Dynamics Mandatory knowledge	Suggested activities
Vectors and scalars	
Definition of vector and scalar quantities. Identification of force, speed, velocity, distance, displacement, acceleration, mass, time and energy as vector or scalar quantities. Calculation of the resultant of two vector quantities in one dimension or at right angles. Determination of displacement and/or distance using scale diagram or calculation. Determination of velocity and/or speed using scale diagram or calculation. Use of appropriate relationships to solve problems involving velocity, speed, displacement, distance and time. $s = vt$ $s = \bar{v}t$ $d = \bar{v}t$ Description of experiments to measure average and instantaneous speed.	Set up an orienteering course in school grounds — calculate displacement and average velocity, distance and average speed. Use route mapper apps to find distance, speed and the magnitudes of displacement and velocity. Discuss and compare the difference between vector and scalar quantities. Calculate average speed/velocity using distance/displacement data and time data from a number of contexts, for example athletics, cars, flight, space and data from apps, light gates, etc. Analyse motion vectors using scale diagrams and/or trigonometry.

Dynamics Mandatory knowledge	Suggested activities
Velocity–time graphs	
Drawing or sketching of velocity–time or speed–time graphs from data. Interpretation of a velocity–time graph to describe the motion of an object. Determination of displacement from a velocity–time graph. $s = \text{area under } v\text{-}t \text{ graph.}$	Plot graphs from data sets (manually or using software). Capture and analyse data using appropriate software, eg trolleys running down slopes. Use video analysis or data logging software to produce speed–time and velocity–time graphs. Observe the v-t graph of bouncing ball using a motion sensor.
Acceleration	
Definition of acceleration in terms of initial velocity, final velocity and time. Use of an appropriate relationship to solve problems involving acceleration, initial velocity (or speed), final velocity (or speed) and time. $a = \frac{v - u}{t}$ Determination of acceleration from a velocity–time graph. $a = \text{gradient of the line on a } v\text{-}t \text{ graph.}$ Description of an experiment to measure acceleration.	Determine the acceleration of a vehicle using two light gates and timer and record times for instantaneous speeds and time between. Determine acceleration from a velocity–time graph by finding the gradient using data software. This could be done from a graph created from data logging or video analysis. Measure the acceleration of a vehicle using a light gate connected to a computer.

Dynamics **Mandatory knowledge**	**Suggested activities**
Newton's laws	
Application of Newton's laws and balanced forces to explain constant velocity (or speed), making reference to frictional forces. Application of Newton's laws and unbalanced forces to explain and/or determine acceleration for situations where more than one force is acting. Use of an appropriate relationship to solve problems involving unbalanced force, mass and acceleration for situations where one or more forces are acting in one dimension or at right angles. $F = ma$ Use of an appropriate relationship to solve problems involving weight, mass and gravitational field strength. $W = mg$ Explanation of motion resulting from a 'reaction' force in terms of Newton's third law. Explanation of free-fall and terminal velocity in terms of Newton's laws.	Investigate 'frictionless movement' using an air hockey puck, linear air-track or model hovercraft. Discuss practical examples of balanced forces, for example gliding, floating in water or tug of war. Investigate Newton's second law using a linear air track or other suitable means. Relate Newton's laws to car safety measures, for example seatbelts, air bags or crumple zones. Experiment with water rockets/compressed air rocket launchers. Investigate parachutes, for example by dropping flat and crushed sheets of paper. Demonstrate balanced forces and terminal velocity by dropping ball bearings into glycerine-filled measuring cylinders.

Dynamics Mandatory knowledge	Suggested activities
Energy	
Explanation of energy conservation and of energy conversion and transfer. Use of an appropriate relationship to solve problems involving work done, unbalanced force and distance/displacement. $E_w = Fd$, or $W = Fd$ Definition of gravitational potential energy. Use of an appropriate relationship to solve problems involving gravitational potential energy, mass, gravitational field strength and height. $E_p = mgh$ Definition of kinetic energy. Use of an appropriate relationship to solve problems involving kinetic energy, mass and speed. $E_k = \frac{1}{2}mv^2$ Use of appropriate relationships to solve problems involving conservation of energy. $E_w = Fd$, $W = Fd$ $E_p = mgh$ $E_k = \frac{1}{2}mv^2$	Investigate the conservation of energy for a model car or trolley released from the top of a slope. Discuss the difference between the values of potential energy and kinetic energy obtained.

