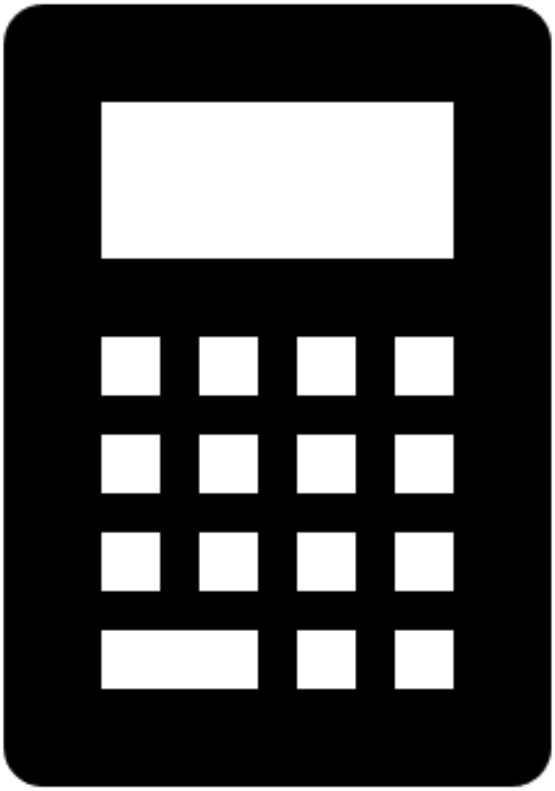
Circuit Calculations



Charge and current

Charge: Negatively charged **electrons** are given a force by a battery (or power supply) and move throughout a circuit. Charge has units of **coulombs.** Each electron carries a charge of -1.6×10^{-19} C. Therefore, there are about 6.25×10^{18} electrons in one coulomb.

Current: The rate of flow of charge (i.e. how much charge is flowing every second). Current has units of **Amps** and is measured with an **ammeter**. The ammeter measures the number of charges that flow through it in one second. They therefore must go in **series**.

Charges flow around a circuit carrying energy. They are given energy by a cell and they transfer this energy at the components.

Charge, current and time are linked by the equation:

$$\mathbf{Q = I \times t}$$

Where I = Current (Amps, A)

Q = Charge (Coulombs, C)

t = Time (s)

Example question: Calculate the current when 4 C of charge passes a point in 8 seconds.

Step 1: Write the equation. Rearrange if necessary.
Q = I × t → Q ÷ t = I
Step 2: Write down the variables
Q = 4 C
t = 8 s
Step 3: Calculate the answer
I = Q ÷ t = 4 ÷ 8 = 0.5 A

Independent practice

1. What is charge?
2. How many electrons in one coulomb?
3. What is Current?
4. What is used to measure current?
5. Extended writing (paragraph required): Describe how energy is carried in a circuit from one location to another.

Basic: Find the unknown quantity – show your working in your books:

a) I = Q = 8 C t = 20 s	b) I = Q = 240 C t = 300 s	c) I = Q = 400 C t = 200 s	d) I = Q = 750 C t = 350 s	e) I = Q = 300 C t = 100 s	f) I = Q = 50 C t = 2 s
g) Re-arrange the equation for Q	h) I = 2.5 A Q = t = 300 s	i) I = 5 A Q = t = 200 s	j) I = 13 A Q = t = 350 s	k) I = 10 A Q = t = 100 s	l) I = 6 A Q = t = 2 s
m) Re-arrange the equation for t	n) I = 4 A Q = 240 C t =	o) I = 20 A Q = 400 C t =	p) I = 5 A Q = 750 C t =	q) I = 6 A Q = 300 C t =	r) I = 2.4 A Q = 50 C t =

Medium: Find the unknown quantity (**CONVERT FIRST to SECONDS**)

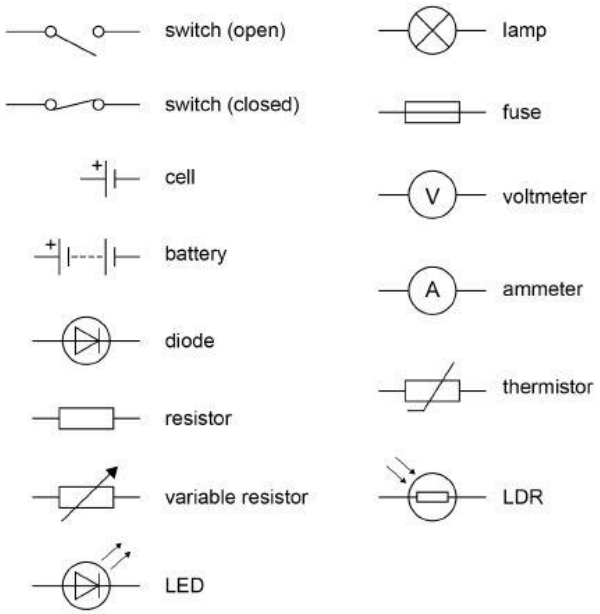
a) I = Q = 140 C t = 4 min = _____ s	b) I = 0.3 A Q = t = 1.5 hours = _____ s	c) I = 0.9 A Q = t = 3 min = _____ s
d) I = Q = 200 C t = 5 min = _____ s	e) I = 1.5 A Q = t = 2 hours = _____ s	f) I = 0.4 A Q = t = 7 min = _____ s

