

2 · Electricity

AQA · GCSE · Physics

Electricity: energy on demand

Press a switch and a lamp lights. Behind that instant is a chain: charge pushed by a potential difference, through wires and components, transferring energy from power station to bulb. This reference covers **AQA GCSE Physics 8463, topic 4.2 Electricity**.

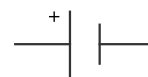
Start with a simple question: a cell, switch and lamp form a series loop. Why does opening the switch stop sustained current? When it is closed, does the lamp use up charge?

The switch must complete a conducting path, and the cell provides a **potential difference**. In a steady series loop the current is the same before and after the lamp. The lamp transfers energy; charge is not consumed. Later calculations link $Q = It$, $E = QV$, $P = VI$ and $E = Pt$.

This reference uses standard **circuit symbols** and the **Physics Equations Sheet** when supplied for the examination. Use the sheet issued for your examination series; practise choosing and rearranging equations rather than assuming every future paper has the same support. AQA uses “potential difference” in questions and accepts correct use of “voltage”. Static electricity and electric fields are physics-only content.

Circuit diagrams, charge and current

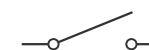
A circuit diagram uses standard symbols. Know these: cell, battery, switch (open, closed), lamp, resistor, variable resistor, ammeter, voltmeter, diode, LED, thermistor, LDR and fuse. Ammeters sit **in series**; voltmeters sit **in parallel** across the component.



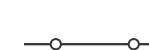
cell



battery



switch (open)



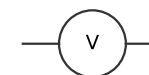
switch (closed)



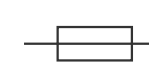
lamp



ammeter



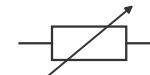
voltmeter



fuse



resistor



variable resistor



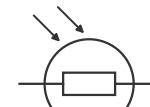
diode



LED



thermistor



LDR

Use repeated long/short plate pairs for a battery; light arrows enter an LDR and leave an LED.

For charge to flow, the circuit must be **closed** and include a source of potential difference. **Electric current** is a flow of electrical **charge**, and its size is the rate of flow:

$$Q = It$$

- Q charge flow in coulombs, C; I current in amperes, A; t time in **seconds**, s.
- Current has the same value at every point of a single series loop.
- Conventional current flows from + to –; electrons flow the opposite way.

■ **Worked reasoning: charge is not current**

Teacher-written: 4.0 C passes a point in 2.0 s in a steady series circuit. Current is charge flow per second:

$$Q = It \Rightarrow I = Q/t$$

$$I = Q/t = 4.0 \text{ C}/(2.0 \text{ s}) = 2.0 \text{ A}$$

One ampere means one coulomb per second. The same 4.0 C passes another point of that steady loop in the same 2.0 s. If the same charge takes 4.0 s instead:

$$I = Q/t = 4.0 \text{ C}/(4.0 \text{ s}) = 1.0 \text{ A}$$

Doubling the time for the same charge halves the current.

■ **Charge-flow practice: attempt before checking**

Teacher-written: a charger supplies a constant 0.90 A for 25 minutes. Find charge in coulombs, then predict the effect of doubling the time at the same current.

Check: use seconds, because amperes measure coulombs per second.

$$t = 25 \text{ min} \times 60 \text{ s/min} = 1500 \text{ s}$$

$$Q = It$$

$$Q = It = 0.90 \text{ A} \times 1500 \text{ s} = 1350 \text{ C}$$

$$Q = It = 0.90 \text{ A} \times 3000 \text{ s} = 2700 \text{ C}$$

Twice the time gives twice the charge, at the same current.

■ **Actual exam calculation: current from charge flow**

AQA GCSE Physics June 2024 Paper 1H Q10.3 gives a fuse wire melting when 2.0 C flows in 400 ms. Calculate current before checking.

Check: known charge and time mean use $Q = It$, rearranged for current.

$$t = 400 \text{ ms} \times 0.001 \text{ s/ms} = 0.400 \text{ s}$$

$$Q = It \Rightarrow I = Q/t$$

$$I = Q/t = 2.0 \text{ C}/(0.400 \text{ s}) = 5.0 \text{ A}$$

This agrees with the official scheme. **Teacher extension:** treating 400 ms as 400 s would make the denominator 1000 times too large and current 1000 times too small. Check the time unit before substituting.

Current, resistance and potential difference

The current through a component depends on both the potential difference across it and its **resistance** :

$$V = IR$$

- V potential difference in volts, V; I current in amperes, A; R resistance in ohms, Ω .
- The greater the resistance, the smaller the current for a given potential difference.

