2c. Content of topics P1 to P9

Topic P1: Matter

P1.1 The particle model

Summary

Knowledge and understanding of the particle nature of matter is fundamental to physics. Learners need to have an appreciation of matter in its different forms, they must also be aware of subatomic particles, their relative charges, masses and positions inside the atom. The structure and nature of atoms are essential to the further understanding of physics. The knowledge of subatomic particles is needed to explain many phenomena, for example the transfer of charges, as well as radioactivity. (Much of this content overlaps with that in the GCSE (9–1) in Chemistry A (Gateway Science content.)

Underlying knowledge and understanding

Learners should be aware of the atomic model, and that atoms are examples of particles. They should also know the difference between atoms, molecules and compounds. Learners should understand how density can be affected by the state materials are in.

Common misconceptions

Learners commonly confuse the different types of particles (subatomic particles, atoms and molecules) which can be addressed through the teaching of this topic. They commonly misunderstand the conversions between different units used in the measurement of volume.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM1.1i	recall and apply: density (kg/m^3) = mass (kg)/volume (m^3)	M1a, M1b, M1c, M3b, M3c, M5c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P1.1a	describe how and why the atomic model has changed over time	the Thomson, Rutherford (alongside Geiger and Marsden) and Bohr models	M5b	WS1.1a, WS1.1c, WS1.1g	Timeline showing the development of atomic theory. Discussion of the different roles played in developing the atomic model and how different scientists worked together.
P1.1b	describe the atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with almost all of the mass in the nucleus		M5b	WS1.1b	Model making (including 3D) of atomic structures.
P1.1c	recall the typical size (order of magnitude) of atoms and small molecules	knowledge that it is typically $1x10^{-10}m$	M1b	WS1.1d	
P1.1d	define density			WS1.2b, WS1.2c, WS1.3c, WS1.3d, WS1.4b, WS1.4e, WS1.4f, WS2a, WS2b, WS2c, WS2d	Measurement of length, volume and mass and using them to calculate density. (PAG P1) Investigation of Archimedes' Principle using eureka cans. (PAG P1)
P1.1e	explain the differences in density between the different states of matter in terms of the arrangements of the atoms and molecules		M5b	WS1.1b	
P1.1f	apply the relationship between density, mass and volume to changes where mass is conserved (M1a, M1b, M1c, M3c)		M1a, M1b, M1c, M3c		

P1.2 Changes of state

Summary

A clear understanding of the foundations of the physical world forms a solid basis for further study of physics. Understanding of the relationship between the states of matter helps to explain different types of everyday physical changes that we see around us.

Underlying knowledge and understanding

Learners should be familiar with the structure of matter and the similarities and differences between solids, liquids and gases. They should have an idea of the particle model and be able to use it to model changes in particle behaviour during changes of state. Learners should be aware of the effect of temperature in the motion and spacing of particles and an understanding that energy can be stored internally by materials.

Common misconceptions

Learners commonly carry misconceptions about matter; assuming atoms are always synonymous with particles. Learners also struggle to explain what is between the particles, instinctively 'filling' the gaps with 'air' or 'vapour'. They often struggle to visualise the 3D arrangement of particles in all states of matter. Learners can find it challenging to understand how kinetic theory applies to heating materials and how to use the term temperature correctly, regularly confusing the terms temperature and heat.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM1.2i	apply: change in thermal energy (J) = mass (kg) x specific heat capacity (J/kg°C) x change in temperature (°C)	M1a, M3b, M3c, M3d
PM1.2ii	apply: thermal energy for a change in state (J) = mass (kg) x specific latent heat (J/kg)	M1a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P1.2a	describe how mass is conserved when substances melt, freeze, evaporate, condense or sublimate			WS1.3a, WS1.3e, WS1.4a, WS2a, WS2c	Use of a data logger to record change in state and mass at different temperatures. (PAG P5) Demonstration of the distillation to show that mass is conserved during evaporation and condensation. (PAG P5)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P1.2b	describe that these physical changes differ from chemical changes because the material recovers its original properties if the change is reversed				
P1.2c	describe how heating a system will change the energy stored within the system and raise its temperature or produce changes of state			WS1.3a, WS1.3e, WS1.4a, WS2a, WS2b, WS2c	Observation of the crystallisation of salol in water under a microscope. Use of thermometer with a range of -10–110°C, to record the temperature changes of ice as it is heated. (PAG P1)
P1.2d	define the term specific heat capacity and distinguish between it and the term specific latent heat			WS1.2e, WS1.3b, WS1.3c, WS1.3h, WS1.4a, WS1.4f, WS2a, WS2b	Investigation of the specific heat capacity of different metals or water using electrical heaters and a joulemeter. (PAG P5)
P1.2e	apply the relationship between change in internal energy of a material and its mass, specific heat capacity and temperature change to calculate the energy change involved (M1a, M3c, M3d)		M1a, M3c, M3d		
P1.2f	apply the relationship between specific latent heat and mass to calculate the energy change involved in a change of state (M1a, M3c, M3d)		M1a, M3c, M3d	WS1.2e, WS1.3b, WS1.3c, WS1.3h, WS1.4a, WS1.4f, WS2a, WS2b	Measurement of the specific latent heat of vaporisation of water. (PAG P5) Measurement of the specific latent heat of stearic acid. (PAG P5)

P1.3 Pressure

Summary
This section develops the understanding of pressure in gases and liquids. Pressure in gases builds on the particle model, and in liquids the increase in pressure with depth is explained as the weight of a column of liquid acting on a unit area.

Underlying knowledge and understanding
Learners should be aware of the change in pressure in the atmosphere and in liquids with height (qualitative relationship only). They should have an understanding of floating and sinking and the effect of upthrust. Learners should know that pressure is measured by a ratio of force over area which is acting at a normal to the surface.

Common misconceptions
Learners commonly have misconceptions about floating and sinking, based on the premise that light or small objects float and heavy or large objects sink. They often misunderstand the role of pressure difference and suction e.g. the collapsing can experiment and the forcing of air into the lungs during inhalation.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM1.3i ☑	apply: for gases: pressure (Pa) x volume (m^3) = constant (for a given mass of gas and at a constant temperature)	M1a, M3b, M3c, M3d
PM1.3ii ☑	**apply: pressure due to a column of liquid (Pa) = height of column (m) x density of liquid (kg/m^3) x g (N/kg)**	**M1a, M1c, M3b, M3c, M3d**

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P1.3a	explain how the motion of the molecules in a gas is related both to its temperature and its pressure	application to closed systems only	M1c, M4a, M5b	WS1.1b, WS1.2a, WS1.2e, WS1.3e, WS1.4a, WS2a	Demonstration of the difference in pressure in an inflated balloon that has been heated and frozen. (PAG P1) Building manometers and using them to show pressure changes in heated/cooled volumes of gas. (PAG P1)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P1.3b	Explain the relationship between the temperature of a gas and its pressure at constant volume (qualitative only)		M1c, M5b	WS1.1b, WS1.2a, WS1.2e, WS1.3e, WS1.4a, WS2a	Demonstration of the exploding can experiment. Building of Alka-Seltzer rockets with film canisters.
P1.3c ☑	recall that gases can be compressed or expanded by pressure changes and that the pressure produces a net force at right angles to any surface		M4a, M5b	WS1.1b, WS1.2a, WS1.2e, WS1.3e, WS1.4a, WS2a	Compressing syringes containing sand, water and air. (PAG P1) Demonstration of the collapsing can experiment. Demonstration of the Cartesian diver experiment.
P1.3d ☑	explain how increasing the volume in which a gas is contained, at constant temperature can lead to a decrease in pressure	behaviour regarding particle velocity and collisions	M1c, M4a, M5b	WS1.1b, WS1.2a, WS1.2e, WS1.3e, WS1.4a	Demonstration of the behaviour of marshmallows in a vacuum.
P1.3e ☑	**explain how doing work on a gas can increase its temperature**	**examples such as a bicycle pump**		WS1.1b, WS1.2a	Demonstration of heat production in a bicycle inner tube as it is pumped up.
P1.3f ☑	describe a simple model of the Earth's atmosphere and of atmospheric pressure	an assumption of uniform density; knowledge of layers is not expected	M5b		
P1.3g ☑	explain why atmospheric pressure varies with height above the surface of the planet				

