GCSE

Physics A

Twenty First Century Science Suite

OCR GCSE in Physics A J245

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Revised Specification Content

This document comprises the 2nd Draft of the content section (section 3) of GCSE Physics A Specification J245. This document is still subject to accreditation by Ofqual, and may change as a result of final proof reading.

The 2nd Draft is provided to assist teachers who are intending to start teaching the new specification from September 2010, before the accreditation process is complete. Changes from the 1st Draft (April 2010) are highlighted in yellow.

The full specification and specimen assessment materials will be published after accreditation.

3 Content of GCSE Physics A

3.1 Summary of content

A module defines the required teaching and learning outcomes.

The specification content in 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 1 (A181). The next three modules (P4 – P6) and their associated Ideas about Science are assessed in Unit 2 (A182). Module P7 is assessed in Unit 3, 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 which, after a short introduction explaining the background to the module, 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 all 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 are introduced or further 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 1 (Modules P1, P2, P3): A181

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 (see Appendix B). The start of each module details the particular Ideas about Science that can be introduced to candidates 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.

However, it is not intended that understanding and application of these 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 the Unit 1 assessment paper (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 Physics A Unit 1 (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

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 both long- 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 for developing mathematics skills. For example:

- develop a sense of scales including distances: size – from the size of the Earth to that of the solar system and the Universe; speeds – 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 using 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
- modelling 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.

Opportunities for ICT

This module offers opportunities for illustrating 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 8 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 5 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. understand 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 4 thousand million years old
5. understand Wegener's theory of continental drift and his evidence for it (mountain chains, geometric fit of continents and their matching fossils and rocks)
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:

    distance = wave speed x time
    (metres, m) (metres per second, m/s) (seconds, s)

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
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

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

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:

wave speed	=	frequency	x	wavelength
(metres per second, m/s)		(hertz, Hz)		(metres, m)

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

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 possibly 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 for developing 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
- activities to show how noise affects analogue and digital signals.

Opportunities for ICT

This module offers opportunities for illustrating 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:

- PowerPoint slides to illustrate evidence of climate change
- video clip to illustrate infrared imaging
- animation to model Sun's radiation and greenhouse effect
- animation to model effect of carbon dioxide levels on global temperature
- computer climate models.
- 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. *(Note: 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 (e.g. 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 • **use data to develop an argument 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, 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 radiation (ultraviolet radiation, X-rays, gamma rays) can break molecules of the substances that absorb them into bits (called ions), **which can then take part in other chemical reactions**
11. understand that ultraviolet radiation, X-rays and gamma rays are known as ionising radiation
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.

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 the harmful effects of ultraviolet radiation.
10. recall that physical barriers absorb some ionising radiation, for example:
    a. 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
    b. sun-screens and clothing can be used to absorb most of the ultraviolet radiation from the Sun.

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 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 green plants remove carbon dioxide from the atmosphere and decomposers return carbon dioxide to the atmosphere 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 one of 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

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 (e.g. light bulbs) and consider the quantitative consequences of various lifestyle choices (e.g. 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 for developing 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 using 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:

- comparing the power consumption of a variety of devices and relating it to the current passing through the device
- investigating factors affecting the output from solar panels and wind turbines
- making a simple electricity generator and investigating the factors that affect the output.

Opportunities for ICT

This module offers opportunities for illustrating 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:

- animation 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

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 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 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**, i.e. 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, thermal and nuclear power stations
7. understand that nuclear power stations produce radioactive waste
8. understand that radioactive waste emits ionising radiation
9. 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
10. understand that many renewable sources of energy drive the turbine directly e.g. hydroelectric, wave and wind
11. interpret a Sankey diagram for electricity generation and distribution that includes information on the efficiency of energy transfers
12. recall that the mains supply voltage to our homes is 230 volts
13. 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)
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 2 (Modules P4, P5, P6): A182

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.

The course content of modules in Unit A182 gives emphasis and space to fundamental ideas in the sciences, ensures that appropriate skills are developed in preparation for further study, and provides 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 (see Appendix B). The start of each module details the particular Ideas about Science that can be introduced to candidates 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.

