Qualification Accredited

OCR
Oxford Cambridge and RSA

GCSE (9-1)
Specification

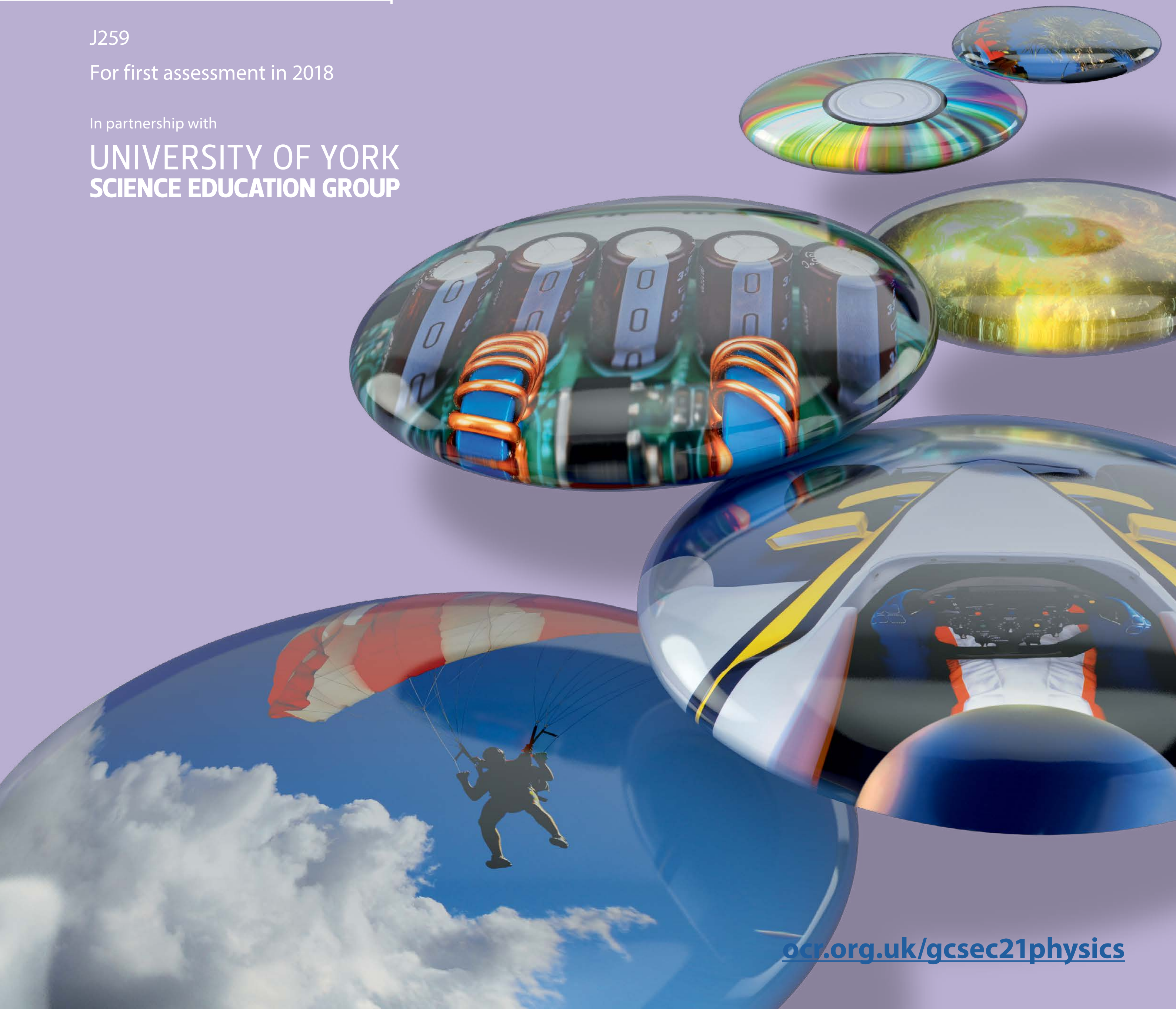
TWENTY FIRST CENTURY SCIENCE PHYSICS B

J259

For first assessment in 2018

In partnership with

UNIVERSITY OF YORK
SCIENCE EDUCATION GROUP



ocr.org.uk/gcsec21physics

Registered office:
1 Hills Road
Cambridge
CB1 2EU

OCR is an exempt charity.

We will inform centres about any changes to the specifications. We will also publish changes on our website. The latest version of our specifications will always be those on our website (**ocr.org.uk**) and these may differ from printed versions.

Oxford Cambridge and RSA is a Company Limited by Guarantee. Registered in England. Registered company number 3484466.

Contents

Support and Guidance

Introducing a new specification brings challenges for implementation and teaching, but it also opens up new opportunities. Our aim is to help you at every stage. We are working hard with teachers and other experts to bring you a package of practical support, resources and training.

Subject Specialists

OCR Subject Specialists provide information and support to centres including specification and non-exam assessment advice, updates on resource developments and a range of training opportunities.

Our Subject Specialists work with subject communities through a range of networks to ensure the sharing of ideas and expertise supporting teachers and students alike. They work with developers to help produce our specifications and the resources needed to support these qualifications during their development.

You can contact our Science Subject Specialists for specialist advice, guidance and support:

01223 553998
science@OCR.org.uk
@OCRScience

Teaching and learning resources

Our resources are designed to provide you with a range of teaching activities and suggestions that enable you to select the best activity, approach or context to support your teaching style and your particular students. The resources are a body of knowledge that will grow throughout the lifetime of the specification, they include:

- Delivery Guides
- Transition Guides
- Topic Exploration Packs
- Lesson Elements.

We also work with a number of leading publishers who publish textbooks and resources for our specifications. For more information on our publishing partners and their resources visit: ocr.org.uk/qualifications/gcse-and-a-level-reform/publishing-partners

Professional development

Our improved Professional Development Programme fulfils a range of needs through course selection, preparation for teaching, delivery and assessment. Whether you want to come to face-to-face events, look at our new digital training or search for training materials, you can find what you're looking for all in one place at the CPD Hub: cpdhub.ocr.org.uk

An introduction to new specifications

We run training events throughout the academic year that are designed to help prepare you for first teaching and support every stage of your delivery of the new qualifications.

To receive the latest information about the training we offer on GCSE and A Level, please register for email updates at: ocr.org.uk/i-want-to/email-updates

Assessment Preparation and Analysis Service

Along with subject-specific resources and tools, you'll also have access to a selection of generic resources that focus on skills development, professional guidance for teachers and results data analysis.

ExamCreator

Enabling you to build, mark and assess tests from OCR exam questions and produce a complete mock GCSE or A Level exam. Find out more at **ocr.org.uk/examcreator**

Subject Specialist Support

Our Subject Specialists provide you with access to specifications, high-quality teaching resources and assessment materials.

Practice Papers

Assess students' progress under formal examination conditions with question papers downloaded from a secure location, well-presented, easy-to-interpret mark schemes and commentary on marking and sample answers.

Skills Guides

These guides cover topics that could be relevant to a range of qualifications, for example communication, legislation and research.

Download the guides at **ocr.org.uk/skillsguides**

Active Results

Our free online results analysis service helps you review the performance of individual students or your whole cohort. For more details, please refer to **ocr.org.uk/activeresults**

1 Why choose an OCR GCSE (9–1) in Physics B (Twenty First Century 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 B (Twenty First Century 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 and Cambridge Technicals.

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 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 B (Twenty First Century Science) is QN601/8685/9

1b. Why choose an OCR GCSE (9–1) in Physics B (Twenty First Century Science)?

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

Physics A (Gateway Science) – 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 (Twenty First Century Science) – 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 physics 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.

Physics B (Twenty First Century Science) has been developed with the University of York Science Education Group (UYSEG) in conjunction with subject and teaching experts. Together we have aimed to produce a specification with up to date relevant content accompanied by a narrative to give context and an idea of the breath of teaching required. Our new GCSE (9–1) in Physics B (Twenty First Century Science) qualification builds on our existing popular course. We have based the development of our GCSE (9–1) sciences on an understanding of what works well in centres large and small. We have 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

GCSE study in the sciences provides the foundation for understanding the material world. Scientific understanding is changing our lives and is vital to world's future prosperity, and all learners should be taught essential aspects of the knowledge, methods, process and uses of science. They should be helped to appreciate how the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas relating to the sciences which are both inter-linked, and are of universal application. These key ideas include:

- the use of conceptual models and theories to make sense of the observed diversity of natural phenomena
- the assumption that every effect has one or more cause
- that change is driven by differences between different objects and systems when they interact
- that many such interactions occur over a distance and over time without direct contact
- that science progresses through a cycle of hypothesis, practical experimentation, observation, theory development and review
- that quantitative analysis is a central element both of many theories and of scientific methods of inquiry.

The Twenty First Century Science suite will enable learners to:

- develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and 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?

Building on research, and on the principles of *Beyond 2000*, the Twenty First Century Science suite was originally developed by the University of York Science Education Group (UYSEG), the Nuffield Foundation and OCR.

The 2016 suite continues to recognise the diversity of interests and future intentions of the learner population who take a science qualification at GCSE level. The specifications will prepare learners for progression to further study of science, whilst at the same time offering an engaging and satisfying course for those who choose not to study academic science further.

The Twenty First Century Science suite will:

- take opportunities to link science to issues relevant to all learners as citizens, and to the cultural aspects of science that are of value and interest to all
- develop learners' abilities to evaluate knowledge claims critically, by looking at the nature, quality and extent of the evidence, and at the arguments that link evidence to conclusions
- develop learners' understanding of the concepts and models that scientists use to explain natural phenomena
- develop learners' ability to plan and carry out practical investigations and their understanding of the role of experimental work in developing scientific explanations.

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).

You can contact the Science Subject Specialists:

E-mail: ScienceGCSE@ocr.org.uk
Telephone: 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:
https://twitter.com/ocr_science

2 The specification overview

2a. OCR's GCSE (9–1) in Physics B (Twenty First Century Science) (J259)

Learners are entered for either Foundation Tier (components 01 and 02) **or** Higher Tier (components 03 and 04) to be awarded the OCR GCSE (9–1) in Physics B (Twenty First Century Science).

2

Content Overview	Assessment Overview	
Foundation Tier, grades 1 to 5		
Content is split into eight teaching chapters: • Chapter P1: Radiation and waves • Chapter P2: Sustainable energy • Chapter P3: Electric circuits • Chapter P4: Explaining motion • Chapter P5: Radioactive materials • Chapter P6: Matter – models and explanations • Chapter P7: Ideas about Science • Chapter P8: Practical Skills Both papers assess content from all eight chapters.	Breadth in physics J259/01 90 marks 1 hour 45 minutes Written paper	**50%** of total GCSE
	Depth in physics J259/02 90 marks 1 hour 45 minutes Written paper	**50%** of total GCSE
Higher Tier, grades 4 to 9		
Content is split into eight teaching chapters: • Chapter P1: Radiation and waves • Chapter P2: Sustainable energy • Chapter P3: Electric circuits • Chapter P4: Explaining motion • Chapter P5: Radioactive materials • Chapter P6: Matter – models and explanations • Chapter P7: Ideas about Science • Chapter P8:Practical Skills Both papers assess content from all eight chapters.	Breadth in physics J259/03 90 marks 1 hour 45 minutes Written paper	**50%** of total GCSE
	Depth in physics J259/04 90 marks 1 hour 45 minutes Written paper	**50%** of total GCSE

2b. Content of GCSE (9–1) in Physics B (Twenty First Century Science) (J259)

2

Layout of specification content

The specification content is divided into eight chapters. The first six chapters describe the science content to be taught and assessed. The seventh chapter describes the *Ideas about Science* that should be taught; this will be assessed in contexts from any of the preceding chapters. The *Ideas about Science* cover the requirements of *Working Scientifically*. The final chapter describes the requirements for practical skills.

In the specification, the content that is assessable is presented in two columns: the teaching and learning narrative and the assessable learning outcomes. The narrative summarises the science story and provides context for the assessable learning outcomes thereby supporting the teaching of the specification. The assessable learning outcomes define the requirements for assessment and any contexts given in the narratives may also be assessed.

Within each chapter:

An overview summarises the science ideas included in the chapter, explaining why these ideas are relevant to learners living in the 21st century and why it is desirable for learners to understand them.

Following the overview is a summary of the knowledge and understanding that learners should have gained from study at Key Stages 1 to 3. Some of these ideas are repeated in the content of the specification and while this material need not be retaught, it can be drawn upon to develop ideas at GCSE (9–1).

Learning at GCSE (9–1) is described in the tables that follow:

Teaching and learning narrative	Assessable learning outcomes	*Linked learning opportunities*
The teaching and learning narrative summarises the science story, including relevant *Ideas about Science* to provide contexts for the assessable learning outcomes. The narrative is intended to support teaching and learning. The requirements for assessment are defined by the assessable learning outcomes and any given context.	The assessable learning outcomes set out the level of knowledge and understanding that learners are expected to demonstrate. The statements give guidance on the breadth and depth of learning. **Emboldened statements will only be assessed in Higher Tier papers.** The mathematical requirements in Appendix 5e are referenced by the prefix M to link the mathematical skills required to the areas of physics content where those mathematical skills could be linked to learning. Opportunities for carrying out practical activities are indicated throughout the specification and are referenced as *PAG1* to *PAG8* (Practical Activity Group; see Chapter P8). ⓘ *Advisory notes clarify the depth of cover required*	The linked learning opportunities suggest ways to develop *Ideas about Science* and practical skills in context, and also highlight links to ideas in other chapters. Note, however, that *Ideas about Science* and practical skills may be taught, and will be assessed, in any context.

The Assessment Objectives in Section 3b make clear the range of ways in which learners will be required to demonstrate their knowledge and understanding in the assessments, and the Sample Assessment Materials (provided on the OCR website at www.ocr.org.uk) provide examples.

Physics key ideas

Physics is the science of the fundamental concepts of field, force, radiation and particle structures, which are inter-linked to form unified models of the behaviour of the material universe. From such models, a wide range of ideas, from the broadest issue of the development of the universe over time to the numerous and detailed ways in which new technologies may be invented, have emerged. These have enriched both our basic understanding of, and our many adaptations to, our material environment.

