OCR
RECOGNISING ACHIEVEMENT

TWENTY FIRST CENTURY SCIENCE SUITE

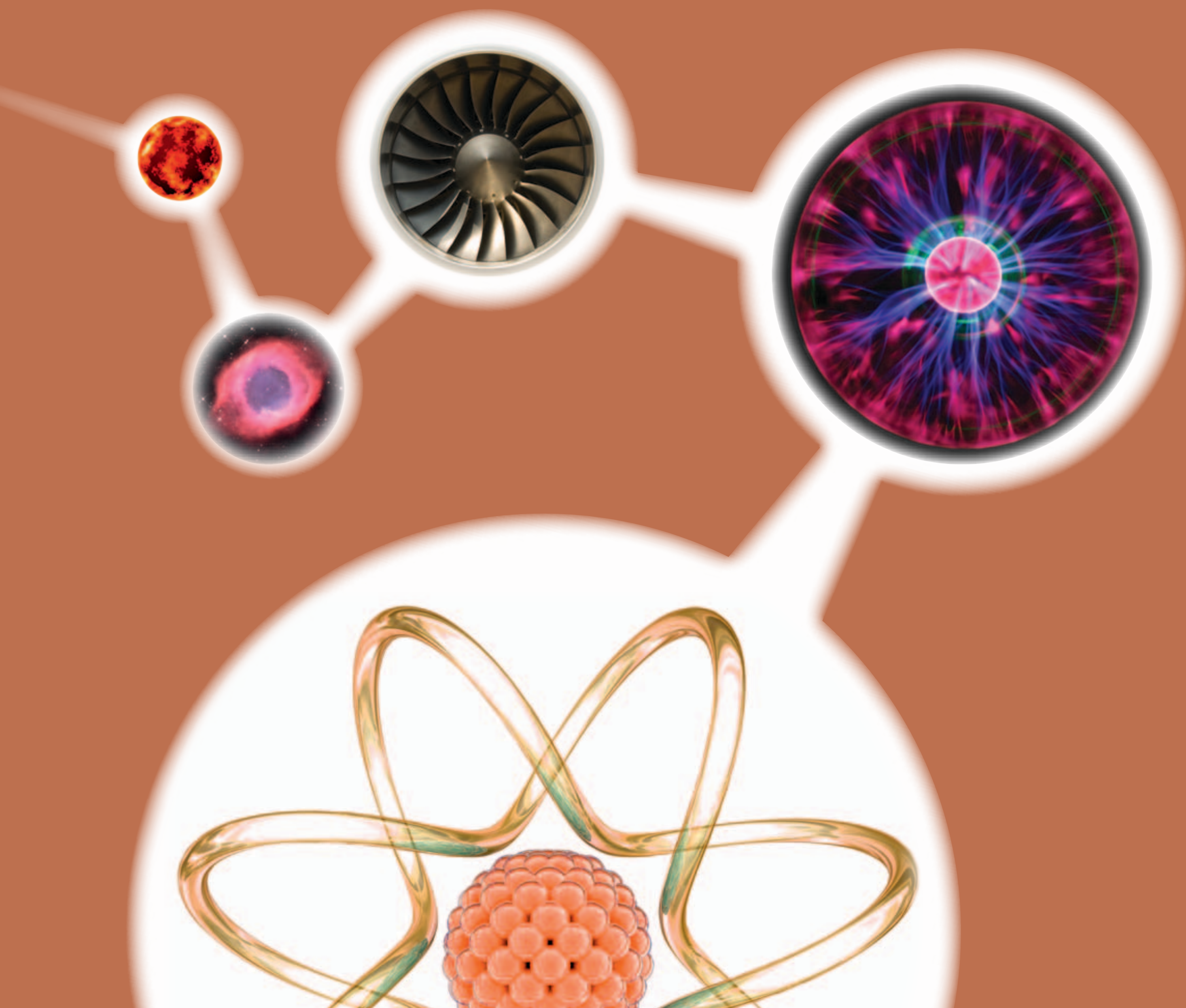
GCSE PHYSICS A

ACCREDITED SPECIFICATION

J245

VERSION 1

MARCH 2011



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- **Working in partnership to support you** – together with teachers we've developed a range of practical help and support to save you time. We provide everything you need to teach our specifications with confidence and ensure your students get as much as possible from our qualifications.
- **A personal service** – as well as providing you with lots of support resources, we're also here to help you with specialist advice, guidance and support for those times when you simply need a more individual service.

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DON'T FORGET
– you can download a copy of this specification and all our support materials at
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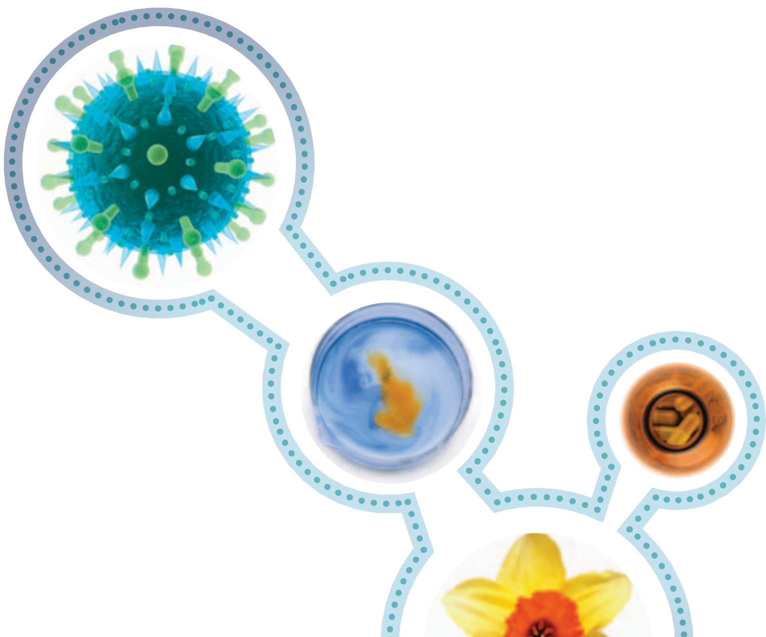

SUPPORTING YOU ALL THE WAY

Our aim is to help you at every stage and we work in close consultation with teachers and other experts, to provide a practical package of high quality resources and support.

Our support materials are designed to save you time while you prepare for and teach our new specifications. In response to what you have told us we are offering detailed guidance on key topics, controlled assessment and curriculum planning.

Our essential FREE support includes:

Materials

- Specimen assessment materials and mark schemes
- Guide to controlled assessment
- Sample controlled assessment material
- Exemplar candidate work
- Teacher's handbook
- Sample schemes of work and lesson plans
- Guide to curriculum planning
- Frequently asked questions
- Past papers.

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Our GCSE Science Get Started events:

- include useful information about our specifications direct from the experts
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Find out more at:
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2) Become an approved OCR centre – if your centre is completely new to OCR and has not previously used us for any examinations, visit **www.ocr.org.uk/centreapproval** to become an approved OCR centre.

TWENTY FIRST CENTURY SCIENCE SUITE

Science today – for scientists of tomorrow

Explore the science that underpins day-to-day life. Enthuse and motivate students using a mix of teaching strategies.

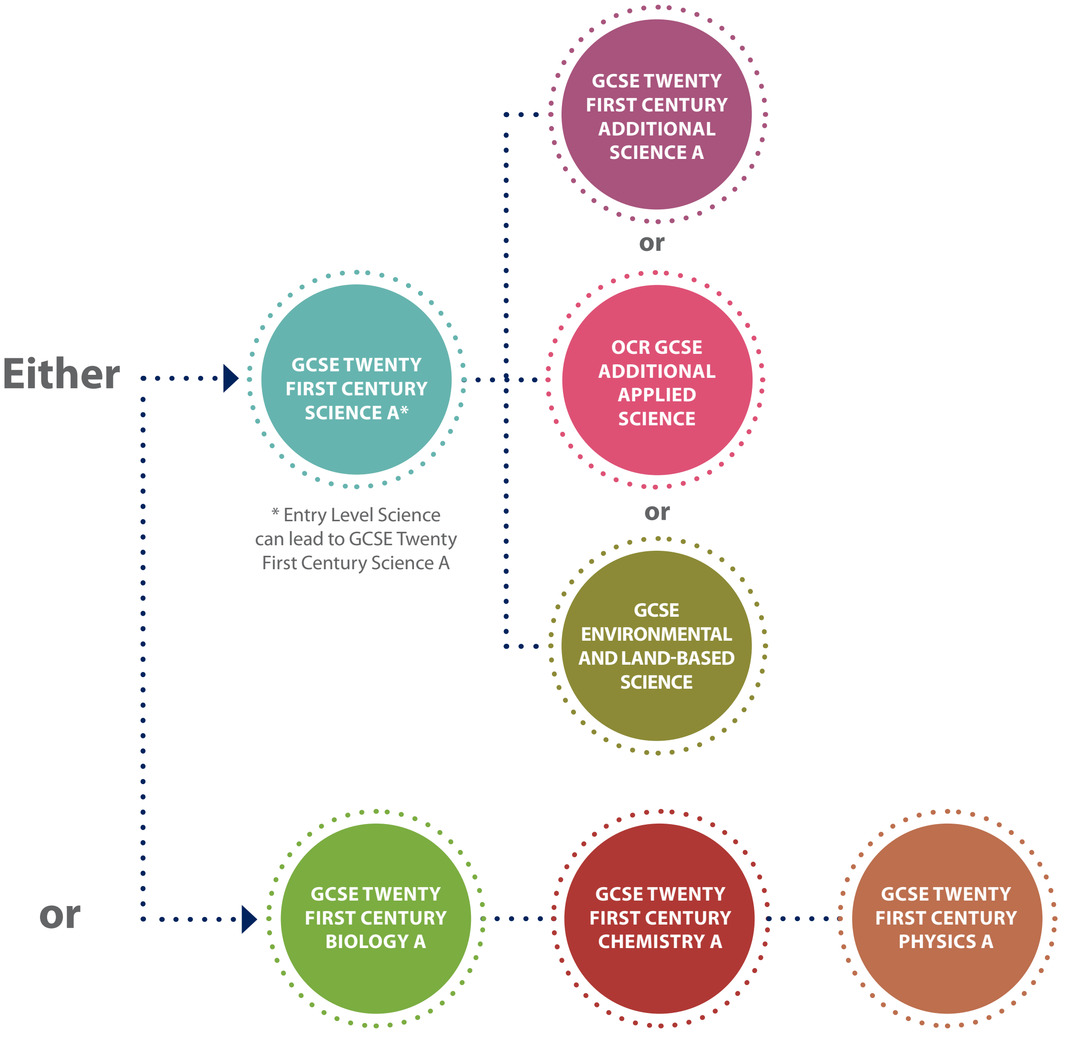
Our Twenty First Century Science suite:

- is engaging to study and motivating for you to teach
- will help your students engage with the course rather than just study it
- gives you the flexibility to choose a delivery style to engage students.

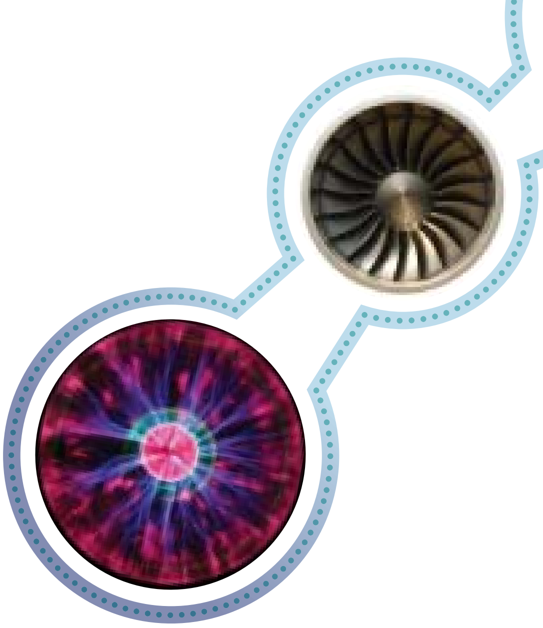
KEY FEATURES

- **Flexible assessments**, which can be arranged to suit your centre and your students – unit exams will be available twice a year, in January and June.
- An **ideal foundation** for students to progress to more-advanced studies and science-related careers.
- A well regarded and proven **concept led** teaching approach to science.

POSSIBLE GCSE COMBINATIONS



GCSE PHYSICS A



KEY FEATURES

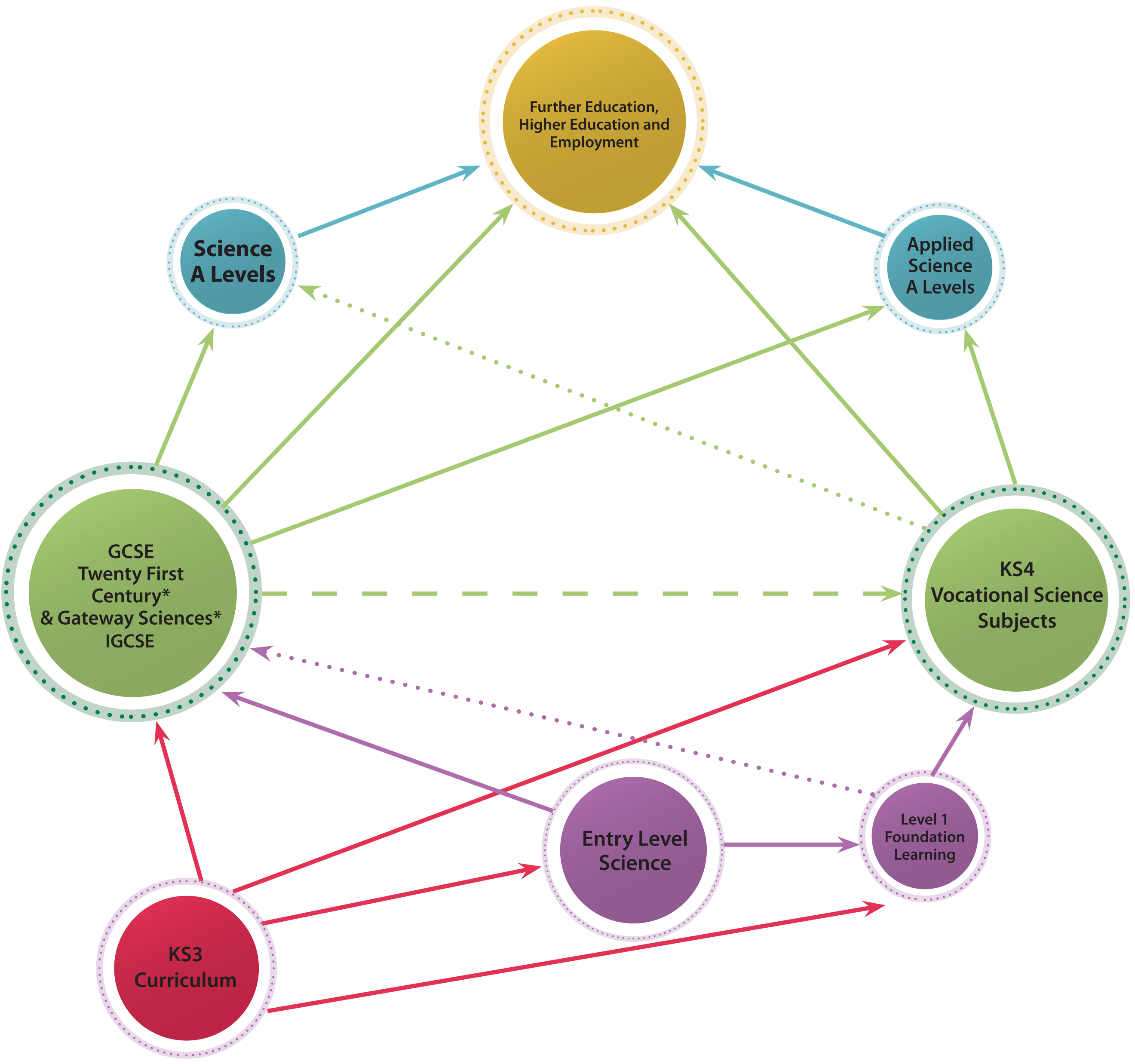
GCSE Physics A provides the opportunity for students to:

- develop interest in, and enthusiasm for, physics
- develop a critical approach to scientific evidence and methods
- acquire and apply skills, knowledge and understanding of how science works and its essential role in society
- acquire scientific skills, knowledge and understanding necessary for progression to further learning.

GCSE Physics A provides distinctive and relevant experience for students who wish to progress to Level 3 qualifications.

COURSE OVERVIEW	ASSESSMENT OVERVIEW		
UNIT A181 Module P1: The Earth in the Universe Module P2: Radiation and life Module P3: Sustainable energy	60 marks 1 hour written paper	**25%** of total GCSE	Three written exams, assessed externally by OCR, each of which: • is offered in Foundation and Higher Tiers • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication
UNIT A182 Module P4: Explaining motion Module P5: Electric circuits Module P6: Radioactive materials	60 marks 1 hour written paper	**25%** of total GCSE	
UNIT A183 Module P7: Further physics – studying the Universe	60 marks 1 hour written paper	**25%** of total GCSE	
UNIT A184 Controlled assessment	64 marks Approx 4.5–6 hours	**25%** of total GCSE	Comprises a Practical Investigation from a choice set by OCR Assessed by teachers, internally standardised and externally moderated by OCR Assesses the quality of written communication

PROGRESSION PATHWAYS IN SCIENCE



This could be a progression route along a particular curriculum pathway. (Stage, not age pathways)

This could be a progression route however students would require additional support.

Alternative qualification options

* Offered as
Science, Additional Science, Biology, Chemistry and Physics.

Contents

Contents

1 Introduction to the Twenty First Century Science suite

The Twenty First Century Science suite comprises five specifications which share a similar approach to teaching and learning, utilise common materials, use a consistent style of examination questions and have a common approach to skills assessment.

The qualifications available as part of this suite are:

- GCSE Science A
- GCSE Additional Science A
- GCSE Biology A
- GCSE Chemistry A
- GCSE Physics A.

GCSE Science A (J241)	which emphasises scientific literacy – the knowledge and understanding which candidates need to engage, as informed citizens, with science-based issues. As with other courses in the suite, this qualification uses contemporary, relevant contexts of interest to candidates, which can be approached through a range of teaching and learning activities.
GCSE Additional Science A (J242)	which is a concept-led course developed to meet the needs of candidates seeking a deeper understanding of basic scientific ideas. The course focuses on scientific explanations and models, and gives candidates an insight into how scientists develop scientific understanding of ourselves and the world we inhabit.
GCSE Biology A (J243)	each of which provides an opportunity for further developing an understanding of science explanations, how science works and the study of elements of applied science, with particular relevance to professional scientists.
GCSE Chemistry A (J244)	
GCSE Physics A (J245)	

The suite emphasises explanations, theories and modelling in science along with the implications of science for society. Strong emphasis is placed on the active involvement of candidates in the learning process and each specification encourages a wide range of teaching and learning activities.

The suite is supported by the Nuffield Foundation Curriculum Programme and the University of York Science Education Group, and by resources published by Oxford University Press.

In addition, an Additional Applied Science course (J251) is available. This can be used in conjunction with Science A as an alternative route to two science GCSEs, for candidates not following GCSE Additional Science A.

Introduction to GCSE Physics A

2.1 Overview of OCR GCSE Physics A

Unit A181: ***Modules P1, P2, P3***	
This is a tiered unit offered in Foundation and Higher Tiers.	Written paper 1 hour 60 marks 25% of the qualification Candidates answer all questions. The unit uses both objective style and free response questions.

+

Unit A182: ***Modules P4, P5, P6***	
This is a tiered unit offered in Foundation and Higher Tiers.	Written paper 1 hour 60 marks 25% of the qualification Candidates answer all questions. The unit uses both objective style and free response questions.

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Unit A183: ***Module P7***	
This is a tiered unit offered in Foundation and Higher Tiers.	Written paper 1 hour 60 marks 25% of the qualification Candidates answer all questions. The unit uses both objective style and free response questions.

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Unit A184: ***Controlled assessment***	
This unit is not tiered.	Controlled assessment Approximately 4.5–6 hours 64 marks 25% of the qualification

2.2 What is new in OCR GCSE Physics A?

	What stays the same?	What changes?
Structure	• The course can be taught as modular or linear. • Four units, comprising three externally assessed units and one internally assessed unit. • Externally assessed units are tiered – Foundation and Higher Tier.	• All four units have equal weightings of 25%. • Controlled assessment replaces coursework. • No 'Ideas in Context' paper, and no pre-release material for externally assessed units.
Content	• Content is divided into seven modules. • Module P7 is equivalent in length to any three modules from P1–P6.	• Module P3, 'Radioactive materials' is reorganised, with some content retained in new P3 'Sustainable energy' and the rest transferred to the new P6 'Radioactive materials'. • Parts of the original P6, 'The wave model of radiation' are transferred to the updated P2, 'Radiation and life'.
Assessment	• The internally assessed unit is based on a Practical Investigation. • Modules are externally assessed within written examination papers. • Ideas about Science (How Science Works) are written into the specification content. • January and June assessments are available for written papers. • Controlled assessment is available in June series only.	• New terminal and re-sit rules apply to science GCSEs. • There will be a choice of controlled assessment tasks set by OCR, each valid for entry in a single examination series. • The controlled assessment for Physics will be based on a Practical Investigation only. • Controlled assessment is worth 25%, and will be simpler to mark and administer. • Ideas about Science are associated with all units. • Quality of written communication (QWC) will be assessed in all units. • Externally assessed papers are each 1 hour long, with a total of 60 marks divided between objective (worth 40%) and free response style questions.

2.3 Guided learning hours

GCSE Physics A requires 120–140 guided learning hours in total.

Content of GCSE Physics A

3.1 Summary of content

A module defines the required teaching and learning outcomes.

The specification content is displayed as seven modules. The titles of these seven modules are listed below.

Modules P1 – P6 are designed to be taught in approximately **half a term each**, in 10% of the candidates' curriculum time. Module P7 is designed to be taught in approximately **one and a half terms** at 10% curriculum time.

Module P1: The Earth in the Universe	Module P2: Radiation and life	Module P3: Sustainable energy
• What do we know about the place of the Earth in the Universe? • What do we know about the Earth and how it is changing?	• What types of electromagnetic radiation are there? What happens when radiation hits an object? • Which types of electromagnetic radiation harm living tissue and why? • What is the evidence for global warming, why might it be occurring, and how serious a threat is it? • How are electromagnetic waves used in communications?	• How much energy do we use? • How can electricity be generated? • Which energy sources should we choose?
Module P4: Explaining motion	**Module P5: Electric circuits**	**Module P6: Radioactive materials**
• How can we describe motion? • What are forces? • What is the connection between forces and motion? • How can we describe motion in terms of energy changes?	• Electric current – a flow of what? • What determines the size of the current in an electric circuit and the energy it transfers? • How do parallel and series circuits work? • How is mains electricity produced? How are voltages and currents induced? • How do electric motors work?	• Why are some materials radioactive? • How can radioactive materials be used and handled safely, including wastes?
Module P7: Further Physics – Studying the Universe		
• Naked eye astronomy • Light, telescopes and images	• Mapping the Universe • The Sun, the stars and their surroundings	• The astronomy community

3.2 Layout of specification content

The specification content is divided into seven modules assessed across three units. Three modules (P1 – P3), together with their associated Ideas about Science (see Appendix B), are assessed in Unit A181. The next three modules (P4 – P6) and their associated Ideas about Science are assessed in Unit A182. Module P7 is assessed in Unit A183, together with **any** of the Ideas about Science from Appendix B.

A summary of each unit precedes the modules that are assessed within that unit, indicating the modules and the associated Ideas about Science that can be assessed.

Each module starts with an overview that explains the background to the module and identifies:

- for Modules P1 – P3:
  - issues for citizens that are likely to be uppermost in their minds when considering the module topic, whatever their understanding of science
  - questions about the topic that science can help to address, which could reasonably be asked of a scientifically literate person
- for Modules P4 – P7:
  - a summary of the topics
- opportunities for mathematics
- opportunities for practical work
- opportunities for ICT.

Following the module overview, the Ideas about Science that can be introduced or developed in the module are outlined. Finally, the module content is presented in detail.

Within the detailed content of each module, several notations are used to give teachers additional information about the assessment. The table below summarises these notations.

Notation	Explanation
Bold	**These content statements will only be assessed on Higher Tier papers.**
ⓘ	*Advisory notes for teachers to clarify depth of cover required.*

3.3 Summary of Physics A Unit A181: *Modules P1, P2, P3*

Unit A181 is the first unit for GCSE Physics A. It assesses the content of Modules P1, P2 and P3 together with their associated Ideas about Science.

The modules in Unit A181 offer students the chance to develop the scientific literacy needed by active and informed citizens in a modern democratic society where science and technology play key roles in shaping our lives. The course content has a clear focus on scientific literacy. Teachers can use a wide range of teaching and learning styles, challenging students to consider critically the issues and choices raised by technology and science. Students will appreciate what science has to say about people, the environment and the Universe.

Ideas about Science in Unit A181

Modules P1, P2 and P3 present learning opportunities for a number of the Ideas about Science. The start of each module details the particular Ideas about Science that can be introduced or developed within the contexts covered in the module. Specific examples of contexts within which Ideas about Science can be taught are given in the OCR scheme of work for GCSE Physics A (published separately).

However, it is not intended that understanding and application of Ideas about Science should be limited to the context in which they are taught; they should be applicable to any appropriate scientific context.

Accordingly, questions in Unit A181 can assess any of the Ideas about Science linked to Modules P1, P2 and P3, and these Ideas about Science may be assessed in the context of any of the learning outcomes covered in the three modules.

In summary, the Ideas about Science that can be assessed in Unit A181, within any of the scientific contexts introduced by Modules P1, P2 and P3, are:

Cause-effect explanations
IaS 2.3 – 2.7
Developing scientific explanations
IaS 3.1 – 3.4
The scientific community
IaS 4.1 – 4.4
Risk
IaS 5.1 – 5.7
Making decisions about science and technology
IaS 6.1 – 6.3, 6.5, 6.6

3.3.1 Module P1: The Earth in the Universe

Overview

Scientific discoveries in the solar system and beyond continue to inspire popular culture and affect our understanding of our place in the Universe. In this module, candidates explore the scale of the Universe and its past, present and future, and consider the ideas scientists have and their evidence for them.

Closer to home, candidates consider long-term and short-term changes in the Earth's crust, and how these changes impact on human life. In particular, they find out about earthquakes and volcanoes – explaining them, predicting them and coping with them.

The module focuses on how we know the things we think we know about the Earth and its place in the Universe. Across the whole module, candidates encounter many examples showing relationships between data and explanations. Through these contexts they learn about the way scientists communicate and develop new explanations.

Issues for citizens	Questions that science may help to answer
How do we know about things we can barely see? How do scientists develop explanations of the Earth and space? Why do mountains come in chains, in particular places? Can we predict earthquakes, especially those that are likely to cause most damage?	Where do the elements of life come from? What do we know about the Universe? How have the Earth's continents moved, and with what consequences?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale, including: size – from the size of the Earth to that of the solar system and the Universe; speed – from the movement of tectonic plates to the speed of light; and time – from the age of the Earth to the age of the Universe
- carry out calculations using experimental data, including finding the mean and the range
- use ideas of inverse proportion in the context of wavelength and frequency
- use equations, including appropriate units for physical quantities.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- use diffraction gratings to look at a variety of spectra
- measure distances using parallax
- investigate the relationship between brightness of a light source and distance from the source
- model the rock cycle and the movement of tectonic plates
- model the changing magnetic pattern on the sea floor
- explore the build up of forces that precede a 'brickquake'
- explore transverse and longitudinal waves on a slinky spring.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- computer modelling of galaxies in collision
- creating a 3D model of the large-scale structure of the Universe from individual galaxy observations
- processing data on movements of the Earth's lithosphere (as evidence to support the theory of plate tectonics)
- analysing wave reflections in seismic explorations.

Use of ICT in teaching and learning can include:

- animations to illustrate the movement of continents as they are carried by tectonic plates
- using the internet to research particular geohazards
- video clips to show examples of wave motion
- animation to show the behaviour of waves in ripple tanks
- modelling software to investigate the implications of the wave equation.

Module P1: The Earth in the Universe – Ideas about Science

Module P1 provides opportunities to develop candidates' understanding of these Ideas about Science

3	**Developing scientific explanations** Candidates should understand that:	A candidate who understands this can, for example:
3.1	• scientific hypotheses, explanations and theories are not simply summaries of the available data. They are based on data but are distinct from them.	• in a given account of scientific work, identify statements which report data and statements of explanatory ideas (hypotheses, explanations, theories) • recognise that an explanation may be incorrect even if the data agree with it.
3.2	• an explanation cannot simply be deduced from data, but has to be thought up creatively to account for the data.	• identify where creative thinking is involved in the development of an explanation.
3.3	• a scientific explanation should account for most (ideally all) of the data already known. It may explain a range of phenomena not previously thought to be linked. It should also enable predictions to be made about new situations or examples.	• recognise data or observations that are accounted for by, or conflict with, an explanation • give good reasons for accepting or rejecting a proposed scientific explanation • identify the better of two given scientific explanations for a phenomenon, and give reasons for the choice.
3.4	• scientific explanations are tested by comparing predictions based on them with data from observations or experiments.	• draw valid conclusions about the implications of given data for a given scientific explanation, in particular: – understand that agreement between a prediction and an observation increases confidence in the explanation on which the prediction is based but does not prove it is correct – understand that disagreement between a prediction and an observation indicates that one or other is wrong, and decreases our confidence in the explanation on which the prediction is based.

4	**The scientific community**	
	Candidates should understand that:	A candidate who understands this can, for example:
4.1	• scientists report their claims to other scientists through conferences and journals. Scientific claims are only accepted once they have been evaluated critically by other scientists.	• describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists • recognise that there is less confidence in new scientific claims that have not yet been evaluated by the scientific community than there is in well-established ones.
4.2	• scientists are usually sceptical about claims that cannot be repeated by anyone else, and about unexpected findings until they have been replicated (by themselves) or reproduced (by someone else).	• identify the fact that a finding has not been reproduced by another scientist as a reason for questioning a scientific claim • explain why scientists see this as important.
4.3	• if explanations cannot be deduced from the available data, 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.	• show awareness that the same data might be interpreted, quite reasonably, in more than one way • suggest plausible reasons why scientists in a given situation disagree(d).
4.4	• an accepted scientific explanation is rarely abandoned just because some new data disagree with its predictions. It usually survives until a better explanation is available.	• discuss the likely consequences of new data that disagree with the predictions of an accepted explanation • **suggest reasons why scientists should not give up an accepted explanation immediately if new data appear to conflict with it.**

Module P1: The Earth in the Universe

P1.1 What do we know about the place of the Earth in the Universe?

1. recall that the Earth is one of eight planets moving in almost circular paths round the Sun which, together with other smaller objects orbiting the Sun (asteroids, dwarf planets, comets) and moons orbiting several planets, make up the solar system
2. describe the principal differences between planets, moons, the Sun, comets and asteroids, including their relative sizes and motions
3. understand that the solar system was formed over very long periods from clouds of gases and dust in space, about five thousand million years ago
4. recall that the Sun is one of thousands of millions of stars in the Milky Way galaxy
5. recall that there are thousands of millions of galaxies, each containing thousands of millions of stars, and that all of these galaxies make up the Universe
6. put in order and recall the relative sizes of: the diameters of the Earth, the Sun, the Earth's orbit, the solar system, the Milky Way, the distance from the Sun to the nearest star, and the distance from the Milky Way to the nearest galaxy
7. understand that all the evidence we have about distant stars and galaxies comes from the radiation astronomers can detect
8. recall that light travels through space (a vacuum) at a very high but finite speed, 300 000 km/s
9. recall that a light-year is the distance travelled by light in a year
10. understand that the finite speed of light means that very distant objects are observed as they were in the past, when the light we now see left them
11. understand how the distance to a star can be measured using parallax (qualitative idea only)
12. understand how the distance to a star can be estimated from its relative brightness
13. understand that light pollution and other atmospheric conditions interfere with observations of the night sky
14. explain why there are uncertainties about the distances of stars and galaxies with reference to the nature and difficulty of the observations on which these are based and the assumptions made in interpreting them
15. understand that the source of the Sun's energy is the fusion of hydrogen nuclei
16. understand that all chemical elements with atoms heavier than helium were made in stars
17. understand that **the redshift in the light coming from them suggests that** distant galaxies are moving away from us
18. **understand that (in general) the further away a galaxy is, the faster it is moving away from us**
19. **understand how the motions of galaxies suggests that space itself is expanding**
20. recall and put in order the relative ages of the Earth, the Sun, and the Universe
21. recall that scientists believe the Universe began with a 'big bang' about 14 thousand million years ago
22. understand that the ultimate fate of the Universe is difficult to predict because of difficulties in measuring the very large distances involved **and the mass of the Universe**, and studying the motion of very distant objects.

Module P1: The Earth in the Universe

P1.2 What do we know about the Earth and how it is changing?

1. understand how rocks provide evidence for changes in the Earth (erosion and sedimentation, fossils, folding)
2. understand that continents would be worn down to sea level by erosion, if mountains were not being continuously formed
3. understand that the rock processes seen today can account for past changes
4. understand that the age of the Earth can be estimated from, and must be greater than, the age of its oldest rocks, which are about four thousand million years old
5. understand Wegener's theory of continental drift and his evidence for it (geometric fit of continents and their matching fossils and rock layers)
6. understand how Wegener's theory accounts for mountain building
7. understand reasons for the rejection of Wegener's theory by geologists of his time (movement of continents not detectable, too big an idea from limited evidence, simpler explanations of the same evidence, Wegener an outsider to the community of geologists)
8. understand that seafloor spreading is a consequence of movement of the mantle (convection due to heating by the core)
9. recall that seafloors spread by a few centimetres a year
10. **understand how seafloor spreading and the periodic reversals of the Earth's magnetic field can explain the pattern in the magnetisation of seafloor rocks on either side of the oceanic ridges**
11. understand that earthquakes, volcanoes and mountain building generally occur at the edges of tectonic plates
12. **understand how the movement of tectonic plates causes earthquakes, volcanoes and mountain building, and contributes to the rock cycle**
13. recall that earthquakes produce wave motions on the surface and inside the Earth which can be detected by instruments located on the Earth's surface
14. recall that earthquakes produce:
    a. P-waves **(longitudinal waves)** which travel through solids and liquids
    b. S-waves **(transverse waves)** which travel through solids but not liquids
15. describe the difference between a transverse and longitudinal wave
16. understand how differences in the **wave speeds and** behaviour of P-waves and S-waves can be used to give evidence for the structure of the Earth
17. in relation to waves, use the equation:

$$\underset{\text{(metres, m)}}{\text{distance}} = \underset{\text{(metres per second, m/s)}}{\text{wave speed}} \times \underset{\text{(seconds, s)}}{\text{time}}$$

18. draw and label a diagram of the Earth to show its crust, mantle and core
19. recall that a wave is a disturbance, caused by a vibrating source, that transfers energy in the direction that the wave travels, without transferring matter

P1.2 What do we know about the Earth and how it is changing?

20. recall that the frequency of waves, in hertz (Hz), is the number of waves each second that are made by the source, or that pass through any particular point
21. recall that the wavelength of waves is the distance between the corresponding points on two adjacent cycles
22. recall that the amplitude of a wave is the distance from the maximum displacement to the undisturbed position
23. draw and interpret diagrams showing the amplitude and the wavelength of waves
24. use the equation:

$$\underset{\text{(metres per second, m/s)}}{\text{wave speed}} = \underset{\text{(hertz, Hz)}}{\text{frequency}} \times \underset{\text{(metres, m)}}{\text{wavelength}}$$

25. understand that for a constant wave speed the wavelength of the wave is inversely proportional to the frequency.

3.3.2 Module P2: Radiation and life

Overview

The possible health risks of radiation, both in nature and from technological devices, are becoming of increasing concern. In some cases, misunderstanding the term 'radiation' generates unnecessary alarm. By considering the need to protect the skin from sunlight, candidates are introduced to a general model of radiation travelling from the source to a receiver. They learn about the electromagnetic spectrum and the harmful effects of some radiation.

The greenhouse effect and photosynthesis illustrate how radiation from the Sun is vital to life, whilst the ozone layer is shown to be a natural protection from harmful radiation. Candidates study evidence of global warming and its relationship to the carbon cycle. Possible consequences and preventative actions are explored.

The importance of electromagnetic radiation for communication is explored with a consideration of how mobile phones are used to send digital images and sounds. Finally, through an investigation of evidence concerning the possible harmful effects of low intensity microwave radiation from devices such as mobile phones, candidates learn to evaluate reported health studies and interpret levels of risk.

When considering the whole electromagnetic spectrum, it is sometimes more appropriate to use a photon model; at other times a wave model is considered.

Issues for citizens	Questions that science may help to answer
What is radiation? Is it safe to use mobile phones? Is it safe to sunbathe? Are there any benefits from radiation? What is global warming, and what can be done to prevent or reduce it?	What types of electromagnetic radiation are there? What happens when radiation hits an object? Which types of electromagnetic radiation harm living tissues and why? What ideas about risk do citizens and scientists use? How does electromagnetic radiation make life on Earth possible? What is the evidence for global warming, why might it be occurring, and how serious a threat is it?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- use ideas of proportion in the context of energy of a photon and the frequency of the radiation
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- extract information from charts, graphs and tables
- use ideas about correlation in the context of information about the possible effects of electromagnetic radiation on health
- use ideas about probability in the context of risk.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- investigate how well different sun-screens filter ultraviolet radiation
- investigate the properties of microwaves using a mobile phone
- investigate climate change models – both physical models and computer models
- carry out image processing to find out how the information in an image file relates to the quality of the image
- show how noise affects analogue and digital signals.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- computer climate modelling
- displaying data on stratospheric ozone concentrations as a false colour map
- processing digital images and sound files.

Use of ICT in teaching and learning can include:

- slides to illustrate evidence of climate change
- video clips to illustrate infrared imaging
- animations to model Sun's radiation and greenhouse effect
- animations to model effect of carbon dioxide levels on global temperature
- spreadsheets to model features of analogue and digital communications systems
- investigating digital images.

Module P2: Radiation and life – Ideas about Science

Module P2 provides opportunities to develop candidates' understanding of these Ideas about Science

2	Cause-effect explanations Candidates should understand that:	A candidate who understands this can, for example:
2.3	• if an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	• suggest and explain an example from everyday life of a correlation between a factor and an outcome • identify where a correlation exists when data are presented as text, as a graph, or in a table. ⓘ *Examples may include both positive and negative correlations, but candidates will not be expected to know these terms.*
2.4	• a correlation between a factor and an outcome does not necessarily mean that the factor causes the outcome; both might, for example, be caused by some other factor.	• use the ideas of correlation and cause when discussing data and show awareness that a correlation does not necessarily indicate a causal link • identify, and suggest from everyday experience, examples of correlations between a factor and an outcome where the factor is (or is not) a plausible cause of the outcome • explain why an observed correlation between a given factor and outcome does not necessarily mean that the factor causes the outcome.
2.5	• in some situations, a factor alters the chance (or probability) of an outcome, but does not invariably lead to it. We also call this a correlation.	• 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.
2.6	• to investigate a claim that a factor increases the chance (or probability) of an outcome, scientists compare samples (eg groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples, the more confident we can be about any conclusions drawn.	• discuss whether given data suggest that a given factor does/does not increase the chance of a given outcome • evaluate critically the design of a study to test if a given factor increases the chance of a given outcome, by commenting on sample size and how well the samples are matched.
2.7	• **even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.**	• **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.**

5	Risk Candidates should understand that:	A candidate who understands this can, for example:
5.1	• everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.	• explain why it is impossible for anything to be completely safe • identify examples of risks which arise from a new scientific or technological advance • suggest ways of reducing a given risk.
5.2	• we can sometimes assess the size of a risk by measuring its chance of occurring in a large sample, over a given period of time.	• interpret and discuss information on the size of risks, presented in different ways.
5.3	• to make a decision about a particular risk, we need to take account both of the chance of it happening and the consequences if it did.	• discuss a given risk, taking account of both the chance of it occurring and the consequences if it did.
5.4	• to make a decision about a course of action, we need to take account of both its risks and benefits, to the different individuals or groups involved.	• identify risks and benefits in a given situation, to the different individuals and groups involved • discuss a course of action, with reference to its risks and benefits, taking account of who benefits and who takes the risks • suggest benefits of activities that are known to have risk.
5.5	• 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.	• offer reasons for people's willingness (or reluctance) to accept the risk of a given activity.
5.6	• **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).**	• **distinguish between perceived and calculated risk, when discussing personal choices** • **suggest reasons for given examples of differences between perceived and measured risk.**
5.7	• governments and public bodies may have to assess what level of risk is acceptable in a particular situation. This decision may be controversial, especially if those most at risk are not those who benefit.	• discuss the public regulation of risk, **and explain why it may in some situations be controversial.**

Module P2: Radiation and life

P2.1 What types of electromagnetic radiation are there? What happens when radiation hits an object?

1. interpret situations in which one object affects another some distance away in terms of a general model of electromagnetic radiation:

    a. one object (a source) emits radiation

    b. the radiation travels outwards from the source and can be reflected, transmitted or absorbed (or a combination of these) by materials it encounters

    c. radiation may affect another object (a detector) some distance away, when it is absorbed

2. understand that light is one of a family of radiations called the electromagnetic spectrum

3. understand that a beam of electromagnetic radiation transfers energy in ‘packets’ called photons

4. understand that the higher the frequency of an electromagnetic radiation, the more energy is transferred by each photon

5. list the electromagnetic radiations in order of the energy transferred by each photon, or in order of frequency:
radio waves, microwaves, infrared, $^{\text{red}}$ visible light $^{\text{violet}}$, ultraviolet, X-rays, gamma rays

6. recall that all types of electromagnetic radiation travel at exactly the same, very high but finite, speed through space (a vacuum) of 300 000 km/s

7. understand that the energy arriving at a **square metre of** surface each second is a useful measure of the strength (or ‘intensity’) of a beam of electromagnetic radiation

8. understand that the energy transferred to an absorber by a beam of electromagnetic radiation depends on both the number of photons arriving and the energy of each photon

9. understand that the intensity of a beam of electromagnetic radiation decreases with distance from the source **and explain why, in terms of the ever increasing surface area it reaches and its partial absorption by the medium it travels through**

10. understand that some electromagnetic radiations (ultraviolet radiation, X-rays, gamma rays) have enough energy to change atoms or molecules, **which can initiate chemical reactions**

11. recall that high energy ultraviolet radiation, X-rays and gamma rays can cause ionisation

12. understand that the electromagnetic radiations which are ionising are those with high enough photon energy to remove an electron from an atom or molecule (ionisation).

Module P2: Radiation and life

P2.2 Which types of electromagnetic radiation harm living tissue and why?

1. understand that the heating effect of absorbed radiation can damage living cells
2. relate the heating effect when radiation is absorbed to its intensity and duration
3. understand that some people have concerns about health risks from low intensity microwave radiation, for example from mobile phone handsets and masts, though the evidence for this is disputed
4. understand that some microwaves are strongly absorbed by water molecules and so can be used to heat objects containing water
5. understand that the metal cases and door screens of microwave ovens reflect or absorb microwave radiation and so protect users from the radiation
6. recall that some materials (radioactive materials) emit ionising gamma radiation all the time
7. understand that with increased exposure to ionising radiation, damage to living cells increases eventually leading to cancer or cell death
8. understand that the ozone layer absorbs ultraviolet radiation, emitted by the Sun, **producing chemical changes in that part of the atmosphere**
9. understand that the ozone layer protects living organisms from some of the harmful effects of ultraviolet radiation
10. recall that sun-screens and clothing can be used to absorb some of the ultraviolet radiation from the Sun
11. recall that physical barriers absorb some ionising radiation, for example: X-rays are absorbed by dense materials so can be used to produce shadow pictures of bones in our bodies or of objects in aircraft passengers' luggage, and radiographers are protected from radiation by dense materials such as lead and concrete.

Module P2: Radiation and life

P2.3 What is the evidence for global warming, why might it be occurring, and how serious a threat is it?

1. understand that all objects emit electromagnetic radiation with a principal frequency that increases with temperature
2. recall that the Earth is surrounded by an atmosphere which allows some of the electromagnetic radiation emitted by the Sun to pass through
3. recall that this radiation warms the Earth's surface when it is absorbed
4. understand that the radiation emitted by the Earth**, which has a lower principal frequency than that emitted by the Sun,** is absorbed or reflected back by some gases in the atmosphere; this keeps the Earth warmer than it would otherwise be and is called the greenhouse effect
5. recall that one of the main greenhouse gases in the Earth's atmosphere is carbon dioxide, which is present in very small amounts
6. recall that other greenhouse gases include methane, present in very small amounts, and water vapour
7. interpret simple diagrams representing the carbon cycle
8. use the carbon cycle to explain:
    a. why, for thousands of years, the amount of carbon dioxide in the Earth's atmosphere was approximately constant
    b. that some organisms remove carbon dioxide from the atmosphere by photosynthesis (eg green plants) and many organisms return carbon dioxide to the atmosphere by respiration as part of the recycling of carbon
    c. why, during the past two hundred years, the amount of carbon dioxide in the atmosphere has been steadily rising
9. recall that the rise in atmospheric carbon dioxide is largely the result of:
    a. burning increased amounts of fossil fuels as an energy source
    b. cutting down or burning forests to clear land
10. **understand that computer climate models provide evidence that human activities are causing global warming**
11. understand how global warming could result in:
    a. it being impossible to continue growing some food crops in particular regions because of climate change
    b. more extreme weather events, **due to increased convection and larger amounts of water vapour in the hotter atmosphere**
    c. flooding of low lying land due to rising sea levels, caused by melting continental ice and expansion of water in the oceans.

Module P2: Radiation and life

P2.4 How are electromagnetic waves used in communications?

1. understand that electromagnetic radiation of some frequencies can be used for transmitting information, since:
   a. some radio waves and microwaves are not strongly absorbed by the atmosphere so can be used to carry information for radio and TV programmes
   b. light and infrared radiation can be used to carry information along optical fibres because the radiation travels large distances through glass without being significantly absorbed
2. recall that information can be superimposed on to an electromagnetic carrier wave, to create a signal
3. recall that a signal which can vary continuously is called an analogue signal
4. recall that a signal that can take only a small number of discrete values (usually two) is called a digital signal
5. recall that sound and images can be transmitted digitally (as a digital signal)
6. recall that, in digital transmission, the digital code is made up from just two symbols, ‘0’ and ‘1’
7. understand that this coded information can be carried by switching the electromagnetic carrier wave off and on to create short bursts of waves (pulses) where ‘0’ = no pulse and ‘1’ = pulse
8. recall that when the waves are received, the pulses are decoded to produce a copy of the original sound wave or image
9. understand that an important advantage of digital signals over analogue signals is that if the original signal has been affected by noise it can be recovered more easily **and explain why**
10. recall that the amount of information needed to store an image or sound is measured in bytes (B)
11. understand that, generally, the more information stored the higher the quality of the sound or image
12. understand that an advantage of using digital signals is that the information can be stored and processed by computers

3.3.3 Module P3: 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 module.

Candidates first survey the ways in which individuals and organisations use energy, and learn how energy demand and use can be measured. They explore the use of energy-efficient devices (eg light bulbs) and consider the quantitative consequences of various lifestyle choices (eg relating to transport and the use of electrical equipment). National data on energy sources introduce a study of electricity generation and distribution; nuclear power generation, the burning of fossil fuels, and renewable resources are compared and contrasted. Finally, candidates review the energy choices available to individuals, organisations and society.

Issues for citizens	Questions that science may help to answer
How can we use less energy? Why do we need to make decisions about nuclear power? Which energy sources should we use?	How is energy used? How can electricity be generated? What are the advantages and disadvantages of different ways of generating electricity?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations using fractions and percentages, particularly in the context of energy efficiency
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use equations, including appropriate units for physical quantities
- extract information from charts, graphs and tables
- use ideas about probability in the context of risk.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- compare the power consumption of a variety of devices and relate it to the current passing through the device
- investigate factors affecting the output from solar panels and wind turbines
- make a simple electricity generator and investigate the factors that affect the output.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- the role of computers in managing energy demands over the National Grid
- the role of computers in remote handling of highly radioactive waste.

Use of ICT in teaching and learning can include:

- animations to illustrate key processes in power stations
- internet research for data allowing the comparison of different energy sources
- use of spreadsheets to process and present data comparing use of different energy sources.

Module P3: Sustainable energy – Ideas about Science

Module P3 provides opportunities to develop candidates' understanding of these Ideas about Science

	Candidates should understand that:	A candidate who understands this can, for example:
5	**Risk**	
5.1	• everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.	• explain why it is impossible for anything to be completely safe • identify examples of risks which arise from a new scientific or technological advance • suggest ways of reducing a given risk.
5.6	• **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).**	• **distinguish between perceived and calculated risk, when discussing personal choices** • **suggest reasons for given examples of differences between perceived and measured risk.**
5.7	• governments and public bodies may have to assess what level of risk is acceptable in a particular situation. This decision may be controversial, especially if those most at risk are not those who benefit.	• discuss the public regulation of risk, **and explain why it may in some situations be controversial.**
6	**Making decisions about science and technology**	
6.1	• science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	• in a particular context, identify the groups affected and the main benefits and costs of a course of action for each group • **suggest reasons why different decisions on the same issue might be appropriate in view of differences in social and economic context.**
6.2	• scientists may identify unintended impacts of human activity (including population growth) on the environment. They can sometimes help us to devise ways of mitigating this impact and of using natural resources in a more sustainable way.	• identify, and suggest, examples of unintended impacts of human activity on the environment • explain the idea of sustainability, and apply it to specific situations • use data (for example, from a Life Cycle Assessment) to compare the sustainability of alternative products or processes.
6.3	• in many areas of scientific work, the development and application of scientific knowledge are subject to official regulations.	• in contexts where this is appropriate, show awareness of, **and discuss**, the official regulation of scientific research and the application of scientific knowledge.

6	Making decisions about science and technology	
	Candidates should understand that:	A candidate who understands this can, for example:
6.5	• some forms of scientific research, and some applications of scientific knowledge, have ethical implications. People may disagree about what should be done (or permitted).	• where an ethical issue is involved: – say clearly what this issue is – summarise different views that may be held.
6.6	• in discussions of ethical issues, one common argument is that the right decision is one which leads to the best outcome for the greatest number of people involved. Another is that certain actions are considered right or wrong whatever the consequences.	• in a given context, identify, **and develop**, arguments based on the ideas that: – the right decision is the one which leads to the best outcome for the greatest number of people involved – certain actions are considered right or wrong whatever the consequences.

Module P3: Sustainable energy

P3.1 How much energy do we use?

1. understand that the demand for energy is continually increasing and that this raises issues about the availability of energy sources and the environmental effects of using these sources
2. recall the main primary energy sources that humans use: fossil fuels (oil, gas, coal), nuclear fuels, biofuels, wind, waves, and radiation from the Sun
3. understand why electricity is called a secondary energy source
4. understand that power stations which burn fossil fuels produce carbon dioxide which contributes to global warming and climate change
5. understand that when electric current passes through a component (or device), energy is transferred from the power supply to the component and/or to the environment
6. recall that the power (in watts, W) of an appliance or device is a measure of the amount of energy it transfers each second**, ie the rate at which it transfers energy**
7. use the following equation to calculate the amount of energy transferred in a process, in joules and in kilowatt hours:

energy transferred	=	power	×	time
(joules, J)		(watts, W)		(seconds, s)
(kilowatt hours, kWh)		(kilowatts, kW)		(hours, h)

8. use the following equation to calculate the rate at which an electrical device transfers energy:

power	=	voltage	×	current
(watts, W)		(volts, V)		(amperes, A)

9. understand that a joule is a very small amount of energy, so a domestic electricity meter measures the energy transfer in kilowatt hours
10. calculate the cost of energy supplied by electricity given the power, the time and the cost per kilowatt hour
11. interpret and process data on energy use, presented in a variety of ways
12. interpret and construct Sankey diagrams to show understanding that energy is conserved
13. use the following equation in the context of electrical appliances and power stations:

$$\text{efficiency} = \frac{\text{energy usefully transferred}}{\text{total energy supplied}} \times 100\%$$

ⓘ *Candidates will be expected to consider / calculate efficiency as a decimal ratio and as a percentage*

14. suggest examples of ways to reduce energy usage in personal and national contexts.

Module P3: Sustainable energy

P3.2 How can electricity be generated?

1. understand that electricity is convenient because it is easily transmitted over distances and can be used in many ways
2. recall that mains electricity is produced by generators
3. understand that generators produce a voltage across a coil of wire by spinning a magnet near it
4. understand that the bigger the current supplied by a generator, the more primary fuel it uses every second
5. understand that in many power stations a primary energy source is used to heat water; the steam produced drives a turbine which is coupled to an electrical generator
6. label a block diagram showing the basic components and structures of hydroelectric, nuclear and other thermal power stations
7. understand that nuclear power stations produce radioactive waste
8. understand that radioactive waste emits ionising radiation
9. understand that with increased exposure to ionising radiation, damage to living cells increases eventually leading to cancer or cell death
10. understand the distinction between contamination and irradiation by a radioactive material, and explain why contamination by a radioactive material is more dangerous than a short period of irradiation from the radioactive material
11. understand that many renewable sources of energy drive the turbine directly eg hydroelectric, wave and wind
12. interpret a Sankey diagram for electricity generation and distribution that includes information on the efficiency of energy transfers
13. recall that the mains supply voltage to our homes is 230 volts
14. understand that electricity is distributed through the National Grid at high voltages to reduce energy losses.

Module P3: Sustainable energy

P3.3 Which energy sources should we choose?

1. discuss both qualitatively and quantitatively (based on given data where appropriate), the effectiveness of different choices in reducing energy demands in:
   a. domestic contexts
   b. work place contexts
   c. national contexts
2. understand that the choice of energy source for a given situation depends upon a number of factors including:
   a. environmental impact
   b. economics
   c. waste produced
   d. carbon dioxide emissions
3. describe advantages and disadvantages of different energy sources, including non-renewable energy sources such as:
   a. fossil fuels
   b. nuclear

   and renewable energy sources such as:

   c. biofuel
   d. solar
   e. wind
   f. water (waves, tides, hydroelectricity)
   g. geothermal
4. interpret and evaluate information about different energy sources for generating electricity, considering:
   a. efficiency
   b. economic costs
   c. environmental impact
   d. power output and lifetime.
5. **understand that to ensure a security of electricity supply nationally, we need a mix of energy sources.**

3.4 Summary of Physics A Unit A182: *Modules P4, P5, P6*

Unit A182 is the second unit for GCSE Physics A. It assesses the content of Modules P4, P5 and P6 together with their associated Ideas about Science. Any of IaS1 (Data: their importance and limitations) and IaS2 (Cause-effect explanations) can also be assessed in this unit.

The modules in Unit A182 give emphasis and space to fundamental ideas in the sciences, ensure that appropriate skills are developed in preparation for further study, and provide a stimulating bridge to advanced level studies in science. The emphasis of the unit is on 'science for the scientist' and those aspects of 'How Science Works' that relate to the process of science.

Ideas about Science in Unit A182

Modules P4, P5 and P6 present learning opportunities for a number of the Ideas about Science. The start of each module details the particular Ideas about Science that can be introduced or developed within the contexts covered in the module. Specific examples of contexts within which Ideas about Science can be taught are given in the OCR scheme of work for GCSE Physics A (published separately).

However, it is not intended that understanding and application of Ideas about Science should be limited to the context in which they are taught; they should be applicable to any appropriate scientific context.

Accordingly, questions in Unit A182 can assess any of the Ideas about Science linked to Modules P4, P5 and P6, as well as IaS1 (Data: their importance and limitations) and IaS2 (Cause-effect explanations). These Ideas about Science may be assessed in the context of any of the learning outcomes covered in the three modules.

In summary, the Ideas about Science that can be assessed in Unit A182, within any of the scientific contexts introduced by Modules P4, P5 and P6, are:

Data: their importance and limitations
IaS 1.1 – 1.6
Cause-effect explanations
IaS 2.1 – 2.7
Developing scientific explanations
IaS 3.1 – 3.4
Risk
IaS 5.1 – 5.7
Making decisions about science and technology
IaS 6.1, 6.3, 6.4

3.4.1 Module 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.

This module starts by looking at how speed is measured and represented graphically and the idea of velocity (as distinct from speed).

The second topic introduces the idea of forces: identifying, describing and using forces to explain simple situations. This is further developed in the third topic where resultant forces and changes in momentum are described.

The final topic considers how we can explain motion in terms of energy changes.

Topics
P4.1 How can we describe motion?
Calculation of speed Velocity Acceleration Graphical representations of speed and velocity
P4.2 What are forces?
The identification of forces and 'partner' forces
P4.3 What is the connection between forces and motion?
Resultant forces and change in momentum Relating momentum to road safety measures
P4.4 How can we describe motion in terms of energy changes?
Work done Changes in energy GPE and KE Losses due to air resistance and friction

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- use ideas of proportion
- plot, draw and interpret graphs from candidates' own and secondary data
- use equations, including appropriate units for physical quantities
- use ideas about probability in the context of risk.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- use data logging to investigate motion
- investigate the behaviour of colliding and ‘exploding’ objects
- investigate the effect of different combinations of surfaces on the frictional forces
- investigate the motion of objects in free fall and the effects of air resistance.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- computer programs that control the motion of spacecraft
- use of computers for collecting, storing and displaying data on forces in simulated vehicle collisions
- computer-enhanced use of radar to predict flight paths of aircraft.

Use of ICT in teaching and learning can include:

- video clips to provide contexts for learning about forces and motion
- animations to illustrate interactive force pairs in various situations
- animations to show the meaning of distance-time and other graphs
- sensors and data loggers to collect measurements of movement for analysis
- modelling software to analyse motion.

Module P4: Explaining motion – Ideas about Science

Module P4 provides opportunities to develop candidates' understanding of these Ideas about Science

1	**Data: their importance and limitations** Candidates should understand that:	A candidate who understands this can, for example:
1.1	• data are crucial to science. The search for explanations starts from data; and data are collected to test proposed explanations.	• use data rather than opinion if asked to justify an explanation • outline how a proposed scientific explanation has been (or might be) tested, referring appropriately to the role of data.
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, make appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

2	Cause-effect explanations Candidates should understand that:	A candidate who understands this can, for example:
2.1	• it is often useful to think about processes in terms of factors which may affect an outcome (or input variables which may affect an outcome variable).	• in a given context, identify the outcome and factors that may affect it • in a given context, suggest how an outcome might alter when a factor is changed.
2.2	• to investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').	• identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive design feature, or the fact that they are not as a design flaw • explain why it is necessary to control all the factors that might affect the outcome other than the one being investigated.
2.3	• if an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	• suggest and explain an example from everyday life of a correlation between a factor and an outcome • identify where a correlation exists when data are presented as text, as a graph, or in a table. ⓘ *Examples may include both positive and negative correlations, but candidates will not be expected to know these terms.*
2.4	• a correlation between a factor and an outcome does not necessarily mean that the factor causes the outcome; both might, for example, be caused by some other factor.	• use the ideas of correlation and cause when discussing data and show awareness that a correlation does not necessarily indicate a causal link • identify, and suggest from everyday experience, examples of correlations between a factor and an outcome where the factor is (or is not) a plausible cause of the outcome • explain why an observed correlation between a given factor and outcome does not necessarily mean that the factor causes the outcome.
2.5	• in some situations, a factor alters the chance (or probability) of an outcome, but does not invariably lead to it. We also call this a correlation.	• 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.
2.6	• to investigate a claim that a factor increases the chance (or probability) of an outcome, scientists compare samples (eg groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples, the more confident we can be about any conclusions drawn.	• discuss whether given data suggest that a given factor does/does not increase the chance of a given outcome • evaluate critically the design of a study to test if a given factor increases the chance of a given outcome, by commenting on sample size and how well the samples are matched.

	Candidates should understand that:	A candidate who understands this can, for example:
2	**Cause-effect explanations**	
2.7	• **even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.**	• **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.**
3	**Developing scientific explanations**	
3.1	• scientific hypotheses, explanations and theories are not simply summaries of the available data. They are based on data but are distinct from them.	• in a given account of scientific work, identify statements which report data and statements of explanatory ideas (hypotheses, explanations, theories) • recognise that an explanation may be incorrect even if the data agree with it.
3.2	• an explanation cannot simply be deduced from data, but has to be thought up creatively to account for the data.	• identify where creative thinking is involved in the development of an explanation.
3.3	• a scientific explanation should account for most (ideally all) of the data already known. It may explain a range of phenomena not previously thought to be linked. It should also enable predictions to be made about new situations or examples.	• recognise data or observations that are accounted for by, or conflict with, an explanation • give good reasons for accepting or rejecting a proposed scientific explanation • identify the better of two given scientific explanations for a phenomenon, and give reasons for the choice.
3.4	• scientific explanations are tested by comparing predictions based on them with data from observations or experiments.	• draw valid conclusions about the implications of given data for a given scientific explanation, in particular: – understand that agreement between a prediction and an observation increases confidence in the explanation on which the prediction is based but does not prove it is correct – understand that disagreement between a prediction and an observation indicates that one or other is wrong, and decreases our confidence in the explanation on which the prediction is based.

Module P4: Explaining motion

P4.1 How can we describe motion?

1. apply the following equation to situations where an average speed is involved:

$$\text{speed (m/s)} = \frac{\text{distance travelled (m)}}{\text{time taken (s)}}$$

2. distinguish between average speed and instantaneous speed (in effect, an average over a short time interval) for examples of motion where speed is changing
3. **understand that the displacement of an object at a given moment is its net distance from its starting point together with an indication of direction**
4. draw and interpret a distance-time **(or displacement-time)** graph for an object that is:
   a. stationary
   b. moving at constant speed
   c. moving with increasing or decreasing speed
5. interpret a steeper gradient of a distance-time graph as a higher speed
6. **calculate a speed from the gradient of a straight section of a distance-time graph**
7. draw and interpret a speed-time graph for an object that is:
   a. stationary
   b. moving in a straight line with constant speed
   c. moving in a straight line with steadily increasing or decreasing speed (but no change of direction)
8. understand that in many everyday situations, acceleration is used to mean the change in speed of an object in a given time interval
9. recall that the instantaneous velocity of an object is its instantaneous speed together with an indication of the direction
10. **understand that the velocity of an object moving in a straight line is positive if it is moving in one direction and negative if it is moving in the opposite direction**
11. **draw and interpret a velocity-time graph for an object that is:**
   a. stationary
   b. moving in a straight line with constant speed
   c. moving in a straight line with steadily increasing or decreasing speed (including situations involving a change of direction).
12. **calculate the acceleration from the gradient of a velocity–time graph (or from a speed-time graph in situations where direction of motion is constant)**
13. calculate acceleration using the equation:

$$\text{acceleration (m/s}^2\text{)} = \frac{\text{change in velocity (m/s)}}{\text{time taken (s)}}$$

Module P4: Explaining motion

P4.2 What are forces?

1. recall that a force arises from an interaction between two objects
2. understand that when two objects interact, both always experience a force and that these two forces form an interaction pair
3. in simple everyday situations:
    a. identify forces arising from an interaction between two objects
    b. identify the ‘partner’ of a given force (ie the other force of the interaction pair)
    c. specify, for each force, the object which exerts it, and the object on which it acts
    d. use arrows to show the sizes and directions of forces acting
4. understand that the two forces in an interaction pair are equal in size and opposite in direction, and that they act on different objects
5. describe the interaction between two surfaces which 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; this interaction is called friction
6. describe the interaction between an object and a horizontal 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 reaction of the surface
7. recall that friction and the reaction of a surface arise in response to the action of an applied force, and their size matches the applied force up to a limit
8. use the ideas of friction and reaction to explain situations such as the driving force on vehicles **and walking**
9. use the idea of a pair of equal and opposite forces to explain in outline how rockets and jet engines produce a driving force.

Module P4: Explaining motion

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

1. interpret situations in which several forces act on an object
2. understand that the resultant force on an object is the sum of all the individual forces acting on it, taking their directions into account
3. understand that if a resultant force acts on an object, it causes a change of momentum in the direction of the force
4. use the definition:

$$\underset{(\text{kg m/s})}{\text{momentum}} = \underset{(\text{kg})}{\text{mass}} \times \underset{(\text{m/s})}{\text{velocity}}$$

5. understand that 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:

$$\underset{(\text{kg m/s})}{\text{change of momentum}} = \underset{(\text{N})}{\text{resultant force}} \times \underset{(\text{s})}{\text{time for which it acts}}$$

6. understand how the horizontal motion of objects (like cars and bicycles) can be analysed in terms of a driving force (produced by the engine or the cyclist), and a counter force (due to friction and air resistance)
7. understand that for an object moving in a straight line, if the driving force is:
    a. greater than the counter force, the vehicle will speed up
    b. equal to the counter force, the vehicle will move at constant speed in a straight line
    c. smaller than the counter force, the vehicle will slow down
8. understand that, 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
9. use ideas about force and momentum to explain road safety measures, such as car seat-belts, crumple zones, air bags, and cycle and motorcycle helmets
10. understand how the vertical motion of objects (falling, or initially thrown upwards) can be analysed in terms of the forces acting (gravity, air resistance)
11. understand that, if the resultant force on an object is zero, its momentum does not change (if it is stationary, it stays at rest; if it is already moving, it continues at a constant velocity [a steady speed in a straight line]).

Module P4: Explaining motion

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

1. recall that the energy of a moving object is called its kinetic energy
2. recall that as an object is raised, its gravitational potential energy increases, and as it falls, its gravitational potential energy decreases
3. recall that when a force moves an object, it does work
4. use the equation:

   $$\underset{\text{(joules, J)}}{\text{work done by a force}} = \underset{\text{(newtons, N)}}{\text{force}} \times \underset{\text{(metres, m)}}{\text{distance moved in the direction of the force}}$$

5. understand that when work is done on an object, energy is transferred to the object and when work is done by an object, energy is transferred from the object to something else, according to the relationship:

   $$\underset{\text{(joules, J)}}{\text{amount of energy transferred}} = \underset{\text{(joules, J)}}{\text{work done}}$$

6. understand that when an object is lifted to a higher position above the ground, work is done by the lifting force; this increases the gravitational potential energy
7. use the equation:

   $$\underset{\text{(joules, J)}}{\text{change in gravitational potential energy}} = \underset{\text{(newtons, N)}}{\text{weight}} \times \underset{\text{(metres, m)}}{\text{vertical height difference}}$$

8. understand that 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 kinetic energy
9. understand that the greater the mass of an object and the faster it is moving, the greater its kinetic energy
10. use the equation:

    $$\underset{\text{(joules, J)}}{\text{kinetic energy}} = \tfrac{1}{2} \times \underset{\text{(kilograms, kg)}}{\text{mass}} \times \underset{\text{([metres per second]}^2\text{, [m/s]}^2\text{)}}{[\text{velocity}]^2}$$

11. understand that if friction and air resistance can be ignored, an object's kinetic energy changes by an amount equal to the work done on it by an applied force
12. understand that air resistance or friction will cause the gain in an object's 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
13. recall that energy is always conserved in any event or process
14. calculate the gain in kinetic energy, **and the speed**, of an object that has fallen through a given height.

3.4.2 Module P5: 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 module, candidates learn how scientists visualise what is going on inside circuits and predict circuit behaviour. The idea of current as a flow of electrons is introduced in the first topic. In the second topic, useful 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 developed in the third topic.

The concepts of current and voltage are further developed in the topic on generation of electricity. The final topic relates these concepts to power, and introduces the idea of efficiency of electrical appliances.

ⓘ *Candidates will only be expected to consider situations in which the internal resistance of batteries or other electrical power supplies is negligible and can be ignored.*

Topics
P5.1 Electric current – a flow of what?
Electric current as a flow of charge How the charge moves
P5.2 What determines the size of the current in an electric circuit and the energy it transfers?
Voltage Current and resistance Series and parallel circuits
P5.3 How do parallel and series circuits work?
Voltage and how it behaves in a series circuit Current and how it behaves in a parallel circuit
P5.4 How is mains electricity produced? How are voltages and currents induced?
How generators work Transformers Alternating current and direct current
P5.5 How do electric motors work?
How motors work and some uses

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations using fractions and percentages
- use ideas of proportion
- use ideas of ratios in the context of transformers
- use equations, including appropriate units for physical quantities
- plot, draw and interpret graphs from candidates' own and secondary data
- use ideas about probability in the context of risk.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- investigating the behaviour of electric circuits
- making both model generators and motors and investigating factors affecting their behaviour
- investigating the behaviour of transformers.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- studying electric fields between charged particles and surfaces
- using computer simulations to construct virtual circuits and test their behaviour.

Use of ICT in teaching and learning can include:

- modelling software to explore electric circuit theory
- animations to illustrate models of electric current as flowing charges.

Module P5: Electric circuits – Ideas about Science

Module P5 provides opportunities to develop candidates' understanding of these Ideas about Science

1	**Data: their importance and limitations** Candidates should understand that:	A candidate who understands this can, for example:
1.1	• data are crucial to science. The search for explanations starts from data; and data are collected to test proposed explanations.	• use data rather than opinion if asked to justify an explanation • outline how a proposed scientific explanation has been (or might be) tested, referring appropriately to the role of data.
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, make appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

2	Cause-effect explanations Candidates should understand that:	A candidate who understands this can, for example:
2.1	• it is often useful to think about processes in terms of factors which may affect an outcome (or input variables which may affect an outcome variable).	• in a given context, identify the outcome and factors that may affect it • in a given context, suggest how an outcome might alter when a factor is changed.
2.2	• to investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').	• identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive design feature, or the fact that they are not as a design flaw • explain why it is necessary to control all the factors that might affect the outcome other than the one being investigated.
2.3	• if an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	• suggest and explain an example from everyday life of a correlation between a factor and an outcome • identify where a correlation exists when data are presented as text, as a graph, or in a table. ⓘ *Examples may include both positive and negative correlations, but candidates will not be expected to know these terms.*
2.4	• a correlation between a factor and an outcome does not necessarily mean that the factor causes the outcome; both might, for example, be caused by some other factor.	• use the ideas of correlation and cause when discussing data and show awareness that a correlation does not necessarily indicate a causal link • identify, and suggest from everyday experience, examples of correlations between a factor and an outcome where the factor is (or is not) a plausible cause of the outcome • explain why an observed correlation between a given factor and outcome does not necessarily mean that the factor causes the outcome.
2.5	• in some situations, a factor alters the chance (or probability) of an outcome, but does not invariably lead to it. We also call this a correlation.	• 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.
2.6	• to investigate a claim that a factor increases the chance (or probability) of an outcome, scientists compare samples (eg groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples, the more confident we can be about any conclusions drawn.	• discuss whether given data suggest that a given factor does/does not increase the chance of a given outcome • evaluate critically the design of a study to test if a given factor increases the chance of a given outcome, by commenting on sample size and how well the samples are matched.

2	Cause-effect explanations	
	Candidates should understand that:	A candidate who understands this can, for example:
2.7	• **even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.**	• **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.**

Module P5: Electric circuits

P5.1 Electric current – a flow of what?

1. explain that when two objects are rubbed together they become charged, because electrons are transferred from one object to the other
2. recall that objects with similar charges repel, and objects with opposite charges attract
3. explain simple electrostatic effects in terms of attraction and repulsion of charges
4. recall that electrons are negatively charged
5. recall that electric current is a flow of charge
6. recall that electric current is measured in amperes
7. understand that in an electric circuit the metal conductors (the components and wires) contain many charges that are free to move
8. understand that when a circuit is made, the battery causes these free charges to move, and that they are not used up but flow in a continuous loop
9. recall that in metallic conductors an electric current is a movement of free electrons that are present throughout such materials
10. understand that in metal conductors there are lots of charges free to move but in an insulator there are few charges free to move.

Module P5: Electric circuits

P5.2 What determines the size of the current in an electric circuit and the energy it transfers?

1. recall that the larger the voltage of the battery in a given circuit, the bigger the current
2. recall that components (for example, resistors, lamps, motors) resist the flow of charge through them
3. recall that the larger the resistance in a given circuit, the smaller the current will be
4. recall that the resistance of connecting wires is so small that it can usually be ignored
5. understand that 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
6. recall that power (in watts, W) is a measure of the rate at which an electrical power supply transfers energy to an appliance or device and/or its surroundings
7. use the equation:

$$\underset{\text{(watts, W)}}{\text{power}} = \underset{\text{(volts, V)}}{\text{voltage}} \times \underset{\text{(amperes, A)}}{\text{current}}$$

8. recall that resistors get hotter when there is an electric current flowing through them, **and understand that this heating effect is caused by collisions between the moving charges and stationary ions in the wire**
9. recall that this heating effect makes a lamp filament hot enough to glow
10. describe how the resistance of an LDR varies with light intensity
11. describe how the resistance of a thermistor (ntc only) varies with temperature
12. recognise and use the electrical symbols for a cell, power supply, filament lamp, switch, LDR, fixed and variable resistor, thermistor, ammeter and voltmeter
13. understand that two (or more) resistors in series have more resistance than either one on its own, because the battery has to move charges through both of them
14. understand that two (or more) resistors in parallel provide more paths for charges to move along than either resistor on its own, so the total resistance is less
15. use the equation:

$$\text{resistance (ohms, }\Omega) = \frac{\text{voltage (volts, V)}}{\text{current (amperes, A)}}$$

16. describe in words, or using a sketch graph, how the current through a component varies with voltage across it when the resistance stays constant.

Module P5: Electric circuits

P5.3 How do parallel and series circuits work?

1. describe how a voltmeter should be connected to measure the potential difference between any two chosen points
2. recall that the voltage across a battery (measured in V) provides a measure of the 'push' of the battery on the charges in the circuit
3. recall that potential difference is another term for voltage
4. 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
5. describe the effect on potential difference and current of adding further identical batteries in series **and in parallel** with an original single one
6. understand that when two **(or more)** components are connected in series to a battery:
   a. the current through each component is the same
   b. the potential differences across the components add up to the potential difference across the battery **(because the work done on each unit of charge by the battery must equal the work done by it on the circuit components)**
   c. the potential difference is largest across the component with the greatest resistance, **because more work is done by the charge moving through a large resistance than through a small one**
   d. a change in the resistance of one component (variable resistor, LDR or thermistor) will result in a change in the potential differences across all the components
7. understand that when several components are connected in parallel directly to a battery:
   a. the potential difference across each component is equal to the potential difference of the battery
   b. the current through each component is the same as if it were the only component present
   c. the total current from (and back to) the battery is the sum of the currents through each of the parallel components
   d. the current is largest through the component with the smallest resistance, **because the same battery voltage causes a larger current to flow through a smaller resistance than through a bigger one.**

Module P5: Electric circuits

P5.4 How is mains electricity produced? How are voltages and currents induced?

1. recall that mains electricity is produced by generators
2. recall that generators produce a voltage by a process called electromagnetic induction
3. understand that when a magnet is moving into a coil of wire a voltage is induced across the ends of the coil
4. understand that if the magnet is moving out of the coil, or the other pole of the magnet is moving into it, there is a voltage induced in the opposite direction
5. understand that if the ends of the coil are connected to make a closed circuit, a current will flow round the circuit
6. understand that a changing magnetic field caused by changes in the current in one coil of wire can induce a voltage in a neighbouring coil
7. describe the construction of a transformer as two coils of wire wound on an iron core
8. **understand that 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**
9. recall that a transformer can change the size of an alternating voltage
10. **use the equation**:

$$\frac{\textbf{voltage across primary coil}}{\textbf{voltage across secondary coil}} = \frac{\textbf{number of turns in primary coil}}{\textbf{number of turns in secondary coil}}$$

11. describe how, in a generator, a magnet or electromagnet is rotated within a coil of wire to induce a voltage across the ends of the coil
12. understand that the size of this induced voltage can be increased by:
    a. increasing the speed of rotation of the magnet or electromagnet
    b. increasing the strength of its magnetic field
    c. increasing the number of turns on the coil
    d. placing an iron core inside the coil
13. **describe how the induced voltage across the coil of an a.c. generator (and hence the current in an external circuit) changes during each revolution of the magnet or electromagnet**
14. understand that when the current is always in the same direction, it is a direct current (d.c.), eg the current from a battery
15. recall that mains electricity is an a.c. supply
16. **understand that a.c. is used because it is easier to generate than d.c., and is easier and simpler to distribute over long distances**
17. recall that the mains domestic supply in the UK is 230 volts.

Module P5: Electric circuits

P5.5 How do electric motors work?

1. understand that a current-carrying wire or coil can exert a force on a permanent magnet, or on another current-carrying wire or coil nearby
2. understand that a current-carrying wire, if placed in a magnetic field whose lines of force are at right-angles to the wire, experiences a force at right angles to both the current direction and the lines of force of the field
3. recall that a current-carrying wire that is parallel to the lines of force of a magnetic field experiences no force
4. explain how the motor effect can result in a turning force on a rectangular current-carrying coil placed in a uniform magnetic field
5. understand that the motor effect can be used to produce continuous rotation of the coil, by using a commutator to ensure that the direction of the current in the coil is reversed at an appropriate point in each revolution
6. explain the role and use of motors in devices including domestic appliances, hard disc drives, DVD players and electric motor vehicles.

3.4.3 Module P6: 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.

The module begins by considering the evidence of a nuclear model of the atom, including Rutherford's alpha particle scattering experiment. This topic then uses ideas about fusion and nuclear energy to introduce Einstein's equation. The properties of alpha, beta and gamma radiation are investigated and ideas about half-life are developed.

The properties of ionising radiation lead to a consideration of some of its many uses and also risks, including nuclear fission.

Through the use of radioactive material in the health sector, candidates learn about its harmful effect on living cells and how it 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.

Topics
P6.1 Why are some materials radioactive?
Structure of the atom
Nuclear fusion
Alpha, beta and gamma radiation
Half-life
P6.2 How can radioactive materials be used and handled safely, including wastes?
Background radiation
Uses of radiation
Nuclear fission and nuclear power stations

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of the size of the constituents of an atom
- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations using fractions in half-life calculations
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use ideas about probability in the context of risk.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- investigations of the properties of ionising radiations
- half-life of radioactive materials
- modelling half-life, using ICT or dice throwing.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- computer tomography used with gamma imaging
- the role of computers in remote handling of highly radioactive waste.

Use of ICT in teaching and learning can include:

- data logging to show decay of protactinium
- animations to illustrate atomic structure and decay
- video clips to illustrate key ideas of risk in the context of radioactive materials
- animations to illustrate key processes in power stations.

Module P6: Radioactive materials – Ideas about Science

Module P6 provides opportunities to develop candidates' understanding of these Ideas about Science

1	**Data: their importance and limitations** Candidates should understand that:	A candidate who understands this can, for example:
1.1	• data are crucial to science. The search for explanations starts from data; and data are collected to test proposed explanations.	• use data rather than opinion if asked to justify an explanation • outline how a proposed scientific explanation has been (or might be) tested, referring appropriately to the role of data.
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, makes appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

2	Cause-effect explanations Candidates should understand that:	A candidate who understands this can, for example:
2.1	• it is often useful to think about processes in terms of factors which may affect an outcome (or input variables which may affect an outcome variable).	• in a given context, identify the outcome and factors that may affect it • in a given context, suggest how an outcome might alter when a factor is changed.
2.2	• to investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').	• identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive design feature, or the fact that they are not as a design flaw • explain why it is necessary to control all the factors that might affect the outcome other than the one being investigated.
2.3	• if an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	• suggest and explain an example from everyday life of a correlation between a factor and an outcome • identify where a correlation exists when data are presented as text, as a graph, or in a table. ⓘ *Examples may include both positive and negative correlations, but candidates will not be expected to know these terms.*
2.4	• a correlation between a factor and an outcome does not necessarily mean that the factor causes the outcome; both might, for example, be caused by some other factor.	• use the ideas of correlation and cause when discussing data and show awareness that a correlation does not necessarily indicate a causal link • identify, and suggest from everyday experience, examples of correlations between a factor and an outcome where the factor is (or is not) a plausible cause of the outcome • explain why an observed correlation between a given factor and outcome does not necessarily mean that the factor causes the outcome.
2.5	• in some situations, a factor alters the chance (or probability) of an outcome, but does not invariably lead to it. We also call this a correlation.	• 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.
2.6	• to investigate a claim that a factor increases the chance (or probability) of an outcome, scientists compare samples (eg groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples, the more confident we can be about any conclusions drawn.	• discuss whether given data suggest that a given factor does/does not increase the chance of a given outcome • evaluate critically the design of a study to test if a given factor increases the chance of a given outcome, by commenting on sample size and how well the samples are matched.

	Candidates should understand that:	A candidate who understands this can, for example:
2	**Cause-effect explanations**	
2.7	• **even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.**	• **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.**
5	**Risk**	
5.1	• everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.	• explain why it is impossible for anything to be completely safe • identify examples of risks which arise from a new scientific or technological advance • suggest ways of reducing a given risk.
5.2	• we can sometimes assess the size of a risk by measuring its chance of occurring in a large sample, over a given period of time.	• interpret and discuss information on the size of risks, presented in different ways.
5.3	• to make a decision about a particular risk, we need to take account both of the chance of it happening and the consequences if it did.	• discuss a given risk, taking account of both the chance of it occurring and the consequences if it did.
5.4	• to make a decision about a course of action, we need to take account of both its risks and benefits, to the different individuals or groups involved.	• identify risks and benefits in a given situation, to the different individuals and groups involved • discuss a course of action, with reference to its risks and benefits, taking account of who benefits and who takes the risks • suggest benefits of activities that are known to have risk.
5.5	• 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.	• offer reasons for people's willingness (or reluctance) to accept the risk of a given activity
5.6	• **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).**	• **distinguish between perceived and calculated risk, when discussing personal choices** • **suggest reasons for given examples of differences between perceived and measured risk.**
5.7	• governments and public bodies may have to assess what level of risk is acceptable in a particular situation. This decision may be controversial, especially if those most at risk are not those who benefit.	• discuss the public regulation of risk, **and explain why it may in some situations be controversial.**

6	**Making decisions about science and technology**	
	Candidates should understand that:	A candidate who understands this can, for example:
6.1	• science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	• in a particular context, identify the groups affected and the main benefits and costs of a course of action for each group • **suggest reasons why different decisions on the same issue might be appropriate in view of differences in social and economic context.**
6.3	• in many areas of scientific work, the development and application of scientific knowledge are subject to official regulations.	• in contexts where this is appropriate, show awareness of, **and discuss**, the official regulation of scientific research and the application of scientific knowledge.
6.4	• some questions, such as those involving values, cannot be answered by science.	• distinguish questions which could in principle be answered using a scientific approach, from those which could not.

Module P6: Radioactive materials

P6.1 Why are some materials radioactive?

1. recall that some elements emit ionising radiation all the time and are called radioactive
2. understand that radioactive elements are naturally found in the environment, contributing to background radiation
3. understand that an atom has a nucleus, made of protons and neutrons, which is surrounded by electrons
4. understand that 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)
5. **understand that protons and neutrons are held together in the nucleus by a strong force which balances the repulsive electrostatic force between the protons**
6. understand that, if brought close enough together, hydrogen nuclei can fuse into helium nuclei releasing energy, and that this is called nuclear fusion
7. **understand that Einstein's equation $E = mc^2$ is used to calculate the energy released during nuclear fusion and fission (where E is the energy produced, m is the mass lost and c is the speed of light in a vacuum)**
8. **understand that every atom of any element has the same number of protons but the number of neutrons may differ, and that forms of the same element with different numbers of neutrons are called isotopes**
9. understand that the behaviour of radioactive materials cannot be changed by chemical or physical processes
10. recall that three types of ionising radiation (alpha, beta and gamma) are emitted by radioactive materials **and that alpha particles consist of two protons and two neutrons, and that beta particles are identical to electrons**
11. recall the penetration properties of each type of radiation
12. **describe radioactive materials in terms of the instability of the nucleus, radiation emitted and the element left behind**
13. **complete nuclear equations for alpha and beta decay**
14. understand that, over time, the activity of radioactive sources decreases
15. understand the meaning of the term half-life
16. understand that radioactive elements have a wide range of half-life values
17. **carry out simple calculations involving half-life.**

Module P6: Radioactive materials

P6.2 How can radioactive materials be used and handled safely, including wastes?

1. understand that ionising radiation can damage living cells and these may be killed or may become cancerous
2. understand that ionising radiation is able to break molecules into bits (called ions), **which can then take part in other chemical reactions**
3. recall **and explain** how ionising radiation can be used:
    a. to treat cancer
    b. to sterilise surgical instruments
    c. to sterilise food
    d. as a tracer in the body.
4. recall that radiation dose (in sieverts) (based on both amount and type of radiation) is a measure of the possible harm done to your body
5. interpret given data on risk related to radiation dose
6. understand that radioactive materials expose people to risk by irradiation and contamination
7. understand that we are irradiated and contaminated by radioactive materials all the time and recall the main sources of this background radiation
8. relate ideas about half-life and background radiation to the time taken for a radioactive source to become safe
9. recall categories of people who are regularly exposed to risk of radiation and that their exposure is carefully monitored, including radiographers and workers in nuclear power stations
10. understand that a nuclear fuel is one in which energy is released by changes in the nucleus
11. **know that in nuclear fission a neutron splits a large and unstable nucleus (limited to uranium and plutonium) into two smaller parts, roughly equal in size, releasing more neutrons**
12. recall that the amount of energy released during nuclear fission is much greater than that released in a chemical reaction involving a similar mass of material
13. **understand how the nuclear fission process in nuclear power stations is controlled, and use the terms chain reaction, fuel rod, control rod and coolant**
14. understand that nuclear power stations produce radioactive waste
15. understand that nuclear wastes are categorised as high level, intermediate level and low level, and relate this to disposal methods.

3.5 Summary of Physics A Unit A183: *Module P7*

Unit A183 is the third unit for GCSE Physics A. It assesses the content of Module P7 together with **any** of the Ideas about Science.

Unit A183 includes additional content to enhance progression and to give a greater understanding of the subjects concerned. This unit continues the emphasis on 'science for the scientist' in preparation for further study, and provides a stimulating bridge to advanced level studies in science.

Ideas about Science in Unit A183

Module P7 presents learning opportunities for a number of the Ideas about Science. The start of the module details the particular Ideas about Science that can be introduced or developed within the contexts covered in the module. Specific examples of contexts within which Ideas about Science can be taught are given in the OCR scheme of work for GCSE Physics A (published separately).

