OCR GATEWAY A GCSE PHYSICS J249 | P3

# ELECTRICITY

# Exam practice notebook

## FOUNDATION TIER

12 diagnostic choices + 18 topic sets
2 extended responses + 5 timed sets
162 marks | Original questions | Detailed answers at the end

P3.1 Static and charge

P3.2 Simple circuits

Name: _____

Class: _____ Date: _____

Independent practice resource. Not an official OCR examination paper. Past-paper questions, mark schemes and logos are not reproduced.

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ROUTE AND TIER COVERAGE

# How to use this notebook

Start with the diagnostic choices, then attempt the topic sets after studying each sub-topic. Allow around 8-10 minutes per six-mark set. Complete each extended response in about 10 minutes. The fresh timed check has 30 marks with a suggested 40 minutes.

> This is a P3 topic practice collection, not a complete GCSE paper. Its marks and timings are independent guidance. No GCSE grade boundaries are assigned.

Calculator allowed. Use the optional reference page if your teacher permits it. Show equations, substitutions and units. Use a ruler for graphs and circuit diagrams. Write component symbols and connections clearly. Use only suitable low-voltage equipment for supervised practical work.

Both tiers assess all P3 content: static charge and fields; current and p.d.; resistance and I-V characteristics; components and sensing; series and parallel circuits; power and energy.

The current P3 specification has no Higher-only outcome statements. The Higher book differentiates by demand: more complex networks, sensing outputs and linked calculations. The Foundation book uses more scaffolded steps. Higher-demand additions are provided in the separate Higher notebook.

## Mark, correct and retry

All answers follow the final score record. Each worked answer includes credit points, the reasoning or calculation method, and a common-error note. Use the marking instructions at the start of that section.

| Command | Answer approach |
|---|---|
| Calculate | Show a relationship, substitute, then give a result with units. |
| Explain | Connect a cause, interaction or observation to its physical consequence. |
| Draw | Use clear labels, appropriate directions and the stated scale. |
| Evaluate | Use evidence to judge a claim and recognise limitations. |

**OPTIONAL SUPPORT | NOT THE OFFICIAL EQUATION SHEET**

# Practice equation reference

| Relationship | Units / conditions |
|---|---|
| $Q = It$ | C; A; s. Convert mA and minutes first. |
| $V = IR$ | V; A; Ω. R = V/I at the operating point. |
| $E = QV$ | J; C; V. P.d. is energy per charge. |
| $P = VI$; $P = I^2R$ | W; V; A; Ω. Use values for the same device. |
| $E = Pt$ | J from W × s; kWh from kW × h. |
| Series: $R_{total} = R_1 + R_2 + ...$ | Same current; component p.d.s add. |
| Parallel: $I_{total} = I_1 + I_2 + ...$ | Same branch p.d.; branch currents add. |
| Equivalent resistance R = Vsupply / Itotal | Use the total current for the whole network. |

Conversions: 1 mA = 0.001 A; 1 kΩ = 1000 Ω; 1 min = 60 s; 1 kW = 1000 W; 1 h = 3600 s; 1 kWh = 3 600 000 J. For constant temperature and fixed geometry, an ohmic resistor has constant resistance.

Source alignment: OCR J249 specification, version 5.0 (July 2026), P3 and relevant practical/mathematical skills. Checked 13 November 2026. AI-assisted preparation. Independent resource; not produced, endorsed or approved by OCR.

Official OCR J249 specification

**2021-2025 | NEWLY WRITTEN QUESTIONS**

# Five-series reference review

P3-relevant tasks and marking guidance in J249/01 (Foundation) and J249/03 (Higher) were reviewed for November 2021 and June 2022, 2023, 2024 and 2025. These are the latest five public question-paper series linked in the assessment archive used for this edition.

The papers guide skill coverage, task formats and demand. These notebook questions use original contexts, data and wording; they are not one-to-one paraphrases of official items. No official paper or marking table is reproduced.

2021: Meter choice and circuit measurements; series-loop reasoning; linked current, resistance and energy calculations.

2022: Charging and circuit measurements; LDR investigations; Higher evaluation of resistance-length evidence.

2023: I-V identification and measurement; thermistor data; Higher diode characteristics and sensing circuits.

2024: Series-circuit behaviour; electron transfer and attraction; comparison of electrical components and fields.

2025: Meter placement; thermistor I-V interpretation; linked power-current calculations and parallel-branch reasoning.

Official archive: question papers and mark schemes

The companion reference record contains the direct official links. This collection practises P3 skills; it does not predict future questions. Tasks may combine outcomes within P3.

**D1-D4 | 4 MARKS**

# Diagnostic multiple choice

D1. An insulating strip loses electrons during rubbing. What is its net charge afterwards? [1]

A Positive  B Negative  C Always zero  D Alternating

Answer: _____

D2. Which observation gives the clearest evidence that two objects have like net charges? [1]

A They both fall.  B They repel.  C They attract.  D They have equal masses.

Answer: _____

D3. Which direction do field arrows show? [1]

A Motion of every electron  B Force on a neutral atom  C Force on a positive test charge  D Direction of gravity

Answer: _____

D4. A 0.20 A current lasts 30 s. What charge passes a point? [1]

A 0.0067 C  B 0.15 C  C 150 C  D 6.0 C

Answer: _____

**D5-D8 | 4 MARKS**

# Diagnostic multiple choice

D5. A component has 3.0 V across it and a current of 0.15 A. What is its resistance? [1]

A 0.45 Ω  B 20 Ω  C 0.050 Ω  D 2.85 Ω

Answer: _____

D6. Which meter arrangement measures a resistor correctly? [1]

A Ammeter in parallel; voltmeter in series.  B Both meters in series.  C Ammeter in series; voltmeter in parallel.  D Both meters directly across the cell.

Answer: _____

D7. At fixed temperature an I-V graph is a straight line through the origin. Which statement follows? [1]

A Current is proportional to p.d.  B Current is independent of p.d.  C Resistance doubles with p.d.  D Charge is used up.

Answer: _____

D8. An NTC thermistor becomes warmer at a fixed p.d. What normally happens? [1]

A Resistance rises and current falls.  B Both resistance and current rise.  C Both resistance and current fall.  D Resistance falls and current rises.

Answer: _____

**D9-D12 | 4 MARKS**

# Diagnostic multiple choice

D9. Two unequal resistors share a single series loop. Which quantity must be equal in both? [1]

A Potential difference  B Power  C Current  D Resistance

Answer: _____

D10. Two resistors are in parallel across an ideal source. What is the same for the branches? [1]

A Potential difference  B Current in every case  C Resistance  D Energy transferred per second in every case

Answer: _____

D11. Which description correctly explains a steady current in a metal loop? [1]

A Electrons are consumed by components.  B Current is the energy transferred per coulomb.  C A closed path guarantees current without a p.d.  D Charge flows each second when a p.d. drives it around a closed conducting path.

