4.1 Energy

The concept of energy emerged in the 19th century. The idea was used to explain the work output of steam engines and then generalised to understand other heat engines. It also became a key tool for understanding chemical reactions and biological systems.

Limits to the use of fossil fuels and global warming are critical problems for this century. Physicists and engineers are working hard to identify ways to reduce our energy usage.

4.1.1 Energy changes in a system, and the ways energy is stored before and after such changes

4.1.1.1 Energy stores and systems

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |  |  |
| A system is an object or group of objects. | The link between work done |
| There are changes in the way energy is stored when a system | (energy transfer) and |
| current flow in a circuit is |
| changes. |
| covered in [Energy transfers](#page28) |
| Students should be able to describe all the changes involved in the |
| (page 28). |  |  |
| way energy is stored when a system changes, for common | WS 4.5 |
| situations. For example: |
|  |  |  |
| • an object projected upwards |  |  |  |
| • a moving object hitting an obstacle |  |  |  |
| • an object accelerated by a constant force |  |  |  |
| • a vehicle slowing down |  |  |  |
| • bringing water to a boil in an electric kettle. |  |  |  |
| Throughout this section on Energy students should be able to |  |  |  |
| calculate the changes in energy involved when a system is changed |  |  |  |
| by: |  |  |  |
| • heating |  |  |  |
| • work done by forces |  |  |  |
| • work done when a current flows |  |  |  |
|  |  |
| • use calculations to show on a common scale how the overall | WS 1.2, 4.3, 4.5, 4.6 |
| energy in a system is redistributed when the system is changed. | MS 1a, c, 3b, c |
|  |
|  |  |  |  |

4.1.1.2 Changes in energy

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  |  |  | **development** |
|  |  |  |  |
| Students should be able to calculate the amount of energy | WS 1.2, 4.3, 4.4, 4.6 |
| associated with a moving object, a stretched spring and an object | MS 1a, c, 3b, c |
| raised above ground level. |
|  |
|  |  |
| The kinetic energy of a moving object can be calculated using the | MS 3b, c |
| equation: | Students should be able to |
|  |  |  |
| *kinetic energ y* = 0.5 × *mass* × *s peed* 2 | recall and apply this |
| *E*k= | 1 | *m v*2 | equation. |
|  |
| 2 |  |
| kinetic energy, *E*k, in joules, J |  |
| mass, *m*, in kilograms, kg |  |
| speed, *v*, in metres per second, m/s |  |
| The amount of elastic potential energy stored in a stretched spring |  |
| can be calculated using the equation: |  |
|  |  |  |  |

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  |  |  |  | **development** |
|  |  |  |  |
| *elastic potential energ y* = 0.5 × *s pring constant* × *extension* 2 | MS 3b, c |
| *E*e | = | 1 | *k e*2 | Students should be able to |
|  |  | 2 |  | apply this equation which is |
| (assuming the limit of proportionality has not been exceeded) | given on the Physics |
| elastic potential energy, *E*e, in joules, J | equation sheet. |
|  |
| spring constant, *k*, in newtons per metre, N/m |  |
| extension, *e*, in metres, m |  |
| The amount of gravitational potential energy gained by an object |  |
| raised above ground level can be calculated using the equation: |  |
|  |  |
| *g* . *p* . *e* . = *mass* × *gravitational f ield strength* × *height* | MS 3b, c |
| *E*p | = *m g h* | Students should be able to |
| gravitational potential energy, *E*p, in joules, J | recall and apply this |
| equation. |
| mass, *m*, in kilograms, kg | AT 1 |
| gravitational field strength, *g*, in newtons per kilogram, N/kg (In any | Investigate the transfer of |
| calculation the value of the gravitational field strength (*g*) will be | energy from a gravitational |
| given.) | potential energy store to a |
| height, *h*, in metres, m | kinetic energy store. |
|  |
|  |  |  |  |  |





