

AQA AS Current potential difference and resistance solutions

Matching solutions and teaching prompts for the class review

Specification points covered

• 3.5.1.1 Basics of electricity: current $I = \Delta Q / \Delta t$; potential difference $V = W / Q$; resistance $R = V / I$.

• 3.5.1.2 Current–voltage characteristics: Ohm's law at constant physical conditions; ohmic conductors, filament lamps and semiconductor diodes; ideal meters; either axis orientation.

Teaching focus

Distinguish charge from energy, and a point resistance V/I from a graph gradient. Check the axes before calculating. Require Ohm's law to include constant physical conditions. For the lamp, link temperature to lattice-ion vibrations and electron scattering.

Charge and energy in the heater

1. Define electric current. [1 mark]

Answer / mark points: Electric current is the rate of flow of electric charge. [1] Accept charge transferred per unit time.

Teacher prompt / common error: Require 'charge', not 'electrons', in the general definition: other charge carriers can form currents.

2. During a short heater test, 0.480 C of charge passes a point in 1.60 s. Calculate the mean current. [1 mark]

Answer / mark points: $I = \Delta Q / \Delta t = 0.480 / 1.60 = 0.300$ A. [1]

Teacher prompt / common error: A mean current uses total charge divided by elapsed time, even if the instantaneous current varies.

3. The heater then carries a constant current of 0.360 A for 2 min 30 s. Calculate (a) the charge transferred and (b) the number of electrons passing a point. The magnitude of the electron charge is 1.60×10^{-19} C. [3 marks]

Answer / mark points: $t = 2 \times 60 + 30 = 150$ s. [1] $Q = It = 0.360 \times 150 = 54.0$ C. [1] $N = Q/e = 54.0 / (1.60 \times 10^{-19}) = 3.38 \times 10^{20}$ electrons. [1] Accept 3.375×10^{20} ; the count has no unit of coulombs.

Teacher prompt / common error: Convert the whole time to seconds. A number of electrons is a count, not an amount of charge.

4. The potential difference across the heater is 12.0 V. Explain what this means in terms of energy and charge, then calculate the energy transferred when 18.0 C passes through it. [2 marks]

Answer / mark points: 12.0 J is transferred per coulomb of charge passing through the heater. [1] $W = VQ = 12.0 \times 18.0 = 216$ J. [1]

Teacher prompt / common error: Potential difference is not the energy by itself: it is energy transferred per unit charge.

5. A technician says, 'The heater uses up charge, so the steady current leaving it is smaller than the current entering it.' Explain why this statement is incorrect. [2 marks]

Answer / mark points: Charge is conserved, so the steady current entering and leaving a component in this unbranched path is the same. [1] Energy is transferred in the heater; charge is not consumed. [1]

Teacher prompt / common error: Ask what the heater transfers and what is conserved. Current is not 'used up'.

Continue your physics journey

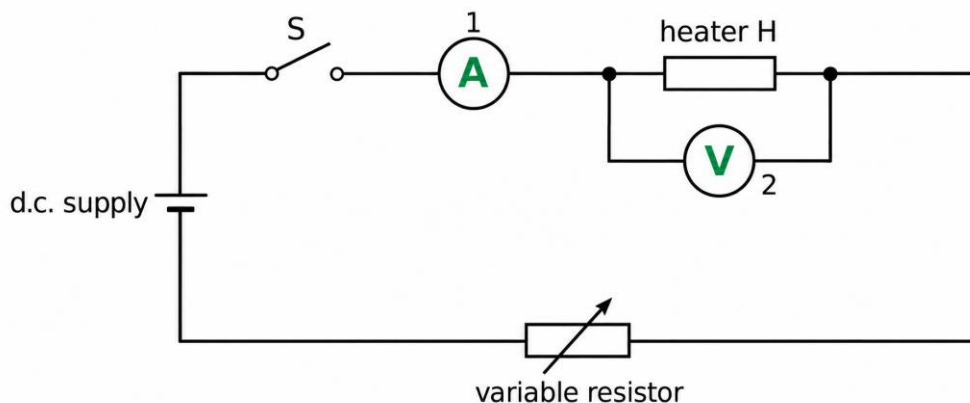
Videos, practice and support for your next step

www.physicsuk.co.uk



Measuring the heater resistance

6. Figure 1 shows the test circuit. Identify meters 1 and 2, and explain why each is connected in its shown position. Switch S is closed for all measurements. [2 marks]



