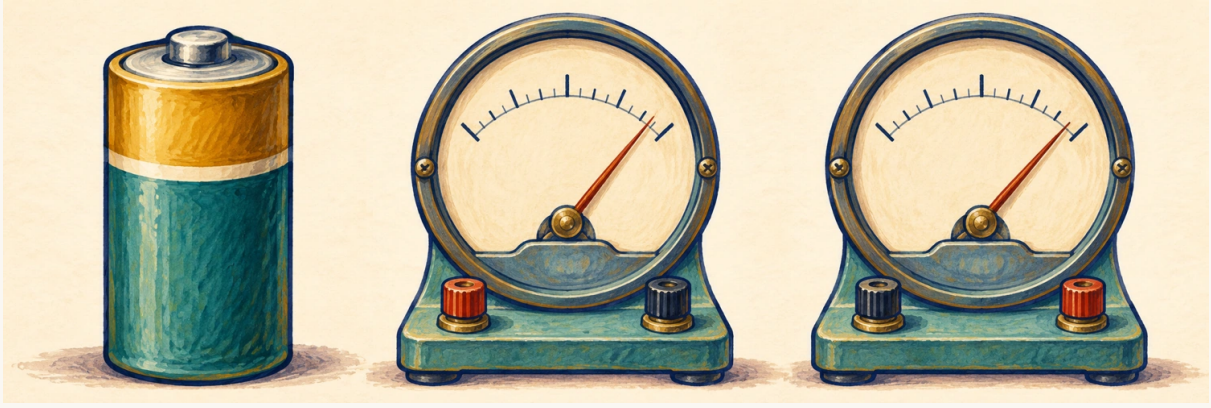
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GRADE 10 / SCIENCE

Chapter 11

Electricity



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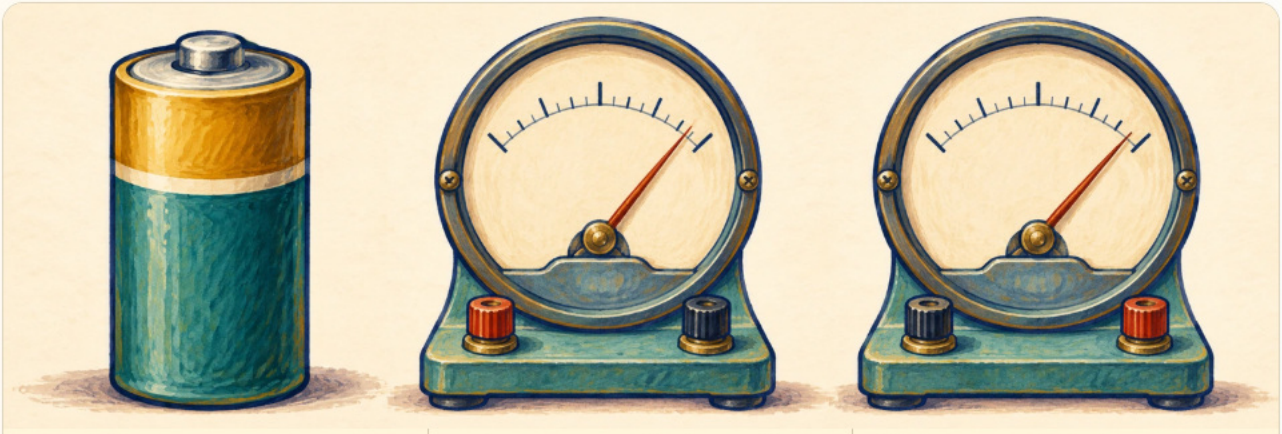
03 Series circuits

04 Parallel circuits

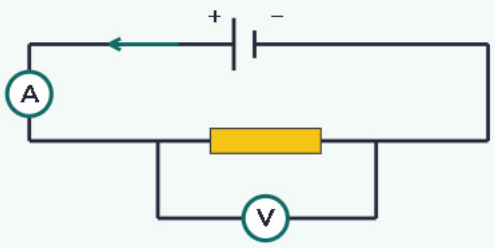
05 Electrical power and energy

Current and potential difference

Current measures how rapidly charge passes a cross-section of a conductor. Potential difference measures the energy transferred per unit charge between two points.



Cell · energy source | Ammeter (A) · in series | Voltmeter (V) · in parallel



Average I = ΔQ/Δt • V = W/Q • 1 A = 1 C/s • 1 V = 1 J/C

A measures current through the resistor. V measures voltage across it.

Current

In a single series path the same current passes each component. Conventional current in an external metal wire flows from positive to negative.

Charge carriers

Electrons drift in the direction opposite to conventional current. The current arrow follows the direction positive charge would move.

Ammeter

Place the ammeter in series with the component, so the current being measured passes through it.