4.1.1.3 Energy changes in systems

|  |  |  |
| --- | --- | --- |
| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |  |  |  |  |
| The amount of energy stored in or released from a system as its |  |  |  |  |  |  |
| temperature changes can be calculated using the equation: |  |  |  |  |  |  |
|  |  |  |
| *change in thermal energ y* = *mass* × *s peci f ic heat ca pacit y* |  | MS 3b, c |
| × *tem perature change* |  | Students should be able to |
| ∆ *E* = *m c* ∆ *θ* |  |
|  | apply this equation which is |
| change in thermal energy, ∆*E*, in joules, J |  | given on the Physics |
|  | equation sheet. |
| mass, *m*, in kilograms, kg |  |
|  | This equation and specific |
| specific heat capacity, *c*, in joules per kilogram per degree Celsius, |  |
|  | heat capacity are also |
| J/kg °C |  | included in [Temperature](#page33) |
|  |  |  |  |  |  |  |
| temperature change, ∆*θ*, in degrees Celsius, °C |  | [changes in a system and](#page33) |
|  |  |  |  |  |  |
|  | [specific heat capacity](#page33) (page |
| The specific heat capacity of a substance is the amount of energy |  |
|  |  |  |  |  |  |
| 33). |  |  |  |  |
| required to raise the temperature of one kilogram of the substance |  |  |  |  |  |  |
| by one degree Celsius. |  |  |  |  |  |  |
|  |  |  |  |  |  |  |



4.1.1.4 Power



|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Content** |  |  |  |  | **Key opportunities for skills** |
|  |  |  |  |  |  |  |  | **development** |
|  |  |  |  |  |  |  |
| Power is defined as the rate at which energy is transferred or the |  | MS 3b, c |
| rate at which work is done. |  | Students should be able to |
|  |  |  |  |  |  |  |  |
| *power* | = | *energ y trans f erred* |  |  | recall and apply both |
| *time* |  |
|  |  |  |  |  | equations. |
|  | *E* |  |  |  |  |  |  |
| *P* = |  |  |  |  |  |  |  |
| *t* |  |  |  |  |  |
|  |  |  |  |  |  |
| *power* | = | *work d one* |  |  |  |
| *time* |  |  |
|  |  |  |  |  |  |
| *P* = | *W* |  |  |  |  |  |  |
| *t* |  |  |  |  |  |
|  |  |  |  |  |  |



power, *P*, in watts, W

energy transferred, *E*, in joules, J

time, *t*, in seconds, s

work done, *W*, in joules, J

An energy transfer of 1 joule per second is equal to a power of 1 watt.

Students should be able to give examples that illustrate the definition of power eg comparing two electric motors that both lift the same weight through the same height but one does it faster than the other.

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Energy can be transferred usefully, stored or dissipated, but cannot |  |
| be created or destroyed. |  |
| Students should be able to describe with examples where there are |  |
| energy transfers in a closed system, that there is no net change to |  |
| the total energy. |  |
| Students should be able to describe, with examples, how in all |  |
| system changes energy is dissipated, so that it is stored in less |  |
| useful ways. This energy is often described as being ‘wasted’. |  |
|  |  |
| Students should be able to explain ways of reducing unwanted | WS 1.4 |
| energy transfers, for example through lubrication and the use of | AT 1, 5 |
| thermal insulation. |
| Investigate thermal |
| The higher the thermal conductivity of a material the higher the rate |
| conductivity using rods of |
| of energy transfer by conduction across the material. |
| different materials. |
| Students should be able to describe how the rate of cooling of a |
|  |
| building is affected by the thickness and thermal conductivity of its |  |
| walls. |  |
| Students do not need to know the definition of thermal conductivity. |  |
|  |  |
|  |  |

4.1.2.1 Energy transfers in a system

**Required practical activity 2 (physics only):** investigate the effectiveness of different materialsas thermal insulators and the factors that may affect the thermal insulation properties of a material.

