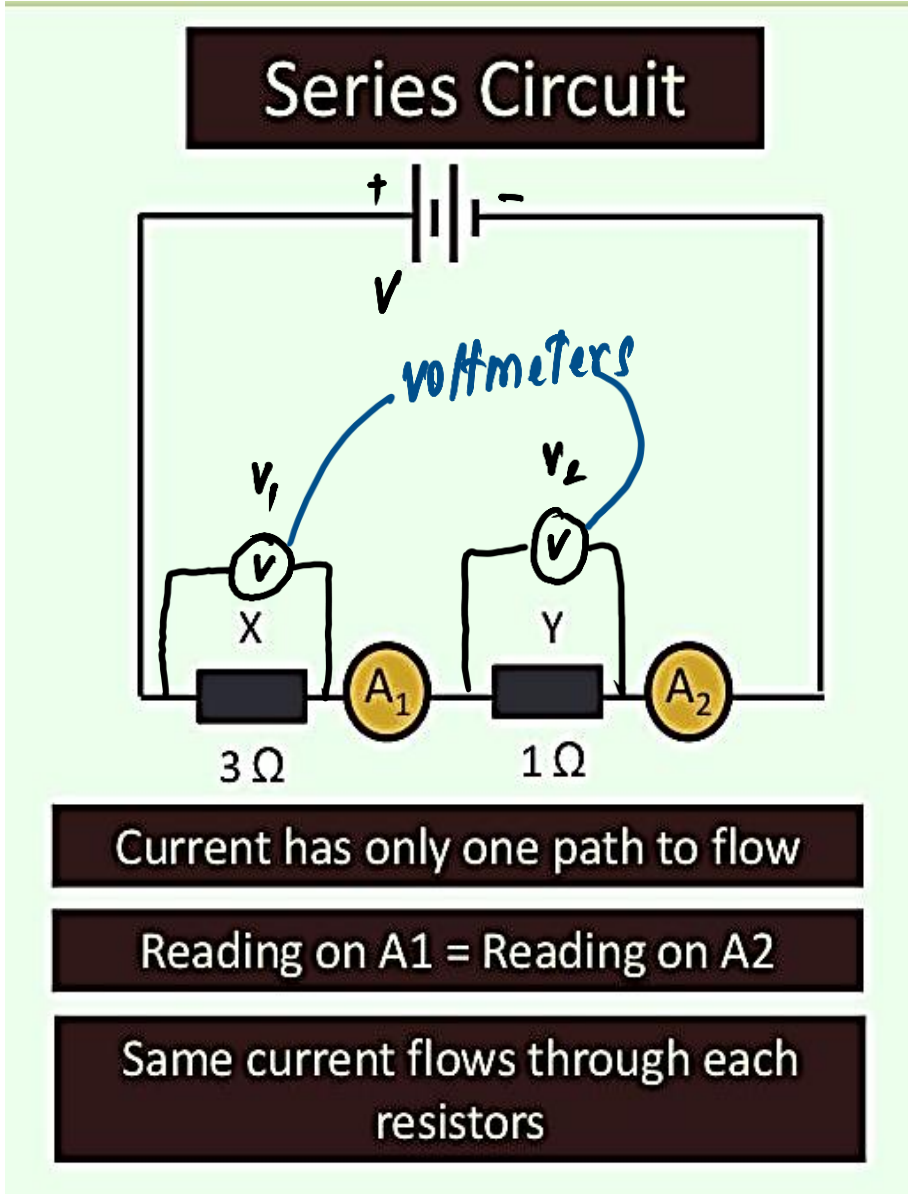
Conductance, $G = \frac{1}{\text{Resistance}}$

Conductivity, K (kappa) $= \frac{1}{\text{Resistivity}}$

RESISTIVITY

SSBCrack EXAMS

COMBINATION OF RESISTORS



X and Y are resistors,

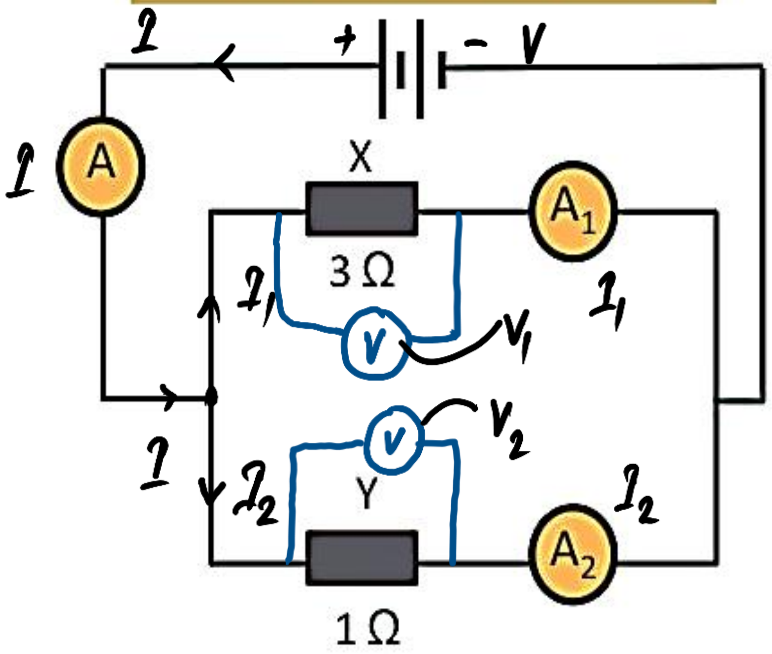
A_1, A_2 → Ammeters (device to find value of current).