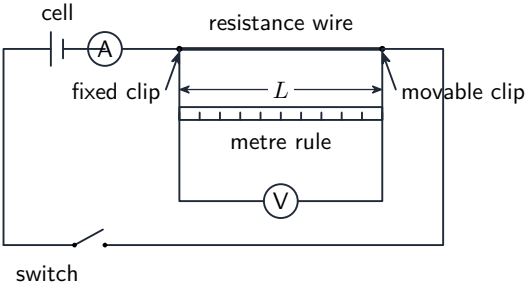
Worked example. A 0.45 V potential difference drives 0.0075 A through a coin. Find the coin’s resistance.

- Known: V and I ; rearrange before substituting.

$$R = \frac{V}{I} = \frac{0.45 \text{ V}}{0.0075 \text{ A}} = 60 \Omega$$

■ **Required practical 3: resistance of a wire and resistor combinations**

Attach a resistance wire (nichrome or constantan) along a metre rule. Measure the selected length between the actual contact points of a fixed clip and a movable clip. The ammeter is in series with that length; the voltmeter is connected across the same two contact points.



Use a low potential difference and switch off between readings to limit heating. Change length only: keep the wire material, cross-sectional area and temperature constant. For each length record the measured potential difference and current, then calculate $R = V/I$. Repeat readings and investigate inconsistent results.

For example, these **teacher-written ideal data** illustrate the calculation; they are not experimental measurements:

Length / cm	Potential difference / V	Current / A	Resistance / Ω
20	0.60	0.30	2.0
40	0.80	0.20	4.0
60	0.90	0.15	6.0

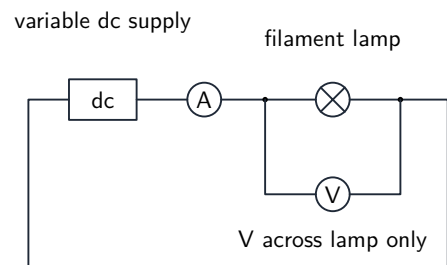
At constant temperature, for the same material and cross-sectional area, resistance is directly proportional to wire length. Plot calculated resistance against length; a straight line through the origin supports this relationship. The measured potential difference need not be identical at each length, so calculate each resistance from its own paired readings.

A non-zero intercept needs investigation. Check that length was measured between the contact points; contact and lead resistance can also affect results. Do not force the graph through the origin or subtract every intercept as a **zero error** without identifying its cause.

In the second part of this practical, connect two equal resistors in series, then in parallel. With the ammeter measuring total current and the voltmeter across the whole combination, measure total potential difference and current and calculate total resistance. Compare with one resistor: series has greater total resistance; parallel has smaller total resistance. For two identical $10\ \Omega$ resistors, ideal totals are $20\ \Omega$ in series and $5\ \Omega$ in parallel. The parallel result can be explained from the doubled total current at the same potential difference, without needing a reciprocal-resistance formula.

Resistors and I–V characteristics

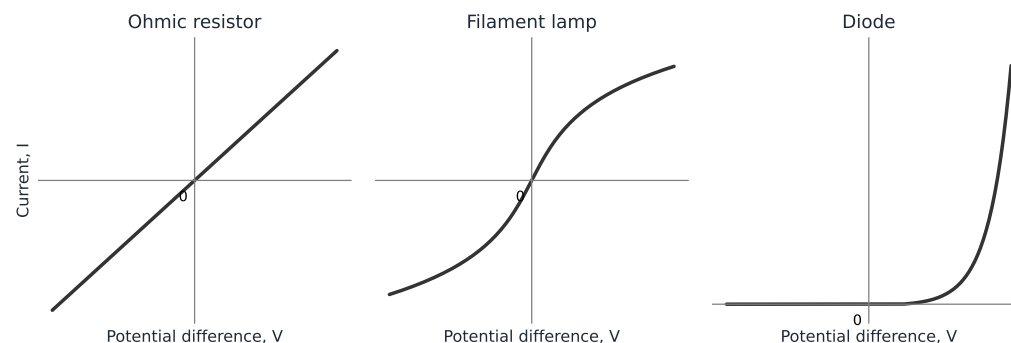
Required practical 4 measures current through a resistor, filament lamp and diode at a range of measured potential differences across each component. Connect an ammeter in series and a voltmeter in parallel with the component. Vary the pd using a variable dc supply, or a variable resistor in series. Start at zero and stay within component ratings. Record paired readings across a suitable range; repeat and investigate inconsistent readings. Switch off before reversing the supply connections to obtain negative values, using meters that can read the reversed polarity. Plot current vertically against potential difference horizontally.