4.1.2.2 Efficiency

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Content** |  |  |  | **Key opportunities for skills** |  |
|  |  |  |  | **development** |  |
|  |  |  |  |  |
| The energy efficiency for any energy transfer can be calculated | MS 3b, c |  |
| using the equation: | Students should be able to |  |
|  |  |  |  |  |
| *e f f icienc y* = | *use f ul out put energ y trans f er* |  | recall and apply both |  |
| *total in put energ y trans f er* |  |
|  | equations. |  |
| Efficiency may also be calculated using the equation: |  |
| MS 1a, c, 3b, c |  |
|  | *use f ul power out put* |  |
| *e f f icienc y* = | Students may be required |  |
| *total power in put* |  |  |
|  |  |  |  | to calculate or use efficiency |  |
|  |  |  |  | values as a decimal or as a |  |
|  |  |  |  | percentage. |  |
|  |  |  |
|  |
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4.1.3 National and global energy resources

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| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| The main energy resources available for use on Earth include: fossil | WS 4.4 |
| fuels (coal, oil and gas), nuclear fuel, bio-fuel, wind, hydro- |  |
| electricity, geothermal, the tides, the Sun and water waves. |  |
| A renewable energy resource is one that is being (or can be) |  |
| replenished as it is used. |  |
| The uses of energy resources include: transport, electricity |  |
| generation and heating. |  |
| Students should be able to: |  |
| • describe the main energy sources available |  |
| • distinguish between energy resources that are renewable and |  |
| energy resources that are non-renewable |  |
| • compare ways that different energy resources are used, the uses |  |
| to include transport, electricity generation and heating |  |
| • understand why some energy resources are more reliable than |  |
| others |  |
|  |  |
| • describe the environmental impact arising from the use of | WS 1.3, 1.4 |
| different energy resources |  |
|  |  |
| • explain patterns and trends in the use of energy resources. | WS 3.5 |
|  |  |
| Descriptions of how energy resources are used to generate |  |
| electricity are **not** required. |  |
|  |  |
| Students should be able to: | WS 1.3, 1.4, 4.4 |
| • consider the environmental issues that may arise from the use of | MS 1c, 2c, 4a |
| different energy resources |  |
| • show that science has the ability to identify environmental issues |  |
| arising from the use of energy resources but not always the |  |
| power to deal with the issues because of political, social, ethical |  |
| or economic considerations. |  |
|  |  |

4.2 Electricity

Electric charge is a fundamental property of matter everywhere. Understanding the difference in the microstructure of conductors, semiconductors and insulators makes it possible to design components and build electric circuits. Many circuits are powered with mains electricity, but portable electrical devices must use batteries of some kind.

Electrical power fills the modern world with artificial light and sound, information and entertainment, remote sensing and control. The fundamentals of electromagnetism were worked out by scientists of the 19th century. However, power stations, like all machines, have a limited lifetime. If we all

continue to demand more electricity this means building new power stations in every generation – but what mix of power stations can promise a sustainable future?

4.2.1 Current, potential difference and resistance

4.2.1.1 Standard circuit diagram symbols



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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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| Circuit diagrams use standard symbols. |  | WS 1.2 |



Students should be able to draw and interpret circuit diagrams.

4.2.1.2 Electrical charge and current

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| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| For electrical charge to flow through a closed circuit the circuit must |  |
| include a source of potential difference. |  |
|  |  |

|  |  |
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| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Electric current is a flow of electrical charge. The size of the electric | MS 3b, c |
| current is the rate of flow of electrical charge. Charge flow, current | Students should be able to |
| and time are linked by the equation: |
| recall and apply this |
| *charge f low* = *current* × *time* |
| equation. |
| *Q* = *I t* |  |
| charge flow, *Q*, in coulombs, C |  |
| current, *I*, in amperes, A (amp is acceptable for ampere) |  |
| time, *t*, in seconds, s |  |
| A current has the same value at any point in a single closed loop. |  |
|  |  |



