InkPhysics

ANSWER BOOK

EMF and internal resistance

Electricity · Year 12

AQA 3.5.1.6 · CIE 10.1.3, 10.1.4, 10.1.5
OCR A 4.2.2(b), 4.2.2(c), 4.2.2(d), 4.3.2(a), 4.3.2(b), 4.3.2(c)(i), 4.3.2(c)(ii)

19 questions · 58 marks

NAVY EDITION

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SECTION A · Warm-up

A1 The emf is the energy transferred to each unit of charge by the source, $\varepsilon = W/Q$ (1). It is measured in volts, or joules per coulomb (1). [2]

A2 $V = \varepsilon - Ir = 6.0 - 0.50 \times 1.0$ (1)
$V = 5.5$ V (1) [2]

A3 $\varepsilon = I(R + r)$ (1), where R is the external resistance and r the internal resistance (1). [2]

A4 When no current flows ($I = 0$), since the lost volts Ir are then zero (1). [1]

A5 Lost volts $= \varepsilon - V = 9.0 - 8.4 = 0.6$ V (1); the energy is dissipated in the internal resistance, warming the battery (1). [2]

A6 The voltmeter draws almost no current from the cell (1), so the lost volts Ir are negligible and the terminal pd is (almost) equal to ε (1). [2]

SECTION B · Standard

B1 $I = \varepsilon/(R + r)$ (1)
$I = 12/(5.0 + 1.0)$ (1)
$I = 2.0$ A (1) [3]

B2 (a) $I = 9.0/(4.0 + 0.50) = 2.0$ A (1)
(b) $V = IR = 2.0 \times 4.0$ (1)
$V = 8.0$ V (1)
(c) $P_{internal} = I^2r = 2.0^2 \times 0.50 = 2.0$ W (1) [4]

B3 Lost volts $= \varepsilon - V = 1.5 - 1.35 = 0.15$ V (1)
$r = (\varepsilon - V)/I = 0.15/0.30$ (1)
$r = 0.50\ \Omega$ (1) [3]

B4 $I = \varepsilon/r$ (1)
$I = 6.0/0.20 = 30$ A (1) [2]

B5 Write $V = \varepsilon - Ir$ for each reading (1); subtracting: $5.7 - 5.1 = r \times (1.8 - 0.60)$, so $r = 0.50\ \Omega$ (1); substitute back: $\varepsilon = 5.7 + 0.60 \times 0.50$ (1) $= 6.0$ V (1). [4]

B6 $r = 0.025\ \Omega$ (1); $V = \varepsilon - Ir = 12.6 - 160 \times 0.025 = 8.6$ V (1); fraction $= IV/I\varepsilon = V/\varepsilon$ (1) $= 8.6/12.6 = 0.68$ (1). [4]

B7 External resistance $= 5.0/2 = 2.5\ \Omega$ (1); $I = \varepsilon/(R + r) = 6.0/(2.5 + 0.50) = 2.0$ A (1); $V = IR = 2.0 \times 2.5 = 5.0$ V (1). [3]

SECTION C · Stretch

C1 From $V = \varepsilon - Ir$, the intercept is the emf, so $\varepsilon = 1.5$ V (1) [4]
The gradient is $-r$, so $r = 0.5\ \Omega$ (1)
At $I = 1.0$ A: $V = 1.5 - 0.5 \times 1.0$ (1)
$V = 1.0$ V (1)

C2 Lost volts $= 12 - 10 = 2.0$ V (1) [4]
$I = (\varepsilon - V)/r = 2.0/2.0 = 1.0$ A (1)
$R = V/I = 10/1.0$ (1)
$R = 10\ \Omega$ (1)

C3 Some energy per unit charge is used driving the current through the battery's own internal resistance, giving 'lost volts' Ir (1). As the current increases, Ir increases (1), so the terminal pd $\varepsilon - Ir$ available to the external circuit falls (1). [3]

C4 Connect the cell in series with the variable resistor, a switch and the ammeter, with the voltmeter across the cell's terminals (1). Vary the resistance to obtain a wide range of currents, recording V and I each time, opening the switch between readings to limit heating (1). Plot terminal pd V against current I; $V = \varepsilon - Ir$ gives a straight line (1). The intercept on the V axis equals the emf (1) and the magnitude of the gradient equals the internal resistance r (1). The intercept extrapolates to $I = 0$, where there are no lost volts, whereas a voltmeter always draws a small current and so reads slightly below ε (1). [6]

C5 P: $V = 6.0 - 2.0 \times 0.90 = 4.2$ V (1); Q: $V = 5.0 - 2.0 \times 0.20 = 4.6$ V (1); only Q's terminal pd exceeds the 4.4 V required, while P falls short (1); choose Q: despite its lower emf, its much lower internal resistance leaves more pd for the motor (1). [4]

C6 Total emf $= 3.0$ V and total internal resistance $= 0.60\ \Omega$, since both add in series (1); $I = 3.0/(2.4 + 0.60) = 1.0$ A (1); $V = IR = 1.0 \times 2.4 = 2.4$ V (1). [3]