For the lamp investigation in AQA June 2023 8463/1H Q06.1, Figure 6 covers $-6\ \text{V}$ to $+6\ \text{V}$ with readings at $1\ \text{V}$ intervals. Collect positive values, then reverse the supply to obtain the negative values; these settings belong to that lamp investigation, rather than every possible component.

For a diode, use a suitable protective resistor in series to limit current and a milliammeter to measure the small current. The **protective resistor**, not the milliammeter,

protects the diode. Measure pd across the diode alone, excluding the protective resistor. Keep the ohmic resistor near constant temperature; the lamp's changing filament temperature is part of the effect being investigated.



Qualitative shapes, not numerical measurement graphs. Current is the vertical axis in all three panels.

- **Ohmic conductor** (fixed resistor at constant temperature): current is directly proportional to potential difference; resistance is constant. Straight line through the origin.
- **Filament lamp** : resistance increases as its filament temperature rises. The current increases less than proportionally with pd, so the I–V curve flattens away from the origin in both directions.
- **Diode** : conducts in the forward direction; reverse current is negligible in this model, so reverse resistance is very high. Do not assume every diode has exactly the same forward voltage.

At a chosen operating point, calculate resistance using $R = V/I$. On a current-against-voltage graph, resistance is not the gradient. For a straight line through the origin, the gradient is $I/V = 1/R$; for a curved characteristic use the coordinates of the chosen point, rather than a tangent gradient.

Worked example, adapted from AQA June 2023 8463/1H Q06.2. At $+3.0\ \text{V}$, the official lamp graph gives approximately $0.16\ \text{A}$:

$$R = \frac{V}{I} = \frac{3.0\ \text{V}}{0.16\ \text{A}} = 18.75\ \Omega \approx 19\ \Omega$$

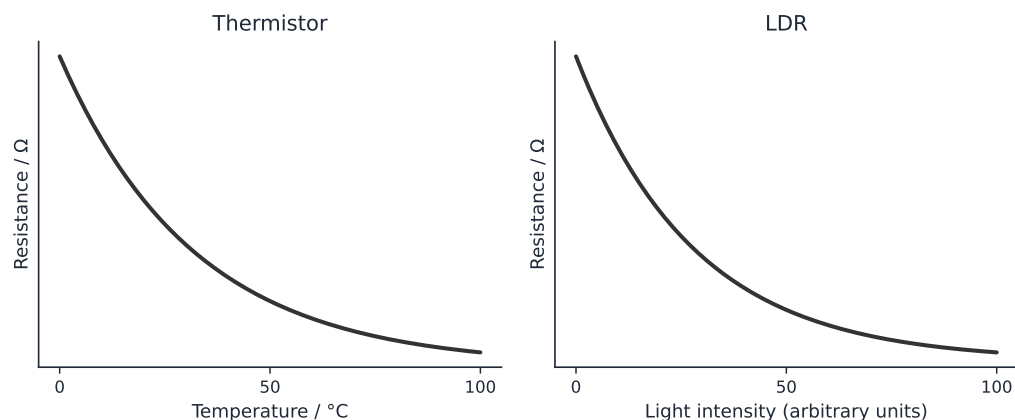
At $6.0\ \text{V}$ the same paper gives $0.21\ \text{A}$ (Q06.3). As a teacher extension, compare the resistance:

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{0.21\ \text{A}} \approx 29\ \Omega$$

The larger resistance is consistent with a hotter filament: increased lattice vibrations

make electron motion more difficult. Current still increases, but by a smaller proportion than pd.

- **Thermistor** : in the type required here, resistance falls as temperature rises – used as a temperature sensor in a thermostat.
- **LDR** : resistance falls as light intensity rises – used as a light sensor in an automatic lighting circuit.

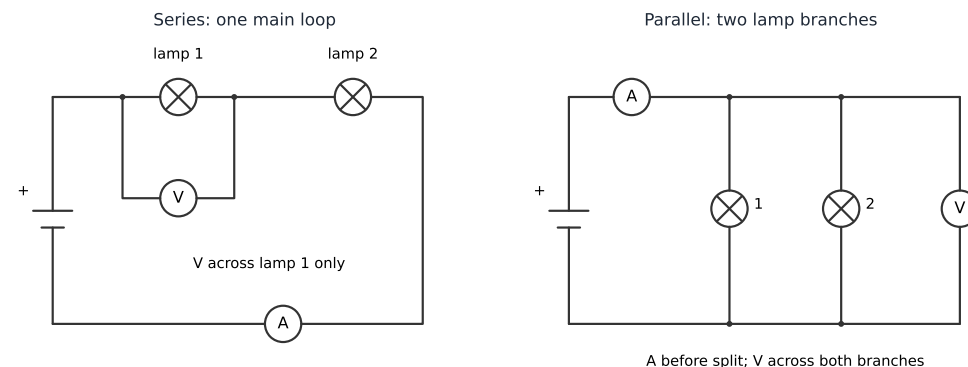


These are resistance-versus-environment graphs, not I - V characteristics.