Learners should be helped to understand how, through the ideas of physics, the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas which are of universal application and which include:

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

A summary of the content for the GCSE (9–1) Physics B (Twenty First Century Science) course is as follows:

Chapter P1: Radiation and waves	Chapter P2: Sustainable energy	Chapter P3: Electric circuits
P1.1 What are the risks and benefits of using radiations? P1.2 What is climate change and what is the evidence for it? P1.3 How do waves behave? P1.4 What happens when light and sound meet different materials? *(separate science only)*	P2.1 How much energy do we use? P2.2 How can electricity be generated?	P3.1 What is electric charge? *(separate science only)* P3.2 What determines the current in an electric circuit? P3.3 How do series and parallel circuits work? P3.4 What determines the rate of energy transfer in a circuit? P3.5 What are magnetic fields? P3.6 How do electric motors work? P3.7 What is the process inside an electric generator? *(separate science only)*

Chapter P4: Explaining motion	Chapter P5: Radioactive materials	Chapter P6: Matter – models and explanations
P4.1 What are forces? P4.2 How can we describe motion? P4.3 What is the connection between forces and motion? P4.4 How can we describe motion in terms of energy transfers?	P5.1 What is radioactivity? P5.2 How can radioactive materials be used safely? P5.3 How can radioactive materials be used to provide energy? *(separate science only)*	P6.1 How does energy transform matter? P6.2 How does the particle model explain the effects of heating? P6.3 How does the particle model relate to material under stress? P6.4 How does the particle model relate to pressure in fluids? *(separate science only)* P6.5 How can scientific models help us understand the Big Bang? *(separate science only)*

Chapter P7: Ideas about Science

IaS1 What needs to be considered when investigating phenomenon scientifically?
IaS4 How do science and technology impact society?
IaS2 What conclusions can we make from data?
IaS3 How are scientific explanations developed?

Chapter P8: Practical Skills

2c. Content of chapters P1 to P8

Chapter P1: Radiation and waves

Overview

There are two key science ideas in this chapter – the first considers the uses of electromagnetic radiation and the possible health risks of radiation; both in nature and from technological devices, which are becoming of increasing concern. The second part of the topic considers a wave model for light and sound.

Topic P1.1 describes the model of radiation, an important scientific model for explaining how one object can affect another at a distance, and links this to the idea that all parts of the electromagnetic spectrum behave in this way. It then goes on to use the radiation model to explain how electromagnetic radiation behaves and to consider the risks and benefits of the technologies that use electromagnetic radiation. In some cases, misunderstanding the term 'radiation' generates unnecessary alarm. Through considering the evidence concerning the possible harmful effects of low-intensity microwave radiation from devices such as mobile phones, learners learn to evaluate reported health studies and interpret levels of risk.

Topic P1.2 introduces the idea that all bodies emit radiation to explain the greenhouse effect. Evidence for global warming is explored; scientific explanations for climate change draw on ideas about the way that radiation is emitted and absorbed by different materials. There is an opportunity to use both physical analogies and computer modelling to demonstrate the explanatory power of models in science.

All waves have properties in common and a wave model can be used to explain a great many phenomena, both natural and artificial. In Topic P1.3 the reflection and refraction of waves on water provide evidence that light and sound can be modelled as waves. Finally Topic P1.4 considers the behaviour of light and sound as they pass through a material interface, including refraction of light in lenses and prisms and the use of sound and ultrasound in imaging and detection.

Learning about radiation and waves before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- have observed waves on water, spring, and strings
- know the meaning of the terms longitudinal, transverse, superposition, and frequency, in the context of waves
- know that sound waves are longitudinal and need a medium to travel through and that sound travels at different speeds in solids, in water, and in air
- know that sound is produced when objects vibrate and that sound waves are detected by the vibrations they cause
- know some of the similarities and differences between light waves and waves in matter
- be able to use a ray model of light to describe and explain reflection in mirrors, refraction and dispersion by glass and the action of convex lenses
- know that light incident on a surface may be absorbed, scattered, or reflected, and that light transfers energy from a source to an absorber, where it may cause a chemical or electrical effect.

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.

P1.1 What are the risks and benefits of using radiations?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
A model of radiation can be used to describe and predict the effects of some processes in which one object affects another some distance away. One object (a source) emits radiation (of some kind). This spreads out from the source and transfers energy to other object(s) some distance away. Light is one of a family of radiations, called the electromagnetic spectrum. All radiations in the electromagnetic spectrum travel at the same speed through space.	1. describe the main groupings of the electromagnetic spectrum – radio, microwave, infrared, visible (red to violet), ultraviolet, X-rays and gamma rays, that these range from long to short wavelengths, from low to high frequencies, and from low to high energies
	2. recall that our eyes can only detect a very limited range of frequencies in the electromagnetic spectrum
	3. recall that all electromagnetic radiation is transmitted through space with the same very high (but finite) speed
	4. explain, with examples, that electromagnetic radiation transfers energy from source to absorber
When radiation strikes an object, some may be transmitted (pass through it), or be reflected, or be absorbed. When radiation is absorbed it ceases to exist as radiation; usually it heats the absorber. Some types of electromagnetic radiation do not just cause heating when absorbed; X-rays, gamma rays and high energy ultraviolet radiation have enough energy to remove an electron from an atom or molecule (ionisation) which can then take part in other chemical reactions.	5. recall that different substances may absorb, transmit, or reflect electromagnetic radiation in ways that depend on wavelength
	6. 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

Linked learning opportunities

Practical work:

- Estimate the speed of microwaves using a microwave oven.
- Investigate how the intensity of radiation changes with distance from the source.

Specification links:

- Why are some materials radioactive? (P6.1)
- How can radioactive materials be used safely (P6 .2).
- How has our understanding of the atom developed over time? (C2.1)

P1.1 What are the risks and benefits of using radiations?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Exposure to large amounts of ionising radiation can cause damage to living cells; smaller amounts can causes changes to cells which may make them grow in an uncontrolled way, causing cancer. Oxygen is acted on by radiation to produce ozone in the upper atmosphere. This ozone absorbs ultraviolet radiation, and protects living organisms, especially animals, from its harmful effects. Radio waves are produced when there is an oscillating current in an electrical circuit. Radio waves are detected when the waves cause an oscillating current in a conductor. Different parts of the electromagnetic spectrum are used for different purposes due to differences in the ways they are reflected, absorbed, or transmitted by different materials. Developments in technology have made use of all parts of the electromagnetic spectrum; every development must be evaluated for the potential risks as well as the benefits (IaS4). Data and scientific explanations of mechanisms, rather than opinion, should be used to justify decisions about new technologies (IaS3).	7. recall that changes in molecules, atoms and nuclei can generate and absorb radiations over a wide frequency range, including: a) gamma rays are emitted from the nuclei of atoms b) X-rays, ultraviolet and visible light are generated when electrons in atoms lose energy c) high energy ultraviolet, gamma rays and X-rays have enough energy to cause ionisation when absorbed by some atoms d) ultraviolet is absorbed by oxygen to produce ozone, which also absorbs ultraviolet, protecting life on Earth e) infrared is emitted and absorbed by molecules
	8. describe how ultra-violet radiation, X-rays and gamma rays can have hazardous effects, notably on human bodily tissues
	9. give examples of some practical uses of electromagnetic radiation in the radio, microwave, infrared, visible, ultraviolet, X-ray and gamma ray regions of the spectrum
	10. recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits

Linked learning opportunities

Ideas about Science:

- Use the radiation model to predict and explain the behaviour of electromagnetic radiation (IaS3).

Practical work

- Investigate absorption, transmission and reflection of electromagnetic radiation e.g. absorption of ultraviolet by sunscreens, reflection and absorption of microwaves, or mobile phone signals.

Ideas about Science

- Discuss the different risks and benefits of technologies that use electromagnetic radiation (IaS4).

P1.2 What is climate change and what is the evidence for it?

Teaching and learning narrative	Assessable learning outcomes *Learners will be able to:*	
All objects emit electromagnetic radiation with a principal frequency that increases with temperature. The Earth is surrounded by an atmosphere which allows some of the electromagnetic radiation emitted by the Sun to pass through; this radiation warms the Earth's surface when it is absorbed. The radiation emitted by the Earth, which has a lower principal frequency than that emitted by the Sun, is absorbed and re-emitted in all directions by some gases in the atmosphere; this keeps the Earth warmer than it would otherwise be and is called the greenhouse effect. One of the main greenhouse gases in the Earth's atmosphere is carbon dioxide, which is present in very small amounts; other greenhouse gases include methane, present in very small amounts, and water vapour. During the past two hundred years, the amount of carbon dioxide in the atmosphere has been steadily rising, largely the result of burning increased amounts of fossil fuels as an energy source and cutting down or burning forests to clear land. Computer climate models provide evidence that human activities are causing global warming. As more data is collected using a range of technologies, the model can be refined further and better predictions made (IaS3).	1.	explain that all bodies emit radiation, and that the intensity and wavelength distribution of any emission depends on their temperatures
	2.	**explain how the temperature of a body is related to the balance between incoming radiation, absorbed radiation and radiation emitted; illustrate this balance, using everyday examples including examples of factors which determine the temperature of the Earth**

Linked opportunities

Specification Links
- What is the evidence for climate change? (C1.2)

Practical work:
- Investigate climate change models – both physical models and computer models.

Ideas about Science
- Use ideas about the way science explanations are developed when discussing climate change (IaS3).
- Use ideas about correlation and cause when discussing evidence for climate change (IaS3).

P1.3 How do waves behave?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
A wave is a regular disturbance that transfers energy in the direction that the wave travels, without transferring matter. For some waves (such as waves along a rope), the disturbance of the medium as the wave passes is at right-angles to its direction of motion. This is called a transverse wave. For other waves (such as a series of compression pulses on a slinky spring), the disturbance of the medium as the wave passes is parallel to its direction of motion. This is called a longitudinal wave. The speed of a wave depends on the medium it is travelling through. Its frequency is the number of waves each second that are made by the source. The wavelength of waves is the distance between the same points on two adjacent disturbances. The ways in which light and sound waves reflect and refract when they meet at an interface between two materials can be modelled with water waves. A wave model for light and sound can be used to describe and predict some behaviour of light and sound.	1. describe wave motion in terms of amplitude, wavelength, frequency and period 2. describe evidence that for both ripples on water surfaces and sound waves in air, it is the wave and not the water or air itself that travels 3. describe the difference between transverse and longitudinal waves 4. describe how waves on a rope are an example of transverse waves whilst sound waves in air are longitudinal waves 5. define wavelength and frequency 6. recall and apply the relationship between speed, frequency and wavelength to waves, including waves on water, sound waves and across the electromagnetic spectrum: wave speed (m/s) = frequency (Hz) × wavelength (m) M1a, M1c, M3c, M3d 7. a) describe how the speed of ripples on water surfaces and the speed of sound waves in air may be measured b) describe how to use a ripple tank to measure the speed/frequency and wavelength of a wave *PAG4* 8. a) describe the effects of reflection and refraction of waves at material interfaces b) describe how to measure the refraction of light through a prism *PAG8* c) describe how to investigate the reflection of light off a plane mirror *PAG8*

Linked learning opportunities

Ideas about Science

- Use the wave model to predict and explain the observed behaviour of light (IaS3).

Practical work:

- Carry out experiments to measure the speed of waves on water and the speed of sound in air.

P1.3 How do waves behave?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*		*Linked learning opportunities*
Refraction of light and sound can be explained by a change in speed of waves when they pass into a different medium; a change in the speed of a wave causes a change in wavelength since the frequency of the waves cannot change, and that this may cause a change in direction.	**9.**	**recall that waves travel in different substances at different speeds and that these speeds may vary with wavelength**	
	10.	**explain how refraction is related to differences in the speed of the waves in different substances**	
	11.	recall that light is an electromagnetic wave	
	12.	recall that electromagnetic waves are transverse	

P1.4 What happens when light and sound meet different materials? (*separate science only*)

Teaching and learning narrative

A beam of light is reflected from a smooth surface, such as a mirror, in a single beam which makes the same angle with the normal as the incident beam (specular reflection).

Light is scattered in all directions from an uneven surface.

Light is refracted at the boundary between glass (and water and Perspex) and air; this property is exploited in prisms and lenses.

When a beam of white light is passed through a prism, the emerging light beam is spread out showing the colours of the spectrum. This can be explained using the wave model, different colours have different wavelengths; different wavelengths travel at different speeds when passing through glass, water or Perspex.

What we perceive as white light is a mixture of different colours, ranging in wavelength from violet light (shortest visible wavelength) to red light (longest visible wavelength). A coloured filter works by allowing light of one or more wavelength through (transmission) and absorbing light of the other wavelengths.

An object appears white if it scatters all the colours of light that fall on it, and black if it scatters none (and absorbs all). It appears coloured if it scatters light of some colours and absorbs light of other colours. Its observed colour is that of the light it scatters.

Assessable learning outcomes

Learners will be required to:

1.	construct and interpret two-dimensional ray diagrams to illustrate specular reflection by mirrors *qualitative only* M5a, M5b
2.	construct and interpret two-dimensional ray diagrams to illustrate refraction at a plane surface and dispersion by a prism *qualitative only* M5a, M5b
3.	use ray diagrams to illustrate the similarities and differences between convex and concave lenses *qualitative only*
4.	describe the effects of transmission, and absorption of waves at material interfaces
5.	explain how colour is related to differential absorption, transmission, and scattering
6.	**describe, with examples, processes in which sound waves are transmitted though solids**
7.	**explain that transmission of sound through the bones in the ear works over a limited frequency range, and the relevance of this to human hearing**

Linked learning opportunities

Practical work:

- Trace light rays through glass blocks, prisms and lenses and when reflected from mirrors.
- Investigate the effects of looking at coloured object through coloured filters.
- Investigate the transmission of light and sound across interfaces.

P1.4 What happens when light and sound meet different materials? (*separate science only*)

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Sound travels better through solids and liquids than through air. The small bones in the middle ear transmit the sound waves from the air outside to the inner ear. The bones transmit frequencies most efficiently in the range 1 kHz and 3 kHz. **The ways in which sound waves are transmitted, reflected and refracted as they pass through liquids and solids are exploited in ultrasound imaging in medicine, in exploring the structure of the Earth and in using SONAR to explore under water.**	**8. 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:** **a) in our bodies (ultrasound imaging)** **b) in the Earth (earthquake waves)** **c) in deep water (SONAR)**	
	9. show how changes, in speed, frequency and wavelength, in transmission of sound waves from one medium to another, are inter-related M1c, M3c	

Chapter P2: Sustainable energy

Overview

Energy supply is one of the major issues that society must address in the immediate future.

Citizens are faced with complex choices and a variety of messages from energy supply companies, environmental groups, the media, scientists and politicians. Some maintain that renewable resources are capable of meeting our future needs, some advocate nuclear power, and some argue that drastic lifestyle changes are required. Decisions about energy use, whether at a personal or a national level, need to be informed by a quantitative understanding of the situation, and this is an underlying theme of the chapter.

Topic P2.1 quantifies the energy used by electrical devices introduces calculations of efficiency and considers ways of reducing dissipation in a variety of contexts. In Topic P2.2 national data on energy sources introduces a study of electricity generation and distribution; nuclear power generation, the burning of fossil fuels and renewable resources are compared and contrasted. Electrical safety in the home and a review the energy choices available to individuals, organisations and society are also included.

2

Learning about energy before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- have compared energy uses and costs in domestic contexts, including calculations using a variety of units
- have considered a variety of processes that involve transferring energy, including heating, changing motion, burning fuels and changing position in a field.