Dynamics Mandatory knowledge	Suggested activities
Projectile motion	
Explanation of projectile motion in terms of constant vertical acceleration and constant horizontal velocity. Use of appropriate relationships to solve problems involving projectile motion from a horizontal launch, including the use of motion graphs. area under v_h-t graphs (horizontal range) area under v_v-t graphs (vertical height) $v_h = \frac{s}{t}$ (constant horizontal velocity) $v_v = u_v + at$ (constant vertical acceleration) Explanation of satellite orbits in terms of projectile motion, horizontal velocity and weight.	Observe the 'String of pearls' experiment (using a strobe light to see the separation of projectile motion). Observe the 'Monkey and hunter' experiment. Use tracking software to analyse a video recording of projectile motion. Investigate and calculate 'drop time' and 'time of flight'. Discuss Newton's 'thought' experiment. Investigate factors affecting the time of flight and horizontal range of a projectile.

<table>
<tr><th>Space
Mandatory knowledge</th><th>Suggested activities</th></tr>
<tr><td colspan="2">Space exploration</td></tr>
<tr><td>Basic awareness of our current understanding of the universse.

Use of the following terms correctly and in context: planet, dwarf planet, moon, Sun, asteroid, solar system, star, exoplanet, galaxy, universe.

Awareness of the benefits of satellites: GPS, weather forecasting, communications, scientific discovery and space exploration (for example Hubble telescope, ISS).

Knowledge that geostationary satellites have a period of 24 hours and orbit at an altitude of 36 000 km.

Knowledge that the period of a satellite in a high altitude orbit is greater than the period of a satellite in a lower altitude orbit.

Awareness of the challenges of space travel:

♦ travelling large distances with the possible solution of attaining high velocity by using ion drive (producing a small unbalanced force over an extended period of time)
♦ travelling large distances using a ‘catapult’ from a fast moving asteroid, moon or planet
♦ manoeuvring a spacecraft in a zero friction environment, possibly to dock with the ISS
♦ maintaining sufficient energy to operate life support systems in a spacecraft, with the possible solution of using solar cells with area that varies with distance from the Sun.</td><td>Discuss space exploration (emphasising that our knowledge of space is continually developing) using suitable simulations and/or DVDs.

Observe lunar landing simulations.

Use interactive software to model lunar landing.

Create an animation of lunar landing and annotate it to show different stages of motion.</td></tr>
</table>

<table>
<tr><th>Space
Mandatory knowledge</th><th>Suggested activities</th></tr>
<tr><td colspan="2">Space exploration (continued)</td></tr>
<tr><td>Awareness of the risks associated with manned space exploration:

♦ fuel load on take-off
♦ potential exposure to radiation
♦ pressure differential
♦ re-entry through an atmosphere

Knowledge of Newton’s second and third laws and their application to space travel, rocket launch and landing.

Use of an appropriate relationship to solve problems involving weight, mass and gravitational field strength, in different locations in the universe.
$W = mg$</td><td>View videos of re-entry, eg Joe Kittinger or Felix Baumgartner.

Discuss the need for thermal protection systems to protect spacecraft on re-entry, including qualitative and quantitative specific heat capacity.</td></tr>
<tr><td colspan="2">Cosmology</td></tr>
<tr><td>Use of the term ‘light-year’ and conversion between light-years and metres.

Basic description of the ‘Big Bang’ theory of the origin of the universe. Knowledge of the approximate estimated age of the universe.

Awareness of the use of the whole electromagnetic spectrum in obtaining information about astronomical objects.

Identification of continuous and line spectra.

Use of spectral data for known elements, to identify the elements present in stars.</td><td>Research recent advances in astronomy and in our knowledge of the universe.

Discuss how radio telescopes, the COBE satellite and the SETI institute have advanced our knowledge of the universe.

Construct a simple spectroscope from a CD disk and examine common light sources.