Hard: WORD PROBLEMS

1. How much current must there be in a circuit if 1000 coulombs flow past a point in the circuit in 4 minutes?
2. A circuit is switched on for half a minute and 90 coulombs of charge flowed. What was the current flowing through the circuit?
3. If there is a current of 10 mA in a circuit for 0.5 s, what quantity of electric charge flows in through the circuit?
4. How much time is required for 0.3 coulombs of charge to flow past a point if the rate of flow (current) is 2 mA?
5. During electrolysis 6A was passed through some copper chloride and a charge of 1.2 kC flowed. How long was the experiment on for?

L2 Circuit Diagrams

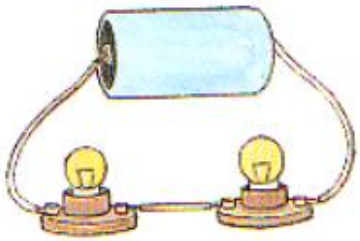
We use circuit symbols to show different **components** (parts) of an electrical circuit. Circuit diagrams are drawn in pencil and a ruler used to draw the connecting wires.



For the circuit to work, it needs to be **complete** (not have any gaps in it)

Fill out the picture opposite with the names of the different components.

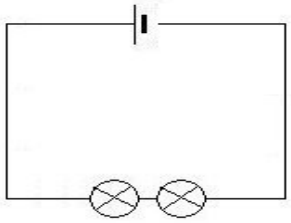
There are two types of circuit, **series** and **parallel**.



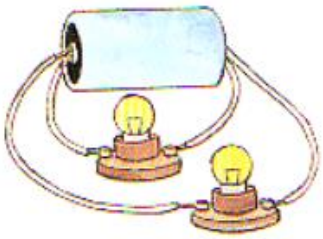
In a **series circuit**:

-There is only one route around the circuit.

-The current needs to flow through all of the components.

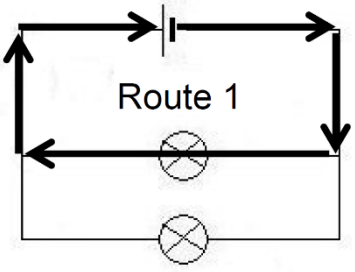


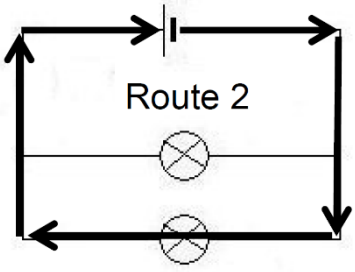
In a **parallel circuit:**



-There is more than one route around the circuit.

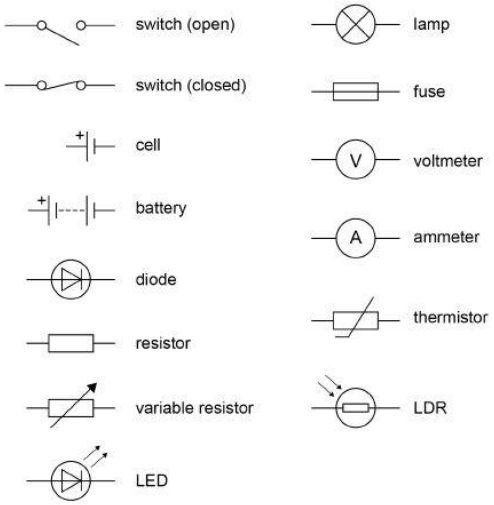
-The current does not need to flow through all of the components.