→ current remains the same through X and Y.

voltage, $V = V_1 + V_2$

COMBINATION OF RESISTORS

Parallel Circuit



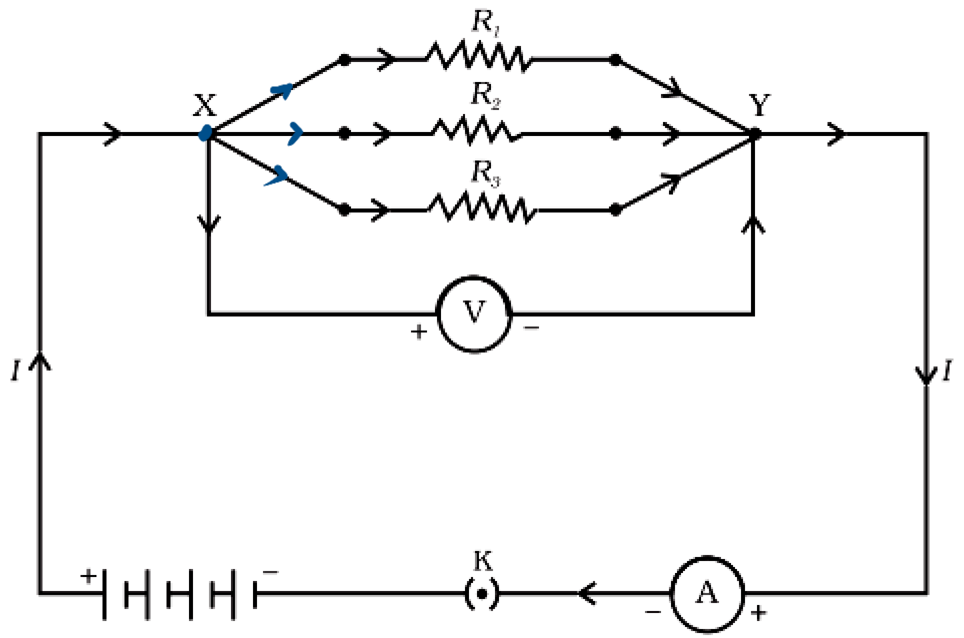
- Current splits into different paths ✓
- Reading on A = Reading on A1 + A2 ✓
- Main current is shared between the two resistors

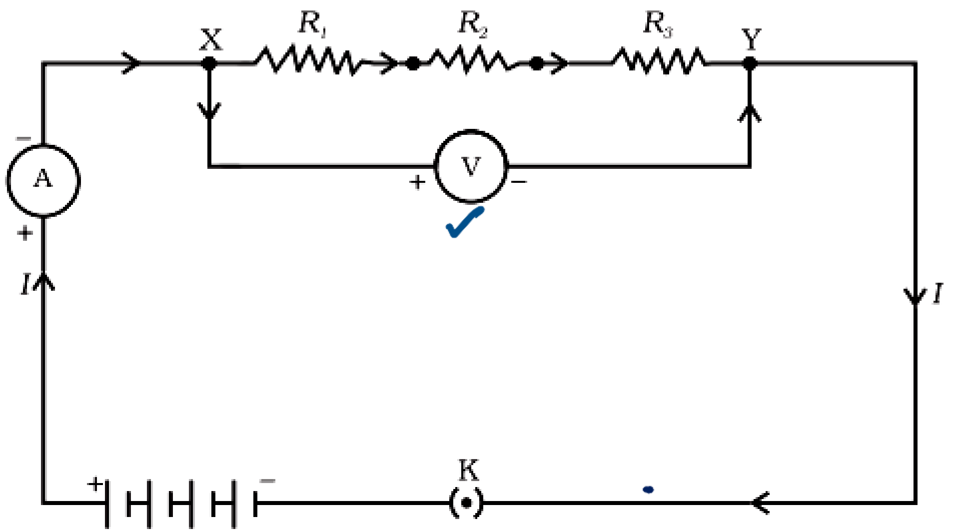
$I = I_1 + I_2$

→ current gets divided.

