Solutions

Each answer shows the steps, then the **result**.

2.1

- the **energy transferred to each unit of charge** from another form into electrical form
- in driving that charge **around a complete circuit**

2.2

- the **e.m.f.** is the energy given **to** each coulomb by the source, as chemical energy becomes electrical
- the **p.d.** is the energy given **up** by each coulomb in the component, as electrical energy becomes thermal or another form

2.3

- use $V = E - Ir$

$$V = 1.5\ \mathrm{V} - 0.60\ \mathrm{A} \times 0.40\ \Omega = \mathbf{1.26}\ \mathrm{V}$$

2.4

- a larger current means a larger p.d. Ir across the **internal resistance**
- the e.m.f. is fixed, so with more of it used inside the cell, less is left for the external circuit and $V = E - Ir$ falls

2.5

- the terminal p.d. **equals the e.m.f.**
- with $I = 0$ there is no p.d. across the internal resistance, so nothing is lost inside the cell

2.6

- the largest current flows when the external resistance is **zero** – the terminals are short-circuited

$$I_{\mathrm{max}} = \frac{E}{r} = \frac{1.5\ \mathrm{V}}{0.40\ \Omega} = \mathbf{3.75}\ \mathrm{A}$$

3.1 C

- the internal resistance is unchanged, but a larger current gives a larger Ir inside the cell, so less of the fixed e.m.f. is left as terminal p.d.
- **D** is the standard error: the e.m.f. does **not** change with current

3.2

(a)

- the battery, the 2.5 Ω resistor and the parallel pair correctly in **series**, with the 6.0 Ω and 3.0 Ω in **parallel** with each other
- the **ammeter in series** with the battery and the **voltmeter in parallel** across its terminals, with correct symbols

(b)

- combine the parallel pair first

$$\frac{1}{R_\text{p}} = \frac{1}{6.0\ \Omega} + \frac{1}{3.0\ \Omega} = \frac{1}{2.0\ \Omega}, \qquad R_\text{p} = 2.0\ \Omega$$

$$R_\text{ext} = 2.5\ \Omega + 2.0\ \Omega = \mathbf{4.5}$$

(c)

- the e.m.f. drives the current through the external resistance **and** the internal resistance

$$I = \frac{E}{R_\text{ext} + r} = \frac{12\ \text{V}}{4.5\ \Omega + 0.50\ \Omega} = \mathbf{2.4}\ \text{A}$$

3.3

(a)

- $V = E - Ir$
- the **intercept** on the V axis is the **e.m.f.** E
- the **gradient** is $-r$, so the internal resistance is minus the gradient

(b)

- the internal resistance is minus the gradient of V against I

$$\text{gradient} = \frac{4.64\ \text{V} - 5.72\ \text{V}}{1.20\ \text{A} - 0.20\ \text{A}} = -1.08\ \Omega$$

$$r = \mathbf{1.08}$$

(c)

- substitute one pair of readings into $E = V + Ir$

$$E = 5.72\ \text{V} + 0.20\ \text{A} \times 1.08\ \Omega = \mathbf{5.94}\ \text{V}$$

(d)

- the power dissipated inside the source is $I^2 r$

$$P = (1.20\ \text{A})^2 \times 1.08\ \Omega = \mathbf{1.6}\ \text{W}$$

(e)

- a real voltmeter draws a small current, so there is a small p.d. Ir inside the cell and the reading is slightly **less** than the e.m.f.