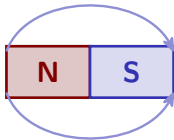


Electricity & Magnetism

IGCSE Physics ■ Topic 4

IGCSE Physics



From field patterns to complete circuit explanations

The teaching route

Describe the pattern → identify the physical change → choose the relation → calculate with units → check the result.

Scope: Cambridge IGCSE 0625, Topic 4, including Supplement. Questions and numerical practice are original unless a source is explicitly named.

1

Magnetism

Read the poles and predict the interaction



N–S attract



N–N repel

Like poles repel; unlike poles attract. Attraction can also occur between a magnet and unmagnetised iron.

Induced magnetism explains attraction

A north pole approaches iron

The nearer end of the iron becomes a south pole; the far end becomes north. Attraction follows between the nearer unlike poles.

Test the claim

Attraction alone does not prove the iron was already a permanent magnet. Repulsion between identified poles is stronger evidence.

Iron, steel, nickel and cobalt are magnetic materials in this syllabus. Copper, plastic and wood are classed as non-magnetic.

Temporary and permanent magnets

Soft iron 软铁

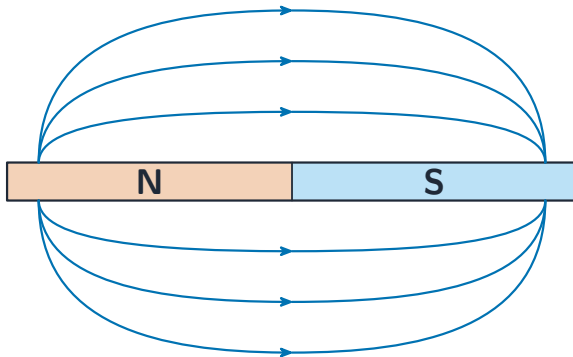
Easy to magnetise and loses most magnetism quickly. Suitable for a relay core that should release when current stops.

Steel 钢

Retains magnetism and is suitable for a permanent magnet, such as a magnetic catch.

Do not claim every core loses all magnetism instantaneously or that steel is the only possible permanent-magnet material.

Field direction and relative strength



Outside the magnet, lines run N to S. A compass north-seeking pole points along the local field; closer lines indicate a stronger field.

What iron filings reveal



Read the real example

Filings align to show a pattern. They do not supply arrows: a plotting compass is needed to determine field direction.

Maciej J. Mrowinski, CC BY-SA 4.0. The diagram and photograph describe the same field in different ways.

Your turn: select and justify

Original practice — attempt before the check

A magnetic catch should keep attracting when no power is supplied. A relay should release when its coil current stops. Choose steel or soft iron for each, and explain the property that makes it suitable.

Check: connect property to function

Catch: steel

Retained magnetism makes it suitable for a permanent catch. It does not require a continuously powered coil.

Relay: soft iron

Low remaining magnetism helps the relay release when the current stops. The current controls the electromagnet's field.

Explain the property and its use, not just the material name.

2

Static electricity

Repulsion between similarly charged hairs



Read the real example

Hairs acquire the same sign of charge and repel one another. The photograph alone does not tell us whether the sign is positive or negative.

U.S. Department of Energy, public domain. This is an observed effect, not evidence that positive nuclei moved between solids.

Charging by friction: track electrons

Rod gains electrons

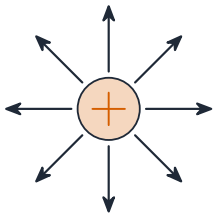
The rod becomes negatively charged because it gains negative electrons. The cloth losing them becomes positive.

Conserve charge

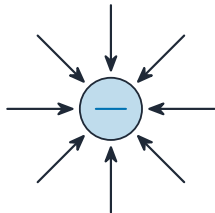
Electrons are transferred, not created. In this process, positive nuclei do not move from one solid to the other.

The direction of transfer depends on the materials. “Every plastic rod becomes negative” is too broad.

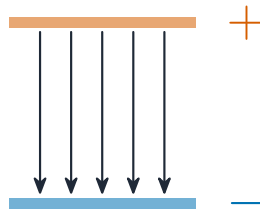
Read electric field arrows



positive charge



negative charge



parallel plates

Arrows show force on a positive test charge. A negative charge feels force in the opposite direction. Plate end effects are ignored.

Test attraction and repulsion

Charged and neutral

A charged rod can attract neutral paper through redistribution of charge. Attraction alone is not a reliable test of the sign.

A known charged reference

Repulsion from a known positive charge indicates positive charge; repulsion from a known negative charge indicates negative charge.

An atom losing electrons forms a positive ion; one gaining electrons forms a negative ion.

A low-voltage conductor test

- 1 Use a supervised cell-and-lamp circuit with a gap for the sample. First show it works with a known conductor.
- 2 Insert the sample with secure contacts. A lit lamp indicates sufficient current passes through the sample.
- 3 If the lamp remains off, check contacts and the circuit before concluding that the sample is an insulator.

