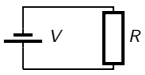
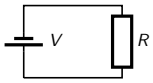
Electric Circuits

AP Physics 2 ▪ Unit 11

AP Physics 2



What we will cover



1 Current

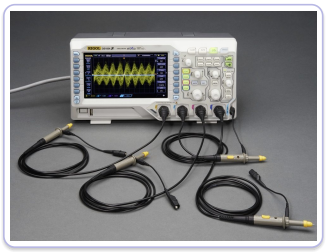
Electric current

Electric current 电流 is the rate charge flows past a point:

Charge per second

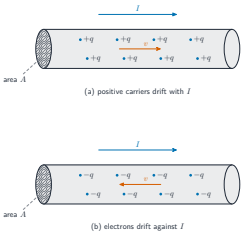
$$I = \frac{\Delta q}{\Delta t} \quad \text{(amperes)}$$

Conventional current 常规电流 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



Charge carriers drift slowly through a conductor to make a current

2 Ohm's law

Simple circuits and Ohm's law

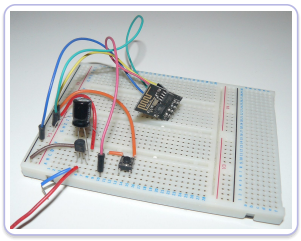
A **battery** 电池 pushes current around a complete loop – break it anywhere and current stops everywhere.

Ohm's law

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

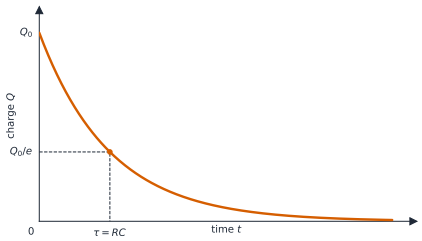
A device is **ohmic** 欧姆性 if its I–V graph is a straight line.

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



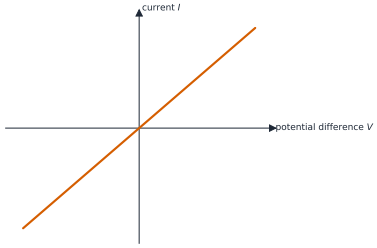
Circuits route charge through components

The charge on a capacitor decays exponentially



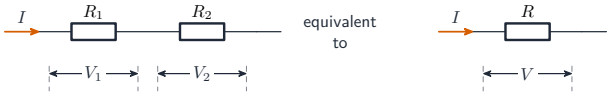
The charge on a capacitor decays exponentially as it discharges

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

3 Power

Electric power

A resistor turns electrical energy into heat or light:

Three forms

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

Energy delivered: $E = Pt$.

Worked example

$3\,\mathrm{A}$ across $12\,\mathrm{V}$:

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

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

4 Series & parallel

Series and parallel resistors

Series – one path, adds up

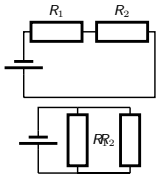
$$R_s = R_1 + R_2 + \dots$$

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 $12\ \Omega$, parallel $3\ \Omega$.

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

resistance 电阻	R opposes current, measured in ohms
Ohm's law 欧姆定律	$V = IR$ 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 基尔霍夫电流定律	current in equals current out – charge is conserved
Kirchhoff's loop rule 基尔霍夫电压定律	the potential changes sum to zero round any loop – energy is conserved
brightness 亮度	a **light bulb** 灯泡's brightness follows its power, not its current or its voltage alone

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

5 Kirchhoff

Kirchhoff's rules

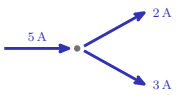
Loop rule (energy)

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

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

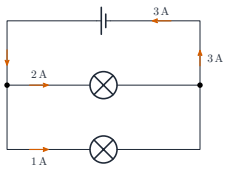
Junction rule (charge)

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



$5 = 2 + 3$

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

6 RC

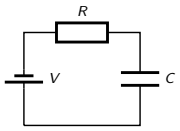
RC circuits

Add a **capacitor** 电容器 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** 稳态): full capacitor blocks current

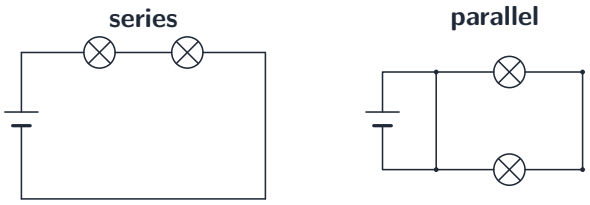


$2\,,3\,\mathrm{F}$: $\tau = 6\,\mathrm{s}$.

Electric Power, continued

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

Simple Circuits



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: $P = IV = I^2R = V^2/R$.

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^2R) 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.

7 Recap

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

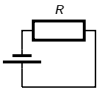
series adds; parallel gives less than any branch

4 Kirchhoff

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

Check yourself

1. $12\,\mathrm{V}$ 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.** $1.5\,\mathrm{A}$ **2.** $2\ \Omega$ **3.** conservation of charge **4.** zero