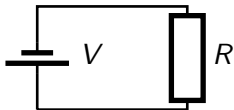


Electric Circuits

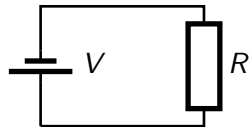
AP Physics 2 ■ Unit 11

AP Physics 2



What we will cover

- 1 Electric current
- 2 Simple circuits and Ohm's law
- 3 Electric power
- 4 Series and parallel resistors
- 5 Kirchhoff's rules
- 6 RC circuits





Electric current

Electric current is the rate charge flows past a point:

Charge per second

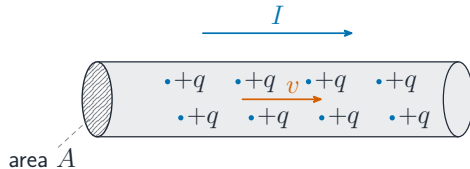
$$I = \frac{\Delta q}{\Delta t} \quad (\text{amperes})$$

Conventional current points the way **positive** charge would flow – opposite to the electron drift.

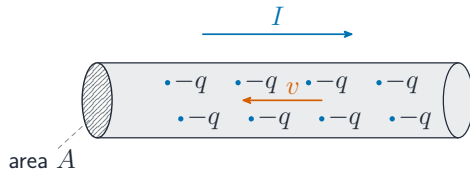


Meters and scopes probe circuit behaviour

Charge carriers drift slowly through a conductor



(a) positive carriers drift with I



(b) electrons drift against I

Charge carriers drift slowly through a conductor to make a current



Simple circuits and Ohm's law

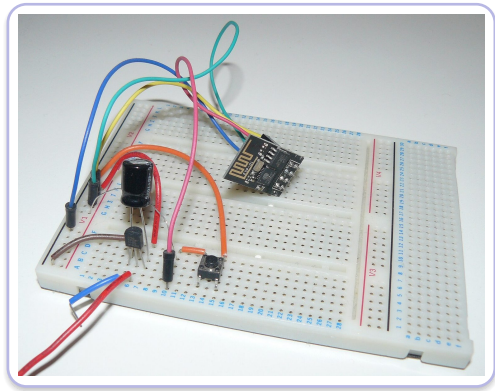
A **battery** pushes current around a complete loop – break it anywhere and current stops everywhere.

Ohm's law

$$V = IR, \quad R = \frac{\rho \ell}{A}$$

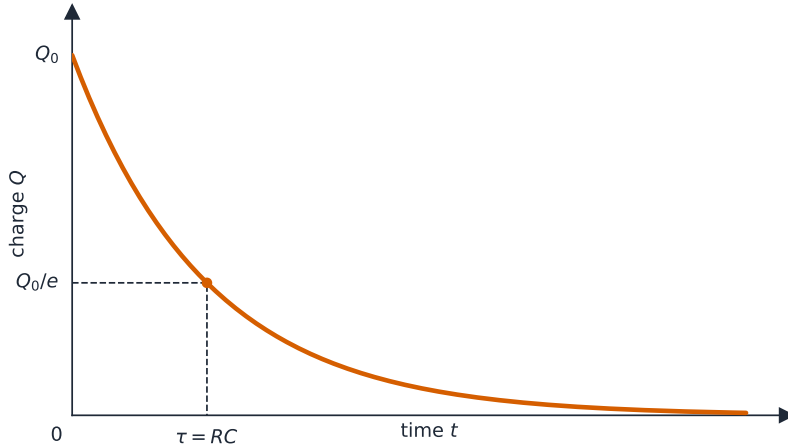
A device is **ohmic** if its I - V graph is a straight line.

12 V across $4\,\Omega$: $I = 3\,\text{A}$.



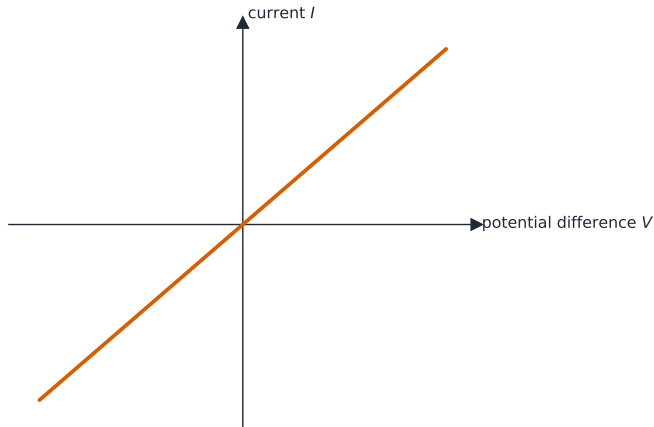
Circuits route charge through components

The charge on a capacitor decays exponentially



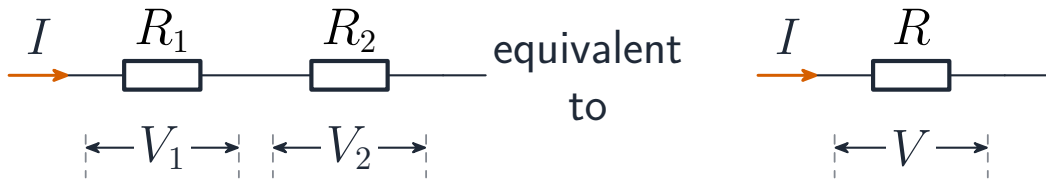
The charge on a capacitor decays exponentially as it discharges

Resistance, Resistivity, and Ohm's Law



The I-V line of an ohmic conductor is straight through the origin

Compound DC Circuits



Resistors in series add to a single equivalent resistance



Electric power

A resistor turns electrical energy into heat or light:

Three forms

$$P = IV = I^2 R = \frac{V^2}{R}$$

Energy delivered: $E = Pt$.