Answer / mark points: Meter 1 is an ammeter and meter 2 a voltmeter. [1 for both] The ammeter is in series so it measures the charge-flow rate through the heater; the voltmeter is in parallel so it measures the potential difference between the heater's terminals. [1 for both placement explanations]

Teacher prompt / common error: Trace the heater path. Meter 2 spans the heater, not the supply and not the series variable resistor.

7. State the resistance of an ideal ammeter and an ideal voltmeter. Explain why the ideal voltmeter in Figure 1 draws no current. [2 marks]

Answer / mark points: Ideal ammeter: 0 Ω ; ideal voltmeter: infinite resistance. [1 for both] The voltmeter's infinite resistance means that no current flows through its branch at a finite potential difference. [1]

Teacher prompt / common error: A large voltmeter resistance reduces loading; a small ammeter resistance reduces its effect on the circuit.

8. The correctly connected ideal meters give 1.44 A and 8.64 V for the heater. Calculate its resistance. Explain why this single pair of readings cannot establish that the heater obeys Ohm's law. [2 marks]

Answer / mark points: $R = V/I = 8.64/1.44 = 6.00 \Omega$. [1] Several pairs of readings are needed to show that I is proportional to V , with temperature and other physical conditions held constant. [1] One pair determines an operating resistance, not a characteristic.

Teacher prompt / common error: Separate finding R at one operating point from establishing an Ohmic relationship over a range.

9. A replacement ammeter has resistance 0.500 Ω and carries 1.20 A. Calculate the potential difference across this ammeter. Explain how its resistance affects the heater current at a fixed supply voltage and variable-resistor setting. Treat the heater resistance as constant. [2 marks]

Answer / mark points: $V = IR = 1.20 \times 0.500 = 0.600 \text{ V}$. [1] The added series resistance increases total circuit resistance, so the heater current decreases for the fixed supply voltage and resistor setting. [1] The ammeter is not electrically negligible.

Teacher prompt / common error: Ideal-meter assumptions are removed only where the question explicitly gives a non-zero meter resistance.

10. An ideal voltmeter is mistakenly placed in series with the heater, with no other current path. Predict the current and explain your answer. [2 marks]

Answer / mark points: Current = 0 A. [1] The infinite resistance of the series voltmeter prevents a current through the only available path. [1]

Teacher prompt / common error: A voltmeter does not belong in the current path. 'Very small' is not the exact ideal-meter prediction.