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.

P2.1 How much energy do we use?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Energy is considered as being stored in a limited number of ways: chemical, nuclear, kinetic, gravitational, elastic, thermal, electrostatic and electromagnetic and can be transferred from one to another by processes called working and heating. Electricity is a convenient way to transfer energy from source to the consumer because it is easily transmitted over distances and can be used to do work in many ways, including heating and driving motors which make things move or to lift weights. When energy is used to do work some energy is usually wasted in doing things other than the intended outcome, it is dissipated into the surroundings, ultimately into inaccessible thermal stores. The power of an appliance or device is a measure of the amount of energy it transfers each second, i.e. the rate at which it transfers energy.	1. describe how energy in chemical stores in batteries, or in fuels at the power station, is transferred by an electric current, doing work on domestic devices, such as motors or heaters
	2. explain, with reference to examples, the relationship between the power ratings for domestic electrical appliances, the time for which they are in use and the changes in stored energy when they are in use
	3. recall and apply the following equation in the context of energy transfers by electrical appliances: energy transferred (J, kWh) = power (W, kW) × time (s, h) M3b, M3c, M3d
	4. describe, with examples, where there are energy transfers in a system, that there is no net change to the total energy of a closed system *qualitative only*
	5. describe, with examples, system changes, where energy is dissipated, so that it is stored in less useful ways
	6. explain ways of reducing unwanted energy transfer e.g. through lubrication, thermal insulation
	7. describe the effects, on the rate of cooling of a building, of thickness and thermal conductivity of its walls *qualitative only*

Linked learning opportunities

Practical work

- Compare the power consumption of a variety of devices and relate it to the changes in stored energy.
- Investigate the effects of insulation on the rate of cooling.

Maths

- Calculate the cost of energy supplied by electricity given the power rating, the time and the cost per kWh (IaS2.2).

P2.1 How much energy do we use?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Sankey diagrams are used to show all the energy transfers in a system, including energy dissipated to the surroundings; the data can be used to calculate the efficiency of energy transfers.	8. recall and apply the equation: efficiency = useful energy transferred ÷ total energy transferred to calculate energy efficiency for any energy transfer, and **describe ways to increase efficiency** M1c	
	9. interpret and construct Sankey diagrams to show understanding that energy is conserved M4a	

P2.2 How can electricity be generated?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
The main energy resources that are available to humans are fossil fuels (oil, gas, coal), nuclear fuels, biofuels, wind, hydroelectric, tides and from the Sun.	1. describe the main energy resources available for use on Earth (including fossil fuels, nuclear fuel, biofuel, wind, hydroelectricity, the tides and the Sun)
In most power stations generators produce a voltage across a wire by spinning a magnet near the wire. Often an energy source is used to heat water; the steam produced drives a turbine which is coupled to an electrical generator. Other energy sources drive the generator directly.	2. explain the differences between renewable and non-renewable energy resources
	3. compare the ways in which the main energy resources are used to generate electricity M2c
The mains supply to our homes is an alternating voltage, at 50 Hz, 230 volts, but electricity is distributed through the National Grid at much higher voltages to reduce energy losses. Transformers are used to increase the voltage for transmission and then decrease the voltage for domestic use.	4. recall that the domestic supply in the UK is a.c., at 50 Hz and about 230 volts and explain the difference between direct and alternating voltage
	5. recall that, in the National Grid, transformers are used to transfer electrical power at high voltages from power stations, to the network and then used again to transfer power at lower voltages in each locality for domestic use
Most mains appliances are connected by a 3 core cable, containing live, neutral and earth wires.	6. recall the differences in function between the live, neutral and earth mains wires, and the potential differences between these wires; hence 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 any earthed object
The demand for energy is continually increasing and this raises issues about the availability and sustainability of energy sources and the environmental effects of using these sources. The introduction and development of new energy sources may provide new opportunities but also introduce technological and environmental challenges. The decisions about the energy sources that are used may be different for different people in different contexts (IaS4).	7. explain patterns and trends in the use of energy resources in domestic contexts, workplace contexts, and national contexts M2c

Linked learning opportunities

Specification links

- What determines the rate of energy transfer in a circuit? (P3.4)
- **What is the process inside a generator? (P3.7)**

Practical work

- Investigate factors affecting the output from solar panels and wind turbines.

Maths

- Use ideas about probability in the context of risk.
- Extract and interpret information about electricity generation and energy use presented in a variety of numerical and graphical forms.

Ideas about Science

- Discuss the risks and benefits of different ways of generating electricity and why different decisions on the same issue might be appropriate (IaS4.3–4.6, 4.11).

Chapter P3: Electric circuits

Overview

Known only by its effects, electricity provides an ideal vehicle to illustrate the use and power of scientific models. During the course of the 20th century, electrical engineers completely changed whole societies, by designing systems for electrical generation and distribution, and a whole range of electrical devices.

In this chapter, learners learn how scientists visualise what is going on inside circuits and predict circuit behaviour. Topic P3.1 introduces the idea of electric charge and electric fields. In Topic P3.2, models of charge moving through circuits driven by a voltage and against a resistance are introduced. A more general understanding of voltage as potential difference is then developed in Topic P3.3, which then continues with an exploration of the difference between series and parallel circuits, leading on to investigating the behaviour of various components in d.c. series circuits. Topic 3.4 concentrates on quantifying the energy transferred in electric circuits and how this is determined by both the potential difference and the current.

A reminder of earlier work on magnets and magnetic fields in Topic P3.5 leads into an introduction to the electric motor in Topic P3.6. Applications of electromagnetism and, in particular the electric motor, have revolutionised people's lives in so many ways – from very small motors used in medical contexts, to very large motors used to propel ships or pump water in pumped storage schemes. In Topic P3.7, the process of electromagnetic induction is placed in the context of power generation and the use of transformers in power distribution.

Learning about electric circuits before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- be familiar with the basic properties of magnets, and use these to explain and predict observations
- know that there is a magnetic field close to any wire carrying an electric current
- be aware of the existence of electric charge, and understand how simple electrostatic phenomena can be explained in terms of the movement of electrons between and within objects
- understand the idea of an electric circuit (a closed conducting loop containing a battery) that conducts an electric current and be able to predict the current in branches of a parallel circuit
- understand the idea of voltage as a measure of the 'strength' of a battery or power supply
- know that electrical resistance is measured in ohms and can be calculated by dividing the voltage across the component by the current through it
- know that the power ratings of electrical appliances are related to the rate at which the appliances transfers 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.

Learning about electric circuits at GCSE (9–1)

P3.1 What is electric charge? (*separate science only*)

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
When two objects are rubbed together they become charged, because electrons are transferred from one object to the other. Electrons are negatively charged. Objects with similar charges repel, and objects with opposite charges attract. Around every electric charge there is an electric field; in this region of space the effects of charge can be felt; when another charge enters the field there is an interaction between them and both charges experience a force.	1. 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 2. explain how transfer of electrons between objects can explain the phenomenon of static electricity 3. explain the concept of an electric field and how it helps to explain the phenomenon of static electricity

Linked learning opportunities

Practical work

- Demonstrate that there are forces between charged objects and that the effect diminishes with increasing distance between the charges.

P3.2 What determines the current in an electric circuit?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
An electric current is the rate of flow of charge; in an electric circuit the metal conductors (the components and wires) contain many charges that are free to move. When a circuit is made, the battery causes these free charges to move, and these charges are not used up but flow in a continuous loop. In a given circuit, the larger the potential difference across the power supply the bigger the current. Components (for example, resistors, lamps, motors) resist the flow of charge through them; the resistance of connecting wires is usually so small that it can be ignored. The larger the resistance in a given circuit, the smaller the current will be. Representational models of electric circuits use physical analogies to help think about how an electric circuit works, and to predict what happens when a variable is changed (IaS3).	1. recall that current is a rate of flow of charge, that for a charge to flow, a source of potential difference and a closed circuit are needed and that a current has the same value at any point in a single closed loop	**Ideas about Science** • Identify limitations in analogies used to represent electric circuits (IaS3). **Practical work** • Design and construct electric circuits to investigate the electrical properties of range of circuit components.
	2. recall and use the relationship between quantity of charge, current and time: charge (C) = current (A) × time (s) M1c, M3b, M3c, M3d	
	3. recall that current (*I*) depends on both resistance (*R*) and potential difference (*V*) and the units in which these quantities are measured	
	4. a) recall and apply the relationship between *I*, *R*, and *V*, to calculate the currents, potential differences and resistances in d.c. series circuits: potential difference (V) = current (A) × resistance (Ω) M1c, M3b, M3c, M3d b) describe an experiment to investigate the resistance of a wire and be able to draw the circuit diagram of the circuit used *PAG7*	
	5. recall that for some components the value of *R* remains constant (fixed resistors) but that in others it can change as the current changes (e.g. heating elements, lamp filaments)	
	6. a) use graphs to explore whether circuit elements are linear or non-linear and relate the curves produced to their function and properties M4c, M4d b) describe experiments to investigate the *I*-*V* characteristics of circuit elements. To include: lamps, diodes, LDRs and thermistors. Be able to draw circuit diagrams for the circuits used *PAG6*	
	7. represent circuits with the conventions of positive and negative terminals, and the symbols that represent common circuit elements, including filament lamps, diodes, LDRs and thermistors	

2

P3.3 How do series and parallel circuits work?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
When electric charge flows through a component (or device), work is done by the power supply and energy is transferred from it to the component and/or its surroundings. Potential difference measures the work done per unit charge. In a series circuit the charge passes through all the components, so the current through each component is the same and the work done on each unit of charge by the battery must equal the total work done by the unit of charge on the components. The potential difference (p.d.) is largest across the component with the greatest resistance and a change in the resistance of one component will result in a change in the potential differences across all the components. In a parallel circuit each charge passes through only one branch of the circuit, so the current through each branch is the same as if it were the only branch present and the work done by each unit of charge is the same for each branch and equal to the work done by the battery on each charge. The current is largest through the component with the smallest resistance, because the same battery p.d. causes a larger current to flow through a smaller resistance than through a bigger one. When two or more resistors are placed in series the effective resistance of the combination (equivalent resistance) is equal to the sum of their resistances, because the battery has to move charges through all of them. Two (or more) resistors in parallel provide more paths for charges to move along than either resistor on its own, so the effective resistance is less. Some components are designed to change resistance in response to changes in the environment e.g. the resistance of an LDR varies with light intensity, the resistance of a thermistor varies with temperature; these properties used in sensing systems to monitor changes in the environment.	1. relate the potential difference between two points in the circuit to the work done on, or by, a given amount of charge as it moves between these points potential difference (V) = work done (energy transferred) (J) ÷ charge (C) M1c, M3b, M3c, M3d 2. a) describe the difference between series and parallel circuits: to include ideas about how the current through each component and the potential difference across each component is affected by a change in resistance of a component b) describe how to practically investigate the brightness of bulbs in series and parallel circuits. Be able to draw circuit diagrams for the circuits used *PAG7* 3. explain, why, if two resistors are in series the net resistance is increased, whereas with two in parallel the net resistance is decreased *qualitative only* 4. solve problems for circuits which include resistors in series, using the concept of equivalent resistance M1c, M3b, M3c, M3d 5. explain the design and use of d.c. series circuits for measurement and testing purposes including exploring the effect of: a) changing current in filament lamps, diodes, thermistors and LDRs b) changing light intensity on an LDR c) changing temperature of a thermistor (NTC only)

Linked learning opportunities

Ideas about Science

- Link the features of a model or analogy to features in an electric circuit, identify evidence for specific aspects of a model and limitations in representations of a model (IaS3).

Practical work

- Use d.c. series circuits, including potential divider circuits to investigate the behaviour of a variety of components.
- Design and construct electric circuits to use a sensor for a particular purpose.

P3.4 What determines the rate of energy transfer in a circuit?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
The energy transferred when electric charge flows through a component (or device), depends on the amount of charge that passes and the potential difference across the component. The power rating (in watts, W) of an electrical device is a measure of the rate at which an electrical power supply transfers energy to the device and/or its surroundings. The rate of energy transfer depends on both the potential difference and the current. The greater the potential difference, the faster the charges move through the circuit, and the more energy each charge transfers. The National Grid uses transformers to step down the current for power transmission. The power output from a transformer cannot be greater than the power input, therefore if the current increases, the potential difference must decrease. Transmitting power with a lower current through the cables results in less power being dissipated during transmission.	1. describe the energy transfers that take place when a system is changed by work done when a current flows through a component
	2. explain, with reference to examples, how the power transfer in any circuit device is related to the energy transferred from the power supply to the device and its surroundings over a given time: power (W) = energy (J) ÷ time (s) M1c, M3b, M3c, M3d
	3. recall and use the relationship between the potential difference across the component and the total charge to calculate the energy transferred in an electric circuit when a current flows through a component: energy transferred (work done) (J) = charge (C) × potential difference (V) M1c, M3b, M3c, M3d
	4. recall and apply the relationships between power transferred in any circuit device, the potential difference across it, the current through it, and its resistance: power (W) = potential difference (V) × current (A) power (W) = (current (A))^2 × resistance (Ω) M1c, M3b, M3c, M3d
	5. use the idea of conservation of energy to show that when a transformer steps up the voltage, the output current must decrease and vice versa a) select and use the equation: potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil M1c, M3b, M3c, M3d
	6. explain how transmitting power at higher voltages is more efficient way to transfer energy

Linked learning opportunities

Practical work

- Compare the power consumption of a variety of devices and relate it to the current passing through the device.

P3.5 What are magnetic fields?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Around any magnet there is a region, called the magnetic field, in which another magnet experiences a force. The magnetic effect is strongest at the poles. The field gets gradually weaker with distance from the magnet. The direction and strength of a magnetic field can be represented by field lines. These show the direction of the force that would be experienced by the N pole of a small magnet, placed in the field. The magnetic field around the Earth, with poles near the geographic north and south, provides evidence that the core of the Earth is magnetic. The N-pole of a magnetic compass will point towards the magnetic north pole. Magnetic materials (such as iron and nickel) can be induced to become magnets by placing them in a magnetic field. When the field is removed permanent magnets retain their magnetisation whilst other materials lose their magnetisation. When there is an electric current in a wire, there is a magnetic field around the wire; the field lines form concentric circles around the wire. Winding the wire into a coil (solenoid) makes the magnetic field stronger, as the fields of each turn add together. Winding the coil around an iron core makes a stronger magnetic field and an electromagnet that can be switched on and off. In loudspeakers and headphones the magnetic field produced due to a current through a coil interacts with the field of a permanent magnet. The 19th century discovery of this electromagnetic effect led quickly to the invention of a number of magnetic devices, including electromagnetic relays, which formed the basis of the telegraph system, leading to a communications revolution (IaS4.1).	1. describe the attraction and repulsion between unlike and like poles for permanent magnets 2. describe the characteristics of the magnetic field of a magnet, showing how strength and direction change from one point to another 3. explain how the behaviour of a magnetic compass is related to evidence that the core of the Earth must be magnetic 4. describe the difference between permanent and induced magnets 5. describe how to show that a current can create a magnetic effect 6. describe the pattern and directions of the magnetic field around a conducting wire 7. recall that the strength of the field depends on the current and the distance from the conductor 8. explain how the magnetic effect of a solenoid can be increased **9. explain how a solenoid can be used to generate sound in loudspeakers and headphones** *(separate science only)*

Linked learning opportunities

Specification links
- Sound waves (P1.4).

