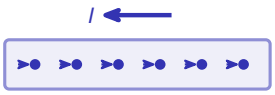
Electricity

AS Physics ▪ Topic 9

A-Level Physics



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

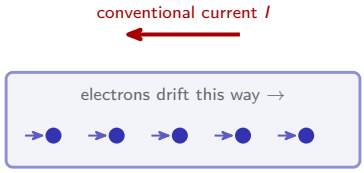
1 Current and charge

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.



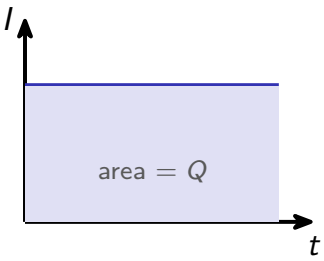
Charge and current

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

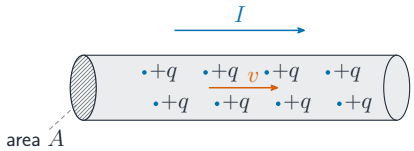
$$I = \frac{Q}{t}, \qquad Q = It.$$

$0.50\,\mathrm{A}$ for 2.0 min

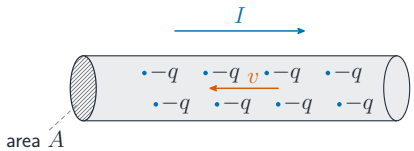
$Q = 0.50 \times 120 = 60\,\mathrm{C}$,
$N = Q/e \approx 3.8 \times 10^{20}$ electrons



Drift velocity



(a) positive carriers drift with I



(b) electrons drift against I

$$I = A\,n\,v\,q$$

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

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

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

2 Potential difference and power

Potential difference and e.m.f.

Energy transferred per unit charge:

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

e.m.f. 电动势

energy given to the charge by the source

p.d.

energy given up to a component

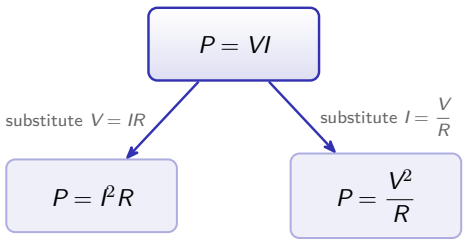
Electrical power

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

Pick the form for the quantities you know.

Kettle "$2.4\,\mathrm{kW}$, $240\,\mathrm{V}$"

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



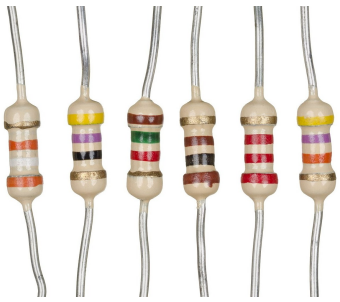
3 Resistance and Ohm's law

Resistance and Ohm's law

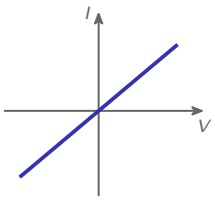
$$R = \frac{V}{I}, \qquad [R] = \Omega = \mathrm{V\,A^{-1}}.$$

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

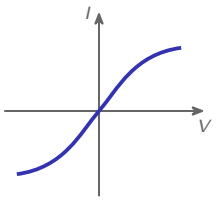
$R = V/I$ defines R for *any* component; only ohmic ones keep it constant.



