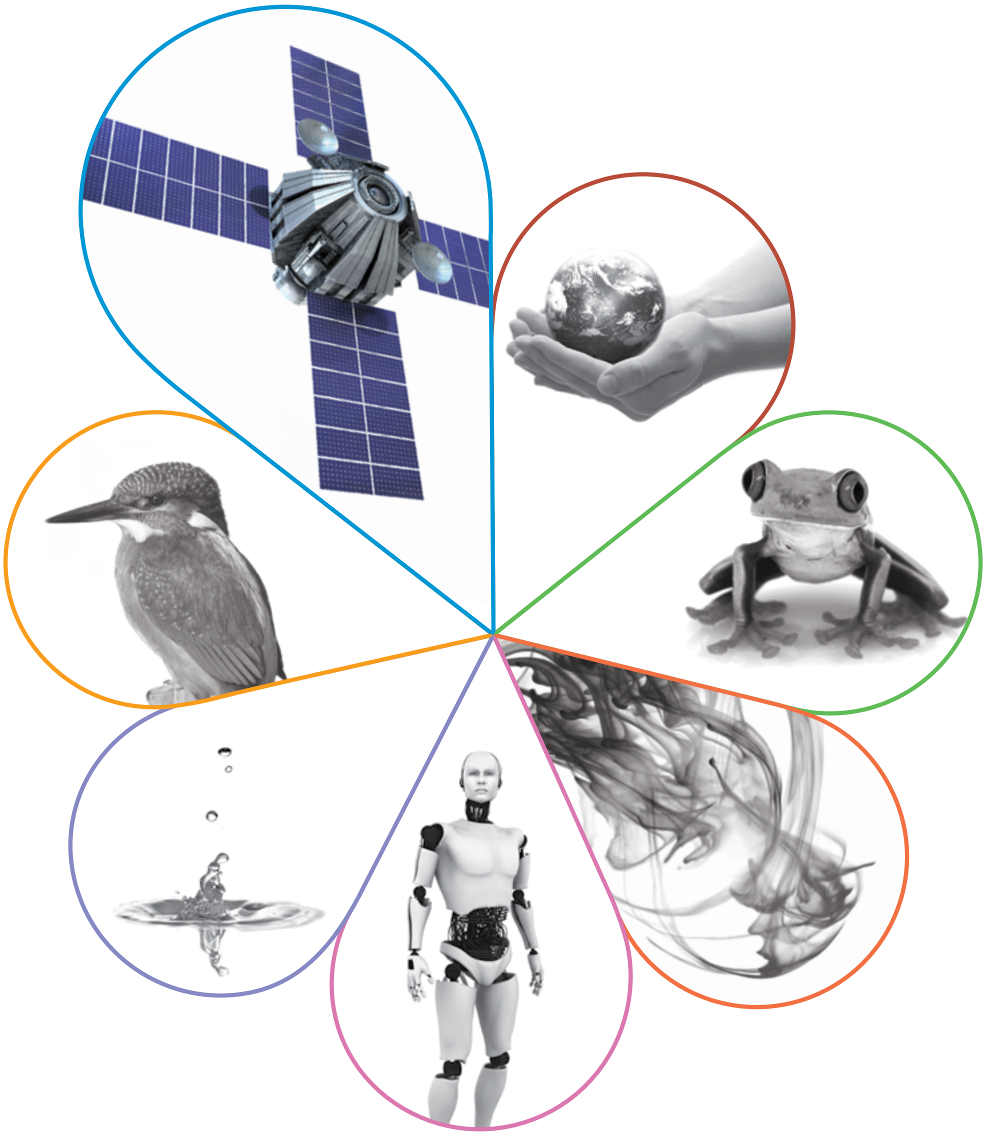
AQA Realising potential

GCSE
PHYSICS
(8463)

Specification
For teaching from September 2016 onwards
For exams in 2018 onwards

Version 1.0 21 April 2016



2 Specification at a glance

This qualification is linear. Linear means that students will sit all their exams at the end of the course.

2.1 Subject content

2.2 Assessments

Paper 1:	+	Paper 2:
What's assessed Topics 1–4: Energy; Electricity; Particle model of matter; and Atomic structure.		**What's assessed** Topics 5–8: Forces; Waves; Magnetism and electromagnetism; and Space physics. Questions in Paper 2 may draw on an understanding of energy changes and transfers due to heating, mechanical and electrical work and the concept of energy conservation from Energy and Electricity.
How it's assessed • Written exam: 1 hour 45 minutes • Foundation and Higher Tier • 100 marks • 50 % of GCSE		**How it's assessed** • Written exam: 1 hour 45 minutes • Foundation and Higher Tier • 100 marks • 50 % of GCSE
Questions Multiple choice, structured, closed short answer and open response.		**Questions** Multiple choice, structured, closed short answer and open response.