A sensor does not by itself specify when an appliance switches on. For example, a controller set to switch a lamp on when LDR resistance is high will turn it on in darkness. A cooling controller can be arranged to switch on as thermistor resistance falls with rising temperature. State the given controller rule and trace the change through it. Only for the same pd across the sensor does falling resistance imply rising current by $I = V/R$; a fixed supply does not guarantee fixed sensor pd in a series circuit.

Series and parallel circuits

In series, the components share one unbranched loop. In parallel, components are connected on separate branches between the same two junctions. Trace these paths in the diagram before applying the current and potential-difference rules.



Same components, very different rules.

For components in **series**:

- the current is the same through each component;
- the supply potential difference is **shared** between components;
- total resistance is the **sum**: $R_{total} = R_1 + R_2$.

For components in **parallel**:

- the potential difference across each component is the **same**;
- the total current is the **sum** of the branch currents;
- the total resistance of two resistors is **less than the smallest** single one.

You must explain both directions: adding resistors in series puts extra opposition in the same unbranched conducting path, so total resistance rises; in parallel each resistor opens an extra path for charge, so more current flows for the same potential difference and the total resistance falls.

You are **not** required to calculate the combined resistance of two parallel resistors – only to compare and explain.

Worked example. A 6.0 V battery drives a lamp in series with a variable resistor set to 6.0 Ω . The lamp has a resistance of 12 Ω at this operating point.

- Known: supply pd and both resistances at this operating point. Keep the unrounded current when finding the voltage shares.

$$R_{total} = R_{lamp} + R_{resistor} = 12 + 6.0 = 18 \Omega$$

$$I = \frac{V}{R_{total}} = \frac{6.0}{18} = \frac{1}{3} \text{ A} \approx 0.33 \text{ A}$$

$$V_{lamp} = IR_{lamp} = \frac{6.0}{18} \times 12 = 4.0 \text{ V}$$

$$V_{resistor} = IR_{resistor} = \frac{6.0}{18} \times 6.0 = 2.0 \text{ V}$$

The shares add to 6.0 V. Equal shares occur only for equal resistances at the operating point; series components do not always share voltage equally.

Teacher-written comparison with fixed resistors. Two 8.0 Ω resistors are connected to an ideal 12 V supply. In series, $R_{total} = R_1 + R_2 = 16\ \Omega$ and $I = V/R_{total} = 0.75\ \text{A}$; each resistor has $V = IR = 6.0\ \text{V}$. In parallel, each branch has 12 V, so each branch current is $I = V/R = 1.5\ \text{A}$ and $I_{total} = I_1 + I_2 = 3.0\ \text{A}$. Adding another parallel resistor gives another current path and increases total current at the same supply pd. No reciprocal-resistance formula is needed here.

For independent parallel branches on an ideal fixed-pd supply, opening one branch stops current in that branch; the other branch still has the same pd. Opening the only series path stops current through both components. If the supply pd changes under load, do not assume the other branch’s current is unchanged.

Integrated worked example, adapted from AQA June 2024 8463/1H Q05.5. At 20 °C the question’s thermistor graph gives about 80 Ω. It is in series with a 400 Ω resistor across 12 V. Find the pd across the thermistor.

$$R_{total} = R_{fixed} + R_{thermistor} = 400 + 80 = 480\ \Omega$$

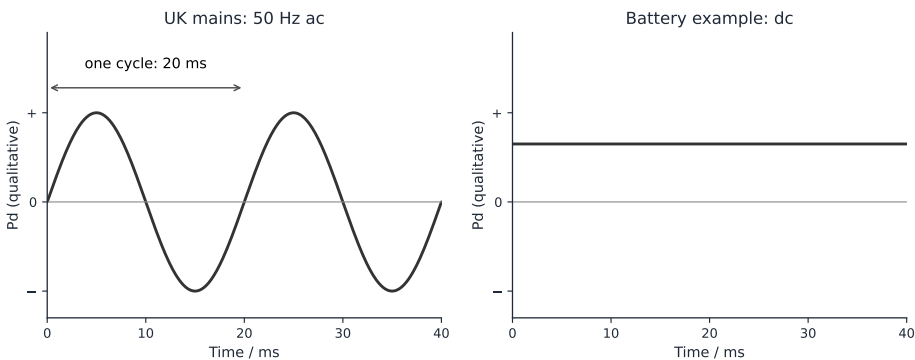
$$I = \frac{V_{supply}}{R_{total}} = \frac{12}{480} = 0.025\ \text{A}$$

$$V_{thermistor} = IR_{thermistor} = 0.025 \times 80 = 2.0\ \text{V}$$

The fixed resistor has the remaining 10 V. This example uses the graph reading supplied above; the complete exam question also requires reading that resistance from the graph. A fixed supply pd does not make the thermistor pd equal to the supply pd.

