Exercise walk-through

Practical circuits ▪ 10.1

eXercise

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

Method — e.m.f. and p.d.

e.m.f. $\varepsilon =$ 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.

Method — Internal resistance

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

$$V = \varepsilon - Ir.$$

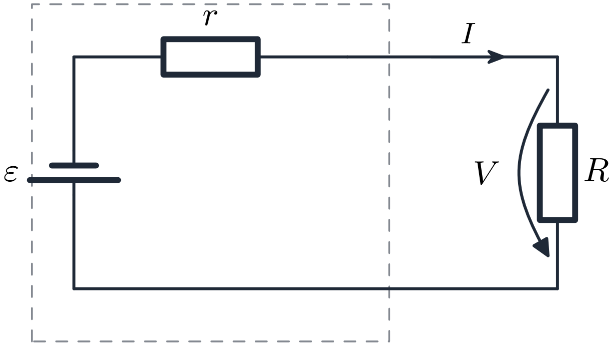
- $I = 0$ (open circuit): $V = \varepsilon$;
- larger current $\to$ smaller terminal p.d.

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.

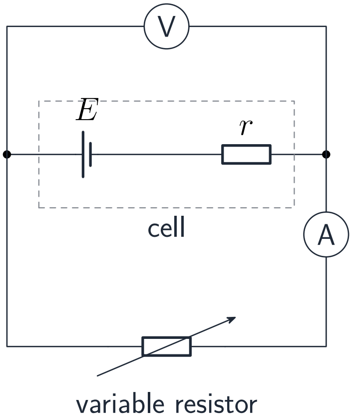
To **measure** r: vary R, plot V against I — the intercept is ε and the gradient is $-r$.

Method — Internal resistance

source: emf ε, internal resistance r



Method — Internal resistance



Internal resistance in a practical cell

Practice 2.1 ▪ 1 mark

Define the **e.m.f.** of a source.

Solution 2.1

Worked steps

The **energy transferred per unit charge** by the source in driving charge **around the complete circuit** B1.

Practice 2.2 ▪ 1 mark

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

Solution 2.2

Method: Internal resistance

Worked steps

$V = \varepsilon - Ir$ **B1**.

Practice 2.3 ▪ 1 mark

State the terminal p.d. of a cell when **no current** flows.

Solution 2.3

Method: Internal resistance

Worked steps

Equal to the **e.m.f.** ε B1.

Practice 2.4 ▪ 1 mark

State **one** cause of a cell's internal resistance.

Solution 2.4

Method: Internal resistance

Worked steps

Any one: the resistance of the **electrolyte** in a cell; the resistance of the **wire windings** in a generator **B1**.

Exam-style 3.1 ▪ 5 marks

A battery of e.m.f. 9.0 V drives two resistors, of $12\ \Omega$ and $6.0\ \Omega$, 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.

Solution 3.1

Method: Internal resistance

Worked steps

External resistance: $\frac{1}{R} = \frac{1}{12} + \frac{1}{6.0}$, so $R = 4.0\ \Omega$ **M1**. The terminal p.d. is across that combination, so $I = \frac{8.0}{4.0} = 2.0$ A **M1**. The "lost volts" are $9.0 - 8.0 = 1.0$ V, so $r = \frac{1.0}{2.0} = 0.50\ \Omega$ **M1** **A1**. Energy wasted per second $= I^2 r = (2.0)^2(0.50) = 2.0$ W, i.e. 2.0 J each second **A1**.

Exam-style 3.2 ▪ 1 mark

As the current drawn from a cell **increases**, the terminal p.d.:

A increases

B decreases

C stays the same

D becomes equal to the e.m.f.

Solution 3.2

Method: Internal resistance

A increases

B decreases ✓

C stays the same

D becomes equal to the e.m.f.

Worked steps

B — decreases (more Ir is lost internally).

Exam-style 3.3 ▪ 2 marks

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

Solution 3.3

Worked steps

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 B1 B1.

Exam-style 3.4 ▪ 2 marks

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

Solution 3.4

Method: Internal resistance

Worked steps

Vary the external resistance and measure V and I B1; plot V against I — the magnitude of the **gradient** is r (and the intercept is ε) B1.