However, it is not intended that understanding and application of Ideas about Science should be limited to the context in which they are taught; they should be applicable to any appropriate scientific context.

Accordingly, questions in Unit A183 can assess any of the Ideas about Science (summarised in Appendix B), and these Ideas about Science may be assessed in the context of any of the learning outcomes covered in Module P7.

In summary, the Ideas about Science that can be assessed in Unit A183, within any of the scientific contexts introduced by Module P7, are:

Data: their importance and limitations
IaS 1.1 – 1.6
Cause-effect explanations
IaS 2.1 – 2.7
Developing scientific explanations
IaS 3.1 – 3.4
The scientific community
IaS 4.1 – 4.4
Risk
IaS 5.1 – 5.7
Making decisions about science and technology
IaS 6.1 – 6.6

3.5.1 Module P7: Further Physics – Studying the Universe

Overview

Since ancient times people have studied 'the heavens', first with the naked eye and later through telescopes; they have identified, and attempted to explain, repeating patterns and one-off events. From an understanding of the motions of the Earth, Moon and planets, to the universal expansion deduced from observing distant galaxies, astronomy has informed our perception of the Universe and our place in it.

Nowadays astronomy is one of the most publicly visible and appealing areas of scientific research. It is inextricably linked with physics. The design and operation of telescopes, the analysis of radiation to deduce information about remote objects, and theories about star formation and evolution all rely on physics and all feature in this module. Modern professional astronomy is 'big science' involving large, often multinational, teams of people who build and use expensive specialised instruments. Case studies in this module illustrate how scientific and other factors play a part in the way the astronomy community works.

The module begins with naked eye astronomy and explains some observations of the Moon, stars and planets, including eclipses (shadows) and twinkling stars (refraction). Attention then turns to telescopes, to the formation of images by a pinhole, by lenses and by curved mirrors, and to the use of prisms and gratings to produce spectra. A study of modern observatories explores the scientific reasons for building large telescopes (to collect a lot of radiation and minimise diffraction) and for placing them at high, remote sites (to minimise atmospheric absorption and to avoid 'noise' from Earth-based sources), and highlights other factors that influence the siting of observatories and the ways astronomers work.

Next, the module addresses the question of distance measurement. Trigonometric parallax is introduced, and the parsec as a unit of distance. The variation of intensity with distance is then explored, with particular reference to the use of Cepheid variable stars. This leads into a discussion of the historical controversy about the nature of 'spiral nebulae' and its resolution, then to Hubble's observation of receding galaxies and its explanation in terms of the expanding Universe.

Questions about the nature of the Sun lead first to a study of thermal radiation and temperature, then to line spectra and their interpretation. The Sun's energy output is explained in terms of nuclear fusion. The Sun is then compared with other stars, using the Hertzsprung-Russell diagram to display luminosity and temperature and to characterise main sequence, giant, and white dwarf stars. An overview of interstellar regions (gas clouds) introduces a study of gases, including the Kelvin temperature scale. Ideas about gas behaviour are then used to explain how stars and planets can form as a cloud collapses under its own gravity. The story continues with main sequence stars, which are explained in terms of nuclear fusion and energy transport. Post-main-sequence evolution involves further fusion, eventually ending with the formation of a white dwarf, or with a supernova explosion and the formation of a neutron star or black hole and the ejection of material that might form new stars and planets. Finally the module looks at evidence for planets around other stars and raises the as-yet-unanswered question of whether there is intelligent life elsewhere in the Universe.

Topics	
P7.1	**Naked eye astronomy**
Observations of Moon, stars, planets	
Angular size, angular coordinates	
Twinkling stars/refraction	
P7.2	**Light, telescopes and images**
Real image formation by pinhole, lens	
Diffraction by aperture, image blurring	
Atmospheric windows	
Background ‘noise’	
Mirror, simple telescope	
Image processing	
Spectra from prism, grating	
P7.3	**Mapping the Universe**
Parallax, parsec	
Brightness, luminosity and distance	
Cepheids	
Nebulae	
Recession of galaxies	
Hubble constant	
P7.4	**The Sun, the stars and their surroundings**
Thermal radiation and temperature	
Line spectra	
Nuclear fusion	
Types of stars	
Interstellar gas clouds	
Gas laws, kinetic theory, absolute zero	
Star formation, gravity and gas behaviour	
Main sequence, nuclear fusion, energy transport	
End points	
Exoplanets and SETI	
P7.5	**The astronomy community**
Organisation of astronomy	
Choice of observing sites	
Observing from the Earth and in space	

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of the solar system, galaxies and the Universe
- carry out calculations using experimental data, including finding the mean and the range
- use ideas of proportion in the context of the gas laws
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use equations, including appropriate units for physical quantities
- extract information from charts, graphs and tables
- use ideas about correlation in the context of Hubble's Law.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- record positions and appearance of astronomical objects over a day (or night) and over a month or longer
- measure the focal length of lenses and relate this to their shape
- build simple telescopes and measure the magnification
- investigate diffraction of light and microwaves
- investigate the use of diffraction gratings and prisms to produce spectra
- use parallax methods to measure distances
- use robotic telescopes to observe astronomical objects
- investigate the relationship between temperature, pressure and volume of a gas
- observe the spectra of a range of elements and link this to spectra of stars.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- remote control of telescopes
- the collection, storage and analysis of astronomical data.

Use of ICT in teaching and learning can include:

- using the internet to find out about astronomy done at telescopes around the world, and to view astronomical images
- processing of astronomical images
- learning from simulations and applets showing star processes.

Module P7: Further Physics – Studying the Universe – Ideas about Science

Module P7 provides opportunities to develop candidates' understanding of these Ideas about Science

	4 The scientific community Candidates should understand that:	A candidate who understands this can, for example:
4.1	• scientists report their claims to other scientists through conferences and journals. Scientific claims are only accepted once they have been evaluated critically by other scientists.	• describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists • recognise that there is less confidence in new scientific claims that have not yet been evaluated by the scientific community than there is in well-established ones.
4.2	• scientists are usually sceptical about claims that cannot be repeated by anyone else, and about unexpected findings until they have been replicated (by themselves) or reproduced (by someone else).	• identify the fact that a finding has not been reproduced by another scientist as a reason for questioning a scientific claim • explain why scientists see this as important.
4.3	• if explanations cannot be deduced from the available data, 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.	• show awareness that the same data might be interpreted, quite reasonably, in more than one way • suggest plausible reasons why scientists in a given situation disagree(d).
4.4	• an accepted scientific explanation is rarely abandoned just because some new data disagree with its predictions. It usually survives until a better explanation is available.	• discuss the likely consequences of new data that disagree with the predictions of an accepted explanation • **suggest reasons why scientists should not give up an accepted explanation immediately if new data appear to conflict with it.**
6	**Making decisions and science and technology**	
6.1	• science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	• in a particular context, identify the groups affected and the main benefits and costs of a course of action for each group • **suggest reasons why different decisions on the same issue might be appropriate in view of differences in social and economic context.**

Module P7: Further Physics – Studying the Universe

P7.1 Naked eye astronomy

1. recall that the Sun appears to travel east-west across the sky once every 24 hours, that the stars appear to travel east-west across the sky once in a very slightly shorter time period, and that the Moon appears to travel east-west across the sky once in a slightly longer time period
2. **explain why a sidereal day, a rotation of 360° of the Earth, is different from a solar day due to the orbital movement of the Earth and that a sidereal day is 4 minutes less than a solar day**
3. understand that the planets Mercury, Venus, Mars, Jupiter and Saturn can be seen with the naked-eye and that all the planets appear to move with the stars but also to change their position relative to the fixed stars
4. explain the apparent motions of the Sun, stars, Moon **and planets** in terms of rotation of the Earth and the orbits of the Earth, Moon **and planets**
5. explain the phases of the Moon in terms of the relative positions of the Sun, Moon and Earth
6. explain both solar and lunar eclipses in terms of the positions of the Sun and Moon **and explain the low frequency of eclipses in terms of the relative tilt of the orbits of the Moon about the Earth and the Earth about the Sun**
7. explain why different stars are seen in the night sky at different times of the year, in terms of the movement of the Earth round the Sun
8. recall that, **and explain why,** planets sometimes appear to move with retrograde motion relative to the ‘fixed’ stars
9. understand that the positions of astronomical objects are described in terms of two angles (eg right ascension and declination) **and understand how the angles relate to the celestial sphere.**

Module P7: Further Physics – Studying the Universe

P7.2 Light, telescopes and images

1. understand that the speed of waves is affected by the medium they are travelling through and that the wave speed will change if a wave moves from one medium into another
2. understand that 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
3. understand that the refraction of light waves can be explained by a change in their speed when they pass into a different medium
4. describe how refraction leads to the formation of an image by a convex/converging lens
5. understand and draw diagrams to show how convex/converging lenses bring parallel light to a focus
6. **draw and** interpret ray diagrams for convex/converging lenses gathering light from distant point sources (stars), off the principal axis of the lens **and extended sources (planets or moons in our solar system, galaxies)**
7. understand that a lens with a more curved surface is more powerful than a lens with a less curved surface made of the same material
8. calculate the power of a lens from:

$$\underset{\text{(dioptres)}}{\text{power}} = \frac{1}{\underset{\text{(metres}^{-1}\text{)}}{\text{focal length}}}$$

9. understand that astronomical objects are so distant that light from them reaches the Earth as effectively parallel sets of rays
10. recall that a simple optical telescope has two converging lenses of different powers, with the more powerful lens as the eyepiece
11. understand that a telescope has two optical elements:
    a. an objective lens or mirror to collect light from the object being observed and form an image of it
    b. an eyepiece which produces a magnified image of the image from the objective that we can view
12. **calculate the angular magnification of a telescope from the powers of the two lenses using:**

$$\textbf{magnification} = \frac{\textbf{focal length of objective lens}}{\textbf{focal length of eyepiece lens}}$$

13. explain why most astronomical telescopes have concave mirrors, not converging lenses, as their objectives
14. understand how concave mirrors bring a parallel beam of light to a focus
15. explain why large telescopes are needed to collect the weak radiation from faint or very distant sources
16. recall that waves can spread out from a narrow gap and that this is called diffraction
17. draw and interpret diagrams showing wave diffraction through gaps

P7.2	Light, telescopes and images
18.	recall that light can be diffracted, and that the effect is most noticeable when light travels through a very small gap, comparable to the wavelength of the wave
19.	**understand that radiation is diffracted by the aperture of a telescope, and that the aperture must be very much larger than the wavelength of the radiation detected by the telescope to produce sharp images**
20.	explain how a spectrum can be produced by refraction in a prism
21.	recall that a spectrum can be produced by a diffraction grating.

Module P7: Further Physics – Studying the Universe

P7.3 Mapping the Universe

1. explain how parallax makes closer stars seem to move relative to more distant ones over the course of a year
2. define the parallax angle of a star as half the angle moved against a background of very distant stars in 6 months
3. understand that a smaller parallax angle means that the star is further away
4. define a parsec (pc) as the distance to a star with a parallax angle of one second of arc
5. calculate distances in parsecs for simple parallax angles expressed as fractions of a second of arc
6. recall that a parsec is similar in magnitude to a light-year and is the unit used by astronomers to measure distance
7. recall that typical interstellar distances are a few parsecs
8. recall that the luminosity of a star depends on its temperature and its size
9. explain qualitatively why the observed intensity of light from a star (as seen on Earth) depends on the star's luminosity and its distance from Earth
10. recall that Cepheid variable stars pulse in brightness, with a period related to their luminosity
11. recall that **and explain qualitatively how** this relationship enables astronomers to estimate the distance to Cepheid variable stars
12. understand the role of observations of Cepheid variable stars in establishing the scale of the Universe and the nature of most spiral nebulae as distant galaxies
13. recall that telescopes revealed that the Milky Way consists of millions of stars and led to the realisation that the Sun was a star in the Milky Way galaxy
14. recall that telescopes revealed the existence of many fuzzy objects in the night sky, and that these were originally called nebulae
15. recall the main issue in the Curtis-Shapley debate: whether spiral nebulae were objects within the Milky Way or separate galaxies outside it
16. recall that Hubble's observations of Cepheid variables in one spiral nebula indicated that it was much further away than any star in the Milky Way, and so he concluded that this nebula was a separate galaxy
17. recall that intergalactic distances are typically measured in megaparsecs (Mpc)
18. recall that data on Cepheid variable stars in distant galaxies has given better values of the Hubble constant
19. use the following equation to calculate, given appropriate data, the speed of recession of a distant galaxy, **the Hubble constant or the distance to the galaxy:**

speed of recession	=	Hubble constant	×	distance
(km/s)		(s^{-1})		(km)
(km/s)		(km/s per Mpc)		(Mpc)

20. **understand how the motions of galaxies suggests that space itself is expanding**
21. recall that scientists believe the Universe began with a 'big bang' about 14 thousand million years ago.

Module P7: Further Physics – Studying the Universe

P7.4 The Sun, the stars and their surroundings

1. recall that all hot objects (including stars) emit a continuous range of electromagnetic radiation, whose luminosity and peak frequency increases with temperature
2. recall that the removal of electrons from atoms is called ionisation and **explain how electron energy levels within atoms give rise to line spectra**
3. recall that specific spectral lines in the spectrum of a star provide evidence of the chemical elements present in it
4. use data on the spectrum of a star, together with data on the line spectra of elements, to identify elements present in it
5. understand that the volume of a gas is inversely proportional to its pressure at a constant temperature and explain this using a molecular model
6. explain why the pressure and volume of a gas vary with temperature using a molecular model
7. understand that both the pressure and the volume of a gas are proportional to the absolute temperature
8. interpret absolute zero using a molecular model and kinetic theory
9. recall that –273°C is the absolute zero of temperature, and convert temperatures in K to temperatures in °C (and vice versa)
10. use the relationships:
    a. pressure × volume = constant
    b. $\frac{\text{pressure}}{\text{temperature}}$ = constant
    c. $\frac{\text{volume}}{\text{temperature}}$ = constant
11. explain the formation of a protostar in terms of the effects of gravity on a cloud of gas, which is mostly hydrogen and helium
12. understand that as the cloud of gas collapses its temperature increases, and relate this to the volume, pressure and behaviour of particles in a protostar
13. understand that nuclear processes discovered in the early 20th Century provided a possible explanation of the Sun's energy source
14. understand that, if brought close enough together, hydrogen nuclei can fuse into helium nuclei releasing energy, and that this is called nuclear fusion
15. complete and interpret nuclear equations relating to fusion in stars to include the emission of positrons to conserve charge
16. understand that energy is liberated when light nuclei fuse to make heavier nuclei with masses up to that of the iron nucleus

P7.4 The Sun, the stars and their surroundings

17. **understand that Einstein's equation $E = mc^2$ is used to calculate the energy released during nuclear fusion and fission (where E is the energy produced, m is the mass lost and c is the speed of light in a vacuum)**

18. recall that the more massive the star, the hotter its core and the heavier the nuclei it can create by fusion

19. recall that the core (centre) of a star is where the temperature and density are highest and where most nuclear fusion takes place

20. understand that energy is transported from core to surface by photons of radiation and by convection

21. recall that energy is radiated into space from the star's surface (photosphere)

22. recall that the Hertzsprung-Russell diagram is a plot of temperature and luminosity and identify regions on the graph where supergiants, giants, main sequence and white dwarf stars are located

23. recall that in a main sequence star, hydrogen fusion to helium takes place in the core

24. recall that a star leaves the main sequence when its core hydrogen runs out; it swells to become a red giant or supergiant and its photosphere cools

25. recall that in a red giant or supergiant star, helium nuclei fuse to make carbon, followed by further reactions that produce heavier nuclei such as nitrogen and oxygen

26. recall that a low-mass star (similar to the Sun) becomes a red giant, which lacks the mass to compress the core further at the end of helium fusion; it then shrinks to form a white dwarf

27. recall that in a white dwarf star there is no nuclear fusion; the star gradually cools and fades

28. recall that in a high-mass star (several times the mass of the Sun) nuclear fusion can produce heavier nuclei up to and including iron; when the core is mostly iron, it explodes as a supernova creating nuclei with masses greater than iron and leaving a dense neutron star or a black hole.

29. understand that astronomers have found convincing evidence of planets around hundreds of nearby stars

30. understand that, if even a small proportion of stars have planets, many scientists think that it is likely that life exists elsewhere in the Universe

31. recall that no evidence of extraterrestrial life (at present or in the past) has so far been detected.

Module P7: Further Physics – Studying the Universe

P7.5 The astronomy community

1. recall that major optical and infrared astronomical observatories on Earth are mostly situated in Chile, Hawaii, Australia and the Canary Islands
2. describe factors that influence the choice of site for major astronomical observatories including:
   a. high elevation
   b. frequent cloudless nights
   c. low atmospheric pollution and dry air
   d. sufficient distance from built up areas that cause light pollution
3. describe ways in which astronomers work with local or remote telescopes
4. explain the advantages of computer control of telescopes including:
   a. being able to work remotely
   b. continuous tracking of objects
   c. more precise positioning of the telescope
   d. computer recording and processing of data collected
5. explain the main advantages and disadvantages of using telescopes outside the Earth's atmosphere including:
   a. avoids absorption and refraction effects of atmosphere
   b. can use parts of electromagnetic spectrum that the atmosphere absorbs
   c. cost of setting up, maintaining and repairing
   d. uncertainties of space programme
6. understand the reasons for international collaboration in astronomical research in terms of economy and pooling of expertise
7. describe two examples showing how international cooperation is essential for progress in astronomy
8. understand that non-astronomical factors are important considerations in planning, building, operating, and closing down an observatory including:
   a. cost
   b. environmental and social impact near the observatory
   c. working conditions for employees.

Assessment of GCSE Physics A

4.1 Overview of the assessment in GCSE Physics A

GCSE Physics A J245	
Unit A181: *Modules P1, P2, P3*	
25% of the total GCSE 1 hr written paper 60 marks	This question paper: • is offered in Foundation and Higher Tiers • assesses modules P1, P2 and P3 • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
Unit A182: *Modules P4, P5, P6*	
25% of the total GCSE 1 hr written paper 60 marks	This question paper: • is offered in Foundation and Higher Tiers • assesses modules P4, P5 and P6 • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
Unit A183: *Module P7*	
25% of the total GCSE 1 hr written paper 60 marks	This question paper: • is offered in Foundation and Higher Tiers • assesses module P7 • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
Unit A184: *Controlled assessment*	
25% of the total GCSE Controlled assessment Approximately 4.5–6 hours 64 marks	This unit: • comprises a Practical Investigation • is assessed by teachers, internally standardised and then externally moderated by OCR • assesses the quality of written communication.

4.2 Tiers

All written papers are offered in Foundation Tier and Higher Tier. Foundation Tier papers assess grades G to C and Higher Tier papers assess Grades D to A*. An allowed grade E may be awarded on the Higher Tier components.

In Units A181, A182 and A183, candidates are entered for an option in either the Foundation Tier or the Higher Tier. Unit A184 (controlled assessment) is not tiered.

Candidates may enter for either the Foundation Tier or Higher Tier in each of the externally assessed units. So a candidate may take, for example, A181/F and A182/H.

4.3 Assessment objectives (AOs)

Candidates are expected to demonstrate their ability to:

AO1	recall, select and communicate their knowledge and understanding of physics;
AO2	apply skills, knowledge and understanding of physics in practical and other contexts;
AO3	analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence.

4.3.1 AO weightings – GCSE Physics A

The relationship between the units and the assessment objectives of the scheme of assessment is shown in the following grid:

Unit	% of GCSE			Total
	AO1	AO2	AO3	
Units A181–A183	30	34	11	75
Unit A184: Controlled assessment	2	5	18	25
Total	**32**	**39**	**29**	**100**

4.4 Grading and awarding grades

GCSE results are awarded on the scale A* to G. Units are awarded a* to g. Grades are indicated on certificates. However, results for candidates who fail to achieve the minimum grade (G or g) will be recorded as *unclassified* (U or u) and this is **not** certificated.

GCSEs are unitised schemes. Candidates can take units across several different series provided the terminal rules are satisfied. They can also re-sit units.

When working out candidates' overall grades OCR needs to be able to compare performance on the same unit in different series when different grade boundaries have been set, and between different units. OCR uses a Uniform Mark Scale to enable this to be done.

A candidate's uniform mark for each unit is calculated from the candidate's raw marks on that unit. The raw mark boundary marks are converted to the equivalent uniform mark boundary. Marks between grade boundaries are converted on a pro rata basis.

When unit results are issued, the candidate's unit grade and uniform mark are given. The uniform mark is shown out of the maximum uniform mark for the unit, eg 60/100.

The uniform mark grade boundaries for each of the assessments are shown below:

(GCSE) Unit Weighting	Maximum Unit Uniform Mark	Unit Grade								
		a*	a	b	c	d	e	f	g	u
25%	100	90	80	70	60	50	40	30	20	0

The written papers will have a total weighting of 75% and controlled assessment a weighting of 25%.

Higher tier candidates who fail to gain a 'd' grade may achieve an "allowed e". Higher tier candidates who miss the allowed grade 'e' will be given a uniform mark in the range f–u but will be graded as 'u'.

Candidate's uniform marks for each unit will be combined to give a total uniform mark for the specification. The candidate's overall grade will be determined by the total uniform mark.

The following table shows the minimum total mark for each overall grade:

Qualification	Max Uniform Mark	Qualification Grade								
		A*	A	B	C	D	E	F	G	U
J245	400	360	320	280	240	200	160	120	80	0

A candidate's uniform mark for each paper will be combined with the uniform mark for the controlled assessment to give a total uniform mark for the specification. The candidate's grade will be determined by the total uniform mark.

4.5 Grade descriptions

Grade descriptions are provided to give a general indication of the standards of achievement likely to have been shown by candidates awarded particular grades. The descriptions must be interpreted in relation to the content in the specification; they are not designed to define that content. The grade awarded will depend in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of the assessment may be balanced by better performance in others.