$V = V_1 = V_2$ (voltage remains the same)

COMBINATION OF RESISTORS





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

(parallel connection)

$$R = R_1 + R_2 + R_3$$

(Series connection)

For 2 resistors in parallel → $R = \frac{R_1 R_2}{R_1 + R_2}$

→ for n resistors with equal resistances 'R' Ω, then equivalent resistance,

$(R_1 = R_2 = R_3 = \dots R_n = R)$

(1) series connection,

$R_{eq} = R + R + R + \dots$ (n times)

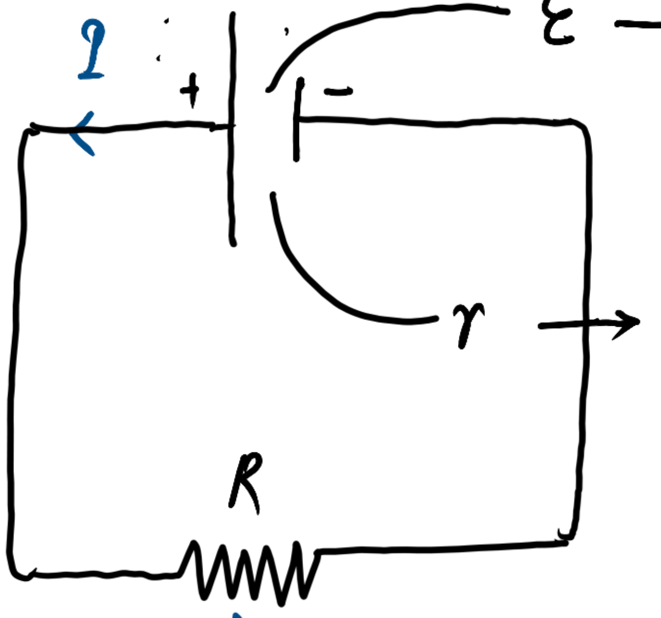
$R_{equivalent} = nR$ (series)

(2) parallel connection,

$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \dots$ (n times)

$\frac{1}{R_{eq}} = n\left(\frac{1}{R}\right) = \frac{n}{R} \Rightarrow R_{eq} = \frac{R}{n}$ (parallel)

CELLS AND INTERNAL RESISTANCE



$\mathcal{E}$ – emf (electromotive force) → not a force, but potential difference,

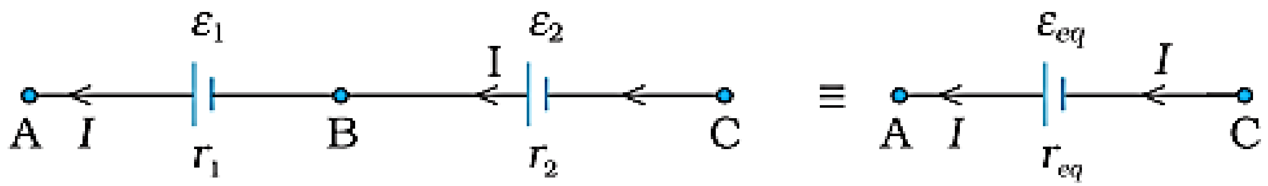
r → internal resistance

voltage ⇒ $V = IR$

$V = \mathcal{E} - Ir$

$$IR = \mathcal{E} - Ir \Rightarrow I(R+r) = \mathcal{E} \Rightarrow I = \frac{\mathcal{E}}{R+r}$$

CELLS – SERIES CONNECTION



Equivalent / Total / Overall emf = $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$

" " " internal resistance, $r_{eq} = r_1 + r_2$

$$V = \varepsilon_{eq} - I r_{eq}$$

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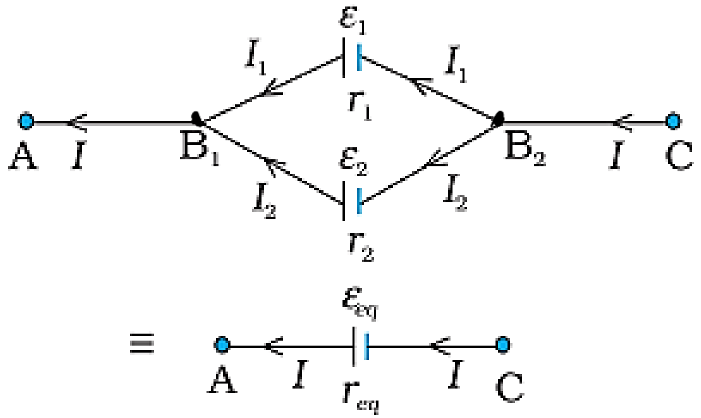
CELLS – PARALLEL CONNECTION



$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \dots + \frac{1}{r_n}$$

$$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \dots + \frac{\varepsilon_n}{r_n}$$

$$\varepsilon_{eq} = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \dots \frac{\varepsilon_n}{r_n}\right) r_{eq}$$

$$\varepsilon_{eq} = \frac{\left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \frac{\varepsilon_3}{r_3} + \dots \frac{\varepsilon_n}{r_n}\right)}{\frac{1}{r_{eq}}}$$

