

Emf, internal resistance and kirchhoff's laws

Physics grades 11-12 (A Level · IB · Class 11-12) · Test answers (mark scheme)

Marks are awarded for a correct formula, a clear substitution and an answer with its unit. Accept answers within rounding error and award method marks if an earlier slip is carried through consistently.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB B.5

Question 1 Emf and lost volts (2 marks)

The **emf** is the total energy per coulomb supplied by the battery. The **terminal p.d.** is smaller because energy per coulomb is lost inside the battery in its internal resistance (lost volts, Ir).

Marking: 1 mark for emf as energy per unit charge supplied, 1 mark for the terminal p.d. being smaller by Ir .

Question 2 Cell and resistor (3 marks)

- a. $I = \epsilon / (R + r) = 6.0 / (2.5 + 0.50) = \mathbf{2.0\ A}$.
- b. Lost volts = $Ir = 2.0 \times 0.50 = \mathbf{1.0\ V}$.
- c. $V = 6.0 - 1.0 = \mathbf{5.0\ V}$.

Marking: 1 mark for each part.

Question 3 Junction (2 marks)

Current in = $4.5 + 1.2 = 5.7\ \text{A}$. Current out = $2.0 + 1.3 + I$. So $I = 5.7 - 3.3 = \mathbf{2.4\ A}$, by Kirchhoff's first law (conservation of charge).

Marking: 1 mark for the answer, 1 mark for naming the law.

Question 4 Loop equation (3 marks)

- a. $15 = 2.0 \times 2.0 + 2.0 \times 3.0 + 2.0 \times R$, i.e. the emf equals the sum of the p.d.s.
- b. $15 = 4.0 + 6.0 + 2.0R$, so $2.0R = 5.0$ and $\mathbf{R = 2.5\ \Omega}$.
- c. $V = IR = 2.0 \times 3.0 = \mathbf{6.0\ V}$.

Marking: 1 mark for each part.

Question 5 Potential divider (3 marks)

- a. $V = 12 \times 1.0 / (3.0 + 1.0) = \mathbf{3.0\ V}$.
- b. The lower resistor and the load are in parallel: $R = 0.50\ \text{k}\Omega$. $V = 12 \times 0.50 / (3.0 + 0.50) = \mathbf{1.71\ V}$.

Marking: (a) 1 mark. (b) 1 mark for the parallel resistance, 1 mark for the output.

Question 6 Power in a battery (3 marks)

- a. $P = \epsilon I = 9.0 \times 1.5 = \mathbf{13.5\ W}$.
- b. $P = I^2 r = 1.5^2 \times 0.60 = \mathbf{1.35\ W}$.
- c. Efficiency = $(13.5 - 1.35) / 13.5 = \mathbf{90\ \%}$.

Marking: 1 mark for each part.

Question 7 Short circuit (2 marks)

$I = \epsilon / r = 12 / 0.040 = \mathbf{300\ A}$. The very large current produces intense heating in the wires and battery, which can cause fire or burns.

Marking: 1 mark for the current, 1 mark for the danger.

Question 8 Falling terminal voltage (2 marks)

The lost volts Ir across the internal resistance is proportional to the current. The terminal p.d. is $V = \epsilon - Ir$, so as I increases, **Ir increases and V decreases** while the emf stays constant.

Marking: 1 mark for lost volts proportional to current, 1 mark for $V = \epsilon - Ir$.