Answer: _____

D12. Which is a unit of energy? [1]

A Ampere  B Kilowatt-hour  C Volt  D Ohm

Answer: _____

TOPIC PRACTICE | Q1 | 6 MARKS

# Charging by electron transfer

Two initially neutral insulating strips, A and B, are rubbed together. Electrons move from A to B. A second experiment transfers electrons in the same way to a fresh strip C made of the same material as B.

Q1(a) State the charge left on A and the charge gained by B. [2]

Q1(b) Explain why the total charge of A and B remains zero. [2]

Q1(c) Predict the force between B and C and explain. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q2 | 6 MARKS

# Attraction does not prove opposite charge

A charged plastic comb attracts a small neutral paper fragment without touching it. A student concludes that the fragment must already have the opposite net charge.

Q2(a) Evaluate the student’s conclusion. [2]

Q2(b) Explain how the paper can be attracted while remaining neutral overall. [3]

Q2(c) Name the field responsible for the interaction. [1]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q3 | 6 MARKS

# Electric field direction and a spark

An isolated positively charged conducting sphere is drawn as a circle. Later its charge builds up until a spark crosses a small gap to an earthed conductor.

Q3(a) Draw the electric field around the positive sphere. Include field-line directions. [3]




Q3(b) State the initial force direction on a small negative charge placed in this field. [1]

Q3(c) Explain how the spark can occur. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q4 | 6 MARKS

# Charge, current and time

A low-voltage sensor draws a steady current of 75 mA for 4.0 minutes.

Q4(a) Convert the current to amperes and the time to seconds. [2]

Q4(b) Calculate the charge passing a point in the sensor circuit. [2]

Q4(c) Explain why the charge leaving a component equals the charge entering it during steady operation. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q5 | 6 MARKS

# Energy transferred per coulomb

A component transfers 84 J of energy while 14 C of charge passes through it.

Q5(a) Calculate the potential difference across the component. [2]

Q5(b) Calculate the energy transferred when 25 C passes through a component at the same potential difference. [2]

Q5(c) Explain the meaning of a potential difference of 6.0 V. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q6 | 6 MARKS

# Current and resistance

A fixed resistor is connected to a 9.0 V supply. The current through it is 0.30 A. Its temperature remains constant.

Q6(a) Calculate the resistance. [2]

Q6(b) Calculate the current if the potential difference becomes 6.0 V at the same temperature. [2]

Q6(c) Explain why keeping the temperature constant matters to this prediction. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q7 | 6 MARKS

# Design a measurement circuit

You need to measure current through a test resistor and potential difference across it. Use a cell, switch, variable resistor, ammeter, voltmeter, test resistor and wires.

Q7(a) Draw a suitable circuit using conventional symbols. Label the test resistor. [4]

Q7(b) Explain why an ammeter must not be placed directly across the cell. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q8 | 6 MARKS

# Plot an ohmic I-V graph

A resistor is tested at constant temperature. Plot current vertically against potential difference horizontally, including negative values. Label both axes with units and draw one straight best-fit line.

| p.d. / V | -4.0 | -2.0 | 0 | 2.0 | 4.0 |
|---|---|---|---|---|---|
| Current / A | -0.20 | -0.10 | 0 | 0.10 | 0.20 |



Q8(a) Complete the graph described above. [3]

Q8(b) Use the 4.0 V point to calculate resistance. [2]

Q8(c) State what the line through the origin shows about current and potential difference. [1]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q9 | 6 MARKS

# A filament lamp heats up

A filament lamp is measured at three steady operating points. Its brightness increases between the first and last point.

| p.d. / V | 1.0 | 3.0 | 6.0 |
|---|---|---|---|
| Current / A | 0.20 | 0.30 | 0.36 |

Q9(a) Calculate its resistance at 1.0 V and at 6.0 V. [2]

Q9(b) Explain the increase in resistance using the metal-particle model. [3]

Q9(c) State whether the lamp is ohmic across these readings. [1]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q10 | 6 MARKS

# A diode in forward and reverse directions

A diode carries 20 mA at a forward potential difference of 0.70 V. At -1.5 V the reverse-current magnitude is below the meter resolution of 0.01 mA. Both readings are within its safe ratings.

Q10(a) Calculate the resistance at the forward operating point. [2]

Q10(b) Explain what the reverse reading shows about the diode’s behaviour. [2]

Q10(c) Explain the purpose of a series current-limiting resistor in a diode test. [2]

Score: ____ / 6 Review: secure / developing / revisit

**TOPIC PRACTICE | Q11 | 6 MARKS**

# Measuring an LDR

An LDR has 4.0 V across it. In dim light its current is 0.40 mA; in bright light its current is 2.0 mA. Its temperature is kept constant.

Q11(a) Calculate its resistance in dim light. [2]

Q11(b) Calculate its resistance in bright light. [2]

Q11(c) Draw the conventional LDR symbol and name one variable, apart from p.d., that should be controlled in the light investigation. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q12 | 6 MARKS

# An NTC thermistor in a water bath

A thermistor is tested in a controlled water bath. At each temperature it has 3.0 V across it. NTC means negative temperature coefficient.

| Temperature / °C | 10 | 30 | 50 |
|---|---|---|---|
| Resistance / Ω | 6000 | 3000 | 1500 |

Q12(a) Calculate its current at 30 °C. [2]

Q12(b) State the factor by which current increases from 30 °C to 50 °C. [1]

Q12(c) Draw the conventional NTC thermistor symbol and explain why readings should be taken only after it reaches the bath temperature. [3]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q13 | 6 MARKS

# Resistors in series

A 12 Ω resistor and an 18 Ω resistor are connected in series across an ideal 6.0 V supply.

Q13(a) Calculate the total resistance and current from the supply. [2]

Q13(b) Calculate the potential difference across each resistor. [2]

Q13(c) Explain why adding another resistor in series reduces the current for the same supply p.d. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q14 | 6 MARKS

# Branch currents in parallel

Two resistors, 15 Ω and 30 Ω, are connected in parallel across an ideal 6.0 V supply.

Q14(a) Calculate the current in each branch. [2]

Q14(b) Calculate the supply current and equivalent resistance. [2]

Q14(c) Explain why opening only the 30 Ω branch does not change the 15 Ω branch current in this ideal circuit. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q15 | 6 MARKS

# Changing a circuit connection

Two identical 24 Ω resistors are first connected in series and then in parallel across the same ideal 12 V supply. Their temperatures remain unchanged.