Metals conduct through mobile electrons. In insulators, electrons are not free to move through the material in the same way.

Your turn: explain a charge observation

Original practice — attempt before the check

A rod gains electrons from a cloth. It then attracts uncharged paper but repels a second rod. State the first rod's sign, explain the cloth's sign, and identify the sign of the second rod.

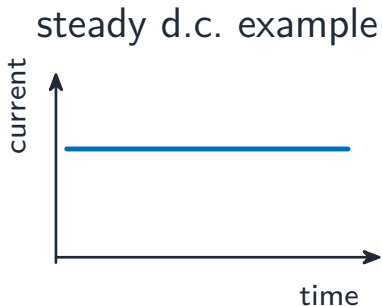
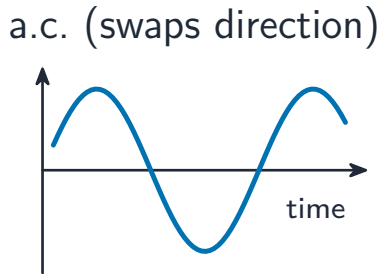
Check: separate transfer and interaction

- 1 The first rod is negative because it gained electrons.
- 2 The cloth is positive because it lost electrons; charging transferred existing charge.
- 3 Repulsion shows the second rod has the same sign: negative. Neutral paper can still be attracted.

3

Electric current

Direction is the distinction between d.c. and a.c.



The illustrated d.c. is steady, but d.c. can vary in magnitude while remaining one-directional. A.c. reverses direction.

Current and electron motion

Electric current 电流

Charge passing a point per unit time. Conventional current in the external circuit is from positive to negative.

Conduction in a metal

Free electrons drift in the opposite direction. Their flow is not the same direction as conventional current.

An ammeter measures current in amperes and is connected in series.

Worked example: charge through a lamp

Known and why this relation applies

$I = 3.0 \text{ A}$, $t = 20 \text{ s}$. Current is charge per unit time; rearrange to find charge.

$$I = \frac{Q}{t}$$

$$Q = It$$

$$Q = (3.0 \text{ A})(20 \text{ s}) = 60 \text{ C}$$

Your turn: find charge with a time conversion

Original practice — attempt before the check

A current of 0.40 A flows for 2.0 minutes. Calculate the charge passing a point. Show the relation, conversion and substitution with units.

Check: convert minutes before substituting

Known and why this relation applies

$I = 0.40 \text{ A}$; $t = 2.0 \text{ minutes}$. Use seconds because an ampere is a coulomb per second.

$$t = 2.0 \times 60 \text{ s} = 120 \text{ s}$$

$$Q = It$$

$$Q = (0.40 \text{ A})(120 \text{ s}) = 48 \text{ C}$$

4

E.m.f. and potential difference

Where the voltmeters are connected

terminal p.d.
across the cell



p.d.
across the lamp

Both meters measure p.d. The cell terminal p.d. equals e.m.f. for the ideal cell assumed in this diagram.

Two uses of energy per unit charge

Electromotive force 电动势

Work done by a source per unit charge around the complete circuit. It is measured in volts.

Potential difference

Work done per unit charge passing through a component. A voltmeter is connected in parallel across it.

Use context and units: the syllabus symbol E can denote e.m.f. in volts or energy in joules in different equations.

Worked example: energy supplied per coulomb

Known and why this relation applies

$W = 120 \text{ J}$ supplied to $Q = 60 \text{ C}$. E.m.f. is work done by the source per unit charge.

$$E = \frac{W}{Q}$$

$$E = \frac{120 \text{ J}}{60 \text{ C}} = 2.0 \text{ V}$$

Meter connection and range

Meter

Connection and choice

Ammeter

Series; low resistance so it changes current as little as possible.

Voltmeter

Parallel; high resistance so it draws little current.

Range

Start high enough to avoid overloading; then choose a suitable lower range that includes the reading.

Analogue meters have a pointer and scale; digital meters show a number. A smaller range does not automatically guarantee accuracy.

5

Resistance

Relate the symbol to a real resistor



Read the real example

Coloured bands identify resistance. A fixed resistor approximates constant resistance when its temperature remains constant.

Afrank99, CC BY-SA 2.5. For a fixed p.d., increasing resistance reduces current.