Continue your physics journey

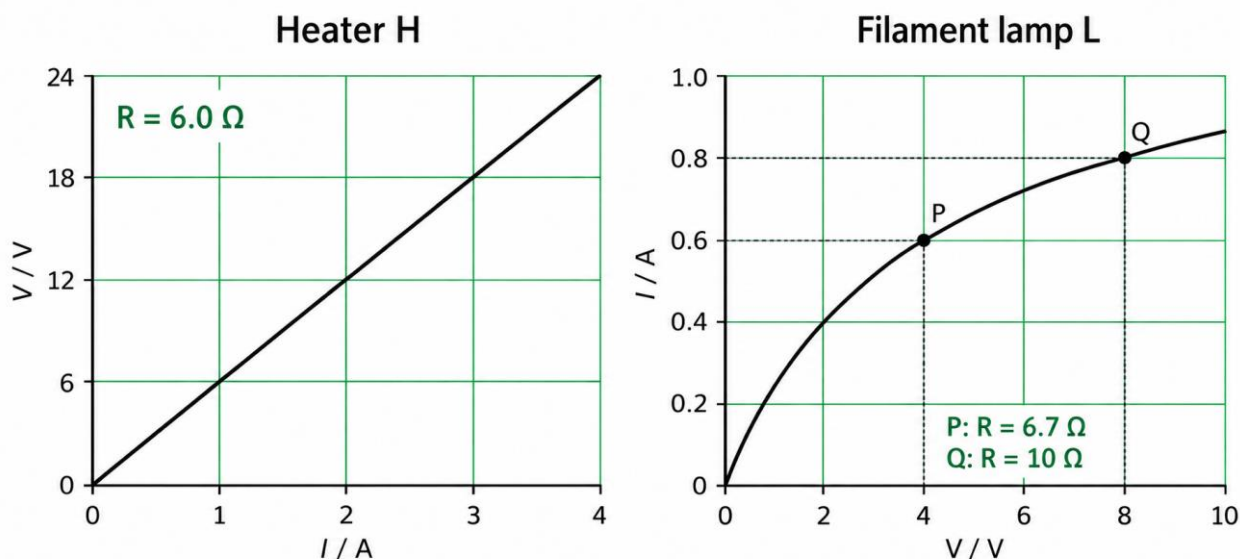
Videos, practice and support for your next step

www.physicsuk.co.uk



Interpreting I–V characteristics

11. Figure 2 shows measurements from separate tests of heater H and filament lamp L. Use the gradient of the heater graph to determine its resistance. State the feature of this graph that is consistent with Ohm's law at constant temperature. [2 marks]



Answer / mark points: Here V is vertical and I horizontal: gradient = $\Delta V / \Delta I = 24/4 = 6.0 \text{ V A}^{-1} = 6.0 \Omega$. [1] The straight line passes through the origin, showing $V \propto I$ at constant temperature. [1]

Teacher prompt / common error: Read axis orientation before using a gradient: V against I gives R; I against V gives $1/R$ for an Ohmic line.

12. Using points P and Q on the lamp graph, calculate the resistance at each point. Explain the increase in resistance in terms of temperature, lattice ions and conduction electrons. [4 marks]

Answer / mark points: At P, $R = 4.0/0.60 = 6.7 \Omega$. [1] At Q, $R = 8.0/0.80 = 10 \Omega$. [1] The filament temperature increases. [1] Lattice ions vibrate with greater amplitude, leading to more frequent scattering/collisions of conduction electrons and therefore greater resistance. [1] Do not require an exact electron-speed argument.

Teacher prompt / common error: Use the sequence: temperature increases $\rightarrow$ lattice-ion vibrations increase $\rightarrow$ electron collisions increase $\rightarrow$ resistance increases.

13. A technician calculates $\Delta V / \Delta I$ between P and Q as 20Ω and calls this 'the lamp's resistance at Q'. Evaluate this claim, giving the correct resistance at Q. [2 marks]

Answer / mark points: The resistance at Q is $V/I = 8.0/0.80 = 10 \Omega$, not 20Ω . [1] $\Delta V / \Delta I$ between P and Q is a ratio of changes (a secant on a V–I graph), not V/I at Q for a non-linear characteristic. [1] The shown lamp graph has I, not V, on the vertical axis.

Teacher prompt / common error: For a non-linear component, use the coordinates at the point. Neither a local tangent nor a secant automatically equals its operating resistance.

14. The lamp is operating at Q. The supply polarity is reversed to give -8.0 V under otherwise identical conditions. State (a) the current, including its sign, and (b) the resistance. [2 marks]

Answer / mark points: (a) $I = -0.80 \text{ A}$. [1] (b) $R = (-8.0)/(-0.80) = +10 \Omega$. [1] The lamp characteristic is symmetric about the origin under identical physical conditions; resistance remains positive.

Teacher prompt / common error: Both V and I change sign. Their ratio remains positive for this lamp.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk



The protection diode and characteristic sketches

Table 1 Diode measurements at constant temperature. Reverse breakdown is not reached. Currents smaller than 0.01 mA in magnitude are recorded as 0.00 mA.

