



4.1.1 Energy changes in a system, and the ways energy is stored before and after such changes			
<b>4.1.1.1 Energy stores and systems</b>	😊	😐	😞
A <b>system</b> is an object or group of objects.			
There are <b>changes</b> in the way energy is <b>stored</b> when a system changes.			
For example: <ul style="list-style-type: none"> <li>• an object projected upwards</li> <li>• a moving object hitting an obstacle</li> <li>• an object accelerated by a constant force</li> <li>• a vehicle slowing down</li> <li>• bringing water to a boil in an electric kettle.</li> </ul>			
Students should be able to:			
★ Describe all the changes involved in the way energy is stored when a system changes, for common situations (including the examples above).			
★ Throughout this Energy topic, calculate the changes in energy involved when a system is changed by: <b>heating, work done by forces, work done when a current flows.</b>			
★ Use calculations to show on a common scale how the overall energy in a system is redistributed when the system is changed.			
<b>4.1.1.2 Changes in energy</b>	😊	😐	😞
The <b>kinetic energy</b> of a <b>moving object</b> can be calculated using the equation:			
$\text{kinetic energy} = 0.5 \times \text{mass} \times (\text{speed})^2$	$E_k = \frac{1}{2} m v^2$		
<ul style="list-style-type: none"> <li>• kinetic energy, <math>E_k</math>, in joules, <b>J</b></li> <li>• mass, <math>m</math>, in kilograms, <b>kg</b></li> <li>• speed, <math>v</math>, in metres per second, <b>m/s</b></li> </ul>			
The amount of <b>elastic potential energy</b> stored in a <b>stretched spring</b> can be calculated using the equation:			
$\text{elastic potential energy} = 0.5 \times \text{spring constant} \times (\text{extension})^2$	$E_e = \frac{1}{2} k e^2$		
(assuming the limit of proportionality has not been exceeded)			
<ul style="list-style-type: none"> <li>• elastic potential energy, <math>E_e</math>, in joules, <b>J</b></li> <li>• spring constant, <math>k</math>, in newtons per metre, <b>N/m</b></li> <li>• extension, <math>e</math>, in metres, <b>m</b></li> </ul>			
The amount of <b>gravitational potential energy</b> gained by an <b>object raised</b> above ground level can be calculated using the equation:			
$\text{gravitational potential energy} = \text{mass} \times \text{gravitational field strength } (g) \times \text{height}$	$E_p = m g h$		

<ul style="list-style-type: none"> <li>gravitational potential energy, <math>E_p</math>, in joules, <b>J</b></li> <li>mass, <math>m</math>, in kilograms, <b>kg</b></li> <li>gravitational field strength, <math>g</math>, in newtons per kilogram, <b>N/kg</b> (In any calculation the value of the gravitational field strength (<math>g</math>) will be given)</li> <li>height, <math>h</math>, in metres, <b>m</b></li> </ul>			
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<p><u>Students should be able to:</u></p> <p>★ Calculate the amount of energy associated with a <b>moving object</b>, a <b>stretched spring</b> and an <b>object raised</b> above ground level.</p>			
<p>★ <b>Recall</b> and apply the equation for <b>kinetic energy</b></p>			
<p>★ Apply the equation for <b>elastic potential energy</b>, which is given on the <b>Physics equation sheet</b></p>			
<p>★ <b>Recall</b> and apply the equation for <b>gravitational potential energy</b></p>			
<p><b>4.1.1.3 Energy changes in systems</b></p>	☺	☹	☹
<p>The amount of energy stored in or released from a system as its <b>temperature changes</b> can be calculated using the equation:</p> <div style="border: 1px solid black; padding: 5px; display: inline-block;"> <p>change in thermal energy = mass × specific heat capacity × temperature change</p> </div> <div style="border: 1px solid black; padding: 5px; display: inline-block; margin-left: 20px;"> <math>\Delta E = m c \Delta \theta</math> </div>			
<ul style="list-style-type: none"> <li>change in thermal energy, <math>\Delta E</math>, in joules, <b>J</b></li> <li>mass, <math>m</math>, in kilograms, <b>kg</b></li> <li>specific heat capacity, <math>c</math>, in joules per kilogram per degree Celsius, <b>J/kg °C</b> □ temperature change, <math>\Delta \theta</math>, in degrees Celsius, <b>°C</b></li> </ul>			
<p>The <b>specific heat capacity of a substance</b> is the amount of <b>energy</b> required to raise the <b>temperature of one kilogram</b> of the substance by <b>one degree Celsius</b>.</p>			
<p><u>Students should be expected to:</u></p> <p>★ Apply the equation for <b>specific heat capacity</b>, which is given on the <b>Physics equation sheet</b>.</p>			
<p><b>REQUIRED PRACTICAL:</b> Specific Heat Capacity. <b>AT 1 and 5.</b></p>			
<p><b>4.1.1.4 Power</b></p>	☺	☹	☹
<p>Power is defined as the <b>rate</b> at which <b>energy is transferred</b> or the rate at which <b>work is done</b>.</p>			
<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <p>power = <math>\frac{\text{energy transferred}}{\text{time}}</math></p> </div> <div style="border: 1px solid black; padding: 5px; display: inline-block; margin-left: 20px;"> <math>P = \frac{E}{t}</math> </div>			
<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <p>power = <math>\frac{\text{work done}}{\text{time}}</math></p> </div> <div style="border: 1px solid black; padding: 5px; display: inline-block; margin-left: 20px;"> <math>P = \frac{W}{t}</math> </div>			
<ul style="list-style-type: none"> <li>power, <math>P</math>, in watts, <b>W</b></li> <li>energy transferred, <math>E</math>, in joules, <b>J</b></li> <li>work done, <math>W</math>, in joules, <b>J</b></li> <li>time, <math>t</math>, in seconds, <b>s</b></li> </ul>			
<p>An energy transfer of <b>1 joule per second</b> is equal to a power of <b>1 watt</b>.</p>			
<p><u>Students should be able to:</u></p> <p>★ <b>Recall</b> and apply both of the equations for <b>power</b>.</p>			