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P1.3h ☑	**describe the factors which influence floating and sinking**				
P1.3i ☑	**explain why pressure in a liquid varies with depth and density and how this leads to an upwards force on a partially submerged object**			WS1.1b, WS1.2a, WS1.3a, WS2a	Discussion of buoyancy of a ping pong ball in water.
P1.3j ☑	**calculate the differences in pressure at different depths in a liquid (M1c, M3c)**	**knowledge that g is the strength of the gravitational field and has a value of 10N/kg near the Earth's surface**	M1c, M3c	WS1.1b, WS1.2a	Demonstration of differences in water pressure using a pressure can with holes.

Topic P2: Forces

P2.1 Motion

Summary

Having looked at the nature of matter which makes up objects, we move on to consider the effects of forces. The interaction between objects leads to actions which can be seen by the observer, these actions are caused by forces between the objects in question. Some of the interactions involve contact between the objects, others involve no contact. We will also consider the importance of the direction in which forces act to allow understanding of the importance of vector quantities when trying to predict the action.

Underlying knowledge and understanding

From their work in Key Stage 3 Science, learners will have a basic knowledge of the mathematical relationship between speed, distance and time. They should also be able to represent this information in a distance-time graph and have an understanding of relative motion of objects.

Common misconceptions

Learners can find the concept of action at a distance challenging. They have a tendency to believe that a velocity must have a positive value and have difficulty in associating a reverse in direction with a change in sign. It is therefore important to make sure learners are knowledgeable about the vector–scalar distinction.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM2.1i	recall and apply: distance travelled (m) = speed (m/s) x time (s)	M1a, M2b, M3a, M3b, M3c, M3d, M4a, M4b, M4c, M4d, M4e
PM2.1ii	recall and apply: acceleration (m/s^2) = change in velocity (m/s) / time (s)	M1a, M3a, M3b, M3c, M3d
PM2.1iii	apply: (final velocity $(m/s))^2$ - (initial velocity $(m/s))^2$ = 2 x acceleration (m/s^2) x distance (m)	M1a, M3a, M3b, M3c, M3d
PM2.1iv	recall and apply: kinetic energy (J) = 0.5 x mass (kg) x (speed $(m/s))^2$	M1a, M3a, M3b, M3c, M3d

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P2.1a	describe how to measure distance and time in a range of scenarios				
P2.1b	describe how to measure distance and time and use these to calculate speed		M4a, M4b, M4c, M4d, M4f	WS1.2b, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3g, WS1.3h, WS1.3i, WS2a, WS2b, WS2c, WS2d	Calculations of the speeds of learners when they walk and run a measured distance. Investigation of trolleys on ramps at an angle and whether this affects speed. (PAG P3)
P2.1c	make calculations using ratios and proportional reasoning to convert units and to compute rates (M1c, M3c)	conversion from non-SI to SI units	M1c, M3c		
P2.1d	explain the vector–scalar distinction as it applies to displacement and distance, velocity and speed				
P2.1e	relate changes and differences in motion to appropriate distance-time, and velocity-time graphs; interpret lines and slopes (M4a, M4b, M4c, M4d)		M4a, M4b, M4c, M4d	WS1.3a	Learners to draw displacement-time and velocity-time graphs of their journey to school. (PAG P3)
P2.1f	**interpret enclosed area in velocity-time graphs (M4a, M4b, M4c, M4d, M4f)**		M4a, M4b, M4c, M4d, M4f		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.1g	calculate average speed for non-uniform motion (M1a, M1c, M2b, M3c)		M1a, M1c, M2b, M3c		
P2.1h	apply formulae relating distance, time and speed, for uniform motion, and for motion with uniform acceleration (M1a, M1c, M2b, M3c)		M1a, M1c, M2b, M3c	WS1.2b, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3g, WS1.3h, WS1.3i, WS2a, WS2b, WS2c, WS2d	Investigation of acceleration. (PAG P3)

P2.2 Newton's laws

Summary

Newton's laws of motion essentially define the means by which motion changes and the relationship between these changes in motion with force and mass.

Underlying knowledge and understanding

Learners should have an understanding of contact and non-contact forces influencing the motion of an object. They should be aware of the Newton and that this is the unit of force. The three laws themselves will be new to the learners. Learners are expected to be able to use force arrows and have an understanding of balanced and unbalanced forces.

Common misconceptions

Learners commonly have misconceptions about objects needing a net force for them to continue to move steadily and can struggle to understand that stationary objects also have forces acting on them. Difficulties faced by learners when trying to differentiate between scalar and vector quantities is the idea of objects with a changing direction not having a constant vector value, for example, objects moving in a circle. This issue also arises with the concept of momentum and changes in momentum of colliding objects.

Tiering

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Reference	Mathematical learning outcomes	Mathematical skills
PM2.2i	recall and apply: force (N) = mass (kg) x acceleration (m/s^2)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.2ii	**recall and apply: momentum (kgm/s) = mass (kg) x velocity (m/s)**	**M1a, M2a, M3a, M3b, M3c, M3d**
PM2.2iii	recall and apply: work done (J) = force (N) x distance (m) (along the line of action of the force)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.2iv	recall and apply: power (W) = work done (J) / time (s)	M1a, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P2.2a	recall examples of ways in which objects interact	electrostatics, gravity, magnetism and by contact (including normal contact force and friction)			
P2.2b	describe how such examples involve interactions between pairs of objects which produce a force on each object				
P2.2c	represent such forces as vectors	drawing free body force diagrams to demonstrate understanding of forces acting as vectors	M5b	WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3h, WS2a, WS2b, WS2d	Measurement of the velocity of ball bearings in glycerol at different temperatures or of differing sizes. (PAG P3)
P2.2d	apply Newton's First Law to explain the motion of an object moving with uniform velocity and also an object where the speed and/or direction change	looking at forces on one body and resultant forces and their effects (qualitative only)		WS1.3e, WS2a	Demonstration of the behaviour of colliding gliders on a linear air track. (PAG P3) Use of balloon gliders to consider the effect of a force on a body.
P2.2e	**use vector diagrams to illustrate resolution of forces, a net force (resultant force), and equilibrium situations (M4a, M5a, M5b)**	**scale drawings**	M4a, M5a, M5b		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.2f	**describe examples of the forces acting on an isolated solid object or system**	**examples of objects that reach terminal velocity for example skydivers and applying similar ideas to vehicles**		WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3h, WS2a, WS2b, WS2d	Learners to design and build a parachute for a mass, and measure its terminal velocity as it is dropped. (PAG P3)
P2.2g	**describe, using free body diagrams, examples where two or more forces lead to a resultant force on an object**				
P2.2h	**describe, using free body diagrams, examples of the special case where forces balance to produce a resultant force of zero (qualitative only)**				
P2.2i	apply Newton's second law in calculations relating forces, masses and accelerations		M1a, M2a, M3b, M3c, M3d	WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3h, WS2a, WS2b, WS2c, WS2d	Use of light gates, weights and trolleys to investigate the link between force and acceleration. (PAG P2)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.2j	**explain that inertia is a measure of how difficult it is to change the velocity of an object and that the mass is defined as the ratio of force over acceleration**				
P2.2k	**define momentum and describe examples of momentum in collisions**	**an idea of the law of conservation of momentum in elastic collisions**		WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3h, WS2a, WS2b, WS2c, WS2d	Use of light gates, weights and trolleys to measure momentum of colliding trollies. (PAG P3) Use of a water rocket to demonstrate that the explosion propels the water down with the same momentum as the rocket shoots up.
P2.2l ☑	apply formulae relating force, mass, velocity and acceleration to explain how the changes involved are inter-related (M3b, M3c, M3d)		M3b, M3c, M3d		
P2.2m	use the relationship between work done, force, and distance moved along the line of action of the force and describe the energy transfer involved		M1a, M2a, M3a, M3b, M3c, M3d	WS1.4a, WS2a, WS2b	Measurement of work done by learners lifting weights or walking up stairs. (PAG P5)
P2.2n	calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules (M1c, M3c)		M1c, M3c	WS1.4e, WS1.4f	
P2.2o	explain, with reference to examples, the definition of power as the rate at which energy is transferred				
P2.2p	recall and apply Newton's third law	application to situations of equilibrium and non-equilibrium			
P2.2q	**explain why an object moving in a circle with a constant speed has a changing velocity (qualitative only)**			WS1.3e	Demonstration of spinning a rubber bung on a string.