4.2.1.3 Current, resistance and potential difference

|  |  |
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| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| The current (*I*) through a component depends on both the |  |
| resistance (*R*) of the component and the potential difference (*V*) |  |
| across the component. The greater the resistance of the component |  |
| the smaller the current for a given potential difference (pd) across |  |
| the component. |  |
| Questions will be set using the term potential difference. Students |  |
| will gain credit for the correct use of either potential difference or |  |
| voltage. |  |
|  |  |
| Current, potential difference or resistance can be calculated using | MS 3b, c |
| the equation: | Students should be able to |
| *potential d i f f erence* = *current* × *resistance* |
| recall and apply this |
| *V* = *I R* | equation. |
|  |
| potential difference, *V*, in volts, V |  |
| current, *I*, in amperes, A (amp is acceptable for ampere) |  |
| resistance, *R*, in ohms, Ω |  |
|  |  |



4.2.1.4 Resistors



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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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Students should be able to explain that, for some resistors, the value of *R* remains constant but that in others it can change as the current changes.

The current through an ohmic conductor (at a constant temperature) is directly proportional to the potential difference across the resistor. This means that the resistance remains constant as the current changes.



The resistance of components such as lamps, diodes, thermistors and LDRs is not constant; it changes with the current through the component.

The resistance of a filament lamp increases as the temperature of the filament increases.



The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction.



|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| The resistance of a thermistor decreases as the temperature |  |
| increases. |  |
| The applications of thermistors in circuits eg a thermostat is |  |
| required. |  |
| The resistance of an LDR decreases as light intensity increases. |  |
|  |  |
| The application of LDRs in circuits eg switching lights on when it | WS 1.2, 1.4 |
| gets dark is required. |  |
| Students should be able to: |  |
|  |  |
| • explain the design and use of a circuit to measure the resistance | AT 6 |
| of a component by measuring the current through, and potential | Investigate the relationship |
| difference across, the component |
| between the resistance of a |
| • draw an appropriate circuit diagram using correct circuit |
| thermistor and temperature. |
| symbols. |
| Investigate the relationship |
|  |
|  | between the resistance of |
|  | an LDR and light intensity. |
|  |  |
| Students should be able to use graphs to explore whether circuit | WS 1.2, 1.4 |
| elements are linear or non-linear and relate the curves produced to | MS 4c, d, e |
| their function and properties. |
|  |
|  |  |

4.2.2 Series and parallel circuits



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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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There are two ways of joining electrical components, in series and in parallel. Some circuits include both series and parallel parts.

For components connected in series:

* there is the same current through each component
* the total potential difference of the power supply is shared between the components
* the total resistance of two components is the sum of the resistance of each component.



|  |  |  |
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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |
| *R***t**o**tal** =*R*1+*R*2 |  | MS 1c, 3b, 3c, 3d |
| resistance, *R*, in ohms, Ω |  |  |
| For components connected in parallel: |  |  |

* the potential difference across each component is the same
* the total current through the whole circuit is the sum of the currents through the separate components
* the total resistance of two resistors is less than the resistance of the smallest individual resistor.

Students should be able to:



|  |  |
| --- | --- |
| • use circuit diagrams to construct and check series and parallel | AT 7 |
| circuits that include a variety of common circuit components |  |

* describe the difference between series and parallel circuits
* explain qualitatively why adding resistors in series increases the total resistance whilst adding resistors in parallel decreases the total resistance



|  |  |  |
| --- | --- | --- |
| • | explain the design and use of dc series circuits for measurement | WS 1.4 |
|  | and testing purposes |  |
|  |  |  |
| • | calculate the currents, potential differences and resistances in dc | MS 1c, 3b, c, d |
|  | series circuits |  |

* solve problems for circuits which include resistors in series using the concept of equivalent resistance.

