InkPhysics

ANSWER BOOK

Circuits and Kirchhoff's laws

Electricity · Year 12

AQA 3.5.1.4 · CIE 9.2.3, 10.1.1, 10.1.2, 10.2.1, 10.2.2, 10.2.3, 10.2.4, 10.2.5, 10.2.6, 10.2.7
OCR A 4.1.1(g), 4.2.1(a), 4.2.1(b), 4.2.5(a), 4.2.5(b), 4.3.1(a), 4.3.1(b), 4.3.1(c), 4.3.1(d), 4.3.1(e), 4.3.1(f)

20 questions · 60 marks

NAVY EDITION

SECTION A · Warm-up

A1 The sum of the currents into a junction equals the sum of the currents out of it (1). This expresses conservation of charge (1). [2]

A2 In series resistances add: $R = 20 + 30$ (1)
$R = 50\ \Omega$ (1) [2]

A3 $1/R = 1/20 + 1/20$ (1)
$R = 10\ \Omega$ (1) [2]

A4 Series: emf = 1.5 + 1.5 = 3.0 V (1). Parallel: emf = 1.5 V, and the cells share the current between them, so each works less hard and the battery lasts longer (1). [2]

A5 Adding a resistor in parallel adds an extra path for current without removing any (1). For the same pd the total current is therefore larger, so the combined resistance V/I is smaller than that of either branch alone (1). [2]

A6 $P = I^2R$ (1), because components in series share the same current (1). [2]

SECTION B · Standard

B1 (a) $1/R = 1/6.0 + 1/3.0$ (1)
$R = 2.0\ \Omega$ (1)
(b) $I = V/R = 12/2.0 = 6.0$ A (1) [3]

B2 (a) $R = 4.0 + 8.0 = 12\ \Omega$ (1)
$I = 12/12 = 1.0$ A (1)
(b) $V_1 = IR_1 = 4.0$ V (1)
$V_2 = IR_2 = 8.0$ V (1) [4]

B3 By Kirchhoff's first law the current in equals the current out (1)
$I_{out} = 3.0 + 2.0 = 5.0$ A (1) [2]

B4 $P = I^2R = 2.0^2 \times 5.0$ (1)
$P = 20$ W (1) [2]

B5 $I = P/V = 10500/230$ (1) $= 46$ A (1); $R = V/I$ (or V^2/P) $= 5.0\ \Omega$ (1). [3]

B6 $t = 45 \times 60 = 2700$ s (1); $E = IVt = 2.1 \times 5.0 \times 2700 = 2.84 \times 10^4$ J (1); 28 kJ is well below the claimed 38 kJ, so the claim is not accurate (1). [3]

B7 Kirchhoff's second law: round the loop the emf equals the sum of the pds (conservation of energy) (1); $V = 24 - 9.0 - 7.5 = 7.5$ V (1). [2]

B8 (a) $R = 4.6 + 4.6 = 9.2\ \Omega$, and $P = V^2/R = 12^2/9.2$ (1) $= 16$ W (1). (b) $R = 4.6/2 = 2.3\ \Omega$ (1); $P = 12^2/2.3 = 63$ W (1). [4]

SECTION C · Stretch

C1 Parallel part: $1/R = 1/6.0 + 1/3.0 = 0.50\ \Omega^{-1}$, so $R = 2.0\ \Omega$ (1) [4]
(a) Total $= 4.0 + 2.0 = 6\ \Omega$ (1)
(b) $I = 12/6 = 2.0$ A (1)
(c) pd across the pair $= I \times 2.0 = 4.0$ V, so $I_6 = 4.0/6.0 = 0.67$ A and $I_3 = 1.33$ A (1)

C2 (a) $E = Pt = 60 \times 300$ (1) [4]
$E = 18000$ J (1)
(b) $E = QV$, so $Q = E/V = 18000/230$ (1)
$Q = 78.3$ C (1)

C3 Around any closed loop, the sum of the emfs equals the sum of the potential differences (1); equivalently, the sum of all pd changes around the loop is zero (1). This expresses conservation of energy (1). [3]

C4 Parallel pair: $R = 6.0/2 = 3.0\ \Omega$ (1); total $R = 3.0 + 0.40 = 3.4\ \Omega$ (1); $I = 12/3.4 = 3.5$ A (1); 3.5 A is below the 5.0 A rating, so the fuse does not melt (1). [4]

C5 $I = 6.0/(3.0 + 9.0) = 0.50$ A through both (1); $P_9 = I^2R = 0.50^2 \times 9.0 = 2.25$ W (1); $P_3 = 0.50^2 \times 3.0 = 0.75$ W (1); the 9.0 Ω resistor runs hotter, since series components share the same current and $P \propto R$ (1). [4]

C6 In series the two identical lamps share the supply pd, so each has half the supply pd across it (1). In parallel each lamp has the full supply pd across it, so each dissipates more power and glows brighter (1). The claim assumes a fixed resistance: with R constant, $P = V^2/R$ would give exactly a quarter (1). A filament lamp is not ohmic, since its resistance rises with temperature, and in series each filament runs cooler, so its resistance is lower than at full power (1). The lower resistance lets each series lamp draw more current than the constant-R model predicts, so the series power is more than a quarter of the parallel power and the total current in parallel is less than four times the series current; the claim is only a rough estimate (1). The parallel arrangement still draws much the larger total current, so charge leaves the battery at a higher rate and it transfers its stored energy sooner (1). [6]