Edexcel GCSE Physics

Your notes

Components in Series & Parallel Circuits

Contents

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Resistors in Series & Parallel

Resistors in Series

- When two or more resistors are connected in series, the **total** (or **combined**) **resistance** is equal to the **sum** of their individual resistances
- For example, for three resistors of resistance R_1, R_2 and R_3, the total resistance can be calculated using:

COMBINED RESISTANCE IN SERIES $R = R_1 + R_2 + R_3 \ldots$

- Where R is the total resistance, in Ohms (Ω)
- Increasing the number of resistors **increases** the overall resistance, as the charge now has **more** resistors to pass through
- The **total voltage** is also the **sum** of the voltages across each of the **individual resistors**
  - In a **series** circuit, the voltage of the power supply is **shared** between all components

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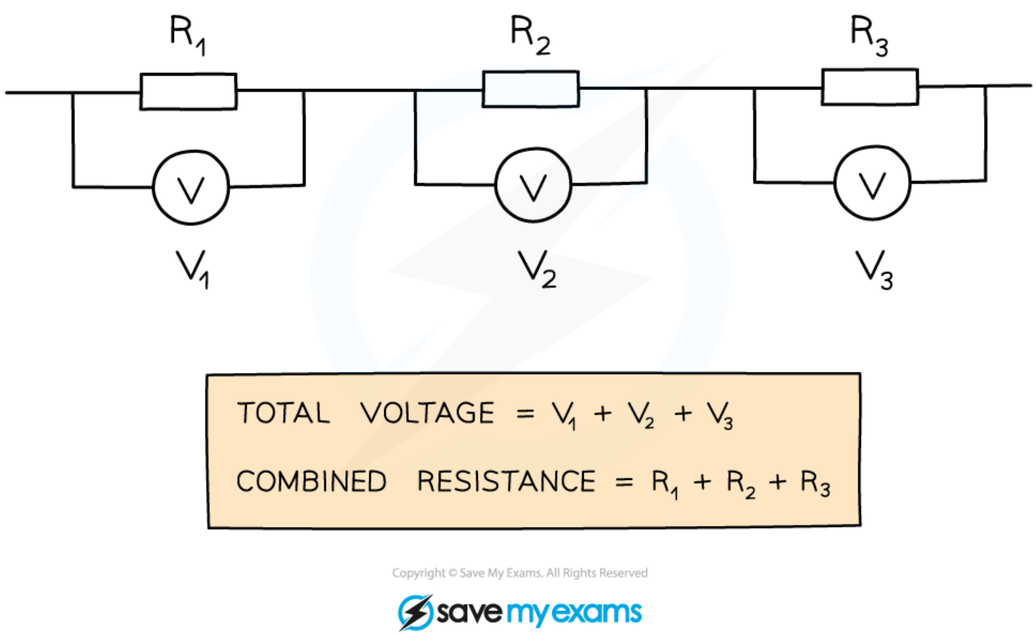

Three resistors connected in series. The total voltage is the sum of the individual voltages, and the total resistance is the sum of the three individual resistances

Resistors in Parallel

- When two or more resistors are connected in **parallel**, the total (or net / combined) resistance **decreases**
- In the below circuit, the combined resistance of the resistors R_1 and R_2 is **less** than if they were connected in series

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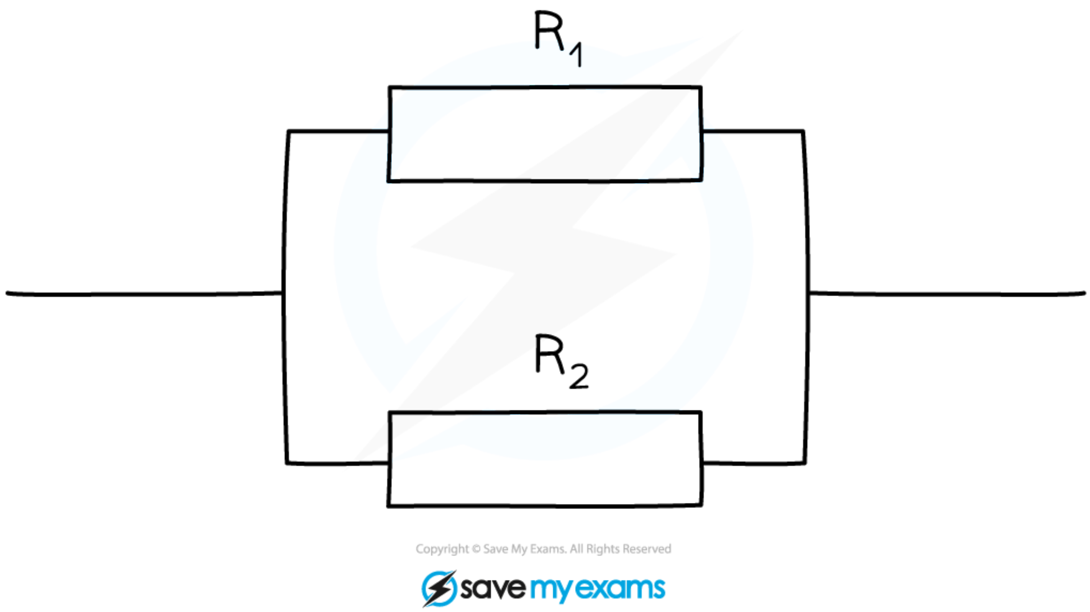

Two resistors connected in parallel. The total resistance is less than if they were connected in series

- This happens because each resistor creates an extra path along which the charge can flow
  - This allows **more charge** to flow overall
  - This leads to a **smaller** overall resistance
- The advantages of this kind of circuit are:
  - The components can be individually controlled, using their own switches
  - If one component stops working the others will continue to function

Calculations involving Series Circuits

Worked Example

The combined resistance R in the following series circuit is 60 Ω.What is the resistance value of R_2?

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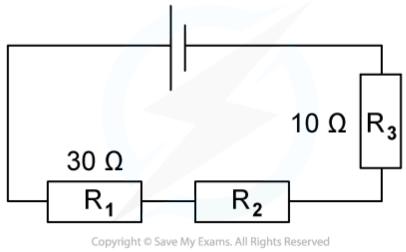

A. 100 Ω

B. 30 Ω

C. 20 Ω

D. 40 Ω

Answer: C

Step 1: Write down the equation for the combined resistance in series

$$R = R_1 + R_2 + R_3$$

Step 2: Substitute the values for total resistance *R* and the other resistors

$$60\ \Omega = 30\ \Omega + R_2 + 10\ \Omega$$

Step 3: Rearrange for R_2

$$R_2 = 60\ \Omega - 30\ \Omega - 10\ \Omega = \mathbf{20\ \Omega}$$

Worked Example

Dennis sets up a series circuit as shown below.

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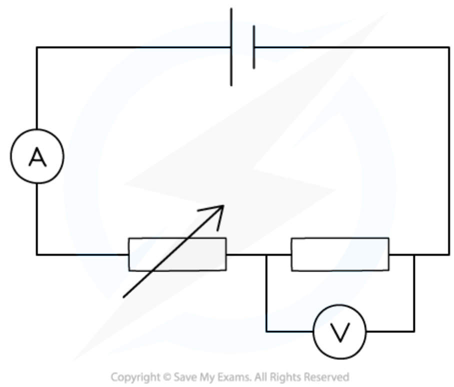

The cell supplies a current of 2 A to the circuit, and the fixed resistor has a resistance of 4 Ω.