Voltmeter

Connect its two terminals across the component. It reads the potential difference between those two points.

WORKED EXAMPLE

18 C passes through a resistor in 9 s. It transfers 36 J. Find I and V.

I = 18/9 = 2 A. V = 36/18 = 2 V. Each coulomb transfers 2 joules in the resistor.

SELF-CHECK

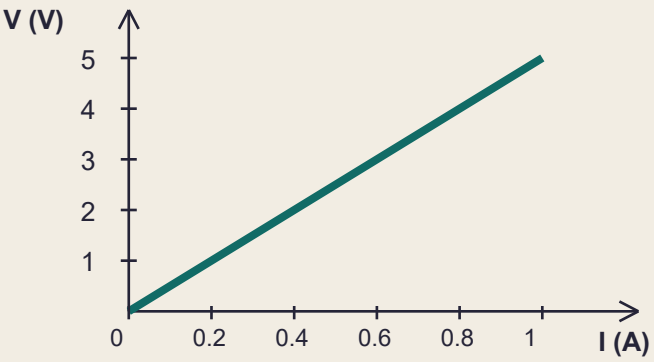
A lamp has a potential difference of 6 V. How much energy is transferred by 4 C?

W = VQ = 6 × 4 = 24 J.

Electricity

Resistance and Ohm's law

An ohmic conductor at constant temperature has a constant ratio of potential difference to current. Its voltage–current graph is a straight line through the origin.



Read the graph

At 1.0 A the voltage is 5.0 V. The slope is 5.0 V/A, or 5 Ω.

Read the slope

On a graph with I on the horizontal axis and V on the vertical axis, slope = ΔV/ΔI = resistance in ohms. Swapping the axes changes the meaning of the slope.

Change the wire

For a uniform wire, R = ρL/A. At fixed material and temperature, doubling length doubles resistance. Doubling cross-sectional area halves it.

WORKED EXAMPLE

A 5 Ω resistor carries 0.6 A. What is the voltage across it?

Use V = IR. Multiplying 0.6 A by 5 Ω gives 3.0 V. The point (0.6 A, 3.0 V) lies on the line for this resistor.

SELF-CHECK

A 2 m nichrome wire has area 0.5 mm² and resistivity 1.1×10^{-6} Ω m. Find R.

0.5 mm² = 0.5×10^{-6} m². R = $(1.1 \times 10^{-6} \times 2)/(0.5 \times 10^{-6})$ = 4.4 Ω.

Electricity

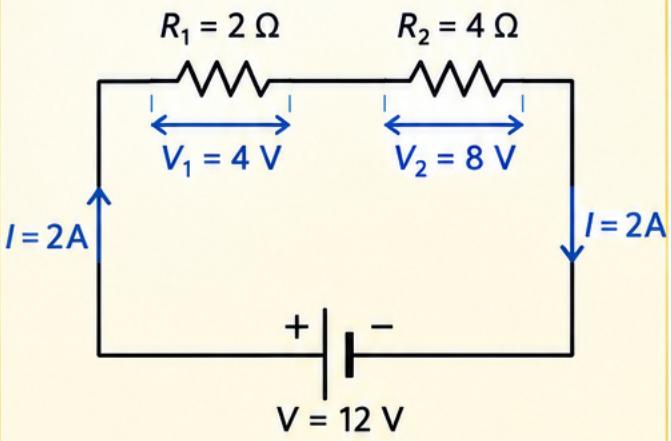
Sheet 3 of 5

Series circuits

What is a series circuit?

A circuit in which components are connected end to end in a single path, so the same current flows through each component.

Example: two resistors in series



Closed circuit

Worked example: reasoning

Two resistors 2 Ω and 4 Ω are connected in series to a 12 V source. Find the current and the voltage across each resistor.

Solution:

(i) Equivalent resistance,

$$R_s = R_1 + R_2 = 2\ \Omega + 4\ \Omega = 6\ \Omega$$

(ii) Current (same in series),

$$I = \frac{V}{R_s} = \frac{12\ \text{V}}{6\ \Omega} = 2\ \text{A}$$

(iii) Voltage across each resistor,

$$V_1 = I R_1 = 2\ \text{A} \times 2\ \Omega = 4\ \text{V}$$

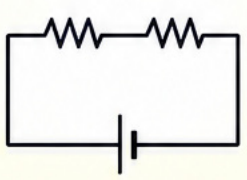
$$V_2 = I R_2 = 2\ \text{A} \times 4\ \Omega = 8\ \text{V}$$

Key results for a series circuit

1. **Current:** same through all components (I is constant).
2. **Voltages:** add up to the source voltage, $V = V_1 + V_2 + \cdots$.
3. **Resistances:** add up, $R_s = R_1 + R_2 + \cdots$.