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. There are changes in the way energy is stored when a system changes. Students should be able to describe all the changes involved in the way energy is stored when a system changes, for common 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	The link between work done (energy transfer) and current flow in a circuit is covered in Energy transfers. WS 4.5
• use calculations to show on a common scale how the overall energy in a system is redistributed when the system is changed.	WS 1.2, 4.3, 4.5, 4.6 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 associated with a moving object, a stretched spring and an object raised above ground level.	WS 1.2, 4.3, 4.4, 4.6 MS 1a, c, 3b, c
The kinetic energy of a moving object can be calculated using the equation: kinetic energy = 0.5 × mass × $(\text{speed})^2$ $\left[E_k = \frac{1}{2} m v^2\right]$ 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:	MS 3b, c Students should be able to recall and apply this equation.
elastic potential energy = 0.5 × spring constant × $(\text{extension})^2$ $\left[E_e = \frac{1}{2} k e^2\right]$ (assuming the limit of proportionality has not been exceeded) elastic potential energy, E_e, in joules, J 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:	MS 3b, c Students should be able to apply this equation which is given on the *Physics equation sheet*.
g.p.e. = mass × gravitational field strength × height $\left[E_p = m\,g\,h\right]$ gravitational potential energy, E_p, in joules, J mass, *m*, in kilograms, kg gravitational field strength, *g*, in newtons per kilogram, N/kg (In any calculation the value of the gravitational field strength (*g*) will be given.) height, *h*, in metres, m	MS 3b, c Students should be able to recall and apply this equation. AT 1 Investigate the transfer of energy from a gravitational potential energy store to a 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 energy = mass × specific heat capacity × temperature change $[\Delta E = m\,c\,\Delta\theta]$ change in thermal energy, ΔE, in joules, J mass, m, in kilograms, kg specific heat capacity, c, in joules per kilogram per degree Celsius, J/kg °C temperature change, $\Delta\theta$, in degrees Celsius, °C The specific heat capacity of a substance is the amount of energy required to raise the temperature of one kilogram of the substance by one degree Celsius.	MS 3b, c Students should be able to apply this equation which is given on the *Physics equation sheet*. This equation and specific heat capacity are also included in Temperature changes in a system and specific heat capacity.

Required practical activity 1: investigation to determine the specific heat capacity of one or more materials. The investigation will involve linking the decrease of one energy store (or work done) to the increase in temperature and subsequent increase in thermal energy stored.

AT skills covered by this practical activity: AT 1 and 5.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development.

4.1.1.4 Power

Content	Key opportunities for skills development
Power is defined as the rate at which energy is transferred or the rate at which work is done. power $= \frac{\text{energy transferred}}{\text{time}}$ $\left[P = \frac{E}{t}\right]$ power $= \frac{\text{work done}}{\text{time}}$ $\left[P = \frac{W}{t}\right]$ 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.	MS 3b, c Students should be able to recall and apply both equations.

4.1.2 Conservation and dissipation of energy

4.1.2.1 Energy transfers in a system

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 energy transfers, for example through lubrication and the use of thermal insulation. The higher the thermal conductivity of a material the higher the rate of energy transfer by conduction across the material. 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.	WS 1.4 AT 1, 5 Investigate thermal conductivity using rods of different materials.

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

AT skills covered by this practical activity: AT 1 and 5.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development.

4.1.2.2 Efficiency

Content	Key opportunities for skills development
The energy efficiency 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: $\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$	MS 3b, c Students should be able to recall and apply both equations. MS 1a, c, 3b, c Students may be required to calculate or use efficiency values as a decimal or as a percentage.
(HT only) Students should be able to describe ways to increase the efficiency of an intended energy transfer.	(HT only) WS 1.4

4.1.3 National and global energy resources

Content	Key opportunities for skills development
The main energy resources available for use on Earth include: fossil fuels (coal, oil and gas), nuclear fuel, biofuel, 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	WS 4.4
• describe the environmental impact arising from the use of different energy resources	WS 1.3, 1.4
• explain patterns and trends in the use of energy resources. Descriptions of how energy resources are used to generate electricity are **not** required.	WS 3.5
Students should be able to: • consider the environmental issues that may arise from the use of 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.	WS 1.3, 1.4, 4.4 MS 1c, 2c, 4a

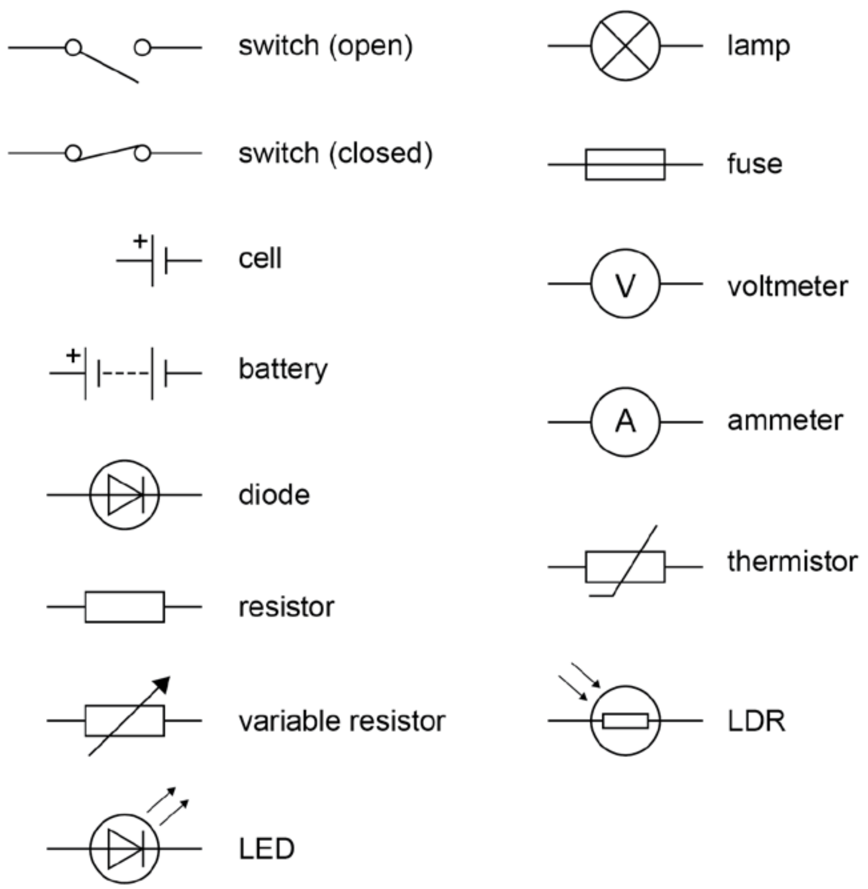
4.2 Electricity

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

Content	Key opportunities for skills development
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

Content	Key opportunities for skills development
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 $[\ Q = I\,t\ ]$ 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.	MS 3b, c Students should be able to recall and apply this equation.

