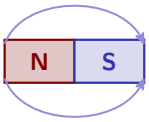
Electricity & Magnetism

IGCSE Physics ▪ Topic 4

IGCSE Physics



What we will cover

1 Magnetism & static

2 Current e.m.f. & resistance

3 Power & circuits

4 Electrical safety

5 Electromagnetic effects

6 Recap

1 Magnetism and static

Magnets and fields

- field lines run N to S outside a magnet and never cross
- closer lines ⇒ stronger field
- like poles repel; unlike poles attract

> A plotting compass's N pole points along the field. Iron filings line up on the same lines.

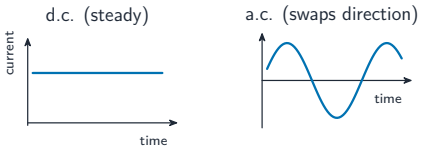
Static electricity

Charge is **electrons** 电子. Rubbing transfers them, so one object goes negative and the other positive.

> Only electrons move. Like charges repel; unlike attract. A charged object can attract a neutral one by induction.

2 Current and resistance

Electric current



Current 电流 $I = \dfrac{Q}{t}$ (A). **Conventional current** 常规电流 $+$ to $-$; electrons the other way.

$3.0\,\mathrm{A}$ for $20\,\mathrm{s}$

$Q = It = 60\,\mathrm{C}$

d.c. 直流电 one way; **a.c.** 交流电 swaps direction.

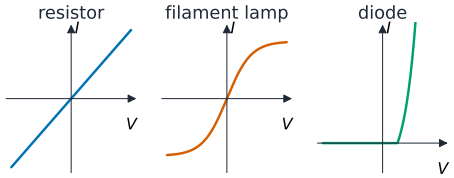
E.m.f., p.d. and resistance

- **e.m.f.** 电动势 & p.d.: $V = \dfrac{W}{Q}$ (volts)
- **resistance** 电阻 $R = \dfrac{V}{I}$ (Ω)
- $R \propto I$, $R \propto \dfrac{1}{A}$

$12\,\mathrm{V}$ drives $0.50\,\mathrm{A}$

$R = \dfrac{12}{0.50} = 24\,\Omega$

I–V graphs



- a longer wire has a bigger resistance – resistance is **directly proportional** 成正比 to length, $R \propto l$;
- a thicker wire has a smaller resistance – resistance is **inversely proportional** 成反比 to **cross-sectional area** 横截面积, $R \propto \dfrac{1}{A}$.

Electrical power and energy

$P = IV, \qquad E = IVt.$

12 V motor, 2.0 A, 30 s

$P = 24\,\mathrm{W}$, $E = Pt = 720\,\mathrm{J}$

Bills use the **kilowatt-hour** 千瓦时:
$\mathrm{kWh} = \mathrm{kW} \times \mathrm{h}$.

Electrical energy is metered and distributed safely

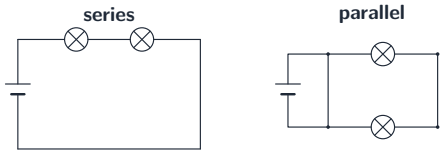
3 Circuits and safety

Circuit components

- cell / battery, lamp, switch, resistor, variable resistor
- **thermistor** 热敏电阻 (temperature) and **LDR** 光敏电阻 (light)
- ammeter in series; voltmeter in parallel

> $I = Q/t$, $V = W/Q$, $R = V/I$.

Series and parallel



- series: same current; $R = R_1 + R_2$
- parallel: same p.d.; $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

$6\,\Omega$ and $3\,\Omega$ in parallel

$\frac{1}{R} = \frac{1}{6} + \frac{1}{3} = \frac{1}{2} \Rightarrow R = 2\,\Omega$

Potential dividers and safety

A **potential divider** 分压器 shares the voltage:

$$\frac{R_1}{R_2} = \frac{V_1}{V_2}.$$

A thermistor/LDR makes the output change with temperature or light.

