OCR Level 1/2 GCSE (9–1) in Physics A (Gateway Science) (J249)

Specification

Awaiting Accreditation

Version 1: First assessment 2018

This draft qualification has not yet been accredited by Ofqual. It is published to enable teachers to have early sight of our proposed approach to GCSE (9–1) in Physics A (Gateway Science). Further changes may be required and no assurance can be given at this time that the proposed qualification will be made available in its current form, or that it will be accredited in time for first teaching in 2016 and first award in 2018.

Contents

1 Why choose an OCR GCSE (9–1) in Physics A (Gateway Science)?

1a. Why choose an OCR qualification?

Choose OCR and you've got the reassurance that you're working with one of the UK's leading exam boards. Our new OCR GCSE (9–1) in Physics A (Gateway Science) course has been developed in consultation with teachers, employers and higher education to provide learners with a qualification that's relevant to them and meets their needs.

We're part of the Cambridge Assessment Group, Europe's largest assessment agency and a department of the University of Cambridge. Cambridge Assessment plays a leading role in developing and delivering assessments throughout the world, operating in over 150 countries.

We work with a range of education providers, including schools, colleges, workplaces and other institutions in both the public and private sectors. Over 13,000 centres choose our A Levels, GCSEs and vocational qualifications including Cambridge Nationals, Cambridge Technicals and Cambridge Progression.

Our Specifications

We believe in developing specifications that help you bring the subject to life and inspire your learners to achieve more.

We've created teacher-friendly specifications based on extensive research and engagement with the teaching community. They're designed to be straightforward and accessible so that you can tailor the delivery of the course to suit your needs. We aim to encourage learners to become responsible for their own learning, confident in discussing ideas, innovative and engaged.

We provide a range of support services designed to help you at every stage, from preparation through to the delivery of our specifications. This includes:

- A wide range of high-quality creative resources including:
  - Delivery Guides
  - Transition Guides
  - Topic Exploration Packs
  - Lesson Elements
  - …and much more.
- Access to subject specialists to support you through the transition and throughout the lifetime of the specification.
- CPD/Training for teachers including face-to-face events to introduce the qualifications and prepare you for first teaching.
- Active Results – our free results analysis service to help you review the performance of individual learners or whole schools.
- ExamCreator – our new online past papers service that enables you to build your own test papers from past OCR exam questions.

All GCSE (9–1) qualifications offered by OCR are accredited by Ofqual, the Regulator for qualifications offered in England. The accreditation number for OCR's GCSE (9–1) in Physics A (Gateway Science) is QNXXXXXX.

1b. Why choose an OCR GCSE (9–1) in Physics A (Gateway Science)?

We appreciate that one size doesn't fit all so we offer two suites of qualifications in each science:

Physics A – Provides a flexible approach to teaching. The specification is divided into topics, each covering different key concepts of physics. Teaching of practical skills is integrated with the theoretical topics and they are assessed through the written papers.

Physics B – Learners study physics using a narrative-based approach. Ideas are introduced within relevant and interesting settings which help learners to anchor their conceptual knowledge of the range of physical topics required at GCSE level. Practical skills are embedded within the specification and learners are expected to carry out practical work in preparation for a written examination that will specifically test these skills.

All of our specifications have been developed with subject and teaching experts. We have worked in close consultation with teachers and other stakeholders with the aim of including up-to-date relevant content within a framework that is interesting to teach and administer within all centres (large and small).

Our new GCSE (9–1) in Physics A (Gateway Science) qualification builds on our existing popular course. We've based the redevelopment of our GCSE sciences on an understanding of what works well in centres large and small. We've undertaken a significant amount of consultation through our science forums (which include representatives from learned societies, HE, teaching and industry) and through focus groups with teachers.

The content is clear and logically laid out for both existing centres and those new to OCR, with assessment models that are straightforward to administer. We have worked closely with teachers to provide high quality support materials to guide you through the new qualifications.

Aims and learning outcomes

OCR's GCSE (9–1) in Physics A (Gateway Science) will encourage learners to:

- develop scientific knowledge and conceptual understanding of physics
- develop understanding of the nature, processes and methods of science, through different types of scientific enquiries that help them to answer scientific questions about the world around them
- develop and learn to apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory, in the field and in other learning environments
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.

1c. What are the key features of this specification?

Our GCSE (9–1) in Physics A (Gateway Science) specification is designed with a content-led approach and provides a flexible way of teaching. The specification:

- is laid out clearly in a series of teaching topics with guidance included where required to provide further advice on delivery
- is co-teachable with the GCSE (9–1) Combined Science A (Gateway Science) qualification
- embeds practical requirements within the teaching topics
- identifies opportunities for carrying out practical activities that enhances learners' understanding of physics theory and practical skills
- exemplifies the mathematical requirements of the course (see Appendix 5g)
- highlights opportunities for the introduction of key mathematical requirements (see Appendix 5g and the To include column for each topic) into your teaching
- identifies, within the Working Scientifically column, how the skills, knowledge and understanding of working scientifically (WS) can be incorporated within teaching.

Teacher support

The extensive support offered alongside this specification includes:

- **delivery guides** – providing information on assessed content, the associated conceptual development and contextual approaches to delivery
- **transition guides** – identifying the levels of demand and progression for different key stages for a particular topic and going on to provide links to high quality resources and 'checkpoint tasks' to assist teachers in identifying learners 'ready for progression'
- **lesson elements –** written by experts, providing all the materials necessary to deliver creative classroom activities
- **Active Results** (see Section 1a)
- **ExamCreator** (see Section 1a)
- **Practice paper service** – a free service offering a practice question paper and mark scheme (downloadable from a secure location).

Along with:

- Subject Specialists within the OCR science team to help with course queries
- teacher training
- *Science Spotlight* (our termly newsletter)
- OCR Science community
- Practical Skills Handbook
- Maths Skills Handbook.

1d. How do I find out more information?

Whether new to our specifications, or continuing on from our legacy offerings, you can find more information on our webpages at www.ocr.org.uk

Visit our subject pages to find out more about the assessment package and resources available to support your teaching. The science team also release a termly newsletter *Science Spotlight* (despatched to centres and available from our subject pages).

Want to find out more?

You can contact the Science Subject Specialists:

ScienceGCSE@ocr.org.uk, 01223 553998

Join our Science community: http://social.ocr.org.uk/

Check what CPD events are available: www.cpdhub.ocr.org.uk

Follow us on Twitter: @ocr_science

2 The specification overview

2a. OCR's GCSE (9–1) in Physics A (Gateway Science) (J249)

Learners are entered for either Foundation tier (Papers 1 and Paper 2) **or** Higher tier (Papers 3 and Paper 4).

<table>
<tr><th>Content Overview</th><th colspan="2">Assessment Overview</th></tr>
<tr><td colspan="3">Foundation tier, grades 5 to 1</td></tr>
<tr><td rowspan="2">Content is split into eight teaching topics:

• Topic P1: Matter
• Topic P2: Forces
• Topic P3: Electricity
• Topic P4: Magnetism and magnetic fields
• Topic P5: Waves in matter
• Topic P6: Radioactive decay – waves and particles
• Topic P7: Energy
• Topic P8: Global challenges

Paper 1 assesses content from Topics P1–P4.

Paper 2 assesses content from Topics P5–P8, with assumed knowledge of Topics P1 – P4.</td><td>Paper 1

J249/01

90 marks

1 hour 45 minutes
Written paper</td><td>50% of total GCSE</td></tr>
<tr><td>Paper 2

J249/02

90 marks

1 hour 45 minutes
written paper</td><td>50% of total GCSE</td></tr>
<tr><td colspan="3">Higher tier, grades 9 to 4</td></tr>
<tr><td rowspan="2">Content is split into eight teaching topics:

• Topic P1: Matter
• Topic P2: Forces
• Topic P3: Electricity
• Topic P4: Magnetism and magnetic fields
• Topic P5: Waves in matter
• Topic P6: Radioactive decay – waves and particles
• Topic P7: Energy
• Topic P8: Global challenges

Paper 3 assesses content from Topics P1–P4.

Paper 4 assesses content from Topics P5–P8, with assumed knowledge of Topics P1 – P4.</td><td>Paper 3

J249/03

90 marks

1 hour 45 minutes
written paper</td><td>50% of total GCSE</td></tr>
<tr><td>Paper 4

J249/04

90 marks

1 hour 45 minutes
written paper</td><td>50% of total GCSE</td></tr>
</table>

J249/02 and J249/04 include synoptic assessment.

2b. Content of GCSE (9–1) in Physics A (Gateway Science) (J249)

The GCSE (9–1) in Physics A (Gateway Science) specification content is divided into eight teaching topics and each topic is further divided into key sub-topics. Each sub-topic is introduced with a short summary text, followed by the underlying knowledge and understanding learners should be familiar with and common misconceptions associated with the topic.

The 'Assessable content' is shown by the purple highlighting: **Assessable mathematical learning outcomes**, **Learning outcomes** and **To include**.

- The **Assessable mathematical learning outcomes** highlight the maths learning outcomes which will be assessed in an examination on that particular topic.
- The **Learning outcomes** may all be assessed in the examinations. The statements in bold are intended for higher tier only. Therefore, higher tier learners need to be taught the entire specification. Foundation tier learners must be taught the entire specification, apart from the statements in bold.
- The **To include** column is included to provide further advice on delivery.

The 'Opportunities for' is divided into three columns: **Maths**, **Working scientifically** and **Practical/research**. Items that are contained within these columns will not be directly assessed, but are intended as a starting point for lesson planning.

- **Maths**: the mathematical skills requirements in Appendix 5g can be assessed throughout the examination. These are referenced in the Maths column by the prefix M to link the mathematical skills required for GCSE (9–1) in Physics A (Gateway Science) to examples of physics content where those mathematical skills could be linked to learning.
- **Working scientifically**: references to working scientifically (Appendix 5f) are included in the Working scientifically column to highlight opportunities to encourage a wider understanding of science.
- **Practical/research**: OCR has split the *list of apparatus and techniques* requirements from the Department for Education 'GCSE subject content' into eight Practical Activity Groups or PAGs. The table in Appendix 5i illustrates the skills required for each PAG and an example practical that may be used to contribute to the PAG. Within the specification there are a number of suggested practicals that are illustrated in the 'Opportunities for' column, which count towards each PAG. We are expecting that centres do a wide range of practical activities during the course. These can be the ones illustrated in the specification or can be practicals that are devised by the centre. Activities can range from whole investigations to simple starters and plenaries.

The specification has been designed to be co-teachable with the standalone GCSE (9–1) in Combined Science A (Gateway Science) qualification.

A summary of the content for the GCSE (9–1) in Physics A (Gateway Science) course is on the next page.

Summary of Content for GCSE (9–1) in Physics A (Gateway Science)

Topic P1: Matter	**Topic P2: Forces**	**Topic P3: Electricity**
P1.1 The particle model P1.2 Changes of state P1.3 Pressure	P2.1 Motion P2.2 Newton's Laws P2.3 Forces in action	P3.1 Static and charge P3.2 Simple circuits
Topic P4: Magnetism and magnetic fields	**Topic P5: Waves in matter**	**Topic P6: Radioactive decay – waves and particles**
P4.1 Magnets and magnetic fields P4.2 Uses of magnetism	P5.1 Wave behaviour P5.2 The electromagnetic spectrum P5.3 Wave interaction	P6.1 Radioactive emissions P6.2 Uses and hazards
Topic P7: Energy	**Topic P8: Global challenges**	
P7.1 Work done P7.2 Power and efficiency	P8.1 Physics on the move P8.2 Powering Earth P8.3 Beyond Earth	

2c. Content of topics P1 to P8

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 the 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 those involving charge and transfer of charges, as well as radioactivity. (Much of this content overlaps with that in the Chemistry content within Combined Science).

Underlying knowledge and understanding
Learners should be aware of a simple 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	Assessable 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

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
P1.1a describe how and why the atomic model has changed over time	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	typically 1x10^{-10}m	M1b	WS1.1d	
P1.1d define density			WS1.2b, WS1.2c, WS1.3c, WS1.3, 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' Principal 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			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, M5c		

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 a simple 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 3 dimensional 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	Assessable mathematical learning outcomes	Mathematical skills
PM1.2i	apply: change in thermal energy = m x specific heat capacity x change in temperature	M1a, M3b, M3c, M3d
PM1.2ii	apply: thermal energy for a change in state = m x specific latent heat	M1a, M3b, M3c, M3d

Assessable content			Opportunities for		
Learning outcomes		To include	Maths	Working scientifically	Practical/research
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/research
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	an understanding that temperature and heat although related are not a measure of the same thing		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 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	Assessable 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

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
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)
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		

Learning outcomes		To include	Maths	Working scientifically	Practical/research
P1.3g	explain why atmospheric pressure varies with height above the surface of the planet				
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**	M1a, M1b, M3b, M3c, M3d	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. A difficulty 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 when trying to handle momentum and changes in momentum of objects colliding.

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	Assessable 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 speed(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, M1c, M2f, M3a, M3b, M3c, M3d
PM2.1iv	recall and apply: kinetic energy (J) = 0.5 x mass (kg) x (speed (m/s))^2	M1a, M1c, M2f, M3a, M3b, M3c, M3d

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
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, and interpret lines, slopes and enclosed areas in such graphs (M4a, M4b, M4c, M4d, M4f)		M4a, M4b, M4c, M4d, M4f	WS1.3a	Learners to draw displacement-time and velocity-time graphs of their journey to school. (PAG P3)
P2.1f calculate average speed for non-uniform motion (M1a, M1c, M2f, M3c)		M1a, M1c, M2b, M2f, M3a, M3b, M3c, M3d		

Learning outcomes	To include	Maths	Working scientifically	Practical/research
P2.1g apply formulae relating distance, time and speed, for uniform motion, and for motion with uniform acceleration (M1a, M1c, M2f, M3c)		M1a, M1c, M2f, M3a, M3b, M3c, M3d, 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	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 Newtons and that this is the measure 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
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	Assessable 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

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
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		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 with ball bearings 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, and equilibrium situations (M4a, M5a, M5b)	**scale drawings**	M4a, M5a, M5b		

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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 (qualitative only)**				
P2.2h	**describe, using free body diagrams, examples of the special case where forces balance to produce a resultant force of zero**				
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/research
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 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)		M1a, M2a, M3a, M3b, M3c, M3d		
P2.2 m	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				

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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.

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. They can also still result in an object changing shape or motion. 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; this 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. Learners should be aware of moments acting as a turning force.

Common misconceptions
Learners commonly have difficulty understanding that the weight of an object is not the same as its mass from the use of the term 'weighing'. The concept of force multipliers can also be challenging even though the basic concepts are ones covered at KS3.

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	Assessable 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

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
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/research
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/research
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)	the gravitational field strength is known as g and has a value of 10N/kg; that this is also known as weight(N) = mass (kg) x g (N/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)		M1a, M2a, M3a, M3b, M3c, M3d		
P2.3k	describe examples in which forces cause rotation	the location of pivot points and whether a resultant turning force will be in a clockwise or anticlockwise direction			

Learning outcomes		To include	Maths	Working scientifically	Practical/research
P2.3l	define and calculate the moment of the force in such examples	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	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	simple hydraulic systems	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 the previous section. 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'. The effects of these charges are not normally seen as objects often contain equal amounts of positive and negative charge so their effects cancel each other out.

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. The role of insulators should not be neglected. 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	Assessable mathematical learning outcomes	Mathematical skills
PM3.1i	recall and apply: charge flow (C)= current (A) x time (s)	M1a, M2a, M3a, M3b, M3c, M3d

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
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 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. The electrical current, potential difference and resistance are all discussed in this section. The relationship between them is considered and learners will represent 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 a basic understanding 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	Assessable mathematical learning outcomes	Mathematical skills
PM3.2i	recall and apply: potential difference (V)= current (A) x resistance (□)	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

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
P3.2a describe the differences between series and parallel circuits	position 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 and thermistors, filament lamps, ammeter, voltmeter, 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/research
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 the design and use of circuits to explore such effects	components such as wire of varying resistance, filament lamps, diodes, thermistors and LDRs			

Learning outcomes		To include	Maths	Working scientifically	Practical/research
P3.2f	use graphs to explore whether circuit elements are linear or non-linear (M4c, M4d, M4e)		M4a, M4b, M4c, M4d, M4e	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)
P3.2g	use graphs and relate the curves produced to the function and properties of circuit elements (M4c, M4d, M4e)	components such as wire of varying resistance, filament lamps, diodes, thermistors and LDRs	M4a, M4b, M4c, M4d, M4e	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/research
P3.2h	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)
P3.2i	calculate the currents, potential differences and resistances in d.c. series and parallel circuits	components such as wire of varying resistance, filament lamps, diodes, 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)
P3.2j	explain the design and use of such circuits for measurement and testing purposes				
P3.2k	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				

Learning outcomes		To include	Maths	Working scientifically	Practical/research
P3.2l	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)		M1a, M1c, M2a, M3a, M3b, M3c, M3d		

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 effects of movement of charge in magnetism. To begin learners will look at 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, is 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.

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
P4.1a	describe the attraction and repulsion between unlike and like poles for permanent magnets			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 of magnetic field patterns around bar magnets to show attraction and repulsion and also depict how the strength of the field varies around them	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/research
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.

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	Assessable 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

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
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 conductor 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/research
P4.2g	**explain how the effect of an alternating current in one circuit, in inducing a current in transformers 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, to the currents (M1c, M3b, M3c)**		M1a, M1b, M1c, M1d, M2a, M3a, M3b, M3c, M3d		
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 they find it challenging to explain how images and traces are formed and to apply their understanding to calculations. Learners often misinterpret displacement 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	Assessable 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

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
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)		M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d		
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)		M1a, M1b, M1c, M3c, M5a		

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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 as rays and waves. 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 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 relate 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.

Assessable content			Opportunities for		
Learning outcomes		To include	Maths	Working scientifically	Practical/research
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, M1b, M1c, M2a, M3a, M3b, M3c, M3d	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	recall that our eyes can only detect a limited range of the electromagnetic spectrum				

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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. Discussion 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**				

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. Learners also tend to believe that mixing of coloured light follows the same rules as the mixing of paints and that the primary colours for both are the same.

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.

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
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/research
P5.3d	construct two-dimensional ray diagrams to illustrate reflection and refraction (qualitative- equations not needed) (M5a, M5b)		M5a, M5b		
P5.3e	explain how colour is related to differential absorption, transmission and reflection	reflection to include specular 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: Radioactive decay – waves and particles

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.

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
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/research
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 Muller 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-radiations in terms of the masses, and charges of the atoms involved (M1b, M1c, M3c)		M1b, M1c, M3c, M3d		
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 black light lamp and tonic water.

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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, M2g		
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 Guiger- 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.

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
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.
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.

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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			

Topic P7: Energy

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 KS2 and KS3 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.

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
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)	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/research
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 and through heating and the use of kWh to measure energy use in electrical appliances in the home	M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d	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 energies into useful and waste energies. They will be able to 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	Assessable 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

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
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			

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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	through lubrication, 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 a previous sub-topic. 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.

Assessable content		Opportunities for		
Learning outcomes	**To include**	**Maths**	**Working scientifically**	**Practical/research**
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		

Learning outcomes	To include	Maths	Working scientifically	Practical/research
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		
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, M2d, M2f, M2h, M3b, M3c)		M1c, M1d, M2c, M2d, M2f, 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				

Learning outcomes		To include	Maths	Working scientifically	Practical/research
P8.1i	estimate, for everyday road transport, the speed, accelerations and forces involved in large accelerations (M1d, M 2b, M2h, M3c)		M1d, M2b, M2h, M3c		

P8.2 Powering Earth

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 topics such as 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	Assessable 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

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
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.

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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)**		M1a, M1b, M1c, M1d, M2a, M3a, M3b, M3c, M3d		
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/research
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			

P8.3 Beyond Earth

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 and due to its proximity to us we have learnt most of our knowledge about stars from it.

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.

Assessable content			Opportunities for		
Learning outcomes		**To include**	**Maths**	**Working scientifically**	**Practical/research**
P8.3a	explain the red-shift of light from galaxies which are receding (qualitative only), that 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			
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 fusion energy	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.

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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 the 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)**				
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**			

Learning outcomes		To include	Maths	Working scientifically	Practical/research
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.

2d. Prior knowledge, learning and progression

- Learners in England who are beginning a GCSE (9–1) course are likely to have followed a Key Stage 3 programme of study and should have achieved a general educational level equivalent to National Curriculum Level 3.
- There are no prior qualifications required in order for learners to enter for a GCSE (9–1) in Physics A (Gateway Science) , nor is any prior knowledge or understanding required for entry onto this course.
- GCSEs (9–1) are qualifications that enable learners to progress to further qualifications either Vocational or General.

There are a number of Science specifications at OCR.

Find out more at www.ocr.org.uk

3 Assessment of GCSE (9–1) in Physics A (Gateway Science)

3a. Forms of assessment

The GCSE (9–1) in Physics A (Gateway Science) is a linear qualification with 100% external assessment.

OCR's GCSE (9–1) in Physics A (Gateway Science) consists of four examined papers that are externally assessed. Two are at Foundation tier and two are at Higher tier. Learners are entered for only the Foundation tier or Higher tier. Each paper carries an equal weighting of 50% for that tier of the GCSE (9–1) qualification. Each paper has a duration of 1 hour and 45 minutes.

Physics Paper 1 and Paper 3

These papers, one at Foundation tier and one at Higher tier, are each worth 90 marks, are split into two sections and assess content from Topics P1 to P4.

Section A contains multiple choice questions. This section of the paper is worth 15 marks.

Section B includes short answer question styles (practical, maths, structured questions) and an extended six-mark Level of Response question. This section of the paper is worth 75 marks.

Physics Paper 2 and Paper 4

These papers, one at Foundation tier and one at Higher tier, are each worth 90 marks, are split into two sections and assess content from Topics P5 to P8, with assumed knowledge of Topics P1 to P4.

Section A contains multiple choice questions. This section of the paper is worth 15 marks.

Section B includes short answer question styles (practical, maths, synoptic questions, structured questions) and an extended six-mark Level of Response question. This section of the paper is worth 75 marks, of which 18 marks will be synoptic.

3b. Assessment objectives (AO)

There are three Assessment Objectives in OCR GCSE (9–1) in Physics A (Gateway Science). These are detailed in the table below:

<table>
<tr><th colspan="2" rowspan="2">Assessment Objectives</th><th colspan="2">Weighting</th></tr>
<tr><th>Higher</th><th>Foundation</th></tr>
<tr><td>AO1</td><td>Demonstrate knowledge and understanding of:
• scientific ideas
• scientific techniques and procedures.</td><td>40%</td><td>40%</td></tr>
<tr><td>AO2</td><td>Apply knowledge and understanding of:
• scientific ideas
• scientific enquiry, techniques and procedures.</td><td>40%</td><td>40%</td></tr>
<tr><td>AO3</td><td>Analyse information and ideas to:
• interpret and evaluate
• make judgements and draw conclusions
• develop and improve experimental procedures.</td><td>20%</td><td>20%</td></tr>
</table>

AO weightings in OCR GCSE (9–1) in Physics A (Gateway Science)

The relationship between the Assessment Objectives and the components are shown in the following table:

	% of overall GCSE (9–1) in Physics A (Gateway Science) (J249)			
Component	**AO1**	**AO2**	**AO3**	**Total**
Paper 1 (Foundation tier) J249/01	20	20	10	50
Paper 2 (Foundation tier) J249/02	20	20	10	50
Total	40	40	20	100
Component	**AO1**	**AO2**	**AO3**	**Total**
Paper 1 (Higher tier) J249/03	20	20	10	50
Paper 2 (Higher tier) J249/04	20	20	10	50
Total	40	40	20	100

3c. Tiers

This scheme of assessment consists of two tiers: Foundation tier and Higher tier. Foundation tier assesses grades 5 to 1 and Higher tier assesses grades 9 to 4. An allowed grade 3 may be awarded on the Higher tier option for learners who are a small number of marks below the grade 3/4 boundary. Learners must be entered for either the Foundation tier or the Higher tier.

3d. Assessment availability

There will be one examination series available each year in May/June to **all** learners.

All examined papers must be taken in the same examination series at the end of the course.

This specification will be certificated from the June 2018 examination series onwards.

3e. Retaking the qualification

Learners can retake the qualification as many times as they wish.

They retake all the papers within a component to be awarded the qualification.

3f. Assessment of extended response

The assessment materials for this qualification provide learners with the opportunity to demonstrate their ability to construct and develop a sustained and coherent line of reasoning and marks for extended responses are integrated into the marking criteria.

Extended response questions are included in all externally assessed papers. At least one question in each paper will be marked by Level of Response, in which the quality of the extended response is explicitly rewarded. These questions will be clearly identified in the assessment papers by an asterisk

3g. Synoptic assessment

Synoptic assessment tests the learners' understanding of the connections between different elements of the subject.

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the GCSE (9–1) course. The emphasis of synoptic assessment is to encourage the development of the understanding of the subject as a discipline. Paper 2 and Paper 4 for each tier contain an element of synoptic assessment.

Synoptic assessment requires learners to make and use connections within and between different areas of physics, for example by:

- applying knowledge and understanding of more than one area to a particular situation or context
- using knowledge and understanding or principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

3h. Calculating qualification results

A learner's overall qualification grade for OCR GCSE (9–1) in Physics A (Gateway Science) will be calculated by adding together their marks from the two components taken to give their total weighted mark. This mark will then be compared to the qualification level grade boundaries for the entry option taken by the learner and for the relevant exam series to determine the learner's overall qualification grade.

4 Admin: what you need to know

The information in this section is designed to give an overview of the processes involved in administering this qualification so that you can speak to your exams officer. All of the following processes require you to submit something to OCR by a specific deadline.

More information about these processes, together with the deadlines, can be found in the OCR *Admin Guide and Entry Codes: 14–19 Qualifications*, which can be downloaded from the OCR website: www.ocr.org.uk

4a. Pre-assessment

Estimated entries

Estimated entries are your best projection of the number of learners who will be entered for a qualification in a particular series.

Estimated entries should be submitted to OCR by the specified deadline. They are free and do not commit your centre in any way.

Final entries

Final entries provide OCR with detailed data for each learner, showing each assessment to be taken. It is essential that you use the correct entry code, considering the relevant entry rules.

Final entries must be submitted to OCR by the published deadlines or late entry fees will apply.

All learners taking a GCSE (9–1) in Physics A (Gateway Science) must be entered for one of the following entry options:

Entry option		**Components**		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
J249 F	Physics A (Gateway Science) (Foundation tier)	01	Paper 1 (Foundation tier)	External Assessment
		02	Paper 2 (Foundation tier)	External Assessment
J249 H	Physics A (Gateway Science) (Higher tier)	03	Paper 3 (Higher tier)	External Assessment
		04	Paper 4 (Higher tier)	External Assessment

Each learner must be entered for either the Foundation tier **or** the Higher tier only. They cannot be entered for a combination of tiers.

4b. Special consideration

Special consideration is a post-assessment adjustment to marks or grades to reflect temporary injury, illness or other indisposition at the time the assessment was taken.

Detailed information about eligibility for special consideration can be found in the JCQ publication *A guide to the special consideration process*.4c.

4c. External assessment arrangements

Regulations governing examination arrangements are contained in the JCQ Instructions for conducting examinations.

4d. Results and certificates

Grade Scale

GCSE (9–1) qualifications are graded on the scale: 9–1, where 9 is the highest. Learners who fail to reach the minimum standard of 1 will be Unclassified (U). Only subjects in which grades 9 to 1 are attained will be recorded on certificates.

Results

Results are released to centres and learners for information and to allow any queries to be resolved before certificates are issued.

Centres will have access to the following results information for each learner:

- the grade for the qualification
- the raw mark for each component
- the total weighted mark for the qualification.

The following supporting information will be available:

- raw mark grade boundaries for each component
- weighted mark grade boundaries for each entry option.

Until certificates are issued, results are deemed to be provisional and may be subject to amendment.

A learner's final results will be recorded on an OCR certificate. The qualification title will be shown on the certificate as 'OCR Level 1/2 GCSE (9–1) in Physics A (Gateway Science)'.

4e. Post-results services

A number of post-results services are available:

- **Enquiries about results** – If you are not happy with the outcome of a learner's results, centres may submit an enquiry about results
- **Missing and incomplete results** – This service should be used if an individual subject result for a learner is missing, or the learner has been omitted entirely from the results supplied
- **Access to scripts** – Centres can request access to marked scripts.

4f. Malpractice

Any breach of the regulations for the conduct of examinations and non-exam assessment may constitute malpractice (which includes maladministration) and must be reported to OCR as soon as it is detected. Detailed information on malpractice can be found in the JCQ publication *Suspected Malpractice in Examinations and Assessments: Policies and Procedures*.

5 Appendices

5a. Grade descriptors

Ofqual to confirm.

5b. Overlap with other qualifications

There is a small degree of overlap between the content of this specification and those for GCSE (9–1) in Combined Science A (Gateway Science), GCSE (9–1) in Biology A (Gateway Science) and GCSE (9–1) in Chemistry A (Gateway Science) courses. The links between the specifications may allow for some co-teaching, particularly in the area of working scientifically.

5c. Accessibility

Reasonable adjustments and access arrangements allow learners with special educational needs, disabilities or temporary injuries to access the assessment and show what they know and can do, without changing the demands of the assessment. Applications for these should be made before the examination series. Detailed information about eligibility for access arrangements can be found in the JCQ *Access Arrangements and Reasonable Adjustments.*

The GCSE (9–1) qualification and subject criteria have been reviewed in order to identify any feature which could disadvantage learners who share a protected Characteristic as defined by the Equality Act 2010. All reasonable steps have been taken to minimise any such disadvantage.

5d. Equations in Physics

Learners are expected to recall and apply the following equations using standard S.I. units:

Reference	Assessable mathematical learning outcomes	Maths skills
PM1.1i	recall and apply: density (kg/m^3)= mass(kg)/volume (m^3)	M1a, M1b, M1c, M3b, M3c
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 speed (m/s) /time(s)	M1a, M3a, M3b, M3c, M3d
PM2.1iv	recall and apply: kinetic energy (J) = 0.5 x mass (kg) x $(\text{speed (m/s)})^2$	M1a, M1c, M2f, M3a, M3b, M3c, M3d
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
PM2.3i	recall and apply: force exerted by a spring(N) = extension(m) x spring constant(N/m)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3iii	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.vi	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
PM3.1i	recall and apply: charge flow (C)= current (A) x time (s)	M1a, M3c, M3d
PM3.2i	recall and apply: potential difference (V)= current (A) x resistance (□)	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) = (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
PM5.1i	recall and apply: wave speed (m/s) = frequency (Hz) x wavelength (m)	M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d
PM7.2i	recall and apply: efficiency = useful output energy transfer (J)/ input energy transfer (J)	M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d

Learners are expected to select and apply the following equations using standard S.I. units:

Reference	Assessable mathematical learning outcomes	Maths skills
PM1.2i	apply: change in thermal energy = m x specific heat capacity x change in temperature	M1a, M3b, M3c, M3d
PM1.2ii	apply: thermal energy for a change in state = m x specific latent heat	M1a, M3b, M3c, M3d
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
PM2.1iii	apply: (final velocity (m/s))^2 - (initial velocity (m/s))^2 = 2 x acceleration (m/s^2) x distance(m)	M1a, M1c, M2f, 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
PM4.2i	**apply: force on a conductor (at right angles to a magnetic field) carrying a current (N) = magnetic field strength (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
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

5e. Units in science

It is expected that learners will show understanding of the physical quantities and corresponding units, SI and derived units listed below. They will be able to use them in qualitative work and calculations. These units and their associated quantities are dimensionally independent.

Fundamental physical quantities		
Physical quantity	Unit(s)	SI unit(s)
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	degree Celsius; kelvin	ºC; K
Current	ampere	A
Voltage	volt	V

Derived quantities and units		
Physical quantity	Unit(s)	Unit(s)
Area	metre squared	m^2
Volume	metre cubed; litre	m^3; l
Density	kilogram per metre cubed	kg/m^3
Speed	metre per second	m/s
Gravitational field strength	Newton per kilogram	N/kg
Acceleration	metre per second squared	m/s^2
Specific heat capacity	Joule per kilogram per degree Celsius	J/kgºC
Specific latent heat	Joule per kilogram	J/kg

Other frequently used units in physics		
Physical quantity	Unit	Unit
Frequency	Hertz	Hz
Force	Newton	N
Energy	Joule	J
Power	Watt	W
Pressure	Pascal	Pa
Electric charge	Coulomb	C
Electric potential difference	Volt	V
Electric resistance	Ohm	Ω
Magnetic flux density	Tesla	T
Radioactivity	Becquerel	Bq
Chemical substance	mole	mol

5f. Working scientifically

The idea that science progresses through a cycle of hypothesis, experimentation, observation, theory development and review is encompassed in this section. It covers aspects of scientific thinking and aims to develop the scientific skills and conventions, fundamental to the study of science. The section also includes understanding of theories and applications of science, the practical aspects of scientific experimentation, and objective analysis and evaluation. This section will enable learners to develop an understanding of the processes and methods of science and, through consideration of the different types of scientific enquiry, learners will become equipped to answer scientific questions about the world around them. Learners will also develop and learn to apply skills in observation, modelling and problem-solving, with opportunities for these skills to be shown through links to specification content. Scientific-based claims require evaluative skills and these are also developed in this section with opportunities for contextual development highlighted. Learners should learn to evaluate through critical analysis of methodology, evidence and conclusions, both qualitatively and quantitatively.

Working scientifically is split into concepts (WS1) and practical skills (WS2). Both of these will be assessed in written examinations and WS2 may also be assessed through the practical activities (see Appendix 5i).

WS1: Working scientifically assessed in a written examination

Summary

The concepts and skills in this section can be assessed in written examinations. There are references to specific apparatus and methods through the content of the specification. WS1 is split into four parts to include the development of scientific thinking, experimental skills and strategies, analysis and evaluation of scientific data and scientific conventions.

WS1.1 Development of scientific thinking

Assessable Content		
Learning outcomes		To include
WS1.1a	understand how scientific methods and theories develop over time	new technology allowing new evidence to be collected and changing explanations as new evidence is found
WS1.1b	use models to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts	representational, spatial, descriptive, computational and mathematical models
WS1.1c	understand the power and limitations of science	how developments in science have led to increased understanding and improved quality of life and questions and problems that science cannot currently answer
WS1.1d	discuss ethical issues arising from developments in science	
WS1.1e	explain everyday and technological applications of science	
WS1.1f	evaluate associated personal, social, economic and environmental implications	

WS1.1g	make decisions based on the evaluation of evidence and arguments	
WS1.1h	evaluate risks both in practical science and the wider societal context	perception of risk in relation to data and consequences
WS1.1i	recognise the importance of peer review of results and of communicating results to a range of audiences	

WS1.2 Experimental skills and strategies

Assessable Content		
Learning outcomes		To include
WS1.2a	use scientific theories and explanations to develop hypotheses	
WS1.2b	plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena	
WS1.2c	apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment	
WS1.2d	recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative	
WS1.2e	evaluate methods and suggest possible improvements and further investigations	

WS1.3 Analysis and evaluation

Assessable Content		
Learning outcomes		To include
	Apply the cycle of collecting, presenting and analysing data, including:	
WS1.3a	presenting observations and other data using appropriate methods	methods to include descriptive, tabular diagrammatic and graphically
WS1.3b	translating data from one form to another	
WS1.3c	carrying out and representing mathematical and statistical analysis	statistical analysis to include arithmetic means, mode, median
WS1.3d	representing distributions of results and make estimations of uncertainty	
WS1.3e	interpreting observations and other data	data presentations to include verbal, diagrammatic, graphical, symbolic or numerical form interpretations to include identifying patterns and trends, making inferences and drawing conclusions
WS1.3f	presenting reasoned explanations	relating data to hypotheses
WS1.3g	evaluating data in terms of accuracy, precision, repeatability and reproducibility	
WS1.3h	identifying potential sources of random and systematic error	
WS1.3i	communicating the scientific rationale for investigations, methods used, findings and reasoned conclusions	presentations through paper-based presentations using diagrammatic, graphical, numerical and symbolic forms

WS1.4 Scientific vocabulary, quantities, units, symbols and nomenclature

Assessable Content		
Learning outcomes		To include
WS1.4a	use scientific vocabulary, terminology and definitions	
WS1.4b	recognise the importance of scientific quantities and understand how they are determined	
WS1.4c	use SI units and IUPAC chemical nomenclature unless inappropriate	SI units: kg, g, mg; km, m, mm; kJ, J
WS1.4d	use prefixes and powers of ten for orders of magnitude	tera, giga, mega, kilo, centi, milli, micro and nano
WS1.4e	interconvert units	
WS1.4f	use an appropriate number of significant figures in calculation	

WS2: Working scientifically skills demonstrated

Summary

A range of practical experiences are a vital part of a scientific study at this level. A wide range of practical skills will be addressed through the course, which are required for the development of investigative skills. Learners should be given the opportunity to practise their practical skills, which will also prepare them for the written examinations.

For further details of the practical activity requirement see section 5i.

Practical skills to be developed		
Learning outcomes		**To include**
WS2a	carry out experiments	due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations, and following written instructions
WS2b	make and record observations and measurements using a range of apparatus and methods	keeping appropriate records
WS2c	presenting observations using appropriate methods	methods to include descriptive, tabular diagrammatic and graphically
WS2d	communicating the scientific rationale for investigations, methods used, findings and reasoned conclusions	presentations through paper-based and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms

5g. Mathematical skills requirement

The assessment of quantitative skills would include at least 30% mathematical skills at the appropriate tier for physics.

These skills will be applied in the context of the relevant physics.

All mathematical content will be assessed within the lifetime of the specification. Skills shown in **bold** type will only be tested in the Higher tier papers.

The mathematical skills required for the GCSE (9–1) in biology (B), chemistry (C), physics (P) and combined science (CS) are shown in the table below.

	Mathematical skills	Subject			
1	Arithmetic and numerical computation				
a	Recognise and use expressions in decimal form	B	C	P	CS
b	Recognise expressions in standard form	B	C	P	CS
c	Use ratios, fractions and percentages	B	C	P	CS
d	Make estimates of the results of simple calculations, without using a calculator	B	C	P	CS
2	Handling data				
a	Use an appropriate number of significant figures	B	C	P	CS
b	Find arithmetic means	B	C	P	CS
c	Construct and interpret frequency tables and diagrams, bar charts and histograms	B	C	P	CS
d	Understand the principles of sampling as applied to scientific data	B			CS
e	Understand simple probability	B			CS
f	Understand the terms mean, mode and median	B		P	CS
g	Use a scatter diagram to identify a correlation between two variables	B		P	CS
h	Make order of magnitude calculations	B	C	P	CS
3	**Algebra**				
a	Understand and use the symbols: =, <, <<, >>, >, ∝, ~	B	C	P	CS
b	Change the subject of an equation		C	P	CS
c	Substitute numerical values into algebraic equations using appropriate units for physical quantities		C	P	CS
d	Solve simple algebraic equations	B		P	
4	**Graphs**				
a	Translate information between graphical and numeric form	B	C	P	CS
b	Understand that y=mx+c represents a linear relationship	B	C	P	CS
c	Plot two variables from experimental or other data	B	C	P	CS
d	Determine the slope and intercept of a linear graph	B	C	P	CS
e	Draw and use the slope of a tangent to a curve as a measure of rate of change		C		CS
f	Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate			P	CS
5	**Geometry and trigonometry**				
a	Use angular measures in degrees			P	CS
b	Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects		C	P	CS
c	Calculate areas of triangles and rectangles, surface areas and volumes of cubes.	B	C	P	CS

5h. Health and safety

In UK law, health and safety is primarily the responsibility of the employer. In a school or college the employer could be a local education authority, the governing body or board of trustees. Employees (teachers/lecturers, technicians etc.), have a legal duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 (as amended) and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful microorganisms is carried out, or hazardous chemicals are used or made, the employer must carry out a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at: https://www.ase.org.uk

For members, the CLEAPSS® guide, *PS90*, *Making and recording risk assessments in school science*[1] offers appropriate advice.

Most education employers have adopted nationally available publications as the basis for their Model Risk Assessments.

Where an employer has adopted model risk assessments an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the learners were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded in a "*point of use text* ", for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed for each practical activity, although a minority of employers may require this.

Where project work or investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or microorganisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS®.

[1] These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications website **www.cleapss.org.uk**. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to **www.cleapss.org.uk**.

5i. Practical activity requirements

OCR has split the requirements from the Department for Education 'GCSE subject content and assessment objectives' – Appendix 4 into eight Practical Activity Groups or PAGs. The following table illustrates the skills required for each PAG and an example practical that may be used to contribute to the PAG. Within the specification there are a number of suggested practicals that are illustrated in the 'opportunities for' column, which count towards each PAG. We are expecting that centres do a wide range of practical activities during the course. These can be the ones illustrated in the specification or can be practicals that are devised by the centre. Activities can range from whole investigations to simple starters and plenaries.

Safety is an overriding requirement for all practical work. Centres are responsible for ensuring appropriate safety procedures are followed whenever their learners complete practical work.

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

Learners will be expected to use suitable apparatus to make and record measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases. Learners should be encouraged to tackle complex and problem solving contexts.

Practical Activity Group	Skills	Example of a suitable activity (a range of practicals are included in the specification and centres can devise their own activity) *
P1 Materials	Use of measurements to determine densities of solid and liquid objects	Determination of the densities of a variety of objects, both solid and liquid.
P2 Forces	Measure and observe the effects of forces including the extension of springs	Hooke's law practical - investigation of forces on springs.
P3 Motion	Use of appropriate apparatus and techniques for measuring motion, including determination of rate of change of speed	Investigate acceleration of a trolley down a ramp.

P4 Measuring Waves	Observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/wavelength	Use a ripple tank to measure the speed, frequency and wavelength of a wave.
P5 Energy	Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers	Determination of the specific heat capacity of a material.
P6 Circuit components	Use of appropriate apparatus to explore the characteristics of a variety of circuit elements	Investigation of I-V characteristics of circuit elements.
P7 Series and Parallel Circuits	Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements to measure current, potential difference (voltage) and resistance	Investigation of the brightness of bulbs in series and parallel.
P8 Interactions of waves	Making observations of electromagnetic waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter	Investigation of the reflection of light off a plane mirror and the refraction of light through glass.

*** Centres are free to substitute alternative practical activities that also cover the skills from Appendix 5i (this table is derived from Appendix 5 of the Department for Education's document 'Biology, Chemistry and Physics GCSE subject content and assessment objectives'.**