Q15(a) Calculate the supply current for the series arrangement. [2]

Q15(b) Calculate the supply current for the parallel arrangement. [2]

Q15(c) Compare the equivalent resistances and explain the effect of the extra parallel route. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q16 | 6 MARKS

# Electrical power by two routes

A heater element of resistance 8.0 Ω carries a steady current of 1.5 A.

Q16(a) Calculate the potential difference across it. [2]

Q16(b) Calculate its power using potential difference and current. [2]

Q16(c) Show that using $P = I^2R$ gives the same result. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q17 | 6 MARKS

# Electrical energy over time

A 24 W device runs for 15 minutes at steady power.

Q17(a) Calculate the energy transferred in joules. [2]

Q17(b) Calculate the same energy in kWh. [2]

Q17(c) Explain how the total energy changes if it runs for twice as long at the same power. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q18 | 6 MARKS

# Resistance and wire length

Different lengths of the same uniform wire are measured at a constant temperature. Voltage and current are recorded for each test length.

| Length / m | 0.20 | 0.40 | 0.60 |
|---|---|---|---|
| p.d. / V | 0.40 | 0.80 | 1.20 |
| Current / A | 0.50 | 0.50 | 0.50 |

Q18(a) Calculate the resistance for the 0.20 m and 0.60 m test lengths. [2]

Q18(b) Use the data to evaluate whether resistance is proportional to length. [2]

Q18(c) Explain why the wire should not be allowed to heat significantly. [2]

Score: ____ / 6 Review: secure / developing / revisit

P3.2f-k; working scientifically | 6 MARKS

# E1: Improve a wire investigation

A student wants to find how wire resistance depends on length. They choose a different piece of wire for each length, use different thicknesses, leave a large current flowing continuously, and take one V-I reading for each. Evaluate this method and describe a better investigation that could support a valid conclusion.

Write a coherent response. Use calculations, evidence and cause-and-effect links as appropriate. Suggested time: 10 minutes.

**P3.1e-f; P3.2a,e,h | 6 MARKS**

# E2: Evaluate three circuit claims

A student makes three claims about a series circuit containing a supply and two components: (1) the first component uses up some current, so less reaches the second; (2) each component always has the full supply p.d.; (3) a filament lamp’s current must double when its p.d. doubles. Evaluate the claims with physical explanations.

Write a coherent response. Use calculations, evidence and cause-and-effect links as appropriate. Suggested time: 10 minutes.

FRESH QUESTIONS | 30 MARKS

# Timed P3 check

Suggested time: 40 minutes. Attempt all 5 sets without consulting answers. Show method and units. The equation reference may be used only if your teacher chooses.

Start time: _____ Finish time: _____
Equation reference permitted? yes / no

Use this check to identify what to practise next. The score is not an official GCSE grade.

**TIMED CHECK | T1 | 6 MARKS**

# T1: A warning indicator

A low-voltage indicator operates at 5.0 V and draws 40 mA for 3.0 minutes.

T1(a) Calculate the charge transferred. [2]

T1(b) Calculate the energy transferred. [2]

T1(c) Calculate the power. [2]

Score: ____ / 6 Review: secure / developing / revisit

**TIMED CHECK | T2 | 6 MARKS**

# T2: A two-resistor chain

A 20 Ω and a 40 Ω resistor are in series across an ideal 12 V supply.

T2(a) Calculate the current. [2]

T2(b) Calculate the p.d. across the 40 Ω resistor. [2]

T2(c) Calculate the power transferred by the 20 Ω resistor. [2]

Score: ____ / 6 Review: secure / developing / revisit

TIMED CHECK | T3 | 6 MARKS

# T3: Two independent branches

Two branches of 8.0 Ω and 24 Ω are in parallel across an ideal 12 V supply.

T3(a) Calculate each branch current. [2]

T3(b) Calculate the supply current and equivalent resistance. [2]

T3(c) Explain what happens to the supply current if the 24 Ω branch alone is opened. [2]

Score: ____ / 6 Review: secure / developing / revisit

**TIMED CHECK | T4 | 6 MARKS**

# T4: Evaluating a hot lamp

A lamp draws 0.10 A at 0.50 V and 0.25 A at 3.0 V after each reading has stabilised.

T4(a) Calculate the resistance at each point. [2]

T4(b) Explain the change in resistance. [3]

T4(c) State why doubling the p.d. cannot automatically be assumed to double the current. [1]

Score: ____ / 6 Review: secure / developing / revisit

TIMED CHECK | T5 | 6 MARKS

# T5: A battery-powered heater

An ideal 12 V source supplies 2.0 A to a heater for 5.0 minutes. Assume steady operating values.

T5(a) Calculate the operating resistance. [2]

T5(b) Calculate the power. [2]

T5(c) Calculate the energy transferred in joules. [2]

Score: ____ / 6 Review: secure / developing / revisit

COMPLETE AFTER MARKING

# Score and improvement record

| Set | Specification focus | Score / 6 |
|---|---|---|
| Q1 | P3.1a-c | |
| Q2 | P3.1a-d | |
| Q3 | P3.1d | |
| Q4 | P3.1e-g; PM3.1i | |
| Q5 | P3.2c; PM3.2ii | |
| Q6 | P3.2c-e; PM3.2i | |
| Q7 | P3.2a-b,k | |
| Q8 | P3.2d-h; graph skills | |
| Q9 | P3.2e,h | |
| Q10 | P3.2b,f-h | |

Diagnostic: ____ / 12 Extended responses: ____ / 12

Topic sets: ____ / 108 Timed check: ____ / 30

Whole notebook: ____ / 162

Question to retry: _____ Correct physics and method:

COMPLETE AFTER MARKING

# Score and improvement record

| Set | Specification focus | Score / 6 |
|---|---|---|
| Q11 | P3.2f,h,k | |
| Q12 | P3.2f,h,k | |
| Q13 | P3.2a,i-j,m | |
| Q14 | P3.2a,i-j | |
| Q15 | P3.2a,i-j | |
| Q16 | P3.2l-m; PM3.2iii | |
| Q17 | P3.2l-m; PM3.2iv | |
| Q18 | P3.2f-k; working scientifically | |
| T1 | P3.1g; P3.2m | |
| T2 | P3.2j,m | |

Diagnostic: ____ / 12 Extended responses: ____ / 12

Topic sets: ____ / 108 Timed check: ____ / 30

Whole notebook: ____ / 162

Question to retry: _____ Correct physics and method:

COMPLETE AFTER MARKING

# Score and improvement record

| Set | Specification focus | Score / 6 |
|---|---|---|
| T3 | P3.2a,i-j | |
| T4 | P3.2d-h | |
| T5 | P3.2l-m | |

Diagnostic: ____ / 12 Extended responses: ____ / 12

Topic sets: ____ / 108 Timed check: ____ / 30

Whole notebook: ____ / 162

Question to retry: _____ Correct physics and method:

DETAILED SOLUTIONS AND MARKING GUIDANCE

# ANSWERS

Stop here until you have attempted the questions. All answers are grouped from this page to the end.