Worked example

3 A across 12 V:

$$P = IV = 3 \times 12 = 36 \text{ W}$$

For 10 s: $E = 360 \text{ J}$. $I^2 R$ and V^2/R give the same 36 W.



Series and parallel resistors

Series – one path, adds up

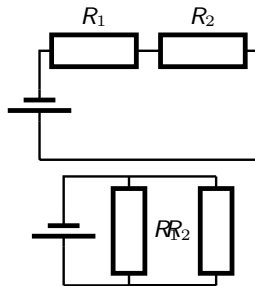
$$R_s = R_1 + R_2 + \dots$$

Same current through each.

Parallel – separate paths, less

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

Same voltage across each.



Two $6\ \Omega$: series 12 , parallel $3\ \Omega$.

Ohm's law, reducing a network, and reading meters

resistance

R opposes current, measured in **ohms**

Ohm's law

$V = IR$ links the three, for an ohmic element

reducing a network

combine series and parallel groups **step by step** to find the total current from the battery, then **work back** to each element

Kirchhoff's junction rule

current in equals current out – charge is conserved

Kirchhoff's loop rule

the potential changes sum to zero round any loop – energy is conserved

brightness

a **light bulb** 's brightness follows its **power**, not its current or its voltage alone

An ideal meter must **barely disturb the circuit**. A **nonideal** ammeter has a small resistance and slightly lowers the current; a real voltmeter draws a little current.



Kirchhoff's rules

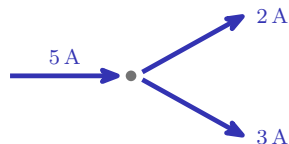
Loop rule (energy)

$$\sum V = 0 \quad \text{around a loop}$$

Batteries raise the potential; resistors drop it – they cancel.

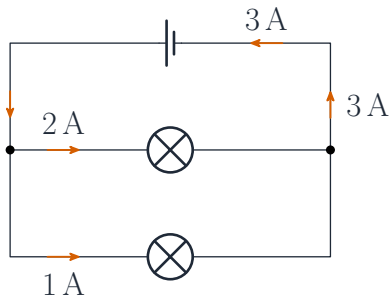
Junction rule (charge)

$$\sum I_{in} = \sum I_{out}$$



$$5 = 2 + 3$$

Current divides at a junction



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

Current divides at a junction: what flows in equals what flows out



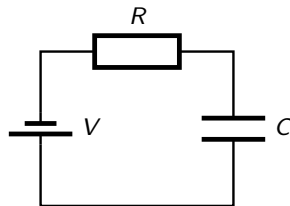
RC circuits

Add a **capacitor** in series and the current changes **smoothly** over time:

Time constant

$$\tau = RC$$

- at first: empty capacitor acts like a wire – current largest
- after a long time (**steady state**): full capacitor blocks current



$$2\,\Omega, 3\,\text{F}: \tau = 6\,\text{s}.$$

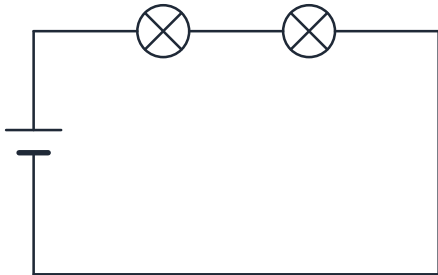
Electric Power, continued



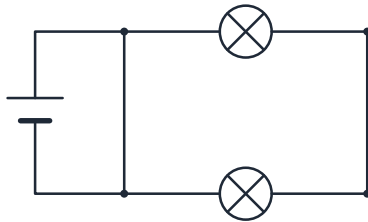
High-voltage power lines: electrical power is transmitted as high voltage so current (and I^2R loss) stays low

Simple Circuits

series



parallel



Components can be joined in series or in parallel

Exam tips

- In **series** the current is the same throughout; in **parallel** the voltage is the same across each branch – never mix these up.
- Combine resistors: series **add**; parallel $1/R_{\text{eq}} = \sum 1/R_i$ (the total is **less** than the smallest).
- Apply **Kirchhoff's rules**: junction (current in = current out, charge conserved) and loop (voltages sum to zero, energy conserved).
- Pick the power form that fits your knowns: $P = IV = I^2 R = V^2/R$.

Exam tips (continued)

- An **ammeter** goes in **series** (ideal: zero resistance); a **voltmeter** goes in **parallel** (ideal: infinite resistance). A real meter slightly disturbs the circuit it measures.
- A bulb is brighter when it dissipates more **power** – in series the biggest resistance ($I^2 R$) glows brightest; in parallel the smallest (V^2/R) does.
- In an **RC circuit** the capacitor acts like a plain wire the instant it starts charging and like a break once fully charged.



Unit 11 – key takeaways

1

Ohm's law

$V = IR$; $R = \rho\ell/A$; ohmic = straight I - V line

2

Power

$P = IV = I^2R = V^2/R$; energy
 $E = Pt$

3

Combinations

series adds; parallel gives less than any branch

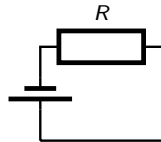
4

Kirchhoff

loop $\sum V = 0$ (energy); junction
 $\sum I_{in} = \sum I_{out}$ (charge)

Check yourself

- 1 12 V across an $8\ \Omega$ resistor – find the current.
- 2 Two $4\ \Omega$ resistors in parallel – what is R_p ?
- 3 What conservation law is the junction rule?
- 4 A fully charged capacitor in steady state – how much current flows?



Answers 1. 1.5 A 2. $2\ \Omega$ 3. conservation of charge 4. zero