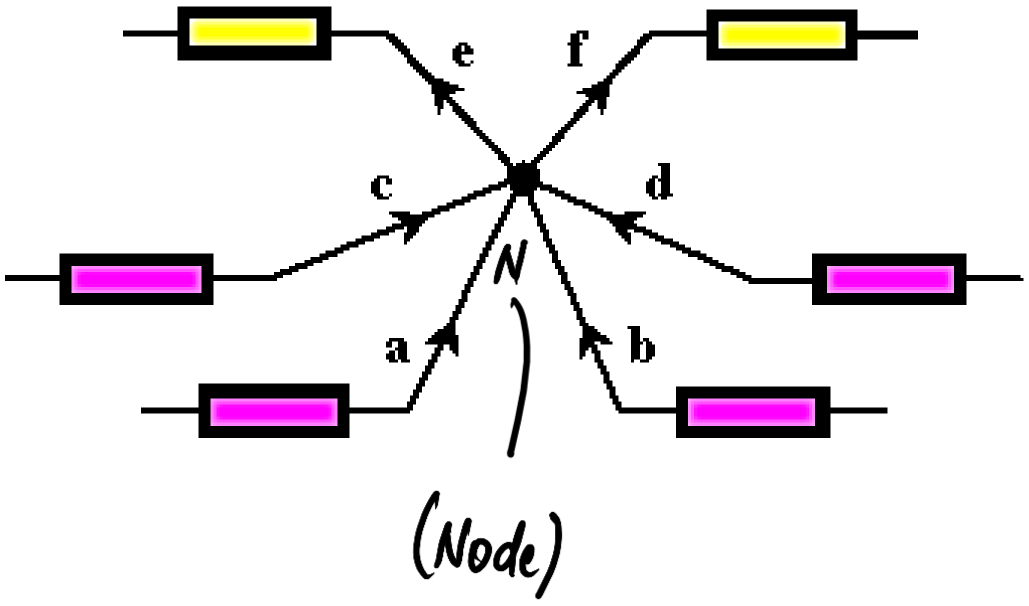
$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \cdots$$

$$\varepsilon_{eq} = \frac{\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \cdots \frac{\varepsilon_n}{r_n}}{\frac{1}{r_{eq}}} = \frac{\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \cdots \frac{\varepsilon_n}{r_n}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \cdots \frac{1}{r_n}}$$

for two cells, $\varepsilon_{eq} = \dfrac{\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}}$

KIRCHOFF'S LAWS

Junction Rule The algebraic sum of all currents meeting at a junction in a closed circuit is zero, *i.e.* $\Sigma I = 0$.
This law follows law of conservation of charge.



current coming towards N → ⊕
" going from " → ⊖

$(+a) + (+c) + (-e) + (-f) + (+d) + (+b) = 0$

$a + c - e - f + d + b = 0$

$a + c + d + b = e + f$

$a + c + d + b = e + f$

currents coming in → $a + c + d + b$

currents going out → $e + f$

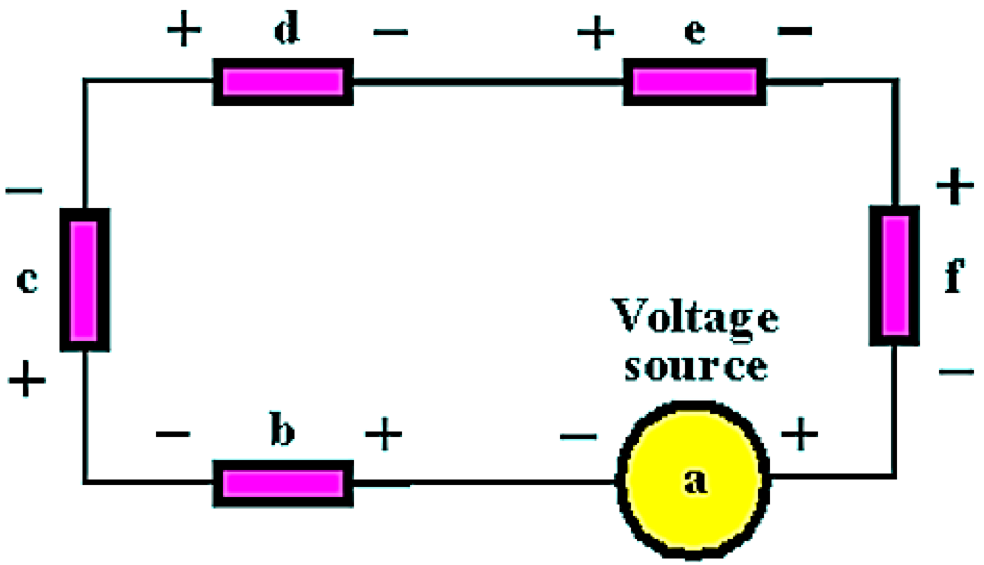
$$\sum I_{in} = \sum I_{out}$$

KIRCHOFF'S LAWS

Loop Rule The algebraic sum of all the potential differences in any closed circuit is zero, *i.e.*