V / V	-1.00	-0.60	0.00	+0.40	+0.60	+0.70
I / mA	0.00	0.00	0.00	0.02	2.00	12.0

15. Table 1 gives results for protection diode D. Calculate its resistance at +0.60 V and at +0.70 V. Use these results to decide whether the diode obeys Ohm's law. [3 marks]

Answer / mark points: At +0.60 V, $I = 2.00 \text{ mA} = 0.00200 \text{ A}$, so $R = 0.60/0.00200 = 300 \Omega$. [1] At +0.70 V, $I = 12.0 \text{ mA} = 0.0120 \text{ A}$, so $R = 0.70/0.0120 = 58 \Omega$ (58.3 Ω unrounded). [1] It is non-Ohmic: V/I is not constant, so I is not proportional to V . [1] Accept consistent rounding from the tabulated voltage precision.

Teacher prompt / common error: Convert mA to A. Avoid teaching a universal diode threshold: the given data determine the response here.

16. The diode is held at +0.70 V for 25.0 s. Use Table 1 to calculate (a) the charge transferred and (b) the energy transferred in the diode. [2 marks]

Answer / mark points: $I = 0.0120 \text{ A}$. $Q = It = 0.0120 \times 25.0 = 0.300 \text{ C}$. [1] $W = VQ = 0.70 \times 0.300 = 0.21 \text{ J}$ (0.210 J unrounded). [1] Accept consistent rounding; do not award a second mark for repeating the current conversion.

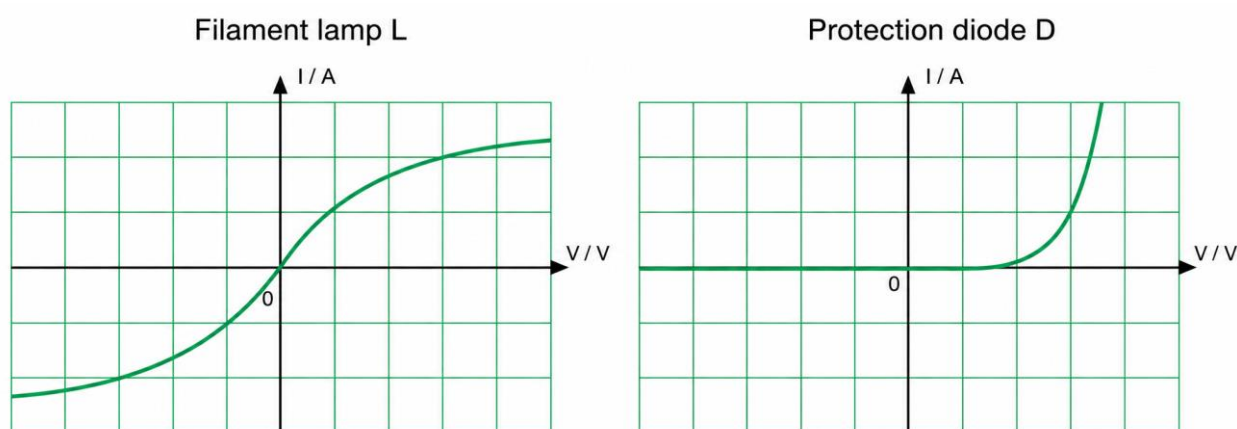
Teacher prompt / common error: Track the unit conversion once, then follow charge into energy using $W = VQ$.

17. The diode should allow current from the battery to the control panel. It is accidentally installed in reverse, with -0.60 V across it. State the effect on this current, using Table 1. [1 mark]

Answer / mark points: The current is negligible; the diode blocks current in this reverse direction, so the intended panel supply is interrupted. [1] 'Zero at the instrument's resolution' is acceptable. Do not claim all real diodes have exactly zero reverse current.

Teacher prompt / common error: The table describes the measured range and resolution, not reverse breakdown or exact zero leakage at all voltages.