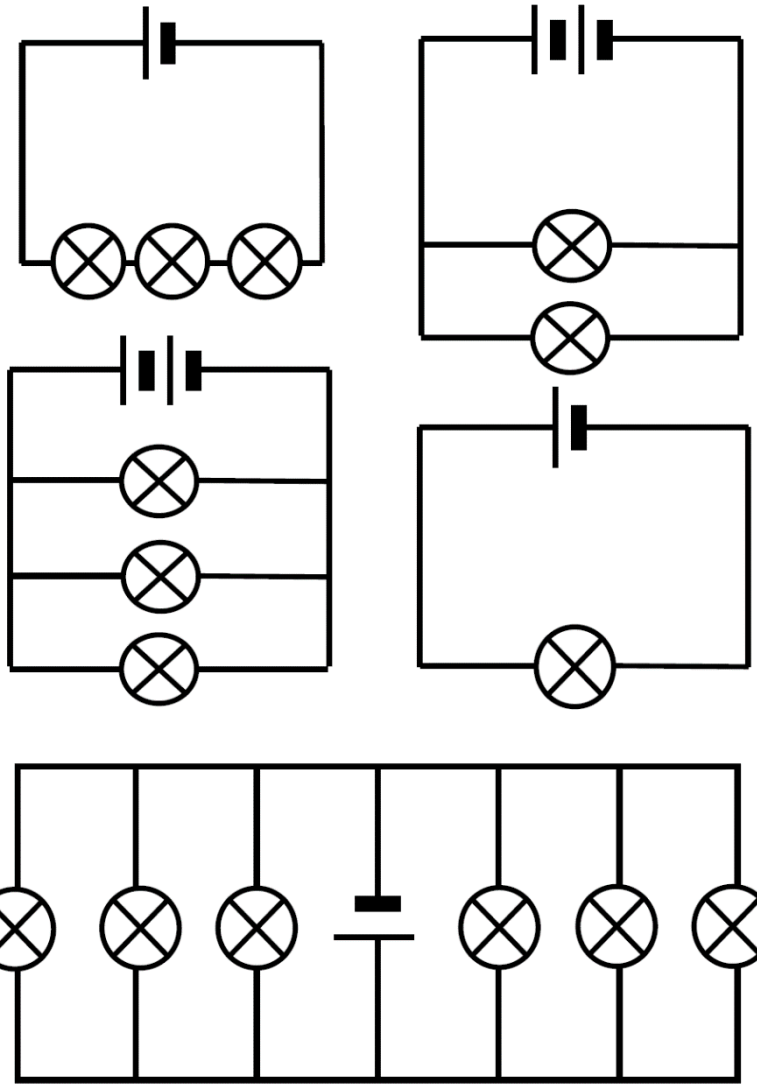


Independent practice

Basic:



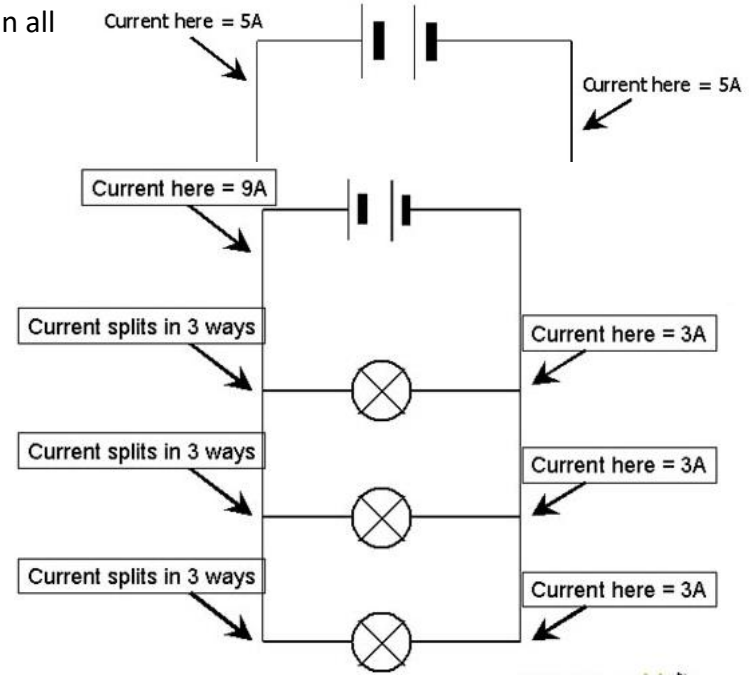
1. Draw the symbols for:
   a) A bulb
   b) A cell
   c) A battery
   d) A voltmeter
   e) An ammeter
   f) A fuse
   g) An LDR
   h) A thermistor
   i) A resistor
   j) A variable resistor
   k) An LED
   l) A switch
2. Look at each of the circuit diagrams to the right. Label each one as either a series or parallel circuit. If the circuit is parallel, write how many different routes there are around the circuit.
3. Draw a circuit with:
   a. A bulb, cell, ammeter
   b. A cell, two bulbs and a voltmeter
   c. A cell and two bulbs connected in parallel.
   d. Two cells and two bulbs in series
   e. A cell, an open switch and two bulbs in series.
   f. A cell a switch and two bulbs in parallel. The switch only controls one bulb



L3 Measuring current

In a series circuit the current flow through one continuous path. This means that the current must be the **same** at all parts in a series circuit.