4.2.1.3 Current, resistance and potential difference

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 the equation: potential difference = current × resistance $[\ V = I\,R\ ]$ potential difference, V, in volts, V current, I, in amperes, A (amp is acceptable for ampere) resistance, R, in ohms, Ω	MS 3b, c Students should be able to recall and apply this equation.

Required practical activity 3: use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits. This should include:

- the length of a wire at constant temperature
- combinations of resistors in series and parallel.

AT skills covered by this practical activity: AT 1, 6 and 7.

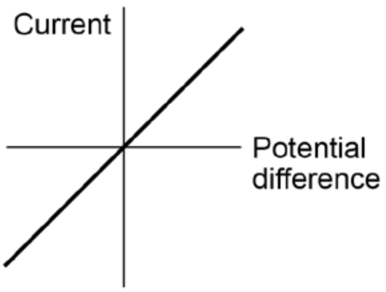
This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development.

4.2.1.4 Resistors

Content	Key opportunities for skills development

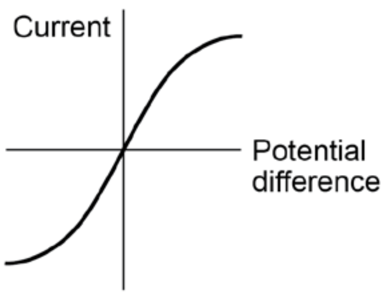
Students should be able to explain that, for some resistors, the value of *R* remains constant but that in others it can change as the current changes.

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.

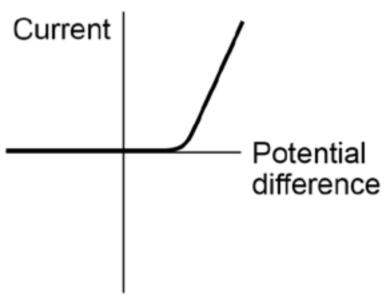


The resistance of components such as lamps, diodes, thermistors and LDRs is not constant; it changes with the current through the component.

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.



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.

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

Required practical activity 4: use circuit diagrams to construct appropriate circuits to investigate the I–V characteristics of a variety of circuit elements, including a filament lamp, a diode and a resistor at constant temperature.

AT skills covered by this practical activity: AT 6 and 7.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development.

4.2.2 Series and parallel circuits

Content	Key opportunities for skills development
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.	
$R_{\text{total}} = R_1 + R_2$	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 circuits that include a variety of common circuit components	AT 7
• 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 and testing purposes	WS 1.4
• calculate the currents, potential differences and resistances in dc series circuits	MS 1c, 3b, c, d
• 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.	

4.2.3 Domestic uses and safety

4.2.3.1 Direct and alternating potential difference

Content	Key opportunities for skills development
Mains electricity is an ac supply. In the United Kingdom the domestic electricity supply has a frequency of 50 Hz and is about 230 V. Students should be able to explain the difference between direct and alternating potential difference.	

4.2.3.2 Mains electricity

Content	Key opportunities for skills development
Most electrical appliances are connected to the mains using three-core cable. The insulation covering each wire is colour coded for easy identification: live wire – brown neutral wire – blue earth wire – green and yellow stripes. The live wire carries the alternating potential difference from the supply. The neutral wire completes the circuit. The earth wire is a safety wire to stop the appliance becoming live. The potential difference between the live wire and earth (0 V) is about 230 V. The neutral wire is at, or close to, earth potential (0 V). The earth wire is at 0 V, it only carries a current if there is a fault. Students should be able to explain: • that a live wire may be dangerous even when a switch in the mains circuit is open • the dangers of providing any connection between the live wire and earth.	WS 1.5

4.2.4 Energy transfers

4.2.4.1 Power

Content	Key opportunities for skills development
Students should be able to explain how the power transfer in any circuit device is related to the potential difference across it and the current through it, and to the energy changes over time: power = potential difference × current $[P = V I]$ power = $(\text{current})^2$ × 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	MS 3b, c WS 4.5 Students should be able to recall and apply both equations.

4.2.4.2 Energy transfers in everyday appliances

Content	Key opportunities for skills development
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:	
energy transferred = power × time [$E = P\,t$] energy transferred = charge flow × potential difference [$E = Q\,V$] 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	MS 3b, c Students should be able to recall and apply both equations. WS 1.4
Students should be able to explain how the power of a circuit device 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.	WS 1.2

4.2.4.3 The National Grid

Content	Key opportunities for skills development
The National Grid is a system of cables and transformers linking power stations to consumers.	
Electrical power is transferred from power stations to consumers using the National Grid.	The construction and operation of transformers is covered Transformers (HT only).
Step-up transformers are used to increase the potential difference from the power station to the transmission cables then step-down transformers are used to decrease, to a much lower value, the potential difference for domestic use.	WS 1.4
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

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 non-contact force between charged objects as well as other electrostatic phenomena such as sparking.	WS 1.2, 1.5

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

Content	Key opportunities for skills development
The density of a material is defined by the equation: density = $\frac{\text{mass}}{\text{volume}}$ [$\rho = \frac{m}{V}$] density, ρ, in kilograms per metre cubed, kg/m^3 mass, m, in kilograms, kg volume, V, in metres cubed, m^3 The particle model can be used to explain • the different states of matter • differences in density.	MS 1a, b, c, 3b, c Students should be able to recall and apply this equation to changes where mass is conserved.
Students should be able to recognise/draw simple diagrams to model the difference between solids, liquids and gases.	WS 1.2
Students should be able to explain the differences in density between the different states of matter in terms of the arrangement of atoms or molecules.	WS 1.2

Required practical activity 5: use appropriate apparatus to make and record the measurements needed 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.