18. Sketch the complete I-V characteristic of each component on Figure 3, including positive and negative potential differences. The axes have no numerical scale. Diode reverse breakdown is outside the range considered. [4 marks]



Answer / mark points: Lamp: curve passes through the origin in the first and third quadrants. [1] Gradient is greatest near the origin and decreases in magnitude as $|V|$ increases; the two branches are symmetric about the origin. [1] Diode: negligible current for negative V and small positive V . [1] A forward knee followed by a steep increase in positive current. [1] A smooth knee is acceptable; no exact threshold value is required. See the solution sketches.

Teacher prompt / common error: Lamp heating bends the I-V curve toward the voltage axis. Do not draw a straight line or a diode branch with large negative current.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk



Planning and checking the anti-icing test

19. Describe a method to obtain the filament lamp's full I–V characteristic and test whether the heater obeys Ohm's law. Organise your answer around: circuit and control; range and signs of readings; reliability and safety; analysis and temperature control. [6 marks]

Answer / mark points: 1. Connect an ammeter in series with the test component and a voltmeter in parallel across it. [1]
 2. Use a variable DC supply adjustable from zero, or a suitable potential divider. Record paired V and I values at several settings across the safe operating range. [1]
 3. Reverse the polarity and record negative V and I to obtain the lamp's negative branch. [1]
 4. Repeat measurements and average consistent readings. Use suitable meter ranges, a current limit and switch off before changing components. [1 for a reliability measure and a sensible safety precaution]
 5. Keep the heater temperature constant, e.g. use low-current short tests with recovery time or a temperature-controlled bath. For the lamp, allow readings to settle at each setting. [1]
 6. Plot labelled axes with units. A straight line through the origin for the constant-temperature heater establishes proportionality; calculate R using V/I or the gradient if V is vertical. The lamp gives a non-linear curve. [1]
 Accept equivalent workable methods. The explanation should connect the steps, rather than just list apparatus. A series rheostat alone need not provide a full zero-to-supply range.

Teacher prompt / common error: Temperature control is required for the heater's Ohm test; the lamp intentionally reaches different steady temperatures at different settings.

20. In a separate test, the heater gives 2.00 A at 12.0 V and, after becoming hotter, 3.20 A at 24.0 V. A technician claims that this contradicts Ohm's law. Calculate both resistances and evaluate the claim. [2 marks]

Answer / mark points: $R_1 = 12.0/2.00 = 6.00 \, \Omega$; $R_2 = 24.0/3.20 = 7.50 \, \Omega$. [1 for both] Ohm's law requires constant physical conditions, including temperature. The heater became hotter, so the condition was not met; this does not contradict the law. [1]

Teacher prompt / common error: Ohm's law has a condition. An increased-temperature test cannot be used to reject the constant-temperature relationship.

21. A window needs at least 3.60 kJ transferred to its heater within 2.00 min. The heater operates steadily at 12.0 V and 2.00 A. Using charge transferred and energy per unit charge, determine whether the target is met and calculate the minimum time required to transfer 3.60 kJ. Assume no change in current or potential difference. [3 marks]

Answer / mark points: In 2.00 min, $t = 120 \, \text{s}$ and $Q = It = 2.00 \times 120 = 240 \, \text{C}$. $W = VQ = 12.0 \times 240 = 2880 \, \text{J} = 2.88 \, \text{kJ}$. [1] This is below 3.60 kJ, so the target is not met. [1] For 3600 J, $Q = W/V = 300 \, \text{C}$ and $t = Q/I = 300/2.00 = 150 \, \text{s} = 2.50 \, \text{min}$. [1] Accept a consistent derivation using $W = VIt$.

Teacher prompt / common error: Link current to charge and potential difference to energy. The question gives electrical energy into the heater, not useful energy in the window.

Language and method check

Award distinct physics points only; accept equivalent valid methods and sensible rounding.

For six-mark-style responses, review how circuit choices, controlled conditions and analysis form a workable method.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk

