3.5 Electricity: 1-hour Pack

AQA 7408 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A piece of copper wire used in a laboratory power supply has a cross-sectional area of 2.0 mm^2. The number density of free (charge-carrying) electrons in copper is 8.5×10^{28} m^{-3}.

(a) The current in the wire is 3.0 A. Calculate the mean drift velocity of the free electrons. Use I = n A v q, where q is the charge on an electron (1.60×10^{-19} C). **(3)**

(b) Explain why the drift velocity of the electrons would be greater in a thinner wire of the same material carrying the same current. **(2)**

(c) A different copper wire is 5.0 m long and has a diameter of 0.60 mm. The resistivity of copper is 1.7×10^{-8} ohm metre. Calculate the resistance of the wire. Use R = resistivity x L / A. **(3)**

(Total for Question 1 is 8 marks)

2 A battery has EMF 6.0 V and internal resistance 0.50 ohm. It is connected to an external resistor of resistance 2.5 ohm. Use the equation EMF = I(R + r), where R is the external resistance and r is the internal resistance.

(a) Calculate the current in the circuit. **(3)**

(b) Calculate the terminal potential difference of the battery. **(2)**

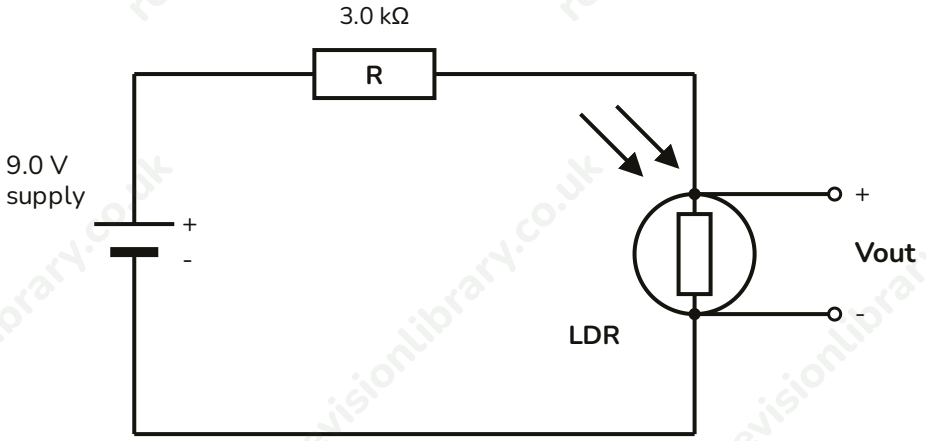
(c) Calculate the power dissipated inside the battery, in its internal resistance. **(2)**

(d) Explain what happens to the terminal potential difference of the battery if the external resistor is replaced with one of much smaller resistance, such as in a short circuit. **(3)**

(Total for Question 2 is 10 marks)

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3 A light-dependent resistor (LDR) is connected in series with a fixed resistor R = 3.0 kilohm across a 9.0 V supply, forming a potential divider. The output voltage, Vout, is taken across the LDR. Use Vout = Vin x R_{LDR} / (R + R_{LDR}).



(a) In bright light the resistance of the LDR is 500 ohm. Calculate Vout. **(3)**

(b) In darkness the resistance of the LDR increases to 12 kilohm. Calculate the new value of Vout. **(2)**

(c) Explain how this potential divider circuit, together with a transistor switch connected to Vout via a suitable switching interface, could be used to switch a garden lamp on automatically at night. **(3)**

(d) State and explain what would happen to Vout in darkness (R_{LDR} = 12 kilohm) if the positions of R and the LDR in the circuit were swapped, so that Vout is now taken across R instead. **(3)**

(Total for Question 3 is 11 marks)

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4 A cylindrical graphite rod is used as a fixed resistor. It has length 55 mm and diameter 2.0 mm. The resistivity of the graphite is 6.5×10^{-5} ohm m.

(a) Calculate the cross-sectional area of the rod. **(1)**

(b) Calculate the resistance of the rod. **(3)**

(c) Using the equation I = nAvq (where n is the number density of charge carriers, A is cross-sectional area, v is drift velocity and q is charge), explain why the resistance of a typical metal wire increases as its temperature rises. **(3)**

(Total for Question 4 is 7 marks)

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5 REQUIRED PRACTICAL. A student investigates the I-V characteristic of a silicon diode. The results are given below.

V (V): 0.00, 0.40, 0.50, 0.55, 0.60, 0.65

I (mA): 0.0, 0.0, 0.1, 0.8, 4.5, 18.0

(a) Describe the shape of the I-V graph for the diode and relate this to its behaviour as a circuit component. **(3)**

(b) Calculate the resistance of the diode at V = 0.65 V. **(2)**

(c) Explain why the diode does not obey Ohm's law, referring to the gradient of the I-V graph. **(2)**

(Total for Question 5 is 7 marks)

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Mark scheme · 3.5 Electricity: 1-hour Pack

Question 1

(a) convert area to m^2: 2.0 mm^2 = 2.0 x 10^{-6} m^2 **M1**

(a) correct rearrangement v = I / (n A q) and substitution **M1**

(a) v = 1.1 x 10^{-4} m/s, awrt 2 sf, cao **A1**

(a) Answer: 1.1 x 10^{-4} m/s

(b) a thinner wire has a smaller cross-sectional area A, with n and q unchanged (same material, same charge carrier) **B1**

(b) since I = n A v q and I is the same, a smaller A means v must be larger to keep I constant, oe **B1**

(b) Answer: The drift velocity increases because A is smaller; since I = nAvq is fixed and n and q are unchanged, v must increase to compensate.