Worked example: resistance at an operating point

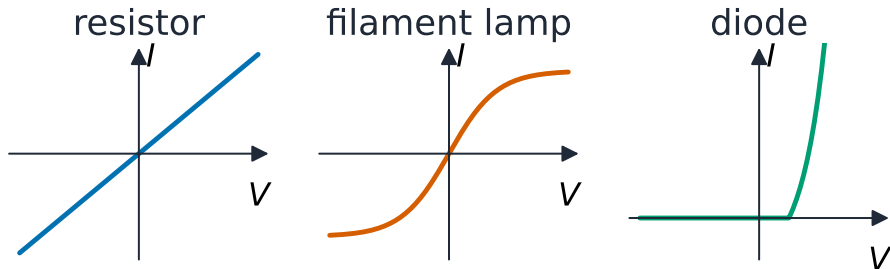
Known and why this relation applies

$V = 12 \text{ V}$ and $I = 0.50 \text{ A}$. Resistance is the ratio of p.d. to current at this point.

$$R = \frac{V}{I}$$
$$R = \frac{12 \text{ V}}{0.50 \text{ A}} = 24 \Omega$$

A filament lamp's resistance can change as it heats; this is not a claim that 24 ohms holds at every voltage.

Identify the characteristic, then explain it



resistor (ohmic): $V = IR$ straight · filament: resistance rises with heat · diode: one-way

I is vertical and V horizontal. The ohmic straight-line gradient is $1/R$; with axes reversed it would be R .

Original measurements for an ohmic resistor

P.d. V	Current I
2.0 V	0.10 A
4.0 V	0.20 A
6.0 V	0.30 A

Temperature is held constant. Use the table to calculate resistance and describe the relationship.

Check: the measurements give one resistance

Known and why this relation applies

$V = 4.0 \text{ V}$ and $I = 0.20 \text{ A}$ from the table. Use the ratio, then compare with the other readings.

$$R = \frac{V}{I}$$
$$R = \frac{4.0 \text{ V}}{0.20 \text{ A}} = 20 \Omega$$

All three pairs give 20 ohms. Doubling V doubles I at constant temperature.

Explain non-ohmic behaviour

Filament lamp

Increasing current heats the filament. Its resistance rises, so I increases less rapidly as V increases. The I - V curve becomes less steep.

Diode

Current is substantial in the forward direction and very small in reverse in the normal operating range. The curve is not a straight line through the origin.

Do not average a lamp's resistance across different temperatures and call it a single constant resistance.

Your turn: change the wire geometry

Original practice — attempt before the check

For wires of the same metal at the same temperature, compare a wire with twice the length and one with twice the cross-sectional area with the original wire. State what must be kept unchanged in each comparison.

Check: change one variable at a time

Twice the length

With cross-sectional area unchanged, resistance doubles because resistance is directly proportional to length.

Twice the area

With length unchanged, resistance halves because resistance is inversely proportional to cross-sectional area.

Doubling diameter is not the same as doubling area; area depends on diameter squared.

6

Electrical energy and power

Worked example: motor power

Known and why this relation applies

$V = 12\text{ V}$ and $I = 2.0\text{ A}$. Electrical power is the rate of energy transfer.

$$P = IV$$

$$P = (2.0\text{ A})(12\text{ V}) = 24\text{ W}$$

Worked example: energy transferred by the motor

Known and why this relation applies

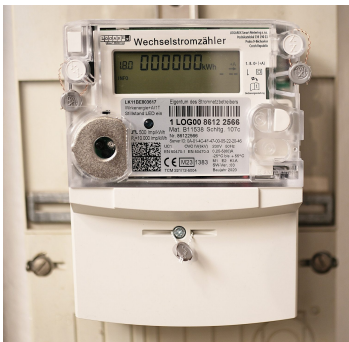
$P = 24 \text{ W}$ and $t = 30 \text{ s}$. Energy transferred equals power multiplied by time.

$$E = Pt$$

$$E = (24 \text{ W})(30 \text{ s}) = 720 \text{ J}$$

Equivalently $E = IVt$. Electrical energy input need not all become useful mechanical output.

A meter measures accumulated energy



Read the real example

A kilowatt-hour is energy, not power. Billing uses the change in the meter reading together with the tariff.

RobbielanMorrison, CC BY 4.0. One kWh is the energy transferred at 1 kW for 1 hour.

Worked example: energy in kilowatt-hours

Known and why this relation applies

$P = 2 \text{ kW}$ and $t = 3 \text{ h}$. For kWh, use power in kW and time in hours.

$$E = Pt$$

$$E = (2 \text{ kW})(3 \text{ h}) = 6 \text{ kWh}$$

Worked example: a fictional energy charge

Known and why this relation applies

$E = 6 \text{ kWh}$; price = 20 cents per kWh. Multiply the energy by the price per unit of energy.

$$\text{cost} = E \times \text{price per kWh}$$

$$\text{cost} = (6 \text{ kWh})(20 \text{ cents/kWh}) = 120 \text{ cents}$$

The tariff is invented for this calculation, not a current electricity price.

Your turn: choose consistent time and power units

Original practice — attempt before the check

A 60 W lamp is used for 5.0 h. Find its energy use in kWh. At a fictional 20 cents per kWh, find the energy charge.