★ Give <b>examples</b> that illustrate the definition of power e.g. comparing two electric motors that both lift the same weight through the same height but one does it faster than the other.			
<b>4.1.2 Conservation and dissipation of energy</b>			
<b>4.1.2.1 Energy transfers in a system</b>	😊	😐	😞
Energy can be <b>transferred</b> usefully, stored or dissipated, but <b>cannot</b> be <b>created</b> or <b>destroyed</b> .			
Whenever there are energy transfers in a system only part of the energy is <b>usefully transferred</b> . The rest of the energy is <b>dissipated</b> so that it is stored in less useful ways. This energy is often described as being ' <b>wasted</b> '.			
Unwanted energy transfers can be reduced in a number of ways, for example through <b>lubrication</b> and the use of <b>thermal insulation</b> .			
The higher the <b>thermal conductivity</b> of a material the higher the <b>rate of energy transfer</b> by conduction across the material.			
<u>Students should be able to:</u>			
★ Describe, with examples, where there are energy transfers in a closed system, that there is no net change to the total energy.			
★ Describe, with examples, how in all system changes energy is dissipated, so that it is stored in less useful ways. The energy is often described as being ' <b>wasted</b> '.			
★ Explain ways of reducing unwanted energy transfers, for example, through lubrication and the use of thermal insulation.			
★ Describe how the rate of cooling of a building is affected by the thickness and thermal conductivity of its walls. <i>Students do not need to know the definition of thermal conductivity.</i>			
<b>4.1.2.2 Efficiency</b>	😊	😐	😞
The <b>energy efficiency</b> for any energy transfer can be calculated using the equation:			
$\text{efficiency} = \frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$			
Efficiency may also be calculated using the equation:			
$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$			
<u>Students should be able to:</u>			
★ <b>Recall</b> and apply both equations for <b>efficiency</b> .			
★ Calculate or use efficiency values as a <b>decimal</b> or as a <b>percentage</b> .			
★ (HT only) Describe ways to <b>increase</b> the <b>efficiency</b> of an intended energy transfer.			
<b>4.1.3 National and global energy resources</b>			
The main <b>energy resources</b> available for use on Earth include: fossil fuels (coal, oil and gas), nuclear fuel, bio-fuel, wind, hydroelectricity, geothermal, the tides, the Sun and water waves.			
A <b>renewable energy</b> resource is one that is being (or can be) <b>replenished</b> as it is used.			
The uses of energy resources include: <b>transport, electricity generation</b> and <b>heating</b> .			

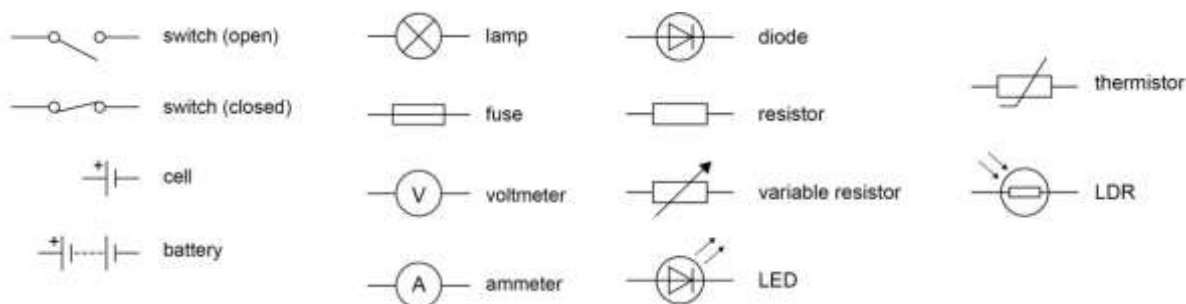
Students should be able to:			
★ Describe the main energy sources available. <i>Descriptions of how energy resources are used to generate electricity are not required.</i>			
★ Distinguish between energy resources that are <b>renewable</b> and energy resources that are <b>nonrenewable</b> .			
★ <b>Compare</b> ways that different energy resources are used, the <b>uses</b> to include transport, electricity generation and heating.			
★ Understand why some energy resources are more <b>reliable</b> than others.			
★ Describe the <b>environmental impact</b> arising from the use of different energy resources.			
★ Explain <b>patterns</b> and <b>trends</b> in the use of energy resources.			
★ Consider the <b>environmental issues</b> that may arise from the use of different energy resources.			
★ Show that science has the ability to identify <b>environmental issues</b> arising from the use of energy resources but not always the <b>power</b> to deal with the issues because of <b>political, social, ethical</b> or <b>economic</b> considerations.			