2

P2.3 Forces in action

Summary
Forces acting on an object can result in a change of shape or motion. Having looked at the nature of matter, we can now introduce the idea of fields and forces causing changes. This develops the idea that force interactions between objects can take place even if they are not in contact. Learners should be familiar with forces associated with deforming objects, with stretching and compressing (springs).

Underlying knowledge and understanding
Learners should have an understanding of forces acting to deform objects and to restrict motion. They should already be familiar with Hooke's Law and the idea that, when work is done by a force, it results in an energy transfer and leads to energy being stored by an object. Learners are expected to know that there is a force due to gravity and that gravitational field strength differs on other planets and stars.

Common misconceptions
Learners commonly have difficulty understanding that the weight of an object is not the same as its mass from the everyday use of the term 'weighing'.
The concept of force multipliers can also be challenging even though the basic concepts are ones covered at Key Stage 3.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM2.3i	recall and apply: force exerted by a spring (N) = extension (m) x spring constant (N/m)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3ii	apply: energy transferred in stretching (J) = 0.5 x spring constant (N/m) x (extension (m))^2	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3iii	recall and apply: gravity force (N) = mass (kg) x gravitational field strength, g (N/kg)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3iv	recall and apply: (in a gravity field) potential energy (J) = mass (kg) x height (m) x gravitational field strength, g (N/kg)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3v ☑	recall and apply: pressure (Pa) = force normal to a surface (N) / area of that surface (m^2)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3vi ☑	recall and apply: moment of a force (Nm) = force (N) x distance (m) (normal to direction of the force)	M1a, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P2.3a	explain that to stretch, bend or compress an object, more than one force has to be applied	applications to real life situations		WS1.1b, WS1.1e, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS2a, WS2b, WS2c	Use of a liquorice bungee or spring to explore extension and stretching. (PAG P2)
P2.3b	describe the difference between elastic and plastic deformation (distortions) caused by stretching forces			WS1.1b, WS1.1e, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS2a, WS2b, WS2c	Comparisons of behaviour of springs and elastic bands when loading and unloading with weights. (PAG P2)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.3c	describe the relationship between force and extension for a spring and other simple systems	graphical representation of the extension of a spring	M1a, M2a, M4a, M4b, M4c	WS1.1b, WS1.1e, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS1.4f, WS2a, WS2b, WS2c	Investigation of forces on springs – Hooke's law. (PAG P2)
P2.3d	describe the difference between linear and non-linear relationships between force and extension		M1a, M2a, M4a, M4b, M4c	WS1.1b, WS1.1e, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS2a, WS2b, WS2c	Investigation of the elastic limit of springs and other materials. (PAG P2)
P2.3e	calculate a spring constant in linear cases		M1a, M2a, M3a, M3b, M3c, M3d		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.3f	calculate the work done in stretching		M1a, M2a, M3a, M3b, M3c, M3d, M4a, M4b, M4c, M4f	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS1.4f, WS2c	Use of data from stretching an elastic band with weights to plot a graph to calculate the work done. (PAG P2)
P2.3g	describe that all matter has a gravitational field that causes attraction, and the field strength is much greater for massive objects				
P2.3h	define weight, describe how it is measured and describe the relationship between the weight of an object and the gravitational field strength (g) (and) has a value of 10N/kg at the Earth's surface	knowledge that the gravitational field strength is known as g and has a value of 10N/kg		WS1.1b	Calculations of weight on different planets.
P2.3i	recall the acceleration in free fall				
P2.3j ☑	apply formulae relating force, mass and relevant physical constants, including gravitational field strength (g), to explore how changes in these are inter-related (M1c, M3b, M3c)		M1c, M3b, M3c		
P2.3k ☑	describe examples in which forces cause rotation	location of pivot points and whether a resultant turning force will be in a clockwise or anticlockwise direction			

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.3l ☑	define and calculate the moment of the force in such examples	application of the principle of moments for objects which are balanced	M1a, M1c, M2a, M3a, M3b, M3c, M3d	WS1.2a, WS1.2b, WS1.3e, WS2a, WS2b, WS2c	Investigation of moments using a meter ruler, pivot and balancing masses. (PAG P2)
P2.3m ☑	explain how levers and gears transmit the rotational effects of forces	an understanding of ratios and how this enables gears and levers to work as force multipliers	M1c		
P2.3n ☑	recall that the pressure in fluids (gases and liquids) causes a net force at right angles to any surface			WS1.1b, WS1.2a, WS1.4a	Demonstration of balloons being pushed onto a single drawing pin versus many drawing pins.
P2.3o ☑	use the relationship between the force, the pressure and the area in contact	an understanding of how simple hydraulic systems work	M1a, M2a, M3a, M3b, M3c, M3d		

Topic P3: Electricity

P3.1 Static and charge

Summary

Having established the nature of matter, consideration is now given to the interactions between matter and electrostatic fields. These interactions are derived from the structure of matter which was considered in Topic P1. The generation of charge is considered. Charge is a fundamental property of matter. There are two types of charge which are given the names 'positive' and 'negative'

Underlying knowledge and understanding

Learners should be aware of electron transfer leading to objects becoming statically charged and the forces between them. They should also be aware of the existence of an electric field.