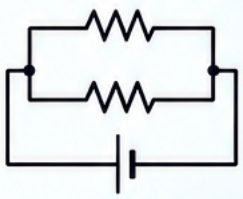
Visual comparison

Series (single path)



- Same current through all.
- Voltages add.
- Resistances add.

Parallel (more than one path)



- Current divides.
- Same voltage across each branch.
- Equivalent resistance is smaller.

Self-check

Connect a 3 Ω and a 6 Ω resistor in series across 9 V. What voltage does each receive? First find the current. R = 9 Ω, so I = 1 A. V_1 = 1 × 3 = 3 V. V_2 = 1 × 6 = 6 V. The two drops add to 9 V.

Electricity — Sheet 4 of 5

Parallel circuits

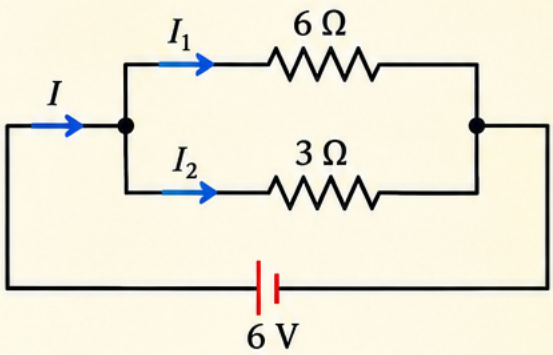
A parallel circuit has two or more branches connected across the same two points. Each branch gets the same potential difference (voltage).

Key facts

- **Voltage** is **same** across every branch ($V_1 = V_2 = \cdots = V$).
- **Branch currents add** to give the total current: $I = I_1 + I_2 + \cdots$.
- The **equivalent resistance** is **smaller** than the smallest branch resistance.

Circuit and example

Two resistors, 6 Ω and 3 Ω, in parallel across a 6 V source.



Worked example (reasoning)

Find the branch currents and equivalent resistance.

For each branch ($V = 6$ V):

$$I_1 = \frac{V}{R_1} = \frac{6\text{ V}}{6\ \Omega} = 1\text{ A},$$

$$I_2 = \frac{V}{R_2} = \frac{6\text{ V}}{3\ \Omega} = 2\text{ A}.$$

Total current: $I = I_1 + I_2 = 1\text{ A} + 2\text{ A} = 3\text{ A}$.

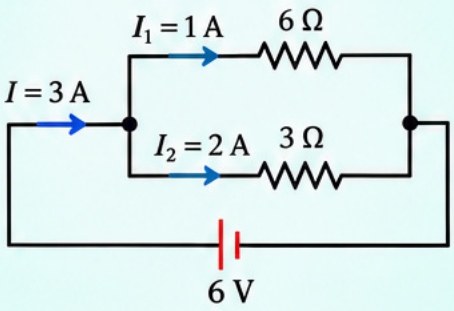
Equivalent resistance:

$$\frac{1}{R_{eq}} = \frac{1}{6\ \Omega} + \frac{1}{3\ \Omega} = \frac{1}{6} + \frac{2}{6} = \frac{3}{6},$$

$$R_{eq} = 2\ \Omega.$$

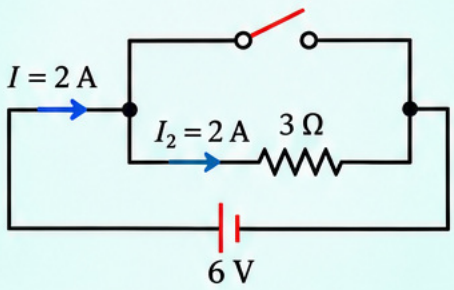
Compared with an open branch

Both branches working



$R_{eq} = 2\ \Omega$ (current = 3 A)

Top branch open (break)



$R_{eq} = 3\ \Omega$ (current = 2 A)

What to note

- Opening one branch stops current only in that branch; the other branch still gets the full supply voltage (here, 6 V).
- Hence, the total current decreases and the equivalent resistance increases (from 2 Ω to 3 Ω).

Self-check

Start with 6 Ω and 3 Ω in parallel across an ideal 6 V supply. What happens if the 3 Ω branch opens? Only the 6 Ω path remains, so I = 6 V ÷ 6 Ω = 1 A. The full 6 V is still across the working branch.

Electricity — Sheet 5 of 5

Electrical power and energy

Electrical power

Rate at which electrical energy is converted (e.g., to heat, light, motion).