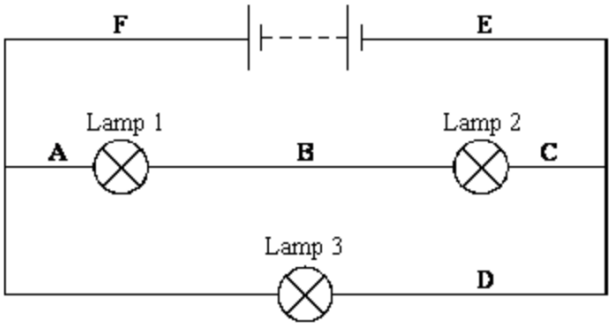
In the series circuit opposite, the current is 5 Amps in all positions.



However, things are more complicated for a parallel circuit. Let's take the circuit to the right. Immediately after the battery there is a current of 9A.

The moving electrons that make up this current then have a decision on where to go. There are overall three separate paths. Therefore (if the bulbs are identical) a third of the current goes in each path. This means that there is 3 Amps in each path. Current **splits** in a parallel circuit.

However, current only splits equally if the resistance in each path is equal.



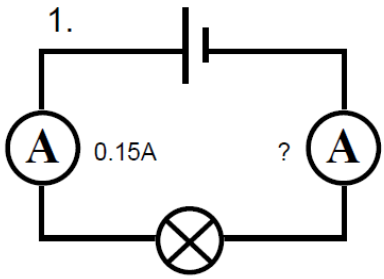
Current prefers to take the path of least resistance.

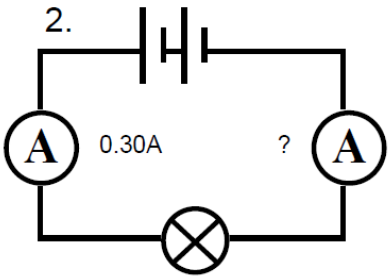
In the diagram above, the path A→B→C has double the resistance of path D. This means that it is twice as hard for the current to pass through A→B→C. Because of this, path D has twice the current of path A→B→C. If path D had a current of 1 Amp flowing, then there would be a current of 0.5A flowing through A→B→C.

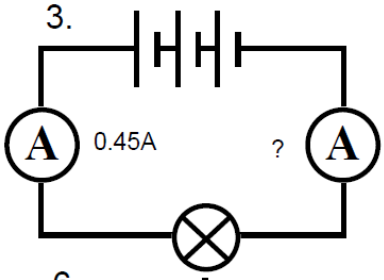
At points E or F the currents from the two paths would combine to form an overall current of 1.5A. **Current is conserved at a junction**.

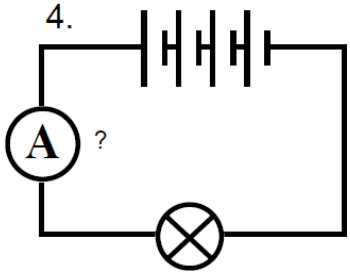
Independent practice

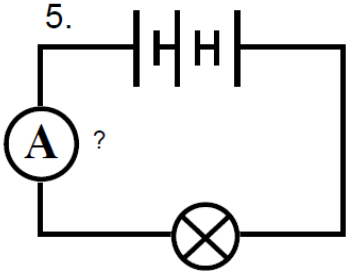
Basic:

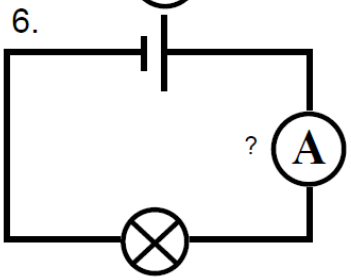




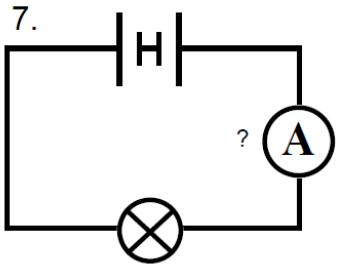


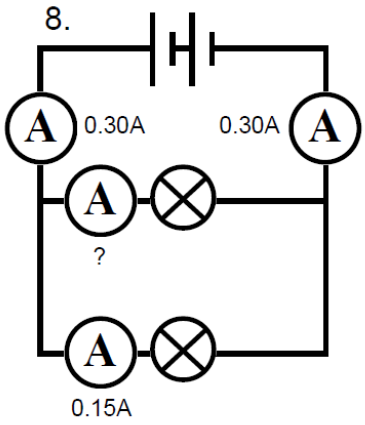


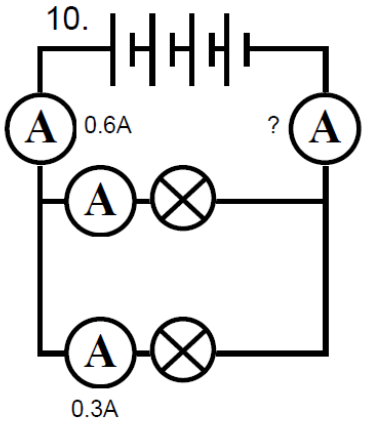


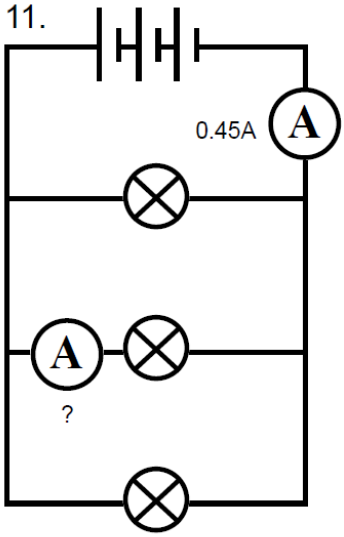


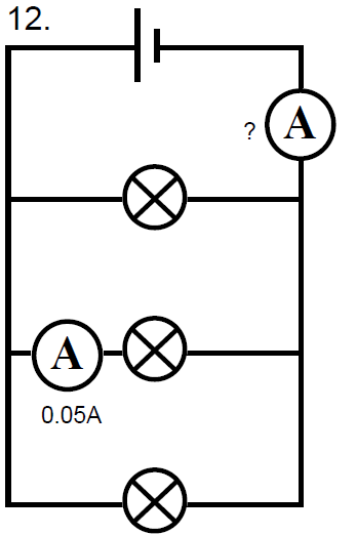
Medium:

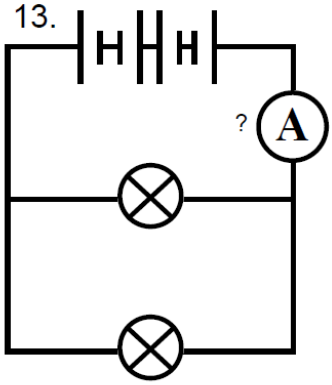






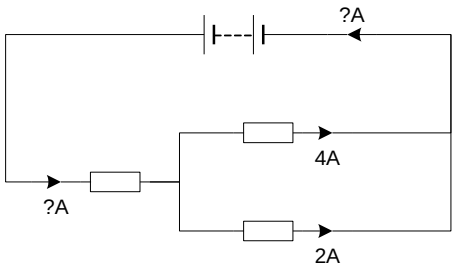


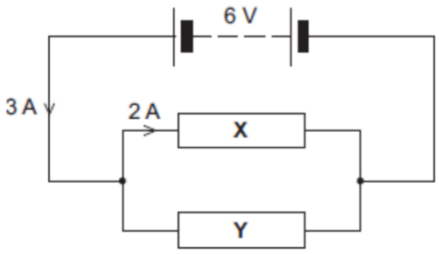




Hard:

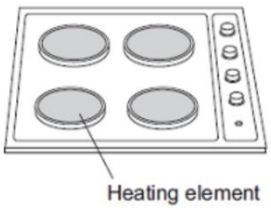
1. The resistors in the circuit opposite are not of equal resistance. What is the current on the remaining ammeters? Explain why.