## Topic 2: Electricity

### 4.2.1 Current, potential difference and resistance

#### 4.2.1.1 Standard circuit diagram symbols

Circuit diagrams use standard symbols.



Students should be able to:

★ Draw and interpret **circuit diagrams**.

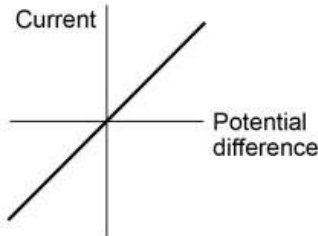
★ **Recall** all the circuit symbols shown above

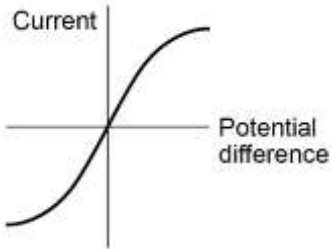
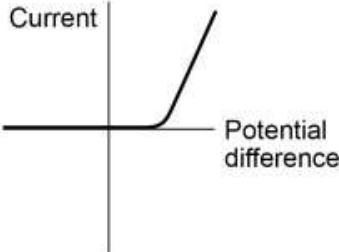
#### 4.2.1.2 Electrical charge and current

For **electrical charge** to flow through a closed circuit the circuit must include a source of **potential difference**.

**Electric current** is a flow of electrical charge. The size of the electric current is the **rate** of **flow** of electrical **charge**.

Charge flow, current and time are linked by the equation:			
charge flow = current × time	$Q = I t$		
<ul style="list-style-type: none"> <li>charge flow, <math>Q</math>, in coulombs, <b>C</b></li> <li>current, <math>I</math>, in amperes, <b>A</b> (amp is acceptable for ampere)</li> <li>time, <math>t</math>, in seconds, <b>s</b></li> </ul>			
The current at any point in a single closed loop of a circuit has the same value as the current at any other point in the same closed loop.			
Students should be able to:			
★ <b>Recall</b> and apply the equation for <b>current</b> stated above.			
<b>4.2.1.3 Current, resistance and potential difference</b>	😊	😐	😞
The <b>current</b> ( $I$ ) through a component depends on both the <b>resistance</b> ( $R$ ) of the component and the <b>potential difference</b> ( $V$ ) across the component.			
The <b>greater the resistance</b> of the component the <b>smaller the current</b> for a given potential difference (p.d.) across the component.			
Current, potential difference or resistance can be calculated using the equation:			
potential difference = current × resistance	$V = I R$		
<ul style="list-style-type: none"> <li>potential difference, <math>V</math>, in volts, <b>V</b></li> <li>current, <math>I</math>, in amperes, <b>A</b> (amp is acceptable for ampere)</li> <li>resistance, <math>R</math>, in ohms, <b>Ω</b></li> </ul>			

Students should be able to:			
★ <b>Recall</b> and apply the equation linking <b>current</b> , <b>potential difference</b> and <b>resistance</b> .			
★ Recognise that <b>potential difference</b> refers to <b>voltage</b> .			
<b>REQUIRED PRACTICAL</b> – Resistance. <b>AT 1, 6 and 7.</b>			
<b>4.2.1.4 Resistors</b>	😊	😐	😞
<p>The current through an <b>ohmic conductor</b> (at a constant temperature) is <b>directly proportional</b> to the potential difference across the resistor. This means that the resistance remains constant as the current changes.</p> 			
The <b>resistance</b> of components such as <b>lamps</b> , <b>diodes</b> , <b>thermistors</b> and <b>LDRs</b> is not constant; it changes with the <b>current</b> through the component.			