Order: diagnostic answers; topic-practice worked answers; extended-response models; timed-check worked answers; electric-field, circuit, I-V and component-symbol reference answers.

## Awarding credit

Each part shows its maximum mark. Award independent points once; accept equivalent scientific language and valid alternative methods. A correct calculation with suitable units earns full credit unless a specific drawing, explanation or method is required.

When an arithmetic error is carried into a later part, credit valid later methods that use it consistently. Do not award accuracy marks for incorrect values. Avoid penalising the same arithmetic error repeatedly. Circuit diagrams must show unambiguous connections and recognisable conventional symbols. Electric-field diagrams must show the correct directions.

The extended responses use six original independent credit points. Model paragraphs show one coherent full-credit response, not the only acceptable wording. They do not reproduce an official OCR level-of-response scheme.

For each diagnostic item award one mark for the single correct option and zero for another choice or multiple selections. Do not subtract marks. For graph plotting, use the stated half-small-square tolerance. For circuits, credit a valid alternative layout with the same connections; physical position on the page is not significant.

No GCSE grade boundaries are assigned. Use the score record to identify calculation, explanation, graph or evaluation skills to revisit.

D1-D4 | REASONS INCLUDED

# Diagnostic answers

## D1: A [1]

Losing negative electrons leaves an excess of positive charge; nuclei are not transferred in this process.

## D2: B [1]

Like net charges repel. Attraction can also occur between a charged object and a neutral polarised object.

## D3: C [1]

Electric-field direction is defined using a positive test charge. Negative charges feel the opposite force.

## D4: D [1]

$Q = It = 0.20 \times 30 = 6.0$ C.

D5-D8 | REASONS INCLUDED

# Diagnostic answers

### D5: B [1]

R = V/I = 3.0/0.15 = 20 Ω.

### D6: C [1]

Current is measured in the branch; p.d. is measured between the resistor’s ends.

### D7: A [1]

A constant ratio I/V means a constant ratio V/I and therefore constant resistance.

### D8: D [1]

NTC resistance decreases as temperature rises. At fixed V, I = V/R therefore increases.

D9-D12 | REASONS INCLUDED

# Diagnostic answers

## D9: C [1]

There is one continuous current path, so the current is the same through both resistors.

## D10: A [1]

Both branches join the same two terminals, giving the same p.d.; their currents and powers may differ.

## D11: D [1]

Current is the rate of charge flow. In a metal the moving carriers are electrons; continuous current requires a closed conducting path and a source of p.d.

## D12: B [1]

A kWh is power multiplied by time. It measures energy, not power or current.

WORKED ANSWER | TOTAL 6 MARKS

# Q1: Charging by electron transfer

## Part (a) / 2

A becomes positive (1); B becomes negative (1).

## Part (b) / 2

The number of electrons lost by A equals the number gained by B (1); equal and opposite charges are produced by transfer rather than charge creation (1).

## Part (c) / 2

They repel (1); both have gained electrons and carry the same negative type of charge (1).

## Reasoning and worked method

Initially neutral objects contain charged particles but have no net charge. Moving negative electrons from A to B leaves A with an electron deficit and B with an electron excess. The positive nuclei do not travel between the insulating strips. The two equal negative charges on B and C produce repulsion.

Common error to avoid: Positive charging here means loss of electrons, not gain of protons. Neutral does not mean that the material contains no charged particles.

WORKED ANSWER | TOTAL 6 MARKS

# Q2: Attraction does not prove opposite charge

## Part (a) / 2

It is not justified/attraction does not prove opposite net charge (1); a charged object can also attract a neutral object (1).

## Part (b) / 3

Charges in the paper redistribute slightly/polarise (1); opposite charge is effectively closer to the comb than like charge (1); the closer attraction is stronger than the farther repulsion, giving a net attraction (1).

## Part (c) / 1

Electric/electrostatic field (1).

## Reasoning and worked method

The neutral fragment can become polarised: positive and negative charge centres are displaced slightly without a net transfer of charge to the paper. Since the electric force is stronger at smaller separation, the near-side attraction can dominate. Repulsion is stronger evidence of like net charge than attraction is of unlike net charge.

Common error to avoid: Do not assume the fragment was negatively or positively charged before the test. Do not describe gravity as the field causing this attraction.

WORKED ANSWER | TOTAL 6 MARKS

# Q3: Electric field direction and a spark

## Part (a) / 3

At least four appropriately spread radial lines (1); arrows pointing away from the sphere (1); lines meet the sphere normally and do not cross (1).

## Part (b) / 1

Towards the positive sphere/opposite the field arrows (1).

## Part (c) / 2

A sufficiently strong electric field ionises the air/makes it conducting (1); charge then flows across the gap in a brief discharge (1).

## Reasoning and worked method

Field arrows show the force direction for a positive test charge, so the positive sphere’s arrows point outward. A negative charge experiences the opposite force. Air is normally a good insulator, but a large electric field can create mobile charged particles, allowing rapid conduction and a spark.

Common error to avoid: Field lines are a model, not tracks followed by every charge. Do not make positive-sphere arrows point inward.

WORKED ANSWER | TOTAL 6 MARKS

# Q4: Charge, current and time

## Part (a) / 2

75 mA = 0.075 A (1); 4.0 min = 240 s (1).

## Part (b) / 2

Q = It = 0.075 × 240 (1); 18 C (1).

## Part (c) / 2

Charge is conserved (1); there is no continuing build-up of charge in the component/charge is not used up (1).

## Reasoning and worked method

One ampere means one coulomb per second. The conversion steps are important because coulombs follow from amperes multiplied by seconds. The calculated 18 C is charge passing a cross-section over time, not charge accumulated inside the sensor. Components transfer energy while circulating charge is conserved.

Common error to avoid: Do not multiply 75 by 4 and label the result coulombs. Use A and s before applying Q = It.

WORKED ANSWER | TOTAL 6 MARKS

# Q5: Energy transferred per coulomb

## Part (a) / 2

V = E/Q = 84/14 (1); 6.0 V (1).

## Part (b) / 2

E = QV = 25 × 6.0 (1); 150 J (1).

## Part (c) / 2

6.0 J of energy is transferred (1) per coulomb of charge between the two points (1).

## Reasoning and worked method

Potential difference compares energy transfer with charge transfer: 6 V means 6 J for every coulomb. It is not a rate per second. A larger total charge at the same potential difference transfers more energy. The relationship E = QV links the energy supplied or transferred by a device to the charge passing through it.