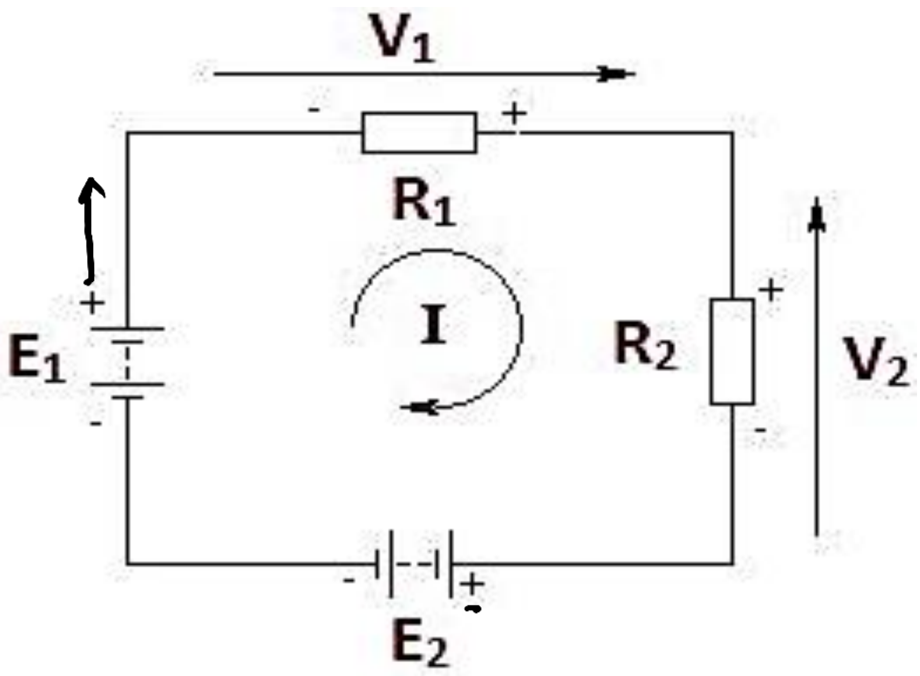
$$\Sigma \Delta V = 0$$

This law follows law of conservation of energy.



$a + b + c + d + e + f = 0$

KIRCHOFF'S LAWS



$$E_1 + V_1 - V_2 - E_2 = 0$$

$$E_1 + V_1 = V_2 + E_2$$

ELECTRIC ENERGY

The energy supplied by any source in maintaining the current in the electric circuit is called electric energy consumed by the electric circuit.

Potential diff. (V) = Work done (W) / Charge (Q)

Current, I = Q (Charge) / t (Time)

$Q = It$

$W = VQ$

$W = VIt$ ⇒ Electrical Energy = VIt

Unit ⇒ Joules

SSBCrack EXAMS

ELECTRIC POWER

$$\text{Electric Power} = \frac{\text{Electrical Energy}}{\text{Time}} = \frac{VIt}{t}$$

Unit ⇒ Watt (W)

$$P = VI$$

Ohm's law, $V = IR$

$$P = (IR)I = I^2R \quad \text{(series connections)}$$

$$P = V\left(\frac{V}{R}\right) = \frac{V^2}{R} \quad \text{(parallel connections)}$$

