

Chapter 3 · Current Electricity

CBSE Class 12 Physics (042) · Unit II · Unit I + II = 16 marks · Ultimate Revision Sheet

60-SECOND RECALL

Drift velocity	$v_d = eE\tau/m \cdot I = neAv_d$
Ohm's law	$V = IR$ · microscopic form $J = \sigma E$
Resistance	$R = \rho L/A$ · $\rho = m/ne^2\tau$
Temperature	Metals $\rho \uparrow$ with T · Semiconductors $\rho \downarrow$ with T
EMF vs terminal V	$V = \mathcal{E} - Ir$ (discharging) · $V = \mathcal{E} + Ir$ (charging)
Kirchhoff	Junction = charge conservation · Loop = energy conservation
Wheatstone	Balanced when $P/Q = R/S \rightarrow$ galvanometer reads zero

1. Current and Drift Velocity

DEFINITIONS Electric current is the rate of flow of charge, $I = q/t$, a *scalar*, unit ampere.

Drift velocity is the *average velocity* gained by free electrons along the conductor under an applied field. Typical value: $\sim 10^{-4} \text{ m s}^{-1}$ — very slow.

Relaxation time τ is the average time between two successive collisions of an electron with the lattice ions.

FORMULAS

$$v_d = eE\tau/m = eV\tau/mL$$

$$I = neAv_d \quad n = \text{number density of free electrons}$$

$$\text{Mobility } \mu = v_d/E = e\tau/m \quad \text{unit } \text{m}^2 \text{V}^{-1} \text{s}^{-1}$$

$$\text{Current density } J = I/A = nev_d = \sigma E$$

TRAP Drift velocity is tiny, yet a bulb lights instantly — because the *electric field* is set up through the wire at nearly the speed of light, and *every* electron in the circuit starts drifting at once.

$v_d \propto I$, and current density J is a **vector** while current I is a *scalar*.

2. Resistance and Resistivity

FORMULAS

$$R = \rho L/A \cdot \rho = m / ne^2\tau \cdot \sigma = 1/\rho = ne^2\tau/m$$

$$R_T = R_0(1 + \alpha\Delta T) \quad \alpha = \text{temperature coefficient of resistance}$$

WHY TEMPERATURE ACTS OPPOSITELY IN THE TWO MATERIALS Metals: n is fixed; heating makes the ions vibrate more, so τ falls $\rightarrow \rho$ rises. α is positive.

Semiconductors: heating frees many more carriers, so n rises sharply — this outweighs the fall in $\tau \rightarrow \rho$ falls. α is negative.

Stretching a wire keeps its volume constant: if length becomes n times, R becomes n^2 times.

3. EMF, Terminal Voltage and Cells

THE DISTINCTION EMF (ϵ) is the potential difference across the cell when no current is drawn (open circuit). Terminal voltage (V) is the potential difference when current flows.

FORMULAS

$$\epsilon = V + Ir \rightarrow V = \epsilon - Ir \text{ (cell discharging)}$$

$$V = \epsilon + Ir \text{ (cell being charged)}$$

$$I = \epsilon / (R + r) \text{ internal resistance } r$$

Cells in series: $\epsilon_{eq} = \epsilon_1 + \epsilon_2$, $r_{eq} = r_1 + r_2$ — use when r is small compared with R .

Cells in parallel: $\epsilon_{eq} = (\epsilon_1 r_2 + \epsilon_2 r_1) / (r_1 + r_2)$, $1/r_{eq} = 1/r_1 + 1/r_2$ — use when r is large.

TRAP Terminal voltage is less than EMF while discharging, and MORE than EMF while charging.

A question that says "the cell is being charged" is testing exactly this sign.

$V = \epsilon$ only when $I = 0$, which is why a voltmeter must have very high resistance.

4. Power and Energy

FORMULAS

$$P = VI = I^2 R = V^2 / R$$

In series the current is common, so use $P = I^2 R$ — the largest R dissipates most.

In parallel the voltage is common, so use $P = V^2 / R$ — the smallest R dissipates most.