Use a spectroscope to look at a range of light sources, eg sodium lamp and other gas discharge lamps.</td></tr>
</table>

Electricity Mandatory knowledge	Suggested activities
Electrical charge carriers	
Definition of electrical current as the electric charge transferred per unit time. Use of an appropriate relationship to solve problems involving charge, current and time. $Q = It$ Knowledge of the difference between alternating and direct current. Identification of a source (as a.c. or d.c.) based on oscilloscope trace or image from data logging software.	Discuss and research the uses of electrostatics. Investigate the interaction of charged objects, eg metallised polystyrene spheres attracted and repelled, Van de Graaff generator discharged through a microammeter. Research the definition of current and its historical context. Use an oscilloscope/data logging software to compare alternating and direct sources.
Potential difference (voltage)	
Knowledge that a charged particle experiences a force in an electric field. Knowledge of the path a charged particle follows: between two oppositely charged parallel plates; near a single point charge; between two oppositely charged points; between two like charged points. Knowledge that the potential difference (voltage) of the supply is a measure of the energy given to the charge carriers in a circuit.	Observe demonstrations of electric fields using Teltron tubes, olive oil and seeds with an EHT supply, Van de Graaff generator, parallel plates and suspended pith ball. Note: HT supplies must not be used with exposed live conductors. Discuss various models for electricity and their suitability for explaining potential difference (voltage). Carry out practical investigations to measure potential differences across components in series circuits. Describe the energy transfers and show that although there is a transfer of energy in the circuit, energy is conserved.

Electricity **Mandatory knowledge**	**Suggested activities**
Ohm's law	
Calculation of the gradient of the line of best fit on a V-I graph to determine resistance. Use of appropriate relationships to solve problems involving potential difference (voltage), current and resistance. $V = IR$ $V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_s$ $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ Knowledge of the qualitative relationship between the temperature and resistance of a conductor. Description of an experiment to verify Ohm's law.	Carry out a range of practical investigations to determine the relationship between potential difference, current and resistance using simple ohmic components. Investigate potential dividers using fixed and non-fixed resistors (eg LDRs, thermistors, variable resistors). Carry out investigations with non-ohmic conductors, for example, a ray-box lamp.
Practical electrical and electronic circuits	
Measurement of current, potential difference (voltage) and resistance, using appropriate meters in simple and complex circuits. Knowledge of the circuit symbol, function and application of standard electrical and electronic components: cell, battery, lamp, switch, resistor, voltmeter, ammeter, LED, motor, microphone, loudspeaker, photovoltaic cell, fuse, diode, capacitor, thermistor, LDR, relay, transistor.	Investigate the function of the named components in practical circuits, for example the function of a transistor as a switch.

Electricity Mandatory knowledge	Suggested activities
Practical electrical and electronic circuits (continued)	
For transistors, knowledge of the symbols for an npn transistor and an n-channel enhancement mode MOSFET. Explanation of their function as a switch in transistor switching circuits. Application of the rules for current and potential difference (voltage) in series and parallel circuits. $I_s = I_1 = I_2 = \ldots$ $V_s = V_1 + V_2 + \ldots$ $I_p = I_1 + I_2 + \ldots$ $V_p = V_1 = V_2 = \ldots$ Knowledge of the effect on the total resistance of a circuit of adding further resistance in series or in parallel. Use of appropriate relationships to solve problems involving the total resistance of resistors in series and in parallel circuits, and in circuits with a combination of series and parallel resistors. $R_T = R_1 + R_2 + \ldots$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$	Investigate the effect on the total resistance of a circuit of combining resistors in series and in parallel. Research and discuss the benefits of a ring circuit over a standard parallel circuit.

Electricity Mandatory knowledge	Suggested activities
Electrical Power	
Definition of electrical power in terms of electrical energy and time. Use of an appropriate relationship to solve problems involving energy, power and time. $P = \frac{E}{t}$ Knowledge of the effect of potential difference (voltage) and resistance on the current in and power developed across components in a circuit.	Measure and compare the power of various electrical devices. Use smart meters to measure voltage, current, energy and power for mains appliances.
Use of appropriate relationships to solve problems involving power, potential difference (voltage), current and resistance in electrical circuits. $P = IV$ $P = I^2R$ $P = \frac{V^2}{R}$	Investigate power loss using model power transmission lines. Carry out a survey into household/educational establishment energy consumption.
Selection of an appropriate fuse rating given the power rating of an electrical appliance. A 3 A fuse should be selected for most appliances rated up to 720 W, a 13 A fuse for appliances rated over 720 W.	Investigate the power rating and recommended fuses for household appliances.