ELECTRIC ENERGY – COMMERCIAL UNIT

#

Power x time = Electrical energy

Power → kilowatt (kW) → 1000 W

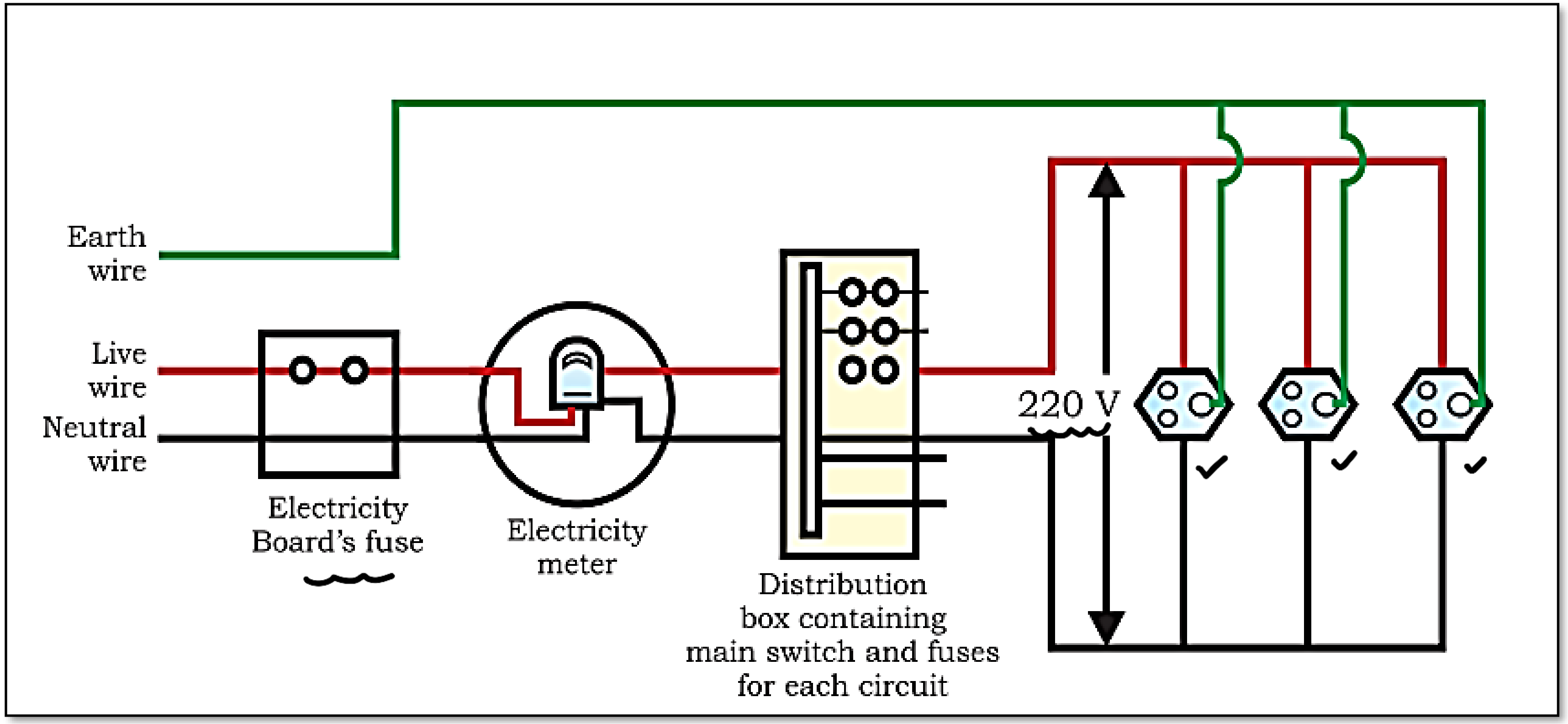
time → hours (h) → 60 x 60 s = 3600 s

Electrical energy → commercial unit ⇒ kWh #

$1\,kWh = 1000\,Js^{-1} \times (3600\,s)$

$1\,kWh = 3.6 \times 10^6\,J$

DOMESTIC ELECTRIC CIRCUITS



220 V,

Frequency = 50 Hz

- One of the wires in this supply, usually with red insulation cover, is called live wire (or positive). Another wire, with black insulation, is called Neutral wire (or negative). The potential difference between the two is 220 V.