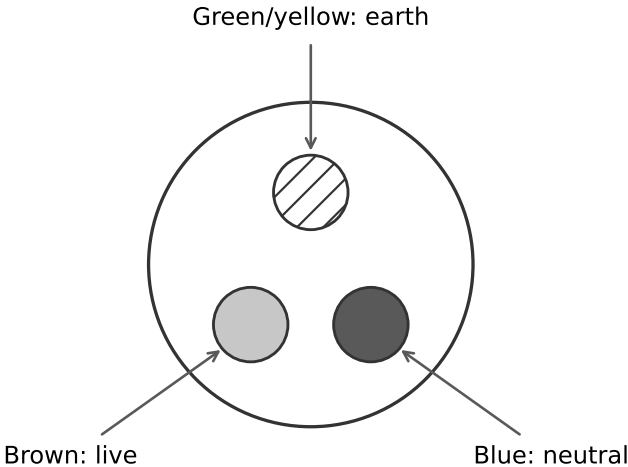
Domestic uses and safety

The UK mains supply is **alternating** (ac): the potential difference repeatedly changes polarity. Its frequency is **50 Hz**, meaning 50 complete cycles per second, and its quoted potential difference is **about 230 V**. Batteries provide **direct** (dc) potential difference with one polarity. A dc potential difference need not be perfectly constant in magnitude; its direction does not reverse.



Qualitative voltage scale: the curve does not plot 230 V as its peak. One complete 50 Hz cycle lasts 20 ms.

Actual exam recall: AQA June 2024 8463/1H Q05.1 asks for UK mains frequency and pd: 50 Hz and 230 V respectively. Fifty cycles per second does not mean only fifty direction changes per second: a sinusoidal cycle includes a positive and a negative half-cycle.

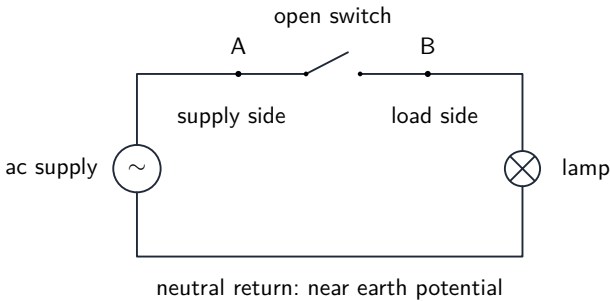


The insulation colours are named on the leaders.

Wire	Insulation colour	Normal role and potential
live	brown	Supplies alternating pd; about 230 V relative to earth.
neutral	blue	Completes the normal circuit; at or near earth potential, about 0 V.
earth	green and yellow stripes	Protective connection to an exposed metal case; near 0 V in the normal model, carrying no normal load current.

Neutral and earth have different jobs despite both normally being near earth potential. Neutral carries normal load current; the protective earth provides a fault-current path.

■ Why an open switch does not make all live wiring harmless



The open switch stops the lamp current in this ideal circuit. Point A remains connected to the live supply, at about 230 V relative to earth. A person making a conducting connection from that live point to earth can receive an electric shock. Do not infer from an unlit appliance that every part of the circuit is isolated. This does not mean that point B after a correctly wired open live switch must also remain live.

The danger depends on the current through the body, its path and duration. A human body is not a zero-resistance wire, but a current much smaller than a typical appliance fuse rating can still cause severe injury. An appliance fuse does not guarantee protection against touching live wiring.

■ Protective earth and fuse in a metal-case fault

For the classroom fault model, suppose the live wire touches an exposed metal case that has a sound protective-earth connection. The earth conductor supplies a low-resistance fault path; the resulting large current heats and melts a suitably rated fuse in the live wire, breaking the live supply. Without that earth connection, a case can become live without enough current to operate the fuse. A fuse’s protection against excessive current is different from a claim that every possible shock current will blow it.

■ Evaluate a broken-neutral fault

Teacher-written ideal model: a lamp is connected to a single-phase live and neutral supply. The neutral connection breaks between the lamp and the supply. The downstream neutral terminal remains connected to live through the lamp; there is no other return path. No normal load current flows, but that downstream terminal can be at live potential.