The grade descriptors have been produced by the regulatory authorities in collaboration with the awarding bodies.

4.5.1 Grade F

Candidates recall, select and communicate limited knowledge and understanding of physics. They show a limited understanding that scientific advances may have ethical implications, benefits and risks. They recognise simple inter-relationships between physics and society. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space.

They apply skills, including limited communication, mathematical, technical and observational skills, knowledge and understanding in practical and some other contexts. They recognise and use hypotheses, evidence and explanations and can explain straightforward models of phenomena, events and processes. Using a limited range of skills and techniques, they answer scientific questions, solve straightforward problems and test ideas.

Candidates interpret and evaluate limited quantitative and qualitative data and information from a narrow range of sources. They can draw elementary conclusions having collected limited evidence.

4.5.2 Grade C

Candidates recall, select and communicate secure knowledge and understanding of physics. They demonstrate understanding of the nature of physics, its laws, principles and applications and the relationship between physics and society. They understand that scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space.

They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding in a range of practical and other contexts. They show understanding of the relationships between hypotheses, evidence, theories and explanations and use models, including mathematical models, to describe abstract ideas, phenomena, events and processes. They use a range of appropriate methods, sources of information and data, applying their skills to address scientific questions, solve problems and test hypotheses.

Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and use evidence and information to develop arguments with supporting explanations. They draw conclusions based on the available evidence.

4.5.3 Grade A

Candidates recall, select and communicate precise knowledge and detailed understanding of physics. They demonstrate a comprehensive understanding of the nature of physics, its laws, principles and applications and the relationship between physics and society. They understand the relationships between scientific advances, their ethical implications and the benefits and risks associated with them. They use scientific and technical knowledge, terminology and conventions appropriately and consistently, showing a detailed understanding of scale in terms of time, size and space.

They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models, including mathematical models, to explain abstract ideas, phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses.

Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations, taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.

4.6 Quality of written communication

Quality of written communication (QWC) is assessed in all units and is integrated into the marking criteria.

Candidates are expected to:

- ensure that text is legible and that spelling, punctuation and grammar are accurate so that the meaning is clear
- present information in a form that suits its purpose
- use a suitable structure and style of writing.

Questions assessing quality of written communication will be indicated by the icon of a pencil (✎).

Controlled assessment in GCSE Physics A

This section provides general guidance on controlled assessment: what controlled assessment tasks are, when and how they are available, how to plan and manage controlled assessment and what controls must be applied throughout the process. More specific guidance and support is provided in the *Guide to controlled assessment for GCSE Twenty First Century Science*, which will be available on the OCR website from Spring 2011.

5.1 Introduction to controlled assessment tasks

All controlled assessment tasks are set by OCR and will be available for submission only in June examination series. Each year a choice of two tasks will be offered, based upon Modules P1 – P7; one of these two tasks will be based on Modules P4 – P6.

Each task will be valid for submission in a single examination series only, but may be undertaken at any point between release of the task by OCR and the examination series for which the task must be submitted. Centres must ensure that candidates undertake a task that is valid for submission in the year in which the candidate intends to submit it. The series in which each task can be submitted will be clearly marked on the front cover of each task. Tasks will not be valid for submission in any examination series other than that indicated.

Every year, two new controlled assessment tasks will be made available on OCR Interchange from 1 June, two years ahead of the examination series for which the tasks are to be submitted. These will be removed upon expiry. Guidance on how to access controlled assessment tasks from OCR Interchange is available on the OCR website: www.ocr.org.uk.

It is not necessary for all candidates from a centre to carry out the same task from the choice of two provided. Staff at each centre can choose whether:

- all candidates from the centre complete the same task
- all candidates in any teaching group carry out the same task, but different groups use different tasks
- candidates complete tasks on an individual basis.

The number of tasks attempted is at the discretion of the centre, but the results of only one complete task may be submitted.

5.2 Nature of controlled assessment tasks

5.2.1 Introduction to skills assessment

The controlled assessment for GCSE Physics A comprises one element: a practical investigation.

Investigations are central to the nature of science as an evidence-based activity and practical investigations provide an effective and valid assessment instrument for a course which is both a basis for further studies and for possible future careers in science. The ability of a candidate to formulate a hypothesis and to explain patterns in results will be related to their knowledge and understanding of the topic.

Controlled assessment tasks for GCSE Physics A practical investigations require candidates to:

- develop hypotheses and plan practical ways to test them, including risk assessment
- manage risks when carrying out practical work
- collect, process, analyse and interpret primary and secondary data, including the use of appropriate technology to draw evidence-based conclusions
- review methodology to assess fitness for purpose
- review hypotheses in the light of outcomes.

Practical investigations therefore draw together the skills of predicting and planning, and collecting, interpreting, evaluating and reviewing primary and secondary data within the context of a whole investigation. Candidates should be familiar with these requirements before starting any controlled assessment task.

It is expected that candidates will be involved in a variety of practical work during the course that will prepare them for this assessment. This should include developing their abilities to handle equipment and carry out practical procedures safely, illustrating science principles with real experiences and learning how to carry out and evaluate investigations.

In addition, candidates' abilities to devise and evaluate suitable methods, to decide on suitable data ranges and to offer explanations will be closely linked to their understanding of some Ideas about Science, particularly:

- IaS1: Data: their importance and limitations
- IaS2: Cause-effect explanations
- IaS3: Developing scientific explanations
- IaS5: Risk.

Candidates should be encouraged to use ideas and vocabulary related to these Ideas about Science in their reports and it is therefore important that candidates are familiar with these ideas before attempting the investigation. Ideas about Science are detailed in Appendix B.

The tasks to be used for the controlled assessment that are set by OCR will be presented in a way which leaves some freedom for each centre to vary the approach as appropriate, to allow for candidates of different abilities and interests, or for differences in the materials, equipment and facilities at different centres.

The tasks provided will be open-ended and investigative in nature. The information provided with each task will include:

- *Information for candidates (1)*: an introduction to the topic of the investigation, to be issued to candidates at the start of the task, placing the work into an appropriate wider context
- *Information for candidates (2)*: secondary data for analysis, to be issued to candidates only on completion of the data collection part of their practical investigation
- *Information for teachers*: an overview of the investigation including notes on possible approaches and assessment issues and guidance for technicians.

At the start of a controlled assessment, candidates will use the information provided to plan how to collect data, including any preliminary work required, and to develop a testable hypothesis before carrying out the investigation. After collecting primary data and interpreting and evaluating the results, candidates will be expected to engage with relevant secondary data to develop and evaluate their conclusions further and review their original hypothesis. Sources of secondary data can include experimental results from other candidates in the class or school, as well as text books and web sites on the internet. In addition, OCR will provide some secondary data relevant to the task set for each practical investigation.

The completed work will be presented for assessment as a written report.

5.2.2 Summary of tasks in Unit A184

Assessment Task	Task Marks	Weighting
Practical investigation	64	25%

5.3 Planning and managing controlled assessment

Controlled assessment tasks will be available up to two years ahead of the examination series for which they are valid, to allow planning time. It is anticipated that candidates will spend a total of about 4.5–6 hours in producing the work for this unit. Candidates should be allowed sufficient time to complete the task.

When supervising tasks, teachers are expected to:

- exercise continuing supervision of work in order to monitor progress and to prevent plagiarism
- provide guidance on the use of information from other sources to ensure that confidentiality and intellectual property rights are maintained
- exercise continuing supervision of practical work to ensure essential compliance with Health and Safety requirements
- ensure that the work is completed in accordance with the specification requirements and can be assessed in accordance with the specified marking criteria and procedures.

Teachers must not provide templates, model answers or feedback on drafts. Candidates must produce their own individual responses to each stage and work independently to produce the report on the final stage (Analysis, evaluation and review).

Suggested steps and timings are included below, with guidance on regulatory controls at each stage of the process. Teachers must ensure that control requirements indicated below are met throughout the process.

5.3.1 Research and planning, and collecting data

- Strategy: research and planning **1.5 – 2 hours**

  In the research and planning stage, a limited level of control is required. This means that candidates can undertake this part of the process without direct teacher supervision and away from the centre, as required. This may also include collection of secondary data where this informs the planning of the work. Candidates are also able to work in collaboration during this stage. During the research phase candidates can be given support and guidance. Teachers can explain the task, advise on how the task could be approached, advise on resources and alert the candidate to key things that must be included in their final piece of work. However, each candidate must develop their own individual response.

- Collecting data **1.5 – 2 hours**

  In the data collection stage, a limited level of control is required. Candidates will carry out practical work under direct teacher supervision to collect primary data. They may work in collaboration during this stage but all candidates must be actively involved and develop their own, individual response in determining how best to collect and record primary data.

  Secondary data may also be collected during this stage to support or extend the conclusions to the investigation. However, it is not permitted to base the assessment solely on secondary data or (computer) simulations, or on data recorded by candidates whilst watching demonstrations.

The OCR-provided secondary data, *Information for candidates (2)*, should be given to candidates **only** after collection of primary data is completed. This can be used in addition to secondary data collected by the candidate, if appropriate. Time should be allowed for further collection of secondary data following the issue of *Information for candidates (2)*.

5.3.2 Analysis, evaluation and review

- Analysis, evaluation and review **1.5 – 2 hours**

  The report for this stage is produced in the centre under conditions of high control, which means that candidates work individually to complete their reports under direct teacher supervision. Teachers must be able to authenticate the work and there must be acknowledgement and referencing of any sources used. If writing up is carried out over several sessions, work must be collected in between each session, including any electronic data storage such as USB memory sticks and rewritable CDs.

5.3.3 Presentation of the final piece of work

Candidates must observe certain procedures in the production of controlled assessment tasks.

- Tables, graphs and spreadsheets may be produced using appropriate ICT. These should be inserted into the final report at the appropriate place.
- Any copied material must be suitably acknowledged.
- Quotations must be clearly marked and a reference provided wherever possible.
- Work submitted for moderation by OCR must be marked with the:
  - centre number
  - centre name
  - candidate number
  - candidate name
  - unit code and title
  - controlled assessment task title.

Work submitted on paper for moderation must be secured by treasury tags. Work submitted in digital format (CD or online) must be in a suitable file structure as detailed in Appendix A at the end of this specification.

5.4 Marking and moderating controlled assessment

All controlled assessment tasks are marked by centre assessor(s) using OCR marking criteria and guidance.

This corresponds to a medium level of control.

5.4.1 Applying the marking criteria

The starting point for marking the tasks is the marking criteria (see section 5.4.5 Marking criteria for controlled assessment tasks). These identify levels of performance for the skills, knowledge and understanding that the candidate is required to demonstrate. Guidance for each specific task will be provided in the '*Information for teachers*' for each task. Before the start of the course, and for use at INSET training events, OCR will provide exemplification through real or simulated candidate work which will help to clarify the level of achievement that assessors should be looking for when awarding marks.

5.4.2 Using the hierarchical marking criteria

A standard method of marking is used for the controlled assessment tasks for Twenty First Century Science GCSE Physics A, based on a grid of hierarchical marking criteria. The marking criteria indicate levels of response and are generic, so can be used for marking any OCR-issued practical investigation. They define the performance for the skills, knowledge and understanding that the candidate is expected to demonstrate at each level. For each task set by OCR, more specific guidance will also be given in the *Information for teachers* on applying the marking criteria in the context of the task.

Candidates' progress through a task is assessed in five strands, each of which corresponds to a different type of performance by the candidate. Three of the five strands include two different aspects of the work. Thus, marking is based on a total of 8 aspects, each of which is shown as a different row in the grid of marking criteria.

For each aspect, a hierarchical set of four marking criteria shows typical performance for candidates working at 1–2, 3–4, 5–6 and 7–8 marks. This provides a level of response mark scheme where achievement is divided into four non-overlapping bands, each covering a range of two marks.

Award of marks in each row of the grid is based on the professional judgement of the teacher and is hierarchical. This means that each of the criteria is considered in turn, working up from the lowest band to the highest band that is fully matched by the candidate's performance. Once a band has been reached which is not fully matched by the work seen, no higher bands can be considered.

Within each two-mark band, the higher mark is available where the performance fully matches the criterion for that mark band (and all preceding, lower mark bands). The lower mark is awarded where the candidate has partially, but not fully, matched this criterion and has exceeded the criteria in the preceding, lower mark bands.

Where there is no evidence of engagement with an aspect of the work, or if the response is not sufficient to merit award of one mark, a mark of zero is awarded for the aspect.

This method of marking can be used even where there is wide variation in performance between different aspects of the work. Weak performance on one aspect need not limit marks in other aspects.

In Strand A, two alternative routes to credit are provided. One row of criteria is used for investigations where the candidate uses graphical display or charts to reveal patterns in the data. The other row is used where the candidate has used statistical or algebraic methods to identify patterns. Only the row which gives the highest mark is counted.

The level awarded in each aspect is recorded on a marking grid, which also serves as a cover sheet if the work is called for moderation.

The total for the assessment is the sum of all the aspect marks, giving a maximum possible mark of 64.

5.4.3 Annotation of candidates' work

Each piece of internally assessed work should show how the marks have been awarded in relation to the marking criteria.

The writing of comments on candidates' work provides a means of dialogue and feedback between teacher and candidate and a means of communication between teachers during internal standardisation.

5.4.4 Overview of marking criteria for controlled assessment tasks

The five strands in the marking criteria are designed to match five main stages in the investigation. However, candidates do not always follow this sequence strictly when writing their investigation reports, and positive achievement should be credited in the appropriate strand wherever it is found in the report.

Strand	Aspect	Notes
S strategy	S(a) – formulating a hypothesis or prediction	Candidates review factors that might affect their results (this may include preliminary tests of these effects) and use their scientific knowledge to choose an effect to study, based on a prediction or testable hypothesis (IaS3). Responses in this aspect will be in extended writing and should be assessed for quality of written communication of the content.
	S(b) – design of techniques and choice of equipment	Candidates test different experimental methods or apparatus, and justify the choices they make (IaS1). They show awareness of safe working practices and the hazards associated with materials (IaS1–3, IaS5). At the highest level, a full risk assessment is included.
C collecting data	C – range and quality of primary data	Candidates make decisions about the amount of data to be collected, the range of values covered, and effective checking for reproducibility (IaS1).
A analysis	A – revealing patterns in data	To allow access to a wider range of activities, this strand has two alternative sets of criteria. One is for the quality of graphical display. The alternative row can be used to award credit for statistical or numerical analysis of data, eg species distribution surveys.
E evaluation	E(a) – evaluation of apparatus and procedures	Candidates show awareness of any limitations imposed by the apparatus or techniques used and suggest improvements to the method.
	E(b) – evaluation of primary data	Candidates consider carefully the reproducibility of their data, recognise outliers and treat them appropriately (IaS1).
R review	R(a) – collection and use of secondary data	Candidates collect secondary data, which can be considered together with their own primary data, to give a broader basis for confirmation, adaptation or extension of the initial hypothesis or prediction.
	R(b) – reviewing confidence in the hypothesis	Candidates make an overall review of the evidence in relation to the underlying scientific theory and consider how well it supports the hypothesis, and what extra work might help to improve confidence in the hypothesis (IaS2 and IaS3). Quality of written communication should be taken into account in assessing this aspect of the work.

5.4.5 Marking criteria for controlled assessment tasks

Marking criteria are to be applied hierarchically (see section 5.4.2).

Strand/ Aspect	0	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks	AOs
S a	*	Make a prediction to test, but without any justification. The response may be simplistic, with frequent errors of spelling, punctuation or grammar and have little or no use of scientific vocabulary.	Suggest a testable prediction and justify it by reference to common sense or previous experience. Some relevant scientific terms are used, but spelling, punctuation and grammar are of variable quality.	Consider major factors and refer to scientific knowledge to make a testable hypothesis about how one factor will affect the outcome. Information is effectively organised with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	After consideration of all relevant factors, select one and propose a testable hypothesis and quantitative prediction about how it will affect the outcomes. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.	AO1: 2 marks AO2: 4 marks AO3: 2 marks
S b	*	Follow a given technique, but with very limited precision or accuracy. Make an appropriate comment about safe working.	Select and use basic equipment to collect a limited amount of data. Correctly identify hazards associated with the procedures used.	Select and use techniques and equipment appropriate for the range of data required, and explain the ranges chosen. Identify any significant risks and suggest some precautions.	Justify the choice of equipment and technique to achieve data which is precise and valid. Complete a full and appropriate risk assessment, identifying ways of minimising risks associated with the work.	AO2: 4 marks AO3: 4 marks
C	*	Record a very limited amount of data (eg isolated individual data points with no clear pattern), covering only part of the range of relevant cases/situations, with no checking for repeatability. Data is generally of low quality.	Record an adequate amount or range of data, allowing some errors in units or labelling, and with little checking for repeatability. Data is of variable quality, with some operator error apparent.	Collect and correctly record data to cover the range of relevant cases/situations, with regular repeats or checks for repeatability. Data is of generally good quality.	Choose an appropriate range of values to test across the range, with regular repeats and appropriate handling of any outliers. Checks or preliminary work are included to confirm or adapt the range and number of measurements to ensure data of high quality.	AO1: 1 mark AO2: 3 marks AO3: 4 marks

Strand/ Aspect	0	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks	AOs
A	*	Display limited numbers of results in tables, charts or graphs, using given axes and scales.	Construct simple charts or graphs to display data in an appropriate way, allowing some errors in scaling or plotting.	Correctly select scales and axes and plot data for a graph, including an appropriate line of best fit, or construct complex charts or diagrams eg species distribution maps.	Indicate the spread of data (eg through scatter graphs or range bars) or give clear keys for displays involving multiple data-sets.	AO3: 8 marks
		Select individual results as a basis for conclusions.	Carry out simple calculations eg correct calculation of averages from repeated readings.	Use mathematical comparisons between results to support a conclusion.	Use complex processing to reveal patterns in the data eg statistical methods, use of inverse relationships, or calculation of gradient of graphs.	
E a	*	Make relevant comments about problems encountered whilst collecting the data.	Describe the limitations imposed by the techniques and equipment used.	Suggest (in outline) improvements to apparatus or techniques, or alternative ways to collect the data; or explain why the method used gives data of sufficient quality to allow a conclusion.	Describe in detail improvements to the apparatus or techniques, or alternative ways to collect the data, and explain why they would be an improvement; or explain fully why no further improvement could reasonably be achieved.	AO3: 8 marks
E b	*	Make a claim for accuracy or repeatability, but without appropriate reference to the data.	Correctly identify individual results which are beyond the range of experimental error (are outliers), or justify a claim that there are no outliers.	Use the general pattern of results or degree of scatter between repeats as a basis for assessing accuracy and repeatability and explain how this assessment is made.	Consider critically the repeatability of the evidence, accounting for any outliers.	AO3: 8 marks
R a	*	Compare own experimental results with at least one piece of secondary data and make basic comments on similarities and/ or differences. Secondary data collected is limited in amount and not always relevant to the investigation.	Identify in detail similarities and differences between the secondary data and primary data. Secondary data collected is relevant to the investigation and sources are referenced, though these may be incomplete.	Describe and explain the extent to which the secondary data supports, extends and/ or undermines the primary data, and identify any areas of incompleteness. A range of relevant secondary data is collected from several fully referenced sources.	Assess the levels of confidence that can be placed on the available data, and explain the reasons for making these assessments. Comment on the importance of any similarities or differences.	AO1: 1 mark AO2: 1 mark AO3: 6 marks

Strand/ Aspect	0	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks	AOs
R b	*	Correctly state whether or not the original prediction or hypothesis is supported, with reference only to common sense or previous experience. The response is simplistic, with frequent errors in spelling, punctuation or grammar and has little or no use of scientific vocabulary.	Comment on whether trends or correlations in the data support the prediction or hypothesis and suggest why by reference to appropriate science. Some relevant scientific terms are used correctly, but spelling, punctuation and grammar are of variable quality.	Explain the extent to which the hypothesis can account for the pattern(s) shown in the data. Use relevant science knowledge to conclude whether the hypothesis has been supported or to suggest how it should be modified to account for the data more completely. Information is organised effectively with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	Give a detailed account of what extra data could be collected to increase confidence in the hypothesis. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.	AO1: 2 marks AO3: 6 marks

* No response, or response not sufficient for award of 1 mark

5.4.6 Assessment objectives (AOs)

Each of the aspects to be assessed addresses one or more of the assessment objectives and these are shown in the marking criteria. The overall balance is shown in the table below.

Assessment Objective	TOTAL
AO1: Recall, select and communicate their knowledge and understanding of physics	6
AO2: Apply skills, knowledge and understanding of physics in practical and other contexts	12
AO3: Analyse and evaluate evidence, make reasoned judgments and draw conclusions based on evidence	46
TOTAL	64

5.4.7 Authentication of work

Teachers must be confident that the work they mark is the candidate's own. This does not mean that a candidate must be supervised throughout the completion of all work but the teacher must exercise sufficient supervision, or introduce sufficient checks, to be in a position to judge the authenticity of the candidate's work.

Wherever possible, the teacher should discuss work-in-progress with candidates. This will not only ensure that work is underway in a planned and timely manner but will also provide opportunities for assessors to check authenticity of the work and provide general feedback.

Candidates must not plagiarise. Plagiarism is the submission of another's work as one's own and/or failure to acknowledge the source correctly. Plagiarism is considered to be malpractice and could lead to the candidate being disqualified. Plagiarism sometimes occurs innocently when candidates are unaware of the need to reference or acknowledge their sources. It is therefore important that centres ensure that candidates understand that the work they submit must be their own and that they understand the meaning of plagiarism and what penalties may be applied. Candidates may refer to research, quotations or evidence but they must list their sources. The rewards from acknowledging sources, and the credit they will gain from doing so, should be emphasised to candidates as well as the potential risks of failing to acknowledge such material.

