

Electricity

AS Physics ■ Topic 9

A-Level Physics



Electricity

What we will cover

- 1 Current and charge
- 2 Potential difference
- 3 Electrical power
- 4 Resistance & Ohm's law
- 5 Sensors: LDR & thermistor
- 6 Recap



1 Current and charge

Electricity

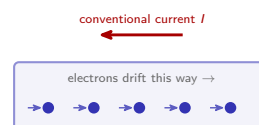
└ Current and charge

Electric current

Current 电流 is a flow of **charge carriers** 载流子.

- metal: conduction **electrons** 电子
- electrolyte: positive & negative **ions** 离子

Conventional current flows the way **positive** charge would – opposite to the electrons in a wire.



Electricity

└ Current and charge

Charge and current

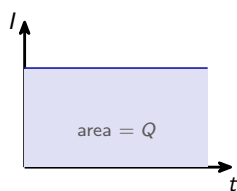
Charge is **quantised** 量子化 in units of $e = 1.60 \times 10^{-19} \text{ C}$.

$$I = \frac{Q}{t}, \quad Q = It.$$

0.50 A for 2.0 min

$$Q = 0.50 \times 120 = 60 \text{ C},$$

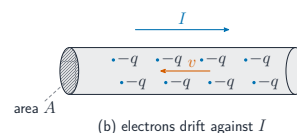
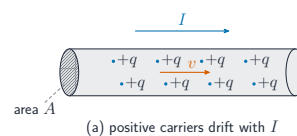
$$N = Q/e \approx 3.8 \times 10^{20} \text{ electrons}$$



Electricity

└ Current and charge

Drift velocity



$$I = Anvq$$

(n = carriers per m^3 , v = **drift velocity** 漂移速度).

Copper, $A = 10^{-6} \text{ m}^2$, $I = 5.0 \text{ A}$

$v \approx 3.7 \times 10^{-4} \text{ m s}^{-1}$ – under 1 mm per second

2 Potential difference and power

Electricity
└ Potential difference and power

Potential difference and e.m.f.

Energy transferred per unit charge:

$$V = \frac{W}{Q}, \quad [V] = \text{J C}^{-1}.$$

e.m.f. 电动势

energy given to the charge
by the source

p.d.

energy given up to a component

Electricity
└ Potential difference and power

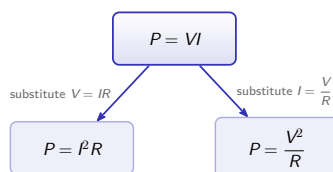
Electrical power

$$P = VI = I^2 R = \frac{V^2}{R}.$$

Pick the form for the quantities you know.

Kettle "2.4 kW, 240 V"

$$I = P/V = 10 \text{ A}, \quad R = V^2/P = 24 \Omega$$



3 Resistance and Ohm's law

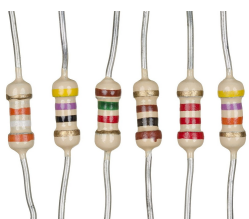
Electricity
└ Resistance and Ohm's law

Resistance and Ohm's law

$$R = \frac{V}{I}, \quad [R] = \Omega = \text{V A}^{-1}.$$

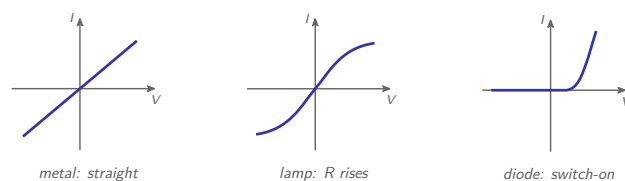
Ohm's law: $I \propto V$ at constant temperature – then R is constant (a straight I - V line).

$R = V/I$ defines R for *any* component; only ohmic ones keep it constant.



Electricity
└ Resistance and Ohm's law

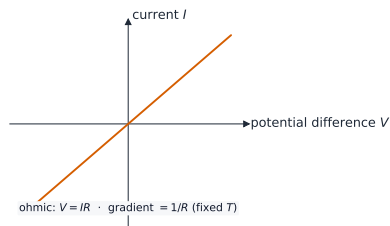
I - V characteristics



A hotter **filament lamp** 灯丝灯泡 has more resistance; a **diode** 二极管 conducts only above $\sim 0.7 \text{ V}$.

