

Electricity

A-Level Physics 9702 · Topic 9 revision notes · AS

Charge on the move: current and drift velocity, potential difference and power, resistance, I-V characteristics and resistivity.

11 definitions to learn word for word, 11 equations in their own column, 7 diagrams and graphs. Read it, cover it, test yourself.

1. 9.1 Electric current
2. 9.2 Potential difference and power
3. 9.3a Resistance, Ohm's law and I-V characteristics
4. 9.3b Resistivity

Definitions (mark-scheme wording) Equations Exam traps

9.1 Electric current

Definitions

Electric current: the rate of flow of charge.

Coulomb: the charge passing a point when a current of one ampere flows for one second ($1 \text{ C} = 1 \text{ A s}$).

Elementary charge (e): the smallest free charge: the magnitude of the charge on an electron or proton, $1.60 \times 10^{-19} \text{ C}$.

Number density (n): the number of free charge carriers per unit volume.

Equations

$$Q = It$$

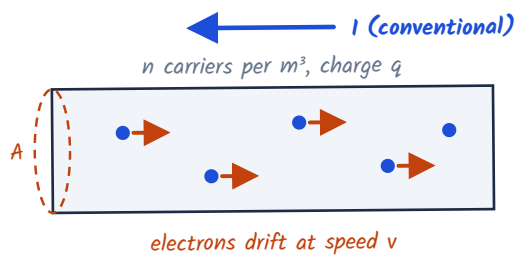
charge = current $\times$ time
C

$$I = Anvq$$

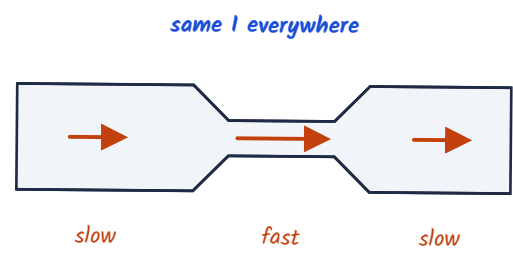
current = area $\times$ number density $\times$ drift speed $\times$ carrier charge
A

Key points

- ✓ Charge is **quantised**: any charge is a whole-number multiple of e .
- ✓ Charge carriers: **electrons** in metals; **ions** (positive and negative) in electrolytes and ionised gases.
- ✓ **Conventional current** flows from + to -, opposite to the electron flow.
- ✓ Drift speed in a metal is **very small** ($\sim 10^{-4} \text{ m s}^{-1}$) because n is huge.
- ✓ Semiconductors have much smaller n , so for the same current the drift speed is much larger.
- ✓ Same current through a thinner section: **drift speed is larger** ($v = I/nAq$).



$I = Anvq$: in one second, all carriers within a length v of the shaded face pass through it. Conventional current is opposite to the electron drift.



$$v = I / nAq$$

Same current I in series: where the wire is thinner (smaller A), the carriers must drift faster.

Watch out!

- ! Use $q = 1.60 \times 10^{-19} \text{ C}$ for an electron in $I = Anvq$; the sign is ignored for the speed.
- ! Current is **not used up**: it is the same at every point in a series loop.

9.2 Potential difference and power

Definitions

Potential difference (p.d.): the energy transferred from electrical to other forms per unit charge.

Volt: one joule per coulomb ($1 \text{ V} = 1 \text{ J C}^{-1}$).

Power: the rate of energy transfer (work done per unit time).

Key points

- ✓ P.d. is measured **across** a component with a voltmeter in **parallel**; current with an ammeter in **series**.
- ✓ Ideal voltmeter: infinite resistance. Ideal ammeter: zero resistance.
- ✓ Three power forms, linked by $V = IR$: pick the one using the quantities you know.
- ✓ For a fixed resistor, $P \propto I^2$: doubling I **quadruples** the power dissipated.
- ✓ Transmission: high voltage means low current, so cable losses (I^2R) are small.

Equations

$$V = W / Q$$

p.d. = energy transferred / charge
 W

$$P = VI$$

power = p.d. $\times$ current
 W

$$P = I^2R$$

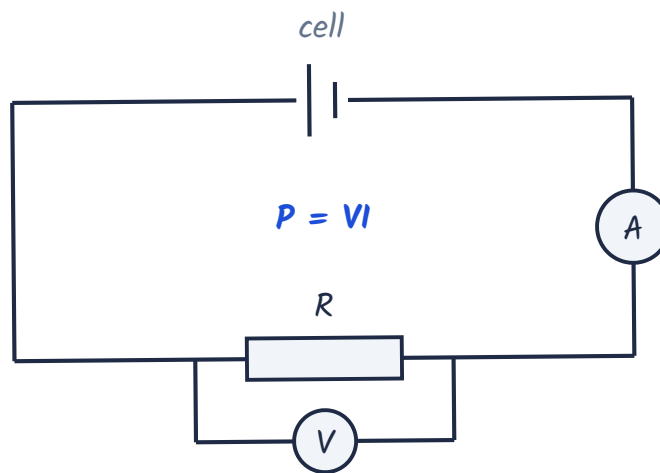
use when I and R are known
 W

$$P = V^2 / R$$

use when V and R are known
 W

$$W = VIt$$

energy transferred in time t
 J



Measuring the power of a resistor: ammeter in series, voltmeter in parallel, then $P = VI$.