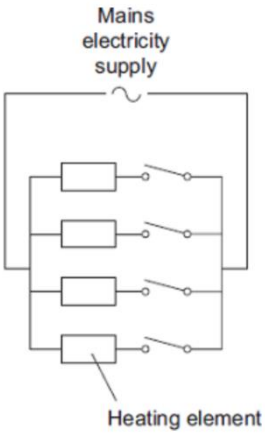




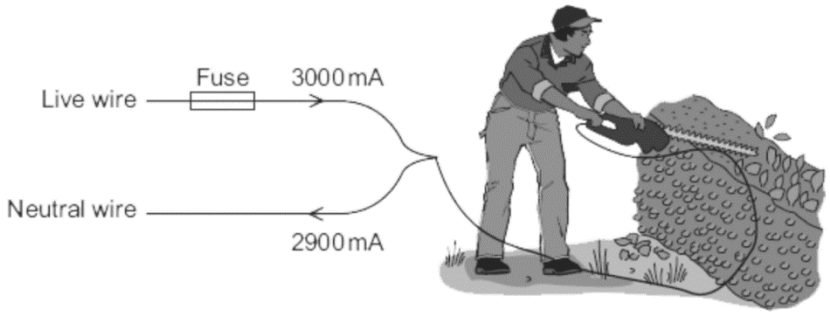
2. What is the current through resistor Y? Explain why.

3. The picture shows an electric cooker hob. The simplified circuit diagram shows how the four heating elements connect to the mains electricity supply. The heating elements are identical.



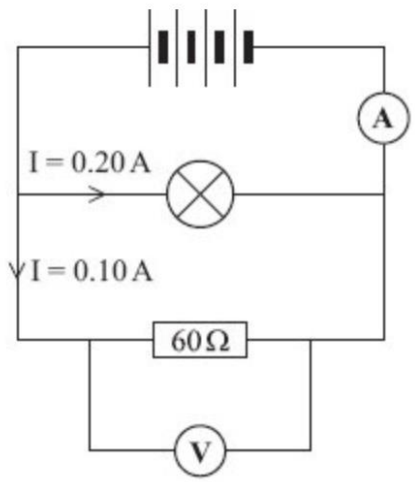


At full power the hob draws a current of 26 A. What is the current through each heating element?



4. The diagram above shows how someone could get an electric shock from accidentally cutting into an electric cable. If this happens, the fuse can overheat and melt.

What is the current in the hedge trimmer above? Why?



5. What is the current in the ammeter in the diagram to the left? Why?

L4 Potential difference

Potential difference is the difference in the amount of energy that charge carriers have between two points in a circuit. The following equation shows this:

$$E = Q \times V$$

Where E is the energy (in Joules)

Q is the charge (in Coulombs)

V is the potential difference (in Volts)

If we rearrange this equation to give $V = E \div Q$, we can see where the definition of potential difference comes from.

Power is a measure of how quickly energy is transferred from one form to another. The following equation shows this:

$$P = E \div t$$

Independent practice

1. Calculate the energy when the charge is 5 C and the potential difference is 10 V.
2. If the energy is 60 J and the potential difference is 8 V, find the charge.
3. Determine the potential difference when the energy is 240 J and the charge is 12 C.
4. If the charge is 3 C and the energy is 45 J, what is the potential difference?
5. Find the charge required to generate 120 J of energy with a potential difference of 15 V.
6. Calculate the potential difference if the charge is 6 C and the energy is 54 J.
7. Given an energy of 100 J and a potential difference of 20 V, what is the charge?
8. Find the energy produced by a charge of 8 C with a potential difference of 6 V.
9. If the charge is 2 C and the potential difference is 25 V, determine the energy.
10. Convert 80 J of energy to kilojoules.
11. Express 15 C of charge in microcoulombs.
12. Convert 200 V of potential difference to kilovolts.
13. If the energy is 300 J and the charge is given in microcoulombs, convert it to coulombs.
14. Calculate the energy in joules when the charge is 10 μC and the potential difference is 50 V.
15. Convert 500 mC of charge to coulombs and then find the energy produced with a potential difference of 12V.

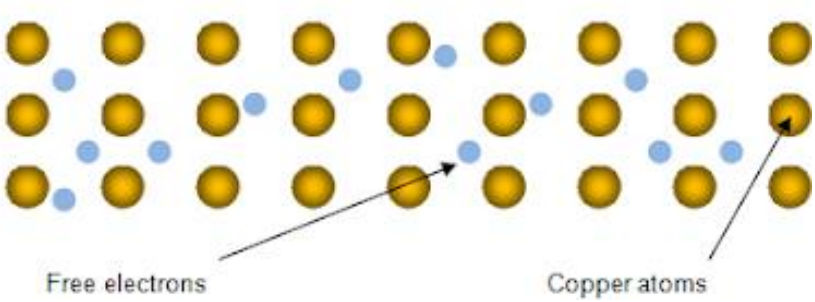
L5 Resistance

Resistance is a measure of how hard it is for the current to pass through a component in a circuit.

The higher the resistance of a component the harder it is for the current to pass through that component.

Resistance is caused when electrons collide with atoms/ions in a metal.