<p>The resistance of a <b>filament lamp</b> increases as the temperature of the filament increases.</p> 			
<p>The current through a <b>diode</b> flows in one direction only. The diode has a very high resistance in the reverse direction.</p> 			
<p>The resistance of a <b>thermistor</b> decreases as the <b>temperature</b> increases.</p>			
<p>The <b>applications</b> of thermistors in circuits e.g. a <b>thermostat</b> is required.</p>			
<p>The resistance of an <b>LDR</b> decreases as <b>light</b> intensity increases.</p>			
<p>The <b>application</b> of LDRs in circuits e.g. <b>switching lights on</b> when it gets dark is required.</p>			
<p>Students should be able to:</p>			
<p>★ <b>Explain</b> that, for some resistors, the value <b>R</b> remains <b>constant</b> but that in others it can <b>change</b> as the <b>current</b> changes.</p>			
<p>★ <b>Explain</b> the design and use of a circuit to measure the <b>resistance</b> of a component by measuring the <b>current</b> through, and <b>potential difference</b> across, the component.</p>			
<p>★ <b>Draw</b> an appropriate circuit diagram using correct circuit symbols.</p>			
<p>★ Use <b>graphs</b> to determine whether circuit components are linear or non-linear and relate the curves produced to the function and properties of the component.</p>			
<p><b>MS 4c</b> Plot two variables from experimental or other data.</p>			

<p><b>MS 4d</b> Determine the slope and intercept of a linear graph.</p>			
<p><b>MS 4e</b> Draw and use the slope of a tangent to a curve as a measure of rate of change.</p>			
<p><b>REQUIRED PRACTICAL</b> – I-V characteristics. <b>AT 6 and 7.</b></p>			
<p><b>4.2.2 Series and parallel circuits</b></p>			
<p>There are two ways of joining electrical components, in <b>series</b> and in <b>parallel</b>. Some circuits include both series and parallel parts.</p>			

<p>For components connected in <b>series</b>:</p> <ul style="list-style-type: none"> <li>• there is the <b>same current</b> through each component.</li> <li>• the total <b>potential difference</b> of the power supply is <b>shared</b> between the components.</li> <li>• the total <b>resistance</b> of two components is the <b>sum</b> of the resistance of each component:</li> </ul> $R_{\text{total}} = R_1 + R_2 + \dots$			
<p>For components connected in <b>parallel</b>:</p> <ul style="list-style-type: none"> <li>• the <b>potential difference</b> across each component is the <b>same</b>.</li> <li>• the <b>total current</b> through the whole circuit is the <b>sum of the currents</b> through the separate components.</li> <li>• the <b>total resistance</b> of two resistors is <b>less</b> than the resistance of the smallest individual resistor.</li> </ul>			
<p><u>Students should be able to:</u></p> <p>★ <b>Describe</b> the <b>difference</b> between <b>series</b> and <b>parallel</b> circuits.</p>			
<p>★ <b>Explain</b> qualitatively why adding resistors in <b>series increases</b> the total resistance whilst adding resistors in <b>parallel decreases</b> the total resistance.</p>			
<p>★ <b>Explain</b> the design and use of d.c. <b>series circuits</b> for measurement and testing purposes.</p>			
<p>★ <b>Calculate</b> the currents, potential differences and resistances in d.c. <b>series</b> circuits.</p>			
<p>★ <b>Solve problems</b> for circuits which include resistors in series using the concept of equivalent resistance.</p>			
<b>4.2.3 Domestic uses and safety</b>			
<b>4.2.3.1 Direct and alternating current</b>	☺	☹	☹
Mains electricity is an <b>a.c. supply</b> . In the United Kingdom it has a <b>frequency</b> of <b>50 Hz</b> and is about <b>230 V</b> .			
An <b>alternating current</b> (a.c.) is one that continuously <b>changes direction</b> .			
Cells and batteries supply current that always passes in the <b>same direction</b> . This is called <b>direct current</b> (d.c.).			
<p><u>Students should be able to:</u></p> <p>★ Explain the difference between <b>direct</b> and <b>alternating potential difference</b>.</p>			
<b>4.4.3.2 Mains electricity</b>	☺	☹	☹
Most electrical appliances are connected to the mains using <b>three-core cable</b> .			
<p>The insulation covering each wire is colour coded for easy identification:</p> <ul style="list-style-type: none"> <li>• <b>live</b> wire – <b>brown</b></li> <li>• <b>neutral</b> wire – <b>blue</b></li> <li>• <b>earth</b> wire – <b>green</b> and <b>yellow</b> stripes.</li> </ul>			
<p>The <b>live</b> wire carries the <b>alternating potential</b> difference from the supply.</p> <p>The <b>neutral</b> wire completes the circuit.</p> <p>The <b>earth</b> wire is a <b>safety wire</b> to stop the appliance becoming live.</p>			