(c) correct area from diameter: A = π$(d/2)^2$ = 2.8 x 10^{-7} m^2 **M1**

(c) correct substitution into R = resistivity x L / A **M1**

(c) R = 0.30 ohm, awrt 2 sf, cao **A1**

(c) Answer: 0.30 ohm

Question 2

(a) correct substitution: 6.0 = I(2.5 + 0.50) **M1**

(a) correct rearrangement I = 6.0/3.0 **M1**

(a) I = 2.0 A, cao **A1**

(a) Answer: 2.0 A

(b) correct method: V = IR (or V = EMF - Ir), ft from (a) **M1**

(b) 5.0 V, cao (ft) **A1**

(b) Answer: 5.0 V

(c) correct substitution into P = I^2 r, ft from (a) **M1**

(c) 2.0 W, cao (ft) **A1**

(c) Answer: 2.0 W

(d) a smaller external resistance R means a smaller total resistance (R + r), so the current I increases, oe **B1**

(d) the pd across the internal resistance (the 'lost volts', Ir) therefore increases **B1**

(d) since terminal pd = EMF - Ir, the terminal pd decreases, approaching zero as R approaches zero (short circuit), oe **B1**

(d) Answer: As R decreases, current increases, so the lost volts (Ir) increase; since terminal pd = EMF - Ir, the terminal pd falls, tending to zero in a short circuit.

Question 3

(a) total resistance R + R_{LDR} = 3000 + 500 = 3500 ohm **M1**

(a) correct substitution into Vout = 9.0 x 500/3500 **M1**

(a) 1.3 V, awrt 2 sf, cao **A1**

(a) Answer: 1.3 V

(b) correct substitution into Vout = 9.0 x 12000/15000 **M1**

(b) 7.2 V, cao **A1**

(b) Answer: 7.2 V

(c) as it gets dark, R_{LDR} increases, so Vout (taken across the LDR) increases, as shown in parts (a) and (b), oe **B1**

(c) a high-input-resistance switching interface has an effective threshold between the bright and dark Vout values, so it drives the transistor on only when Vout rises above that threshold, oe **B1**

(c) the transistor then allows current to flow in the output circuit (e.g. via a relay), switching on the lamp **B1**

(c) Answer: As darkness falls, R_{LDR} and Vout increase. A high-input-resistance switching interface with an effective threshold between the bright and dark Vout values drives the transistor on in darkness, switching on the lamp circuit.

(d) Vout would now be small in darkness (rather than large), because it is taken across R rather than the LDR, oe **B1**

(d) reasoning: as R_{LDR} increases, the larger share of the supply pd is now across the LDR, leaving a smaller share across R (Vout), oe **B1**

(d) correct supporting calculation: Vout = 9.0 x 3000/15000 = 1.8 V (ecf from correct method) **B1**

(d) Answer: Vout would fall to about 1.8 V in darkness (rather than rising), because Vout is now across the fixed resistor R, and R's share of the total pd decreases as R_{LDR} increases.

Question 4

(a) A = π $(1.0 \times 10^{-3})^2$ = 3.14 x 10^{-6} m^2 cao **B1**

(a) Answer: 3.14 x 10^{-6} m^2

(b) quote R = ρ L / A **M1**

(b) substitute R = (6.5 x 10^{-5} x 0.055) / (3.14 x 10^{-6}) **M1**

(b) R = 1.14 ohm cao **A1**

(b) Answer: 1.14 ohm

(c) as temperature rises, the amplitude of vibration of the (fixed) positive ions in the lattice increases **B1**

(c) this causes more frequent collisions between the conduction electrons and the vibrating ions **B1**

(c) so, for a given current, the drift velocity (and hence the ease of electron flow) is reduced, meaning the wire's resistance increases oe **B1**

(c) Answer: Increased temperature increases the vibration amplitude of the lattice ions, causing more frequent collisions with conduction electrons; this reduces the drift velocity attainable for a given current, so the wire's resistance increases.

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Question 5

(a) little or no current flows until the pd reaches a threshold (turn-on) voltage of approximately 0.5-0.6 V **B1**

(a) above the threshold, the current rises very steeply (rapidly increasing gradient) with only small further increases in pd **B1**

(a) this shows the diode is non-ohmic (does not obey Ohm's law) and conducts easily in the forward direction only once the threshold pd is exceeded oe **B1**

(a) Answer: Below about 0.5-0.6 V almost no current flows; above this threshold voltage the current rises very steeply for small further increases in voltage, showing non-ohmic behaviour typical of a forward-biased diode.

(b) $R = V/I = 0.65 / (18.0 \times 10^{-3})$ **M1**

(b) R = 36 ohm cao **A1**

(b) Answer: 36 ohm

(c) Ohm's law requires current to be directly proportional to pd, i.e. a constant gradient (constant resistance) through the origin **B1**

(c) the diode's I-V graph has a gradient (1/R) that changes markedly with V (near zero below threshold, very large above it), so its resistance is not constant oe **B1**

(c) Answer: Ohm's law requires a constant ratio V/I (constant gradient); the diode's gradient changes sharply once past the threshold voltage, so its resistance is not constant and it does not obey Ohm's law.

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