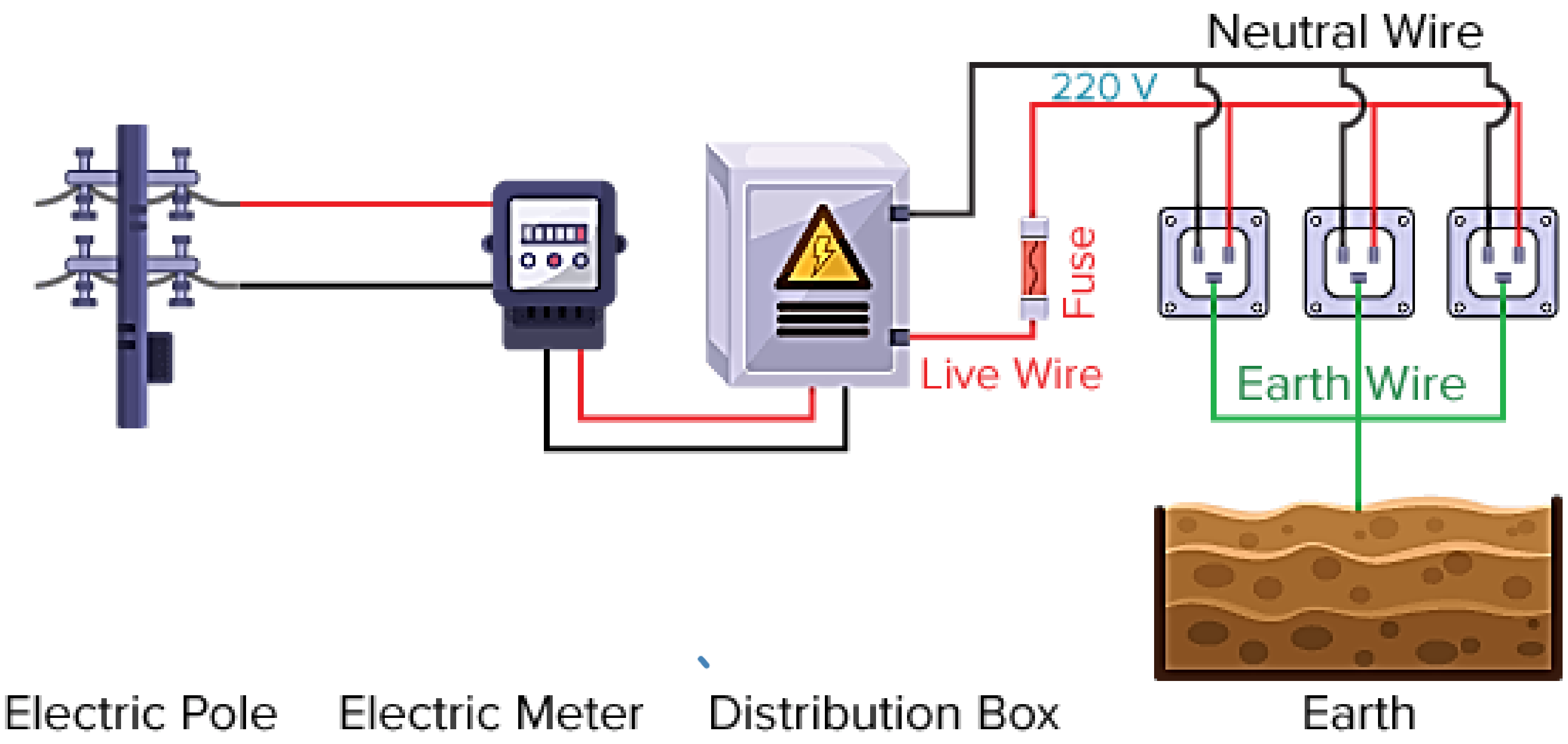
DOMESTIC ELECTRIC CIRCUITS

- The Earth wire, which has insulation of green colour, is usually connected to a metal plate deep in the earth near the house. This is used as a safety measure, especially for those appliances that have a metallic body, for example, electric press, toaster, table fan, refrigerator, etc.

(Lightning conductor)

- The metallic body is connected to the earth wire, which provides a low-resistance conducting path for the current. Thus, it ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and the user may not get a severe electric shock.