Common misconceptions

Learners commonly have difficulty classifying materials as insulators or conductors. They find it difficult to remember that positive charge does not move to make a material positive, rather it is the movement of electrons.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM3.1i	recall and apply: charge flow (C) = current (A) x time (s)	M1a, M2a, M3a, M3b, M3c, M3d

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Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P3.1a	describe that charge is a property of all matter and that there are positive and negative charges. The effects of the charges are not normally seen on bodies containing equal amounts of positive and negative charge, as their effects cancel each other out			WS1.1b, WS1.1e, WS1.2a, WS1.3e, WS2a	Use of charged rods to repel or attract one another. Use of a charged rod to deflect water or pick up paper. Discussion of why charged balloons are attracted to walls.
P3.1b	describe the production of static electricity, and sparking, by rubbing surfaces, and evidence that charged objects exert forces of attraction or repulsion on one another when not in contact	the understanding that static charge only builds up on insulators		WS1.1b, WS1.1e, WS1.2a, WS1.3e	Use of a Van de Graaff generator.
P3.1c	explain how transfer of electrons between objects can explain the phenomena of static electricity			WS1.1b, WS1.3e, WS1.3f, WS2a	Use of the gold leaf electroscope and a charged rod to observe and discuss behaviour.
P3.1d ☑	explain the concept of an electric field and how it helps to explain the phenomena of static electricity	how electric fields relate to the forces of attraction and repulsion	M5b	WS1.3e	Demonstration of semolina on castor oil to show electric fields.
P3.1e	recall that current is a rate of flow of charge (electrons) and the conditions needed for charge to flow	conditions for charge to flow: source of potential difference and a closed circuit			
P3.1f	recall that current has the same value at any point in a single closed loop				
P3.1g	recall and use the relationship between quantity of charge, current and time		M1a, M2a, M3a, M3b, M3c, M3d		

P3.2 Simple circuits

Summary

Electrical currents depend on the movement of charge and the interaction of electrostatic fields. Electrical current, potential difference and resistance are all discussed in this section. The relationship between them is considered and learners will investigate this using circuits.

Underlying knowledge and understanding

Learners should have been introduced to the measurement of conventional current and potential difference in circuits. They will have an understanding of how to assemble series and parallel circuits and of how they differ with respect to conventional current and potential difference. Learners are expected to have an awareness of the relationship between potential difference, current and resistance and the units in which they are measured.

Common misconceptions

Learners find the concept of potential difference very difficult to grasp. They find it difficult to understand the behaviour of charge in circuits and through components and how this relates to energy or work done within a circuit.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM3.2i	recall and apply: potential difference (V) = current (A) x resistance (Ω)	M1a, M2a, M3a, M3b, M3c, M3d
PM3.2ii	recall and apply: energy transferred (J) = charge (C) x potential difference (V)	M1a, M2a, M3a, M3b, M3c, M3d
PM3.2iii	recall and apply: power (W) = potential difference (V) x current (A) = $(\text{current (A)})^2$ x resistance (Ω)	M1a, M2a, M3a, M3b, M3c, M3d
PM3.2iv	recall and apply: energy transferred (J, kWh) = power (W, kW) x time (s, h) = charge (C) x potential difference (V)	M1a, M2a, M3a, M3b, M3c, M3d

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Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P3.2a	describe the differences between series and parallel circuits	positioning of measuring instruments in circuits and descriptions of the behaviour of energy, current and potential difference		WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Building of circuits to measure potential difference and current in both series and parallel circuits. (PAG P7)
P3.2b	represent d.c. circuits with the conventions of positive and negative terminals, and the symbols that represent common circuit elements	diodes, LDRs, ntc thermistors, filament lamps, ammeter, voltmeter and resistors		WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Building circuits from diagrams. (PAG P7)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P3.2c	recall that current (I) depends on both resistance (R) and potential difference (V) and the units in which these are measured	the definition of potential difference		WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Recording of p.d. across and current through different components and calculate resistances. (PAG P6)
P3.2d	recall and apply the relationship between I, R and V, and that for some resistors the value of R remains constant but that in others it can change as the current changes		M1a, M2a, M3a, M3b, M3c, M3d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Investigation of resistance in a wire. (PAG P6) Investigation of the effect of length on resistance in a wire. (PAG P7)
P3.2e	explain that for some resistors the value of R remains constant but that in others it can change as the current changes				
P3.2f	explain the design and use of circuits to explore such effects	components such as wire of varying resistance, filament lamps, diodes, ntc thermistors and LDRs			

Learning outcomes		To include	Maths	Working scientifically	Practical suggestion
P3.2g	use graphs to explore whether circuit elements are linear or non-linear (M4c, M4d)		M4c, M4d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Investigation of I-V characteristics of circuit elements. (PAG P6)
P3.2h	use graphs and relate the curves produced to the function and properties of circuit elements (M4c, M4d)	components such as wire of varying resistance, filament lamps, diodes, ntc thermistors and LDRs	M4c, M4d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Use of wires, filament lamps, diodes, in simple circuits. Alter p.d. and keep current same using variable resistor. Record and plot results. (PAG P6)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P3.2i	explain why, if two resistors are in series the net resistance is increased, whereas with two in parallel the net resistance is decreased (qualitative explanation only)		M1c	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Investigation of the brightness of bulbs in series and parallel. (PAG P7)
P3.2j	calculate the currents, potential differences and resistances in d.c. series and parallel circuits	components such as wire of varying resistance, filament lamps, diodes, ntc thermistors and LDRs	M1a, M2a, M3a, M3b, M3c, M3d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Investigation of resistance of a thermistor in a beaker of water being heated. (PAG P6) Investigation of resistance of an LDR with exposure to different light intensities. (PAG P6) Investigation of how the power of a photocell depends on its surface area and its distance from the light source. (PAG P6)
P3.2k	explain the design and use of such circuits for measurement and testing purposes				
P3.2l	explain how the power transfer in any circuit device is related to the potential difference across it and the current, and to the energy changes over a given time				
P3.2m	apply the equations relating potential difference, current, quantity of charge, resistance, power, energy, and time, and solve problems for circuits which include resistors in series, using the concept of equivalent resistance (M1c, M3b, M3c, M3d)		M1c, M3b, M3c, M3d		

2

Topic P4: Magnetism and magnetic fields

P4.1 Magnets and magnetic fields

Summary
Having an understanding of how charge can be generated and its effects, we can now consider the link between movement of charge and magnetism. To begin, learners will investigate magnets and magnetic fields around magnets and current-carrying wires.

Underlying knowledge and understanding
Learners should have been introduced to magnets and the idea of attractive and repulsive forces. They should have an idea of the shape of the fields around bar magnets. Learners are expected to have an awareness of the magnetic effect of a current and electromagnets.

Common misconceptions
Common misconceptions that learners have include the idea that larger magnets will always be stronger magnets. They also have difficulty understanding the concept of field line density being an indicator of field strength. Learners often do not know that the geographic and magnetic poles are not located in the same place.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P4.1a	describe the attraction and repulsion between unlike and like poles for permanent magnets	diagrams of magnetic field patterns around bar magnets to show attraction and repulsion		WS1.1b, WS1.2a, WS1.2b, WS2a, WS2b	Use of suspended magnets to show attraction and repulsion.
P4.1b	describe the difference between permanent and induced magnets				
P4.1c	describe the characteristics of the magnetic field of a magnet, showing how strength and direction change from one point to another	diagrams to show how the strength of the field varies around them and ways of investigating this	M5b	WS1.1b, WS1.2a, WS1.2b, WS2a, WS2b, WS2c	Plotting of magnetic fields around different shaped magnets.
P4.1d	explain how the behaviour of a magnetic (dipping) compass is related to evidence that the core of the Earth must be magnetic				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P4.1e	describe how to show that a current can create a magnetic effect and describe the directions of the magnetic field around a conducting wire			WS1.1b, WS1.2a, WS1.2b, WS2a, WS2b, WS2c	Investigation of the magnetic field around a current-carrying wire using plotting compasses.
P4.1f	recall that the strength of the field depends on the current and the distance from the conductor		M1c		
P4.1g	explain how solenoid arrangements can enhance the magnetic effect		M1c	WS1.1b, WS1.2a, WS1.2b, WS2a, WS2b, WS2c, WS2d	Investigation of the magnetic field around a current-carrying solenoid using plotting compasses. Investigation of the factors that can affect the magnetic effect e.g. number of turns, current, length and cross sectional area.