AT skills covered by this practical activity: AT 1.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development.

4.3.1.2 Changes of state

Content	Key opportunities for skills development
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.	

4.3.2.2 Temperature changes in a system and specific heat capacity

Content	Key opportunities for skills development
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: change in thermal energy = mass × specific heat capacity × temperature change $[\Delta E = m\, c\, \Delta\theta]$ change in thermal energy, ΔE, in joules, J mass, m, in kilograms, kg specific heat capacity, c, in joules per kilogram per degree Celsius, J/kg °C temperature change, $\Delta\theta$, in degrees Celsius, °C. The specific heat capacity of a substance is the amount of energy required to raise the temperature of one kilogram of the substance by one degree Celsius.	MS 1a, 3b, c, d Students should be able to apply this equation, which is given on the *Physics equation sheet*, to calculate the energy change involved when the temperature of a material changes. This equation and specific heat capacity are also included in Energy changes in systems.

4.3.2.3 Changes of heat and specific latent heat

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

4.3.3 Particle model and pressure

4.3.3.1 Particle motion in gases

Content	Key opportunities for skills development
The molecules of a gas are in constant random motion. The temperature of the gas is related to the average kinetic energy of the molecules. Changing the temperature of a gas, held at constant volume, changes the pressure exerted by the gas.	WS 1.2
Students should be able to: • explain how the motion of the molecules in a gas is related to both its temperature and its pressure • explain qualitatively the relation between the temperature of a gas and its pressure at constant volume.	WS 1.2

4.3.3.2 Pressure in gases (physics only)

Content	Key opportunities for skills development
A gas can be compressed or expanded by pressure changes. The pressure produces a net force at right angles to the wall of the gas container (or any surface).	WS 1.2
Students should be able to use the particle model to explain how increasing the volume in which a gas is contained, at constant temperature, can lead to a decrease in pressure. For a fixed mass of gas held at a constant temperature: pressure × volume = constant [$p\,V = constant$] pressure, *p*, in pascals, Pa volume, *V*, in metres cubed, m^3 Students should be able to calculate the change in the pressure of a gas or the volume of a gas (a fixed mass held at constant temperature) when either the pressure or volume is increased or decreased.	MS 3b, c Students should be able to apply this equation which is given on the *Physics equation sheet*.

4.3.3.3 Increasing the pressure of a gas (physics only) (HT only)

Content	Key opportunities for skills development
Work is the transfer of energy by a force. Doing work on a gas increases the internal energy of the gas and can cause an increase in the temperature of the gas.	
Students should be able to explain how, in a given situation eg a bicycle pump, doing work on an enclosed gas leads to an increase in the temperature of the gas.	WS 1.2

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.

4.4.1 Atoms and isotopes

4.4.1.1 The structure of an atom

Content	Key opportunities for skills development
Atoms are very small, having a radius of about 1×10^{-10} metres. The basic structure of an atom is a positively charged nucleus composed of both protons and neutrons surrounded by negatively charged electrons. The radius of a nucleus is less than 1/10 000 of the radius of an atom. Most of the mass of an atom is concentrated in the nucleus. The electrons are arranged at different distances from the nucleus (different energy levels). The electron arrangements may change with the absorption of electromagnetic radiation (move further from the nucleus; a higher energy level) or by the emission of electromagnetic radiation (move closer to the nucleus; a lower energy level).	MS 1b WS 4.4 Students should be able to recognise expressions given in standard form.

4.4.1.2 Mass number, atomic number and isotopes

Content	Key opportunities for skills development
In an atom the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge. All atoms of a particular element have the same number of protons. The number of protons in an atom of an element is called its atomic number. The total number of protons and neutrons in an atom is called its mass number. Atoms can be represented as shown in this example: (Mass number) 23 (Atomic number) 11 $^{23}_{11}\mathrm{Na}$ Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes of that element. Atoms turn into positive ions if they lose one or more outer electron(s).	
Students should be able to relate differences between isotopes to differences in conventional representations of their identities, charges and masses.	WS 4.1

4.4.1.3 The development of the model of the atom (common content with chemistry)

Content	Key opportunities for skills development
New experimental evidence may lead to a scientific model being changed or replaced. Before the discovery of the electron, atoms were thought to be tiny spheres that could not be divided. The discovery of the electron led to the plum pudding model of the atom. The plum pudding model suggested that the atom is a ball of positive charge with negative electrons embedded in it.	WS 1.1, 1.6 This historical context provides an opportunity for students to show an understanding of why and describe how scientific methods and theories develop over time.
The results from the alpha particle scattering experiment led to the conclusion that the mass of an atom was concentrated at the centre (nucleus) and that the nucleus was charged. This nuclear model replaced the plum pudding model. Niels Bohr adapted the nuclear model by suggesting that electrons orbit the nucleus at specific distances. The theoretical calculations of Bohr agreed with experimental observations. Later experiments led to the idea that the positive charge of any nucleus could be subdivided into a whole number of smaller particles, each particle having the same amount of positive charge. The name proton was given to these particles. The experimental work of James Chadwick provided the evidence to show the existence of neutrons within the nucleus. This was about 20 years after the nucleus became an accepted scientific idea. Students should be able to describe:	WS 1.2
• why the new evidence from the scattering experiment led to a change in the atomic model	WS 1.1
• the difference between the plum pudding model of the atom and the nuclear model of the atom.	WS 1.2
Details of experimental work supporting the Bohr model are not required. Details of Chadwick's experimental work are not required.	