Check: watts must become kilowatts

Known and why this relation applies

$P = 60 \text{ W} = 0.060 \text{ kW}$; $t = 5.0 \text{ h}$. Use kW and hours for energy in kWh.

$$E = Pt$$

$$E = (0.060 \text{ kW})(5.0 \text{ h}) = 0.30 \text{ kWh}$$

$$\text{cost} = E \times \text{price per kWh}$$

$$\text{cost} = (0.30 \text{ kWh})(20 \text{ cents/kWh}) = 6.0 \text{ cents}$$

7

Circuits

Circuit symbols: sources, control and measurement



cell



battery



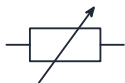
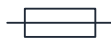
switch



lamp



resistor

variable
resistor

fuse



ammeter

Identify the cell, battery, switch, lamp, resistors, fuse and ammeter. Explain how the switch changes the conducting path.

Circuit symbols: sensors, diode and machines



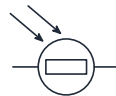
voltmeter



diode



thermistor



LDR



LED



motor

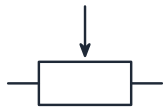


generator

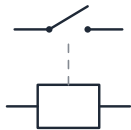
a.c. power
supply

A voltmeter measures across a component; NTC and LDR resistance respond to their surroundings. An LED emits light in forward conduction.

Circuit symbols: changing voltage and magnetic control



potential
divider



relay



transformer



magnetising
coil

A potential divider selects an output p.d.; a relay controls separate contacts; a transformer links coils through a changing magnetic field.

Sensors and one-way components

NTC thermistor and LDR

For the NTC thermistor studied here, resistance falls when temperature rises. LDR resistance falls when light intensity rises.

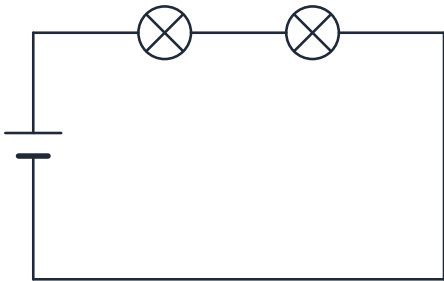
Diode and LED

A diode conducts mainly one way. An LED also emits light when forward current flows; current must be limited in a circuit.

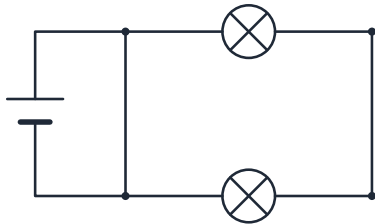
A component's behaviour must be related to where it is connected, not just memorised as a label.

One path or separate branches?

series



parallel



Series: same current and shared supply p.d. Parallel: same p.d. across each branch and currents add at junctions.

Your turn: two fixed resistors in series

Original practice — attempt before the check

An ideal 6.0 V source supplies fixed $2.0\ \Omega$ and $4.0\ \Omega$ resistors in series. Find total resistance, current and the p.d. across each resistor. Assume constant temperature.

Check: total resistance and current in series

Known and why this relation applies

$V = 6.0 \text{ V}$, $R_1 = 2.0 \Omega$, $R_2 = 4.0 \Omega$. One path means resistances add; then use the whole-circuit p.d.

$$R_T = R_1 + R_2$$

$$R_T = 2.0 \Omega + 4.0 \Omega = 6.0 \Omega$$

$$I = \frac{V}{R_T}$$

$$I = \frac{6.0 \text{ V}}{6.0 \Omega} = 1.0 \text{ A}$$

Check: the two p.d.s add to the supply

Known and why this relation applies

$I = 1.0 \text{ A}$ in both resistors. Each p.d. is current multiplied by that resistor's resistance.

$$V_1 = IR_1$$

$$V_1 = (1.0 \text{ A})(2.0 \Omega) = 2.0 \text{ V}$$

$$V_2 = IR_2$$

$$V_2 = (1.0 \text{ A})(4.0 \Omega) = 4.0 \text{ V}$$

The two p.d.s total 6.0 V. Charge is conserved; current is not used up by the first resistor.

Your turn: move the resistors to parallel branches

Original practice — attempt before the check

Connect the same fixed $2.0\ \Omega$ and $4.0\ \Omega$ resistors in parallel across the ideal $6.0\ \text{V}$ source. Find each branch current and the current from the source.

Check: each branch has the full p.d.

Known and why this relation applies

$V = 6.0 \text{ V}$ across each branch. Apply the resistance relation separately to each branch.

$$I_1 = \frac{V}{R_1}$$

$$I_1 = \frac{6.0 \text{ V}}{2.0 \Omega} = 3.0 \text{ A}$$

$$I_2 = \frac{V}{R_2}$$

$$I_2 = \frac{6.0 \text{ V}}{4.0 \Omega} = 1.5 \text{ A}$$

Check: junction currents add

Known and why this relation applies

$I_1 = 3.0 \text{ A}$ and $I_2 = 1.5 \text{ A}$. Charge entering a junction equals charge leaving it.

$$I_T = I_1 + I_2$$

$$I_T = 3.0 \text{ A} + 1.5 \text{ A} = 4.5 \text{ A}$$

The supply current exceeds either branch current. Separate switches can control parallel lamps independently.