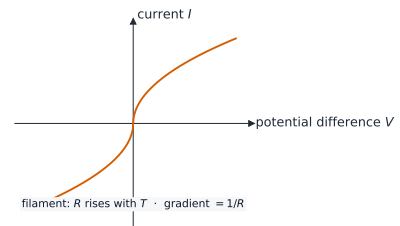
Characteristic 1 – a metal wire

Straight through the origin: R is **constant**, so the wire obeys Ohm's law (provided its temperature does not change).



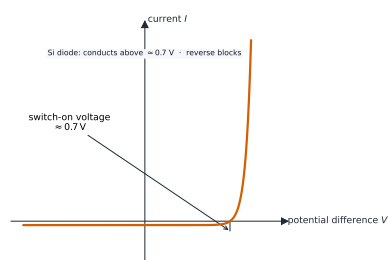
Characteristic 2 – a filament lamp

The curve **bends over**: as the current heats the filament its resistance rises, so equal steps in V buy less and less current.



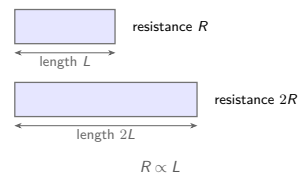
Characteristic 3 – a diode

Conducts one way only, and only above about 0.6 V ; in reverse the current is negligible until breakdown.



Resistivity

same area A – twice the length gives twice R



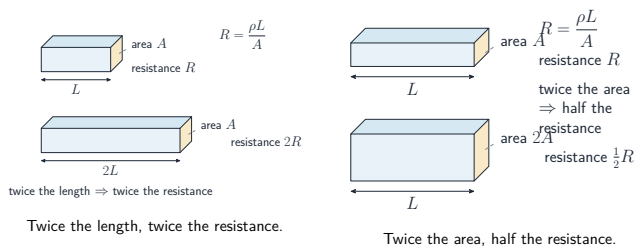
$$R = \frac{\rho L}{A}$$

ρ is the **resistivity** 电阻率 (a material property, $\Omega\text{ m}$).

Copper: $L = 2.0\text{ m}$, $A = 1.7 \times 10^{-7}\text{ m}^2$

$$R = \frac{(1.7 \times 10^{-8})(2.0)}{1.7 \times 10^{-7}} = 0.20\ \Omega$$

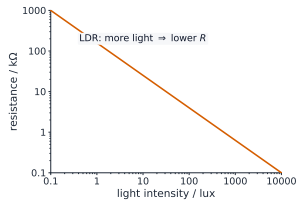
What $R = \rho L/A$ is saying



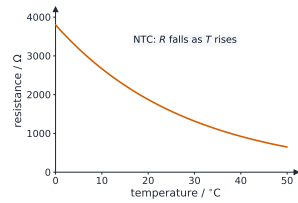
ρ is the property of the **material**; R also depends on the shape.

4 Sensors

Light-dependent resistor and thermistor



LDR 光敏电阻: R falls as light rises



thermistor 热敏电阻: R falls as temp. rises

In a semiconductor, more heat/light **fre**es more **carriers** – the opposite of a metal.

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Recap

Topic 9 – key takeaways

1 Current

$I = Q/t = Anvq$; conventional = positive flow

2 Power

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

3 Resistance

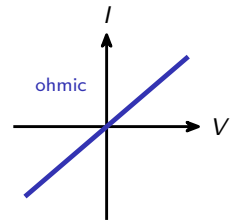
$R = V/I = \rho L/A$; Ohm's law if T constant

4 Sensors

LDR and thermistor: R falls with light / heat

Check yourself

- 1 Charge passing in 10 s at 2.0 A?
- 2 Three forms of the power equation?
- 3 Why does a filament lamp's I - V line curve?
- 4 What happens to an LDR's R in the dark?



Answers 1. $Q = It = 20 \text{ C}$ 2. VI , $I^2 R$, V^2 / R 3. R rises as it heats 4. rises (to $M\Omega$)