Properties of matter Mandatory knowledge	Suggested activities
Specific heat capacity	
Knowledge that different materials require different quantities of heat to raise the temperature of unit mass by one degree Celsius. Use of an appropriate relationship to solve problems involving mass, heat energy, temperature change and specific heat capacity. $E_h = cm\Delta T$ Knowledge that the temperature of a substance is a measure of the mean kinetic energy of its particles. Use of the principle of conservation of energy to determine heat transfer.	Heat different masses of water in similar kettles predicting which will reach boiling point first and explain the reasons for this prediction. Carry out an investigation to compare the heat energy stored in different materials of the same mass when heated to the same temperature. Carry out experiments to determine the specific heat capacity of various metals. Research clothing used for specialist jobs, eg fire fighter, astronaut and polar explorer. Explain why some foods seem much warmer on the tongue than others when cooked, eg tomatoes in a cheese and tomato toastie. Design a heating system, for example heat pump, solar-heat traps, ground-storage systems, etc. Design a central-heating boiler to be as 'efficient' as possible and discuss how to reduce heat energy dissipation through the walls of the boiler.
Specific latent heat	
Knowledge that different materials require different quantities of heat to change the state of unit mass. Knowledge that the same material requires different quantities of heat to change the state of unit mass from solid to liquid (fusion) and to change the state of unit mass from liquid to gas (vaporisation). Use of an appropriate relationship to solve problems involving mass, heat energy and specific latent heat. $E_h = ml$	Plot cooling curves for substances in a temperature range which involves a change of state. Carry out practical investigations to compare the energy required to melt a mass of ice at 0 °C and to boil the same mass of water at 100 °C.

Properties of matter Mandatory knowledge	Suggested activities
Gas laws and the kinetic model	
Definition of pressure in terms of force and area. Use of an appropriate relationship to solve problems involving pressure, force and area. $p = \frac{F}{A}$	Investigation into the relationship between pressure and force using a gas syringe and masses.
Description of how the kinetic model accounts for the pressure of a gas. Knowledge of the relationship between Kelvin and degrees Celsius and the absolute zero of temperature. $0\ \text{K} = -273\ ^{\circ}\text{C}$	Research the kinetic theory of gases. Use a mechanical model to investigate kinetic theory (eg motor-driven polystyrene beads or small ball bearings). Observe Brownian motion in a smoke cell or an animation. Research the role of Lord Kelvin in the determination of the absolute scale of temperature.
Explanation of the pressure–volume, pressure–temperature and volume-temperature laws qualitatively in terms of a kinetic model. Use of appropriate relationships to solve problems involving the volume, pressure and temperature of a fixed mass of gas. $p_1V_1 = p_2V_2$ $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $\frac{pV}{T} = \text{constant}$	Investigate the relationships between the pressure, volume and temperature of a fixed mass of gas. Research and discuss the limitations of the behaviour of real gases. Carry out experiments to verify Boyle's law, Gay-Lussac's law and Charles' law.
Description of experiments to verify the pressure–volume law (Boyle's law), the pressure–temperature law (Gay-Lussac's law) and the volume–temperature law (Charles' law).	

Waves **Mandatory knowledge**	**Suggested activities**
Wave parameters and behaviours	
Knowledge that waves transfer energy. Definition of transverse and longitudinal waves. Knowledge that sound is an example of a longitudinal wave and electromagnetic radiation and water waves are examples of transverse waves. Determination of the frequency, period, wavelength, amplitude and wave speed for longitudinal and transverse waves. Use of appropriate relationships to solve problems involving wave speed, frequency, period, wavelength, distance, number of waves and time. $v = \frac{d}{t}$ $f = \frac{N}{t}$ $v = f\lambda$ $T = \frac{1}{f}$	View video of effects of energy carried by large waves. View simulations of longitudinal and transverse waves. Investigate the wave equation using video analysis of waves on 'slinkies'. Identify, measure and calculate frequency, wavelength and speed for sound waves or water waves, eg using data loggers, or echo methods.
Knowledge that diffraction occurs when waves pass through a gap or around an object. Comparison of long wave and short wave diffraction. Draw diagrams using wave fronts to show diffraction when waves pass through a gap or around an object.	Investigate the diffraction of waves around objects and through gaps using ripple tanks or microwave kit. Consider radio and TV reception in hilly terrain.

