CHAPTER 3

Current Electricity

CBSE · Physics · Class 12

WHAT THIS CHAPTER DOES

Boards prep that builds confidence, not anxiety.

TODAY'S MISSION

Today's Mission

WHY THIS MATTERS

The Big Picture

TOPIC

Before You Start, You Should Know

TOPIC

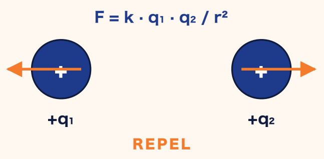
A

Part A — Microscopic View

WORKED EXAMPLE

Drift Velocity — Derivation

1. Apply field E -> force F = eE on each electron
2. Acceleration a = eE/m
3. Average time between collisions = tau (relaxation time)
4. Drift velocity v_d = a*tau = (eE/m)*tau
5. Substitute E = V/L to get v_d = eV*tau/(mL)



TOPIC

How Small is Drift Velocity?

TOPIC

Mobility and Conductivity

POINT 1	POINT 2

TOPIC

B

Part B — Ohm's Law and Resistance

THEOREM · LOAD-BEARING RESULT

Ohm's Law

> " For an ohmic conductor at constant temperature, the current through the conductor is directly proportional to the potential difference across its ends: V = IR, where R is the resistance.

STATEMENT

For an ohmic conductor at constant temperature, the current through the conductor is directly proportional to the potential difference across its ends: V = IR, where R is the

WHY THIS MATTERS

- Microscopically, I = (ne^2 tau / m) * (V/L) * A
- Grouping the material+geometry factors gives R = rho L/A.

WATCH OUT FOR

NOTE R is constant ONLY for ohmic materials at fixed T. Filament bulbs, diodes, thermistors are NON-ohmic.

TRY IT · SOLVE BEFORE YOU PEEK

Quick Test — 60 Seconds

Work it out before you flip the answer.

SOLUTION

TOPIC

Resistance Depends On...

POINT 1	POINT 2	POINT 3	POINT 4

TOPIC

C

Part C — Cells, EMF, and Internal Resistance

WORKED EXAMPLE

Terminal Voltage Numerical

1. Total resistance = R + r = 2.5 + 0.5 = 3 Ohm
2. Current I = epsilon / (R + r) = 6 / 3 = 2 A
3. Terminal voltage V = epsilon - I r = 6 - 2*0.5 = 5 V
4. Cross-check: V = I R = 2 * 2.5 = 5 V

TOPIC

Cells in Series vs Parallel

POINT 1	POINT 2

TOPIC

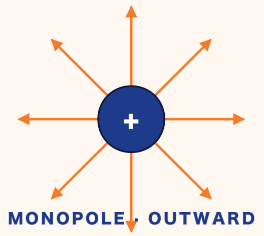
D

Part D — Kirchhoff and Wheatstone

WORKED EXAMPLE

Wheatstone Bridge — Balance Condition

1. Label currents: I_1 through P then Q; I_2 through R then S; $I_g = 0$
2. KVL loop ABDA: $I_1 P - I_2 R = 0 \Rightarrow I_1 P = I_2 R$
3. KVL loop BCDB: $I_1 Q - I_2 S = 0 \Rightarrow I_1 Q = I_2 S$
4. Divide: $(I_1 P)/(I_1 Q) = (I_2 R)/(I_2 S) \Rightarrow P/Q = R/S$



TOPPER TEMPLATE · MARK-BY-MARK

Topper Template — Drift Velocity Derivation

1. **SETUP**
   1 m
2. **FORCE ON ELECTRON**
   1 m
3. **CURRENT RELATION**
   1 m

PYQ PATTERNS

5 PYQ Patterns You Must Recognise

MARKS DISTRIBUTION

Where the 8-10 Marks Come From

TRY IT · SOLVE BEFORE YOU PEEK

Mid-Chapter Pulse Check

Work it out before you flip the answer.

SOLUTION

TOPIC

Trap

TRAP → TRUTH

× **MISTAKE** Drift velocity is the speed at which an electron moves through the wire

✓ **CORRECT** Drift velocity is the AVERAGE velocity of electrons under field; it is tiny (~10^-4 m/s). Electrons also have random thermal velocity (~10^5 m/s) which averages to zero. Current flows fast because the FIELD propagates at near c, not the drift.

TOPIC

Trap

TRAP → TRUTH

× **MISTAKE** Bulb lights up only after electrons travel from switch to bulb

✓ **CORRECT** Wrong — the electric field is established along the wire almost instantly (~speed of light). Electrons already in the filament start drifting immediately the moment the field arrives.

TOPIC

Trap

TRAP → TRUTH

× **MISTAKE** Resistance depends only on the material

✓ **CORRECT** R = rho L/A depends on material (rho), length (L) and cross-section (A). Even copper resistance can vary 100x by changing wire geometry.

TOPIC

Trap

TRAP → TRUTH

× **MISTAKE** Ohm's law applies to ALL conductors

✓ **CORRECT** Ohm's law ($V=IR$ with constant R) holds only for OHMIC conductors at constant temperature. Diodes, filament bulbs (R changes with T), thermistors, electrolytes are non-Ohmic — V-I graph is not a straight line through origin.