Practical work
- Use plotting compasses to map the magnetic field near a permanent bar magnet, between facing like/opposite poles of two magnets, a single wire, a flat coil of wire and a solenoid.
- Investigate the relationship between the number of turns on a solenoid and the strength of the magnetic field.
- **Build a loudspeaker.**

Ideas about Science
- Developments of electromagnets have led to major changes in people's lives, including applications in communications systems, MRI scanners and on cranes in scrapyards.

P3.6 How do electric motors work?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	
The magnetic fields of a current-carrying wire and a nearby permanent magnet will interact and the wire and magnet exert a force on each other. This is called the 'motor effect'. **If the current-carrying wire is placed at right angles to the magnetic field lines, the force will be at right angles to both the current direction and the lines of force of the field. The direction of the force can be inferred using Fleming's left-hand rule.** **The size of the force is proportional to the length of wire in the field, the current and the strength of the field.** **The motor effect can result in a turning force on a rectangular current-carrying coil placed in a uniform magnetic field; this is the principle behind all electric motors.** **The invention and development of practical electric motors have made an impact on almost every aspect of daily life (IaS4.1).**	**1.**	**describe the interaction forces between a magnet and a current-carrying conductor to include ideas about magnetic fields**
	2.	**show that Fleming's left-hand rule represents the relative orientations of the force, the conductor and the magnetic field**
	3.	**select and apply the equation that links the force (F) on a conductor to the strength of the field (B), the size of the current (I) and the length of conductor (l) to calculate the forces involved:** **force (N) = magnetic field strength (T) × current (A) × length of conductor (m)** M1b, M1c, M3b, M3c, M3d
	4.	**explain how the force on a conductor in a magnetic field is used to cause rotation in the rectangular coil of a simple electric motor** ⓘ ***Detailed knowledge of the construction of motors not required***

Linked learning opportunities

Practical work

- Investigate the motor effect for a single wire in a magnetic field and apply the principles to build a simple electric motor.
- Build a simple electric motor and explain how it works.

Ideas about Science

- Describe and explain examples of uses of electric motors that have made significant improvements to people's lives. (IaS4.1).

P3.7 What is the process inside an electric generator? (*separate science only*)

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Mains electricity is produced using the process of electromagnetic induction. When a magnet is moving into a coil of wire a potential difference is induced across the ends of the coil; if the magnet is moving out of the coil, or the other pole of the magnet is moving into it, there is a potential difference induced in the opposite direction. If the ends of the coil are connected to make a closed circuit, a current will flow round the circuit. In a moving coil microphone sound waves cause a diaphragm to vibrate. The diaphragm is attached to a coil which is in the field of a permanent magnet. Sounds make the coil vibrate, inducing a changing potential difference across the ends of the coil. This potential difference drives a changing current in an electric circuit. **In a generator, a magnet or electromagnet is rotated within a coil of wire to induce a voltage across the ends of the coil.** **The induced voltage across the coil of an alternating current (a.c.) generator (and hence the current in an external circuit) changes during each revolution of the magnet or electromagnet.** **To generate a d.c. split-ring commutator is used so that the current always passes from the same side of the generator.**	**1. 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** **2. explain the action of a moving coil microphone in converting the pressure variations in sound waves into variations in current in electrical circuits** **3. recall that the direction of the induced potential difference drives a current which generates a second magnetic field that would oppose the original change in field** **4. use ideas about electromagnetic induction to explain a potential difference/time graph showing the output from an alternator being used to generate a.c.** **5. explain how an alternator can be adapted to produce a dynamo to generate d.c., including explaining a potential difference/time graph** **6. explain how the effect of an alternating current in one circuit in inducing a current in another is used in transformers** **7. describe how the ratio of the potential differences across the two circuits of a transformer depends on the ratio of the numbers of turns in each**

Linked learning opportunities

Specification links
- How can electricity be generated? (P2.2)
- Sound waves (P1.4).

Practical work
- Investigate electromagnetic induction in transformers and generators.

Ideas about Science
- Describe and explain examples of technological applications of science that have made significant positive differences to people's lives (IaS4).
- Identify examples of risks which arise from a new scientific or technological advance (IaS4).

P3.7 What is the process inside an electric generator? (*separate science only*)

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
A changing magnetic field caused by changes in the current in one coil of wire can induce a voltage in a neighbouring coil. **A simple transformer has two coils of wire wound on an iron core; a changing current in one coil of a transformer will cause a changing magnetic field in the iron core, which in turn will induce a changing potential difference across the other transformer coil.** **The discovery of electromagnetic induction and the subsequent development of power generators transformed the way we live, although with new developments in technology there are often unintended consequences (IaS4).**	**8. apply the equations linking the potential differences and numbers of turns in the two coils of a transformer, to the currents and the power transfer involved and relate these to the advantages of power transmission at high voltages:** **a) potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil** **b) potential difference across primary coil ÷ potential difference across secondary coil = number of turns in primary coil ÷ number of turns in secondary coil** M1c, M3b, M3c	

Chapter P4: Explaining motion

Overview

Simple but counterintuitive concepts of forces and motion, developed by Galileo and Newton, can transform young people's insight into everyday phenomena. These ideas also underpin an enormous range of modern applications, including spacecraft, urban mass transit systems, sports equipment and rides at theme parks.

Topic P4.1 reviews the idea of forces: identifying, describing and using forces to explain simple situations. Topic P4.2 looks at how speed is measured and represented graphically and introduces the vector quantities of velocity and displacement. The relationships between distance, speed, acceleration and time are an example of simple mathematical modelling that can be used to predict the speed and position of a moving object.

The relationship between forces and motion is developed in Topic P4.3, where resultant forces and changes in momentum are described. These ideas are then applied in the context of road safety.

Topic P4.4 considers how we can describe motion in terms of energy transfers.

Learning about forces and motion before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- describe motion using words and with distance–time graphs
- use the relationship average speed = distance ÷ time
- identify the forces when two objects in contact interact; pushing, pulling, squashing, friction, turning
- use arrows to indicate the different forces acting on objects, and predict the net force when two or more forces act on an object
- know that the forces due to gravity, magnetism and electric charge are all non-contact forces
- understand how the forces acting on an object can be used to explain its motion.

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.

Learning about motion at GCSE (9–1)

P4.1 What are forces?

Teaching and learning narrative	Assessable learning outcomes *Learners will be able to:*
Force arises from an interaction between two objects, and when two objects interact, both always experience a force and that these two forces form an interaction pair. The two forces in an interaction pair are the same kind of force, equal in size and opposite in direction, and act on different objects (Newton's third law). Friction is the interaction between two surfaces that slide (or tend to slide) relative to each other: each surface experiences a force in the direction that prevents (or tends to prevent) relative movement. There is an interaction between an object and the surface it is resting on: the object pushes down on the surface, the surface pushes up on the object with an equal force, and this is called the normal contact force. In everyday situations, a downward force acts on every object, due to the gravitational attraction of the Earth. This is called its weight. It can be measured (in N) using a spring (or top-pan) balance. The weight of an object is proportional to its mass. Near the Earth's surface, the weight of a 1 kg object is roughly 10 N. The Earth's gravitational field strength is therefore 10 N/kg. Newton's insight that linked the force that causes objects to fall to Earth with the force that keeps the Moon in orbit around the Earth led to the first universal law of nature.	1. recall and apply Newton's third law 2. recall examples of ways in which objects interact: by gravity, electrostatics, magnetism and by contact (including normal contact force and friction) 3. describe how examples of gravitational, electrostatic, magnetic and contact forces involve interactions between pairs of objects which produce a force on each object 4. represent interaction forces as vectors 5. define weight 6. describe how weight is measured 7. recall and apply the relationship between the weight of an object, its mass and the gravitational field strength: weight (N) = mass (kg) × gravitational field strength (N/kg) M1c, M3b, M3c

Linked opportunities

Practical work

- Investigate the effect of different combinations of surfaces on the frictional forces.

Ideas about science

- Explain how Newton's discovery of the universal nature of gravity is an example of the role of imagination in scientific discovery (IaS3).

P4.2 How can we describe motion?

Teaching and learning narrative	Assessable learning outcomes *Learners will be able to:*
The motion of a moving object can be described using the speed the object is moving, the direction it is travelling and whether the speed is changing. The distance an object has travelled at a given moment is measured along the path it has taken. The displacement of an object at a given moment is its net distance from its starting point together with an indication of direction. The velocity of an object at a given moment is its speed at that moment, together with an indication of its direction. Distance and speed are scalar quantities; they give no indication of direction of motion. Displacement and velocity are vector quantities, and include information about the direction. In everyday situations, acceleration is used to mean the change in speed of an object in a given time interval. Distance–time graphs and speed-time graphs can be used to describe motion. The average speed can be calculated from the slope of a distance–time graph. The average acceleration of an object moving in a straight line can be calculated from a speed-time graph. The distance travelled can be calculated from the area under the line on a speed-time graph.	1. recall and apply the relationship: average speed (m/s) = distance (m) ÷ time (s) M1a, M1c, M3b, M3c, M3d 2. recall typical speeds encountered in everyday experience for wind, and sound, and for walking, running, cycling and other transportation systems 3. a) make measurements of distances and times, and calculate speeds b) describe how to use appropriate apparatus and techniques to investigate the speed of a trolley down a ramp M2b, M2f *PAG3* 4. make calculations using ratios and proportional reasoning to convert units, to include between m/s and km/h M1c, M3c 5. explain the vector–scalar distinction as it applies to displacement and distance, velocity and speed 6. a) recall and apply the relationship: acceleration (m/s^2) = change in speed (m/s) ÷ time taken (s) M1c, M3b, M3c, M3d b) explain how to use appropriate apparatus and techniques to investigate acceleration *PAG3* 7. select and apply the relationship: (final speed (m/s))^2 – (initial speed(m/s))^2 = 2 × acceleration (m/s^2) × distance (m) M1a, M1c, M3b, M3c, M3d

Linked opportunities

Practical work:
- Use a variety of methods to measure distances, speeds and times and to calculate acceleration.
- Compare methods of measuring the acceleration due to gravity.

Ideas about Science
- Use mathematical and computational models to make predictions about the motion of moving objects (IaS3).
- Explore using simple computer models to predict motion of a moving object.

P4.2 How can we describe motion?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be able to:*	*Linked opportunities*
The mathematical relationships between acceleration, speed, distance, and time are a simple example of a computational model. The model can be used to predict the speed and position of an object moving at constant speed or with constant acceleration.	8. draw and use graphs of distances and speeds against time to determine the speeds and accelerations involved	
	9. interpret distance–time and velocity–time graphs, including relating the lines and slopes in such graphs to the motion represented M4a, M4b, M4c, M4d	
	10. interpret enclosed areas in velocity – time graphs M4a, M4b, M4c, M4d, M4f	
	11. recall the value of acceleration in free fall and calculate the magnitudes of everyday accelerations using suitable estimates of speeds and times	

P4.3 What is the connection between forces and motion?

Teaching and learning narrative	Assessable learning outcomes *Learners will be able to:*
When forces act on an object the resultant force is the sum of all the individual forces acting on it, taking their directions into account. **If a resultant force acts on an object, it causes a change of momentum in the direction of the force.** **The size of the change of momentum of an object is proportional to the size of the resultant force acting on the object and to the time for which it acts (Newton's second law).** For an object moving in a straight line: a. if the resultant force is zero, the object will move at constant speed in a straight line (Newton's first law). b. if the resultant force is in the direction of the motion, the object will speed up (accelerate). c. if the resultant force is in the opposite direction to the motion, the object will slow down. **In situations involving a change in momentum (such as a collision), the longer the duration of the impact, the smaller the average force for a given change in momentum.** In situations where the resultant force on a moving object is not in the line of motion, the force will cause a change in direction. **If the force is perpendicular to the direction of motion the object will move in a circle at a constant speed – the speed doesn't change but the velocity does. For example, a planet in orbit around the Sun – gravity acts along the radius of the orbit, at right angles to the planet's path.**	1. describe examples of the forces acting on an isolated solid object or system 2. describe, using free body diagrams, examples where several forces lead to a resultant force on an object and the special case of balanced forces (equilibrium) when the resultant force is zero *qualitative only* **3. use scale drawings of vector diagrams to illustrate the addition of two or more forces, in situations when there is a net force, or equilibrium** ⓘ ***Limited to parallel and perpendicular vectors only*** M4a, M5a, M5b **4. recall and apply the equation for momentum and describe examples of the conservation of momentum in collisions:** **momentum (kg m/s) = mass (kg) × velocity (m/s)** M1c, M3b, M3c, M3d **5. select and apply Newton's second law in calculations relating force, change in momentum and time:** **change of momentum (kg m/s) =** **resultant force (N) × time for which it acts (s)** M1c, M3b, M3c, M3d 6. apply Newton's first law to explain the motion of objects moving with uniform velocity and also the motion of objects where the speed and/or direction changes **7. explain with examples that motion in a circular orbit involves constant speed but changing velocity** ***qualitative only***

Linked opportunities

Practical work

- Investigate factors that might affect human reaction times.
- Investigate the use of crumple zones to reduce the stopping forces.

P4.3 What is the connection between forces and motion?

Teaching and learning narrative	Assessable learning outcomes *Learners will be able to:*	*Linked opportunities*
In some situations a resultant force acts to make an object rotate about a fixed point (pivot). The rotational effect is called the moment of the force; the further the force acts from the pivot, the greater the turning effect. Levers and gears are used to transmit rotational forces.	8. describe examples in which forces cause rotation *(separate science only)* 9. define and calculate the moment of examples of rotational forces using the equation: moment of a force (N m) = force (N) × distance (m) (normal to direction of the force) *(separate science only)* M1c, M3b, M3c, M3d 10. explain, with examples, how levers and gears transmit the rotational effects of forces *(separate science only)*	**Practical work** • **Investigate forces that cause rotation, including the use of levers and gears.**
The mass of an object can be thought of as the amount of matter in an object – the sum of all the atoms that make it up. Mass is measured in kilograms. The mass of an object is also a measure of its resistance to any change in its motion (its inertia); using this definition the inertial mass is the ratio of the force applied to the resulting acceleration. **Newton wrote about how the length of time a force acted on an object would change the object's 'amount of motion', and the way he used the term makes it clear that he is describing what we now call momentum, this has led to Newton's second law being expressed in two ways – in terms of change in momentum and in terms of acceleration.** Newton's explanation of motion is one of the great intellectual leaps of humanity. It is a good example of the need for creativity and imagination to develop a scientific explanation of something that had been observed and discussed for many years (IaS3).	**11. explain that inertial mass is a measure of how difficult it is to change the velocity of an object and that it is defined as the ratio of force over acceleration** 12. recall and apply Newton's second law relating force, mass and acceleration: force (N) = mass (kg) × acceleration (m/s^2) M1c, M3b, M3c, M3d 13. Use and apply equations relating force, mass, velocity, acceleration, and **momentum** to explain relationships between the quantities M3b, M3c, M3d	**Ideas about Science** • Explain why Newton's explanation of motion is an example of the need for creative thinking in developing new scientific explanations (IaS3).