Candidates and teachers must both declare that the work is the candidate's own:

- **Each candidate** must sign a declaration before submitting their work to their teacher. A candidate authentication statement that can be used is available to download from the OCR website. These statements should be retained within the centre until all enquiries about results, malpractice and appeals issues have been resolved. **A mark of zero must be recorded if a candidate cannot confirm the authenticity of their work.**

- **Teachers** are required to declare that the work submitted for internal assessment is the candidate's own work by sending the moderator a centre authentication form (CCS160) for each unit at the same time as the marks. If a centre fails to provide evidence of authentication, **we will set the mark for that candidate(s) to Pending (Q) for that component until authentication can be provided.**

5.5 Internal standardisation

It is important that all internal assessors of this controlled assessment work to common standards. Centres must ensure that the internal standardisation of marks across assessors and teaching groups takes place using an appropriate procedure.

This can be done in a number of ways. In the first year, reference material and OCR training meetings will provide a basis for centres' own standardisation. In subsequent years, this, or centres' own archive material, may be used. Centres are advised to hold preliminary meetings of staff involved to compare standards through cross-marking a small sample of work. After most marking has been completed, a further meeting at which work is exchanged and discussed will enable final adjustments to be made.

5.6 Submitting marks and authentication

All work for controlled assessment is marked by the teacher and internally standardised by the centre. Marks are then submitted to OCR **and** your moderator: refer to the OCR website for submission dates of the marks to OCR.

There should be clear evidence that work has been attempted and some work produced. If a candidate submits no work for an internally assessed component, then the candidate should be indicated as being absent from that component. If a candidate completes any work at all for an internally assessed component, then the work should be assessed according to the internal assessment objectives and marking instructions and the appropriate mark awarded, which may be zero.

The centre authentication form (CCS160) must be sent to the moderator with the marks.

5.7 Submitting samples of candidate work

5.7.1 Sample requests

Once you have submitted your marks, your exams officer will receive an email requesting a moderation sample. Samples will include work from across the range of attainment of the candidates' work.

The sample of work which is presented to the moderator for moderation must show how the marks have been awarded in relation to the marking criteria defined in Section 5.4.5. Each candidate's work should have a cover sheet attached to it with a summary of the marks awarded for the task.

When making your entries, the entry option specifies how the sample for each unit is to be submitted. For each of these units, all candidate work must be submitted using the **same entry option**. It is not possible for centres to offer both options for a unit within the same series. You can choose different options for different units. Please see the Section 8.2.1 for entry codes.

5.7.2 Submitting moderation samples via post

The sample of candidate work must be posted to the moderator within three days of receiving the request. You should use one of the labels provided to send the candidate work.

We would advise you to keep evidence of work submitted to the moderator, eg copies of written work or photographs of practical work. You should also obtain a certificate of posting for all work that is posted to the moderator.

5.7.3 Submitting the moderation samples via the OCR Repository

The OCR Repository, which is accessed via Interchange, is a system which has been created to enable centres to submit candidate work electronically for moderation. It allows centres to upload work for several candidates at once but does not function as an e-portfolio for candidates.

OCR GCSE Physics A Unit A184 can be submitted via the OCR Repository.

Once you receive your sample request, you should upload the work to the OCR Repository within three days of receiving the request. Instructions for how to upload files to OCR using the OCR Repository can be found on the OCR website and in the *Guide to controlled assessment for GCSE Twenty First Century Science*, which will be available on the OCR website from Spring 2011.

It is the centre's responsibility to ensure that any work submitted to OCR electronically is virus-free.

5.8 External moderation

The purpose of moderation is to ensure that the standard of the award of marks for work is the same for each centre and that each teacher has applied the standards appropriately across the range of candidates within the centre.

At this stage, if necessary, centres may be required to provide an additional sample of candidate work (if marks are found to be in the wrong order) or carry out some re-marking. If you receive such a request, please ensure that you respond as quickly as possible to ensure that your candidates' results are not delayed.

6 Support for GCSE Physics A

6.1 Free support and training from OCR

OCR recognises that the introduction of the new specifications and controlled assessment will bring challenges for implementation and teaching.

Working in close consultation with teachers, publishers and other experts, centres can expect a high level of support, services and resources for OCR qualifications.

Essential FREE support materials including:

- New OCR GCSE Sciences website www.gcse-science.com to access information and support materials quickly and easily
- Specimen assessment materials and mark schemes
- Guide to controlled assessment
- Sample controlled assessment materials
- Exemplar candidate work
- Teacher's handbook
- Sample schemes of work and lesson plans
- Guide to curriculum planning
- Frequently asked questions

Essential FREE support services including:

- Free INSET training – for information visit www.gcse-science.com
- Interchange – a completely secure, free website to help centres reduce administrative tasks at exam time
- E-alerts – register now for regular updates at www.ocr.org.uk/2011signup
- Active Results – detailed item level analysis of candidate results
- Answers@OCR – a free online service providing answers to frequently asked questions about GCSE science

6.2 OCR endorsed resources

OCR works with publishers to ensure centres can access a choice of quality, 'Official Publisher Partner' and 'Approved publication' resources, endorsed by OCR for use with individual specifications.

You can be confident that resources branded with 'Official Publisher Partner' or 'Approved publication' logos have undergone OCR's thorough quality assurance process and are endorsed for use with the relevant specification.

These endorsements do not mean that the materials are the only suitable resources available or necessary to achieve an OCR qualification. All responsibility for the content of the published resources rests with the publisher.

6.2.1 Publisher partner

Official Publisher Partnership

We have been working closely with Oxford University Press, our publisher partner for OCR GCSE Twenty First Century Science 2011, to help ensure their new resources are available when you need them and match the new specifications.

Oxford University Press is working with our science team, the Nuffield Foundation and University of York Science Education Group to publish new editions of the popular Twenty First Century Science resources. These resources are lively, engaging and make science relevant to every student.

The second edition of these resources is packed with up to date sciences, as well as the familiar topics you enjoy teaching, including step by step guidance for answering all types of exam questions, extended response questions and support for the new Controlled Assessment.

To order an Evaluation Pack, or for further details, please visit the Oxford University Press website at www.oxfordsecondary.co.uk/twentyfirstcenturyscience.

6.2.2 Endorsed publishers

Approved publication

Other endorsed resources available for this specification include OCR GCSE Twenty First Century Science from Collins.

Collins is working with a team of experienced authors to provide resources which will help you deliver the new OCR GCSE Twenty First Century Science specifications. The Science, Additional Science and Separate Science components build on each other so your department can buy as needed and use them with all students taking different 2011 GCSE science routes.

Reduce planning time – the student books, teacher packs, homework activities, interactive books and assessment package are fully integrated and matched to the Collins GCSE Twenty First Century Science scheme of work so you can get started straight away.

For further details and to order an Evaluation Pack visit www.collinseducation.com/gcsescience2011.

6.3 Training

6.3.1 Get ready... introducing the new specification

If you would like an overview of the new OCR Science specifications, we have half-day 'Get ready' courses running in three locations. For more information and to book online visit www.ocreventbooker.org.uk using **course code OSCP3.**

6.3.2 Get started... towards successful delivery of the new specification

Our 'Get started' courses will look at the new specification in more depth, with emphasis on first delivery. The courses planned for summer 2011 will focus on controlled assessment. For more information about our full range of OCR GCSE Science courses visit www.ocr.org/science2011/training.

6.4 OCR support services

6.4.1 Active Results

Active Results is available to all centres offering the OCR GCSE Physics A specification.

activeresults

Active Results is a free results analysis service to help teachers review the performance of individual candidates or whole schools.

Devised specifically for the UK market, data can be analysed using filters on several categories such as gender and other demographic information, as well as providing breakdowns of results by question and topic.

Active Results allows you to look in greater detail at your results in a number of ways:

- richer and more granular data will be made available to centres, including question-level data available from e-marking
- you can identify the strengths and weaknesses of individual candidates and your centre's cohort as a whole
- our systems have been developed in close consultation with teachers so that the technology delivers what you need.

Further information on Active Results can be found on the OCR website.

6.4.2 OCR Interchange

OCR Interchange has been developed to help you to carry out day-to-day administration functions online, quickly and easily. The site allows you to register and enter candidates online. In addition, you can gain immediate and free access to candidate information at your convenience. Sign up at https://interchange.ocr.org.uk.

7 Access to GCSE Physics A

7.1 Disability Discrimination Act (DDA) information relating to GCSE Physics A

GCSEs often require assessment of a broad range of competencies. This is because they are general qualifications and, as such, prepare candidates for a wide range of occupations and higher level courses.

The revised GCSE qualifications and subject criteria were reviewed by the regulators to identify whether any of the competencies required by the subject presented a potential barrier to any disabled candidates. If this was the case, the situation was reviewed again to ensure that such competencies were included only where essential to the subject. The findings of this process were discussed with disability groups and with disabled people.

Reasonable adjustments are made for disabled candidates in order to enable them to access the assessments and to demonstrate what they know and can do. For this reason, very few candidates will have a complete barrier to the assessment. Information on reasonable adjustments is found in *Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations* produced by the Joint Council www.jcq.org.uk.

Candidates who are unable to access part of the assessment, even after exploring all possibilities through reasonable adjustments, may still be able to receive an award based on the parts of the assessment they have taken.

The access arrangements permissible for use in this specification are in line with QCDA's GCSE subject criteria equalities review and are as follows:

	Yes/No	Type of Assessment
Readers	Yes	All assessments
Scribers	Yes	All assessments
Practical assistants	Yes	All controlled assessments. The practical assistant may assist with assessed practical task under instruction from the candidate.
Word processors	Yes	All assessments
Transcripts	Yes	All assessments
BSL interpreters	Yes	All assessments
Oral language modifiers	Yes	All assessments
MQ papers	Yes	All assessments
Extra time	Yes	All assessments

7.2 Arrangements for candidates with particular requirements

All candidates with a demonstrable need may be eligible for access arrangements to enable them to show what they know and can do. The criteria for eligibility for access arrangements can be found in the JCQ document *Access Arrangements, Reasonable Adjustments and Special Consideration.*

Candidates who have been fully prepared for the assessment but who have been affected by adverse circumstances beyond their control at the time of the examination may be eligible for special consideration. Centres should consult the JCQ document *Access Arrangements, Reasonable Adjustments and Special Consideration*.

8 Administration of GCSE Physics A

8.1 Availability of assessment

There are two examination series each year, in January and June. GCSE Physics A units will be assessed from January 2012. Assessment availability and unit weighting can be summarised as follows:

	Unit A181 (25%)	Unit A182 (25%)	Unit A183 (25%)	Unit A184 (25%)	Certification availability
January 2012	✓				–
June 2012	✓	✓			–
January 2013	✓	✓			–
June 2013	✓	✓	✓	✓	✓*
January 2014	✓	✓	✓		✓*
June 2014	✓	✓	✓	✓	✓*

GCSE certification is available for the first time in June 2013 for GCSE Physics A, and each January and June thereafter.

*Centres are reminded that at least 40% of the assessment must be taken in the examination series in which the qualification is certificated. This can be any combination of assessment units, including written papers and controlled assessment units.

8.2 Making entries

Centres must be registered with OCR in order to make any entries, including estimated entries. It is recommended that centres apply to OCR to become a registered centre well in advance of making their first entries.

Submitting entries accurately and on time is critical to the successful delivery of OCR's services to centres. Entries received after the advertised deadlines can ultimately jeopardise the final production and delivery of results. Therefore, please make sure that you are aware of the entry deadlines, which are available on the OCR website.

8.2.1 Making unit entries

Centres must have made an entry for a unit in order for OCR to supply the appropriate forms and/or moderator details for controlled assessment.

It is essential that unit entry codes are quoted in all correspondence with OCR.

Unit entry code	Component code	Assessment method	Unit title
A181 F	01	Written paper	Unit A181: Modules P1, P2 and P3 (Foundation Tier)
A181 H	02	Written paper	Unit A181: Modules P1, P2 and P3 (Higher Tier)
A182 F	01	Written paper	Unit A182: Modules P4, P5 and P6 (Foundation Tier)
A182 H	02	Written paper	Unit A182: Modules P4, P5 and P6 (Higher Tier)
A183 F	01	Written paper	Unit A183: Module P7 (Foundation Tier)
A183 H	02	Written paper	Unit A183: Module P7 (Higher Tier)

Controlled assessment unit

For the controlled assessment Unit A184, candidates must be entered for either the OCR Repository option or the postal moderation option. Centres must enter all of their candidates for ONE of the options. It is not possible for centres to offer both components within the same series.

Unit entry code	Component code	Assessment method	Unit title
A184 A	01	Moderated via OCR Repository	Controlled assessment
A184 B	02	Moderated via postal moderation	Controlled assessment

8.2.2 Qualification entries

Candidates must enter for qualification certification separately from unit assessment(s). If a certification entry is **not** made, no overall grade can be awarded.

Candidates may enter for:

- GCSE certification code J245.

A candidate who has completed all the units required for the qualification must enter for certification in the same examination series in which the terminal rules are satisfied.

GCSE certification is available for the first time in June 2013 for GCSE Physics A, and each January and June thereafter.

8.3 Terminal rule

Candidates must take at least 40% of the overall assessment in the same series they enter for the qualification certification.

Guidance on the terminal rule can be found on the OCR website.

8.4 Unit and qualification re-sits

Candidates may re-sit each unit once before entering for certification for a GCSE. The better result for each unit will count towards the final qualification, **provided that the terminal rule is satisfied**.

However, candidates may enter for the qualification an unlimited number of times.

Please refer to the Admin Guide on the OCR website for more information.

8.5 Enquiries about results

Under certain circumstances, a centre may wish to query the result issued to one or more candidates. Enquiries about results for GCSE units must be made immediately following the series in which the relevant unit was taken (by the Enquiries about Results deadline).

Please refer to the JCQ *Post-Results Services* booklet and the OCR Admin Guide for further guidance about action on the release of results. Copies of the latest versions of these documents can be obtained from the OCR website.

8.6 Shelf-life of units

Individual unit results, prior to certification of the qualification, have a shelf-life limited only by that of the qualification.

8.7 Prohibited qualifications and classification code

Every specification is assigned a national classification code indicating the subject area to which it belongs. The classification code for this specification is 1210.

Centres should be aware that candidates who enter for more than one GCSE qualification with the same classification code will have only one grade (the highest) counted for the purpose of the School and College Performance Tables.

Centres may wish to advise candidates that, if they take two specifications with the same classification code, schools and colleges are very likely to take the view that they have achieved only one of the two GCSEs. The same view may be taken if candidates take two GCSE specifications that have different classification codes but have significant overlap of content. Candidates who have any doubts about their subject combinations should seek advice, for example from their centre or the institution to which they wish to progress.

9 Other information about GCSE Physics A

9.1 Overlap with other qualifications

This specification has been developed alongside GCSE Science A, GCSE Additional Science A, GCSE Biology A, GCSE Chemistry A and GCSE Additional Applied Science.

Modules 1–3 of this specification are also included in GCSE Science A. Modules 4–6 of this specification are also included in GCSE Additional Science A.

Aspects of the controlled assessment of skills are common across GCSE Additional Science A, GCSE Biology A, GCSE Chemistry A and GCSE Physics A.

9.2 Progression from this qualification

GCSE qualifications are general qualifications which enable candidates to progress either directly to employment, or to proceed to further qualifications.

Progression to further study from GCSE will depend upon the number and nature of the grades achieved. Broadly, candidates who are awarded mainly Grades D to G at GCSE could either strengthen their base through further study of qualifications at Level 1 within the National Qualifications Framework or could proceed to Level 2. Candidates who are awarded mainly Grades A* to C at GCSE would be well prepared for study at Level 3 within the National Qualifications Framework.

9.3 Avoidance of bias

OCR has taken great care in preparation of this specification and assessment materials to avoid bias of any kind.

9.4 Code of Practice/Common criteria requirements/Subject criteria

This specification complies in all respects with the current GCSE, GCE, Principal Learning and Project Code of Practice as available on the Ofqual website, *The Statutory Regulation of External Qualifications 2004*, and the subject criteria for GCSE Physics.

9.5 Language

This specification and associated assessment materials are in English only.

9.6 Spiritual, moral, ethical, social, legislative, economic and cultural issues

This specification offers opportunities which can contribute to an understanding of these issues in the following topics.

The table below gives some examples which could be used when teaching the course.

Issue	Opportunities for teaching the issues during the course
Moral issues The commitment of scientists to publish their findings and subject their ideas to testing by others.	Practical investigation: reviewing the strategy and procedures.
Ethical issues The ethical implications of selected scientific issues.	P3: Long-term and short-term economic and environmental costs and benefits related to the use of various energy sources.
Economic issues The range of factors which have to be considered when weighing the costs and benefits of scientific activity.	P2: People's response to the risks associated with electromagnetic radiation. P2: Risks associated with contamination or irradiation by radioactive materials.
Cultural issues Scientific explanations which give insight into the local and global environment.	P1, P7: Study of the life history of stars, the possible futures for the Universe, and the possibility of life in other parts of the Universe.

9.7 Sustainable development, health and safety considerations and European developments, consistent with international agreements

This specification supports these issues, consistent with current EU agreements, as outlined below.

The specification incorporates specific modules on health and welfare and on the environment within its content. These modules encourage candidates to develop environmental responsibility based upon a sound understanding of the principle of sustainable development.

9.8 Key Skills

This specification provides opportunities for the development of the Key Skills of *Communication, Application of Number, Information Technology, Working with Others, Improving Own Learning and Performance* and *Problem Solving* at Levels 1 and/or 2. However, the extent to which this evidence fulfils the Key Skills criteria at these levels will be totally dependent on the style of teaching and learning adopted for each unit.

The following table indicates where opportunities may exist for at least some coverage of the various Key Skills criteria at Levels 1 and/or 2 for each unit.

Unit	C		AoN		IT		WwO		IoLP		PS	
	1	2	1	2	1	2	1	2	1	2	1	2
A181	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A182	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A183	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A184	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Detailed opportunities for generating Key Skills evidence through this specification are posted on the OCR website (www.ocr.org.uk). A summary document for Key Skills Coordinators showing ways in which opportunities for Key Skills arise within GCSE courses has been published.

9.9 ICT

In order to play a full part in modern society, candidates need to be confident and effective users of ICT. This specification provides candidates with a wide range of appropriate opportunities to use ICT in order to further their study of physics.

Opportunities for ICT include:

- using video clips to provide the context for topics studied and to illustrate the practical importance of the scientific ideas
- gathering information from the internet and software libraries
- gathering data using sensors linked to data-loggers or directly to computers
- using spreadsheets and other software to process data
- using animations and simulations to visualise scientific ideas
- using modelling software to explore theories
- using software to present ideas and information on paper and on screen.

Particular opportunities for the use of ICT appear in the introductions to each of the modules.

9.10 Citizenship

From September 2002, the National Curriculum for England at Key Stage 4 includes a mandatory programme of study for Citizenship.

GCSE Physics A is designed as a science education for future citizens which not only covers aspects of the Citizenship programme of study but also extends beyond that programme by dealing with important aspects of science which all people encounter in their everyday lives.

Appendix A: Guidance for the production of electronic controlled assessment

A

Structure for evidence

A controlled assessment portfolio is a collection of folders and files containing the candidate's evidence. Folders should be organised in a structured way so that the evidence can be accessed easily by a teacher or moderator. This structure is commonly known as a folder tree. It would be helpful if the location of particular evidence is made clear by naming each file and folder appropriately and by use of an index called 'Home Page'.

There should be a top level folder detailing the candidate's centre number, candidate number, surname and forename, together with the unit code A184, so that the portfolio is clearly identified as the work of one candidate.

Each candidate produces an assignment for controlled assessment. The evidence should be contained within a separate folder within the portfolio. This folder may contain separate files.

Each candidate's controlled assessment portfolio should be stored in a secure area on the centre's network. Prior to submitting the controlled assessment portfolio to OCR, the centre should add a folder to the folder tree containing controlled assessment and summary forms.

Data formats for evidence

In order to minimise software and hardware compatibility issues it will be necessary to save candidates' work using an appropriate file format.

Candidates must use formats appropriate to the evidence that they are providing and appropriate to viewing for assessment and moderation. Open file formats or proprietary formats for which a downloadable reader or player is available are acceptable. Where this is not available, the file format is not acceptable.

Electronic controlled assessment is designed to give candidates an opportunity to demonstrate what they know, understand and can do using current technology. Candidates do not gain marks for using more sophisticated formats or for using a range of formats. A candidate who chooses to use only word documents will not be disadvantaged by that choice.

Evidence submitted is likely to be in the form of word processed documents, PowerPoint presentations, digital photos and digital video.

To ensure compatibility, all files submitted must be in the formats listed below. Where new formats become available that might be acceptable, OCR will provide further guidance. OCR advises against changing the file format that the document was originally created in. It is the centre's responsibility to ensure that the electronic portfolios submitted for moderation are accessible to the moderator and fully represent the evidence available for each candidate.

A Accepted file formats

Movie formats for digital video evidence
MPEG (*.mpg)
QuickTime movie (*.mov)
Macromedia Shockwave (*.aam)
Macromedia Shockwave (*.dcr)
Flash (*.swf)
Windows Media File (*.wmf)
MPEG Video Layer 4 (*.mp4)

Audio or sound formats
MPEG Audio Layer 3 (*.mp3)

Graphics formats including photographic evidence
JPEG (*.jpg)
Graphics file (*.pcx)
MS bitmap (*.bmp)
GIF images (*.gif)

Animation formats
Macromedia Flash (*.fla)

Structured markup formats
XML (*.xml)

Text formats
Comma Separated Values (.csv)
PDF (.pdf)
Rich text format (.rtf)
Text document (.txt)

Microsoft Office suite
PowerPoint (.ppt)
Word (.doc)
Excel (.xls)
Visio (.vsd)
Project (.mpp)

Appendix B: Ideas about Science

B

The specifications within the Twenty First Century Science suite are unique in having interpreted and extrapolated the principles of ‘How Science Works’ into a series of ‘Ideas about Science’. It is intended that the Ideas about Science will ensure students understand how scientific knowledge is obtained, how it is reported in the world outside the classroom, and the impacts of scientific knowledge on society.