TOPIC

Trap

TRAP → TRUTH

× **MISTAKE** Terminal voltage = EMF

✓ **CORRECT** Terminal voltage V = epsilon - Ir, where r is internal resistance. They are equal only when I = 0 (open circuit) or r = 0 (ideal cell).

TOPIC

Trap

TRAP → TRUTH

× **MISTAKE** In a Wheatstone bridge, current through galvanometer is always zero

✓ **CORRECT** $I_g = 0$ ONLY at BALANCE ($P/Q = R/S$). At any other ratio, current flows through the galvanometer and it deflects. We adjust the variable resistor till $I_g = 0$.

TOPIC

Trap

TRAP → TRUTH

× **MISTAKE** Resistivity rho and resistance R mean the same thing

✓ **CORRECT** rho is a MATERIAL property (Ohm-m), independent of size. R = rho L/A is a DEVICE property (Ohm). Two copper wires have same rho but can have very different R.

TOPIC

Trap

TRAP → TRUTH

× **MISTAKE** Series cells always boost current

✓ **CORRECT** Series boosts EMF, not necessarily current. I = epsilon_eq/(R + r_eq) — series also increases internal resistance. For LOW external R, parallel cells give more current.

TOPPER TEMPLATE · MARK-BY-MARK

Derive drift velocity expression (3 marks)

1	**SETUP + ASSUMPTION** 1 m	Consider a conductor of length L, area A with n free electrons per unit volume. In absence of field, average thermal velocity sums to zero. Apply potential V across ends; this sets up electric field E = V/L throughout the conductor.
2	**APPLY F = MA TO SINGLE ELECTRON** 1 m	Force on each electron F = eE. Acceleration a = eE/m. Between successive collisions (relaxation time tau), electron gains velocity v = a*tau = eE*tau/m. This is the DRIFT VELOCITY v_d.
3	**CONNECT TO CURRENT I = NEAV_D** 1 m	Charge crossing area A in time dt: dQ = neA v_d dt. So I = dQ/dt = neA v_d = neA(eE*tau/m) = (ne^2 tau/m) AE. This gives Ohm's law I proportional to V.

TOPPER TEMPLATE · MARK-BY-MARK

Derive Wheatstone bridge balance condition (3 marks)

1. **DIAGRAM + LABEL CURRENTS** — 1 m

   Draw the bridge: four resistors P (AB), Q (BC), R (AD), S (DC); cell across AC, galvanometer across BD. Let I1 flow through P and Q; I2 through R and S; Ig through galvanometer.

2. **APPLY KVL WITH IG = 0** — 1 m

   At BALANCE, Ig = 0, so I1 flows fully through P then Q, and I2 through R then S. KVL loop ABDA: I1*P = I2*R (no drop across galvanometer). KVL loop BCDB: I1*Q = I2*S.

3. **DIVIDE AND CONCLUDE** — 1 m

   Divide the two equations: (I1*P)/(I1*Q) = (I2*R)/(I2*S), giving P/Q = R/S. This is the WHEATSTONE balance condition. Used in metre bridge and resistance measurement.

TOPPER TEMPLATE · MARK-BY-MARK

Cells in series vs parallel — derive equivalent EMF and r (3 marks)

1	**SERIES CASE** 1 m	Two cells (ϵ_1, r_1) and (ϵ_2, r_2) in series with same polarity: total EMF = $\epsilon_1 + \epsilon_2$; total internal resistance = $r_1 + r_2$. If opposing polarity: $\epsilon_{eq} = \lvert \epsilon_1 - \epsilon_2 \rvert$.
2	**PARALLEL CASE DERIVATION** 1 m	For parallel cells, terminal voltage V is same. $I = I_1 + I_2$ where $I_1 = (\epsilon_1 - V)/r_1$ and $I_2 = (\epsilon_2 - V)/r_2$. Comparing with $V = \epsilon_{eq} - I r_{eq}$ gives: $1/r_{eq} = 1/r_1 + 1/r_2$ and $\epsilon_{eq}/r_{eq} = \epsilon_1/r_1 + \epsilon_2/r_2$.
3	**WHEN TO USE WHICH** 1 m	Series: when external R is LARGE — boosts driving EMF. Parallel: when external R is SMALL — minimises internal resistance and supplies more current. State both with one-line justification.

PYQ PATTERNS

Top PYQ patterns to drill

#1	Derive drift velocity expression and relate it to current I = neAv_d (3 marks)	90%
#2	Wheatstone bridge	derive balance condition P/Q = R/S using KCL+KVL (3 marks) — 85%
#3	Cells in series/parallel	find equivalent EMF and internal resistance, then I (3 marks) — 80%
#4	Numerical: terminal voltage V = epsilon - Ir; find internal resistance from open and closed circuit readings (2 marks)	75%
#5	Potentiometer	explain why it is preferred over a voltmeter to

RECAP · MEMORISE THESE

Chapter Summary

WHAT'S NEXT

Next Class

→

Your Move Tonight

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Boards prep that builds confidence, not anxiety.