DOMESTIC ELECTRIC CIRCUITS



HEATING EFFECT

Heat generated by electric current, $H = I^2 R t$

- I → current
- R → resistance
- t → time for which current was flowing,

$H = I^2 R t$ ⇒ Joule's law of Heating

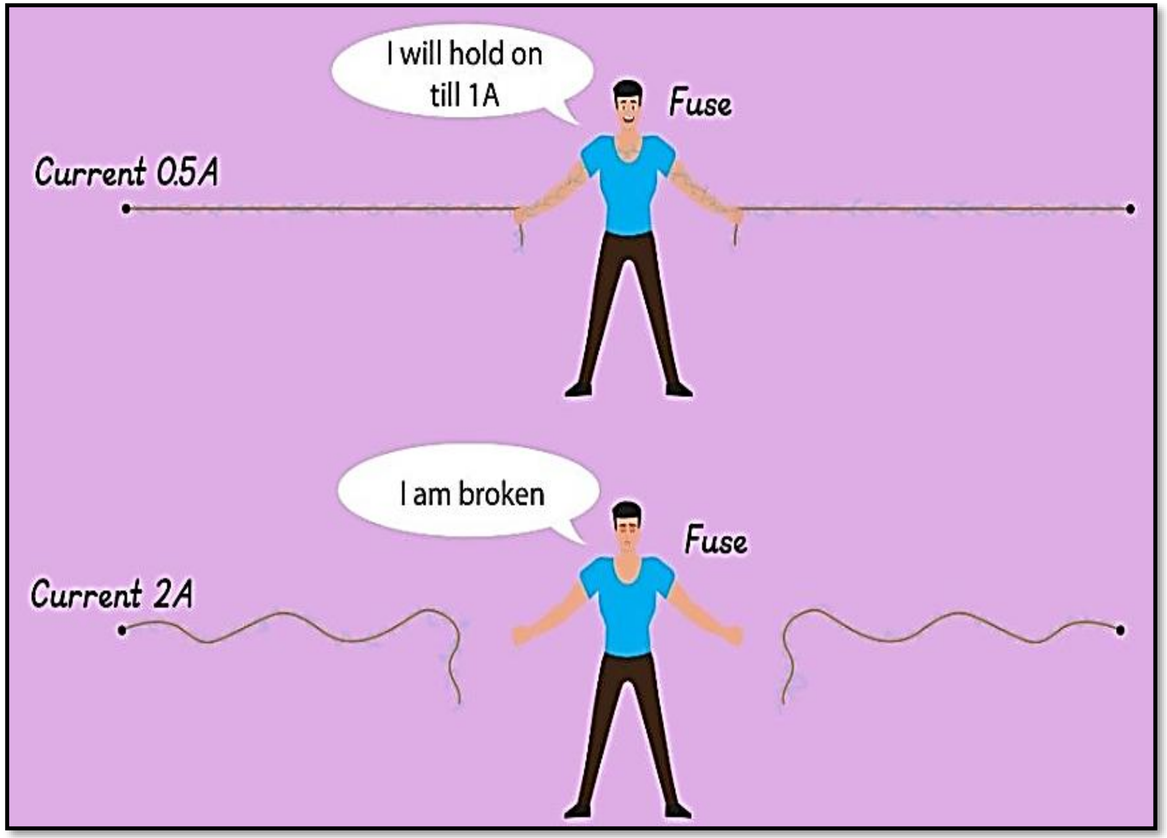
SSBCrack EXAMS

FUSE

- The use of an electric fuse prevents the electric circuit and the appliance from a possible damage by stopping the flow of unduly high electric current.
- The Joule heating that takes place in the fuse melts it to break the electric circuit.

principle of working

Short- circuit situation,



SUMMARY

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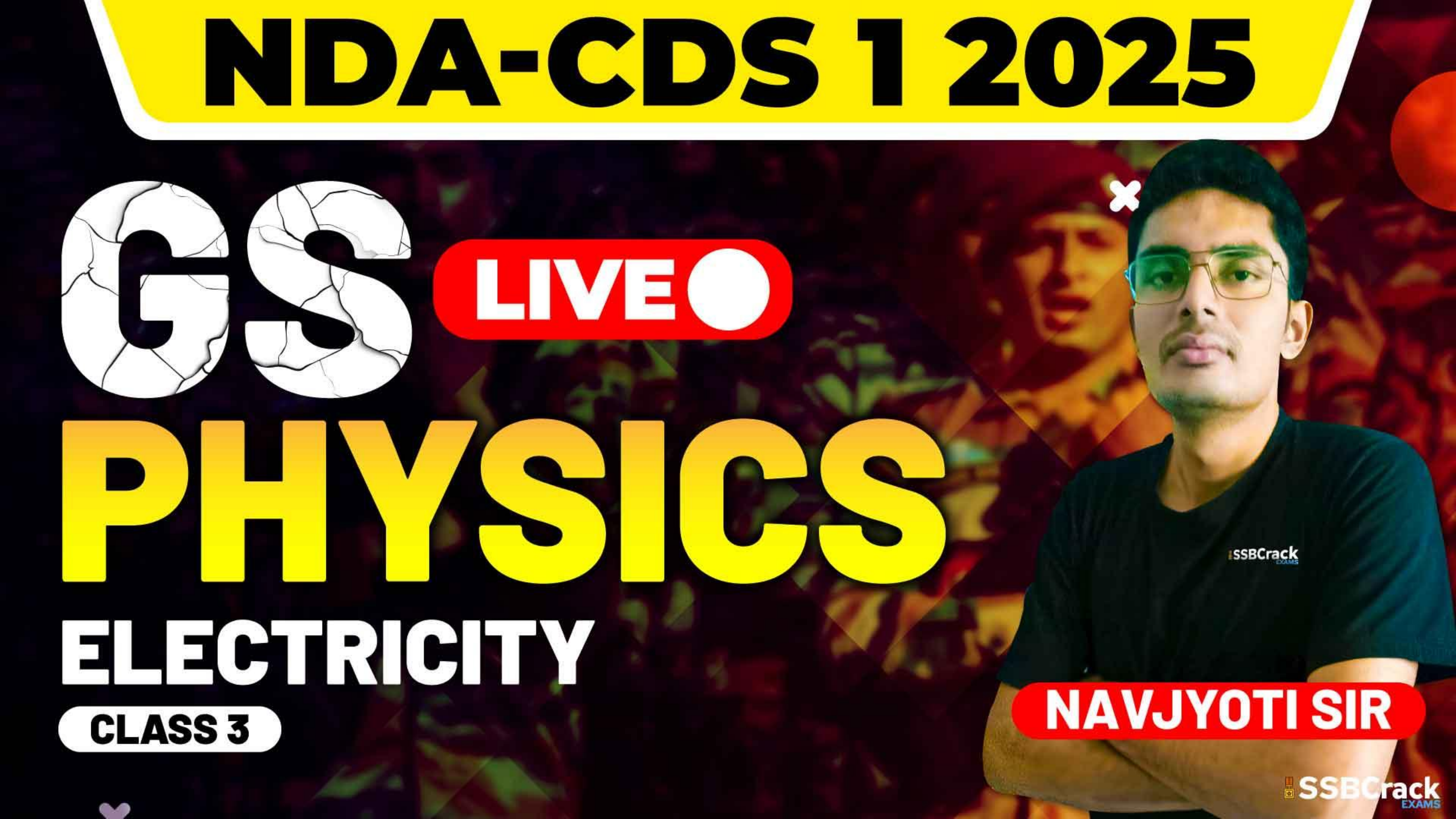
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