P4.3 What is the connection between forces and motion?

Teaching and learning narrative	Assessable learning outcomes *Learners will be able to:*	*Linked opportunities*
Ideas about force and **momentum** can be used to explain road safety measures, such as stopping distances, car seatbelts, crumple zones, air bags, and cycle and motorcycle helmets. Improvements in technology based on Newton's laws of motion (together with the development of new materials) have made all forms of travel much safer.	14. explain methods of measuring human reaction times and recall typical results 15. explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies and the implications for safety M2c **16.** explain the dangers caused by large decelerations **and estimate the forces involved in typical situations on a public road** 17. given suitable data, estimate the distance required for road vehicles to stop in an emergency, and describe how the distance varies over a range of typical speeds *(separate science only)* M1c, M1d, M2c, M2h, M3b, M3c 18. in the context of everyday road transport, use estimates of speeds, times and masses to calculate the accelerations and forces involved in events where large accelerations occur *(separate science only)* M1d, M2b, M2h, M3c	**Ideas about Science** • Describe and explain examples of how application of Newton's laws of motion have led developments in road safety (IaS4). • Discuss people's willingness to accept risk in the context of car safety and explain ways in which the risks can be reduced (IaS4).

P4.4 How can we describe motion in terms of energy transfers?

Teaching and learning narrative

Energy is always conserved in any event or process. Energy calculations can be used to find out if something is possible and what will happen, but not explain why it happens.

The store of energy of a moving object is called its kinetic energy.

As an object is raised, its store of gravitational potential energy increases, and as it falls, its gravitational potential energy decreases.

When a force moves an object, it does work on the object, energy is transferred to the object; when work is done by an object, energy is transferred from the object to something else, for example:

- when an object is lifted to a higher position above the ground, work is done by the lifting force; this increases the store of gravitational potential energy.
- when a force acting on an object makes its velocity increase, the force does work on the object and this results in an increase in its store of kinetic energy.

If friction and air resistance can be ignored, an object's store of kinetic energy changes by an amount equal to the work done on it by an applied force; in practice air resistance or friction will cause the gain in kinetic energy to be less than the work done on it by an applied force in the direction of motion, because some energy is dissipated through heating.

Assessable learning outcomes

Learners will be able to:

1. describe the energy transfers involved when a system is changed by work done by forces including:
   a) to raise an object above ground level
   b) to move an object along the line of action of the force
2. recall and apply the relationship to calculate the work done (energy transferred) by a force:
   work done (Nm or J) = force (N) × distance (m) (along the line of action of the force)
   M1a, M3b, M3c, M3d
3. recall the equation and calculate the amount of energy associated with a moving object:
   kinetic energy (J) = 0.5 × mass (kg) × (speed (m/s))^2
   M1a, M3b, M3c, M3d
4. recall the equation and calculate the amount of energy associated with an object raised above ground level
   gravitational potential energy (J) = mass (kg) × gravitational field strength (N/kg) × height (m)
   M1a, M3b, M3c, M3d
5. make calculations of the energy transfers associated with changes in a system, recalling relevant equations for mechanical processes
   M1a, M1c, M3c
6. calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules
   M1c, M3c

Linked opportunities

Specification links:

- **P2 Sustainable energy.**

Practical work

- Use datalogging software to calculate the efficiency of energy transfers when work is done on a moving object.
- Measure the work done by an electric motor lifting a load, and calculate the efficiency.

P4.4 How can we describe motion in terms of energy transfers?

Teaching and learning narrative	Assessable learning outcomes *Learners will be able to:*	*Linked opportunities*
Calculating the work done when climbing stairs or lifting a load, and the power output, makes a link back to the usefulness of electrical appliances for doing many everyday tasks.	7. describe all the changes involved in the way energy is stored when a system changes, for common situations: including 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	
	8. explain, with reference to examples, the definition of power as the rate at which energy is transferred (work done) in a system	
	9. recall and apply the relationship: power (W) = energy transferred (J) ÷ time (s) M1a, M3b, M3c, M3d	

Chapter P5: Radioactive materials

Overview

The terms 'radiation' and 'radioactivity' are often interchangeable in the public mind. Because of its invisibility, radiation is commonly feared. A more objective evaluation of risks and benefits is encouraged through developing an understanding of the many practical uses of radioactive materials.

Topic P5.1 begins by considering the evidence of a nuclear model of the atom, including Rutherford's alpha particle scattering experiment. It then uses the nuclear model to explain what happens during radioactive decay. The properties of alpha, beta and gamma radiation are investigated and ideas about half-life are developed. In Topic P5.2 learners learn about the penetration properties of ionising radiation which leads to a consideration of the use of radioactive materials in the health sector, and how they can be handled safely. In the context of health risks associated with irradiation and/or contamination by radioactive material, they also learn about the interpretation of data on risk.

Topic P5.3 describes nuclear fission and nuclear fusion. Learners have the opportunity to learn more about the issues that surround decisions about the best way to generate electricity.

Learning about the radioactivity before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- recall that in each atom its electrons are arranged at different distances from the nucleus
- recall that gamma rays are emitted from the nuclei of atoms
- be able to describe how ionising radiation can have hazardous effects, notably on human bodily tissues.

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.

Learning about radioactivity at GCSE (9–1)

P5.1 What is radioactivity?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
An atom has a nucleus, made of protons and neutrons, which is surrounded by electrons. The modern model of the atom developed over time as scientists rejected earlier models and proposed new ones to fit the currently available evidence. Each stage relied on scientists using reasoning to propose models which fitted the evidence available at the time. Models were rejected, modified and extended as new evidence became available (IaS3). After the discovery of the electron in the 19th century by Thomson scientists imagined that atoms were small particles of positive matter with the negative electrons spread through, like currants in a cake. This was the model used until 1910 when the results of the Rutherford-Geiger-Marsden alpha particle scattering experiment provided evidence that a gold atom contains a small, massive, positive region (the nucleus). Atoms are small – about 10^{-10} m across, and the nucleus is at the centre, about a hundred-thousandth of the diameter of the atom. Each atom has a nucleus at its centre and that nucleus is made of protons and neutrons. For an element, the number of the protons is always the same but the number of neutrons may differ. Forms of the same element with different numbers of neutrons are called the isotopes of the element. Interpreting the unexpected results of the Rutherford-Geiger-Marsden experiment required imagination to consider a new model of the atom.	1. 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 2. describe how and why the atomic model has changed over time to include the main ideas of Dalton, Thomson, Rutherford and Bohr 3. recall the typical size (order of magnitude) of atoms and small molecules 4. recall that atomic nuclei are composed of both protons and neutrons, and that the nucleus of each element has a characteristic positive charge 5. recall that nuclei of the same element can differ in nuclear mass by having different numbers of neutrons, these are called isotopes 6. use the conventional representation to show the differences between isotopes, including their identity, charge and mass 7. recall that some nuclei are unstable and may emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma rays 8. relate emissions of alpha particles, beta particles, or neutrons, and gamma rays to possible changes in the mass or the charge of the nucleus, or both

Linked learning opportunities

Specification links

- How has our understanding of the structure of atoms developed over time? (C2.1)

Ideas about Science

- Explain how the development of the nuclear model of the atom is an example of how scientific explanations become accepted (IaS3).

Practical work

- Collect data to calculate the half-life of a radioactive isotope.
- Use a random event such as dice-throwing to model radioactive decay.

P5.1 What is radioactivity?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	
Some substances emit ionising radiation all the time and are called radioactive. The ionising radiation (alpha, beta, gamma, and neutron) is emitted from the unstable nucleus of the radioactive atoms, which as a result become more stable. Alpha particles consist of two protons and two neutrons, and beta particles are identical to electrons. Gamma radiation is very high frequency electromagnetic radiation.	9.	use names and symbols of common nuclei and particles to write balanced equations that represent the emission of alpha, beta, gamma, and neutron radiations during radioactive decay M1b, M1c, M3c
	10.	explain the concept of half-life and how this is related to the random nature of radioactive decay
Radioactive decay is a random process. For each radioactive isotope there is a different constant chance that any nucleus will decay. Over time the activity of radioactive sources decreases, as the number of undecayed nuclei decreases.	**11.**	**calculate the net decline, expressed as a ratio, in a radioactive emission after a given (integral) number of half-lives** M1c, M3d
The time taken for the activity to fall to half is called the half-life of the isotope and can be used to calculate the time it takes for a radioactive material to become relatively safe.	12.	interpret activity-time graphs to find the half-life of radioactive materials M1c, M2g, M4a, M4c

Linked learning opportunities

P5.2: How can radioactive materials be used safely?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Ionising radiation can damage living cells and these may be killed or may become cancerous, so radioactive materials must be handled with care. In particular, a radioactive material taken into the body (contamination) poses a higher risk than the same material outside as the material will continue to emit ionising radiation until it leaves the body. Whilst ionising radiation can cause cancer, it can also be used for imaging inside the body and to kill cancerous cells. Doctors and patients need to consider the risks and benefits when using ionising radiation to treat diseases.	1. recall the differences in the penetration properties of alpha particles, beta particles and gamma rays 2. recall the differences between contamination and irradiation effects and compare the hazards associated with each of these 3. describe the different uses of nuclear radiations for exploration of internal organs, and for control or destruction of unwanted tissue 4. explain how ionising radiation can have hazardous effects, notably on human bodily tissues 5. explain why the hazards associated with radioactive material differ according to the radiation emitted and the half-life involved

Linked learning opportunities

Specification links:
- What are the risks and benefits of using electromagnetic radiations? (P1.2)

Practical work
- Collect and interpret data to show the penetration properties of ionising radiations.

Ideas about Science
- Discuss ideas about correlation and cause in the context of links between ionising radiation and cancer (IaS3).
- Discuss the uses of ionising radiation, with reference to its risks and benefits (IaS4).

P5.3 How can radioactive materials be used to provide energy? (*separate science only*)

Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Nuclear fuels are radioactive materials that release energy during changes in the nucleus.	1. recall that some nuclei are unstable and may split into two nuclei and that this is called nuclear fission
In nuclear fission a neutron splits a large and unstable nucleus (such as some isotopes of uranium and plutonium) into two smaller parts, roughly equal in size, releasing more neutrons, which may go on to make further collisions.	2. relate the energy released during nuclear fission to the emission of ionising radiation and the kinetic energy of the resulting particles
Energy is released from the nucleus, carried away as kinetic energy of the particles and also by gamma radiation. This release of energy from the nuclear store is analogous to that released from the chemical store of explosives like TNT but it is considerably larger.	3. explain how nuclear fission can lead to further fission events in a chain reaction
If brought close enough together, hydrogen nuclei can fuse into helium nuclei, releasing energy, and this is called nuclear fusion. The demand for energy is continually increasing and nuclear fuels are an alternative energy source to fossil fuels. The risks and benefits need to be compared when making decisions about how to generate electricity.	4. describe the process of nuclear fusion and recall that in this process some of the mass may be converted into the energy of radiation

Linked learning opportunities

Specification links:

- How should electricity be generated? (P3.2)

Ideas about Science

- Discuss the risks and benefits of generating electricity using nuclear fission. Suggest reasons why different decisions on the same issue might be appropriate in view of differences in personal, social, or economic context (IaS4).

Chapter P6: Matter – models and explanations

Overview

Richard Feynman said: “If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis (or the atomic fact, or whatever you wish to call it) that all things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied.” (*Six Easy Pieces*, p.4)

In this chapter the particle model described by Feynman is used to predict and explain some properties of matter. Topic P6.1 explores the relationship between energy and temperature and the ways in which energy transfer transforms matter. Topic P6.2 considers how the particle model explains the differences in densities between solids, liquids and gases and the effect of heating both in terms of temperature changes and changes of state. Topic P6.3 considers the behaviour of materials under stress and how the particle model can explain differences in behaviour. Topic 6.4 deals with pressure, and how it varies in fluids (liquids and gases), with the particle model used to explain the law discovered by Robert Boyle. Finally, in Topic P6.5 ideas about forces and also the particle model are considered in the context of planets, moons and satellites in their orbit, and the formation of the solar system, before briefly describing the early stage of the Universe and the Big Bang.

Learning about matter and particles before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- be able to use a particulate model of matter to explain states of matter and changes of state
- have investigated stretching and compressing materials and identifying those that obey Hooke’s law
- be able to describe how the extension or compression of an elastic material changes as a force is applied, and make a link between the work done and energy transfer during compression or extension
- have investigated pressure in liquids and related this to floating and sinking
- be able to relate atmospheric pressure to the weight of air overhead.

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.

P6.1 How does energy transform matter?

Teaching and learning narrative

It took the insight of a number of eighteenth and nineteenth century scientists to appreciate that heat and work were two aspects of the same quantity, which we call energy. Careful experiments devised by Joule showed that equal amounts of mechanical work would always produce the same temperature rise.

Energy can be supplied to raise the temperature of a substance by heating using a fuel, or an electric heater, or by doing work on the material.

Mass – the amount of matter in an object – depends on its volume and the density of the material of which it consists.

The temperature rise of an object when it is heated depends on its mass and the amount of energy supplied. Different substances store different amounts of energy per kilogram for each °C temperature rise – this is called the specific heat capacity of the material.

Assessable learning outcomes

Learners will be required to:

1.	a) define density b) describe how to determine the densities of solid and liquid objects using measurements of length, mass and volume M1c, M5c *PAG1*
2.	recall and apply the relationship between density, mass and volume to changes where mass is conserved: density (kg/m^3) = mass (kg) ÷ volume (m^3) M1a, M1b, M1c, M3c
3.	describe the energy transfers involved when a system is changed by heating (in terms of temperature change and specific heat capacity)
4.	define the term specific heat capacity and distinguish between it and the term specific latent heat
5.	a) select and apply the relationship between change in internal energy of a material and its mass, specific heat capacity and temperature: change in internal energy (J) = mass (kg) × specific heat capacity (J/kg°C) × change in temperature (°C) M1a, M1c, M3d b) explain how to safely use apparatus to determine the specific heat capacity of materials *PAG5*

Linked learning opportunities

Specification links

- How much energy do we use? (P2.1)
- What determines the rate of energy transfer in a circuit? (P3.4)
- How can we describe motion in terms of energy transfers? (P4.4)

Practical work

- Devise a method to measure the density of irregular objects.
- Measure the specific heat capacity of a range of substances such as water, copper, aluminium.
- Measure the latent heat of fusion of a substance in the solid state and the latent heat of vaporisation of a substance in the liquid state.
- Show that the same amount of work always results in the same temperature rise.
- Collect data, plot and interpret graphs that show how the temperature of a substance changes when heated by a constant supply of energy.

