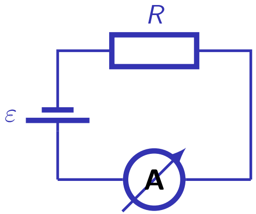
D.C. Circuits

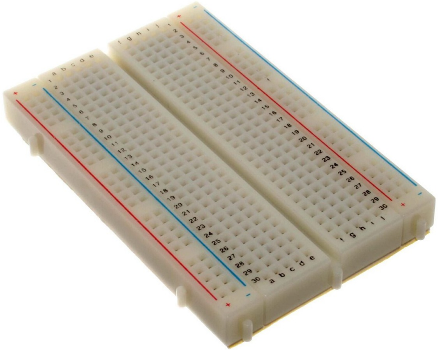
AS Physics ▪ Topic 10

A-Level Physics



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



e.m.f. and p.d.

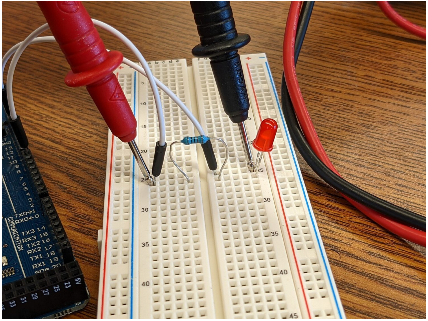
Both in volts – they differ in the direction of energy:

e.m.f. 电动势 ε

energy into the circuit (source)

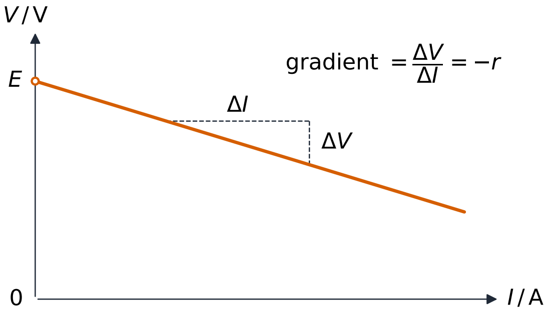
energy out

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



breadboard multimeter

Internal resistance



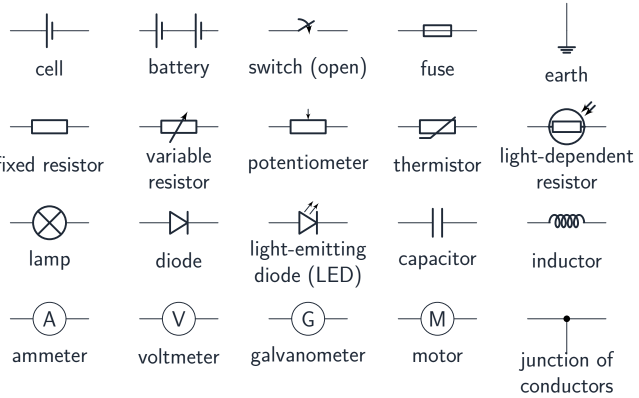
A real source has **internal resistance** 内阻 r:

$$V_{\text{terminal}} = \varepsilon - Ir.$$

$\varepsilon = 1.5\,\mathrm{V},\ r = 0.50\,\Omega,\ R = 2.5\,\Omega$

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

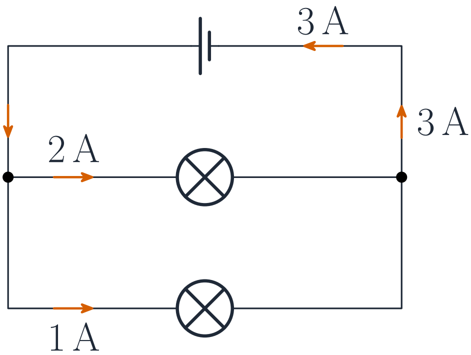
Circuit symbols



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

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

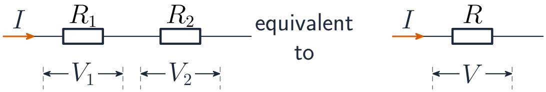
Kirchhoff's two laws



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

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

Resistors in series

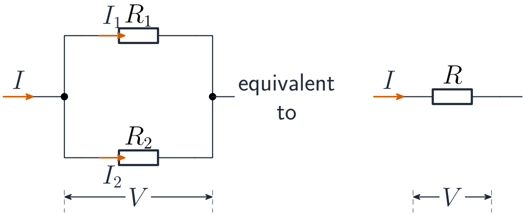


Same current; p.d.s add:

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

Always larger than any single resistor.

Resistors in parallel



Same p.d.; currents add:

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

$4.0\,\Omega$ and $12\,\Omega$ in parallel

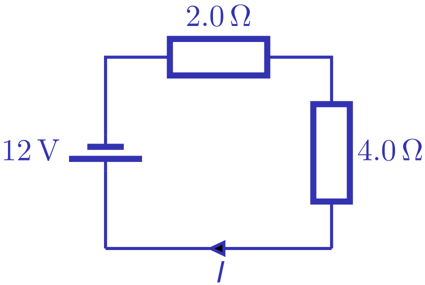
$\frac{1}{R} = \frac{1}{4} + \frac{1}{12} = \frac{1}{3} \Rightarrow R = 3.0\,\Omega$

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.

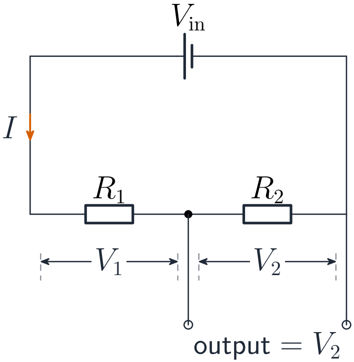
loop rule: $12 = 2.0\,I + 4.0\,I = 6.0\,I$

$I = 2.0\,\mathrm{A}$; $V_1 = 4.0\,\mathrm{V}$, $V_2 = 8.0\,\mathrm{V}$

Check with the loop: $4.0 + 8.0 = 12\,\mathrm{V}$

✓ – the p.d.s use up the e.m.f.

Potential dividers



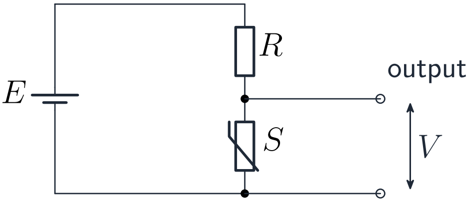
Two series resistors split the p.d. in proportion:

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

6.0 V, 2.0 & 4.0 k

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

Sensor dividers

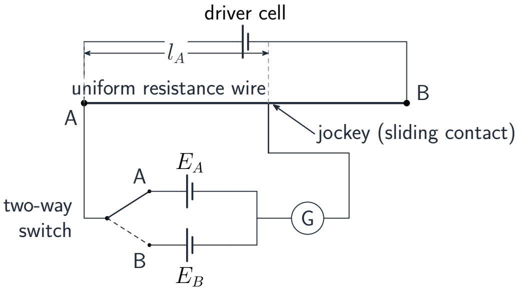


Swap one resistor for a **sensor** 传感器:

- **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:

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}.$$

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

Topic 10 – key takeaways

1 Internal resistance

$V_{\text{term}} = \varepsilon - Ir$

2 Kirchhoff

junction: charge; loop: energy

3 Resistors

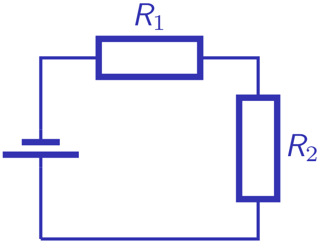
series add; parallel $1/R = \sum 1/R_i$

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