Condition	Live-to-earth pd	Load-side neutral-to-earth pd	Pd across lamp
normal	about 230 V	about 0 V	about 230 V
neutral return broken	about 230 V	about 230 V	about 0 V

This ideal model explains an unlit lamp with a dangerous downstream terminal. Both lamp terminals are at approximately the same potential, so the lamp pd is near zero; either can still have a large pd relative to earth. It is inconsistent to assign 230 V both across this unlit ideal lamp and from each of its terminals to earth in the stated single-phase model.

Energy transfers: power and appliances

Electrical appliances transfer energy from batteries or the mains. A motor transfers energy mechanically to moving objects; a heater transfers energy to the thermal store of its surroundings. **Power is the rate of energy transfer:** 1 W means 1 J each second. A rating states this rate at the specified working potential difference; it is not the total energy used.

Known quantities	Equation	Target
pd and current	$P = VI$	power in W
current and resistance	$P = I^2R$	resistive power in W
power and time	$E = Pt$	energy in J
charge and pd	$E = QV$	energy in J

Use seconds with watts to obtain joules. Use amperes, volts, ohms and coulombs with these equations. For a resistive model, substituting $V = IR$ into $P = VI$ gives $P = (IR)I = I^2R$. If current is unknown, rearrange $I^2 = P/R$ and take the square root: $I = \sqrt{P/R}$, not P/R .

Worked example – AQA June 2023 8463/1H Q06.3. A lamp carries 0.21 A at 6.0 V for 30 minutes. Calculate the energy transferred. Current and pd give power; power and time give energy.

Convert time: 30 min = 30 × 60 s = 1800 s.

$$P = VI = 6.0 \text{ V} \times 0.21 \text{ A} = 1.26 \text{ W}$$

$$E = Pt = 1.26 \text{ W} \times 1800 \text{ s} = 2268 \text{ J} \approx 2300 \text{ J}$$

Alternative route using charge. The same current and time give charge; each coulomb transfers 6.0 J across the lamp.

$$Q = It = 0.21\text{ A} \times 1800\text{ s} = 378\text{ C}$$

$$E = QV = 378\text{ C} \times 6.0\text{ V} = 2268\text{ J}$$

Both routes agree and are accepted in the official scheme. Retain intermediate values until the final answer; write J for energy, not W.

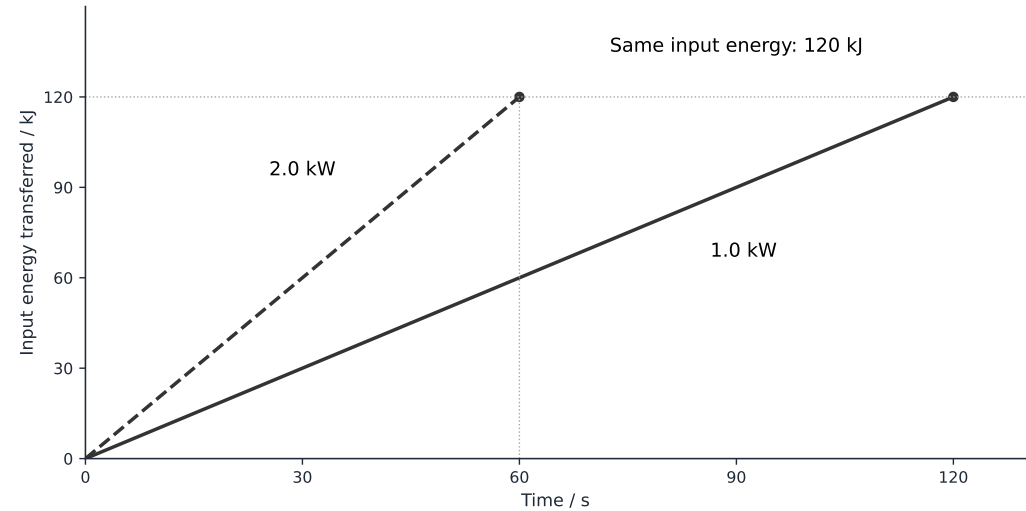
Worked example – AQA June 2025 8463/1H Q09.2. The question gives pump-motor power 4.86 W and resistance 6.0 Ω and asks for charge flow in 30 minutes. Use the question’s prescribed $P = I^2R$ model; this is not a general statement that all electrical input to a real running motor is resistance heating. Power and resistance give current; current and time give charge.

$$I^2 = \frac{P}{R} = \frac{4.86\text{ W}}{6.0\text{ }\Omega} = 0.81\text{ A}^2$$

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{4.86\text{ W}}{6.0\text{ }\Omega}} = 0.90\text{ A}$$

$$Q = It = 0.90\text{ A} \times 1800\text{ s} = 1620\text{ C}$$

Compare power ratings – teacher-written. Two devices transfer the same 120 kJ of input energy at constant powers 1.0 kW and 2.0 kW. Convert 120 kJ to 120 000 J and kW to W before using $t = E/P$.