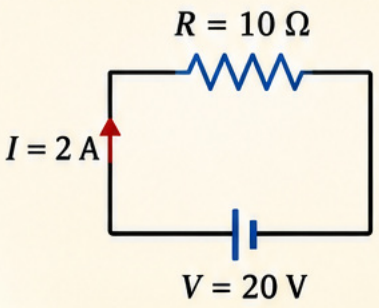
$$P = VI$$

P : power (W)
V : potential difference (V)
I : current (A)

For a resistor (R)

Using $V = IR$, power can also be written as

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



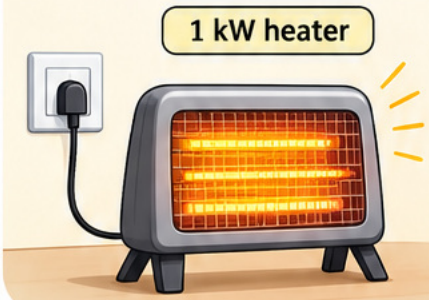
$P = I^2R$
$= (2\text{ A})^2 \times 10\ \Omega$
$= 40\text{ W}$

Joule heating

Electrical energy converted into heat in a resistor (Joule's law):

$$H = I^2Rt$$

H : heat energy (J)
I : current (A)
R : resistance (Ω)
t : time (s)



In 30 min,
$E = Pt$
$= 1\text{ kW} \times 0.5\text{ h}$
$= 0.5\text{ kWh}$
$= 1.8\text{ MJ}$

Power vs energy

Aspect	Power (P)	Electrical energy (E)
Meaning	Rate of using/ converting electrical energy	Total electrical energy used
Unit	watt (W) (1 kW = 1000 W)	joule (J) or kilowatt-hour (kWh) (1 kWh = 3.6 MJ)
Relation	$E = Pt$ (for constant power)	

Worked example (reasoning)

A resistor of 5 Ω is connected to a 10 V supply for 2 min. Find (i) the power and (ii) the heat produced.

Solution:

(i) $P = \frac{V^2}{R} = \frac{10^2}{5} = 20\text{ W}.$

(ii) $t = 2\text{ min} = 120\text{ s}.$

$H = I^2Rt,$ where $I = \frac{V}{R} = \frac{10}{5} = 2\text{ A}.$

$H = (2\text{ A})^2 \times 5\ \Omega \times 120\text{ s} = 2400\text{ J}$
$= 2.4\text{ kJ}.$

Self-check (answered)

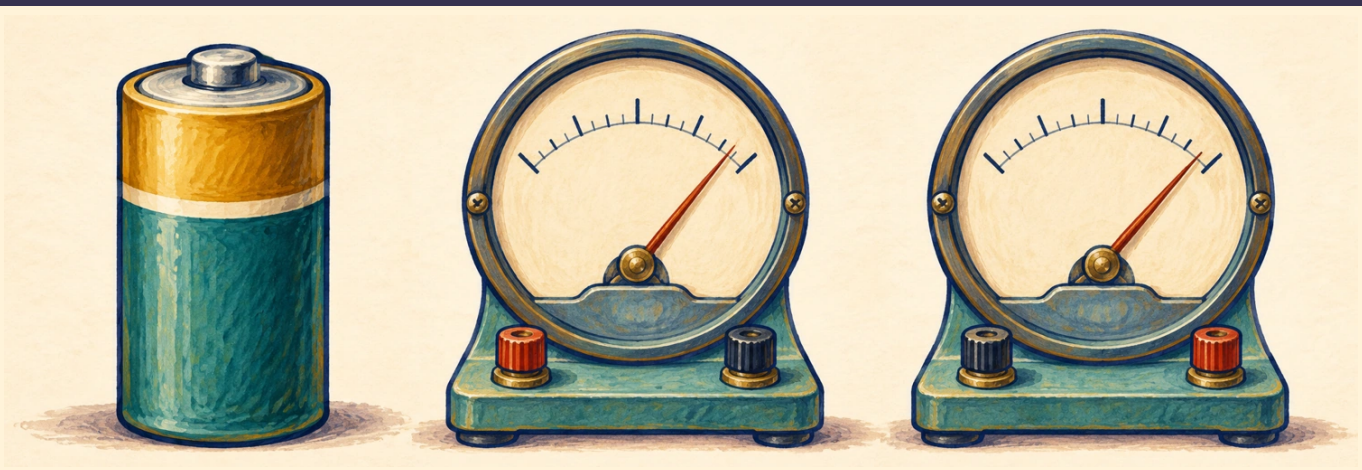
A 100 W bulb is used for 5 h. How much electrical energy is consumed?

Answer: $E = Pt = 100\text{ W} \times 5\text{ h}$
$= 500\text{ Wh} = 0.5\text{ kWh}$
$= 0.5 \times 3.6\text{ MJ} = 1.8\text{ MJ}.$

ONE LAST CHALLENGE

What does a volt buy you?

A lamp transfers 12 joules of energy as 2 coulombs of charge pass through it. What will a voltmeter across the lamp read?



THE REVEAL

6 volts.

Divide energy by charge: 12 J / 2 C = 6 J per coulomb. Each coulomb transfers 6 joules of energy in the lamp.

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