However, it is not intended that understanding and application of these 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 the Unit 2 assessment paper (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 Physics A Unit 2 (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 – 5.5
Making decisions about science and technology
IaS 6.1, 6.3, 6.4

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 exciting 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 for developing 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 using 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 for illustrating 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
- animation to illustrate interactive force pairs in various situations
- animation 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. *(Note: 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 (e.g. 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 • **use data to develop an argument 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.**
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 (i.e. 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.

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:

   momentum = mass × velocity
   (kg m/s) (kg) (m/s)

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:

   change of momentum = resultant force × time for which it acts
   (kg m/s) (N) (s)

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:

   work done by a force (joules, J) = force (newtons, N) × distance moved in the direction of the force (metres, m)

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:

   amount of energy transferred (joules, J) = work done (joules, J)

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:

   change in gravitational potential energy (joules, J) = weight (newtons, N) × vertical height difference (metres, m)

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:

    kinetic energy (joules, J) = ½ × mass (kilograms, kg) × $[\text{velocity}]^2$ ($[\text{metres per second}]^2$, $[\text{m/s}]^2$)

11. explain 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

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 so 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, include that of a liquid in a narrow tube and a belt between pressure pads. A more general understanding of voltage as potential difference is developed in the third topic and a model based on height differences can be introduced.

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 ac and dc
P5.5 How do electric motors work?
How motors work and some uses

Opportunities for mathematics

This module offers opportunities for developing 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 using 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 for illustrating 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
- animation to illustrate model 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. *(Note: 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 • know that individual cases do not provide convincing evidence for or against a correlation, and can explain why.
2.6	• to investigate a claim that a factor increases the chance (or probability) of an outcome, scientists compare samples (e.g. 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 • **use data to develop an argument 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.**

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.

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. explain that in an electric circuit the metal conductors (the components and wires) contain many charges that are free to move
8. explain 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. explain 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. explain 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. explain 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 through them, **and 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. explain 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. explain 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:

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

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. explain 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.), e.g. the current from a battery
15. recall that mains electricity is an a.c. supply
16. **explain 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.

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.

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 for developing 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 for illustrating 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
- animation to illustrate atomic structure and decay
- video clips to illustrate key ideas of risk in context of radioactive materials
- animation 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. *(Note: 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.	• uses the ideas of correlation and cause when discussing data and shows 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 (e.g. 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 • **use data to develop an argument 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.**
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.

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.**
6.3	• in many areas of scientific work, the development and application of scientific knowledge are subject to official regulations.	• in contexts where this is appropriate, shows 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. **explain 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 3 (Module P7): A183

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 (see Appendix B). The start of the module details the particular Ideas about Science that can be introduced to candidates 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.

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

Accordingly, questions in the Unit 3 assessment paper (A183) can assess any of the Ideas about Science linked to Modules P1 through to P7, 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 Physics A Unit 3 (A183), within any of the science 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

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 for developing 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 using 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:

- recording positions and appearance of astronomical objects over a day (or night) and over a month or longer
- measuring the focal length of lenses and relating it to their shape
- building simple telescopes and measuring the magnification
- investigating diffraction of light and microwaves
- investigating the use of diffraction gratings and prisms to produce spectra
- using parallax methods to measure distances
- using robotic telescopes to observe astronomical objects
- investigating the relationship between temperature, pressure and volume of a gas
- observing the spectra of a range of elements and linking that to spectra of stars.

Opportunities for ICT

This module offers opportunities for illustrating 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:

- 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.

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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 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.**

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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 that the positions of astronomical objects are measured in terms of angles as seen from Earth
8. 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
9. recall that, **and explain why** planets sometimes appear to move with retrograde motion relative to the ‘fixed’ stars.

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. explain 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:

$$\text{power} = \frac{1}{\text{focal length}}$$

(dioptres) (metres^{-1})

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 that 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
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. **explain 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**

P7.2 Light, telescopes and 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.

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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. explain 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.

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. pressure / temperature = constant
    c. volume / 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. explain 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
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. explain 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)

P7.4 The Sun, the stars and their surroundings

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. explain 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. explain 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 hundreds of planets around 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. **understand** that no evidence of extraterrestrial life (at present or in the past) has so far been detected**.**

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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 astronomical 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. distant 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.