The steeper line transfers energy faster. The endpoints show equal energy, with different times.

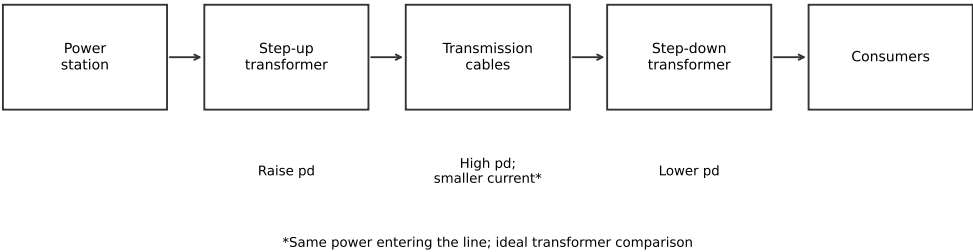
$$t_1 = \frac{E}{P_1} = \frac{120\,000\text{ J}}{1000\text{ W}} = 120\text{ s}$$

$$t_2 = \frac{E}{P_2} = \frac{120\,000\text{ J}}{2000\text{ W}} = 60\text{ s}$$

At the same run time, the 2.0 kW device transfers twice the energy. For the stated equal input energy, it takes half the time. A greater rating alone does not prove a greater total energy use or total cost for a job: duration and, for useful output, efficiency matter. For the same material and amount of water, a larger useful heating power raises temperature faster when losses are comparable.

The National Grid

The **National Grid** transfers electrical energy from power stations to consumers through cables and transformers.



Arrows show the system’s energy-transfer route, not individual circuit wires.

A **step-up transformer** raises the pd before transmission. For the same power entering the line, a higher sending-end pd means a smaller current: $I = P_{\text{in}}/V$. With the same cable resistance, heating loss $P_{\text{loss}} = I^2R$ is smaller. More of the input energy reaches consumers, so efficiency increases. Loss is reduced, not eliminated.

A **step-down transformer** lowers the transmission pd for consumers; UK domestic appliances use about 230 V. This is a lower and more suitable value than transmission pd; it can still cause a dangerous electric shock. Transformer construction and operation are taught in topic 4.7; this section explains their system-level roles.

Actual exam explanation – AQA June 2022 8463/1H Q06.1–06.2. The paper places transformer X before the overhead transmission cables and Y before consumers. X raises pd, reduces current, reduces heating transfer to surroundings and increases transmission efficiency. Y lowers pd to a safer value for consumers. Do not replace the X explanation with only “it is more efficient”: state the physical chain.

■ Compare two sending potential differences

Teacher-written simplified comparison. Hold sending-end input power at 500 kW and total cable resistance at $2.0\ \Omega$. Compare sending-end pd 10 kV with 20 kV. Use a simplified single-line resistive model and ideal transformers; this is not a calculation of the real three-phase UK network. Convert kW and kV to W and V.

At 10 kV:

$$I_1 = \frac{P_{\text{in}}}{V_1} = \frac{500\,000\ \text{W}}{10\,000\ \text{V}} = 50\ \text{A}$$

$$P_{\text{loss},1} = I_1^2 R = (50\ \text{A})^2 \times 2.0\ \Omega = 5000\ \text{W}$$

At 20 kV:

$$I_2 = \frac{P_{\text{in}}}{V_2} = \frac{500\,000\ \text{W}}{20\,000\ \text{V}} = 25\ \text{A}$$

$$P_{\text{loss},2} = I_2^2 R = (25\ \text{A})^2 \times 2.0\ \Omega = 1250\ \text{W}$$

Twice the sending pd gives half the current and one quarter of the cable loss. Input power is unchanged; output power increases because less is lost. A current-and-resistance calculation gives the loss, but cannot by itself give efficiency: total input power or energy is also needed.

Sheet2.7 comparison. At 2000 A through $40\ \Omega$, $P_{\text{loss}} = I^2 R = (2000\ \text{A})^2 \times 40\ \Omega = 1.6 \times 10^8\ \text{W}$. At 500 A through the same resistance, $P_{\text{loss}} = I^2 R = (500\ \text{A})^2 \times 40\ \Omega = 1.0 \times 10^7\ \text{W}$. Current is one quarter, so loss is one sixteenth. Without a stated input, do not claim these losses are a small percentage of the total.