The thinner the wire, the greater the resistance as there is a higher chance of a collision. If the wire is hotter then the atoms vibrate faster and so again there is a higher chance of a collision. This causes resistance to again increase.



Ohm's law states that **the current through a resistor is proportional to the potential difference provided that the temperature is constant.**

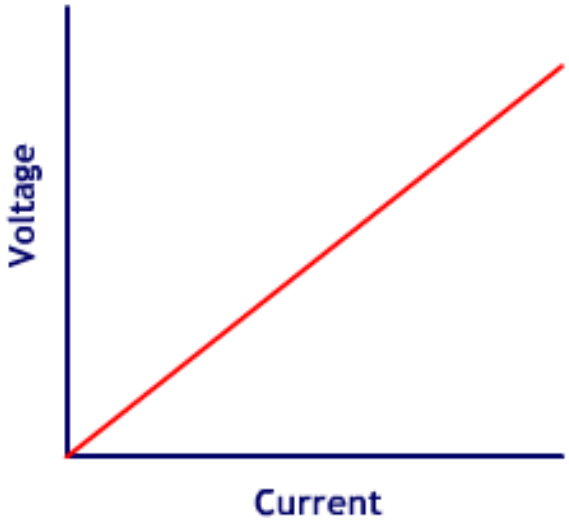
V = I x R

where:

I → current in amps (A)

V → potential difference in volts (V)

R → resistance in ohms (Ω)



If an electric component has a I-V graph that is a straight line (directly proportional) then we say that the component is **Ohmic**. For example, a resistor (at constant temperature) is Ohmic.

Resistances **add together** in a series circuit $\mathbf{R_{TOT} = R_1 + R_2}$ (all in Ω). In a parallel circuit the overall resistance decreases.

Independent practice

1. What is resistance?
2. How does resistance affect current?
3. What causes resistance?
4. Extended writing – 8mins of writing required:
   Rav says that Resistance, current and voltage are not linked. Explain why they are wrong.

Calculations:

BASIC

Calculate the voltage V for each of the following:

1. I = 8 A and R = 10 Ω
2. I = 5 A and R = 2.5 Ω
3. I = 10 A and R = 0.2 Ω

$$V = I \times R$$

Calculate the current I for each of the following:

4. V = 20 V and R = 10 Ω
5. V = 10 V and R = 20 Ω
6. V = 0.2 V and R = 5 Ω

Calculate the resistance R for each of the following:

7. I = 4 A and V = 20 V
8. I = 20 A and V = 10 V
9. I = 15.5 A and V = 5.5 V

MEDIUM

Calculate the voltage V if I = 1000 mA and R = 5 Ω

Calculate the current I if V = 100 mV and R = 2.5 Ω

Calculate the resistance R if I = 20 mA and V = 10 mV

To go from mA to A → ÷ 1000

To go from mV to V → ÷ 1000

HARD

An electric kettle uses mains voltage (230 V). The current is 10 A. What is the resistance?
A light bulb with resistance 60 Ω is connected to a 12 V battery. What is the current?
A hairdryer uses mains voltage (230 V). It takes a current of 5 A. Work out the resistance.
A toy tractor has a 4.5 V battery operated motor. The resistance of the motor is 15 Ω. What is the current?
A portable CD player takes a 6 V battery. The loudspeaker has a resistance of 4 Ω. What is the maximum current through the loudspeaker?
A torch takes a 3 V battery. The light bulb for the torch has '0.2 A' stamped on the side, so 3 V gives a current of 0.2 A.
What is the resistance of the bulb?
An old battery with voltage 1.5 V is used instead. How much current will flow through the torch bulb?
What effect will this have on the torch?
A torch has resistance 120 Ω and the current is 100 mA. What is the battery voltage?
When a 5 kΩ resistor is connected to a power supply 18 mA of current passes through it. What is the voltage of the power supply?

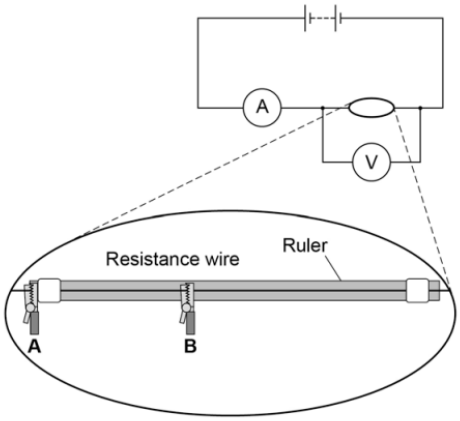
L7 RPA investigating resistance.