Common error to avoid: Do not define voltage as charge per second; that defines current. Keep energy in joules distinct from charge in coulombs.

WORKED ANSWER | TOTAL 6 MARKS

# Q6: Current and resistance

## Part (a) / 2

R = V/I = 9.0/0.30 (1); 30 Ω (1).

## Part (b) / 2

I = V/R = 6.0/30 (1); 0.20 A (1).

## Part (c) / 2

A metal resistor’s resistance can change with temperature (1); the calculation assumes the same 30 Ω resistance at both readings (1).

## Reasoning and worked method

Resistance is the potential difference divided by current at the operating point. For a metal resistor at constant temperature, current is proportional to potential difference. Reducing the supply to two thirds of its former value reduces current to two thirds if the resistance remains unchanged.

Common error to avoid: Do not state that all components have constant resistance. State the condition for an ohmic metal resistor.

WORKED ANSWER | TOTAL 6 MARKS

# Q7: Design a measurement circuit

## Part (a) / 4

Cell, switch, variable resistor and test resistor form a complete series path (1); ammeter correctly in series (1); voltmeter across the test resistor only (1); recognisable conventional symbols and unambiguous connections (1).

## Part (b) / 2

An ammeter has very low resistance (1); this could create a very large current/short circuit and damage the meter or supply (1).

## Reasoning and worked method

The ammeter measures the charge flow through the test branch, so it belongs in that same path. The voltmeter compares the two ends of the test resistor and therefore bridges it in parallel. The variable resistor controls current; the switch allows the circuit to be opened between readings. Use only a suitable low-voltage supply under supervision.

Common error to avoid: Do not connect the voltmeter in series or put the ammeter across the source. The complete model circuit is in the final reference answers.

WORKED ANSWER | TOTAL 6 MARKS

# Q8: Plot an ohmic I-V graph

## Part (a) / 3

Correctly labelled axes with consistent positive and negative scales (1); all five points within half a small square of the coordinates (1); suitable straight line through the origin (1).

## Part (b) / 2

R = V/I = 4.0/0.20 (1); 20 Ω (1).

## Part (c) / 1

They are directly proportional at this constant temperature (1).

## Reasoning and worked method

The coordinates are (-4,-0.20), (-2,-0.10), (0,0), (2,0.10) and (4,0.20). The graph is symmetrical about the origin for this resistor. On an I-against-V graph the gradient is I/V = 1/R, not R. Here the gradient is 0.050 A/V and its reciprocal is 20 Ω. The complete model graph is in the final reference answers.

Common error to avoid: Use R = V/I for the component. Do not read the slope of an I-V graph as resistance without checking which quantity is on each axis.

WORKED ANSWER | TOTAL 6 MARKS

# Q9: A filament lamp heats up

## Part (a) / 2

At 1.0 V: R = 1.0/0.20 = 5.0 Ω (1); at 6.0 V: R = 6.0/0.36 ≈ 16.7 Ω (1).

## Part (b) / 3

The filament becomes hotter (1); metal ions vibrate more strongly (1); conduction electrons suffer more frequent collisions, opposing their drift (1).

## Part (c) / 1

No; resistance is not constant/current is not proportional to p.d. (1).

## Reasoning and worked method

The resistance changes from 5.0 Ω to about 16.7 Ω. A larger voltage gives a larger current, but not in the same proportion. The filament’s changing temperature alters resistance. On an I-V plot with I vertical, the curve becomes less steep as the filament heats.

Common error to avoid: Do not say the current has been used up in the hot filament. The filament transfers energy, while charge is conserved.

WORKED ANSWER | TOTAL 6 MARKS

# Q10: A diode in forward and reverse directions

## Part (a) / 2

20 mA = 0.020 A and R = V/I (1); 0.70/0.020 = 35 Ω (1).

## Part (b) / 2

It conducts very little in reverse within these ratings (1); its reverse resistance is much higher than its forward resistance (1).

## Part (c) / 2

It limits the current as forward conduction increases (1); this reduces the risk of overheating/damaging the diode (1).

## Reasoning and worked method

The forward-point resistance is calculated from the ratio V/I at that point; it is not constant for all diode voltages. A reverse reading below resolution is evidence of a very small current, not proof of mathematically zero current. A limiting resistor must keep the current within the component rating.

Common error to avoid: Do not assume a diode is an ohmic resistor or apply its forward-point resistance in reverse. Observe the stated safe operating range.

WORKED ANSWER | TOTAL 6 MARKS

# Q11: Measuring an LDR

## Part (a) / 2

0.40 mA = 0.00040 A and R = V/I (1); 4.0/0.00040 = 10 000 Ω (1).

## Part (b) / 2

2.0 mA = 0.0020 A and R = V/I (1); 4.0/0.0020 = 2000 Ω (1).

## Part (c) / 2

Recognisable resistor inside a circle with two light arrows pointing towards it (1); keep temperature constant (1).

## Reasoning and worked method

At fixed p.d., a larger current means a smaller resistance. Bright light gives five times the current and one fifth the resistance. Resistance should be calculated from the p.d. across the LDR, not automatically from the entire supply if another component is in series. The standard LDR symbol has a resistor inside a circle and arrows directed towards it to represent incident light. Keep temperature constant so a temperature effect is not confused with a light effect.

Common error to avoid: Convert milliamperes correctly. More light lowers LDR resistance; it does not normally increase it.

WORKED ANSWER | TOTAL 6 MARKS

# Q12: An NTC thermistor in a water bath

## Part (a) / 2

I = V/R = 3.0/3000 (1); 0.0010 A or 1.0 mA (1).

## Part (b) / 1

It doubles/increases by a factor of 2 (1).

## Part (c) / 3

Recognisable resistor rectangle crossed by the thermistor diagonal with a short foot (1); initially its temperature may differ from the bath thermometer reading (1); waiting for equilibrium matches measured resistance to the recorded temperature (1).

## Reasoning and worked method

The NTC resistance decreases as temperature rises. For a fixed 3 V, this raises current. The bath thermometer measures the water, so readings taken too quickly can pair the water temperature with a sensor that has not caught up. Keep connections dry and use suitable low-voltage equipment.

Common error to avoid: A thermistor and a metal filament do not have the same resistance-temperature trend.

WORKED ANSWER | TOTAL 6 MARKS

# Q13: Resistors in series

## Part (a) / 2

Rtotal = 12 + 18 = 30 Ω (1); I = 6.0/30 = 0.20 A (1).

## Part (b) / 2

Across 12 Ω: V = 0.20 × 12 = 2.4 V (1); across 18 Ω: V = 0.20 × 18 = 3.6 V (1).

## Part (c) / 2

The total resistance increases (1); I = V/R therefore decreases when V is fixed (1).