P6.1 How does energy transform matter?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
When a substance in the solid state is heated its temperature rises until it reaches the melting point of the substance, but energy must continue to be supplied for the solid to melt. Its temperature does not change while it melts, and the change in density on melting is very small. Similarly as a substance in the liquid state is heated its temperature rises until it reaches boiling point; its temperature does not change, although energy continues to be supplied while it boils. The change in density on boiling is very great; a small volume of liquid produces a large volume of vapour. Different substances require different amounts of energy per kilogram to change the state of the substance – this is called the specific latent heat of the substance.	6. select and apply the relationship between energy needed to cause a change in state, specific latent heat and mass: energy to cause a change of state (J) = mass (kg) × specific latent heat (J/kg) M1a, M1c, M3d 7. describe all the changes involved in the way energy is stored when a system changes, and the temperature rises, for example: a moving object hitting an obstacle, an object slowing down, water brought to a boil in an electric kettle 8. make calculations of the energy transfers associated with changes in a system when the temperature changes, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes M1a, M1c, M2a, M3b, M3c, M3d

Linked learning opportunities

Ideas about Science

- Describe and explain how careful experimental strategy can yield high quality data (IaS1).
- Describe and explain an example of how a developing a new scientific explanation takes creative thinking (IaS3).

P6.2 How does the particle model explain the effects of heating?

Teaching and learning narrative

The particle model of matter describes the arrangements and behaviours of particles (atoms and molecules); it can be used to predict and explain the differences in properties between solids, liquids and gases. In this model:

- All matter is made of very tiny particles.
- There is no other matter except these particles (in particular, no matter between them).
- Particles of any given substance are all the same.
- Particles of different substances have different masses.
- There are attractive forces between particles. These differ in strength from one substance to another.
- In the solid state, the particles are close together and unable to move away from their neighbours.
- In the liquid state, the particles are also close together, but can slide past each other.
- In the gas state, the particles are further apart, and can move freely.

The particle model is an example of how scientists use models as tools for explaining observed phenomena.

The particle model can be used to describe and predict physical changes when matter is heated.

- The particles are always moving: in the solid state, they are vibrating; in the liquid state, they are vibrating and jostling around; in the gas state, they are moving freely in random directions.
- A substance in the gas state exerts pressure on its container because the momentum of the particles changes when they collide with walls of the container.
- The hotter something is, the higher its temperature is and the faster its particles are vibrating or moving.

Careful experimentation and mathematical analysis showed that the temperature of a substance was linked to the kinetic energy of its atoms or molecules.

Assessable learning outcomes

Learners will be required to:

1. explain the differences in density between the different states of matter in terms of the arrangements of the atoms or molecules
2. use the particle model of matter to describe how mass is conserved, when substances melt, freeze, evaporate, condense or sublimate, but that these physical changes differ from chemical changes and the material recovers its original properties if the change is reversed
3. use the particle model to describe how heating a system will change the energy stored within the system and raise its temperature or produce changes of state
4. explain how the motion of the molecules in a gas is related both to its temperature and its pressure: hence explain the relationship between the temperature of a gas and its pressure at constant volume
   qualitative only

Linked learning opportunities

Ideas about Science

- Use the particle model to explain familiar or unfamiliar phenomena and make predictions (IaS3).

P6.3 How does the particle model relate to material under stress?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
When more than one force is applied to a solid material it may be compressed, stretched or twisted. When the forces are removed it may return to its original shape or become permanently deformed. These effects can be explained using ideas about particles in the solid state. A substance in the solid state is a fixed shape due to the forces between the particles. Compressing or stretching the material changes the separation of the particles, and the forces between the particles. Elastic materials spring back to their original shape. If the forces are too large the material becomes plastic and is permanently distorted. For some materials, the extension is proportional to the applied force, but in other systems, such as rubber bands, the relationship is not linear, even though they are elastic. When work is done by a force to compress or stretch an spring or other simple system, energy is stored, this energy can be recovered when the force is removed.	1. explain, with examples, that to stretch, bend or compress an object, more than one force has to be applied
	2. describe **and use the particle model to explain** the difference between elastic and plastic deformation caused by stretching forces
	3. a) describe the relationship between force and extension for a spring and other simple systems b) describe how to measure and observe the effect of forces on the extension of a spring M2b, M2f *PAG2*
	4. describe the difference between the force-extension relationship for linear systems and for non-linear systems
	5. recall and apply the relationship between force, extension and spring constant for systems where the force-extension relationship is linear force exerted by a spring (N) = extension (m) × spring constant (N/m) M1c, M3b, M3c
	6. a) calculate the work done in stretching a spring or other simple system, by calculating the appropriate area on the force-extension graph M4f b) describe how to safely use apparatus to determine the work done in stretching a spring
	7. select and apply the relationship between energy stored, spring constant and extension for a linear system: energy stored in a stretched spring (J) = ½ × spring constant (N/m) × $(\text{extension (m)})^2$ M1c, M3b, M3c, M3d

Linked learning opportunities

Practical work

- Investigate the force-extension properties of a variety of materials, identifying those that obey Hooke's law, those that behave elastically, and those that show plastic deformation.

P6.4 How does the particle model relate to pressures in fluids? (*separate science only*)

Teaching and learning narrative		**Assessable learning outcomes** *Learners will be required to:*
An object immersed in a fluid (a liquid or a gas) experiences forces acting at right angles to all its surfaces due to the pressure of the fluid. The pressure of the fluid is due to collisions of the particles of the fluid with the surface of the object. The particles of gas in a container collide with the surfaces of the container, exerting a pressure. If the volume of the container is increased, the particles have further to travel between collisions and the pressure of the gas falls. When a gas is compressed the particles are much closer together and will collide with the walls of the container more frequently, exerting a greater outward pressure. The atmosphere of the Earth exerts a pressure perpendicular to the surface of any object in it, and this pressure is the same in all directions at a particular height. Atmospheric pressure decreases with height above the surface of the Earth. The pressure at a point in a fluid increases with depth, because it is caused by the gravitational force on the fluid above that point. A fluid with greater density will experience a greater gravitational force and so exert a greater pressure.	1.	recall that the pressure in fluids causes a force normal to any surface
	2.	recall and apply the relationship between the force, the pressure, and the area in contact: pressure (Pa) = force normal to a surface (N) ÷ area of that surface (m^2) M3b, M3c
	3.	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
	4.	use the particle model of matter to explain how increasing the volume in which a gas is contained, at constant temperature, can lead to a decrease in pressure
	5.	select and apply the equation: pressure × volume = constant (for a given mass of gas at constant temperature) M1c, M3b, M3c, M3d
	6.	describe a simple model of the Earth's atmosphere and of atmospheric pressure, and explain why atmospheric pressure varies with height above the surface
	7.	**explain why pressure in a liquid varies with depth and density**

Linked learning opportunities

Practical work

- **Investigate the relationship between density of an immersed object and density of the fluid and the net force on the object.**
- **Devise an experiment to show that pressure in a fluid varies with depth.**
- **Investigate the relationships between the pressure of a gas and its volume and its temperature.**

P6.4 How does the particle model relate to pressures in fluids? (*separate science only*)

Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	*Linked learning opportunities*
Because pressure increases with depth, the force on the lower surface of an immersed object will be greater than the force on the upper surface, resulting in a net force upwards. This explains why the apparent weight of an object immersed in a liquid is less than its weight in air. It was Dalton's careful study of the atmosphere and gases that led to him giving a quantitative significance to the atomic theory which provides the basis for the particle model of matter.	**8. select and apply the equation to calculate the differences in pressure at different depths in a liquid: pressure = density × gravitational field strength × depth** M1c, M3c **9. explain how the increase in pressure with depth in a fluid leads to an upwards force on a partially submerged object** **10. describe and explain the factors which influence whether a particular object will float or sink**	

P6.5 How can scientific models help us understand the Big Bang? (*separate science only*)

Teaching and learning narrative

The gravitational interaction between the planets and the Sun keeps the planets in (almost) circular orbits around the Sun, all in the same direction. Similarly, it is the gravitational interaction between a planet and its moons or artificial satellites that keeps them in orbit.

The force needed to keep an object moving in a circle depends on the speed of the object and the radius of the circle. The greater the speed and/or the smaller the radius, the greater the force needed. If a satellite or planet slows down, it will be pulled in to a smaller radius orbit.

The solar system was formed over long periods from clouds of gases and dust drawn together by the force of gravity. When a force is used to compress a gas, work is done on the gas, leading to an increase in temperature.

During the formation of a star such as the Sun, a cloud of gas is pulled together by gravity, its temperature increases and the hydrogen nuclei gain sufficient energy to fuse into helium nuclei, releasing more energy.

The Universe contains thousands of millions of galaxies. The light coming from distant galaxies shows a red-shift that suggests that distant galaxies are moving away from us. The further away a galaxy is, the faster it is moving away from us; this suggests that space itself is expanding. Scientists' explanation for these observations is that the Universe began with a 'Big Bang' about 14 thousand million years ago.

The acceptance of the 'Big Bang' model to describe the early stages of the Universe depends on the interpretation of observations, as more observations were made, the theory became more secure.

Telescope designs have improved over the last 100 years, and modifications have made it possible to observe regions of the electromagnetic spectrum other than visible light. Placing these instruments outside the atmosphere has improved the range and quality of data obtained, and these improved data have increased the confidence in the 'Big Bang' model (IaS3).

Assessable learning outcomes

Learners will be able to:

1. recall the main features of our solar system, including the similarities and distinctions between the planets, their moons, and artificial satellites
2. **explain, for the circular orbits, how the force of gravity can lead to changing velocity of a planet but unchanged speed**
3. **explain how, for a stable orbit, the radius must change if this speed changes**
   qualitative only
4. recall that the solar system was formed from dust and gas drawn together by gravity
5. **use the particle model of matter to explain how doing work on a gas can increase its temperature (e.g. bicycle pump, in stars)**
6. explain how the Sun was formed when collapsing cloud of dust and gas resulted in fusion reactions, leading to an equilibrium between gravitational collapse and expansion due to the fusion energy
7. explain the red-shift of light from galaxies which are receding
   qualitative only
8. explain that the relationship between the distance of each galaxy and its speed is evidence of an expanding universe model
9. explain how the evidence of an expanding universe leads to the 'Big Bang' model

Linked opportunities

Specification links

- **Nuclear fusion (P5.3).**

Practical work

- Investigate the relationship between the force, speed and radius of path for an object moving in a circle.

Ideas about Science

- Use the development of the 'Big Bang' model of the beginning of the Universe as an example of how scientific explanations become accepted (IaS3).

2

Chapter P7: Ideas about Science

Overview

In order to make sense of the scientific ideas that learners encounter in lessons and in everyday life outside of school, they need an understanding of how science explanations are developed, the kinds of evidence and reasoning behind them, their strengths and limitations, and how far we can rely on them.

Learners also need opportunities to consider the impacts of science and technology on society, and how we respond individually and collectively to new ideas, artefacts and processes that science makes possible.

It is intended that the *Ideas about Science* will help learners understand how scientific knowledge is obtained, how to respond to science stories and issues in the world outside the classroom, and the impacts of scientific knowledge on society.

Note that:

- although particular *Ideas about Science* have been linked to particular contexts throughout the specification as examples, the assessable learning outcomes in this chapter should be developed, and will be assessed, in any context from chapters P1–P6
- the assessable learning outcomes in this chapter will be assessed in all of the written examination papers
- terms associated with measurement and data analysis are used in accordance with their definitions in the Association of Science Education publication *The Language of Measurement* (2010).

Learning about How Science Works before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- understand that science explanations are based on evidence and that as new evidence is gathered, explanations may change
- have devised and carried out scientific enquiries, in which they have selected the most appropriate techniques and equipment, collected and analysed data and drawn conclusions.

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.

IaS1 What needs to be considered when investigating a phenomenon scientifically?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
The aim of science is to develop good explanations for natural phenomena. There is no single 'scientific method' that leads to good explanations, but scientists do have characteristic ways of working. In particular, scientific explanations are based on a cycle of collecting and analysing data. Usually, developing an explanation begins with proposing a hypothesis. A hypothesis is a tentative explanation for an observed phenomenon ("this happens because . . ."). The hypothesis is used to make a prediction about how, in a particular experimental context, a change in a factor will affect the outcome. A prediction can be presented in a variety of ways, for example in words or as a sketch graph. In order to test a prediction, and the hypothesis upon which it is based, it is necessary to plan an experimental strategy that enables data to be collected in a safe, accurate and repeatable way.	1. in given contexts use scientific theories and tentative explanations to develop and justify hypotheses and predictions 2. suggest appropriate apparatus, materials and techniques, justifying the choice with reference to the precision, accuracy and validity of the data that will be collected 3. recognise the importance of scientific quantities and understand how they are determined 4. identify factors that need to be controlled, and the ways in which they could be controlled 5. suggest an appropriate sample size and/or range of values to be measured and justify the suggestion M2d 6. plan experiments or devise procedures by constructing clear and logically sequenced strategies to: – make observations – produce or characterise a substance – test hypotheses – collect and check data – explore phenomena 7. identify hazards associated with the data collection and suggest ways of minimizing the risk 8. use appropriate scientific vocabulary, terminology and definitions to communicate the rationale for an investigation and the methods used using diagrammatic, graphical, numerical and symbolic forms	

IaS2 What processes are needed to draw conclusions from data?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
The cycle of collecting, presenting and analysing data usually involves translating data from one form to another, mathematical processing, graphical display and analysis; only then can we begin to draw conclusions. A set of repeat measurements can be processed to calculate a range within which the true value probably lies and to give a best estimate of the value (mean). Displaying data graphically can help to show trends or patterns, and to assess the spread of repeated measurements. Mathematical comparisons between results and statistical methods can help with further analysis.	1. present observations and other data using appropriate formats
	2. when processing data use SI units where appropriate (e.g. kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate
	3. when processing data use prefixes (e.g. tera, giga, mega, kilo, centi, milli, micro and nano) and powers of ten for orders of magnitude
	4. be able to translate data from one form to another M2c, M4a
	5. when processing data interconvert units
	6. when processing data use an appropriate number of significant figures M2a
	7. when displaying data graphically select an appropriate graphical form, use appropriate axes and scales, plot data points correctly, draw an appropriate line of best fit, and indicate uncertainty (e.g. range bars) M2c, M4a, M4c
	8. when analysing data identify patterns/trends, use statistics (range and mean) and obtain values from a line on a graph (including gradient, interpolation and extrapolation), M2b, M2f, M2g, M4b, M4d, M4e, M4f

Linked learning opportunities
P6.2 (mechanical equivalent of heat) Describe and explain how careful experimental strategy can yield high quality data.