2

P4.2 Uses of magnetism

Summary

Forces show the existence of fields and how they interact with one another but here the force itself is discussed in more depth and then quantified. These forces also lead to the use of magnetic fields to induce electrical currents and the applications of this electromagnetic induction in motors, dynamos and transformers.

Underlying knowledge and understanding

This topic will predominantly be new content for learners with some understanding of D.C. motors. Learners will have looked at fields in the previous subtopic and now this knowledge will be built on to give learners the understanding of the application.

Common misconceptions

Learners find understanding the manner in which electric and magnetic fields interact to produce a force challenging. Learners commonly have difficulty with the right angles and three-dimensional requirements of Fleming's left-hand rule. Their ability to visualise this will impact how they deal with this concept. Learners find the action of a commutator difficult to apply in the D.C. motor. The application of changing direction of field in the transformer is found challenging by many learners and hence often leads to a superficial grasp of the working of the transformer.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM4.2i	**apply: force on a conductor (at right angles to a magnetic field) carrying a current (N) = magnetic flux density (T) x current (A) x length (m)**	**M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d**
PM4.2ii ☑	**apply: potential difference across primary coil (V)/potential difference across secondary coil (V) = number of turns in primary coil / number of turns in secondary coil**	**M1a, M1b, M1c, M1d, M2a, M3a, M3b, M3c, M3d**

Topic content			Opportunities to cover:		
Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P4.2a	**describe how a magnet and a current-carrying conductor exert a force on one another**			WS1.1b, WS1.1e, WS1.2a, WS1.3e	Demonstration of the jumping wire experiment.
P4.2b	**show that Fleming's left-hand rule represents the relative orientations of the force, the current and the magnetic field**				
P4.2c	**apply the equation that links the force on a conductor to the magnetic flux density, the current and the length of conductor to calculate the forces involved**		M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d		
P4.2d	**explain how the force exerted from a magnet and a current-carrying conductor is used to cause rotation in electric motors**	**an understanding of how electric motors work but knowledge of the structure of a motor is not expected**		WS1.1e, WS1.3e, WS2a	Construction of simple motors.
P4.2e ☑	**recall that a change in the magnetic field around a conductor can give rise to an induced potential difference across its ends, which could drive a current, generating a magnetic field that would oppose the original change**			WS1.1e, WS1.3e, WS2a	Examination of wind up radios or torches to investigate how dynamos work. Demonstration of induction using a strong magnet and a wire using a zero point galvanometer.
P4.2f ☑	**explain how this effect is used in an alternator to generate a.c., and in a dynamo to generate d.c.**			WS1.1a, WS1.1e, WS1.4a	Research the structure of dynamos and compare with DC motors.

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P4.2g ☑	**explain how the effect of an alternating current in one circuit, in inducing a current in another, is used in transformers**				
P4.2h ☑	**explain how the ratio of the potential differences across the two depends on the ratio of the numbers of turns in each**		M1c	WS1.1e, WS1.2a, WS1.2b, WS1.3a, WS1.3b, WS1.3e, WS1.3h, WS2a, WS2b	Building of a step-up and step-down transformer to investigate their effects.
P4.2i ☑	**apply the equations linking the potential differences and numbers of turns in the two coils of a transformer (M1c, M3b, M3c)**		M1c, M3b, M3c		
P4.2j ☑	**explain the action of the microphone in converting the pressure variations in sound waves into variations in current in electrical circuits, and the reverse effect as used in loudspeakers and headphones**	**an understanding of how dynamic microphones work using electromagnetic induction**		WS1.1e, WS1.2a, WS1.3e, WS1.3h, WS2a, WS2b	Examination of the construction of a loudspeaker. Building of a loud speaker.

Topic P5: Waves in matter

P5.1 Wave behaviour

Summary

Waves are means of transferring energy and the two main types of wave are introduced in this section: mechanical and electromagnetic. This section considers both what these types of waves are and how they are used. The main terms used to describe waves are defined and exemplified in this topic.

Underlying knowledge and understanding

Learners should have prior knowledge of transverse and longitudinal waves through sound and light. Learners should be aware of how waves behave and how the speed of a wave may change as it passes through different media. They may already have knowledge of how sound is heard and the hearing ranges of different species.

Common misconceptions

Although they will often have heard of the terms ultrasound and sonar, learners find it challenging to explain how images and traces are formed and to apply their understanding to calculations. Learners often misinterpret distance and displacement–time graphical presentations of waves.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM5.1i	recall and apply: wave speed (m/s) = frequency (Hz) x wavelength (m)	M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P5.1a	describe wave motion in terms of amplitude, wavelength, frequency and period			WS1.1b, WS1.3b, WS1.3e	Observing sound waves on an oscilloscope.
P5.1b	define wavelength and frequency				
P5.1c	describe and apply the relationship between these and the wave velocity		M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d	WS1.1b, WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS1.3d, WS2a, WS2b	Investigation of reflection in a ripple tank (PAG P4)
P5.1d	apply formulae relating velocity, frequency and wavelength (M1c, M3c)		M1c, M3c		
P5.1e	describe differences between transverse and longitudinal waves	direction of travel and direction of vibration	M5b	WS1.1b, WS1.3e	Use of a slinky to model waves.
P5.1f ☑	show how changes, in velocity, frequency and wavelength, in transmission of sound waves from one medium to another, are inter-related (M1c, M3c)		M1c, M3c		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P5.1g ☑	describe the effects of reflection, transmission, and absorption of waves at material interface	examples such as ultrasound and sonar		WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3e, WS1.3f, WS1.3h, WS2a, WS2b, WS2c	Refraction of light through a glass block. (PAG P8) Investigation of reflection with a plane mirror. (PAG P8) Demonstration of refraction of white light through a prism.
P5.1h ☑	**describe, with examples, processes which convert wave disturbances between sound waves and vibrations in solids**	**knowledge of a simple structure of the parts of the ear is expected**		WS1.1b, WS1.1f, WS1.3b, WS1.3e	Use of a signal generator and loudspeaker. Demonstration of sound waves using a Rubens' tube or an oscilloscope.
P5.1i ☑	**explain why such processes only work over a limited frequency range, and the relevance of this to human hearing**	**why hearing (audition) changes due to ageing**			
P5.1j	describe how ripples on water surfaces are used to model transverse waves whilst sound waves in air are longitudinal waves, and how the speed of each may be measured			WS1.1b, WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS1.3d, WS2a, WS2b	Investigation of refraction in a ripple tank. (PAG P8)
P5.1k	describe evidence that in both cases it is the wave and not the water or air itself that travels				

P5.2 The electromagnetic spectrum

Summary

Having looked at mechanical waves, waves in the electromagnetic spectrum are now considered. This section includes the application of electromagnetic waves with a specific focus on the behaviour of light. Alongside this, it explores the application of other types of electromagnetic radiation for use in medical imaging.