Students are **not** required to calculate the total resistance of two resistors joined in parallel.

|  |  |
| --- | --- |
| 4.2.4 Energy transfer |  |
|  |
| 4.2.4.1 Power |  |
|  |  |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Students should be able to explain how the power transfer in any | MS 3b, c |
| circuit device is related to the potential difference across it and the | WS 4.5 |
| current through it, and to the energy changes over time: |
| Students should be able to |
| *power* = *potential d i f f erence* × *current* |
| recall and apply both |
| *P* = *V I* |
| equations. |
| *power* = current2× *resistance* |  |
| *P* = *I*2 *R* |  |
| power, *P*, in watts, W |  |
| potential difference, *V*, in volts, V |  |
| current, *I*, in amperes, A (amp is acceptable for ampere) |  |
| resistance, *R*, in ohms, Ω |  |
|  |  |



4.2.4.2 Energy transfers in everyday appliances



|  |  |  |
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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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Everyday electrical appliances are designed to bring about energy transfers.

The amount of energy an appliance transfers depends on how long the appliance is switched on for and the power of the appliance.

Students should be able to describe how different domestic appliances transfer energy from batteries or ac mains to the kinetic energy of electric motors or the energy of heating devices.

Work is done when charge flows in a circuit.

The amount of energy transferred by electrical work can be calculated using the equation:



|  |  |  |  |
| --- | --- | --- | --- |
| *energ y trans f erred* | = *power* × *time* |  | MS 3b, c |
| *E* = *P t* |  |  | Students should be able to |
| *energ y trans f erred* | = *charge f low* | × *potential d i f f erence* | recall and apply both |
| equations. |
|  |  |  |
| *E* = *Q V* |  |  | WS 1.4 |
| energy transferred, *E*, in joules, J |  |  |



power, *P*, in watts, W

time, *t*, in seconds, s

charge flow, *Q*, in coulombs, C

potential difference, *V*, in volts, V



Students should be able to explain how the power of a circuit device WS 1.2 is related to:

* the potential difference across it and the current through it
* the energy transferred over a given time.

Students should be able to describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use.

4.2.4.3 The National Grid



|  |  |  |
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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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The National Grid is a system of cables and transformers linking power stations to consumers.



|  |  |  |
| --- | --- | --- |
| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |  |  |  |
| Electrical power is transferred from power stations to consumers |  | The construction and |
| using the National Grid. |  | operation of transformers is |
| Step-up transformers are used to increase the potential difference |  | covered [Transformers (HT](#page71) |
|  |  |  |  |  |
|  | [only)](#page71) (page 71). |
| from the power station to the transmission cables then step-down |  |
|  |  |  |  |  |
| transformers are used to decrease, to a much lower value, the |  | WS 1.4 |
| potential difference for domestic use. |  |  |  |  |  |
| Students should be able to explain why the National Grid system is |  |  |  |  |  |
| an efficient way to transfer energy. |  |  |  |  |  |
|  |  |  |  |  |  |

4.2.5 Static electricity (physics only)

4.2.5.1 Static charge

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| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| When certain insulating materials are rubbed against each other |  |
| they become electrically charged. Negatively charged electrons are |  |
| rubbed off one material and on to the other. The material that gains |  |
| electrons becomes negatively charged. The material that loses |  |
| electrons is left with an equal positive charge. |  |
| When two electrically charged objects are brought close together |  |
| they exert a force on each other. Two objects that carry the same |  |
| type of charge repel. Two objects that carry different types of |  |
| charge attract. Attraction and repulsion between two charged |  |
| objects are examples of non-contact force. |  |
| Students should be able to: |  |
| • describe the production of static electricity, and sparking, by |  |
| rubbing surfaces |  |
| • describe evidence that charged objects exert forces of attraction |  |
| or repulsion on one another when not in contact |  |
| • explain how the transfer of electrons between objects can |  |
| explain the phenomena of static electricity. |  |
|  |  |

4.2.5.2 Electric fields

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| A charged object creates an electric field around itself. The electric |  |
| field is strongest close to the charged object. The further away from |  |
| the charged object, the weaker the field. |  |
| A second charged object placed in the field experiences a force. |  |
| The force gets stronger as the distance between the objects |  |
| decreases. |  |
| Students should be able to: |  |
| • draw the electric field pattern for an isolated charged sphere |  |
| • explain the concept of an electric field |  |
|  |  |
| • explain how the concept of an electric field helps to explain the | WS 1.2, 1.5 |
| non-contact force between charged objects as well as other |  |
| electrostatic phenomena such as sparking. |  |
|  |  |

4.3 Particle model of matter

The particle model is widely used to predict the behaviour of solids, liquids and gases and this has many applications in everyday life. It helps us to explain a wide range of observations and engineers use these principles when designing vessels to withstand high pressures and temperatures, such as submarines and spacecraft. It also explains why it is difficult to make a good cup of tea high up a mountain!