Firstly, let's explore how the resistance of a wire changes with its length. For this experiment, you'll need a few things:

A power supply
A variable resistor
An ammeter
A voltmeter
A wire (e.g., constantan wire)
Crocodile clips
Ruler
A table for recording data

Here's a step-by-step guide:

Set Up Your Circuit:



- Connect the power supply to the variable resistor and then to one end of the wire.
- Connect the other end of the wire to the ammeter.
- Connect the voltmeter in parallel to the wire.

Adjust Variables:

- Keep the temperature constant (room temperature is fine).
- Ensure the wire is straight and taut.
- Start with a short length of wire and record the voltage and current readings.
- Vary the Length:

- Increase the wire's length by using the ruler and crocodile clips.
- Record the voltage and current for each length.

Analyze the Data:

- Plot a graph of voltage against current.
- The gradient of the graph represents the resistance.

Repeat and Improve:

- Repeat the experiment for accuracy.
- To enhance accuracy, calculate the average resistance for each length.

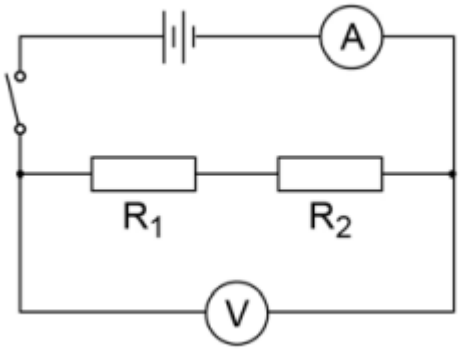
Investigating Total Resistance in Series and Parallel Circuits:

Now, let's move on to exploring total resistance in circuits. We'll cover both series and parallel configurations.

Series Circuit:

In a series circuit, components are connected end-to-end. The total resistance (R_total) is the sum of individual resistances (R1 + R2 + ...):

Set Up the Circuit:
Connect a power supply to two resistors in series.
Connect an ammeter in series to measure the total current.
Take Readings:



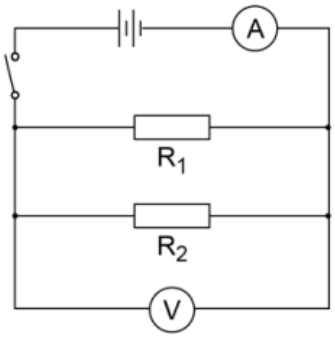
Record the current passing through the circuit.
Measure the voltage across each resistor.

Calculate Total Resistance:
Use Ohm's Law (R = V/I) to find the resistance of each resistor.
Add these resistances to get the total resistance.

Parallel Circuit:

In a parallel circuit, components share the same voltage but have different currents. The reciprocal of the total resistance (1/R_total) is the sum of reciprocals of individual resistances:

Set Up the Circuit:
Connect a power supply to two resistors in parallel.
Measure the total current with an ammeter.
Take Readings:



Record the current passing through each resistor.
Measure the voltage across both resistors.
Calculate Total Resistance:

Use Ohm's Law to find the resistance of each resistor.
Find the reciprocals and add them to get the total resistance.

Increasing Accuracy:
Repeat the Experiment: Repeating the experiments ensures reliability and helps identify any outliers.
Maintain Consistency: Keep factors like temperature and wire material constant for accurate comparisons.
Use Averaging: Calculate averages to minimize the impact of any random errors.
Precision Instruments: Use high-precision instruments to measure voltage and current.
Check Connections: Ensure all connections are secure to avoid fluctuations in readings.

Independent practice

Short Answer Questions:

Resistance Investigation:

1. What is the purpose of changing the length of the wire in the resistance investigation experiment?
2. How does the resistance of the wire change as its length increases? Explain.
3. Describe how to investigate how the length of a wire affects resistance. Draw a circuit diagram with your description. **Extended writing (paragraph required).**

Total Resistance - Series Circuit:

1. In a series circuit, how does the total resistance relate to the individual resistances of the components?
2. If you have two resistors in series with resistances R_1 and R_2, how do you calculate the total resistance?

Total Resistance - Parallel Circuit:

1. Describe the arrangement of components in a parallel circuit.
2. How does the total resistance in a parallel circuit compare to the individual resistances of the components?

Increasing Accuracy:

1. Why is it important to repeat the resistance investigation experiment?
2. List three factors to consider increasing the accuracy of your experimental results.

Extended Writing Questions (8 minutes each):

Application of Total Resistance:

1. Imagine you have a circuit with three resistors: R_1, R_2, and R_3. R_1 and R_2 are connected in series, while R_3 is in parallel to the series combination. Explain how you would calculate the total resistance in this complex circuit.