Watch out!

- ! $P = I^2R$ and $P = V^2/R$ need the I or V of **that component**, not of the whole circuit.
- ! Energy in joules needs time in **seconds**, not minutes or hours.

9.3a Resistance, Ohm's law and I-V characteristics

Definitions

Resistance: the ratio of the potential difference across a component to the current in it ($R = V/I$).

Ohm: the resistance of a component with a p.d. of one volt across it when the current is one ampere ($1 \Omega = 1 \text{ V A}^{-1}$).

Ohm's law: for a metallic conductor at constant temperature, the current is directly proportional to the potential difference.

Equations

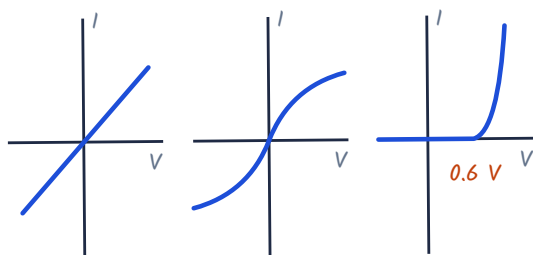
$$R = V / I$$

resistance = p.d. / current

Ω

Key points

- ✓ Resistance at a point on an I-V graph = V/I at that point, not the gradient.
- ✓ Metallic conductor at constant temperature: **straight line through the origin** (ohmic).
- ✓ Filament lamp: curve flattens. Larger current, **higher temperature**, more lattice vibration, so R increases.
- ✓ Semiconductor diode: almost no current in reverse; conducts above about **0.6 V** forward, then R falls sharply.
- ✓ Thermistor (NTC): resistance **decreases as temperature increases**.
- ✓ Light-dependent resistor (LDR): resistance **decreases as light intensity increases**.

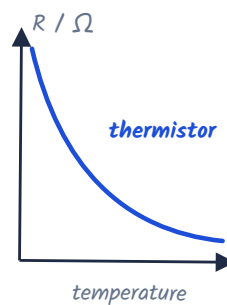


metal wire
(constant T)

filament lamp

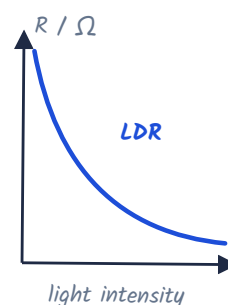
diode

I-V characteristics: metallic conductor at constant temperature (ohmic), filament lamp (R rises with current), diode (conducts one way only).



thermistor

temperature



LDR

light intensity

Sensing resistors: thermistor resistance falls as temperature rises; LDR resistance falls as light intensity rises.

Watch out!

- ! A curved I-V graph does not mean $R = 1/\text{gradient}$. Use $R = V/I$ read from the point.
- ! On an I-V graph (I up, V across) a curve bending towards the V axis means resistance is **increasing**.

9.3b Resistivity

Definitions

Resistivity (ρ): the resistance of a sample of the material of unit length and unit cross-sectional area; defined by $\rho = RA/L$.

Key points

- ✓ Resistivity is a property of the **material** (and temperature); resistance depends also on the shape.
- ✓ $R \propto L$ and $R \propto 1/A$: double the length doubles R ; double the diameter quarters R .
- ✓ Experiment: measure diameter with a **micrometer** at several places; $A = \pi d^2/4$.
- ✓ Measure R for several lengths (V/I or ohmmeter); plot **R against L** : gradient = ρ/A .
- ✓ Keep the current small so the wire does not heat up and change ρ .

Equations

$$R = \rho L / A$$

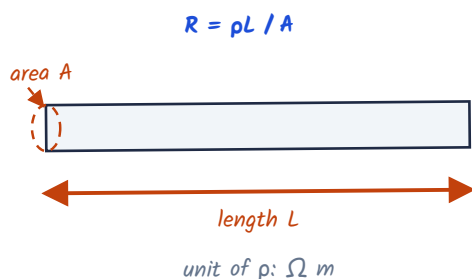
resistance from resistivity, length and cross-sectional area
 Ω

$$\rho = RA / L$$

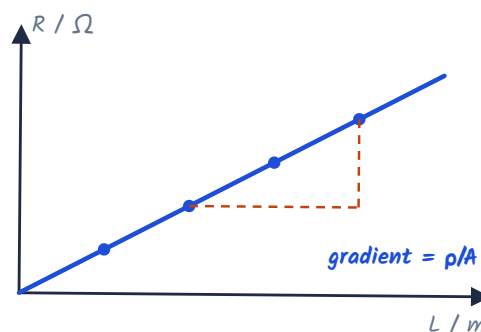
resistivity
 $\Omega \text{ m}$

$$A = \pi d^2 / 4$$

area of a wire of diameter d
 m^2



Geometry sets the resistance: R is proportional to length and inversely proportional to cross-sectional area.



Finding resistivity: R against L is a straight line through the origin with gradient ρ/A , so $\rho = \text{gradient} \times A$.

Watch out!

- ! The unit of resistivity is $\Omega \text{ m}$, not Ω/m or $\Omega \text{ m}^{-1}$.
- ! Use the **radius** in πr^2 , or d in $\pi d^2/4$; do not mix them. Convert mm to m first.

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