## Reasoning and worked method

The same current passes through both resistors. The voltage drops add to the supply: 2.4 + 3.6 = 6.0 V. The larger resistance takes the larger share of the p.d. Series resistance is the sum because each component adds opposition in the same current path.

Common error to avoid: Current does not divide between series resistors. Do not assign the full supply p.d. to each one.

WORKED ANSWER | TOTAL 6 MARKS

# Q14: Branch currents in parallel

## Part (a) / 2

15 Ω branch: 6.0/15 = 0.40 A (1); 30 Ω branch: 6.0/30 = 0.20 A (1).

## Part (b) / 2

Supply current = 0.40 + 0.20 = 0.60 A (1); equivalent R = 6.0/0.60 = 10 Ω (1).

## Part (c) / 2

The 15 Ω resistor still has the same 6.0 V across it (1); its resistance is unchanged, so V/R remains 0.40 A (1).

## Reasoning and worked method

Parallel branches connect to the same pair of supply terminals and have the same p.d. Their currents add at the supply junction. The 10 Ω equivalent is lower than either branch resistance. Opening one branch decreases total supply current, but an ideal fixed-voltage source maintains the other branch’s voltage.

Common error to avoid: Do not share the 6 V between parallel branches. Equal p.d. does not require equal branch current when resistances differ.

WORKED ANSWER | TOTAL 6 MARKS

# Q15: Changing a circuit connection

## Part (a) / 2

Rseries = 24 + 24 = 48 Ω (1); I = 12/48 = 0.25 A (1).

## Part (b) / 2

Each branch current = 12/24 = 0.50 A (1); total = 1.0 A (1).

## Part (c) / 2

The parallel equivalent is 12 Ω, smaller than 48 Ω in series (1); the parallel route allows more total current at the same supply p.d., so equivalent resistance is lower (1).

## Reasoning and worked method

In series the two resistors share the 12 V supply and carry 0.25 A. In parallel each has 12 V across it and carries 0.50 A; the supply current is their sum, 1.0 A. The ratio of total currents is four, which agrees with the inverse ratio of equivalent resistances at fixed voltage.

Common error to avoid: A pair of identical parallel resistors has half the resistance of one resistor, not twice its resistance.

WORKED ANSWER | TOTAL 6 MARKS

# Q16: Electrical power by two routes

## Part (a) / 2

V = IR = 1.5 × 8.0 (1); 12 V (1).

## Part (b) / 2

P = VI = 12 × 1.5 (1); 18 W (1).

## Part (c) / 2

P = $1.5^2$ × 8.0 (1); 18 W, equal to the part (b) result (1).

## Reasoning and worked method

Combining P = VI with V = IR gives P = $I^2R$. Both methods describe the same operating point. A power of 18 W means 18 J is transferred each second. For a real heater, the quoted resistance must correspond to its operating temperature.

Common error to avoid: Square the current in $I^2R$. Do not square the resistance or confuse power in W with energy in J.

WORKED ANSWER | TOTAL 6 MARKS

# Q17: Electrical energy over time

## Part (a) / 2

Time = 15 × 60 = 900 s and E = Pt (1); 24 × 900 = 21 600 J (1).

## Part (b) / 2

Power = 0.024 kW and time = 0.25 h (1); 0.024 × 0.25 = 0.0060 kWh (1).

## Part (c) / 2

The energy doubles to 43 200 J or 0.012 kWh (1); E = Pt makes energy proportional to time at fixed power (1).

## Reasoning and worked method

The joule route uses W and s, while the kWh route uses kW and h. They agree because 1 kWh = 3 600 000 J and 0.0060 × 3 600 000 = 21 600 J. A kWh is an energy unit even though its name contains the word watt.

Common error to avoid: Do not multiply watts by hours and label the result kWh without first converting watts to kilowatts.

WORKED ANSWER | TOTAL 6 MARKS

# Q18: Resistance and wire length

## Part (a) / 2

At 0.20 m: R = 0.40/0.50 = 0.80 Ω (1); at 0.60 m: R = 1.20/0.50 = 2.4 Ω (1).

## Part (b) / 2

The middle resistance is 0.80/0.50 = 1.6 Ω, so doubling/tripling length doubles/triples resistance (1); all readings give R/L = 4.0 Ω/m, consistent with proportionality over the tested range (1).

## Part (c) / 2

Temperature changes metal resistance (1); heating would change another variable and prevent attributing the resistance change only to length (1).

## Reasoning and worked method

All three readings give R/L = 4.0 Ω/m. Proportionality is supported by the data but should not be asserted without considering measurement uncertainty or contact resistance. Use the same wire material and cross-sectional area, measure between consistent contacts, use low currents and switch off between readings.

Common error to avoid: A longer wire does not necessarily have greater resistance than any shorter wire of another material or thickness. Control those properties.

EXTENDED RESPONSE | 6 MARKS

# E1: Improve a wire investigation: model answer

Use the same uniform wire, or wires of identical material and cross-sectional area, changing only the length between contacts. Measure the test length accurately from consistent contact points. Connect an ammeter in series and a voltmeter across that test length, then calculate R = V/I for each length. Keep temperature approximately constant by using a low current and opening the switch between readings, because heating changes metal resistance. Repeat measurements and inspect any anomalous results rather than relying on one reading. Plot R against length, checking whether the data follow a straight line through the origin and considering any fixed lead/contact resistance.

## Credit points: one mark each

1. Keep wire material and cross-sectional area the same while varying measured test length.
2. Measure between consistent contact points with a suitable ruler.
3. Use ammeter in series, voltmeter across the test length, and R = V/I.
4. Control heating with low current/switching off, explaining that temperature affects resistance.
5. Repeat readings and check anomalies/spread to assess reliability.
6. Use an R-length plot to test proportionality and recognise a possible contact-resistance intercept.

Improvement note: State a control and why it matters. Repeats cannot compensate for changing the wire thickness at the same time as its length.

EXTENDED RESPONSE | 6 MARKS

# E2: Evaluate three circuit claims: model answer

Claim 1 is incorrect for a steady single loop. Charge is conserved and does not build up continuously inside a component, so the current is the same through both components. Claim 2 is incorrect: the potential differences across series components add to the supply p.d.; each component takes a share that depends on its resistance. Claim 3 is not valid for a normally operating filament lamp because increasing p.d. heats the filament, increasing resistance as ion vibrations and electron collisions increase. The current therefore does not generally rise in direct proportion to the p.d.

## Credit points: one mark each

1. Reject claim 1 and state equal current around the single loop.

2. Link equal current to conservation of charge/no continuing accumulation.

3. Reject claim 2 and state that series component p.d.s add to the supply.

4. Explain that components share the p.d. according to their resistances.

5. Reject the fixed doubling claim because the lamp heats and resistance changes.

6. Link higher temperature to stronger ion vibrations/more electron collisions, or explicitly explain non-proportional current.