The potential difference between the <b>live</b> wire and earth (0 V) is about 230 V. The <b>neutral</b> wire is at, or close to, earth potential (0 V). The <b>earth</b> wire is at 0 V, it only carries a current if there is a fault.			
Our bodies are at earth potential (0 V). Touching the live wire produces a large potential difference across our body. This causes a current to flow through our body, resulting in an <b>electric shock</b> .			
<u>Students should be able to:</u> ★ <b>Explain</b> that a <b>live wire</b> may be dangerous even when a switch in the mains circuit is open.			
★ <b>Explain</b> the <b>dangers</b> of providing any connection between the live wire and earth.			
<b>4.2.4 Energy transfers</b>			
<b>4.2.4.1 Power</b>	😊	😐	😞
The power of a device is related to the potential difference across it and the current through it by the equation:  power = potential difference × current $P = V I$			
power = (current) <sup>2</sup> × resistance $P = I^2 R$			
<ul style="list-style-type: none"> <li>power, <math>P</math>, in watts, <b>W</b></li> <li>potential difference, <math>V</math>, in volts, <b>V</b></li> <li>current, <math>I</math>, in amperes, <b>A</b> (amp is acceptable for ampere) □      resistance, <math>R</math>, in ohms, <b>Ω</b></li> </ul>			
<u>Students should be able to:</u> ★ <b>Recall</b> and apply both equations for <b>power</b> .			
★ <b>Explain</b> how the <b>power</b> transfer in any circuit device is related to the <b>potential difference</b> across it and the <b>current</b> through it, and the energy changes over time.			
<b>4.2.4.2 Energy transfers in everyday appliances</b>	😊	😐	😞
Everyday electrical appliances are designed to bring about <b>energy transfers</b> .			
The amount of energy an appliance transfers depends on <b>how long</b> the appliance is switched on for and the <b>power</b> of the appliance.			
The amount of energy transferred by <b>electrical work</b> can be calculated using the equation:  energy transferred = power × time $E = P t$			
<ul style="list-style-type: none"> <li>energy transferred, <math>E</math>, in joules, <b>J</b></li> <li>power, <math>P</math>, in watts, <b>W</b></li> <li>time, <math>t</math>, in seconds, <b>s</b></li> </ul>			
<b>Work</b> is done when <b>charge flows</b> in a circuit.			
energy transferred = charge flow × potential difference $E = Q V$			
<ul style="list-style-type: none"> <li>energy transferred, <math>E</math>, in joules, <b>J</b></li> <li>charge flow, <math>Q</math>, in coulombs, <b>C</b></li> <li>potential difference, <math>V</math>, in volts, <b>V</b></li> </ul>			



Students should be able to:			
★ <b>Recall</b> and apply both equations for <b>energy transfer</b> .			
★ <b>Describe</b> how different domestic appliances transfer energy from <b>batteries</b> or <b>a.c.</b> mains to the <b>kinetic energy</b> of electric <b>motors</b> or the energy of <b>heating devices</b> .			
★ <b>Explain</b> how the power of a circuit device is related to: <ul style="list-style-type: none"> <li>the <b>p.d.</b> across it and the <b>current</b> through it.</li> <li>the <b>energy</b> transferred over a given <b>time</b>.</li> </ul>			
★ <b>Describe</b> , with examples, the relationship between the <b>power ratings</b> for domestic electrical appliances and the changes in stored energy when they are in use.			
<b>4.2.4.3 The National Grid</b>	😊	😐	😞
The <b>National Grid</b> is a system of <b>cables</b> and <b>transformers</b> linking power stations to consumers.			
Electrical power is transferred from power stations to consumers using the National Grid.			
<b>Step-up transformers</b> are used to <b>increase</b> the <b>potential difference</b> from the power station to the transmission cables then <b>step-down transformers</b> are used to <b>decrease</b> , to a much lower value, the potential difference for domestic use.			
This is done because, for a given power, increasing the potential difference <b>reduces</b> the <b>current</b> , and hence <b>reduces</b> the <b>energy losses</b> due to <b>heating</b> in the <b>transmission cables</b> .			
Students should be able to:			
★ <b>Explain</b> why the National Grid system is an efficient way to transfer energy.			




## Topic 3: Particle model of matter

### 4.3.1 Changes of state and the particle model

<b>4.3.1.1 Density of materials</b>	😊	😐	😞
The <b>density</b> of a material is defined by the equation:			
$\text{density} = \frac{\text{mass}}{\text{volume}} \quad \left  \quad \rho = \frac{m}{V} \right.$			
<ul style="list-style-type: none"> <li>density, <math>\rho</math>, in kilograms per metre cubed, <b>kg/m<sup>3</sup></b></li> <li>mass, <math>m</math>, in kilograms, <b>kg</b></li> <li>volume, <math>V</math>, in metres cubed, <b>m<sup>3</sup></b></li> </ul>			
The <b>particle model</b> can be used to explain <ul style="list-style-type: none"> <li>the different states of matter</li> <li>differences in density</li> </ul>			
Students should be able to:			
★ <b>Recall</b> and apply the equation for <b>density</b> .			
★ <b>Recognise/draw</b> simple diagrams to model the difference between <b>solids, liquids</b> and <b>gases</b> [ <i>links with chemistry</i> ].			