(a) How much current flows through the fixed resistor?

(b) What is the reading on the voltmeter?

Answer:

Part (a)

Step 1: Recall that current is conserved in a series circuit

- Since current is conserved in a series circuit, it is the **same size** if measured anywhere in the series loop
- This means that since the cell supplies 2 A to the circuit, current is 2 A everywhere
- Therefore, **2 A** flows through the fixed resistor

Part (b)

Step 1: List the known quantities

- Current I = 2 A
- Resistance R = 4 Ω

Step 2: State the equation linking potential difference, resistance and current

- The equation linking potential difference, resistance and current is:

$$V = IR$$

Step 3: Substitute the known values into the equation and calculate the potential difference

$$V = 2 \times 4 = 8 \text{ V}$$

- Therefore, the voltmeter reads **8 V** across the fixed resistor

Examiner Tips and Tricks

Circuit questions can be confusing. Remember to label any voltages, currents or resistances on the circuit to help with the calculations and most of all, remember how voltage, current and resistance differs between a series and parallel circuit (as you may get a question on a combination of both circuits!)

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Comparing Series & Parallel Circuits

Series & Parallel Circuits

Current in Series & Parallel

- In a **series** circuit, the current is the **same** at all points
- In a **parallel** circuit, the current **splits** at junctions – some of it going one way and the rest going the other

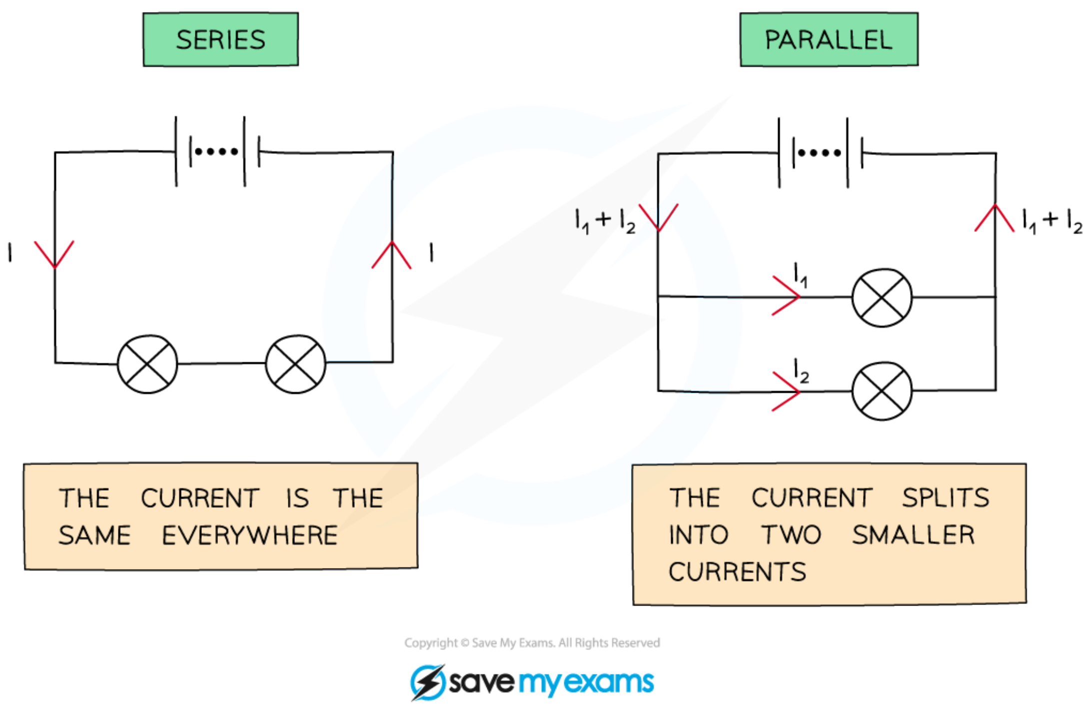

Diagram showing the behaviour of current in series and parallel circuits

Potential Difference in Series & Parallel

- In a **series** circuit, the voltage of the power supply is **shared** between the components
- In a **parallel** circuit, the voltage across each component is the **same**

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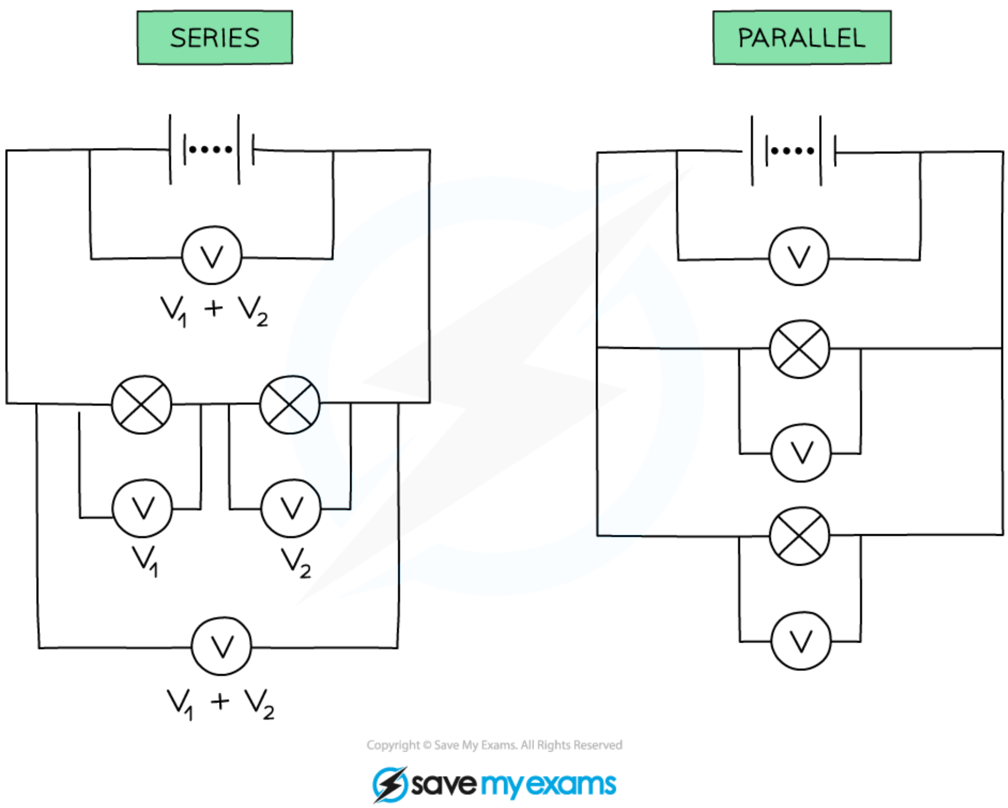


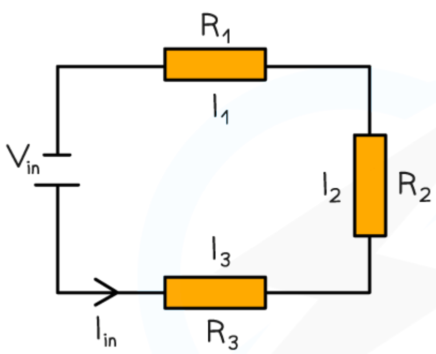
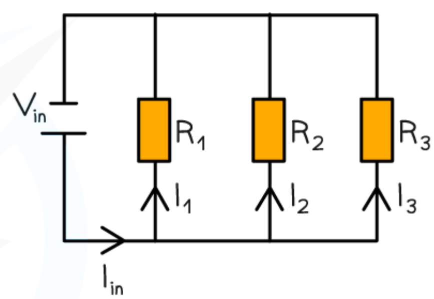
Diagram showing the behaviour of voltage in series and parallel circuits