Actual efficiency calculation – AQA June 2023 8463/1H Q01.5. Input energy is 34.2 GJ and efficiency is 0.992. Use $\eta = E_{\text{useful}}/E_{\text{in}}$ and rearrange before substituting. Both energies use GJ here, so the ratio needs no conversion to J.

$$E_{\text{useful}} = \eta E_{\text{in}} = 0.992 \times 34.2\ \text{GJ} = 33.9264\ \text{GJ} \approx 33.9\ \text{GJ}$$

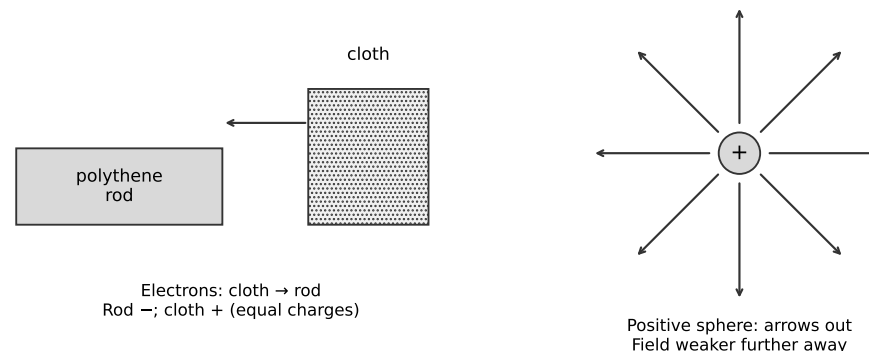
Static electricity (physics only)

When two insulating materials are rubbed together, **electrons** – negative charges – are rubbed off one and onto the other:

- the material gaining electrons becomes **negatively charged**;
- the material losing electrons is left with an equal **positive charge**.

Charged objects exert forces without contact: **like charges repel; unlike charges attract** – a non-contact force. A large potential difference can create a strong **electric field** across a small air gap. If the field is strong enough, the air becomes conducting (electrical breakdown), and charge flows briefly across the gap as a **spark**. An earthed conductor can receive a spark; earthing does not remove a nearby high-voltage source.

A charged object creates an electric field around itself: a region where another charge feels a force.



Electrons move; the field tells the force. The field is strongest close to the object and weaker further away.

You must draw the field pattern for an isolated charged sphere: straight radial lines pointing **away** from a positive charge (or towards a negative one), spaced wider as they get further from the sphere.

■ Link the explanation to real exam questions

AQA June2022 8463/1H Q05.1: electrons move from cloth to rod; electrons are negative, so the cloth is left with excess positive charge. Do not describe positive charge transferring. **Q05.4:** the large pd can cause air breakdown; electrons flow through the air from the negative rod to the earthed conductor.

AQA June2024 8463/1H Q04.1–04.3: electrons transfer to the student, her hairs gain the same negative charge, and like charges repel. The electric field is a region where another charged object experiences a force; its strength decreases with distance.

Q04.4: a spark transfers 0.60 J with 2.0 microcoulombs of charge. Convert $Q = 2.0 \times 10^{-6}\ \text{C}$. Choose $E = QV$ and rearrange:

$$V = E/Q = 0.60\ \text{J}/(2.0 \times 10^{-6}\ \text{C}) = 3.0 \times 10^5\ \text{V}$$

Neutral-object extension for sheet2.8. A charged rod can attract neutral paper because it slightly separates positive and negative charge within the paper. The nearer opposite charges feel stronger attraction than the repulsion of the further like charges. In an insulating wall, bound charges shift slightly; do not assume electrons flow freely through it. Attraction alone does not prove opposite net charges. In the sheet's rod question, all rods are stated to be charged, so the unlike-charge rule applies.

Checklist before you call this topic done

- Draw the standard symbols; place ammeters in series, voltmeters in parallel.
- Use $Q = It$, $V = IR$, $P = VI$, $P = I^2R$, $E = Pt$, $E = QV$ – chosen from the words of the question.
- Describe RP3: $R \propto L$, controls, intercept and heating checks; RP4: circuits and I–V shapes.
- State series/parallel current, pd and resistance rules; explain the resistance trends.
- Recall mains: 230 V, 50 Hz, ac; wire colours and jobs; explain live-wire dangers.
- Explain the National Grid's efficiency with $P = I^2R$.
- (physics only) Explain charging by friction with electrons, and draw the radial field of a charged sphere.