Improvement note: Distinguish charge transfer, energy transfer per charge and energy transfer per second. A lamp transfers energy without consuming circulating charge.

WORKED ANSWER | TOTAL 6 MARKS

# T1: A warning indicator

## Part (a) / 2

I = 0.040 A, t = 180 s and Q = It (1); Q = 7.2 C (1).

## Part (b) / 2

E = QV = 7.2 × 5.0 (1); 36 J (1).

## Part (c) / 2

P = VI = 5.0 × 0.040 (1); 0.20 W (1).

## Reasoning and worked method

The conversions give 0.040 A and 180 s. The energy result can be checked by E = Pt = 0.20 × 180 = 36 J. Each equation links a different pair of physical quantities; the device does not store all the charge that passes through it.

Common error to avoid: Do not use milliamperes as amperes. Check energy with a second route if time allows.

WORKED ANSWER | TOTAL 6 MARKS

# T2: A two-resistor chain

## Part (a) / 2

Total R = 20 + 40 = 60 Ω (1); I = 12/60 = 0.20 A (1).

## Part (b) / 2

V = IR = 0.20 × 40 (1); 8.0 V (1).

## Part (c) / 2

P = $I^2R$ = $0.20^2$ × 20, or V = 4.0 V then P = VI (1); 0.80 W (1).

## Reasoning and worked method

The same 0.20 A flows through both resistors. Their voltage drops are 4.0 V and 8.0 V. The 20 Ω resistor transfers 0.80 W; the other transfers 1.6 W. Their sum is 2.4 W, matching supply power 12 × 0.20.

Common error to avoid: Use the component voltage or component resistance for its power, not automatically the full source voltage.

WORKED ANSWER | TOTAL 6 MARKS

# T3: Two independent branches

## Part (a) / 2

8.0 Ω branch: 12/8.0 = 1.5 A (1); 24 Ω branch: 12/24 = 0.50 A (1).

## Part (b) / 2

Supply current = 1.5 + 0.50 = 2.0 A (1); equivalent R = 12/2.0 = 6.0 Ω (1).

## Part (c) / 2

It falls to 1.5 A (1); that branch stops taking current while the 8.0 Ω branch retains the same 12 V and current (1).

## Reasoning and worked method

Equal p.d. across branches is the starting point. Current divides inversely with resistance, giving a three-to-one current ratio. An equivalent resistance of 6 Ω is smaller than the smallest branch, as expected. The ideal source assumption lets the remaining branch keep its voltage after the other is opened.

Common error to avoid: Do not divide total current equally between unequal parallel resistors.

WORKED ANSWER | TOTAL 6 MARKS

# T4: Evaluating a hot lamp

## Part (a) / 2

Rlow = 0.50/0.10 = 5.0 Ω (1); Rhigh = 3.0/0.25 = 12 Ω (1).

## Part (b) / 3

The filament heats up (1); its ions vibrate more strongly (1); electrons collide more often, increasing resistance (1).

## Part (c) / 1

The lamp’s resistance changes with operating temperature/it is non-ohmic (1).

## Reasoning and worked method

Current rises when voltage rises, but the resistance increase shows it does not rise proportionally. The steady readings describe different filament temperatures. A constant-resistance prediction would need the temperature to stay fixed, which is not the case for a normally operating lamp.

Common error to avoid: Do not infer ohmic behaviour merely because both voltage and current increase.

WORKED ANSWER | TOTAL 6 MARKS

# T5: A battery-powered heater

## Part (a) / 2

R = V/I = 12/2.0 (1); 6.0 Ω (1).

## Part (b) / 2

P = VI = 12 × 2.0 (1); 24 W (1).

## Part (c) / 2

Time = 300 s and E = Pt (1); 24 × 300 = 7200 J (1).

## Reasoning and worked method

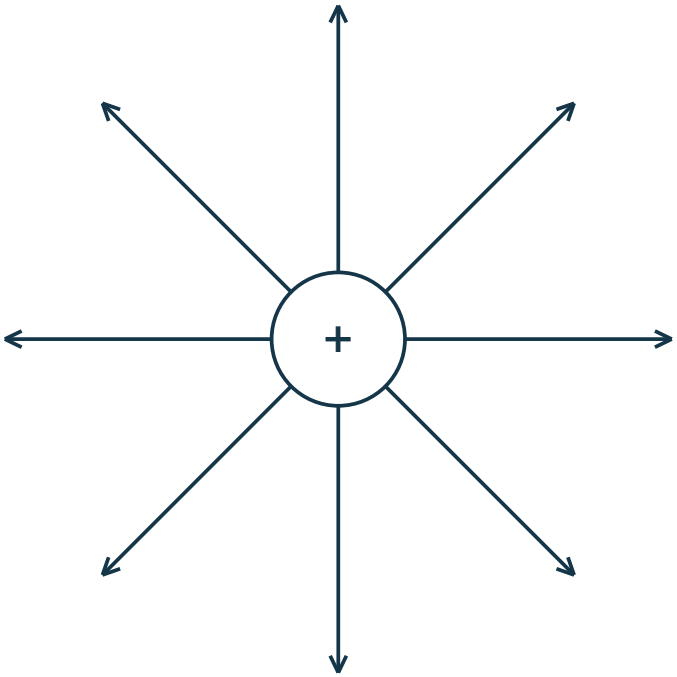
The 6 Ω is the resistance at the stated operating point. Power is 24 J each second; in 300 s this gives 7200 J. A charge check gives Q = 2 × 300 = 600 C and E = QV = 600 × 12 = 7200 J.

Common error to avoid: Use seconds with watts to obtain joules. Do not confuse five minutes with five seconds.

Q3(a) | FIELD CHECK

# Electric-field reference answer

This schematic model shows an isolated positive sphere. The field is radial and arrows indicate force on a positive test charge.

