InkPhysics

ANSWER BOOK

Current, charge and the direction problem

Electricity · Year 12

AQA 3.5.1.1 · CIE 9.1.1, 9.1.2, 9.1.3, 9.1.4, 9.2.1, 9.2.2, 9.3.1, 9.3.2
OCR A 4.1.1(a), 4.1.1(b), 4.1.1(c), 4.1.1(d), 4.1.1(e), 4.1.1(f), 4.1.2(a), 4.1.2(b), 4.1.2(c), 4.2.2(a), 4.2.2(d), 4.2.2(e), 4.2.3(a)

20 questions · 58 marks

NAVY EDITION

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SECTION A · Warm-up

A1 $I = \Delta Q/\Delta t = 30/10$ (1) [2]
$I = 3.0$ A (1)

A2 One coulomb is the charge that passes a point when a current of one ampere flows for one second (1); that is, 1 C = 1 A s (1). [2]

A3 $V = W/Q = 12/4.0$ (1) [2]
$V = 3.0$ V (1)

A4 Use of $Q = I\Delta t$ with $t = 2.4 \times 10^{-3}$ s (1); $Q = 0.75 \times 2.4 \times 10^{-3} = 1.8 \times 10^{-3}$ C (1). [2]

A5 $I = 3.2$ A and $t = 3600$ s (1); $Q = It = 3.2 \times 3600 = 1.15 \times 10^{4}$ C (1). [2]

A6 $V = W/Q$ (1); $V = (8.0 \times 10^{-19})/(1.60 \times 10^{-19}) = 5.0$ V (1). [2]

SECTION B · Standard

B1 (a) $Q = It = 0.50 \times 120$ (1) [3]
$Q = 60$ C (1)
(b) $N = Q/e = 60/(1.60 \times 10^{-19}) = 3.75 \times 10^{20}$ (1)

B2 $R = V/I = 6.0/0.25$ (1) [2]
$R = 24\ \Omega$ (1)

B3 $W = QV = 8.0 \times 12$ (1) [2]
$W = 96$ J (1)

B4 $Q = It = 2.0 \times 300$ (1) [2]
$Q = 600$ C (1)

B5 (a) $A = \pi d^2/4 = \pi \times (1.2 \times 10^{-3})^2/4 = 1.1 \times 10^{-6}$ m^2 (1). (b) Use of $I = nAvq$ rearranged to $v = I/nAq$ (1); $v = 13/(8.5 \times 10^{28} \times 1.1 \times 10^{-6} \times 1.60 \times 10^{-19})$ (1) $= 8.5 \times 10^{-4}$ m s^{-1} (1). [4]

B6 The drift velocity doubles (1). The current is the same at every cross-section, because charge cannot accumulate at any point (conservation of charge) (1). In $I = nAvq$, n and q are unchanged, so halving A means v must double to carry the same current (1). [3]

B7 $t = 600$ s (1); $W = VIt = 3.0 \times 0.20 \times 600$ (1) $= 360$ J (1). [3]

SECTION C · Stretch

C1 (a) $Q = It = 3.0 \times 3600$ (1) [4]
$Q = 10800$ C (1)
(b) $W = QV = 10800 \times 230 = 2.48 \times 10^6$ J (1)
(c) $N = Q/e = 6.75 \times 10^{22}$ (1)

C2 Conventional current is defined as the direction in which positive charge would flow (1), from the positive terminal to the negative terminal in the external circuit (1). In a metal the charge carriers are electrons, which are negative (1) and therefore drift in the opposite direction to the conventional current (1). [4]

C3 The convention was fixed long before the electron was discovered (1), and all the established laws and circuit rules were written in terms of it (1). They work correctly as they are, so changing the convention would cause confusion for no benefit; the direction is simply treated as that of positive charge flow (1). [3]

C4 $t = 8.0 \times 3600 = 28800$ s (1); $Q = It = 6.5 \times 28800 = 1.87 \times 10^5$ C (1); this is less than 2.0×10^5 C, so the battery does not charge fully (1). [3]

C5 From $I = nAvq$, with I, A and q the same for both, $v \propto 1/n$ (1); ratio $= n_{Cu}/n_{semi} = (8.5 \times 10^{28})/(5.0 \times 10^{19})$ (1) $= 1.7 \times 10^9$ (1). [3]

C6 In a metal the charge carriers are free electrons, drifting slowly along the wire (1). The current is $I = nAvq$, so its size depends on the carrier density n as well as the drift velocity v (1). n is enormous, around 10^{28} to 10^{29} per m^3, so even a tiny v gives a current of several amperes (1). When the switch closes, an electric field is established around the whole circuit at close to the speed of light (1). Electrons everywhere in the circuit, including inside the lamp, begin to drift at almost the same instant (1). The lamp therefore lights immediately; no individual electron needs to travel from the switch to the lamp (1). [6]

C7 (a) $W = QV = 1.9 \times 10^4 \times 9.0$ (1) $= 1.71 \times 10^5$ J $\approx 1.7 \times 10^5$ J (1). (b) $t = Q/I = (1.9 \times 10^4)/(6.0 \times 10^{-5}) = 3.2 \times 10^8$ s (1); $t = 10.1$ years, so the claim is (just) justified (1). [4]