Underlying knowledge and understanding

Learners may be familiar with uses of some types of radiation but an understanding of all parts of the electromagnetic spectrum is not expected and should be taught as new content.

Common misconceptions

Learners can have misconceptions such as gamma rays, x-rays, ultraviolet light, visible light, infrared light, microwaves and radio waves being independent entities and not being able to view it as a spectrum. They struggle to link the features that waves have in common, alongside the differences and how these relate to their different properties.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P5.2a	recall that electromagnetic waves are transverse and are transmitted through space where all have the same velocity				
P5.2b	explain that electromagnetic waves transfer energy from source to absorber	examples from a range of electromagnetic waves			
P5.2c	apply the relationships between frequency and wavelength across the electromagnetic spectrum (M1a, M1c, M3c)		M1a, M1c, M3c	WS1.1b, WS1.3b, WS1.3e	Investigation of electromagnetic waves on chocolate or processed cheese in a microwave to measure wavelength. (PAG P4)
P5.2d	describe the main groupings of the electromagnetic spectrum and that these groupings range from long to short wavelengths and from low to high frequencies	radio, microwave, infra-red, visible (red to violet), ultra-violet, X-rays and gamma-rays		WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1h, WS1.1i	Research and design a poster to show the properties, uses and dangers of the different electromagnetic wave groups.
P5.2e	describe that our eyes can only detect a limited range of the electromagnetic spectrum				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P5.2f	recall that light is an electromagnetic wave				
P5.2g	give examples of some practical uses of electromagnetic waves in the radio, micro-wave, infra-red, visible, ultra-violet, X-ray and gamma-ray regions			WS1.1b, WS1.1d, WS1.1e, WS1.1f, WS1.1h, WS1.1i, WS1.3e, WS1.3f	Demonstration of how microwaves can be used to light a bulb in a beaker of water and of how this shows that microwaves heat water in foods. Use a microwave emitter and absorber to demonstrate behaviour of waves. (PAG P8) Use of a phone camera to look at the infra-red emitter on a remote control. (PAG P8)
P5.2h	describe how ultra-violet waves, X-rays and gamma-rays can have hazardous effects, notably on human bodily tissues			WS1.1a, WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1h, WS1.1i	Show images of x-rays to discuss how the images are formed; their advantages and disadvantages. Investigation of the balance of risks for staff and patients during radiotherapy.
P5.2i ☑	**explain, in qualitative terms, how the differences in velocity, absorption and reflection between different types of waves in solids and liquids can be used both for detection and for exploration of structures which are hidden from direct observation, notably in our bodies**	**the use of infra-red, X-rays, gamma rays and ultrasound as an alternative in medical imaging**			
P5.2j	**recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits**				

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P5.3 Wave interactions

Summary

Having studied the electromagnetic spectrum learners now go on to look at the interactions of waves with materials, this will include absorption, refraction and reflection. Learners will also be expected to draw ray diagrams to illustrate the refraction of rays through lenses.

Underlying knowledge and understanding

Learners will already be familiar with the properties and behaviour of light. They are expected to have an understanding of behaviour such as reflection, refraction, absorption and scattering. Learners should know that colours are produced by light at different frequencies.

Common misconceptions

A common misconception is that when light passes through a coloured filter, the filter will add colour to the light. In addition, learners are often confused about which colours are primary colours.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P5.3a	**recall that different substances may absorb, transmit, refract, or reflect electromagnetic waves in ways that vary with wavelength**				
P5.3b	**explain how some effects are related to differences in the velocity of electromagnetic waves in different substances**				
P5.3c ☑	use ray diagrams to illustrate reflection, refraction and the similarities and differences between convex and concave lenses (qualitative only)	how the behaviour of convex and concave lenses determine how they may be used, for example, to correct vision	M5a, M5b	WS1.1b, WS1.2c, WS1.3a, WS1.3e, WS2a, WS2b, WS2c	Use of concave and convex lenses to investigate how they alter the path of light in different ways. (PAG P4) Investigation using convex lenses to see how the image of a light bulb varies with the distance of the bulb from the lens. (PAG P4)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P5.3d ☑	construct two-dimensional ray diagrams to illustrate reflection and refraction (qualitative only –equations not needed) (M5a, M5b)		M5a, M5b		
P5.3e ☑	explain how colour is related to differential absorption, transmission and reflection	specular reflection and scattering		WS1.1b, WS1.2c, WS1.3a, WS1.3e, WS2a, WS2b, WS2c	Use of coloured filters and light sources to investigate how filters work. (PAG P4)

Topic P6: Radioactivity

P6.1 Radioactive emissions

Summary
Having considered the general characteristics of waves and particles, we now move on to look at radioactive decay which combines these two ideas. The idea of isotopes is introduced, leading into looking at the different types of emissions from atoms.

Underlying knowledge and understanding
Learners should have prior understanding of the atomic model, chemical symbols and formulae. An understanding of radioactivity is not expected and should be taught as new content.

Common misconceptions
Learners tend to struggle with the concept that radioactivity is a random and unpredictable process. The idea of half-life is another area that can lead to confusion. Learners often find it difficult to understand that objects being irradiated does not lead to them becoming radioactive.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		
Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P6.1a	recall that atomic nuclei are composed of both protons and neutrons, that the nucleus of each element has a characteristic positive charge		M5b		
P6.1b	recall that atoms of the same elements can differ in nuclear mass by having different numbers of neutrons				
P6.1c	Use the conventional representation for nuclei to relate the differences between isotopes	identities, charges and masses			

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P6.1d	recall that some nuclei are unstable and may emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma rays			WS1.1a, WS1.1b, WS1.2a, WS1.2d, WS1.3b, WS1.3f	Use of a Geiger-Müller tube and radioactive sources to investigate activity.
P6.1e	relate these emissions to possible changes in the mass or the charge of the nucleus, or both				
P6.1f	use names and symbols of common nuclei and particles to write balanced equations that represent radioactive decay				
P6.1g	balance equations representing the emission of alpha-, beta- or gamma-radiation in terms of the masses, and charges of the atoms involved (M1b, M1c, M3c)		M1b, M1c, M3c		
P6.1h	recall that in each atom its electrons are arranged at different distances from the nucleus, that such arrangements may change with absorption or emission of electromagnetic radiation and that atoms can become ions by loss of outer electrons	knowledge that inner electrons can be 'excited' when they absorb energy from radiation and rise to a higher energy level. When this energy is lost by the electron it is emitted as radiation. When outer electrons are lost this is called ionisation			
P6.1i	recall that changes in atoms and nuclei can also generate and absorb radiations over a wide frequency range	an understanding that these types of radiation may be from any part of the electromagnetic spectrum which includes gamma rays		WS1.1b, WS1.3e	Demonstration of fluorescence with a black light lamp and tonic water.

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P6.1j	explain the concept of half-life and how this is related to the random nature of radioactive decay		M1c, M3d, M4a, M4c	WS1.1b, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS2a	Using dice to model random decay and half-life. Research how half-life can be used in radioactive dating.
P6.1k	**calculate the net decline, expressed as a ratio, during radioactive emission after a given (integral) number of half-lives (M1c, M3d)**	**half-life graphs**	M1c, M3d		
P6.1l	recall the differences in the penetration properties of alpha-particles, beta-particles and gamma-rays			WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3f, WS1.3g, WS1.3h	Use of Geiger-Müller tube, sources and aluminium plates of varying thicknesses to investigate change in count rate.