4.4.2 Atoms and nuclear radiation

4.4.2.1 Radioactive decay and nuclear radiation

Content	Key opportunities for skills development
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 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.	WS 1.4, 1.5

4.4.2.2 Nuclear equations

Content	Key opportunities for skills development
Nuclear equations are used to represent radioactive decay. In a nuclear equation an alpha particle may be represented by the symbol: $^{4}_{2}\mathrm{He}$ and a beta particle by the symbol: $^{0}_{-1}\mathrm{e}$ 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: $^{219}_{86}\text{radon} \longrightarrow {}^{215}_{84}\text{polonium} + {}^{4}_{2}\mathrm{He}$ So alpha decay causes both the mass and charge of the nucleus to decrease. $^{14}_{6}\text{carbon} \longrightarrow {}^{14}_{7}\text{nitrogen} + {}^{0}_{-1}\mathrm{e}$ 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.	WS 1.2, 4.1 MS 1b, c, 3c

4.4.2.3 Half-lives and the random nature of radioactive decay

Content	Key opportunities for skills development
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.	
Students should be able to explain the concept of half-life and how it is related to the random nature of radioactive decay.	WS 1.2
Students should be able to determine the half-life of a radioactive isotope from given information.	MS 4a
(HT only) Students should be able to calculate the net decline, expressed as a ratio, in a radioactive emission after a given number of half-lives.	(HT only) MS 1c, 3d

4.4.2.4 Radioactive contamination

Content	Key opportunities for skills development
Radioactive contamination is the unwanted presence of materials 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.	WS 1.5
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 contamination and irradiation.	WS 1.5
Suitable precautions must be taken to protect against any hazard that the radioactive source used in the process of irradiation may present.	WS 1.5
Students should understand that it is important for the findings of 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.	WS 1.6

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

4.4.3.1 Background radiation

Content	Key opportunities for skills development
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

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

4.4.3.3 Uses of nuclear radiation

Content	Key opportunities for skills development
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 exploration of internal organs, and for control or destruction of unwanted tissue	WS 1.4
• evaluate the perceived risks of using nuclear radiations in relation to given data and consequences.	WS 1.5

4.4.4 Nuclear fission and fusion (physics only)

4.4.4.1 Nuclear fission

Content	Key opportunities for skills development
Nuclear fission is the splitting of a large and unstable nucleus (eg uranium or plutonium). Spontaneous fission is rare. Usually, for fission to occur the unstable nucleus must first absorb a neutron. The nucleus undergoing fission splits into two smaller nuclei, roughly equal in size, and emits two or three neutrons plus gamma rays. Energy is released by the fission reaction. All of the fission products have kinetic energy. The neutrons may go on to start a chain reaction. The chain reaction is controlled in a nuclear reactor to control the energy released. The explosion caused by a nuclear weapon is caused by an uncontrolled chain reaction. Students should be able to draw/interpret diagrams representing nuclear fission and how a chain reaction may occur.	

4.4.4.2 Nuclear fusion

Content	Key opportunities for skills development
Nuclear fusion is the joining of two light nuclei to form a heavier nucleus. In this process some of the mass may be converted into the energy of radiation.	

4.9 Key ideas

The complex and diverse phenomena of the natural and man-made world can be described in terms of a small number of key ideas in physics.

These key ideas are of universal application, and we have embedded them throughout the subject content. They underpin many aspects of the science assessment and will therefore be assessed across all papers.

Key ideas in physics include:

- the use of models, as in the particle model of matter or the wave models of light and of sound
- the concept of cause and effect in explaining such links as those between force and acceleration, or between changes in atomic nuclei and radioactive emissions
- the phenomena of 'action at a distance' and the related concept of the field as the key to analysing electrical, magnetic and gravitational effects
- that differences, for example between pressures or temperatures or electrical potentials, are the drivers of change
- that proportionality, for example between weight and mass of an object or between force and extension in a spring, is an important aspect of many models in science
- that physical laws and models are expressed in mathematical form.

8 Practical assessment

Practical work is at the heart of physics, so we have placed it at the heart of this specification.

There are three interconnected, but separate reasons for doing practical work in schools. They are:

1. To support and consolidate scientific concepts (knowledge and understanding).

   This is done by applying and developing what is known and understood of abstract ideas and models. Through practical work we are able to make sense of new information and observations, and provide insights into the development of scientific thinking.
2. To develop investigative skills. These transferable skills include:
   - devising and investigating testable questions
   - identifying and controlling variables
   - analysing, interpreting and evaluating data.
3. To build and master practical skills such as:
   - using specialist equipment to take measurements
   - handling and manipulating equipment with confidence and fluency
   - recognising hazards and planning how to minimise risk.

By focusing on the reasons for carrying out a particular practical, teachers will help their students understand the subject better, to develop the skills of a scientist and to master the manipulative skills required for further study or jobs in STEM subjects.

Questions in the written exams will draw on the knowledge and understanding students have gained by carrying out the practical activities listed below. These questions will count for at least 15 % of the overall marks for the qualification. Many of our questions will also focus on investigative skills and how well students can apply what they know to practical situations often in novel contexts.