5. Kirchhoff's Rules

STATE THEM WITH THEIR CONSERVATION LAW — that is a separate mark Junction rule: the algebraic sum of currents at any junction is zero ($\sum I = 0$). It follows from the conservation of charge.

Loop rule: the algebraic sum of changes in potential around any closed loop is zero ($\sum \Delta V = 0$). It follows from the conservation of energy.

WHEATSTONE BRIDGE

$$\text{Balanced when } P/Q = R/S \rightarrow \text{current through the galvanometer is zero}$$

At balance the bridge is independent of the cell's EMF and of the galvanometer's resistance, which is why it measures an unknown resistance so accurately.

Sensitivity is greatest when all four resistances are of the same order.

WORKED EXAMPLE A cell of EMF 2 V and internal resistance $0.5\ \Omega$ drives a $4.5\ \Omega$ resistor.

$$I = \varepsilon / (R + r) = 2 / (4.5 + 0.5) = 0.4\text{ A}$$

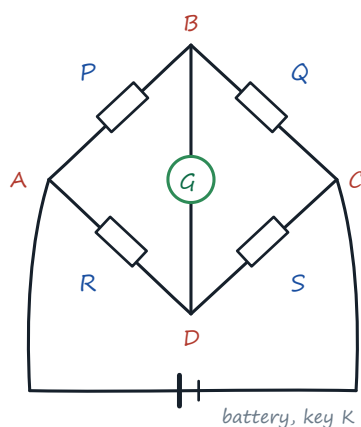
$$\text{Terminal voltage } V = \varepsilon - Ir = 2 - (0.4 \times 0.5) = 1.8\text{ V}$$

$$\text{Check with } V = IR = 0.4 \times 4.5 = 1.8\text{ V} \checkmark$$

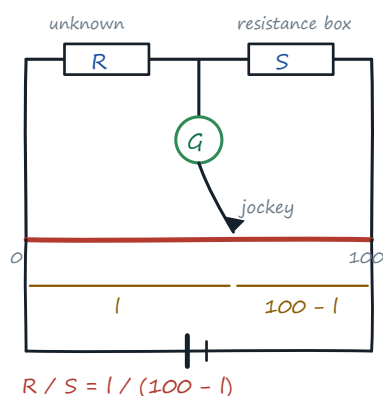
$$\text{Power in the resistor} = I^2 R = 0.16 \times 4.5 = 0.72\text{ W}$$

$$\text{Power wasted inside the cell} = I^2 r = 0.16 \times 0.5 = 0.08\text{ W}$$

(a) Wheatstone bridge



(b) Metre bridge



At balance $P/Q = R/S$. The galvanometer reading zero is the condition — it is **not** that no current flows anywhere, only that none flows through G .

6. Question Triggers what the wording is really asking

If the question says...	Use
"wire is stretched to n times its length"	R becomes $n^2 R$ (volume constant)
"resistance of a semiconductor on heating"	Decreases — n rises sharply
"galvanometer shows no deflection"	Wheatstone balance , $P/Q = R/S$
"terminal voltage is greater than EMF"	The cell is being charged
"complex network, several cells"	Kirchhoff's rules
"maximum power / which bulb glows brighter"	Series $\rightarrow I^2 R$, parallel $\rightarrow V^2 / R$
"drift velocity when current doubles"	$v_d \propto I \rightarrow$ also doubles

MOST-ASKED BOARD QUESTIONS

- [3M] Derive $I = neAv_d$, and hence deduce **Ohm's law** in the form $\rho = m/ne^2\tau$.
- [3M] State Kirchhoff's rules and use them to solve a two-loop network.
- [3M] Draw a **Wheatstone bridge** and derive its balance condition.
- [2M] Distinguish between **EMF** and **terminal voltage**.
- [2M] Explain why resistivity **rises** for a metal but **falls** for a semiconductor when heated.

6. [1M] Define *mobility* and give its SI unit.

7. [1M] Is current a scalar or a vector? → *Scalar* (current density is the vector)

THE HABIT THAT SCORES — In any Kirchhoff problem, mark the assumed current direction on the diagram *before* writing equations, and keep it even if the answer comes out negative. A negative answer simply means the real current flows the other way — it is not a mistake, and redrawing mid-solution is how sign errors creep in.