★ <b>Explain</b> the differences in <b>density</b> between the different states of matter in terms of the arrangement of atoms or molecules.			
<b>REQUIRED PRACTICAL – Density. AT 1.</b>			
<b>4.3.1.2 Changes of state</b>	😊	😐	😞
Changes of state are <b>physical changes</b> : the change does not produce a new substance. If the change is reversed the substance recovers its original properties.			
<u>Students should be able to:</u> ★ <b>Describe</b> how when substances <b>change state</b> (melt, freeze, boil, evaporate, condense or sublimate), mass is conserved.			

<b>4.3.2 Internal energy and energy transfers</b>			
<b>4.3.2.1 Internal energy</b>	😊	😐	😞
Energy is <b>stored</b> inside a system by the <b>particles</b> (atoms and molecules) that make up the system. This is called <b>internal energy</b> .			
<b>Internal energy</b> is the <b>total kinetic energy and potential energy</b> of all the particles (atoms and molecules) that make up a system.			
<b>Heating</b> changes the energy stored within the system by increasing the energy of the particles that make up the system. This either raises the <b>temperature</b> of the system or produces a <b>change of state</b>			
<b>4.3.2.2 Temperature changes in a system and specific heat capacity</b>	😊	😐	😞
If the temperature of the system increases: The increase in <b>temperature</b> depends on the <b>mass</b> of the substance heated, the type of <b>material</b> and the <b>energy input</b> to the system.			
<div style="border: 1px solid black; padding: 5px; display: inline-block;">           change in thermal energy = mass × specific heat capacity            × temperature change         </div> <div style="border: 1px solid black; padding: 5px; display: inline-block; margin-left: 20px;"> <math>\Delta E = m c \Delta \theta</math> </div>			
<ul style="list-style-type: none"> <li>change in thermal energy, <math>\Delta E</math>, in joules, <b>J</b></li> <li>mass, <math>m</math>, in kilograms, <b>kg</b></li> <li>specific heat capacity, <math>c</math>, in joules per kilogram per degree Celsius, <b>J/kg °C</b> □ temperature change, <math>\Delta\theta</math>, in degrees Celsius, <b>°C</b></li> </ul>			
The <b>specific heat capacity</b> of a substance is the amount of energy required to raise the temperature of one kilogram of the substance by one degree Celsius.			
<u>Students should be able to:</u> ★ <b>Apply</b> the equation for <b>specific heat capacity</b> which is given on the <b>Physics equation sheet</b> .			
<b>4.3.2.3 Changes of heat and specific latent heat</b>	😊	😐	😞
If a change of state happens: The energy needed for a substance to <b>change state</b> is called <b>latent heat</b> . When a change of state occurs, the energy supplied changes the energy stored ( <b>internal energy</b> ) but <b>not the temperature</b> .			
The <b>specific latent heat</b> of a substance is the amount of energy required to change the state of one kilogram of the substance with no change in temperature.			

The following equation applies:			
thermal energy for a change of state = mass × specific latent heat	$E = m L$		
<ul style="list-style-type: none"> <li>energy, <math>E</math>, in joules, <b>J</b></li> <li>mass, <math>m</math>, in kilograms, <b>kg</b></li> <li>specific latent heat, <math>L</math>, in joules per kilogram, <b>J/kg</b></li> </ul>			
Specific latent heat of <b>fusion</b> – change of state from solid to liquid			
Specific latent heat of <b>vaporisation</b> – change of state from liquid to vapour			
Students should be able to:			
★ <b>Interpret</b> heating and cooling <b>graphs</b> that include changes of state.			
★ <b>Distinguish</b> between specific heat capacity and specific latent heat.			
★ <b>Apply</b> the equation for <b>specific latent heat</b> which is given on the <b>Physics equation sheet</b> .			
<b>4.3.3 Particle model and pressure</b>			
<b>4.3.3.1 Particle motion in gases</b>			
The molecules of a gas are in <b>constant random motion</b> . The <b>temperature</b> of the gas is related to the <b>average kinetic energy</b> of the molecules. The higher the temperature the greater the average kinetic energy and so the faster the average speed of the molecules.			
When the molecules <b>collide</b> with the wall of their container they exert a <b>force</b> on the wall. The total force exerted by all of the molecules inside the container on a <b>unit area</b> of the walls is the gas <b>pressure</b> .			
Changing the <b>temperature</b> of a gas, held at constant volume, changes the <b>pressure</b> exerted by the gas.			
Students should be able to:			
★ <b>Explain</b> how the motion of the molecules in a gas is related to both its <b>temperature</b> and its <b>pressure</b> .			
★ <b>Explain</b> qualitatively the relationship between <b>temperature</b> of a gas and its <b>pressure</b> at constant <b>volume</b> .			

## Topic 4: Atomic Structure

### 4.4.1 Atoms and isotopes

#### 4.4.1.1 The structure of an atom

Atoms are very small, having a radius of about  $1 \times 10^{-10}$  metres.