The practical handbook will help teachers plan purposeful practical work that develops both practical and investigative skills and encourages the thinking behind the doing so that they can reach their potential.

Teachers are encouraged to further develop students' abilities by providing other opportunities for practical work throughout the course. Opportunities are signposted in the right hand column of the content section of this specification for further skills development.

Our physics scheme of work will provide ideas and suggestions for good practical activities that are manageable with large classes.

8.1 Use of apparatus and techniques

All students are expected to have carried out the required practical activities in Required practical activities. These develop skills in the use of the following apparatus and techniques.

The following list includes opportunities for choice and use of appropriate laboratory apparatus for a variety of experimental problem-solving and/or enquiry-based activities.

Safety is an overriding requirement for all practical work. Schools and colleges are responsible for ensuring that appropriate safety procedures are followed whenever their students undertake practical work, and should undertake full risk assessments.

Use and production of appropriate scientific diagrams to set up and record apparatus and procedures used in practical work is common to all science subjects and should be included wherever appropriate.

AT 1–7 are common with combined science. AT 8 is physics only.

	Apparatus and techniques
AT 1	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects (links to A-level AT a and b).
AT 2	Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs (links to A-level AT a).
AT 3	Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration) (links to A-level AT a, b and d).
AT 4	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/wavelength. Making observations of the effects of the interaction of electromagnetic waves with matter (links to A-level AT i and j).
AT 5	Safe use of appropriate apparatus in a range of contexts to measure energy changes/ transfers and associated values such as work done (links to A-level AT a, b).
AT6	Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements (links to A-level AT f).
AT 7	Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements (links to A-level AT g).
AT 8 (physics only)	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter (links to A-level AT h, j).

8.2 Required practical activities

The following practical activities must be carried out by all students taking GCSE Physics.

Following any revision by the Secretary of State of the apparatus or techniques specified, we will review and revise the required practical activities as appropriate.

Schools and colleges will be informed of any changes in a timely manner and the amended specification will be published, highlighting the changes accordingly.

Teachers are encouraged to vary their approach to these practical activities. Some are more suitable for highly structured approaches that develop key techniques while others allow opportunities for students to develop investigative approaches.

This list is not designed to limit the practical activities carried out by students. A rich practical experience will include more than the ten required practical activities. The explicit teaching of practical skills will build students' competence. Many teachers will also use practical approaches to introduce content knowledge in the course of their normal teaching.

Schools and colleges are required to provide a practical science statement to AQA, that is a true and accurate written statement, which confirms that it has taken reasonable steps to secure that each student has:

- completed the required practical activities detailed in this specification
- made a contemporaneous record of such work undertaken during the activities and the knowledge, skills and understanding derived from those activities.

We will provide a form for the head of centre to sign. You must submit the form to us by the date published at aqa.org.uk/science. We will contact schools and colleges directly with the deadline date and timely reminders if the form is not received. Failure to send this form counts as malpractice/ maladministration, and may result in formal action or warning for the school or college.

Practicals 1, 3–8 and 10 are common with GCSE Combined Science: Trilogy and GCSE Combined Science: Synergy. Practicals 2 and 9 are GCSE Physics only.

8.2.1 Required practical activity 1

An investigation to determine the specific heat capacity of one or more materials. The investigation will involve linking the decrease of one energy store (or work done) to the increase in temperature and subsequent increase in thermal energy stored.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 1 – use appropriate apparatus to make and record measurements of mass, time and temperature accurately.

AT 5 – use, in a safe manner, appropriate apparatus to measure energy changes/transfers and associated values such as work done.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories and explanations to develop hypotheses.

WS 2.2 – plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

WS 2.6 – make and record observations and measurements using a range of apparatus and methods.

WS 2.7 – evaluate methods and suggest possible improvements and further investigations.

WS 3.1 – present observations and other data using appropriate methods.

WS 3.2 – translate data from one form to another.

WS 3.3 – carry out and represent mathematical and statistical analysis.

WS 3.4 – represent the distribution of results and make estimations of uncertainty.

WS 3.5 – interpret observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions.

WS 3.6 – present reasoned explanations including relating data to hypotheses.

WS 3.7 – be objective, evaluate data in terms of accuracy, precision, repeatability and reproducibility and identify potential sources of random and systematic error.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.2 – recognise the importance of scientific quantities and understand how they are determined.

WS 4.3 – use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.

WS 4.6 – use an appropriate number of significant figures in calculation.

MS 2a – use an appropriate number of significant figures.

MS 2b – find arithmetic means.

MS 3b – change the subject of an equation.

MS 3c – substitute numerical values into algebraic equations using appropriate units for physical quantities.

8.2.2 Required practical activity 2 (physics only)

Investigate the effectiveness of different materials as thermal insulators and the factors that may affect the thermal insulation properties of a material.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 1 – use appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature.

AT 5 – use, in a safe manner, appropriate apparatus to measure energy changes/transfers.

8.2.3 Required practical activity 3

Use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits. This should include:

- the length of a wire at constant temperature
- combinations of resistors in series and parallel.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 1 – use appropriate apparatus to measure and record length accurately.

AT 6 – use appropriate apparatus to measure current, potential difference and resistance.

AT 7 – use circuit diagrams to construct and check series and parallel circuits.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories and explanations to develop hypotheses.

WS 2.2 – plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

WS 2.5 – recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative.

WS 2.6 – make and record observations and measurements using a range of apparatus and methods.

WS 2.7 – evaluate methods and suggest possible improvements and further investigations.