Worked example: combined parallel resistance

Known and why this relation applies

$R_1 = 6.0\ \Omega$, $R_2 = 3.0\ \Omega$. Use the reciprocal relation because both branches have the same p.d.

$$\begin{aligned}\frac{1}{R_T} &= \frac{1}{R_1} + \frac{1}{R_2} \\ \frac{1}{R_T} &= \frac{1}{6.0\ \Omega} + \frac{1}{3.0\ \Omega} = \frac{1}{2.0\ \Omega} \\ R_T &= 2.0\ \Omega\end{aligned}$$

Two parallel paths give a combined resistance smaller than either resistor.

Cells and potential dividers

Cells in series

When the cells point the same way, their e.m.f.s add. Opposed cells subtract. Read long and short lines before adding values.

Two series resistors

They carry the same current, so the larger resistance has the larger p.d. Their p.d.s add to the supply.

For a divider: $R_1/R_2 = V_1/V_2$. State which component the output is measured across.

Your turn: a temperature-dependent output

Original practice — attempt before the check

An ideal 6.0 V source supplies a fixed $2.0\text{ k}\Omega$ resistor in series with an NTC thermistor. The unloaded output is across the thermistor. Find the output when its resistance is $4.0\text{ k}\Omega$, then $1.0\text{ k}\Omega$.

Check: cool thermistor, larger output share

Known and why this relation applies

$R_F = 2.0 \text{ k}\Omega$, $R_T = 4.0 \text{ k}\Omega$, $V_S = 6.0 \text{ V}$. The resistance and p.d. ratios are equal; p.d.s sum to the supply.

$$\frac{V_F}{V_T} = \frac{R_F}{R_T}$$

$$\frac{V_F}{V_T} = \frac{2.0 \text{ k}\Omega}{4.0 \text{ k}\Omega} = \frac{1}{2}$$

$$V_S = V_F + V_T = \frac{1}{2}V_T + V_T$$

$$V_T = \frac{V_S}{1.5} = \frac{6.0 \text{ V}}{1.5} = 4.0 \text{ V}$$

Check: warmer thermistor, smaller output share

Known and why this relation applies

$R_F = 2.0 \text{ k}\Omega$, $R_T = 1.0 \text{ k}\Omega$, $V_S = 6.0 \text{ V}$. The output is still across the thermistor; its share now falls.

$$\frac{V_F}{V_T} = \frac{R_F}{R_T}$$

$$\frac{V_F}{V_T} = \frac{2.0 \text{ k}\Omega}{1.0 \text{ k}\Omega} = 2$$

$$V_S = V_F + V_T = 2V_T + V_T$$

$$V_T = \frac{V_S}{3} = \frac{6.0 \text{ V}}{3} = 2.0 \text{ V}$$

Output depends on where it is measured

Across the NTC thermistor

Warming lowers its resistance. Its share of the supply p.d. falls: the worked example gives 4 V, then 2 V.

Across the fixed resistor

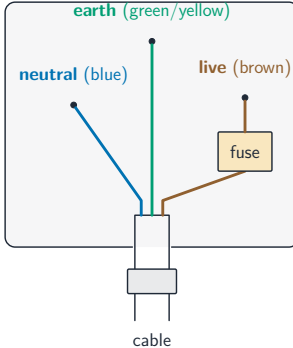
The fixed resistor takes the remaining share. Its p.d. rises from 2 V to 4 V. The two p.d.s still total 6 V.

The output is unloaded in this model. A variable potential divider changes the output by moving a contact.

8

Electrical safety

Identify the live connection in the diagram



The three insulated wires are separate. The switch and fuse belong in the live wire. This diagram supports identification, not a mains practical.

Hazards: explain the dangerous effect

Damaged insulation and dampness

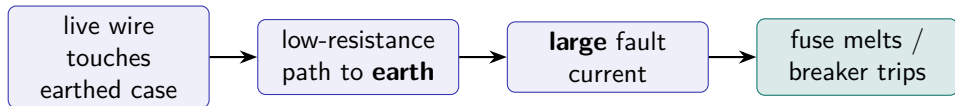
Exposed conductors can allow shock; damp conditions can reduce resistance through a person. A dangerous current path may result.

Overloading

Excess current heats cables and can cause fire. Adding appliances can exceed the socket or lead's rating.

A switch being off is not proof that equipment is safely isolated for work.

Earthing and protection work together



- 1 A live conductor touching an earthed metal case creates a fault path through the earth connection.
- 2 The low-resistance path allows a large fault current to operate a fuse or suitable circuit breaker.
- 3 The protective device disconnects the supply, limiting the fault duration. It is not correct to say the case can never briefly become live.