The basic structure of an atom is a <b>positively charged nucleus</b> composed of both <b>protons</b> and <b>neutrons</b> surrounded by <b>negatively charged electrons</b> .			
The radius of a nucleus is less than 1/10 000 of the radius of an atom. Most of the <b>mass</b> of an atom is concentrated in the <b>nucleus</b> .			
The electrons are arranged at different distances from the nucleus (different <b>energy levels</b> ). The electron arrangements may change with the <b>absorption</b> of <b>electromagnetic radiation</b> (move further from the nucleus; a higher energy level) or by the <b>emission</b> of electromagnetic radiation (move closer to the nucleus; a lower energy level).			
<u>Students should be able to:</u> ★ Recognise expressions given in <b>standard form</b> .			
<b>4.4.1.2 Mass number, atomic number and isotopes</b>	😊	😐	😞
In an atom the number of <b>electrons</b> is <b>equal</b> to the number of <b>protons</b> in the nucleus. Atoms have no overall electrical charge.			
All atoms of a particular <b>element</b> have the <b>same number</b> of <b>protons</b> . The number of protons in an atom of an element is called its <b>atomic number</b> .			
The total number of <b>protons</b> and <b>neutrons</b> in an atom is called its <b>mass number</b> .			
Atoms can be represented as shown in this example: (Mass number) 23 (Atomic number) 11 <b>Na</b>			
Atoms of the same element can have <b>different</b> numbers of <b>neutrons</b> ; these atoms are called <b>isotopes</b> of that element.			
Atoms turn into <b>positive ions</b> if they <b>lose</b> one or more outer <b>electron(s)</b> .			

<u>Students should be able to:</u> ★ Relate differences between <b>isotopes</b> to differences in conventional representations of their identities, charges and masses.			
<b>4.4.1.3 The development of the model of the atom</b> ( <i>common content with chemistry</i> )	😊	😐	😞
New experimental evidence may lead to a <b>scientific model</b> being changed or replaced.			
Before the discovery of the electron, <b>atoms</b> were thought to be tiny spheres that could not be divided.			
The discovery of the electron led to the <b>plum pudding model</b> of the atom. The plum pudding model suggested that the atom was a ball of positive charge with negative electrons embedded in it.			
The results from the <b>alpha particle scattering experiment</b> led to the conclusion that the mass of an atom was concentrated at the centre (nucleus) and that the nucleus was charged. This <b>nuclear model</b> replaced the plum pudding model.			
<b>Niels Bohr</b> adapted the nuclear model by suggesting that <b>electrons orbit</b> the nucleus at specific distances. The theoretical calculations of Bohr agreed with experimental observations.			

Later experiments led to the idea that the <b>positive charge</b> of any nucleus could be subdivided into a whole number of smaller particles, each particle having the same amount of positive charge. The name <b>proton</b> was given to these particles.			
The experimental work of <b>James Chadwick</b> provided the evidence to show the existence of <b>neutrons</b> within the nucleus. This was about 20 years after the nucleus became an accepted scientific idea.			
<u>Students should be able to:</u>			
★ <b>Describe</b> the <b>difference</b> between the <b>plum pudding model</b> of the atom and the <b>nuclear model</b> of the atom.			
★ <b>Describe</b> why the <b>new evidence</b> from the scattering experiment led to a <b>change</b> in the atomic model. <i>Details of experimental work supporting the Bohr model are not required. Details of these experiments are not required. Details of Chadwick's experimental work are not required.</i>			
<b>4.4.2 Atoms and nuclear radiation</b>			
<b>4.4.2.1 Radioactive decay and nuclear radiation</b>	☺	☹	☹
Some atomic nuclei are <b>unstable</b> . The nucleus gives out radiation as it changes to become more stable. This is a <b>random</b> process called <b>radioactive decay</b> .			
<b>Activity</b> is the <b>rate</b> at which a source of unstable nuclei decays.			
<b>Activity</b> is measured in <b>becquerel (Bq)</b>			
<b>Count-rate</b> is the number of decays recorded <b>each second</b> by a detector (e.g. Geiger-Muller tube).			
The nuclear radiation emitted may be:			
<input type="checkbox"/> an <b>alpha particle</b> ( $\alpha$ ) – this consists of <b>two neutrons</b> and <b>two protons</b> , it is the same as a helium nucleus			
<input type="checkbox"/> a <b>beta particle</b> ( $\beta$ ) – a high speed <b>electron</b> ejected from the nucleus as a neutron turns into a proton			
<input type="checkbox"/> a <b>gamma ray</b> ( $\gamma$ ) – <b>electromagnetic radiation</b> from the nucleus			
<input type="checkbox"/> a <b>neutron</b> (n).			
<b>Alpha</b> particles have a range in air of just a <b>few centimetres</b> and are absorbed by a thin sheet of <b>paper</b> . Alpha particles are <b>strongly ionising</b> .			
<b>Beta</b> particles have a range in air of a <b>few metres</b> and are completely absorbed by a sheet of <b>aluminium</b> about 5 mm thick. Beta particles are <b>moderately ionising</b> .			