IaS2 What processes are needed to draw conclusions from data?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	
Data obtained must be evaluated critically before we can make conclusions based on the results. There could be many reasons why the quality (accuracy, precision, repeatability and reproducibility) of the data could be questioned, and a number of ways in which they could be improved. Data can never be relied on completely because observations may be incorrect and all measurements are subject to uncertainty (arising from the limitations of the measuring equipment and the person using it). A result that appears to be an outlier should be treated as data, unless there is a reason to reject it (e.g. measurement or recording error)	9.	in a given context evaluate data in terms of accuracy, precision, repeatability and reproducibility, identify potential sources of random and systematic error, and discuss the decision to discard or retain an outlier
	10.	evaluate an experimental strategy, suggest improvements and explain why they would increase the quality (accuracy, precision, repeatability and reproducibility) of the data collected, and suggest further investigations
Agreement between the collected data and the original prediction increases confidence in the tentative explanation (hypothesis) upon which the prediction is based, but does not prove that the explanation is correct. Disagreement between the data and the prediction indicates that one or other is wrong, and decreases our confidence in the explanation.	11.	in a given context interpret observations and other data (presented in diagrammatic, graphical, symbolic or numerical form) to make inferences and to draw reasoned conclusions, using appropriate scientific vocabulary and terminology to communicate the scientific rationale for findings and conclusions
	12.	explain the extent to which data increase or decrease confidence in a prediction or hypothesis

Linked learning opportunities

IaS3 How are scientific explanations developed?

Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Scientists often look for patterns in data as a means of identifying correlations that can suggest cause-effect links – for which an explanation might then be sought. The first step is to identify a correlation between a factor and an outcome. The factor may then be the cause, or one of the causes, of the outcome. In many situations, a factor may not always lead to the outcome, but increases the chance (or the risk) of it happening. In order to claim that the factor causes the outcome we need to identify a process or mechanism that might account for the observed correlation.	1. use ideas about correlation and cause to: – identify a correlation in data presented as text, in a table, or as a graph M2g – distinguish between a correlation and a cause-effect link – suggest factors that might increase the chance of a particular outcome in a given situation, but do not invariably lead to it – explain why individual cases do not provide convincing evidence for or against a correlation – identify the presence (or absence) of a plausible mechanism as reasonable grounds for accepting (or rejecting) a claim that a factor is a cause of an outcome	*Considering correlation and cause:* evidence for risks of X-rays (P1.2) evidence for human activities causing global warming (P1.3)
Scientific explanations and theories do not 'emerge' automatically from data, and are separate from the data. Proposing an explanation involves creative thinking. Collecting sufficient data from which to develop an explanation often relies on technological developments that enable new observations to be made. As more evidence becomes available, a hypothesis may be modified and may eventually become an accepted explanation or theory. A scientific theory is a general explanation that applies to a large number of situations or examples (perhaps to all possible ones), which has been tested and used successfully, and is widely accepted by scientists. A scientific explanation of a specific event or phenomenon is often based on applying a scientific theory to the situation in question.	2. describe and explain examples of scientific methods and theories that have developed over time and how theories have been modified when new evidence became available	*Developing scientific explanations:* Climate change (P1.3) **Big Bang model (P4.5)** Nuclear model of the atom (P5.1) The link between work, heat and temperature (P6.2)

IaS3 How are scientific explanations developed?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Findings reported by an individual scientist or group are carefully checked by the scientific community before being accepted as scientific knowledge. Scientists are usually sceptical about claims based on results that cannot be reproduced by anyone else, and about unexpected findings until they have been repeated (by themselves) or reproduced (by someone else). Two (or more) scientists may legitimately draw different conclusions about the same data. A scientist's personal background, experience or interests may influence his/her judgments. An accepted scientific explanation is rarely abandoned just because new data disagree with it. It usually survives until a better explanation is available.	3. describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists	*Explanations that relied on technological development:* **Telescopes and the Big Bang model (P4.5)**
Models are used in science to help explain ideas and to test explanations. A model identifies features of a system and rules by which the features interact. It can be used to predict possible outcomes. Representational models use physical analogies or spatial representations to help visualise scientific explanations and mechanisms. Descriptive models are used to explain phenomena. Mathematical models use patterns in data of past events, along with known scientific relationships, to predict behaviour; often the calculations are complex and can be done more quickly by computer. Models can be used to investigate phenomena quickly and without ethical and practical limitations, but their usefulness is limited by how accurately the model represents the real world.	4. use a variety of models (including representational, spatial, descriptive, computational and mathematical models) to: – solve problems – make predictions – develop scientific explanations and understanding – identify limitations of models	*Examples of models:* Radiation model of light (P1.2); Wave model of light (P1.3); Physical analogies of electric circuits (P2.2, P2.3) Equations of motion(P4.2) Atomic model (P5.1) Particle model of matter (P6.1, P6.2)

IaS4 How do science and technology impact society?

Teaching and learning narrative

Science and technology provide people with many things that they value, and which enhance their quality of life. However some applications of science can have unintended and undesirable impacts on the quality of life or the environment. Scientists can devise ways of reducing these impacts and of using natural resources in a sustainable way (at the same rate as they can be replaced).

Everything we do carries a certain risk of accident or harm. New technologies and processes can introduce new risks.

The size of a risk can be assessed by estimating its chance of occurring in a large sample, over a given period of time.

To make a decision about a course of action, we need to take account of both the risks and benefits to the different individuals or groups involved. People are generally more willing to accept the risk associated with something they choose to do than something that is imposed, and to accept risks that have short-lived effects rather than long-lasting ones. People's perception of the size of a particular risk may be different from the statistically estimated risk. People tend to over-estimate the risk of unfamiliar things (like flying as compared with cycling), and of things whose effect is invisible or long-term (like ionising radiation).

Some forms of scientific research, and some applications of scientific knowledge, have ethical implications. In discussions of ethical issues, a common argument is that the right decision is one which leads to the best outcome for the greatest number of people.

Scientists must communicate their work to a range of audiences, including the public, other scientists, and politicians, in ways that can be understood. This enables decision-making based on information about risks, benefits, costs and ethical issues.

Assessable learning outcomes

Learners will be required to:

1. describe and explain everyday examples and technological applications of science that have made significant positive differences to people's lives
2. identify examples of risks that have arisen from a new scientific or technological advance
3. for a given situation:
   - identify risks and benefits to the different individuals and groups involved
   - discuss a course of action, taking account of who benefits and who takes the risks
   - suggest reasons for people's willingness to accept the risk
   - **distinguish between perceived and calculated risk**
4. suggest reasons why different decisions on the same issue might be appropriate in view of differences in personal, social, economic or environmental context, and be able to make decisions based on the evaluation of evidence and arguments
5. distinguish questions that could in principle be answered using a scientific approach, from those that could not; where an ethical issue is involved clearly state what the issue is and summarise the different views that may be held
6. explain why scientists should communicate their work to a range of audiences.

Linked learning opportunities

Positive applications of science:

use of the electromagnetic spectrum (P1.2);

development of electromagnetism and electric motors (P2.4, P2.5); generating and distributing electricity (P3.3);

road safety (P4.3);

Sustainability:

energy demands and choices of sources to generate electricity (P3.2)

Risks, benefits and ethical issues:

biodiversity (B6.4) technologies that use ionising radiation (P1.2, P5.2);

energy sources to generate electricity (P3.2, **P3.3, P5.3);** car safety (P4.3);

use of ionising radiation to treat disease (P5.2)

Chapter P8: Practical skills

Compliance with the requirements for practical work

It is compulsory that learners complete at least *eight* practical activities.

OCR has split the requirements from the Department for Education '*Biology, chemistry and physics GCSE subject content, July 2015*' – Appendix 4 into eight Practical Activity Groups or PAGs.

The Practical Activity Groups allow centres flexibility in their choice of activity. Whether centres use OCR suggested practicals or centre-substituted practicals, they must ensure completion of at least eight practical activities and each learner must have had the opportunity to use all of the apparatus and techniques described in the following tables of this chapter.

The tables illustrate the apparatus and techniques required for each PAG and an example practical that may be used to contribute to the PAG. It should be noted that some apparatus and techniques can be used in more than one PAG. It is therefore important that teachers take care to ensure that learners do have the opportunity to use all of the required apparatus and techniques during the course with the activities chosen by the centre.

Within the specification there are a number of practicals that are described in the 'Assessable learning outcomes' column. These can count towards each PAG. We are expecting that centres will provide learners with opportunities to carry out a wide range of practical activities during the course. These can be the ones described in the specification or can be practicals that are devised by the centre. Activities can range from whole investigations to simple starters and plenaries.

It should be noted that the practicals described in the specification need to be covered in preparation for the questions in the written examinations that will assess practical skills. No less than 15% of the questions will assess practical skills. Learners also need to be prepared to answer questions using their knowledge and understanding of practical techniques and procedures in written papers.

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.

Revision of the requirements for practical work

OCR will review the practical activities detailed in Chapter P8 of this specification following any revision by the Secretary of State of the apparatus or techniques published specified in respect of the GCSE Physics B (Twenty First Century Science) qualification.

OCR will revise the practical activities if appropriate.

If any revision to the practical activities is made, OCR will produce an amended specification which will be published on the OCR website. OCR will then use the following methods to communicate the amendment to Centres such as a Notice to Centres sent to all Examinations Officers, e-alerts to Centres that have registered to teach the qualification and social media

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

Practical Activity Group (PAG)	Apparatus and techniques that the practical must use or cover	Example of a suitable physics activity (a range of practicals are included in the specification and centres can devise their own activity) *
1 Materials	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature.[1]	Determine the densities of a variety of objects both solid and liquid
	Use of such measurements to determine densities of solid and liquid objects[1]	
2 Forces	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature.[1]	Investigate the effect of forces on springs
	Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs[2]	
3 Motion	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature.[1]	Investigate acceleration of a trolley down a ramp
	Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration)[3]	
4 Measuring Waves	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature.[1]	Use of a ripple tank to measure the speed, frequency and wavelength of a wave
	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/wavelength.[4]	
5 Energy	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature.[1]	Determine the specific heat capacity of a metal
	Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done[5]	
6 Circuit components	Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements[6]	Investigate the I-V characteristics of circuit elements
7 Series and Parallel Circuits	Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements[7]	Investigate the brightness of bulbs in series and parallel
8 Interactions of waves	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter[8]	Investigate the reflection of light off a plane mirror and the refraction of light through prisms
	Making observations of the effects of the interaction of electromagnetic waves with matter[4]	

*** Centres are free to substitute alternative practical activities that also cover the apparatus and techniques from DfE: *Biology, chemistry and physics GCSE subject content, July 2015* Appendix 4.**

[1–8] These apparatus and techniques may be covered in any of the groups indicated. Number corresponds to that used in DfE: *Biology, chemistry and physics GCSE subject content, July 2015* Appendix 4.

Choice of activity

Centres can include additional apparatus and techniques within an activity beyond those listed as the minimum in the above tables. Learners *must* complete a *minimum* of eight practicals covering all the apparatus and techniques listed.

The apparatus and techniques can be covered:

(i) by using OCR suggested activities (provided as resources)
(ii) through activities devised by the Centre.

Centres can receive guidance on the suitability of their own practical activities through our free coursework consultancy service.
E-mail: ScienceGCSE@ocr.org.uk

Where Centres devise their own practical activities to cover the apparatus and techniques listed above, the practical must cover all the requirements and be of a level of demand appropriate for GCSE.
Each set of apparatus and techniques described in the middle column can be covered by more than one Centre devised practical activity e.g. "Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects." could be split into two or more activities (rather than one).

2

Practical science statement

Centres must provide a written 'practical science statement' to OCR confirming that they have taken reasonable steps to secure that each learner:

a) has completed the practical activities set by OCR as detailed in Chapter P8
b) has made a contemporaneous record of
   (i) the work which the learner has undertaken during those practical activities, and
   (ii) the knowledge, skills and understanding which that learner has derived from those practical activities.

Centres must provide practical science opportunities for their learners. This does not go so far as to oblige centres to ensure that all of their learners take part in all of the practical science opportunities. There is always a risk that an individual learner may miss the arranged practical science work, for example because of illness. It could be costly for the centre to run additional practical science opportunities for the learner.

However, the opportunities to take part in the specified range of practical work must be given to all learners. Learners who do not take up the full range of opportunities may be disadvantaged as there will be questions on practical science in the GCSE Physics B (Twenty First Century Science) assessment.

Centres must provide the practical science statement by 15 May in the year the learner certificates.
Any failure by a centre to provide a practical science statement to OCR in a timely manner will be treated as malpractice and/or maladministration [under General Condition A8 (*Malpractice and maladministration*)].

Private candidates

Private candidates can be entered for examinations at an OCR-approved centre even if they are not enrolled as a learner there.

Private candidates may be home-schooled, receiving private tuition or self-taught. They must be based in the UK.

The GCSE Physics B (Twenty First Century Science) qualification requires learners to complete eight practical activities. These practical activities are an essential part of the course and will allow learners to develop skills for further study or employment as well as imparting important knowledge that is part of the specification.

Private candidates need to make contact with a centre where they will be allowed to carry out the required practical activities. The centre may charge for this facility and OCR recommends that the arrangement is made early in the course.

There is no direct assessment of the practical skills part of the course. However, learners will need to have completed the activities to prepare fully for the written examinations as there will be questions that assess practical skills.

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.
- There are no prior qualifications required in order for learners to enter for a GCSE (9–1) in Physics B (Twenty First Century Science).
- 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 B (Twenty First Century Science)

3a. Forms of assessment

The GCSE (9–1) in Physics B (Twenty First Century Science) is a linear qualification with 100% external assessment.

OCR's GCSE (9–1) in Physics B (Twenty First Century Science) consists of four examined components that are externally assessed. Two are at Foundation Tier and two are at Higher Tier. Each component carries an equal weighting of 50% for that tier of the GCSE (9–1) qualification. Each component has a duration of 1 hour and 45 minutes.

3

Assessment approach

The assessment of the content of Physics B (Twenty First Century Science) is achieved using two components at each tier.

Breadth paper: this paper can assess content from across the whole specification. The paper will include short answer response questions. These will include structured questions, calculations and questions based on practical skills. Extended response questions are not found on the Breadth paper.

Depth paper: this paper can assess content from across the whole specification. The focus of the Depth paper is to allow learners to demonstrate their depth of understanding of specific aspects of the content. This will be achieved by the inclusion of some short answer response questions. These will include structured questions, calculations and questions based on practical skills. The paper will have at least two extended response questions marked using Level of Response mark schemes, each with a total of 6 marks.

