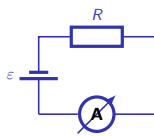


D.C. Circuits

AS Physics ■ Topic 10

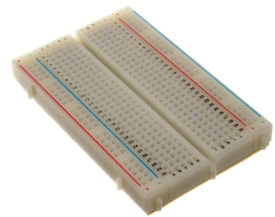
A-Level Physics



D.C. Circuits

What we will cover

- 1 e.m.f. and p.d.
- 2 Internal resistance
- 3 Kirchhoff's laws
- 4 Combining resistors
- 5 Potential dividers
- 6 Recap



1 e.m.f. and p.d.

D.C. Circuits
└ e.m.f. and p.d.

e.m.f. and p.d.

Both in volts – they differ in the **direction** of energy:

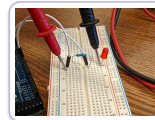
e.m.f. 电动势 $\mathcal{E}$

energy **into** the circuit (source)

p.d. V

energy **out** (resistor, lamp, motor)

Build and test on a **breadboard** 面包板; measure with a **multimeter** 万用表.



Breadboard multimeter

D.C. Circuits
└ e.m.f. and p.d.

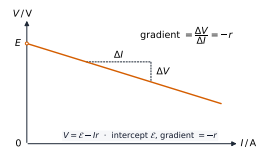
Internal resistance

A real source has **internal resistance** 内阻 r :

$$V_{\text{terminal}} = \mathcal{E} - Ir$$

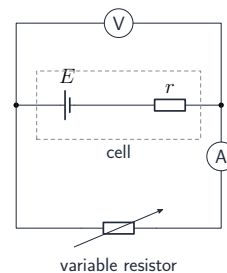
$$\mathcal{E} = 1.5 \text{ V}, r = 0.50 \Omega, R = 2.5 \Omega$$

$$I = \frac{1.5}{3.0} = 0.50 \text{ A}, V = 1.25 \text{ V}$$



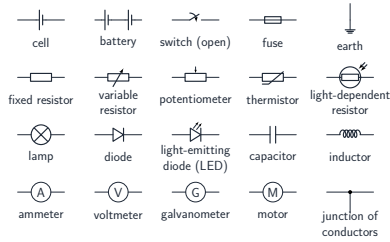
D.C. Circuits
└ e.m.f. and p.d.

The cell drawn with its own resistance



A real cell is an e.m.f. $\mathcal{E}$ in series with r , so the terminal p.d. is $V = \mathcal{E} - Ir$: it **falls** as more current is drawn, and the "lost volts" Ir heat the cell itself.

Circuit symbols

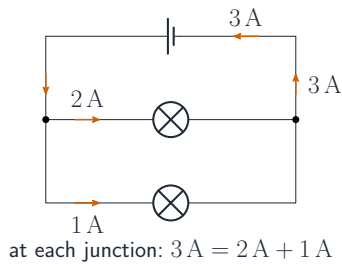


Ideal **ammeter** 电流表:
zero R , in **series**.

Ideal **voltmeter** 电压表:
infinite R , in **parallel**.

2 Kirchhoff's laws

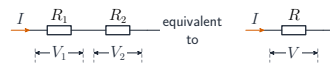
Kirchhoff's two laws



- **First law (junction):** current in = current out (**charge conserved** 电荷守恒)
- **Second law (loop):** $\sum \mathcal{E} = \sum V$ (**energy conserved** 能量守恒)

at each junction: $3\text{ A} = 2\text{ A} + 1\text{ A}$

Resistors in series

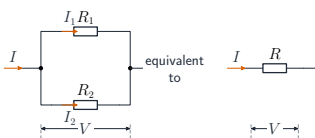


Same **current** 电流; p.d.s add:

$$R_{\text{series}} = R_1 + R_2 + \dots$$

Always **larger** than any single resistor 电阻器.

Resistors in parallel



Same p.d.; currents add:

$$\frac{1}{R_{\text{par}}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

4.0 Ω and 12 Ω in parallel

$$\frac{1}{R} = \frac{1}{4} + \frac{1}{12} = \frac{1}{3} \Rightarrow R = 3.0\ \Omega$$

Solving a circuit

1 label every current & direction

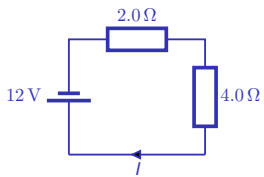
2 junction rule at each node

3 loop rule around each loop

4 $V = IR$ for each resistor

5. solve the equations together

Worked example: one loop



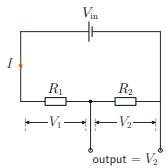
Find I and each p.d.

loop rule: $12 = 2.0 I + 4.0 I = 6.0 I$
 $I = 2.0 \text{ A}; V_1 = 4.0 \text{ V}, V_2 = 8.0 \text{ V}$

Check with the loop: $4.0 + 8.0 = 12 \text{ V}$
 ✓ – the p.d.s use up the e.m.f.

3 Potential dividers

Potential dividers



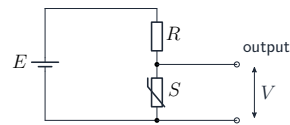
Two series resistors split the p.d. in proportion:

$$V_2 = V_{\text{in}} \cdot \frac{R_2}{R_1 + R_2}$$

6.0 V, 2.0 & 4.0 k

$$V_2 = 6.0 \times \frac{4.0}{6.0} = 4.0 \text{ V}$$

Sensor dividers

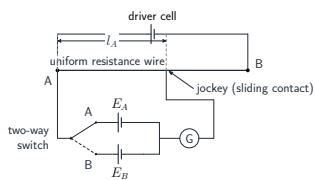


Swap one resistor for a **sensor** 传感器:

- **thermistor** 热敏电阻: output changes with temperature
- **LDR** 光敏电阻: output changes with light

Feed the output to a switch at a **threshold** 阈值.

Potentiometer – the null method



Slide the contact until the **galvanometer** 检流计 reads zero:

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{l_1}{l_2}$$

At balance no current flows, so the cell's internal resistance does not matter.

4 Recap

Topic 10 – key takeaways

1 Internal resistance

$$V_{\text{term}} = \mathcal{E} - Ir$$

3 Resistors

series add; parallel $1/R = \sum 1/R_i$

2 Kirchhoff

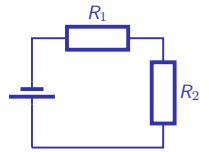
junction: charge; loop: energy

4 Dividers

$$V_2 = V_{\text{in}} R_2 / (R_1 + R_2)$$

Check yourself

- 1 Terminal p.d. of a cell on open circuit?
- 2 Two $6\ \Omega$ resistors in parallel – combined R ?
- 3 Which law comes from conservation of charge?
- 4 Why use the null method to compare e.m.f.s?



Answers 1. equals the e.m.f. ($I = 0$) 2. $3\ \Omega$ 3. the junction (first) law 4. internal resistance has no effect at balance