

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

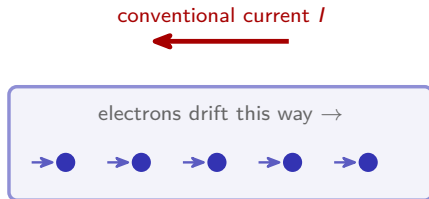
Current and charge

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

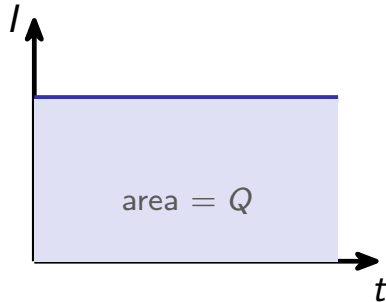
Charge is **quantised** 量子化: every free charge is a whole-number multiple of the **elementary charge** 基本电荷 $e = 1.60 \times 10^{-19} \text{ C}$, measured in **coulombs** 库仑. **Current** 电流 is the **rate of flow of charge** past a point:

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

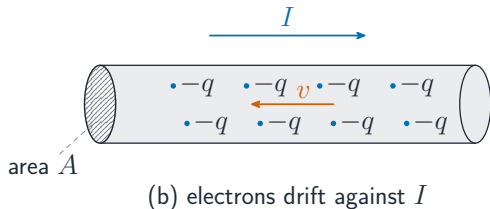
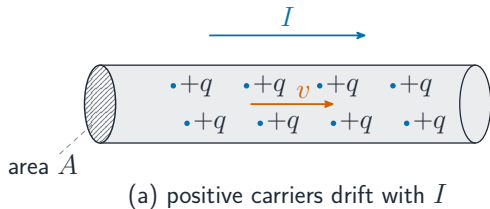
0.50 A for 2.0 min

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

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



Drift velocity



$$I = Anvq$$

A is the **cross-sectional area** 横截面积, n the **number density** 数密度 of carriers, q their charge and v the **drift velocity** 漂移速度.

A thinner wire at the same I needs a **faster** drift. In **series** 串联, I is the same everywhere, so nv must change to compensate.

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

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Potential difference and power

Potential difference and e.m.f.

Voltage 电压 is energy transferred per unit charge, measured in **volts** 伏特:

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

e.m.f. 电动势

energy given **to** the charge
by the source

p.d.

energy given **up** to a component

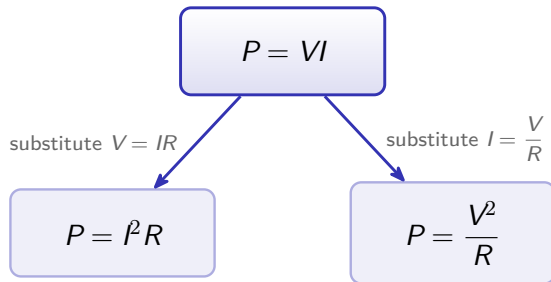
Electrical power

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

Pick the form for the quantities you know.

Kettle “2.4 kW, 240 V”

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



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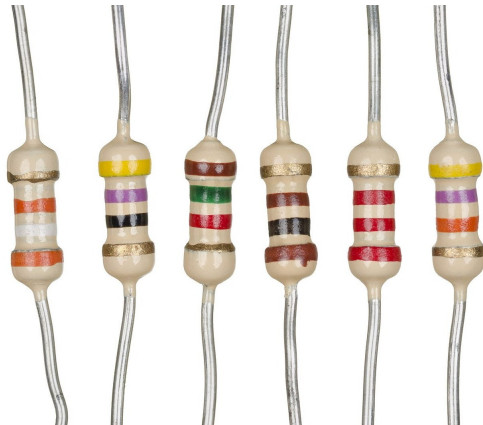
Resistance and Ohm's law