A fuse melts; an overcurrent breaker trips and can be reset after the fault is corrected. Their operating times depend on the device and fault.

Different protection devices have different jobs



Read the real example

An MCB responds to overcurrent.
An RCD detects imbalance
between live and neutral currents.
Its printed current ratings describe
different properties.

Evry Electrical, CC BY 4.0. An RCD does not replace all other protection or make every electrical fault safe.

Double insulation and fuse choice

Double-insulated appliance

Double or reinforced insulation separates the user from live parts. A non-conducting outer case is common, but plastic appearance alone is not proof. No protective earth is required.

Fuse rating in exam problems

Choose a supplied rating above normal current that also suits the stated cable/appliance limits. The fuse still protects cabling in a double-insulated appliance.

For actual equipment, use its specified protection. “The next larger fuse always works” is not a universal practical rule.

Your turn: choose from supplied fuse ratings

Original practice — attempt before the check

In an exam model, an appliance normally draws 2.0 A . Available fuses are 1 A , 3 A and 13 A ; the cable is rated at 5 A . Choose a suitable fuse and explain why the other options are unsuitable.

Check: normal current and cable limit

Choice and reasons

The 3 A fuse exceeds the normal 2.0 A current and is below the cable's 5 A limit.
The 1 A rating is below normal operation; 13 A exceeds the stated cable limit.

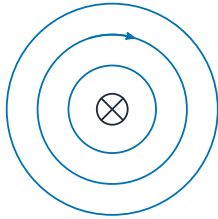
The task supplies a simplified model. No mains demonstration is required.

9

Electromagnetic effects

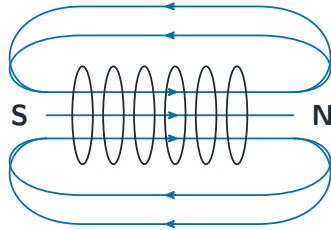
A current produces a magnetic field

straight wire



current into page;
field is circles round it

solenoid (coil)



field like a bar magnet

Right-hand grip: thumb follows conventional current, fingers follow the field around a straight wire. For a solenoid, fingers follow coil current and thumb points to its north end.

Change field strength or direction

Straight wire

More current strengthens the field.
It is weaker farther from the wire.
Reversing current reverses the circular field direction.

Solenoid

At fixed length, more current or more turns strengthens the field. A soft-iron core increases it; reversing current swaps the poles.

Filings show pattern; a plotting compass supplies direction. Keep measurement position unchanged when comparing strength.

Apply the effect in a relay and loudspeaker

Relay

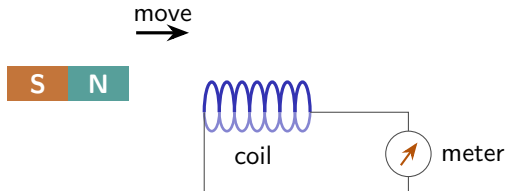
A small coil current magnetises a soft-iron core, moving contacts in a separate circuit that can carry a larger current.

Loudspeaker

Changing coil current in a magnetic field reverses or varies the force. The coil and cone vibrate, moving air to produce sound.

Magnetic forces arise through interactions of fields. The relay's separate circuits are electrically distinct.

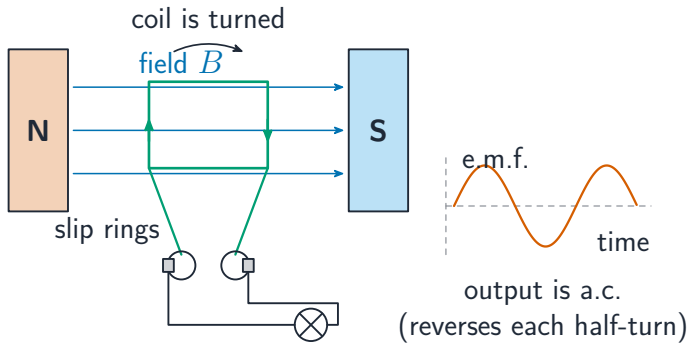
Demonstrate electromagnetic induction



- 1 Connect a coil to a sensitive meter. Move a magnet towards it: the meter deflects while the field linking the coil changes.
- 2 Hold the magnet still relative to the coil: no sustained deflection. Withdraw it: deflection reverses.
- 3 Faster motion, a stronger magnet or more coil turns can produce a larger induced e.m.f.

A changing field induces e.m.f.; a closed conducting path is required for an induced current. The induced effect opposes the change causing it.

An a.c. generator converts mechanical energy



Slip rings and brushes connect the rotating coil to the external circuit. The waveform is schematic; its starting phase depends on the specified coil position.