Resistors in Series & Parallel

- In a **series** circuit, the total resistance is the **sum** of the resistance in each component
  - Two resistors in series will have a **larger** overall resistance than just one
  - This is because the charge has to push through **multiple components** when flowing around the circuit
  - The more components the charge has to travel through, the **higher** the number of **collisions** that occur
- In a **parallel** circuit, the total resistance **decreases** and is less than the resistance of any of the individual components
  - Two resistors in parallel will have a **smaller** overall resistance than just one
  - This is because the charge has more than one **pathway** to take, so only some charge will flow along each path

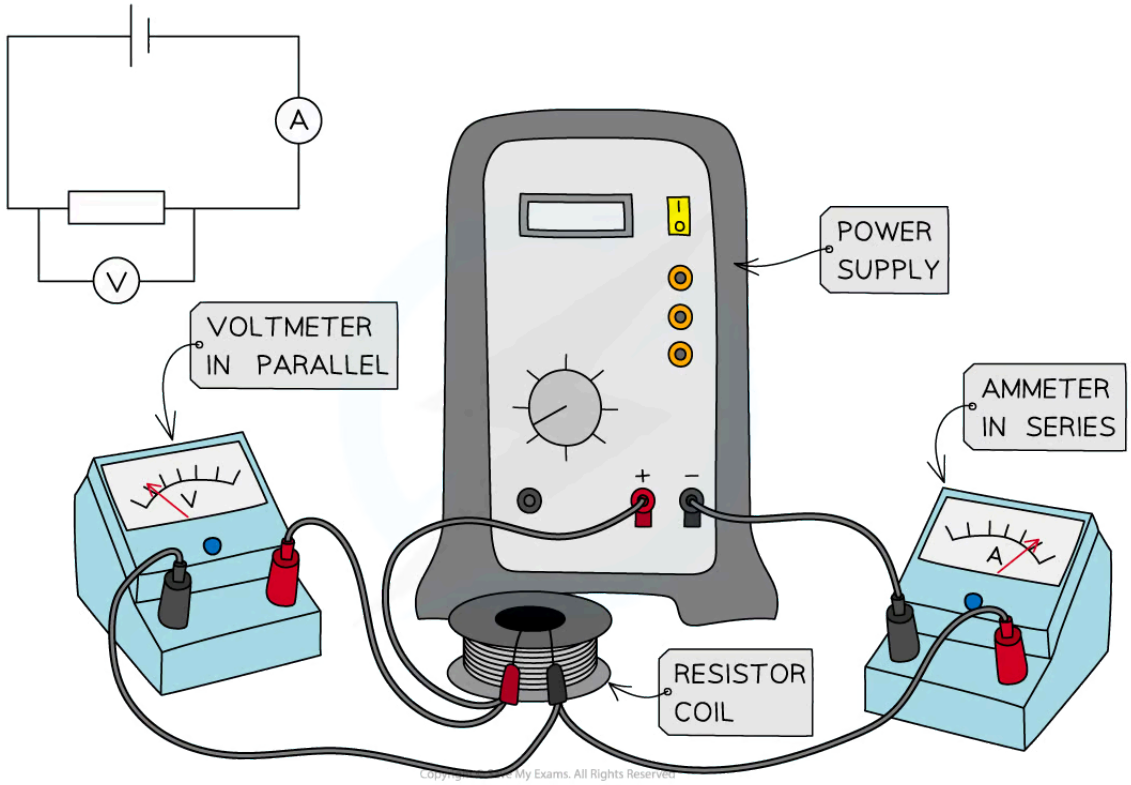
- The more pathways there are, the **smaller** the **amount** of charge in each path

Series and Parallel Circuit Summary Table

	Series	Parallel
Circuit		
Voltage	$V_{in} = V_1 + V_2 + V_3$	$V_{in} = V_1 = V_2 = V_3$
Current	$I_{in} = I_1 = I_2 = I_3$	$I_{in} = I_1 + I_2 + I_3$
Resistance	$R_{total} = R_1 + R_2 + R_3$	$R_{total} < R_1 + R_2 + R_3$

The Design of Series Circuits

- A **series** circuit consists of a string of components connected in the **same loop** to a power supply
- In a series circuit:
  - The current is the same at all points around the loop
  - The potential difference of the power supply is shared between the individual components
- Two disadvantages of series circuits are:
  - If one of the components breaks, all of the others will stop working
  - The components cannot be controlled (switched on and off) separately



Construction of a simple series circuit with an ammeter, voltmeter, cell and resistor

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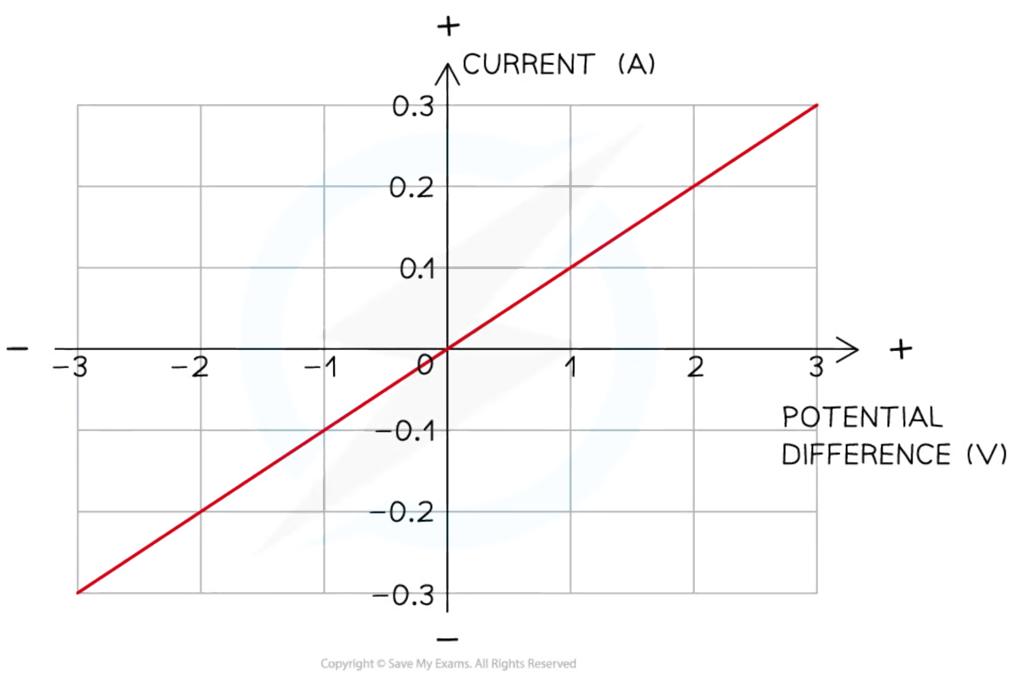
Electrical Components

I-V Graphs

Fixed Resistors

- The **current** through a fixed resistor **increases** as the **potential difference** across it **increases**
- In other words, current is **directly proportional** to the potential difference for a fixed resistor
- An I-V graph shows that the line is **straight** and goes through the **origin,** as shown in the *I-V* graph below:



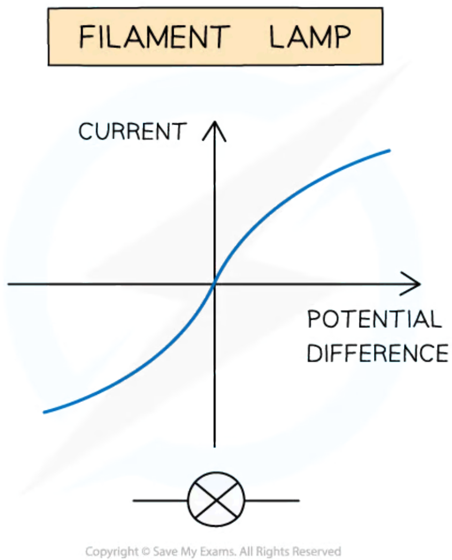
I-V graph for a fixed resistor. The current is directly proportional to the potential difference as the graph is a straight line through the origin

- This relationship is true because the resistance of a fixed resistor is **constant**

Filament Lamps

- For a filament lamp, current and potential difference are **not** directly proportional
  - This is because the resistance of the filament lamp **increases** as the **temperature** of the filament **increases**

- The *I–V* graph for a filament lamp shows the current increasing at a proportionally slower rate than the potential difference



***I–V* graph for a filament lamp**

- This is because:
  - As the **current** increases, the **temperature** of the filament in the lamp increases
  - The higher temperature causes the atoms in the metal lattice of the filament to **vibrate** more
  - This causes an increase in resistance as it becomes more difficult for **free electrons** (the current) to pass through
  - Resistance **opposes** the current, causing the current to increase at a **slower** rate
- Where the graph is a straight line, the resistance is **constant**
- The resistance **increases** as the graph **curves**
- Reversing the potential difference reverses the current and makes no difference to the shape of the curve

Diodes

- A diode allows current to flow in **one** direction only
  - This is called **forward bias**
- In the reverse direction, the diode has very high resistance, and therefore **no** current flows

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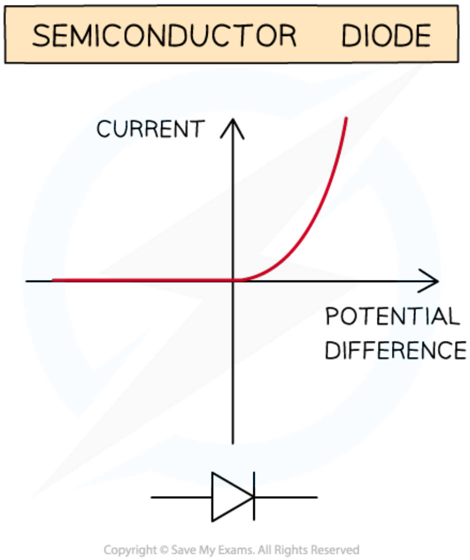
- This is called **reverse bias**



I–V graph for a semiconductor diode

- The *I–V* graph for a diode is slightly different:
  - When the current is in the direction of the arrowhead symbol, this is **forward bias**
    - This is shown by the sharp increase in potential difference and current on the right side of the graph
  - When the diode is switched around, this is **reverse bias**
    - This is shown by a zero reading of current or potential difference on the left side of the graph

Examiner Tips and Tricks

Make sure to practice drawing which current-voltage graph is for which component, as this is a common exam question!

LDRs

- A light-dependent resistor (LDR) is a type of **sensory** resistor
  - This means it is a resistor which has a resistor that changes with its surroundings
- The circuit symbol for an LDR is:

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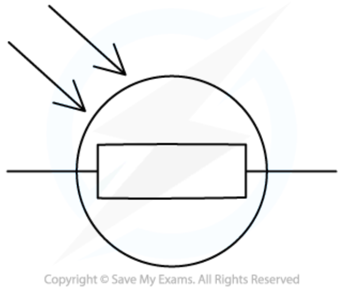
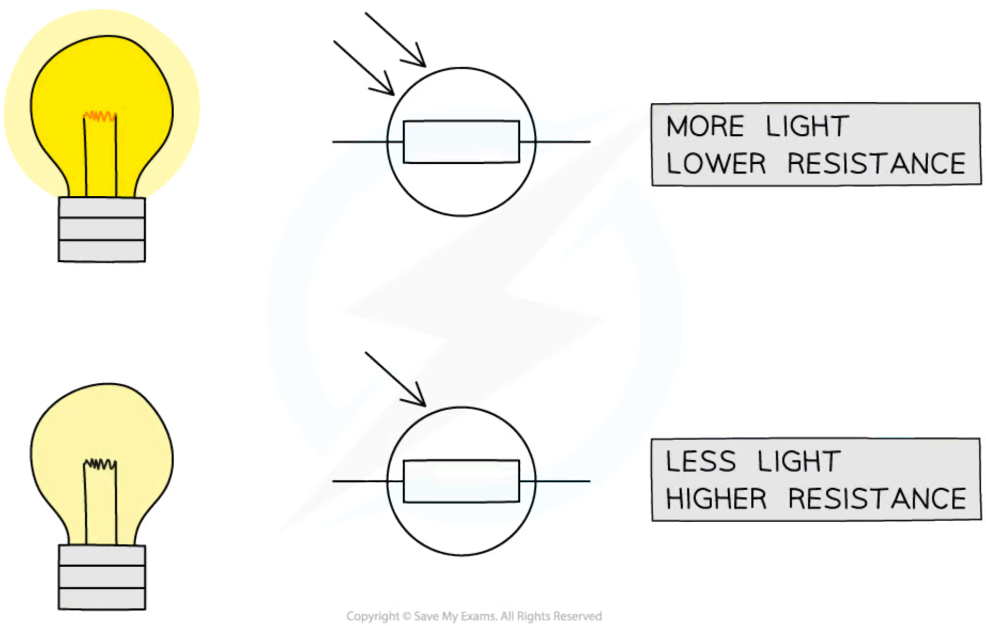


LDR circuit symbol

- The resistance of an LDR changes depending on the **light intensity** on it
  - As the light intensity **increases** the resistance of an LDR **decreases** and vice versa



The resistance of an LDR is dependent on the amount of light intensity on it

- LDRs can be used as light sensors, so, they are useful in circuits which automatically switch on lights when it gets dark, for example, street lighting and garden lights

Thermistors

- A thermistor is also a type of sensory resistor
- It is represented by the following circuit symbol:

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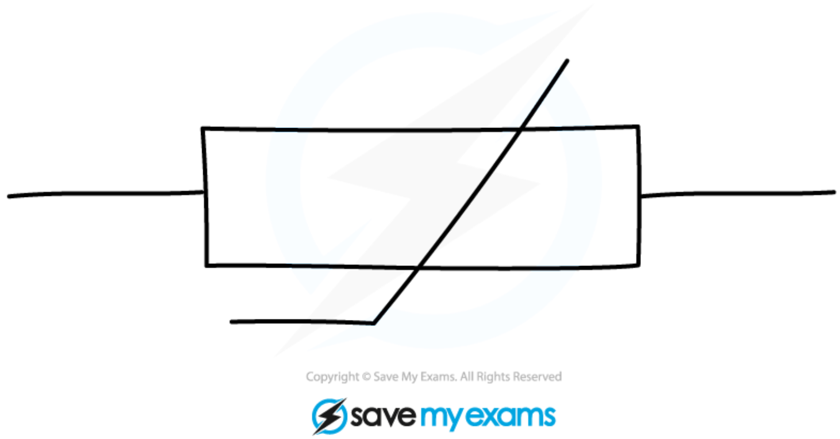
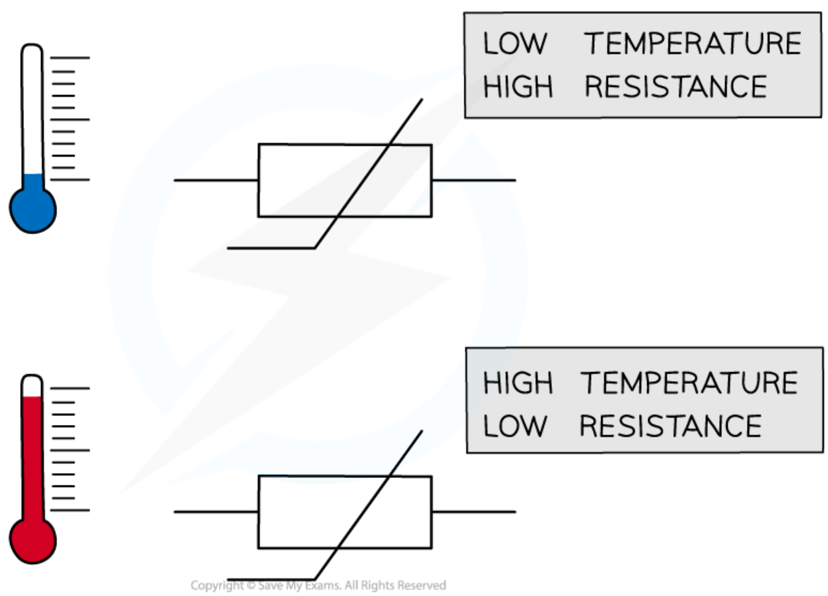


Thermistor circuit symbol

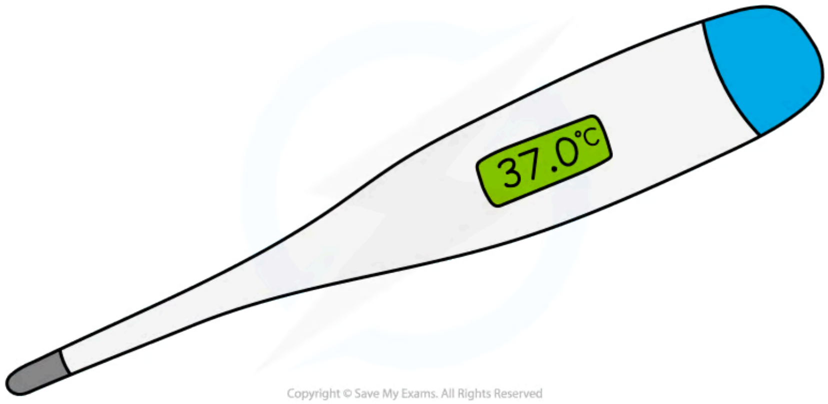
- The resistance of a thermistor changes depending on its **temperature**
  - As the temperature **increases** the resistance of a thermistor **decreases** and vice versa



The resistance through a thermistor is dependent on temperature

- Thermistors are temperature sensors and are used in circuits in ovens, fire alarms and digital thermometers

- As the thermistor gets **hotter**, its resistance **decreases**
- As the thermistor gets **cooler**, its resistance **increases**

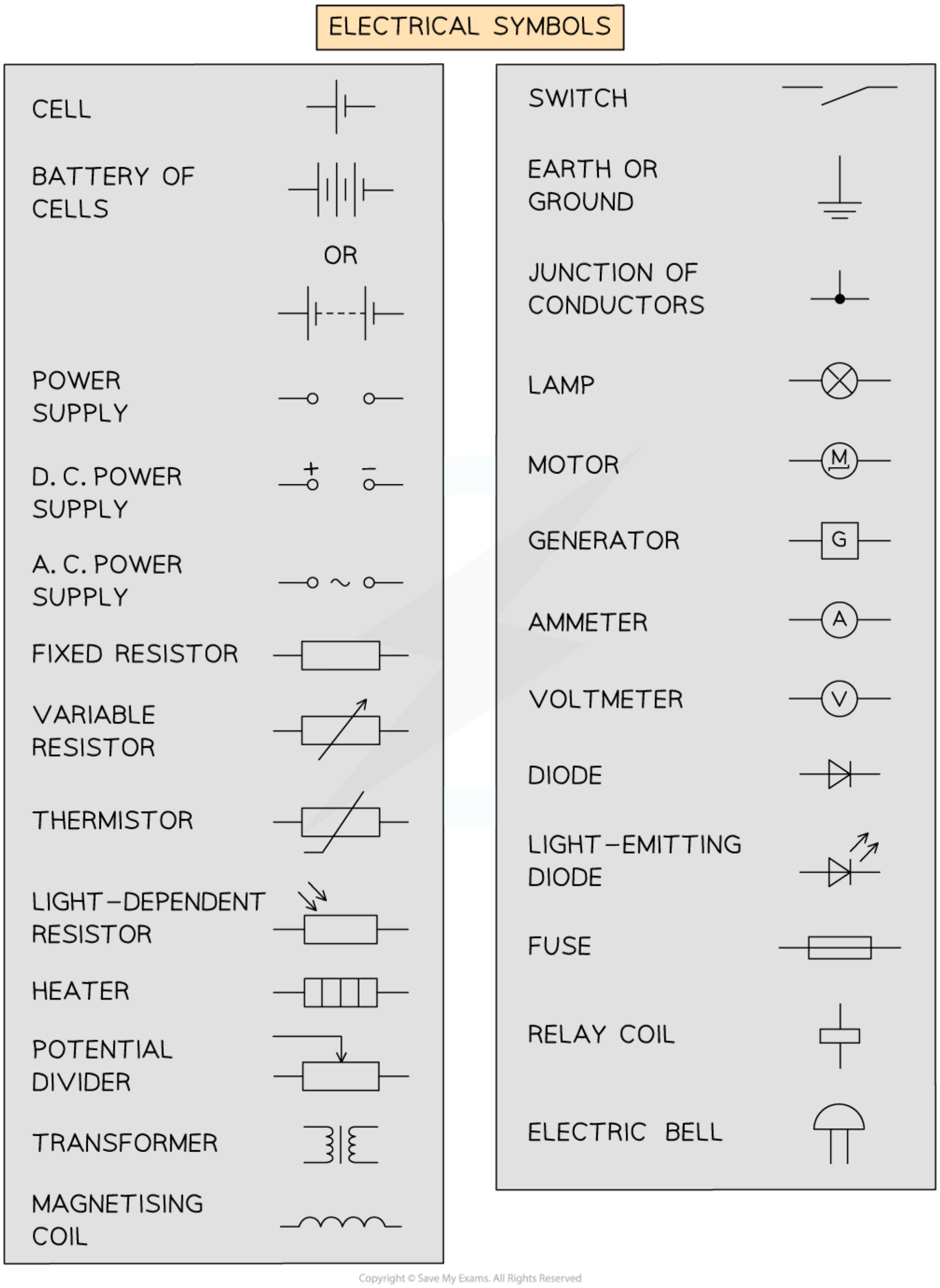


A digital thermometer uses a thermistor

Examiner Tips and Tricks

Here is a list of all the circuit symbols you need to know for your exam:

Your notes


ELECTRICAL SYMBOLS
CELL
BATTERY OF CELLS
OR
POWER SUPPLY
D. C. POWER SUPPLY
+
−
A. C. POWER SUPPLY
FIXED RESISTOR
VARIABLE RESISTOR
THERMISTOR
LIGHT−DEPENDENT RESISTOR
HEATER
POTENTIAL DIVIDER
TRANSFORMER
MAGNETISING COIL
SWITCH
EARTH OR GROUND
JUNCTION OF CONDUCTORS
LAMP
MOTOR
M
GENERATOR
G
AMMETER
A
VOLTMETER
V
DIODE
LIGHT−EMITTING DIODE
FUSE
RELAY COIL
ELECTRIC BELL
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Testing Components

Your notes

Testing Components

- The GCSE examination will require an understanding of the variation of **resistance** in the following devices:
  - Filament lamps
  - Diodes
  - Thermistors
  - LDRs
- Luckily, the design and use of the circuits to investigate how resistance varies is broadly similar for each component

Resistance in Filament Lamps & Diodes

- In order to investigate the variation of resistance in a filament lamp or diode, the following circuits should be set up:
- The **current** is the **independent variable**
  - The **variable resistor** is used to change the current flowing through the filament lamp / diode
- The **voltage** is the **dependent variable**
  - The **voltmeter** is used to measure the voltage across the filament lamp / diode
- Calculate the resistance of the filament lamp / diode for each chosen value of current and measured value of voltage using the equation:

$$R = \frac{V}{I}$$

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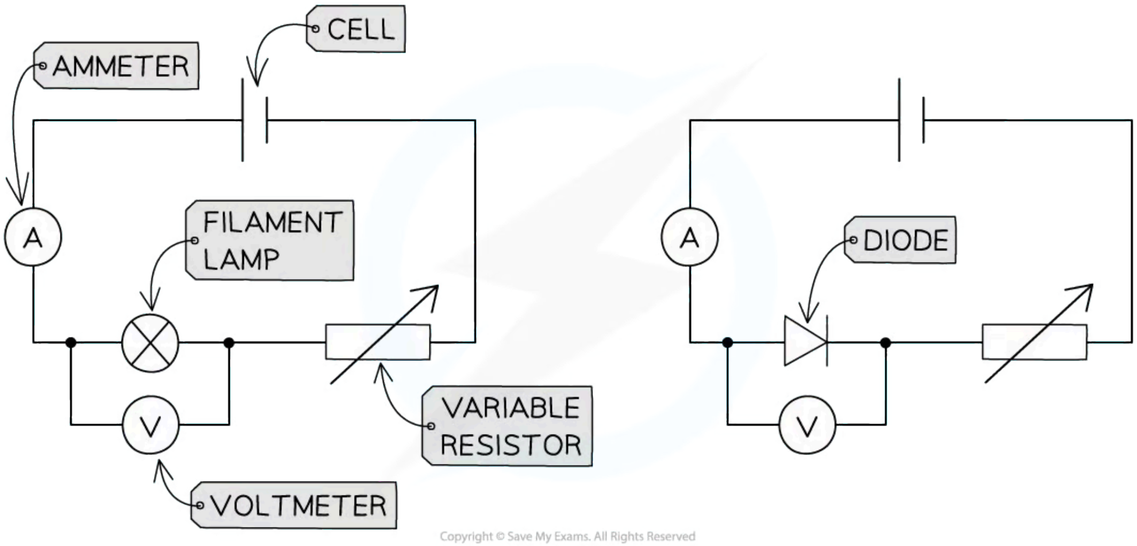

These circuits enable the variation of resistance in a filament lamp or a diode to be investigated

Resistance in LDRs & Thermistors

- In order to investigate the variation of resistance in a LDR or a thermistor, the following circuits should be set up:

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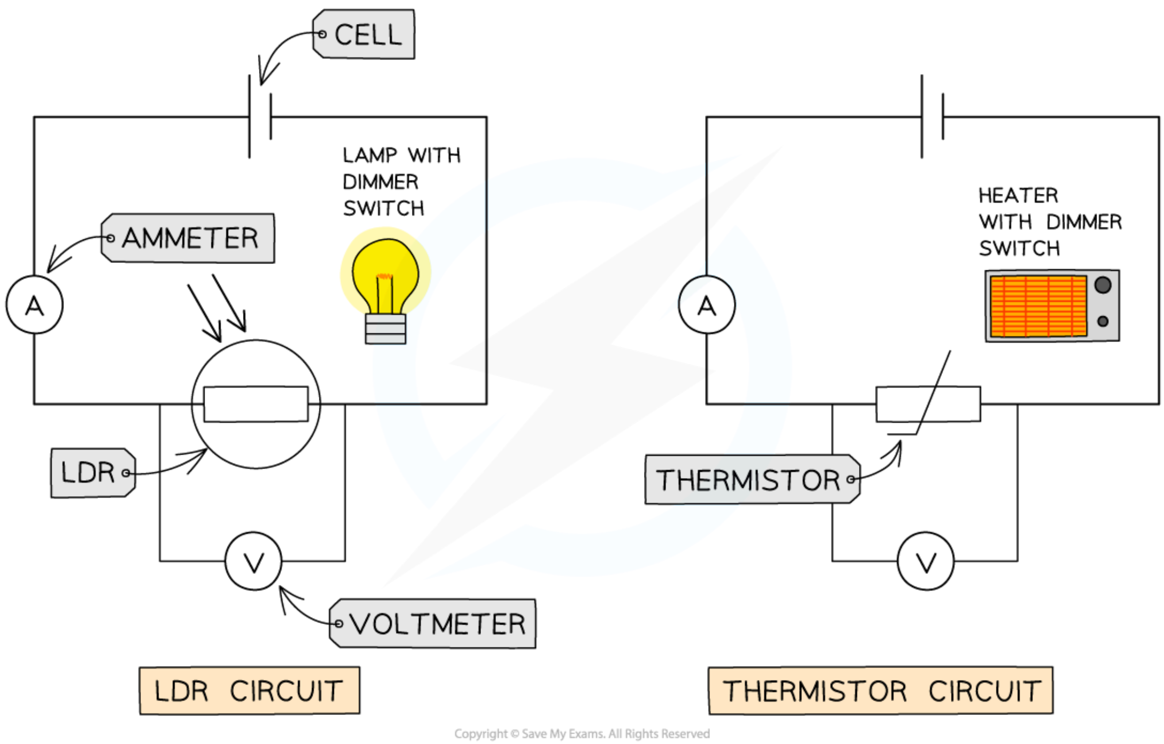


These circuits enable the variation of resistance in a LDR or a thermistor to be investigated

- For the LDR circuit:
  - Begin with the lamp turned off in a **dark room**
  - Record the reading on the **voltmeter** and **ammeter**
  - Slowly increase the **light intensity** of the lamp using the dimmer switch
  - Record the reading on the voltmeter and ammeter for each increase in light intensity
- For the thermistor circuit:
  - Begin with the heater turned **off**
  - Record the reading on the **voltmeter** and **ammeter**
  - Slowly increase the **temperature** of the heater using the dimmer switch
  - Record the reading on the voltmeter and ammeter for each increase in temperature of the heater
- In both situations, make sure the lamp and heater are close, but not touching, the LDR and thermistor respectively

- Wait a few seconds before taking the voltmeter and ammeter readings to allow the LDR and thermistor to react to the change in the environment
- Calculate the resistance of the LDR or thermistor for each change in light intensity or temperature using the equation:

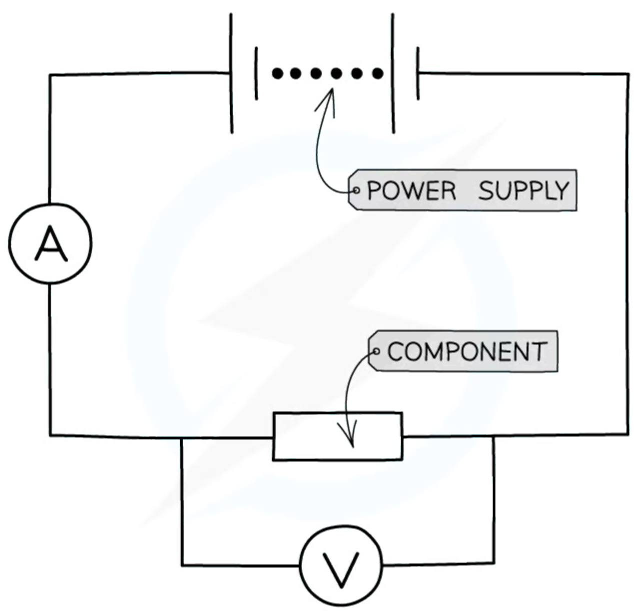
$$R = \frac{V}{I}$$

Your notes

Examiner Tips and Tricks

It's really common for examiners to test your understanding of setting up and using a circuit to measure current, voltage and resistance of a component. Generally, make sure the following are included in your circuit diagrams:

- The **ammeter** is connected in **series** to the component
- The **voltmeter** is connected in **parallel** to the component
- The **component** with the appropriate circuit symbol
- If you need to vary the current, include a **variable resistor**
- The component is connected to a **power supply** with a low voltage (below 15 V) otherwise too high a current in the circuit will start to affect the resistance of the component



Circuit diagram for measuring the variation of resistance of a component, using current and voltage

Your notes

Core Practical: Investigating & Testing Circuits

Your notes

Core Practical 4: Investigating & Testing Circuits

Equipment List

Equipment	Purpose
Ammeter	To measure the current through the resistor / filament lamp
Voltmeter	To measure the voltage across the resistor / filament lamp
Variable resistor	To vary the current through the circuit
Fixed resistors (between 100 Ω and 500 Ω)	To investigate the relationship between current and voltage
Filament lamp	To investigate the relationship between current and voltage
Voltage Supply	Source of potential difference to the circuit
Wires	To connect all components in the circuits

- Resolution of measuring equipment:
  - Variable resistor = 0.005 Ω
  - Voltmeter = 0.1 V
  - Ammeter = 0.01 A

Experiment 1: Investigating Potential Difference, Current & Resistance

Aim of the Experiment

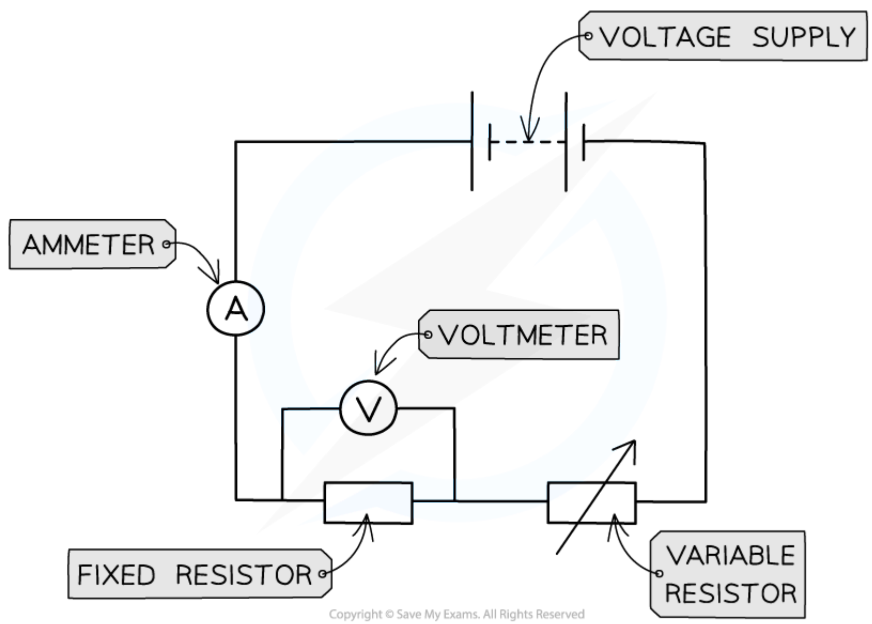
Your notes

- The aim of the experiment is to investigate the relationship between potential difference, current and resistance for a **resistor** and a **filament lamp**

Variables:

- Independent variable = Potential difference, *V*
- Dependent variable = Current, *I*
- Control variables:
  - Potential difference of the power supply
  - Use of the same equipment e.g. wires

Method



Circuit diagram of the apparatus set up. The fixed resistor will be replaced by a filament lamp

1. Set up the circuit as shown with the fixed resistor
2. Vary the voltage across the component by changing the resistance of the variable resistor, using a wide range of voltages (between 8–10 readings). Check the appropriate voltage reading on the voltmeter
3. For each voltage, record the value of the current from the ammeter 3 times and calculate the average current

Your notes

4. Increase the voltage further in steps of 0.5 V and repeat steps 2 and 3
5. Make sure to switch off the circuit in between readings to prevent heating of the component and wires
6. Reverse the terminals of the power supply and take readings for the negative voltage (and therefore negative current)
7. Replace the fixed resistor with the filament lamp and repeat the experiment from step 1

- An example of a suitable table might look like this:

VOLTAGE / V	CURRENT I_1 / A	CURRENT I_2 / A	CURRENT I_3 / A	AVERAGE CURRENT I / A
0.5				
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

Analysis of Results

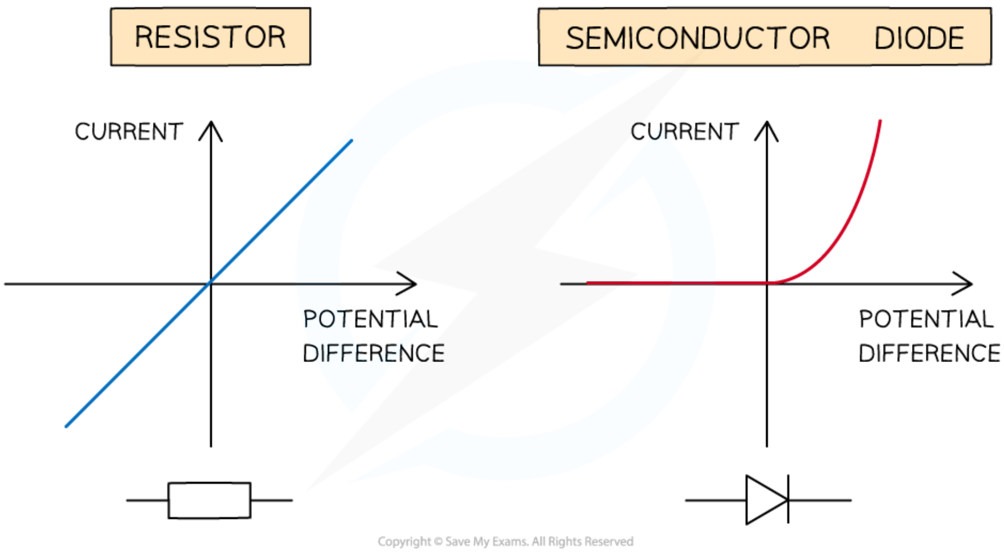
- Plot a graph of average current against voltage (an *I*–*V* graph) for each component
- If the *I*–*V* graph is a **straight line** through the **origin**, current is **directly proportional** to voltage. This is expected from the fixed resistor:
  - The equation that relates the voltage to the current is given by:

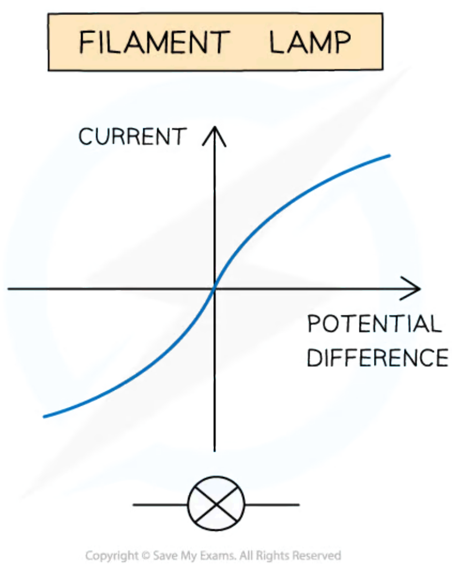
$$V = IR$$

- This equation shows that *V* is proportional to *I* (i.e. if voltage increases, current increases at the same rate) if *R* is **constant**, which is true for a fixed resistor
- If the *I*–*V* graph is curved, then current is **not** directly proportional to voltage
  - This is expected from the filament lamp

- As the current increases through a filament lamp, its **temperature increases**
- This increases the **resistance** of the filament, so it does not remain constant

- Compare the results from the graphs obtained to the known *I–V* graphs for the resistor, filament lamp and diode. These should look like:





The expected I–V graphs for the resistor, diode and filament lamp

Your notes

Experiment 2: Testing Series & Parallel Circuits

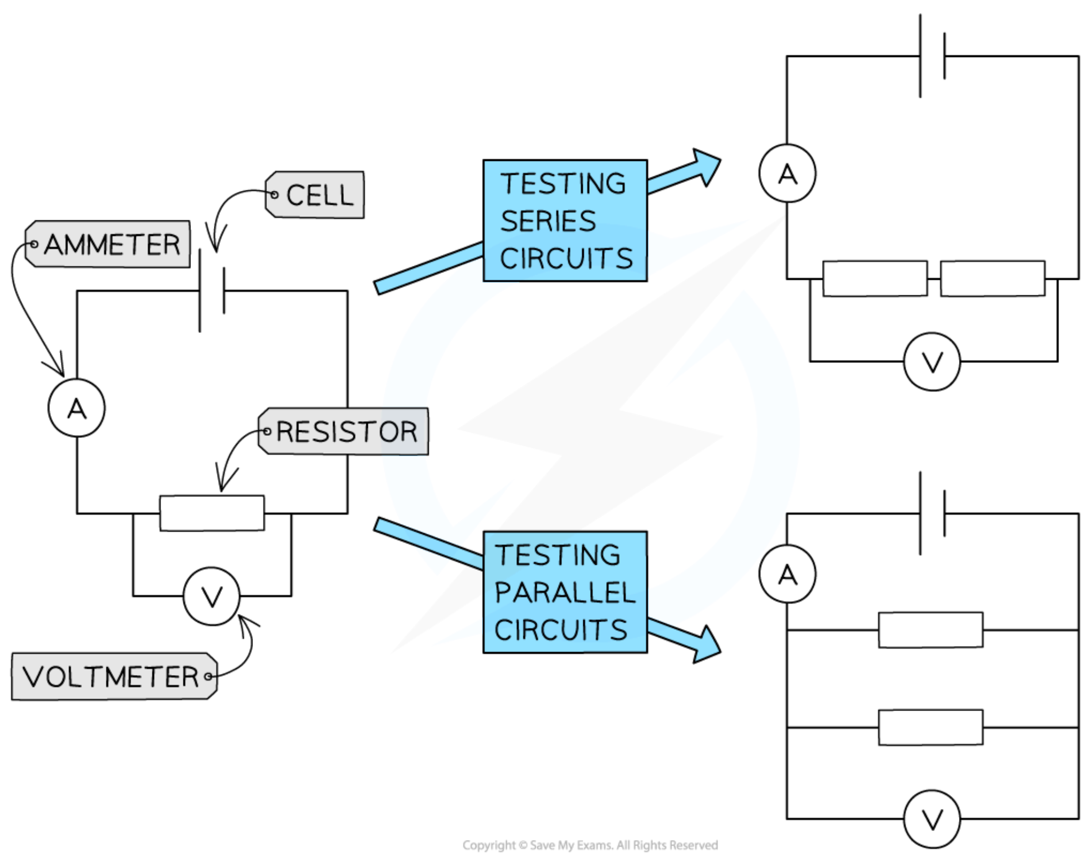
Aim of the Experiment

- The aim of the experiment is to test **series** and **parallel circuits** using resistors and filament lamps. There are a variety of methods to test series and parallel circuits but this starts with a single resistor / filament lamp in series with a cell, and builds on this circuit with an additional resistor in series or in parallel.

Variables:

- Independent variable = Potential difference, *V*
- Dependent variable = Current, *I*
- Control variables:
  - Potential difference of the power supply
  - Use of the same equipment e.g. wires

Method



Circuit diagram of the apparatus set up. The fixed resistors will be replaced by a filament lamps

Your notes

1. Set up the circuit as shown with the single fixed resistor
2. Record the voltage using the voltmeter and the current using the ammeter
3. For each pair of voltage and current, calculate the resistance and record this
4. Change the resistor and repeat step 2 and 3
5. Arrange the two resistors in series as shown in the image, then repeat step 2
6. Arrange the two resistors in parallel as shown in the image, then repeat step 2
7. Replace the fixed resistor with a filament lamp and repeat the experiment from step 1

- An example of a suitable table might look like this:

$R = \frac{V}{I}$

RESISTOR	VOLTAGE / V	CURRENT / A	RESISTANCE / Ω
R_1			
R_2			
IN SERIES			
IN PARALLEL			

Analysis of Results

- The value of the resistance for each voltage and current reading is calculated using the equation:

$$R = \frac{V}{I}$$

- In series, the total resistance of the two resistors is equal to the **sum** of the two individual resistances
- In parallel, the total resistance of the two resistors is **less** than either of the two individual resistances

Evaluating the Experiment

Your notes

Systematic Errors:

- The voltmeter and ammeters should start from zero, to avoid **zero error** in the readings

Random Errors:

- In practice, the voltmeter and ammeter will still have some resistance, therefore the voltages and currents displayed may be slightly inaccurate
- The temperature of the equipment could affect its resistance. This must be controlled carefully
- Taking multiple readings of the current for each component will provide a more accurate result and reduce uncertainties

Safety Considerations

- When there is a high current and a thin wire, the wire will become very hot
  - Make sure never to touch the wire directly when the circuit is switched on
- Switch off the power supply right away if burning is smelled
- Make sure there are no liquids close to the equipment, as this could damage the electrical equipment
- The components will get hot especially at higher voltages
  - Be careful when handling them – especially the filament lamp
- Disconnect the power supply in between readings to avoid the components heating up too much