4.3.1 Changes of state and the particle model

4.3.1.1 Density of materials



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| **Content** |  |  |  | **Key opportunities for skills** |
|  |  |  |  |  |  | **development** |
|  |  |  |  |  |  |
| The density of a material is defined by the equation: |  | MS 1a, b, c, 3b, c |
| *d ensit y* = | *mass* |  | Students should be able to |
|  |  |  |  |  |
|  |  |  | *volume* |  |  | recall and apply this |
|  |  |  |  |  |  |
| *ρ* = | *m* |  |  |  | equation to changes where |
| *V* |  |  |  |  | mass is conserved. |
| density, *ρ*, in kilograms per metre cubed, kg/m3 |  |  |
| mass, *m*, in kilograms, kg |  |  |
| volume, *V*, in metres cubed, m3 |  |  |
| The particle model can be used to explain |  |  |



* the different states of matter
* differences in density.



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|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Students should be able to recognise/draw simple diagrams to | WS 1.2 |
| model the difference between solids, liquids and gases. |  |
|  |  |
| Students should be able to explain the differences in density | WS 1.2 |
| between the different states of matter in terms of the arrangement |  |
| of atoms or molecules. |  |
|  |  |

**Required practical activity 5:** use appropriate apparatus to make and record the measurementsneeded to determine the densities of regular and irregular solid objects and liquids. Volume should be determined from the dimensions of regularly shaped objects, and by a displacement technique for irregularly shaped objects. Dimensions to be measured using appropriate apparatus such as a ruler, micrometer or Vernier callipers.

4.3.1.2 Changes of state

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| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
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| Students should be able to describe how, when substances change |  |
| state (melt, freeze, boil, evaporate, condense or sublimate), mass is |  |
| conserved. |  |
| Changes of state are physical changes which differ from chemical |  |
| changes because the material recovers its original properties if the |  |
| change is reversed. |  |
| 4.3.2 Internal energy and energy transfers |  |
|  |
| 4.3.2.1 Internal energy |  |
|  |  |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Energy is stored inside a system by the particles (atoms and |  |
| molecules) that make up the system. This is called internal energy. |  |
| Internal energy is the total kinetic energy and potential energy of all |  |
| the particles (atoms and molecules) that make up a system. |  |
| Heating changes the energy stored within the system by increasing |  |
| the energy of the particles that make up the system. This either |  |
| raises the temperature of the system or produces a change of state. |  |
|  |  |



1. Visit [aqa.org.uk/8463](http://aqa.org.uk/8463) for the most up-to-date specification, resources, support and administration

GCSE Physics 8463. GCSE exams June 2018 onwards. Version 1.0 21 April 2016



4.3.2.2 Temperature changes in a system and specific heat capacity

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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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| If the temperature of the system increases, the increase in |  |  |  |  |  |
| temperature depends on the mass of the substance heated, the |  |  |  |  |  |
| type of material and the energy input to the system. |  |  |  |  |  |
|  |  |
| The following equation applies: | MS 1a, 3b, c, d |
| *change in thermal energ y* = *mass* × *s peci f ic heat ca pacit y* | Students should be able to |
| × *tem perature change* | apply this equation, which is |
| ∆ *E* = *m c* ∆ *θ* | given on the Physics |
| equation sheet, to calculate |
| change in thermal energy, ∆*E*, in joules, J |
| the energy change involved |
| mass, *m*, in kilograms, kg | when the temperature of a |
| material changes. |
| specific heat capacity, *c*, in joules per kilogram per degree Celsius, |
| This equation and specific |
| J/kg °C |
| heat capacity are also |
| temperature change, ∆*θ*, in degrees Celsius, °C. |
| included in [Energy changes](#page19) |
|  |  |  |  |  |  |
| The specific heat capacity of a substance is the amount of energy | [in systems](#page19) (page 19). |
|  |  |  |  |  |
| required to raise the temperature of one kilogram of the substance |  |  |  |  |  |
| by one degree Celsius. |  |  |  |  |  |
|  |  |  |  |  |  |