P6.2 Uses and hazards

Summary

We now address the hazards and applications of radioactive decay. The processes of fission and fusion as a source of energy are also considered.

Underlying knowledge and understanding

Learners may have prior understanding of the term radioactivity from the previous sub topic and may be familiar with some uses, but will not have covered this content prior to this topic.

Common misconceptions

Learners tend to think that radioactivity will always cause physical mutations when humans or animals come into contact with it. They tend to only think of the negative impacts of radiation and not the positive uses.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P6.2a	recall the differences between contamination and irradiation effects and compare the hazards associated with these two			WS1.1a, WS1.1b, WS1.2a, WS1.2d, WS1.3b, WS1.3f	Use of spark chamber to demonstrate a different type of activity counter.
P6.2b ☑	explain why the hazards associated with radioactive material differ according to the half-life involved			WS1.1a, WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1h, WS1.1i	Illustrate an everyday use of radioactive sources in smoke detectors and discuss why they might be suitable.

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P6.2c ☑	describe the different uses of nuclear radiations for exploration of internal organs, and for control or destruction of unwanted tissue			WS1.1a, WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1h, WS1.1i	Research the medical uses of radioactive tracers and radiotherapy.
P6.2d ☑	recall that some nuclei are unstable and may split, and relate such effects to radiation which might emerge, to transfer of energy to other particles and to the possibility of chain reactions	knowledge of the term nuclear fission			
P6.2e ☑	describe the process of nuclear fusion	knowledge that mass may be converted into the energy of radiation			

P7.1 Work done

Summary
We now move on to consider how energy can be stored and transferred. This topic acts to consolidate the ideas of energy that have been covered in previous topics as it is a fundamental concept that underpins many of the ways in which matter interacts.

Underlying knowledge and understanding
Learners may have prior knowledge of energy listed as nine types, as this is the teaching approach often taken at Key Stage 2 and Key Stage 3 to increase accessibility to an abstract concept. Learners may find it difficult to move away from this idea but need to be able to approach systems in terms of energy transfers and stores. They will have an understanding that energy can be transferred in processes such as changing motion, burning fuels and in electrical circuits. Learners should also be aware of the idea of conservation of energy and that it has a quantity that can be calculated.

Common misconceptions
Learners may have misconceptions around energy being a fuel-like substance that matter has to 'use up', that resting objects do not have any energy and that all energy is transferred efficiently. There is also often confusion between forces and energy.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P7.1a	describe for situations where there are energy transfers in a system, that there is no net change to the total energy of a closed system (qualitative only)	the law of conservation of energy			
P7.1b	describe all the changes involved in the way energy is stored when a system changes for common situations	an object projected upwards or up a slope, a moving object hitting an obstacle, an object being accelerated by a constant force, a vehicle slowing down, bringing water to a boil in an electric kettle		WS1.2a, WS1.2b, WS1.3c, WS1.3f, WS1.4a, WS1.4e, WS2a, WS2b, WS2c	Exploring energy stores and transfers in different object in a circus based activity. Objects could include a wind up toy, a weight on a spring, a weight being lifted or dropped, water being heated, electrical appliances.

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P7.1c	describe the changes in energy involved when a system is changed by heating (in terms of temperature change and specific heat capacity), by work done by forces, and by work done when a current flows				
P7.1d	make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (M1a, M1c, M3c)	work done by forces, current flow, through heating and the use of kWh to measure energy use in electrical appliances in the home	M1a, M1c, M3c	WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS2a, WS2b	Use of a joulemeter to measure the energy used by different electrical appliances. (PAG P5)
P7.1e	calculate the amounts of energy associated with a moving body, a stretched spring and an object raised above ground level		M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS2a, WS2b	Use of light gates and trolleys to investigate kinetic energy. (PAG P5) Use of a joulemeter and electrical motor to lift a weight to investigate potential energy. (PAG P5) Investigation of energy changes and efficiency of bouncy balls. (PAG P5)

P7.2 Power and efficiency

Summary
This considers the idea of conservation and dissipation of energy in systems and how this leads to the efficiency. Ways of reducing unwanted energy transfers and thereby increasing efficiency will be explored.

Underlying knowledge and understanding
Learners should be aware of the transfer of energy into useful and waste energies. They will have an understanding of power and how domestic appliances can be compared. Learners will have knowledge of insulators and how energy transfer is influenced by temperature. They should have an awareness of ways to reduce heat loss in the home.

Common misconceptions
Learners have the common misconception that energy can be "used up" or that energy is truly lost in many energy transformations. They also tend to have the belief that energy can be completely changed from one form to another with no energy dissipated.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM7.2i	recall and apply: efficiency = useful output energy transfer (J) / input energy transfer (J)	M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P7.2a	describe, with examples, the process by which energy is dissipated, so that it is stored in less useful ways				
P7.2b	describe how, in different domestic devices, energy is transferred from batteries or the a.c. from the mains	how energy may be wasted in the transfer to and within motors and heating devices			

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P7.2c	describe, with examples, the relationship between the power ratings for domestic electrical appliances and how this is linked to the changes in stored energy when they are in use			WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS2a, WS2b	Use of a joulemeters to investigate the power output of different electrical appliances. (PAG P5)
P7.2d	calculate energy efficiency for any energy transfer		M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d		
P7.2e	**describe ways to increase efficiency**				
P7.2f	explain ways of reducing unwanted energy transfer	lubrication and thermal insulation		WS1.1b, WS1.1e, WS1.1f, WS1.1g, WS1.1i, WS1.3b	Research, design and building of energy efficient model houses. Examination of thermograms of houses.
P7.2g	describe how the rate of cooling of a building is affected by the thickness and thermal conductivity of its walls (qualitative only)			WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS1.3i, WS2a, WS2b, WS2c, WS2d	Investigation of rate of cooling with insulated and non-insulated copper cans. (PAG P5)

Topic P8: Global challenges

This topic seeks to integrate learners' knowledge and understanding of physical systems and processes, with the aim of applying it to global challenges. Applications of physics can be used to help humans improve their own lives and strive to create a sustainable world for future generations, and these challenges are considered in this topic. It therefore provides opportunities to draw together the concepts covered in earlier topics, allowing synoptic treatment of the subject of physics.

P8.1 Physics on the move

Summary

Learners will use their knowledge of forces and motion to develop their ideas about how objects are affected by external factors. They will develop a better understanding of these external factors to be able to understand how the design of objects such as cars may be modified to operate more safely.

Underlying knowledge and understanding

Learners should be familiar with how forces affect motion of objects. They will also need to have a good understanding of momentum from P2.2. Learners may already have some knowledge of how vehicles are adapted to increase safety.