GCSE Physics A aims to develop students’ understanding of the Ideas about Science alongside their growing understanding of scientific ideas and explanations of the behaviour of the natural world.

Why are Ideas about Science important?

In order to make sense of the scientific ideas that students encounter in lessons and read or hear about outside of school, they need to develop an understanding of science itself – of how scientific knowledge is obtained, the kinds of evidence and reasoning behind it, its strengths and limitations, and how far we can therefore rely on it. They also need opportunities to reflect on the impacts of scientific knowledge on society, and how we respond individually and collectively to the new ideas, artefacts and processes that science makes possible.

Reports of scientific claims, inventions and discoveries are prolific in the media of the twenty first century, and an understanding of the Ideas about Science will ensure that students are well-equipped to critically evaluate the science stories they read and hear.

The kind of understanding of science that we would wish students to have by the end of their school science education might be summarised as follows:

How science works

The aim of science is to find explanations for the behaviour of the natural world. There is no single ‘method of science’ that leads automatically to scientific knowledge. Scientists do, however, have characteristic ways of working. In particular, data from observations and measurements are of central importance. All data, however, have to be interpreted, and this is influenced by the ideas we bring to it. Scientific explanations do not ‘emerge’ automatically from data. Proposing an explanation involves creative thinking. So, it is quite possible (and may be quite reasonable) for different people to arrive at different explanations for the same data.

Causes and effects

Scientists often look for cause-effect explanations. 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.

Theories, explanations and predictions

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 theory might propose a model involving objects (and their behaviour) that cannot be observed directly, to account for what we observe. Or it might define quantities and ways of measuring them, and state some mathematical relationships between them.

A scientific explanation of a specific event or phenomenon is often based on applying a scientific theory (or theories) to the situation in question.

A proposed scientific explanation (whether it is a very general scientific theory or a more specific explanation) is tested by comparing predictions based on it with observations or measurements. If these agree, it increases our confidence that the explanation might be correct. This can never be conclusively proved, but accumulating evidence can bring us to the point where it is hard to imagine any other possible explanation. If prediction and data disagree, then one or other must be wrong. Data can never be relied on completely because observations may be incorrect and all measurements are subject to uncertainty, arising from the inevitable limitations of the measuring equipment or the person using it. If we believe the data are accurate, then the prediction must be wrong, lowering our confidence in the proposed explanation.

Science and scientists

The scientific community has established robust procedures for testing and checking the claims of individual scientists, and reaching an agreed view. Scientists report their findings to other scientists at conferences and in peer-reviewed journals. Claims are not accepted until they have survived the critical scrutiny of the scientific community. In some areas of enquiry, it has proved possible to eliminate all the explanations we can think of but one – which then becomes the accepted explanation (until, if ever, a better one is proposed).

Where possible, scientists choose to study simple situations in order to gain understanding. This, however, can make it difficult to apply this understanding to complex, real-world situations. So there can be legitimate disagreements about scientific explanations of particular phenomena or events, even though there is no dispute about the fundamental scientific knowledge involved.

Science and society

The application of scientific knowledge, in new technologies, materials and devices, greatly enhances our lives, but can also have unintended and undesirable side-effects. Often we need to weigh up the benefits against the disadvantages – and also consider who gains and who loses. An application of science may have social, economic and political implications, and sometimes also ethical ones. Personal and social decisions require an understanding of the science involved, but also involve knowledge and values that go beyond science

How can Ideas about Science be developed in teaching?

Within this Appendix all of the Ideas about Science are listed together, in an order that shows clearly how they relate to one another and build up the understanding of science that we would like students to develop.

In addition to this Appendix, specific Ideas about Science are identified at the start of each module within the specification, to indicate that there are good opportunities within the content of the module to introduce and develop them. The OCR scheme of work for GCSE Physics A (published separately) will also highlight teaching opportunities for specific Ideas about Science.

What are the Ideas about Science?

The following pages set out in detail the Ideas about Science and what candidates should be able to do to demonstrate their understanding of them. The statements in the left-hand column specify the understandings candidates are expected to develop; the entries in the right-hand column are suggestions about some ways in which evidence of understanding can be demonstrated.

1 Data: their importance and limitations

Data are the starting point for scientific enquiry – and the means of testing scientific explanations. But data can never be trusted completely, and scientists need ways of evaluating how good their data are.

	Candidates should understand that:	A candidate who understands this can, for example:
1.1	• data are crucial to science. The search for explanations starts from data; and data are collected to test proposed explanations.	• use data rather than opinion if asked to justify an explanation • outline how a proposed scientific explanation has been (or might be) tested, referring appropriately to the role of data.
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, make appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

2 Cause-effect explanations

Scientists look for patterns in data, as a means of identifying correlations that might suggest possible cause-effect links – for which an explanation might then be sought.

	Candidates should understand that:	A candidate who understands this can, for example:
2.1	• it is often useful to think about processes in terms of factors which may affect an outcome (or input variables which may affect an outcome variable).	• in a given context, identify the outcome and factors that may affect it • in a given context, suggest how an outcome might alter when a factor is changed.
2.2	• to investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').	• identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive design feature, or the fact that they are not as a design flaw • explain why it is necessary to control all the factors that might affect the outcome other than the one being investigated.
2.3	• if an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	• suggest and explain an example from everyday life of a correlation between a factor and an outcome • identify where a correlation exists when data are presented as text, as a graph, or in a table. ⓘ *Examples may include both positive and negative correlations, but candidates will not be expected to know these terms.*
2.4	• a correlation between a factor and an outcome does not necessarily mean that the factor causes the outcome; both might, for example, be caused by some other factor.	• use the ideas of correlation and cause when discussing data and show awareness that a correlation does not necessarily indicate a causal link • identify, and suggest from everyday experience, examples of correlations between a factor and an outcome where the factor is (or is not) a plausible cause of the outcome • explain why an observed correlation between a given factor and outcome does not necessarily mean that the factor causes the outcome.
2.5	• in some situations, a factor alters the chance (or probability) of an outcome, but does not invariably lead to it. We also call this a correlation.	• 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.

	Candidates should understand that:	A candidate who understands this can, for example:
2.6	• to investigate a claim that a factor increases the chance (or probability) of an outcome, scientists compare samples (eg groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples, the more confident we can be about any conclusions drawn.	• discuss whether given data suggest that a given factor does/does not increase the chance of a given outcome • evaluate critically the design of a study to test if a given factor increases the chance of a given outcome, by commenting on sample size and how well the samples are matched.
2.7	• **even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.**	• **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.**

3 Developing scientific explanations

The aim of science is to develop good explanations for natural phenomena. Initially, an explanation is a hypothesis that might account for the available data. As more evidence becomes available, it may become an accepted explanation or theory. Scientific explanations and theories do not 'emerge' automatically from data, and cannot be deduced from the data. Proposing an explanation or theory involves creative thinking. It can then be tested – by comparing its predictions with data from observations or measurements.

	Candidates should understand that:	A candidate who understands this can, for example:
3.1	• scientific hypotheses, explanations and theories are not simply summaries of the available data. They are based on data but are distinct from them.	• in a given account of scientific work, identify statements which report data and statements of explanatory ideas (hypotheses, explanations, theories) • recognise that an explanation may be incorrect even if the data agree with it.
3.2	• an explanation cannot simply be deduced from data, but has to be thought up creatively to account for the data.	• identify where creative thinking is involved in the development of an explanation.
3.3	• a scientific explanation should account for most (ideally all) of the data already known. It may explain a range of phenomena not previously thought to be linked. It should also enable predictions to be made about new situations or examples.	• recognise data or observations that are accounted for by, or conflict with, an explanation • give good reasons for accepting or rejecting a proposed scientific explanation • identify the better of two given scientific explanations for a phenomenon, and give reasons for the choice.
3.4	• scientific explanations are tested by comparing predictions based on them with data from observations or experiments.	• draw valid conclusions about the implications of given data for a given scientific explanation, in particular: — understand that agreement between a prediction and an observation increases confidence in the explanation on which the prediction is based but does not prove it is correct — understand that disagreement between a prediction and an observation indicates that one or the other is wrong, and decreases our confidence in the explanation on which the prediction is based.

4 The scientific community

Findings reported by an individual scientist or group are carefully checked by the scientific community before being accepted as scientific knowledge.

	Candidates should understand that:	A candidate who understands this can, for example:
4.1	• scientists report their claims to other scientists through conferences and journals. Scientific claims are only accepted once they have been evaluated critically by other scientists.	• describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists • recognise that there is less confidence in new scientific claims that have not yet been evaluated by the scientific community than there is in well-established ones.
4.2	• scientists are usually sceptical about claims that cannot be repeated by anyone else, and about unexpected findings until they have been replicated (by themselves) or reproduced (by someone else).	• identify the fact that a finding has not been reproduced by another scientist as a reason for questioning a scientific claim • explain why scientists see this as important.
4.3	• if explanations cannot be deduced from the available data, 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.	• show awareness that the same data might be interpreted, quite reasonably, in more than one way • suggest plausible reasons why scientists in a given situation disagree(d).
4.4	• an accepted scientific explanation is rarely abandoned just because some new data disagree with its predictions. It usually survives until a better explanation is available.	• discuss the likely consequences of new data that disagree with the predictions of an accepted explanation • **suggest reasons why scientists should not give up an accepted explanation immediately if new data appear to conflict with it.**

B

5 Risk

Every activity involves some risk. Assessing and comparing the risks of an activity, and relating these to the benefits we gain from it, are important in decision making.

	Candidates should understand that:	A candidate who understands this can, for example:
5.1	• everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.	• explain why it is impossible for anything to be completely safe • identify examples of risks which arise from a new scientific or technological advance • suggest ways of reducing a given risk.
5.2	• we can sometimes assess the size of a risk by measuring its chance of occurring in a large sample, over a given period of time.	• interpret and discuss information on the size of risks, presented in different ways.
5.3	• to make a decision about a particular risk, we need to take account both of the chance of it happening and the consequences if it did.	• discuss a given risk, taking account of both the chance of it occurring and the consequences if it did.
5.4	• to make a decision about a course of action, we need to take account of both its risks and benefits, to the different individuals or groups involved.	• identify risks and benefits in a given situation, to the different individuals and groups involved • discuss a course of action, with reference to its risks and benefits, taking account of who benefits and who takes the risks • suggest benefits of activities that are known to have risk.
5.5	• 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.	• offer reasons for people's willingness (or reluctance) to accept the risk of a given activity.
5.6	• **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).**	• **distinguish between perceived and calculated risk, when discussing personal choices** • **suggest reasons for given examples of differences between perceived and measured risk.**
5.7	• governments and public bodies may have to assess what level of risk is acceptable in a particular situation. This decision may be controversial, especially if those most at risk are not those who benefit.	• discuss the public regulation of risk, **and explain why it may in some situations be controversial.**

6 Making decisions about science and technology

To make sound decisions about the applications of scientific knowledge, we have to weigh up the benefits and costs of new processes and devices. Sometimes these decisions also raise ethical issues. Society has developed ways of managing these issues, though new developments can pose new challenges to these.

	Candidates should understand that:	A candidate who understands this can, for example:
6.1	• science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	• in a particular context, identify the groups affected and the main benefits and costs of a course of action for each group • **suggest reasons why different decisions on the same issue might be appropriate in view of differences in social and economic context.**
6.2	• scientists may identify unintended impacts of human activity (including population growth) on the environment. They can sometimes help us to devise ways of mitigating this impact and of using natural resources in a more sustainable way.	• identify, and suggest, examples of unintended impacts of human activity on the environment • explain the idea of sustainability, and apply it to specific situations • use data (for example, from a Life Cycle Assessment) to compare the sustainability of alternative products or processes.
6.3	• in many areas of scientific work, the development and application of scientific knowledge are subject to official regulations.	• in contexts where this is appropriate, show awareness of, **and discuss**, the official regulation of scientific research and the application of scientific knowledge.
6.4	• some questions, such as those involving values, cannot be answered by science.	• distinguish questions which could in principle be answered using a scientific approach, from those which could not.
6.5	• some forms of scientific research, and some applications of scientific knowledge, have ethical implications. People may disagree about what should be done (or permitted).	• where an ethical issue is involved: — say clearly what this issue is — summarise different views that may be held.
6.6	• in discussions of ethical issues, one common argument is that the right decision is one which leads to the best outcome for the greatest number of people involved. Another is that certain actions are considered right or wrong whatever the consequences.	• in a given context, identify, **and develop**, arguments based on the ideas that: — the right decision is the one which leads to the best outcome for the greatest number of people involved — certain actions are considered right or wrong whatever the consequences.

C Appendix C: Mathematics skills for GCSE science qualifications

Candidates are permitted to use calculators in all assessments.

Candidates should be able to:

- understand number, size and scale and the quantitative relationship between units
- understand when and how to use estimation
- carry out calculations involving +, – , ×, ÷, either singly or in combination, decimals, fractions, percentages and positive whole number powers
- provide answers to calculations to an appropriate number of significant figures
- understand and use the symbols =, <, >, ~
- understand and use direct proportion and simple ratios
- calculate arithmetic means
- understand and use common measures and simple compound measures such as speed
- plot and draw graphs (line graphs, bar charts, pie charts, scatter graphs, histograms), selecting appropriate scales for the axes
- substitute numerical values into simple formulae and equations using appropriate units
- translate information between graphical and numeric form
- extract and interpret information from charts, graphs and tables
- understand the idea of probability
- calculate area, perimeter and volume of simple shapes.

In addition, higher tier candidates should be able to:

- **interpret, order and calculate with numbers written in standard form**
- **carry out calculations involving negative powers (only –1 for rate)**
- **change the subject of an equation**
- **understand and use inverse proportion**
- **understand and use percentiles and deciles.**

Appendix D: Physical quantities and units

It is expected that candidates will show an understanding of the physical quantities and corresponding SI units listed below, and will be able to use them in quantitative work and calculations. Whenever they are required for such questions, units will be provided and, where necessary, explained.

Fundamental physical quantities

Physical quantity	Unit(s)
length	metre (m); kilometre (km); centimetre (cm); millimetre (mm); nanometre (nm)
mass	kilogram (kg); gram (g); milligram (mg)
time	second (s); millisecond (ms) ; year (a); million years (Ma); billion years (Ga)
temperature	degree Celsius (°C); kelvin (K)
current	ampere (A); milliampere (mA)

Derived physical quantities and units

Physical quantity	Unit(s)
area	cm^2; m^2
volume	cm^3; dm^3; m^3; litre (l); millilitre (ml)
density	kg/m^3; g/cm^3
speed, velocity	m/s; km/h
acceleration	m/s^2
momentum	kg m/s
force	newton (N)
pressure	N/m^2; pascal (Pa)
gravitational field strength	N/kg
energy	joule (J); kilojoule (kJ); megajoule (MJ); kilowatt hour (kWh); megawatt hour (MWh)
power	watt (W); kilowatt (kW); megawatt (MW)
frequency	hertz (Hz); kilohertz (kHz)
information	bytes (B); kilobytes (kB); megabytes (MB)
potential difference	volt (V)
resistance	ohm (Ω)
radiation dose	sievert (Sv)
distance (in astronomy)	light-year (ly); parsec (pc)
power of a lens	dioptre (D)

Prefixes for units			
nano (n)	one thousand millionth	0.000000001	$\times 10^{-9}$
micro (μ)	one millionth	0.000001	$\times 10^{-6}$
milli (m)	one thousandth	0.001	$\times 10^{-3}$
kilo (k)	× one thousand	1000	$\times 10^{3}$
mega (M)	× one million	1 000 000	$\times 10^{6}$
giga (G)	× one thousand million	1 000 000 000	$\times 10^{9}$
tera (T)	× one million million	1 000 000 000 000	$\times 10^{12}$

Appendix E: Health and safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for GCSE, this is likely to be the local education authority or the governing body. Employees, ie teachers and lecturers, have a duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment.

For members, the CLEAPSS® guide, *Managing Risk Assessment in Science** offers detailed advice. Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X.

Topics in Safety, 3rd edition, 2001, ASE ISBN 0 86357 316 9;

Safeguards in the School Laboratory, 11th edition, 2006, ASE ISBN 978 0 86357 408 5;

CLEAPSS® *Hazcards*, 2007 edition and later updates*;

CLEAPSS® *Laboratory Handbook**;

Hazardous Chemicals, A Manual for Science Education, 1997, SSERC Limited

ISBN 0 9531776 0 2

Where an employer has adopted these or other publications as the basis of their 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.

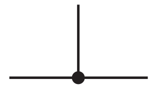
Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes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

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or micro-organisms, 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® (or, in Scotland, SSERC).

*These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications CD-ROM issued annually to members. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to www.cleapss.org.uk. In Scotland, SSERC (www.sserc.org.uk) has a similar role to CLEAPSS® and there are some reciprocal arrangements.

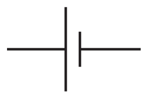
F Appendix F: Electrical symbols

junction of conductors



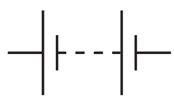
switch

primary or secondary cell



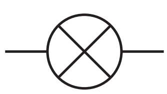
battery of cells

or

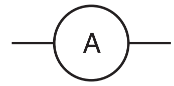


power supply

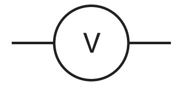
lamp



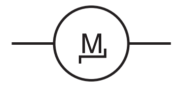
ammeter



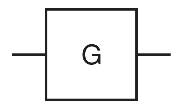
voltmeter



motor

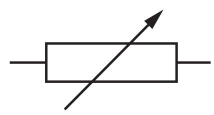


generator

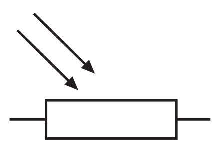


fixed resistor

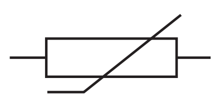
variable resistor



light dependent resistor (LDR)



thermistor



YOUR CHECKLIST

OUR AIM IS TO PROVIDE YOU WITH ALL THE INFORMATION AND SUPPORT YOU NEED TO DELIVER OUR SPECIFICATIONS.

- ☑ Bookmark **www.gcse-science.com**
- ☑ Be among the first to hear about support materials and resources as they become available. Register for email updates at **www.ocr.org.uk/updates**
- ☑ Book your INSET training place online at **www.ocr.org.uk/eventbooker**
- ☑ Find out about controlled assessment support at **www.ocr.org.uk/science2011/support**
- ☑ Learn more about Active Results at **www.ocr.org.uk/activeresults**
- ☑ Join our social network community for teachers at **www.social.ocr.org.uk**

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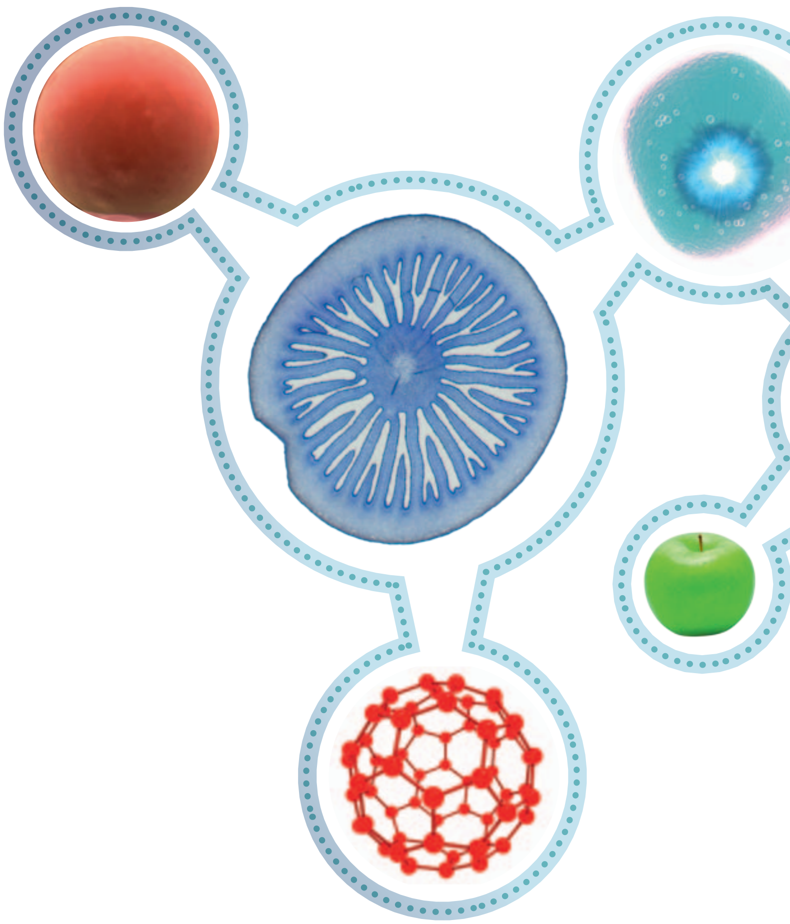
Here's how to contact us for specialist advice

Phone:	01223 553998
Email:	science@ocr.org.uk
Online:	http://answers.ocr.org.uk
Fax:	01223 552627
Post:	Customer Contact Centre, OCR, Progress House, Westwood Business Park, Coventry CV4 8JQ

WHAT TO DO NEXT

1) Sign up to teach – let us know you will be teaching this specification to ensure you receive all the support and examination materials you need. Simply complete the online form at **www.ocr.org.uk/science/signup**

2) Become an approved OCR centre – if your centre is completely new to OCR and has not previously used us for any examinations, visit **www.ocr.org.uk/centreapproval** to become an approved OCR centre.



GENERAL QUALIFICATIONS
Telephone 01223 553998
Facsimile 01223 552627

science@ocr.org.uk
1 Hills Road, Cambridge CB1 2EU

www.gcse-science.com

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