Relate coil position to the output

Coil plane relative to field

Perpendicular

Parallel

After another half-turn

E.m.f. at constant rotation speed

Zero: the rate of change of field linkage is momentarily zero.

Maximum magnitude: the rate of change of linkage is greatest.

The same magnitude at a corresponding position, with opposite polarity.

Use the field as a reference. “Flat” and “upright” have no fixed meaning when the drawing is rotated.

Your turn: time a generator cycle

Original practice — attempt before the check

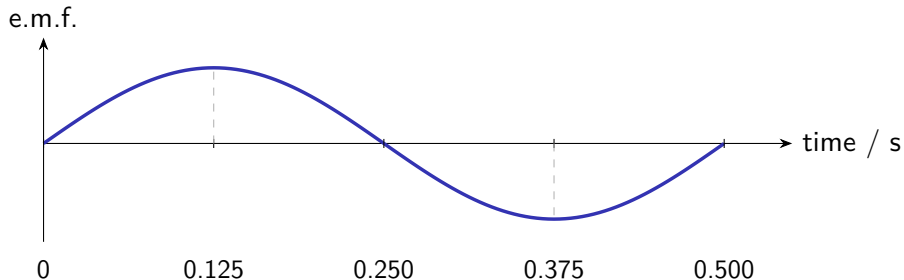
A coil turns twice per second. Its plane starts perpendicular to the field at $t = 0$. State the times of the next peak, zero, opposite peak and return to the starting position. Choose the first peak as positive.

Check: one turn takes half a second

Time	Position in the cycle / e.m.f.
0 s	Start / zero
0.125 s	Quarter-turn / positive peak
0.250 s	Half-turn / zero
0.375 s	Three-quarter-turn / negative peak
0.500 s	Full turn / zero

Reverse rotation or terminal reference and the signs reverse. The period remains 0.50 s.

Sketch the generator output from a stated start



One turn takes 0.50 s. The coil starts with its plane perpendicular to the field, so e.m.f. starts at zero. Peak height is schematic; no voltage amplitude is supplied.

Use the hand rule for the quantity being predicted

Motor effect: left hand

Given conventional current and magnetic field, predict force.

Thumb: force; first finger: field; second finger: current.

Induction: right hand

Given conductor motion and field, predict induced conventional current in a closed path. Thumb: motion; first finger: field; second finger: current.

Use conventional current for the fingers. Electron motion is in the opposite direction.

Your turn: motion, field and induced current

Original practice — attempt before the check

A straight conductor moves upward across a magnetic field directed to the right. It is connected in a closed circuit. Use the right-hand rule to determine whether induced conventional current is into or out of the page.

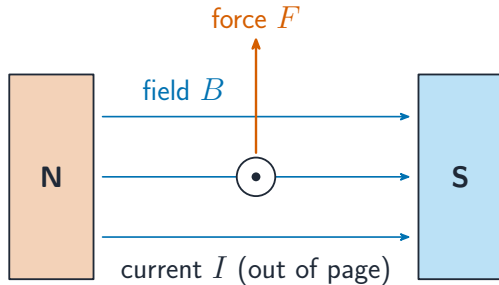
Check: induction opposes the motion causing it

Predict and verify

Right hand: thumb upward for motion, first finger right for field. The second finger points into the page, giving induced conventional current into the page.

Check the opposing effect: a current into the page in a rightward field has a downward motor-effect force. This opposes the upward motion that caused induction.

Determine the motor-effect force direction



F , B and I are all at 90° (Fleming's left-hand rule)

Conventional current out of the page and field to the right give upward force. Current parallel to the field gives no motor-effect force.

Your turn: reverse current and field

Original practice — attempt before the check

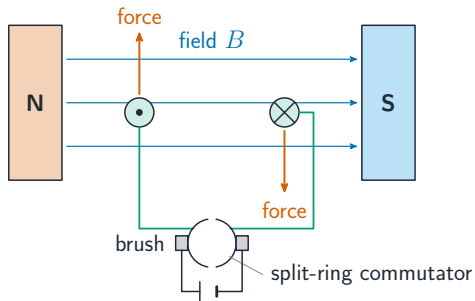
Use the wire diagram: current is out of the page, field is right, force is up.
Predict the force if only current reverses, only field reverses, and both reverse.

Check: one reversal or two?

Change	Force direction
Current only	Down
Field only	Down
Current and field	Up: the two reversals cancel

Left hand: thumb force, first finger field, second finger conventional current. For an electron beam, conventional current is opposite electron motion.

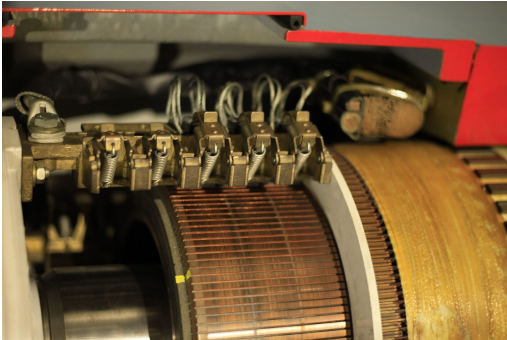
Opposite forces turn the motor coil



the two forces form a couple that turns the coil

A split-ring commutator reverses current in the coil each half-turn, maintaining the turning direction. More turns, current or field strength increases the turning effect.