Common misconceptions

Learners tend to confuse the factors that affect thinking distance and braking distance, thinking that alcohol, drugs and tiredness will affect braking distance rather than thinking distance. It needs to be made clear the distinction between these two terms and that the combination of these gives us the stopping distance.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P8.1a	recall typical speeds encountered in everyday experience for wind and sound, and for walking, running, cycling and other transportation systems		M1d		
P8.1b	estimate the magnitudes of everyday accelerations		M1d		
P8.1c	make calculations using ratios and proportional reasoning to convert units and to compute rates (M1c, M3c)	conversion from non-SI to SI units	M1c, M3c		

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P8.1d	explain methods of measuring human reaction times and recall typical results		M1a, M2a, M2b	WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3g, WS1.3h, WS2a, WS2b, WS2c, WS2d	Investigation of reaction time using ruler drop experiments. (PAG P3)
P8.1e	explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies and the implications for safety	factors that affect thinking and braking distance and overall stopping distance			
P8.1f ☑	estimate how the distances required for road vehicles to stop in an emergency, varies over a range of typical speeds (M1c, M1d, M2c, M2h, M3b, M3c)		M1c, M1d, M2c, M2h, M3b, M3c	WS1.1e, WS1.1h	Research stopping distances using the Highway Code.
P8.1g	explain the dangers caused by large decelerations			WS1.1e, WS1.1f, WS1.1h, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS2a, WS2b	Research and building of casing on trolleys for eggs to investigate crumple zones and safety features in cars.
P8.1h ☑	**estimate the forces involved in typical situations on a public road**				
P8.1i ☑	estimate, for everyday road transport, the speed, accelerations and forces involved in large accelerations (M1d, M2b, M2h, M3c)		M1d, M2b, M2h, M3c		

Summary

We are reliant on electricity for everyday life and this topic explores the production of electricity. Consideration will be given to the use of non-renewable and renewable sources and the problems that are faced in the efficient transportation of electricity to homes and businesses. Safe use of electricity in the home is also covered in this topic. It may be an opportunity to revisit power and efficiency.

Underlying knowledge and understanding

Learners should already be familiar with renewable and non-renewable energy sources. Learners are expected to have a basic understanding of how power stations work and the cost of electricity in the home. They may have some idea of electrical safety features in the home.

Common misconceptions

Learners often confuse the idea of energy with terms including the word power such as solar power. There are often difficulties in understanding that higher voltages are applied across power lines and not along them. Another common misconception is that batteries and wall sockets have current inside them ready to escape.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
PM8.2i	apply: potential difference across primary coil (V) x current in primary coil (A) = potential difference across secondary coil (V) x current in secondary coil (A)	M1a, M1b, M1c, M1d, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P8.2a	describe the main energy sources available for use on Earth, compare the ways in which they are used and distinguish between renewable and non-renewable sources	fossil fuels, nuclear fuel, bio-fuel, wind, hydro-electricity, tides and the Sun		WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1g, WS1.1h, WS1.1i, WS1.3e	Research of different energy sources. Demonstration of a steam engine and discussion of the transfer of energy taking place.

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P8.2b	explain patterns and trends in the use of energy resources	the changing use of different resources over time		WS1.1a, WS1.1b, WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1g, WS1.1h, WS1.1i	Research and present information to convince people to invest in energy saving measures. Research how the use of electricity has changed in the last 150 years.
P8.2c	recall that, in the national grid, electrical power is transferred at high voltages from power stations, and then transferred at lower voltages in each locality for domestic use				
P8.2d	recall that step-up and step-down transformers are used to change the potential difference as power is transferred from power stations			WS1.1b, WS1.1e, WS1.1f, WS1.3e	Use of a model power line to demonstrate the energy losses at lower voltage and higher current.
P8.2e	explain how the national grid is an efficient way to transfer energy				
P8.2f ☑	**link the potential differences and numbers of turns of a transformer to the power transfer involved; relate this to the advantages of power transmission at high voltages (M1c, M3b, M3c)**		M1c, M3b, M3c		
P8.2g	recall that the domestic supply in the UK is a.c. at 50Hz and about 230 volts				
P8.2h	explain the difference between direct and alternating voltage			WS1.3b, WS1.3e	Use of a data logger to compare a.c. and d.c. output traces. (PAG P7)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P8.2i	recall the differences in function between the live, neutral and earth mains wires, and the potential differences between these wires			WS2a	Wiring of a plug.
P8.2j	explain that a live wire may be dangerous even when a switch in a mains circuit is open, and explain the dangers of providing any connection between the live wire and earth	the protection offered by insulation of devices			

Summary
In this astrophysics topic learners will look in more detail at how we can investigate the characteristics of planets. To begin with learners will investigate bodies that are close to our own planet and consider factors that affect natural and artificial satellites. The topic then moves onto considering bodies within the universe, and will apply their knowledge of fusion processes to understand the life cycle of a star and waves to consider black body radiation. The Big Bang theory will be studied and the evidence that supports it as a scientific theory.

Underlying knowledge and understanding
Learners should already be familiar with the bodies within our own solar system and the behaviour of satellites. They may have a basic understanding of the Big Bang theory and that distances to other celestial bodies is large.

Common misconceptions
A common misconception among learners is that the Sun is not a star but a separate entity; it needs to be instilled in learners that the sun is a star. In addition, learners have difficulty grasping how far away celestial objects are.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P8.3a ☑	explain the red-shift of light as seen from galaxies which are receding (qualitative only). The change with distance of each galaxy's speed is evidence of an expanding universe	understanding of changes in frequency and wavelength		WS1.1b	Use of a Doppler ball to model red-shift. Use of a balloon to illustrate why galaxies are moving away from us and that expansion is from the centre of the universe.
P8.3b ☑	explain how red shift and other evidence can be linked to the Big-Bang model	CMBR			

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P8.3c ☑	recall that our Sun was formed from dust and gas drawn together by gravity and explain how this caused fusion reactions, leading to equilibrium between gravitational collapse and expansion due to the energy released during fusion	lifecycle of a star		WS1.1a, WS1.1b, WS1.1c	Research and produce a poster illustrating the life cycle of a star.
P8.3d ☑	explain that all bodies emit radiation, and that the intensity and wavelength distribution of any emission depends on their temperatures	an understanding that hot objects can emit a continuous range of electromagnetic radiation at different energy values and therefore frequencies and wavelengths		WS1.1a, WS1.1b, WS1.1c, WS1.1d, WS1.1f, WS1.1g, WS1.1i, WS1.3e	Comparison of temperature changes inside sealed transparent containers with different gases inside. Research evidence of global warming from the last 200 years.
P8.3e ☑	recall the main features of our solar system, including the similarities and distinctions between the planets, their moons, and artificial satellites	the 8 planets and knowledge of minor planets, geostationary and polar orbits for artificial satellites and how these may be similar to or differ from natural satellites		WS1.1a, WS1.1b, WS1.1c, WS1.1g, WS1.1i	Building a model of the solar system to demonstrate scale. Research the evidence for the presence of the Moon as a result of a collision between the Earth and another planet. Research the uses of geostationary and polar satellites.
P8.3f ☑	**explain for circular orbits, how the force of gravity can lead to changing velocity of a planet but unchanged speed (qualitative only)**				
P8.3g ☑	**explain how, for a stable orbit, the radius must change if this speed changes (qualitative only)**				

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P8.3h ☑	**explain how the temperature of a body is related to the balance between incoming radiation absorbed and radiation emitted; illustrate this balance using everyday examples and the example of the factors which determine the temperature of the Earth**	**an understanding that Earth's atmosphere affects the electromagnetic radiation from the Sun that passes through it**			
P8.3i ☑	**explain, in qualitative terms, how the differences in velocity, absorption and reflection between different types of waves in solids and liquids can be used both for detection and for exploration of structures which are hidden from direct observation, notably in the Earth's core and in deep water**	**P and S waves, use of sonar**	M5b	WS1.1a, WS1.1b, WS1.1c, WS1.1f, WS1.1h, WS1.3b	Examination of seismographic traces of recent earthquakes. Research the design of buildings that are in countries that experience earthquakes regularly and how the design is linked to P and S wave characteristics.