4.3.2.3 Changes of heat and specific latent heat

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| **Content** | **Key opportunities for skills** |
|  | **development** |
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| If a change of state happens: |  |
| The energy needed for a substance to change state is called latent |  |
| heat. When a change of state occurs, the energy supplied changes |  |
| the energy stored (internal energy) but not the temperature. |  |
| The specific latent heat of a substance is the amount of energy |  |
| required to change the state of one kilogram of the substance with |  |
| no change in temperature. |  |
|  |  |

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| **Content** | **Key opportunities for skills** |
|  | **development** |
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| *energ y f or a change o f state* = *mass* × *s peci f ic latent heat* | MS 1a, 3b, c, d |
| *E* = *m L* | Students should be able to |
| energy, *E*, in joules, J | apply this equation, which is |
| given on the Physics |
|  |
| mass, *m*, in kilograms, kg | equation sheet, to calculate |
| specific latent heat, *L*, in joules per kilogram, J/kg | the energy change involved |
| in a change of state. |
|  |
| Specific latent heat of fusion – change of state from solid to liquid | MS 4a |
|  |
| Specific latent heat of vaporisation – change of state from liquid to | AT 5 |
| vapour |
| Perform an experiment to |
|  |
|  | measure the latent heat of |
|  | fusion of water. |
|  |  |
| Students should be able to interpret heating and cooling graphs that | WS 3.5 |
| include changes of state. |  |
| Students should be able to distinguish between specific heat |  |
| capacity and specific latent heat. |  |

4.4 Atomic structure

Ionising radiation is hazardous but can be very useful. Although radioactivity was discovered over a century ago, it took many nuclear physicists several decades to understand the structure of atoms, nuclear forces and stability. Early researchers suffered from their exposure to ionising radiation. Rules for radiological protection were first introduced in the 1930s and subsequently improved. Today radioactive materials are widely used in medicine, industry, agriculture and electrical power generation.

4.4.2 Atoms and nuclear radiation

4.4.2.1 Radioactive decay and nuclear radiation

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| **Content** | **Key opportunities for skills** |
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| Some atomic nuclei are unstable. The nucleus gives out radiation |  |
| as it changes to become more stable. This is a random process |  |
| called radioactive decay. |  |
| Activity is the rate at which a source of unstable nuclei decays. |  |
| Activity is measured in becquerel (Bq) |  |
| Count-rate is the number of decays recorded each second by a |  |
| detector (eg Geiger-Muller tube). |  |
| The nuclear radiation emitted may be: |  |
| • an alpha particle (α) – this consists of two neutrons and two |  |
| protons, it is the same as a helium nucleus |  |
| • a beta particle (β) – a high speed electron ejected from the |  |
| nucleus as a neutron turns into a proton |  |
| • a gamma ray (γ) – electromagnetic radiation from the nucleus |  |
| • a neutron (n). |  |
|  |  |
| Required knowledge of the properties of alpha particles, beta | WS 1.4, 1.5 |
| particles and gamma rays is limited to their penetration through |  |
| materials, their range in air and ionising power. |  |
| Students should be able to apply their knowledge to the uses of |  |
| radiation and evaluate the best sources of radiation to use in a |  |
| given situation. |  |
|  |  |

4.4.2.2 Nuclear equations



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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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| Nuclear equations are used to represent radioactive decay. |  | WS 1.2, 4.1 |
| In a nuclear equation an alpha particle may be represented by the |  | MS 1b, c, 3c |
| symbol: |  |  |



and a beta particle by the symbol:



The emission of the different types of nuclear radiation may cause a change in the mass and /or the charge of the nucleus. For example:



So alpha decay causes both the mass and charge of the nucleus to decrease.