Recognise commutator and brushes

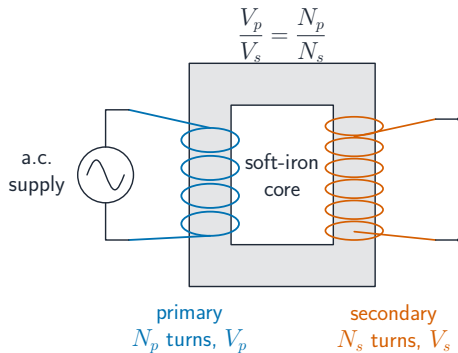


Read the real example

Stationary carbon brushes contact rotating commutator segments. They maintain the electrical connection as the coil turns.

Christian Kral, CC BY 4.0. A generator's slip rings and a motor's split-ring commutator have different roles.

A changing primary field links the secondary



The soft-iron core links the coils. A changing field is needed: steady d.c. does not give a sustained secondary output.

Worked example: secondary voltage

Known and why this relation applies

$V_p = 240 \text{ V}$, $N_p = 1200$, $N_s = 100$. Use the ideal voltage-to-turns ratio and rearrange.

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

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

$$V_s = (240 \text{ V}) \frac{100}{1200} = 20 \text{ V}$$

Fewer secondary turns give a lower secondary voltage: a step-down transformer.

Worked example: ideal input current

Known and why this relation applies

$V_p = 240 \text{ V}$, $V_s = 20 \text{ V}$, $I_s = 3.0 \text{ A}$. For 100% efficiency, input power equals output power.

$$I_p V_p = I_s V_s$$

$$I_p = \frac{I_s V_s}{V_p}$$

$$I_p = \frac{(3.0 \text{ A})(20 \text{ V})}{240 \text{ V}} = 0.25 \text{ A}$$

At equal power, lower voltage means higher current; energy is conserved.

A real transformer near consumers



Read the real example

A distribution transformer reduces a higher network voltage to domestic supply voltage. The output is still hazardous mains electricity.

Bidgee, CC BY 3.0. The photograph shows hardware; it does not supply a turns ratio or measured efficiency.

Why transmit at high voltage?



Read the real example

At fixed transmitted power, $P = IV$ means higher voltage requires lower current. With cable resistance unchanged, $P_{\text{loss}} = I^2 R$ then falls.

Simon Koopmann, CC BY-SA 3.0 de. High voltage does not itself lower the cable's resistance.

Your turn: compare transmission losses

Original practice — attempt before the check

The same power is transmitted through cables of the same resistance. Voltage is increased by a factor of ten. Explain the factors by which current and heating loss change.

Check: square the current change

Known and why this relation applies

$P_{\text{transmitted}}$ and cable R are unchanged; $V_{\text{new}} = 10V_{\text{old}}$. Rearrange $P=IV$, then compare I -squared losses.

$$I = \frac{P_{\text{transmitted}}}{V}$$

$$I_{\text{new}} = \frac{P_{\text{transmitted}}}{10V_{\text{old}}} = \frac{I_{\text{old}}}{10}$$

$$P_{\text{loss}} = I^2 R$$

$$P_{\text{loss,new}} = \left(\frac{I_{\text{old}}}{10} \right)^2 R = \frac{P_{\text{loss,old}}}{100}$$

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Exam tips

Diagnose a circuit explanation

Claim

“Current is used up.”

“The gradient is resistance.”

“A.c. and d.c. differ in size.”

“A field means induction.”

What must be checked

Charge is conserved; energy is transferred.

Which variable is on each axis?

Do they reverse direction?

Is field linkage changing?

State the condition, use the relevant relation and give units. Check physical sense after calculating.

Sources and demand grounding

Scope: local Cambridge IGCSE 0625 syllabus extracts 4.1–4.5, including Supplement.

Demand spot-check: June 2025 Paper 41 Q6–8 and official schemes: magnetic materials, graph identification, resistance, timed energy, branch currents, generator phase, turns ratio and transmission.

This deck's practice is original. Safety checks: Electrical Safety First, HSE and ASE; full links and image credits are in the handout and metadata. Existing animations remain available in the handout.

Check yourself

- 1 Explain why attraction alone does not prove permanent magnetism.
- 2 Calculate the charge for 2.0 A over 10 s .
- 3 Explain current and p.d. rules for series and parallel circuits.
- 4 Distinguish a motor commutator and generator slip rings.
- 5 Explain high-voltage transmission using fixed power and cable resistance.