Topic B.5

CURRENT AND CIRCUITS

Every Formula, Trick & Trap on a Page
& IB-Style Quick Reference

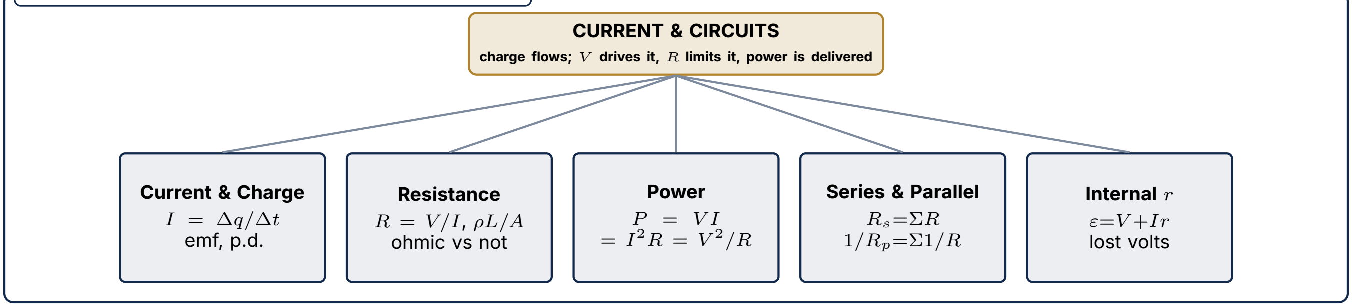
Topics Covered

Current, PD & Resistance
Ohm's Law & I–V Graphs
Resistivity $R = \rho L/A$
Series & Parallel Circuits
EMF, Internal Resistance & Power

Exam Relevance

P1 & P2 (with & without GDC)
$V = IR$; ohmic vs non-ohmic
$R = \rho L/A$
Series & parallel rules
$\varepsilon = I(R + r)$, $P = VI$

The Big Picture — How B.5 Fits Together



1 §1 — Current and Charge

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Current = rate of flow of charge: $I = \dfrac{\Delta q}{\Delta t}$ [$\mathrm{A} = \mathrm{C/s}$; ampere is the SI *base* unit, $1\,\mathrm{C} = 1\,\mathrm{A\,s}$]

Charge carriers: electrons (metals), ions (solutions), holes (semiconductors).
dc: carriers flow one way only. **ac:** current periodically reverses (mains).
Conventional current: positive to negative (opposite to electron drift).
Drift speed: $I = nAvq$ (n = carrier number density, very slow: $\sim 10^{-4}\,\mathrm{m/s}$).
Charge capacity: amp-hours; $1\,\mathrm{A\,h} = 3600\,\mathrm{C}$.

TRICK To find number of electrons: $N = \dfrac{\Delta q}{e}$ where $e = 1.60 \times 10^{-19}\,\mathrm{C}$.

TRAP Current is the same at all points in a series circuit — charge is not "used up".

FROM THE PHOTON QUESTION BANK
Convert $\mathrm{mm}^2 \to \mathrm{m}^2$ ($\times 10^{-6}$) before using $I = nAvq$; and $\Delta q = I\Delta t$ before counting electrons.

2 §2 — EMF and Potential Difference

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EMF (ε): energy supplied per unit charge by a source. $\varepsilon = \dfrac{W}{q}$

Potential difference (V): energy transferred per unit charge between two points. $V = \dfrac{W}{q}$

Both measured in **volts** ($1\,\mathrm{V} = 1\,\mathrm{J/C}$).

NOTE EMF is the "total" voltage of the source; p.d. is what appears across the external circuit.

3 §3 — Resistance, Resistivity and Ohm's Law

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Resistance: $R = \dfrac{V}{I}$ [Ω]

Resistivity: $R = \dfrac{\rho L}{A}$ so $\rho = \dfrac{RA}{L}$ [$\Omega\,\mathrm{m}$]
Ohm's law: $V \propto I$ at constant temperature (constant R). $V = IR$.

TRICK For a circular wire: $A = \pi r^2 = \pi(d/2)^2$. Watch for diameter vs radius, and convert mm to m.

TRAP $R = V/I$ is always valid (definition). Ohm's law additionally requires R to be constant. A filament lamp obeys $R = V/I$ but **not** Ohm's law.

FROM THE PHOTON QUESTION BANK

$R \propto 1/d^2$: halving a wire's diameter quarters A and *quadruples* R. Watch diameter-vs-radius.