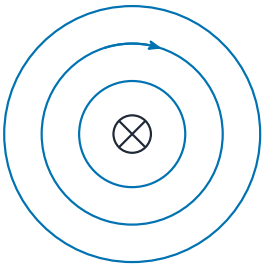
> Fuses and circuit breakers protect by cutting the current when it is too large – never rely on the appliance alone.

4 Electromagnetic effects

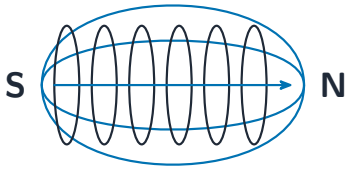
The magnetic effect of a current

A current makes a magnetic field – circles round a wire, bar-magnet-like for a **solenoid** 螺线管. Stronger with more current, more turns, or a soft-iron core.

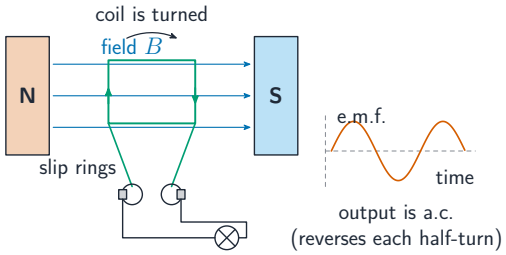
straight wire



solenoid (coil)

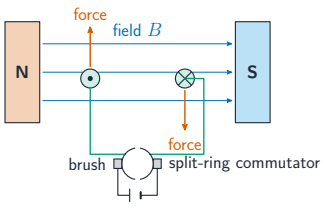


Electromagnetic induction & the generator



Move a wire across a field ⇒ an e.m.f. is **induced** 感应. An **a.c. generator** 交流发电机 spins a coil in a field; **slip rings** 滑环 carry the a.c. out. Bigger e.m.f. with a stronger magnet, faster spin, more turns.

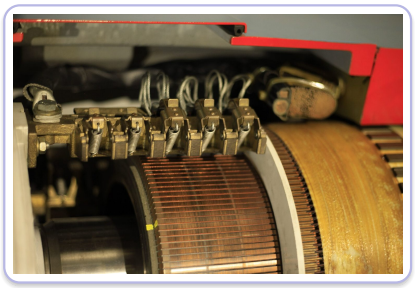
The motor effect and d.c. motor



the two forces form a couple that turns the coil

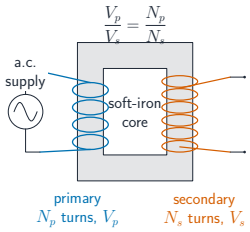
commutator 换向器 *keeps it turning*

Left-hand rule: thumb = force, first finger = field, second = current.



Motors convert electrical energy into motion

The transformer



$$\frac{V_p}{V_s} = \frac{N_p}{N_s}.$$

$N_p = 1200$, $N_s = 100$, $V_p = 240\,\text{V}$

$$V_s = \frac{240}{12} = 20\,\text{V}$$ (step-down)

High-voltage transmission

Power lost in cables is $P = I^2R$.

> Step up the voltage ⇒ lower current ⇒ far less wasted power. Step down again for homes.

5 Recap

Topic 4 – key takeaways

1 Current

$I = Q/t$; $R = V/I$; $P = IV$

2 Circuits

series adds R; parallel lowers it

3 Induction

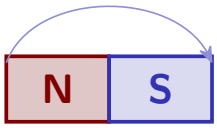
move a wire in a field → e.m.f.

4 Transformer

$V_p/V_s = N_p/N_s$; high V for transmission

Check yourself

1. Charge through a $2\,\mathrm{A}$ lamp in $10\,\mathrm{s}$?
2. Two $4\,\Omega$ resistors in parallel – combined R?
3. Which wire holds the switch and fuse?
4. Why send power at high voltage?



Answers **1.** $Q = It = 20\,\mathrm{C}$ **2.** $2\,\Omega$ **3.** the live wire **4.** lower current ⇒ less heat lost