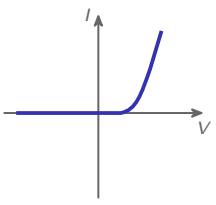
I–V characteristics



metal: straight



lamp: R rises

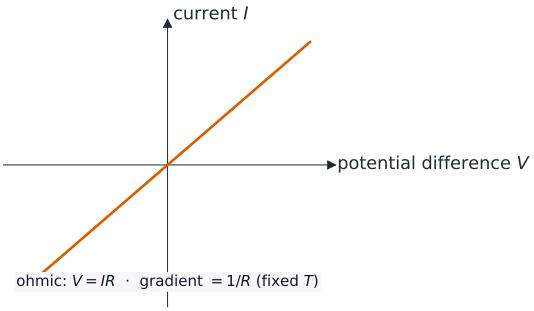


diode: switch-on

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

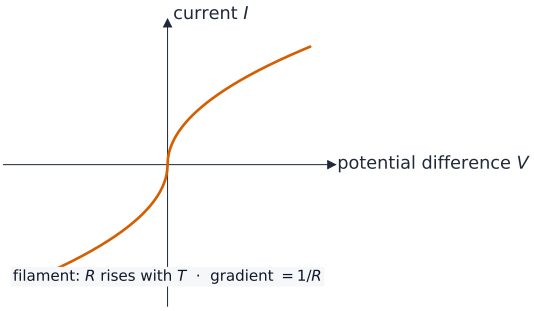
Characteristic 1 – a metal wire

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



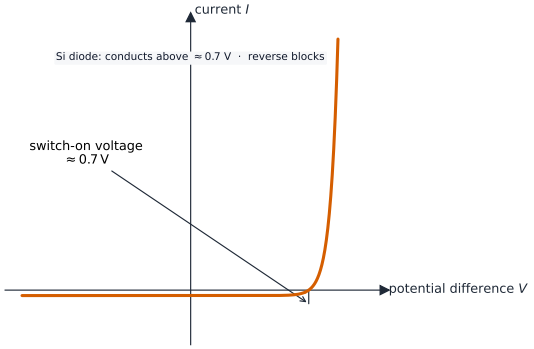
Characteristic 2 – a filament lamp

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



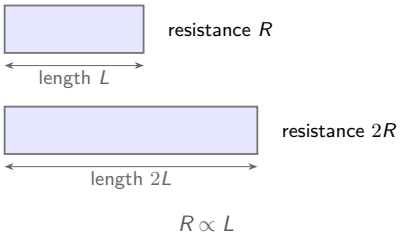
Characteristic 3 – a diode

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



Resistivity

same area A – twice the length gives twice R



$R \propto L$

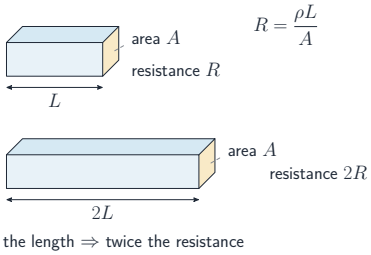
$$R = \frac{\rho L}{A}.$$

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

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

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

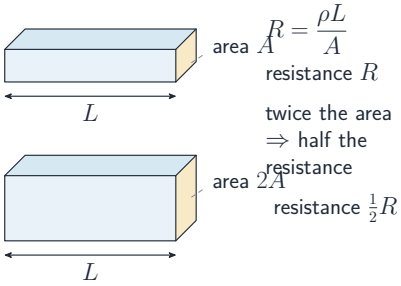
What $R = \rho L/A$ is saying



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

twice the length $\Rightarrow$ twice the resistance

Twice the length, twice the resistance.



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

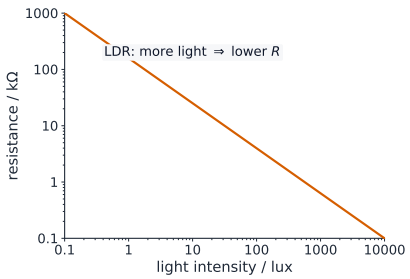
twice the area $\Rightarrow$ half the resistance

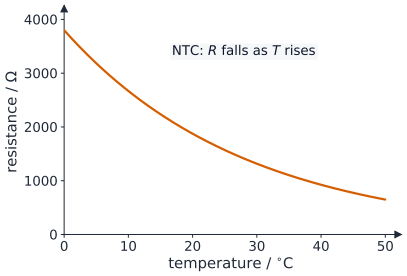
Twice the area, half the resistance.

> 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 frees more carriers – the opposite of a metal.

5 Recap

Topic 9 – key takeaways

1 Current

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

2 Power

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

3 Resistance

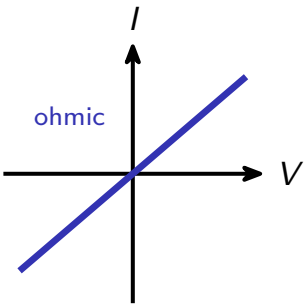
$R = V/I = \rho L/A$; Ohm's law if T constant

4 Sensors

LDR and thermistor: R falls with light / heat

Check yourself

1. Charge passing in $10\,\mathrm{s}$ at $2.0\,\mathrm{A}$?
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.** $Q = It = 20\,\mathrm{C}$ **2.** VI, I^2R, V^2/R **3.** R rises as it heats **4.** rises (to $\mathrm{M}\Omega$)