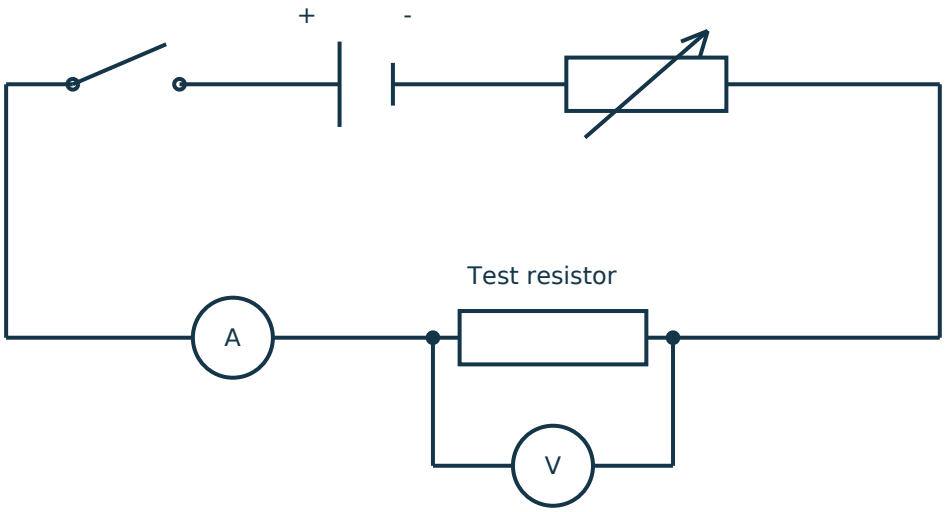



A negative test charge feels a force towards the sphere, opposite the arrows. Field lines meet the conducting sphere at right angles, do not cross, and are not material tracks.

Q7(a) | MEASUREMENT CIRCUIT

# Circuit reference answer

The ammeter is in series with the test resistor. The voltmeter is connected only across its two ends. The switch and variable resistor are also in the main series path.




Use a low-voltage supply, a suitable current range and component ratings. Open the switch before changing a component. Check connections before closing the circuit.

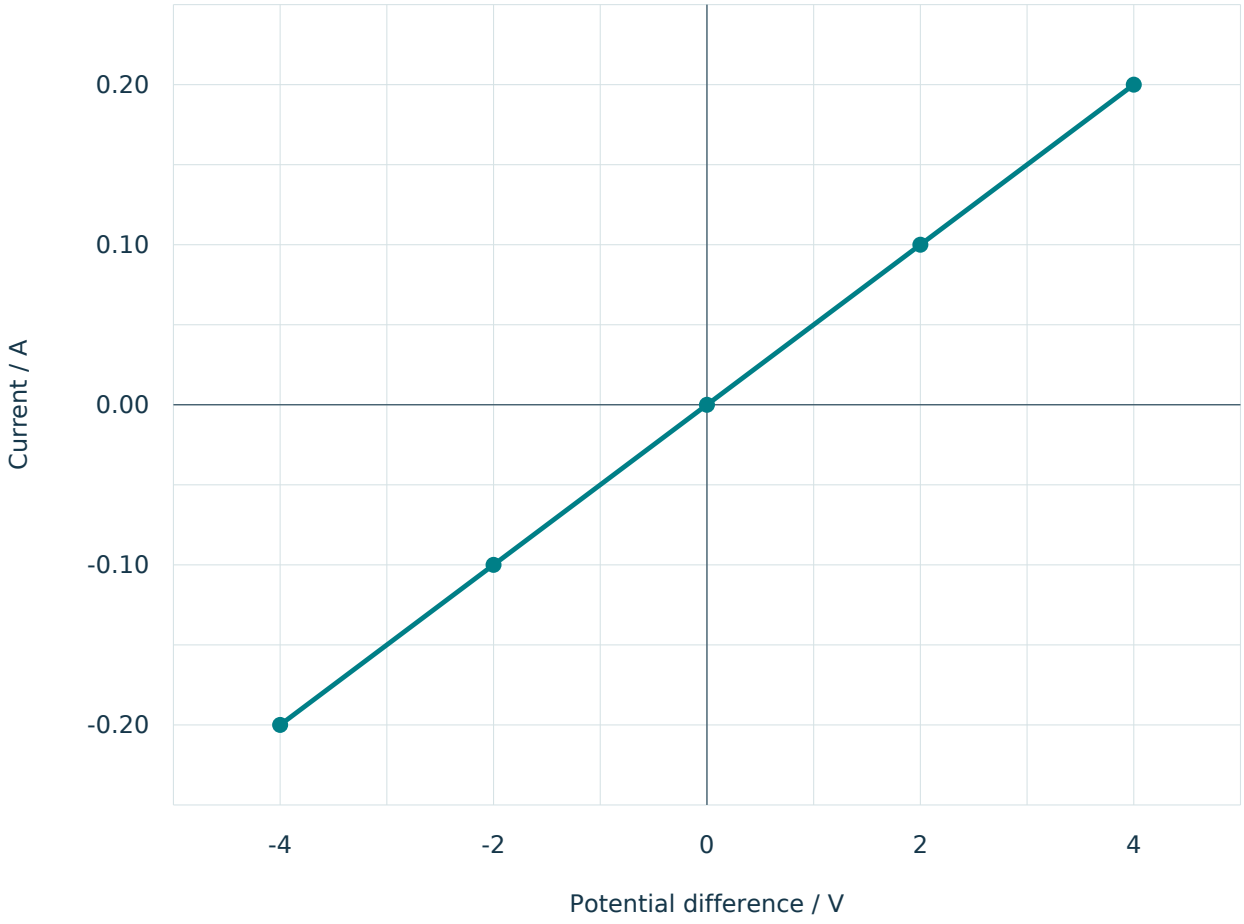
The cell symbol represents the source. Its long line is positive. The diagonal arrow on the upper resistor identifies the variable resistor. The main-loop ammeter measures test current; the parallel voltmeter measures test p.d.

For an ideal voltmeter, negligible current enters its branch. A real high-resistance voltmeter makes that extra current small. A directly connected low-resistance ammeter could short the source.

Q8(a) | GRAPH CHECK

# Ohmic I-V reference answer

Alternative clear scales are acceptable. Plot I vertically and V horizontally, using consistent negative and positive axes.

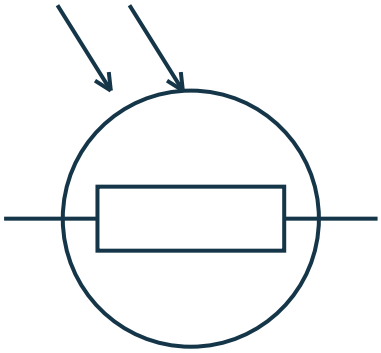



At 4.0 V, I = 0.20 A and R = V/I = 20 Ω. The I-against-V gradient is 0.050 A/V, whose reciprocal is 20 Ω. The straight line passes through the origin.

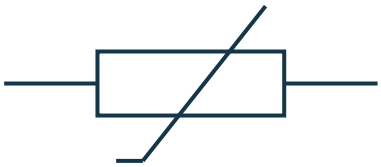
Q11(c), Q12(c) | DRAWING CHECK

# Component-symbol reference

Use conventional circuit symbols, straight wires and clear junctions. These symbols describe function rather than the physical shape of a component.



LDR: arrows point inwards



NTC thermistor



Filament lamp

LDR: more light lowers resistance. NTC thermistor: higher temperature lowers resistance. Filament lamp: its hot metal has greater resistance. Do not swap the light and temperature symbols.