4 §4 — I-V Characteristics B.5

Ohmic resistor	Straight line through origin; constant R (metal at constant temp.)
Filament lamp	Curve flattens at high V; R increases as temperature rises
Diode	Conducts in forward direction above threshold ($\approx 0.6\,\mathrm{V}$); very high R in reverse

NOTE The heating effect of current explains why filament lamps are non-ohmic: increased temperature causes more lattice vibrations, increasing resistance.

5 §5 — Electrical Power B.5

$$\boxed{P = IV = I^2R = \frac{V^2}{R}} \qquad [\mathrm{W}]$$

TRICK Pick the formula with the two known quantities to avoid propagation of rounding errors.

6 §6 — Series and Parallel Circuits B.5

	Series	**Parallel**
Current	$I = I_1 = I_2$	$I = I_1 + I_2$
Voltage	$V = V_1 + V_2$	$V = V_1 = V_2$
Resistance	$R_s = R_1 + R_2$	$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

TRICK For two resistors in parallel: $R_p = \frac{R_1R_2}{R_1 + R_2}$ (product over sum).

TRICK **Two ways parallel R drops:** more branches = more paths for current (less resistance); or conductances add $1/R_p = \Sigma 1/R$. R_p is always below the smallest branch.

TRAP Don't forget to take the reciprocal after adding $1/R$ values! Also, R_p is always less than the smallest resistor.

7 §7 — EMF and Internal Resistance B.5

$$\boxed{\varepsilon = I(R + r) = V + Ir}$$

Terminal p.d.: $V = \varepsilon - Ir$ ("lost volts" $= Ir$)

V-I graph: y-intercept $= \varepsilon$; gradient $= -r$.

TRAP When $I = 0$ (open circuit), $V = \varepsilon$. When the external resistance $R \to 0$ (short circuit), $I_{\max} = \varepsilon/r$.

TRICK **Two ways EMF $\neq$ terminal V:** ε is total energy per coulomb; terminal $V = \varepsilon - Ir$ is what's left after "lost volts" Ir. Only at $I = 0$ (open circuit) does a voltmeter read ε.

FROM THE PHOTON QUESTION BANK

To find ε, r from a V–I line: intercept $= \varepsilon$, gradient magnitude $= r$. Short-circuit current $= \varepsilon/r$.

8 §8 — Variable Resistors

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Thermistor (NTC)	R decreases as temperature increases
LDR	R decreases as light intensity increases
Potentiometer	Sliding contact varies effective resistance; output voltage adjustable from 0 to V_{supply}

NOTE Ammeters are ideal (zero resistance, in series) and voltmeters are ideal (infinite resistance, in parallel) unless stated otherwise. Real meters have finite non-ideal resistance.

9 §9 — Kirchhoff's Circuit Laws

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First law (junction): $\sum I = 0$ — current in $=$ current out (*conservation of charge*).
Second law (loop): $\sum V = 0$ — p.d.s around a closed loop sum to zero (*conservation of energy*).

TRICK In a series loop the component p.d.s add up to the emf — use this as an instant check.

TRAP When a switch changes the circuit, re-identify series vs parallel *before* reusing any total resistance.

10 §10 — Potential Divider and Sensors

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Divider (output across R_2): $V_{\text{out}} = \dfrac{R_2}{R_1 + R_2} V_{\text{in}}$
Potentiometer: 3 terminals; output adjustable $0 \to V_{\text{in}}$ (rheostat cannot reach 0).
Sensor circuit: swap one resistor for an **LDR** ($R \downarrow$ as light $\uparrow$) or **NTC thermistor** ($R \downarrow$ as temp $\uparrow$).

NOTE To predict V_{out}: ask whether the *sensor's* share of resistance rose or fell, then apply the divider ratio.

FROM THE PHOTON QUESTION BANK
A "null" (balanced) voltmeter means two dividers have equal ratios — solve for the unknown resistance.

B.5 Current and Circuits

Student Self-Check Table

Ref	Topic	Formulas	Tricks	Confidence
§1	Current and charge	☐	☐	☐☐☐☐☐
§2	EMF and p.d.	☐	☐	☐☐☐☐☐
§3	Resistance and resistivity	☐	☐	☐☐☐☐☐
§4	I-V characteristics	☐	☐	☐☐☐☐☐
§5	Electrical power	☐	☐	☐☐☐☐☐
§6	Series and parallel	☐	☐	☐☐☐☐☐
§7	EMF and internal resistance	☐	☐	☐☐☐☐☐
§8	Variable resistors	☐	☐	☐☐☐☐☐
§9	Kirchhoff's circuit laws	☐	☐	☐☐☐☐☐
§10	Potential divider & sensors	☐	☐	☐☐☐☐☐

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