<b>Gamma</b> rays travel great distances through the air and pass through most materials but are absorbed by a <b>thick sheet of lead</b> or several metres of <b>concrete</b> . Gamma rays are <b>weakly ionising</b> .			
<u>Students should be able to:</u>			
★ <b>Apply</b> their knowledge to the uses of radiation and <b>evaluate</b> the best sources of radiation to use in a given situation.			
Required knowledge of the properties of alpha particles, beta particles and gamma rays is limited to their <b>penetration</b> through materials, their <b>range</b> in air and <b>ionising power</b> .			

4.4.2.2 Nuclear equations	😊	😐	😞
Nuclear equations are used to represent radioactive decay.			
In a nuclear equation an <b>alpha particle</b> may be represented by the symbol: ${}^4_2\text{He}$			
And a <b>beta particle</b> by the symbol: ${}^0_{-1}\text{e}$			
The emission of the different types of nuclear radiation may cause a change in the <b>mass</b> and /or the <b>charge</b> of the <b>nucleus</b> . For example: ${}^{219}_{86}\text{radon} \longrightarrow {}^{215}_{84}\text{polonium} + {}^4_2\text{He}$ So <b>alpha decay</b> causes both the <b>mass</b> and <b>charge</b> of the nucleus to decrease.			
${}^{14}_6\text{carbon} \longrightarrow {}^{14}_7\text{nitrogen} + {}^0_{-1}\text{e}$ So <b>beta decay</b> does not cause the mass of the nucleus to change but does cause the <b>charge</b> of the nucleus to increase. <i>Students are not required to recall these two examples.</i>			
The emission of a <b>gamma ray</b> does not cause the mass or the charge of the nucleus to change.			
<u>Students should be able to:</u> ★ Use the <b>names</b> and <b>symbols</b> of common nuclei and particles to write <b>balanced equations</b> that show single <b>alpha</b> ( $\alpha$ ) and <b>beta</b> ( $\beta$ ) decay. This is limited to balancing the atomic numbers and mass numbers. <i>The identification of daughter elements from such decays is not required.</i>			
4.4.2.3 Half-lives and the random nature of radioactive decay	😊	😐	😞
Radioactive decay is <b>random</b> . It is not possible to predict which individual nucleus will decay next. But, with a large enough number of nuclei, it is possible to predict how many will decay in a certain amount of time.			
The <b>half-life</b> of a radioactive isotope is the <b>time</b> it takes for the <b>number of nuclei</b> of the isotope in a sample to <b>halve</b> , or the time it takes for the <b>count rate</b> (or activity) from a sample containing the isotope to fall to <b>half</b> its initial level.			
<u>Students should be able to:</u>			
★ <b>Explain</b> the concept of half-life and how it is related to the random nature of radioactive decay.			
★ <b>Determine</b> the half-life of a radioactive isotope from given information.			
★ (HT only) <b>Calculate</b> the net decline, expressed as a <b>ratio</b> , in a radioactive emission after a given number of half-lives.			
4.4.2.4 Radioactive contamination	😊	😐	😞
Radioactive contamination is the <b>unwanted</b> presence of materials containing <b>radioactive atoms</b> on other materials.			
The <b>hazard</b> from contamination is due to the <b>decay</b> of the contaminating atoms. The <b>type of radiation</b> emitted affects the <b>level</b> of hazard.			
<b>Irradiation</b> is the process of <b>exposing</b> an object to nuclear radiation. The irradiated object does <u>not</u> become radioactive.			

Suitable <b>precautions</b> must be taken to protect against any hazard that the <b>radioactive source</b> used in the process of <b>irradiation</b> may present.			
<u>Students should be able to:</u> ★ <b>Compare</b> the hazards associated with contamination and irradiation.			
★ <b>Understand</b> that it is important for the findings of studies into the effects of radiation on humans to be <b>published</b> and <b>shared</b> with other scientists so that the findings can be checked by <b>peer review</b> .			

A copy of the equation sheet that will be provided in the exams can be found on the following page.

# GCSE Combined Science: Trilogy

## Physics Equation sheet

1	$(\text{final velocity})^2 - (\text{initial velocity})^2 = 2 \times \text{acceleration} \times \text{distance}$	$v^2 - u^2 = 2 a s$
2	elastic potential energy = $0.5 \times \text{spring constant} \times (\text{extension})^2$	$E_e = \frac{1}{2} k e^2$
3	change in thermal energy = mass $\times$ specific heat capacity $\times$ temperature change	$\Delta E = m c \Delta \theta$
4	period = $\frac{1}{\text{frequency}}$	
5	<b>force on a conductor (at right angles to a magnetic field) carrying a current</b> = magnetic flux density $\times$ current $\times$ length	$F = B I l$
6	thermal energy for a change of state = mass $\times$ specific latent heat	$E = m L$
7	<b>potential difference across primary coil <math>\times</math> current in primary coil</b> = <b>potential difference across secondary coil <math>\times</math> current in secondary coil</b>	$V_s I_s = V_p I_p$