WS 3.1 – present observations and other data using appropriate methods.

WS 3.2 – translate data from one form to another.

WS 3.3 – carry out and represent mathematical and statistical analysis.

WS 3.4 – represent the distribution of results and make estimations of uncertainty.

WS 3.5 – interpret observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions.

WS 3.6 – present reasoned explanations including relating data to hypotheses.

WS 3.7 – be objective, evaluate data in terms of accuracy, precision, repeatability and reproducibility and identify potential sources of random and systematic error.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.2 – recognise the importance of scientific quantities and understand how they are determined.

WS 4.3 – use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.

WS 4.6 – use an appropriate number of significant figures in calculation.

MS 2a – use an appropriate number of significant figures.

MS 2b – find arithmetic means.

MS 4b – understand that $y = mx + c$ represents a linear relationship.

MS 4c – plot two variables from experimental or other data.

MS 4d – determine the slope and intercept of a linear graph.

8.2.4 Required practical activity 4

Use circuit diagrams to construct appropriate circuits to investigate the I–V characteristics of a variety of circuit elements including a filament lamp, a diode and a resistor at constant temperature.

8.2.4.1 Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 6 – use appropriate apparatus to measure current and potential difference and to explore the characteristics of a variety of circuit elements.

AT 7 – use circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories and explanations to develop hypotheses.

WS 2.2 – plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

WS 2.5 – recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative.

WS 2.6 – make and record observations and measurements using a range of apparatus and methods.

WS 2.7 – evaluate methods and suggest possible improvements and further investigations.

WS 3.1 – present observations and other data using appropriate methods.

WS 3.2 – translate data from one form to another.

WS 3.3 – carry out and represent mathematical and statistical analysis.

WS 3.4 – represent the distribution of results and make estimations of uncertainty.

WS 3.5 – interpret observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions.

WS 3.6 – present reasoned explanations including relating data to hypotheses.

WS 3.7 – be objective, evaluate data in terms of accuracy, precision, repeatability and reproducibility and identify potential sources of random and systematic error.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.2 – recognise the importance of scientific quantities and understand how they are determined.

WS 4.3 – use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.

WS 4.6 – use an appropriate number of significant figures in calculation.

MS 2a – use an appropriate number of significant figures.

MS 2g – use a scatter diagram to identify a correlation between two variables.

MS 4b – understand that $y = mx + c$ represents a linear relationship.

MS 4c – plot two variables from experimental or other data.

8.2.5 Required practical activity 5

Use appropriate apparatus to make and record the measurements needed 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.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 1 – use appropriate apparatus to make and record measurements of length, area, mass and volume accurately. Use such measurements to determine the density of solid objects and liquids.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 1.2 – use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts.

WS 2.1 – use scientific theories and explanations to develop hypotheses.

WS 2.2 – plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

WS 2.6 – make and record observations and measurements using a range of apparatus and methods.

WS 2.7 – evaluate methods and suggest possible improvements and further investigations.

WS 3.1 – present observations and other data using appropriate methods.

WS 3.5 – interpret observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.2 – recognise the importance of scientific quantities and understand how they are determined.

WS 4.3 – use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.

WS 4.6 – use an appropriate number of significant figures in calculation.

MS 2a – use an appropriate number of significant figures.

MS 2b – find arithmetic means.

MS 5c – calculate areas of triangles and rectangles, surface areas and volumes of cubes.

8.2.6 Required practical activity 6

Investigate the relationship between force and extension for a spring.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 1 – use appropriate apparatus to make and record length accurately.

AT 2 – use appropriate apparatus to measure and observe the effect of force on the extension of springs and collect the data required to plot a force-extension graph.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories and explanations to develop hypotheses.

WS 2.2 – plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

WS 2.6 – make and record observations and measurements using a range of apparatus and methods.

WS 3.1 – present observations and other data using appropriate methods.

WS 3.2 – translate data from one form to another.

WS 3.3 – carry out and represent mathematical and statistical analysis.

WS 3.5 – interpret observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.6 – use an appropriate number of significant figures in calculation.

MS 2a – use an appropriate number of significant figures.

MS 2b – find arithmetic means.

MS 4a – translate information between graphical and numeric form.

MS 4b – understand that $y = mx + c$ represents a linear relationship.

MS 4c – plot two variables from experimental or other data.

8.2.7 Required practical activity 7

Investigate the effect of varying the force on the acceleration of an object of constant mass and the effect of varying the mass of an object on the acceleration produced by a constant force.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 1 – use appropriate apparatus to make and record measurements of length, mass and time accurately.

AT 2 – use appropriate apparatus to measure and observe the effect of force.

AT 3 – use appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration).

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories and explanations to develop hypotheses.

WS 2.2 – plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

WS 2.6 – make and record observations and measurements using a range of apparatus and methods.

WS 2.7 – evaluate methods and suggest possible improvements and further investigations.

WS 3.1 – present observations and other data using appropriate methods.

WS 3.2 – translate data from one form to another.

WS 3.3 – carry out and represent mathematical and statistical analysis.

WS 3.4 – represent the distribution of results and make estimations of uncertainty.

WS 3.5 – interpret observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions.

WS 3.6 – present reasoned explanations including relating data to hypotheses.

WS 3.7 – be objective, evaluate data in terms of accuracy, precision, repeatability and reproducibility and identify potential sources of random and systematic error.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.2 – recognise the importance of scientific quantities and understand how they are determined.

WS 4.3 – use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.

WS 4.6 – use an appropriate number of significant figures in calculation.

MS 2a – use an appropriate number of significant figures.