Resistance and Ohm's law

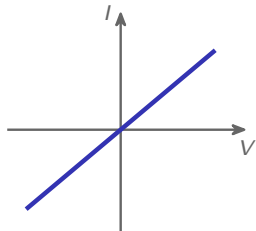
$$R = \frac{V}{I}, \quad [R] = \Omega = \text{V A}^{-1}.$$

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

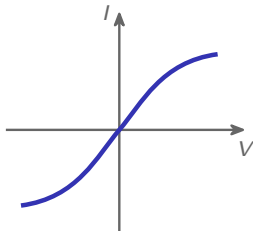
$R = V/I$ defines R for *any* component; only ohmic ones keep it constant. A metal's resistivity **rises** with temperature – more **lattice vibration** 晶格振动 **scatters** 散射 the electrons. An **insulator** 绝缘体 sits near $10^{15} \Omega \text{ m}$.



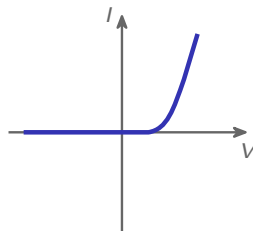
I - V characteristics



metal: straight



lamp: R rises

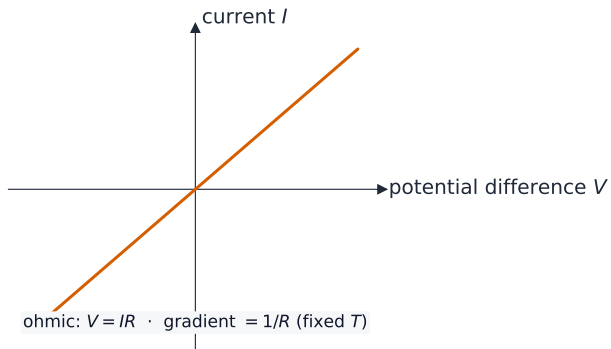


diode: switch-on

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

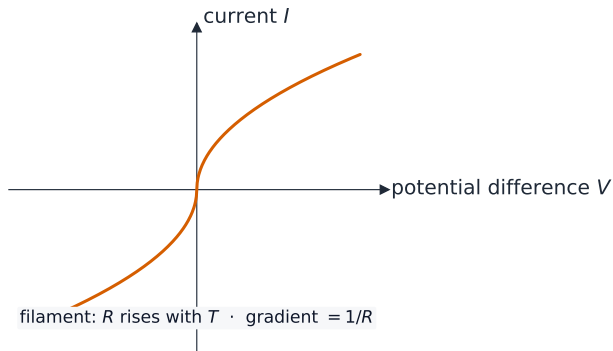
Characteristic 1 – a metal wire

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.

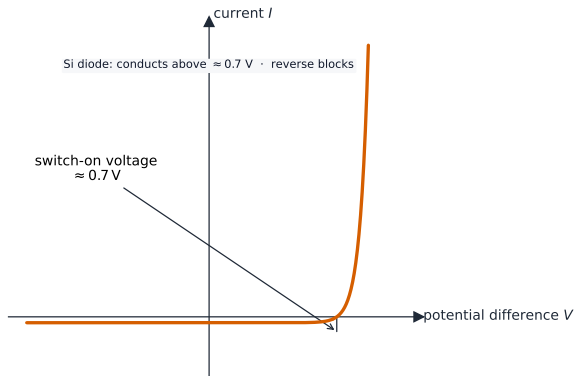


Characteristic 3 – a diode

A **semiconductor**

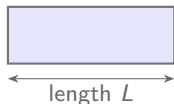
diode 半导体二极管 conducts **one way only**, and only above about 0.6 V.

In reverse the current is negligible until breakdown – which is why a diode can turn a.c. into d.c.