Waves Mandatory knowledge	Suggested activities
Electromagnetic spectrum	
Knowledge of the relative frequency and wavelength of bands of the electromagnetic spectrum. Knowledge of typical sources, detectors and applications for each band in the electromagnetic spectrum. Knowledge that all radiations in the electromagnetic spectrum are transverse and travel at the speed of light.	Explore, discuss and compare applications of e-m spectrum beyond the visible, eg thermal imaging camera, IR webcam, fluorescence with UV, radio/mobile phone communication. Discuss and compare limitations for applications of e-m waves in relation to frequency and image resolution.
Refraction of light	
Knowledge that refraction occurs when waves pass from one medium to another. Description of refraction in terms of change of wave speed, change in wavelength and change of direction (where the angle of incidence is greater than 0°), for waves passing into both a more dense and a less dense medium. Identification of the normal, angle of incidence and angle of refraction in ray diagrams showing refraction.	Investigate the reason for the 'apparent depth' of water. Investigate the qualitative relationship between angle of incidence and the angle of refraction. Research practical applications of refraction in medicine and industry.

Radiation Mandatory knowledge	Suggested activities
Nuclear radiation	
Knowledge of the nature of alpha (α), beta (β) and gamma (γ) radiation. Knowledge of the term 'ionisation' and the effect of ionisation on neutral atoms. Knowledge of the relative ionising effect and penetration of alpha, beta and gamma radiation. Definition of activity in terms of the number of nuclear disintegrations and time. Use of an appropriate relationship to solve problems involving activity, number of nuclear disintegrations and time. $A = \frac{N}{t}$ Knowledge of sources of background radiation. Knowledge of the dangers of ionising radiation to living cells and of the need to measure exposure to radiation. Use of appropriate relationships to solve problems involving absorbed dose, equivalent dose, energy, mass and weighting factor. $D = \frac{E}{m}$ $H = Dw_r$	View demonstrations/simulations of the relative penetration of alpha, beta and gamma radiation. Research the extraction of naturally occurring radioactive materials. Measure background radiation in a number of locations. Discuss or debate the risks and benefits of radioactivity in society. Discuss or debate the biological effects of radiation. Compare the count rate from potassium chloride and sodium chloride. Research society's reliance on radioactivity for a range of medical and industrial applications, including energy sources.

Radiation Mandatory knowledge	Suggested activities
Nuclear radiation (continued)	
Use of an appropriate relationship to solve problems involving equivalent dose rate, equivalent dose and time. $\dot{H} = \frac{H}{t}$ Comparison of equivalent dose due to a variety of natural and artificial sources. Knowledge of equivalent dose rate and exposure safety limits for the public and for workers in the radiation industries in terms of annual effective equivalent dose. ♦ Average annual background radiation in UK: 2·2 mSv. ♦ Annual effective dose limit for member of the public: 1 mSv. ♦ Annual effective dose limit for radiation worker: 20 mSv. Awareness of applications of nuclear radiation: electricity generation, cancer treatment and other industrial and medical uses. Definition of half-life.	 Research the significance of half-life in medical and industrial applications.
Use of graphical or numerical data to determine the half-life of a radioactive material. Description of an experiment to measure the half-life of a radioactive material.	View a demonstration of an experiment to determine half-life. Carry out a virtual experiment of half-life measurement. Observe the decay of the daughter products of radon from a charged balloon.
Qualitative description of fission, chain reactions, and their role in the generation of energy. Qualitative description of fusion, plasma containment, and their role in the generation of energy.	Research current applications and developments of fission and fusion reactions to generate energy. Research the fission process in nuclear power stations. Research developments into creating the conditions for nuclear fusion.

Units, prefixes and scientific notation **Mandatory knowledge**	Suggested activities
Use of appropriate SI units and the prefixes nano (n), micro (μ), milli (m), kilo (k), mega (M), giga (G). Use of the appropriate number of significant figures in final answers. This means that the final answer can have no more significant figures than the value with least number of significant figures used in the calculation. Appropriate use of scientific notation.	