MS 2b – find arithmetic means.

MS 2g – use a scatter diagram to identify a correlation between two variables.

MS 4a – translate information between graphical and numeric form.

MS 4b – understand that $y = mx + c$ represents a linear relationship.

MS 4c – plot two variables from experimental or other data.

8.2.8 Required practical activity 8

Make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in a ripple tank and waves in a solid and take appropriate measurements.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 4 – make observations of waves in fluids and solids to identify the suitability of apparatus to measure speed, frequency and wavelength.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.

WS 2.6 – make and record observations and measurements using a range of apparatus and methods.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.2 – recognise the importance of scientific quantities and understand how they are determined.

WS 4.3 – use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.

8.2.9 Required practical activity 9 (physics only)

Investigate the reflection of light by different types of surface and the refraction of light by different substances.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 4 – make observations of the effects of the interaction of electromagnetic waves (light) with matter.

AT 8 – make observations of waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories and explanations to develop hypotheses.

WS 2.2 – plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

WS 2.7 – evaluate methods and suggest possible improvements and further investigations.

WS 3.1 – present observations and other data using appropriate methods.

WS 3.4 – represent the distribution of results and make estimations of uncertainty.

WS 3.6 – present reasoned explanations including relating data to hypotheses.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.2 – recognise the importance of scientific quantities and understand how they are determined.

WS 4.3 – use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.

MS 2g – use a scatter diagram to identify a correlation between two variables.

MS 4c – plot two variables from experimental or other data.

MS 5a – use angular measures in degrees.

MS 5b – visualise and represent 2D and 3D forms including two dimensional representations of 3D objects.

8.2.10 Required practical activity 10

Investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.

Apparatus and techniques

In doing this practical students should cover these parts of the apparatus and techniques requirements.

AT 1 – use appropriate apparatus to make and record temperature accurately.

AT 4 – make observations of the effects of the interaction of electromagnetic waves with matter.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 3.8 – communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.

WS 4.2 – recognise the importance of scientific quantities and understand how they are determined.

WS 4.3 – use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.

WS 4.6 – use an appropriate number of significant figures in calculation.

MS 2c – construct and interpret frequency tables and diagrams, bar charts and histograms.

9 Appendix A: Physics equations

In solving quantitative problems, students should be able to recall and apply the following equations, using standard SI units.

Equations required for Higher Tier papers only are indicated by HT in the left hand column.

Equation number	Word equation	Symbol equation
1	weight = mass × gravitational field strength (g)	$W = m\ g$
2	work done = force × distance (along the line of action of the force)	$W = F\ s$
3	force applied to a spring = spring constant × extension	$F = k\ e$
4	moment of a force = force × distance (normal to direction of force)	$M = F\ d$
5	pressure = $\frac{\text{force normal to a surface}}{\text{area of that surface}}$	$p = \frac{F}{A}$
6	distance travelled = speed × time	$s = v\ t$
7	acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$	$a = \frac{\Delta v}{t}$
8	resultant force = mass × acceleration	$F = m\ a$
9 HT	momentum = mass × velocity	$p = m\ v$
10	kinetic energy = 0.5 × mass × (speed)^2	$E_k = \frac{1}{2} m\ v^2$
11	gravitational potential energy = mass × gravitational field strength (g) × height	$E_p = m\ g\ h$
12	power = $\frac{\text{energy transferred}}{\text{time}}$	$P = \frac{E}{t}$
13	power = $\frac{\text{work done}}{\text{time}}$	$P = \frac{W}{t}$
14	efficiency = $\frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$	
15	efficiency = $\frac{\text{useful power output}}{\text{total power input}}$	
16	wave speed = frequency × wavelength	$v = f\ \lambda$
17	charge flow = current × time	$Q = I\ t$
18	potential difference = current × resistance	$V = I\ R$
19	power = potential difference × current	$P = V\ I$
20	power = (current)^2 × resistance	$P = I^2\ R$
21	energy transferred = power × time	$E = P\ t$
22	energy transferred = charge flow × potential difference	$E = Q\ V$
23	density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$

Students should be able to select and apply the following equations from the *Physics equation sheet*.

Equations required for Higher Tier papers only are indicated by HT in the left hand column.

Equation number	Word equation	Symbol equation
1 HT	pressure due to a column of liquid = height of column × density of liquid × gravitational field strength (g)	$p = h \rho g$
2	(final velocity)^2 – (initial velocity)^2 = 2 × acceleration × distance	$v^2 - u^2 = 2 a s$
3 HT	force = $\frac{\text{change in momentum}}{\text{time taken}}$	$F = \frac{m \Delta v}{\Delta t}$
4	elastic potential energy = 0.5 × spring constant × (extension)^2	$E_e = \frac{1}{2} k e^2$
5	change in thermal energy = mass × specific heat capacity × temperature change	$\Delta E = m c \Delta \theta$
6	period = $\frac{1}{\text{frequency}}$	
7	magnification = $\frac{\text{image height}}{\text{object height}}$	
8 HT	force on a conductor (at right angles to a magnetic field) carrying a current = magnetic flux density × current × length	$F = B I l$
9	thermal energy for a change of state = mass × specific latent heat	$E = m L$
10 HT	$\frac{\text{potential difference across primary coil}}{\text{potential difference across secondary coil}} = \frac{\text{number of turns in primary coil}}{\text{number of turns in secondary coil}}$	$\frac{V_p}{V_s} = \frac{n_p}{n_s}$
11 HT	potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil	$V_s I_s = V_p I_p$
12	For gases: pressure × volume = constant	$p V = constant$