A-LEVEL PHYSICS • EXERCISE SHEET

10.1 Practical circuits

Name: ____________ Class: _________ Date: ___________ **Total: 14 marks**

KEY WORDS resistance 电阻 • internal resistance 内阻 • terminal p.d. 端电压 • open circuit 开路 • cell 电池

Objective

Build the skills to answer exam questions on **practical circuits** — e.m.f., p.d., and internal resistance.

You must be able to:

- define **e.m.f.** and distinguish it from **p.d.**
- explain **internal resistance** and use $V = \varepsilon - Ir$
- describe how to measure internal resistance

1 Worked examples

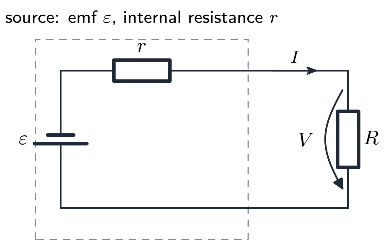
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

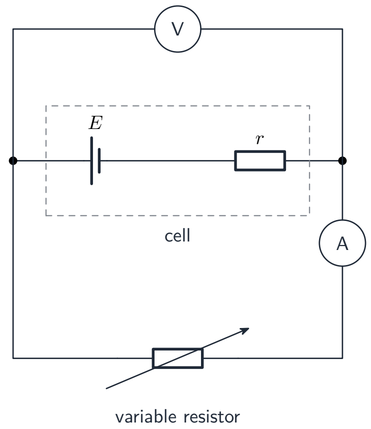
■ e.m.f. and p.d.

e.m.f. ε = energy given to each coulomb by the source (in driving it round the whole circuit). **p.d.** = energy transferred from electrical form by each coulomb in a component. Both in volts.

■ Internal resistance

A real cell has **internal resistance** r. When current flows, Ir is ”lost” inside it, so the **terminal p.d.** is:





Internal resistance in a practical cell

$$V = \varepsilon - Ir.$$

- $I = 0$ (open circuit): $V = \varepsilon$;
- larger current → smaller terminal p.d.

Worked example. $\varepsilon = 1.5$ V, $r = 0.50\ \Omega$, $R = 2.5\ \Omega$: $I = \dfrac{\varepsilon}{R+r} = \dfrac{1.5}{3.0} = 0.50$ A; $V = \varepsilon - Ir = 1.5 - 0.25 = 1.25$ V.

To **measure** r: vary R, plot V against I — the intercept is ε and the gradient is $-r$.

2 Practice

Now apply the methods above.

2.1 Define the **e.m.f.** of a source. [1]

2.2 Write the equation linking **terminal p.d.**, e.m.f., current and internal resistance. [1]

2.3 State the terminal p.d. of a cell when **no current** flows. [1]

2.4 State **one** cause of a cell's internal resistance. [1]

3 Exam-style questions

3.1 A battery of e.m.f. 9.0 V drives two resistors, of 12 Ω and 6.0 Ω, connected in **parallel** with each other. The terminal p.d. is measured as 8.0 V. **Determine** the internal resistance of the battery, and the energy wasted inside it each second. [5]

3.2 As the current drawn from a cell **increases**, the terminal p.d.: [1]

- **A** increases
- **B** decreases
- **C** stays the same
- **D** becomes equal to the e.m.f.

3.3 Explain, in terms of **energy**, the difference between e.m.f. and p.d. [2]

3.4 Describe how a graph can be used to find the **internal resistance** of a cell. [2]

Solutions

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

2.1

- the **energy transferred per unit charge** by the source in driving charge **around the complete circuit**

2.2

- $V = \varepsilon - Ir$

2.3

- equal to the **e.m.f.** ε

2.4

- any one: the resistance of the **electrolyte** in a cell; the resistance of the **wire windings** in a generator

3.1

- the 12 Ω and 6.0 Ω are in parallel

$$\frac{1}{R} = \frac{1}{12\ \Omega} + \frac{1}{6.0\ \Omega} = \frac{1}{4.0\ \Omega} \Rightarrow R = 4.0\ \Omega$$

- the terminal p.d. 8.0 V is across that combination, so $I = V/R$

$$I = \frac{8.0\ \text{V}}{4.0\ \Omega} = 2.0\ \text{A}$$

- lost volts $= \varepsilon - V = 9.0\ \text{V} - 8.0\ \text{V} = 1.0\ \text{V}$, and $r = (\varepsilon - V)/I$

$$r = \frac{1.0\ \text{V}}{2.0\ \text{A}} = \mathbf{0.50}$$

- energy wasted per second $= I^2 r$

$$P = (2.0\ \text{A})^2(0.50\ \Omega) = \mathbf{2.0}\ \text{W} = 2.0\ \text{J s}^{-1}$$

3.2 B

- $V = \varepsilon - Ir$: a larger current means a larger Ir drop inside the cell, so the terminal p.d. **decreases**
- **A** is the opposite; **C** would need $r = 0$; **D** is the open-circuit case ($I = 0$)

3.3

- **e.m.f.** is energy put **into** the circuit per coulomb by the source
- **p.d.** is energy taken **out** of the electrical form per coulomb in a component

3.4

- vary the external resistance and measure V and I
- plot V against I: the magnitude of the **gradient** is r (and the intercept is ε)