So beta decay does not cause the mass of the nucleus to change but does cause the charge of the nucleus to increase.

Students are not required to recall these two examples.

Students should be able to use the names and symbols of common nuclei and particles to write balanced equations that show single alpha (α) and beta (β) decay. This is limited to balancing the atomic numbers and mass numbers. The identification of daughter elements from such decays is not required.

The emission of a gamma ray does not cause the mass or the charge of the nucleus to change.

4.4.2.3 Half-lives and the random nature of radioactive decay



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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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Radioactive decay is random.

The half-life of a radioactive isotope is the time it takes for the number of nuclei of the isotope in a sample to halve, or the time it takes for the count rate (or activity) from a sample containing the isotope to fall to half its initial level.



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| **Content** | **Key opportunities for skills** |
|  | **development** |
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| Students should be able to explain the concept of half-life and how | WS 1.2 |
| it is related to the random nature of radioactive decay. |  |
|  |  |
| Students should be able to determine the half-life of a radioactive | MS 4a |
| isotope from given information. |  |
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4.4.2.4 Radioactive contamination

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| **Content** | **Key opportunities for skills** |
|  | **development** |
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| Radioactive contamination is the unwanted presence of materials | WS 1.5 |
| containing radioactive atoms on other materials. The hazard from |  |
| contamination is due to the decay of the contaminating atoms. The |  |
| type of radiation emitted affects the level of hazard. |  |
| Irradiation is the process of exposing an object to nuclear radiation. |  |
| The irradiated object does not become radioactive. |  |
|  |  |
| Students should be able to compare the hazards associated with | WS 1.5 |
| contamination and irradiation. |  |
|  |  |
| Suitable precautions must be taken to protect against any hazard | WS 1.5 |
| that the radioactive source used in the process of irradiation may |  |
| present. |  |
|  |  |
| Students should understand that it is important for the findings of | WS 1.6 |
| studies into the effects of radiation on humans to be published and |  |
| shared with other scientists so that the findings can be checked by |  |
| peer review. |  |

4.4.3 Hazards and uses of radioactive emissions and of background radiation (physics only)

4.4.3.1 Background radiation

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| **Content** | **Key opportunities for skills** |
|  | **development** |
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| Background radiation is around us all of the time. It comes from: |  |
| • natural sources such as rocks and cosmic rays from space |  |
| • man-made sources such as the fallout from nuclear weapons |  |
| testing and nuclear accidents. |  |
| The level of background radiation and radiation dose may be |  |
| affected by occupation and/or location. |  |
|  |  |
| Radiation dose is measured in sieverts (Sv) | WS 4.4 |
| 1000 millisieverts (mSv) = 1 sievert (Sv) |  |
| Students will not need to recall the unit of radiation dose. |  |
|  |  |

4.4.3.2 Different half-lives of radioactive isotopes

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| **Content** | **Key opportunities for skills** |
|  | **development** |
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| Radioactive isotopes have a very wide range of half-life values. | MS 1b |
| Students should be able to explain why the hazards associated with | Students should be able to |
| radioactive material differ according to the half-life involved. | use data presented in |
|  | standard form. |
|  |  |

4.4.3.3 Uses of nuclear radiation



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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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Nuclear radiations are used in medicine for the:

* exploration of internal organs
* control or destruction of unwanted tissue.

Students should be able to:



|  |  |  |
| --- | --- | --- |
| • | describe and evaluate the uses of nuclear radiations for | WS 1.4 |
|  | exploration of internal organs, and for control or destruction of |  |
|  | unwanted tissue |  |
|  |  |  |
| • | evaluate the perceived risks of using nuclear radiations in | WS 1.5 |
|  | relation to given data and consequences. |  |