Physics Breadth paper (Components 01 and 03)

These components, one at Foundation Tier and one at Higher Tier, are each worth 90 marks and assess content from across all teaching chapters P1 to P7. Learners answer all the questions.

Physics Depth paper (Components 02 and 04)

These components, one at Foundation Tier and one at Higher Tier, are each worth 90 marks and assess content from across all teaching chapters P1 to P7. Learners answer all the questions.

3b. Assessment objectives (AO)

There are three Assessment Objectives in OCR GCSE (9–1) in Physics B (Twenty First Century Science). These are detailed in the table below.

Assessment Objectives		Weighting (%)	
		Higher	Foundation
AO1	**Demonstrate knowledge and understanding of:** • scientific ideas • scientific techniques and procedures	40	40
AO2	**Apply knowledge and understanding of:** • scientific ideas • scientific enquiry, techniques and procedures	40	40
AO3	**Analyse information and ideas to:** • interpret and evaluate • make judgements and draw conclusions • develop and improve experimental procedures	20	20

AO weightings in OCR GCSE (9–1) in Physics B (Twenty First Century Science)

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

Component (Foundation Tier)	% of overall GCSE (9–1) in Physics B (Twenty First Century Science) (J259)			
	AO1	AO2	AO3	Total
Breadth paper (Foundation Tier) J259/01	24	18	8	50
Depth paper (Foundation Tier) J259/02	16	22	12	50
Total	40	40	20	100
Component (Higher Tier)	**AO1**	**AO2**	**AO3**	**Total**
Breadth paper (Higher Tier) J259/03	24	18	8	50
Depth paper (Higher Tier) J259/04	16	22	12	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 components 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.

3

3e. Retaking the qualification

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

They retake all components in the tier of entry of the qualification.

3f. Assessment of extended response

Extended response questions which are marked using a level of response mark scheme are included in the Depth in biology components (02 and 04). These are indicated in papers and mark schemes by an asterisk (*). Extended response questions provide learners with the opportunity to demonstrate their ability to construct and develop a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

3g. Synoptic assessment

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

Synoptic assessment has been defined, for the purposes of this qualification, as allowing learners the opportunity to demonstrate the ability to draw together different areas of knowledge, skills and/or understanding from across the full course of study. The emphasis of synoptic assessment is to encourage the development of the understanding of Physics B (Twenty First Century Science) as a discipline. All papers 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.

3

3h. Calculating qualification results

A learner's overall qualification grade for OCR GCSE (9–1) in Physics B (Twenty First Century 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 Topic 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 B (Twenty First Century Science) must be entered for one of the following entry options:

Entry option		Components		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
J259 F	Physics B (Twenty First Century Science) (Foundation Tier)	01	Breadth in physics Foundation Tier	External Assessment
		02	Depth in physics Foundation Tier	External Assessment
J259 H	Physics B (Twenty First Century Science) (Higher Tier)	03	Breadth in physics Higher Tier	External Assessment
		04	Depth in physics Higher Tier	External Assessment

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. External assessment arrangements

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

Learners are permitted to use a scientific or graphical calculator for components 01, 02, 03 and 04. Calculators are subject to the rules in the document *Instructions for Conducting Examinations* published annually by JCQ (www.jcq.org.uk).

4

Head of centre annual declaration

The Head of Centre is required to provide a declaration to the JCQ as part of the annual NCN update, conducted in the autumn term, to confirm that the centre is meeting all of the requirements detailed in the specification.

Any failure by a centre to provide the Head of Centre Annual Declaration will result in your centre status being suspended and could lead to the withdrawal of our approval for you to operate as a centre.

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 B (Twenty First Century 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. 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 B, GCSE (9–1) in Chemistry B and GCSE (9–1) in Biology B courses. The links between the specifications may allow for some co-teaching, particularly in the area of working scientifically.

5b. 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.

5c. Units in science

It is expected that learners will show understanding of the SI base units 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.

SI base units		
Physical quantity	**Unit**	**Unit**
Length	Metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Current	Ampere	A
Amount of a substance	mole	mol

SI derived units		
Physical quantity	**Unit(s)**	**Unit(s)**
Area	squared metre	m^2
Volume	cubic metre; litre; cubic decimetre	m^3; *l*; dm^3
Density	kilogram per cubic metre	kg/m^3
Temperature	degree Celsius	°C
Pressure	Pascal	Pa
Specific heat capacity	joule per kilogram per degree Celsius	J/kg°C
Specific latent heat	joule per kilogram	J/kg
Speed	metre per second	m/s
Force	Newton	N
Gravitational field strength	newton per kilogram	N/kg
Acceleration	metre per squared second	m/s^2
Frequency	hertz	Hz
Energy	joule	J
Power	watt	W
Electric charge	coulomb	C
Electric potential difference	volt	V
Electric resistance	ohm	Ω
Magnetic flux density	tesla	T

5

5d. Mathematical skills

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			
M1	Arithmetic and numerical computation				
a	Recognise and use expressions in decimal form	B	C	P	CS
b	Recognise and use 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	B	C	P	CS
M2	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
M3	**Algebra**				
a	Understand and use the symbols: =, <, <<, >>, >, $\propto$, ~	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	CS
M4	**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
M5	**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

5e. Mathematical skills requirement

In order to be able to develop their skills, knowledge and understanding in GCSE (9–1) in Physics B (Twenty First Century Science), learners need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table of coverage below.

The questions and tasks used to target mathematical skills will be at a level of demand that is appropriate to GCSE (9–1) Physics.

In the Foundation Tier question papers, the questions that assess mathematical skills will not be of a lower demand than that which is expected of learners at Key Stage 3, as outlined in the Department for Education's document "Mathematics programme of study: key stage 3".

In the Higher Tier question papers, the questions that assess mathematical skills will not be lower demand than that of questions and tasks in the assessment for the Foundation Tier in a GCSE qualification in Mathematics.

The assessment of quantitative skills would include at least 30% GCSE (or above) 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.

This list of examples is not exhaustive and is not limited to GCSE examples. These skills could be developed in other areas of specification content from those indicated.

5

	Mathematical skills	Specification reference
M1	Arithmetic and numerical computation	
a	Recognise and use expressions in decimal form	1.3.6, 4.2.1, 4.2.7, 4.4.2, 4.4.3, 4.4.4, 4.4.5 4.4.9, 6.1.2, 6.1.5, 6.1.6, 6.1.8
b	Recognise and use expressions in standard form	3.6.3, 5.1.9, 6.1.2
c	Use ratios, fractions and percentages	1.3.6, 1.4.9, 2.1.8, 3.2.2, 3.2.4a, 3.3.1, 3.3.4, 3.4.2, 3.4.3, 3.4.4, 3.4.5b, 3.6.3, 3.7.8b, 4.1.7, 4.2.1, 4.2.4, 4.2.6a, 4.2.7, 4.3.4, 4.3.5, 4.3.9, 4.3.12, 4.3.17, 4.4.5, 4.4.6, 5.1.9, 5.1.11, 5.1.12, 6.1.2, 6.1.5a, 6.1.6 6.1.8, 6.3.5, 6.3.7, 6.4.5, 6.4.8
d	Make estimates of the results of simple calculations	4.3.17, 4.3.18
M2	Handling data	
a	Use an appropriate number of significant figures	6.1.8, IaS2.6
b	Find arithmetic means	4.2.3b, 4.3.18, 6.3.3b, IaS2.8
c	Construct and interpret frequency tables and diagrams, bar charts and histograms	2.2.3, 2.2.7, 4.2.4, 4.3.15, 4.3.17, IaS2.4, IaS2.7
f	Understand the terms mean, mode and median	4.2.3, 6.3.3b, IaS2.8

	Mathematical skills	Specification reference
g	Use a scatter diagram to identify a correlation between two variables	5.1.12, IaS2.8, IaS3.1
h	Make order of magnitude calculations	4.3.17, 4.3.18
M3	Algebra	
a	Understand and use the symbols: =, <, <<, >>, >, ∝ , ~	4.3.13* *No direct specification statement but skill will be assessed
b	Change the subject of an equation	2.1.3, 3.2.2, 3.2.4a, 3.3.1, 3.3.4, 3.4.2, 3.4.3, 3.4.4, 3.4.5, 3.6.3, 3.7.8, 4.1.7, 4.2.1, 4.2.6a, 4.2.7, 4.3.4, 4.3.5, 4.3.9, 4.3.12, 4.3.13, 4.3.17, 4.4.2, 4.4.3, 4.4.4, 4.4.9, 6.1.8, 6.3.5, 6.3.7, 6.4.2, 6.4.5
c	Substitute numerical values into algebraic equations using appropriate units for physical quantities	1.3.6, 1.4.9, 2.1.3, 3.2.2, 3.2.4a, 3.3.1, 3.3.4, 3.4.2, 3.4.3, 3.4.4, 3.4.5, 3.6.3, 3.7.8 4.1.7, 4.2.1, 4.2.6a, 4.2.4 4.2.7, 4.3.4, 4.3.5, 4.3.9, 4.3.12, 4.3.13, 4.3.17, 4.3.18, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.4.9, 5.1.9, 6.1.2, 6.1.8, 6.3.5, 6.3.7, 6.4.2, 6.4.5, 6.4.8
d	Solve simple algebraic equations	1.3.6, 2.1.3, 3.2.2, 3.2.4a, 3.3.1, 3.3.4, 3.4.2, 3.4.3, 3.4.4, 3.4.5, 3.6.3, 4.2.1, 4.2.6a, 4.2.7, 4.3.4, 4.3.5, 4.3.9, 4.3.12, 4.3.13, 4.4.2, 4.4.3, 4.4.4, 4.4.9, 5.1.11, 6.1.5a, 6.1.6, 6.1.8, 6.3.7, 6.4.5, 6.4.8
M4	Graphs	
a	Translate information between graphical and numeric form	2.1.9, 4.2.9, 4.2.10, 4.3.3, 5.1.12, IaS2.4, IaS2.7
b	Understand that y=mx+c represents a linear relationship	4.2.9, 4.2.10, IaS2.8
c	Plot two variables from experimental or other data	3.2.6a, 4.2.9, 4.2.10, 5.1.12 IaS2.7
d	Determine the slope and intercept of a linear graph	3.2.6a, 4.2.9, 4.2.10, IaS2.8
f	Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate	4.2.10, 6.3.6, IaS2.8
M5	Geometry and trigonometry	
a	Use angular measures in degrees	1.4.1, 1.4.2, 4.3.3
b	Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects	1.4.1, 1.4.2, 4.3.3
c	Calculate areas of triangles and rectangles, surface areas and volumes of cubes.	6.1.1b

5f. 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

5g. Equations in Physics

Equations required for Higher Tier only are in bold.

(a) In solving quantitative problems, students should be able correctly to recall, and apply the following relationships, using standard SI units:

force = mass × acceleration (P4.3.12, P4.3.13)

kinetic energy = 0.5 × mass × $(\text{speed})^2$ (P4.4.3)

momentum = mass × velocity (P4.3.4.) (P4.3.13)

work done = force × distance (along the line of action of the force) (P4.4.2)

power = energy ÷ time (P3.4.2, P4.4.9)

efficiency = useful energy transferred ÷ total energy transferred (P2.1.8)

weight = mass × gravitational field strength (g) (P4.1.7)

In a gravity field: gravitational potential energy = mass × gravitational field strength (g) × height (P4.4.4)

force exerted by a spring = extension × spring constant (P6.3.5)

moment of a force = force × distance (normal to direction of the force) (P4.3.9)

5

average speed = distance ÷ time (P4.2.1)

acceleration = change in speed ÷ time taken(P4.2.6a)

wave speed = frequency × wavelength (P1.3.6)

charge = current × time (P3.2.2)

potential difference = current × resistance (P3.2.4a)

power = potential difference × current = $(\text{current})^2$ × resistance (P3.4.4)

energy transferred (work done) = power × time = charge flow × potential difference (P2.1.3, P3.4.3)

density = mass ÷ volume (P6.1.2)

pressure = force normal to a surface ÷ area of that surface (P6.4.2)

potential difference = work done (energy transferred) ÷ charge (P3.3.1)

(b) In addition, students should be able correctly to select from a list and apply the following relationships:

$(\text{final speed})^2$ – $(\text{initial speed})^2$ = 2 × acceleration × distance (P4.2.7)

change in internal energy = mass × specific heat capacity × change in temperature (P6.1.5a)

energy to cause a change of state = mass × specific latent heat (P6.1.6)

energy stored in a stretched spring = $\frac{1}{2}$ × spring constant × $(\text{extension})^2$ (P6.3.7)

force = magnetic field strength × current × length of conductor (P3.6.3)

potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil (P3.4.5)

potential difference across primary coil ÷ potential difference across secondary coil = number of turns in primary coil ÷ number of turns in secondary coil (P3.7.8b)

for gases: pressure × volume = constant (for a given mass of gas and at a constant temperature) (P6.4.5)

pressure due to a column of liquid = height of column × density of liquid × g (P6.4.8)
change in momentum = resultant force × time for which it acts (P4.3.5)

YOUR CHECKLIST

Our aim is to provide you with all the information and support you need to deliver our specifications.

- ☐ Bookmark **ocr.org.uk/gcsec21physics** for all the latest resources, information and news on GCSE (9-1) Twenty First Century Science Physics B
- ☐ Be among the first to hear about support materials and resources as they become available – register for Twenty First Century Science Physics B updates at **ocr.org.uk/updates**
- ☐ Find out about our professional development at **cpdhub.ocr.org.uk**
- ☐ View our range of skills guides for use across subjects and qualifications at **ocr.org.uk/skillsguides**
- ☐ Discover our new online past paper service at **ocr.org.uk/examcreator**
- ☐ Learn more about Active Results at **ocr.org.uk/activeresults**
- ☐ Join our Twenty First Century Science Physics B social network community for teachers at **social.ocr.org.uk**

Download high-quality, exciting and innovative GCSE (9-1) Twenty First Century Science Physics B resources from ocr.org.uk/gcsec21physics

Resources and support for our GCSE (9-1) Twenty First Century Science Physics B qualification, developed through collaboration between our Physics Subject Specialists, teachers and other subject experts, are available from our website. You can also contact our Physics Subject Specialists who can give you specialist advice, guidance and support.

Meet the team at **ocr.org.uk/scienceteam** and contact them at:
01223 553998
science@ocr.org.uk
@OCR_science

To stay up to date with all the relevant news about our qualifications, register for email updates at **ocr.org.uk/updates**

Physics Community

The social network is a free platform where teachers can engage with each other – and with us – to find and offer guidance, discover and share ideas, best practice and a range of Physics support materials.
To sign up, go to **social.ocr.org.uk**

facebook.com/ocrexams **linkedin.com/company/ocr** **@OCR_science** **youtube.com/ocrexams**

ISO 9001 001

A DIVISION OF CAMBRIDGE ASSESSMENT