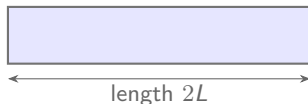


Resistivity

same area A – twice the length gives twice R



resistance R



resistance $2R$

$$R \propto L$$

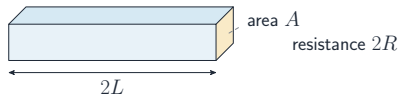
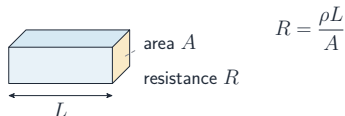
$$R = \frac{\rho L}{A}$$

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

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

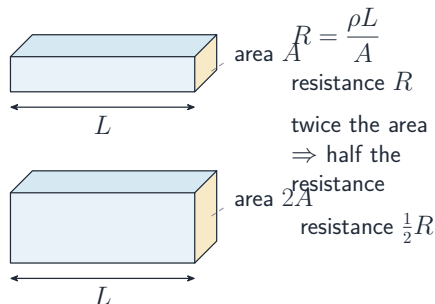
$$R = \frac{(1.7 \times 10^{-8})(2.0)}{1.7 \times 10^{-7}} = 0.20 \Omega$$

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



twice the length $\Rightarrow$ twice the resistance

Twice the length, twice the resistance.



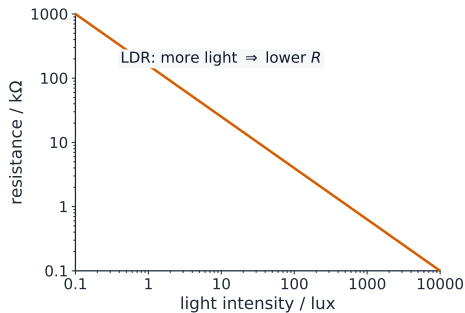
Twice the area, half the resistance.

ρ is the **resistivity** 电阻率, a property of the **material** alone, in $\Omega \text{ m}$; R also depends on the shape.

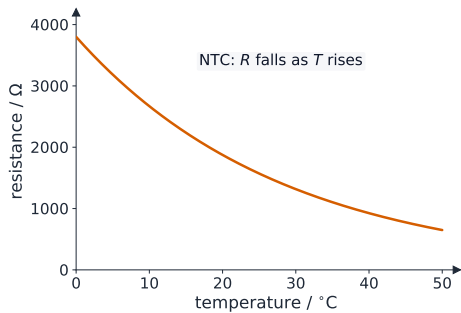
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Sensors

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

Both are semiconductors: light or heat **frees more carriers**, so R **falls** – the opposite of a metal.

Two words the definitions turn on

E.m.f.

The **electromotive force** 电动势 (e.m.f.) of a source is the energy given **per unit charge by the source**; potential difference is the energy *delivered* per unit charge to a component.

Potential divider

Put a thermistor or LDR in a **potential divider** 分压器 and the output voltage changes with temperature or light – the standard sensing circuit.

In parallel

Two resistors in **parallel** 并联 across the same **voltage** 电压: the *smaller* resistance takes more power, since $P = V^2/R$.

E.m.f. and p.d. share a unit and a symbol but not a meaning. Say “per unit charge” in both definitions, and name which way the energy goes.

Exam tips

- Use $I = Q/t$, $V = W/Q$ (energy per unit charge) and $P = VI = I^2R = V^2/R$.
- **Ohm's law** ($V = IR$) applies only to an ohmic conductor at constant temperature – a filament lamp is non-ohmic.
- Sketch and interpret the I - V **characteristics** of a resistor, filament lamp and diode.
- An **LDR's** resistance falls with light; a **thermistor's** falls as temperature rises.

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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

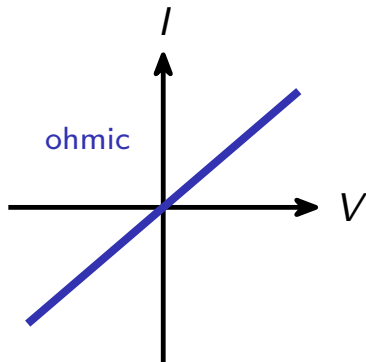
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Sensors

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 $M\Omega$)