OCR RECOGNISING ACHIEVEMENT

GCSE

Physics A

Twenty First Century Science Suite

OCR GCSE in Physics A J635

Foreword to the Second Edition

This Second Edition of the OCR GCSE Physics A specification has been produced to correct minor errors found in the original edition (published in Dec 2005). There are no changes to actual content or the scheme of assessment. Centres should note however the grade descriptions in Appendix A have now been replaced with the correct versions.

Section 6.6 has been updated (amended in Oct 2007).

QAN 100/5565/4

Contents

1 About this Qualification

1.1 About the Twenty First Century Science Suite

The Twenty First Century Science suite comprises six specifications which share common material, use a similar style of examination questions and have a common approach to skills assessment. The qualifications available as part of this suite are:

GCSE Science A (J630)	which emphasises scientific literacy – the knowledge and understanding which candidates need to engage, as informed citizens, with science-based issues. As with other courses in the suite, this qualification uses contemporary, relevant contexts of interest to candidates, which can be approached through a range of teaching and learning activities.
GCSE Additional Science A (J631)	which is a concept-led course developed to meet the needs of candidates seeking a deeper understanding of basic scientific ideas. The course focuses on scientific explanations and models, and gives candidates an insight into how scientists develop scientific understanding of ourselves and the world we inhabit.
GCSE Additional Applied Science A (J632)	which meets the needs of candidates who wish to develop their scientific understanding through authentic, work related contexts. The course focuses on procedural and technical knowledge that underpins the work of practitioners of science and gives candidates an insight into what is involved in being a practitioner of science.
GCSE Biology A (J633) **GCSE Chemistry A (J634)** **GCSE Physics A (J635)**	each of which provides an opportunity for further developing an understanding of science explanations, how science works and the study of elements of applied science, with particular relevance to professional scientists.

This suite is supported by the Nuffield Curriculum Centre and The University of York Science Education Group.

1.2 About this Physics Specification

This booklet contains OCR's GCSE specification in Physics for teaching from September 2006 and first certification in June 2008.

This specification aims to provide candidates with the scientific understanding needed to progress to further studies of physics, should they choose to undertake them. Candidates should gain an insight into:

- what is involved in being a practitioner of science;
- how scientists develop scientific understanding of ourselves and the world we inhabit;
- how these understandings can be applied to the benefit of humanity.

Candidates must have a broad understanding of the scientific ideas that provide a conceptual foundation for further studies of science. These are referred to as 'Science Explanations'. But, candidates also need to be able to reflect on scientific knowledge itself, the practices that have produced it, the kinds of reasoning that are used in developing a scientific argument, and on the issues that arise when scientific knowledge is put to practical use. These are referred to as 'Ideas about Science' (IaS). This specification provides a combination of these two essential elements.

This specification comprises seven teaching modules which are assessed through four units. Candidates take Units 1, 2 and 3 **and** either Unit 4 **or** 5.

Unit	Unit Code	Title	Duration	Weighting	Total Mark
1	A331	Physics A Unit 1 – modules P1,P2, P3	40 mins	16.7%	42
2	A332	Physics A Unit 2 – modules P4, P5, P6	40 mins	16.7%	42
3	A333	Physics A Unit 3 – Ideas in Context plus P7	60 mins	33.3%	55
4	A339	Physics A Unit 4 – Practical Data Analysis and Case Study	-	33.3%	40
5	A340	Physics A Unit 5 – Practical Investigation	-	33.3%	40

1.3 Qualification Titles and Levels

This qualification is shown on a certificate as OCR GCSE in Physics.

This qualification is approved by the regulatory authority, QCA, as part of the National Qualifications Framework.

Candidates who gain grades G to D will have achieved an award at Foundation Level (Level 1 of the National Qualifications Framework).

Candidates who gain grades C to A* will have achieved an award at Intermediate Level (Level 2 of the National Qualifications Framework).

1.4 Aims

The aims of this GCSE specification are to encourage candidates to:

- acquire a systematic body of scientific knowledge, and the skills needed to apply this in new and changing situations in a range of domestic, industrial and environmental contexts;
- acquire an understanding of scientific ideas, how they develop, the factors which may affect their development and their power and limitations;
- plan and carry out investigative tasks, considering and evaluating critically their own data and that obtained from other sources, and using ICT where appropriate;
- use electronic (internet, CD ROMs, databases, simulations etc.) and/or more traditional sources or information (books, magazines, leaflets etc.) to research and plan an investigation.
- select, organise and present information clearly and logically, using appropriate scientific terms and conventions, and using ICT where appropriate;
- interpret and evaluate scientific data from a variety of sources;

1.5 Prior Learning/Attainment

Candidates who are taking courses leading to this qualification at Key Stage 4 should normally have followed the corresponding Key Stage 3 programme of study within the National Curriculum.

Other candidates entering this course should have achieved a general educational level equivalent to National Curriculum Level 3, or a distinction at Entry Level within the National Qualifications Framework.

2 Summary of Content

A module defines the required teaching and learning outcomes.

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

Modules P1 - 6 are designed to be taught in approximately half a term, 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

- What do we know about the Earth and Space?
- How have the Earth's continents moved, and with what consequences?
- What is known about stars and galaxies?
- How do scientists develop explanations of the Earth and Space?

Module P2: Radiation and Life

- What types of electromagnetic radiation are there? What happens when radiation hits an object?
- Which types of electromagnetic radiation harm living tissue and why?
- 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?
- What ideas about risk do citizens and scientists have?

Module P3: Radioactive Materials

- Why are some materials radioactive?
- How can radioactive materials be used and handled safely, including wastes?
- How should electricity be generated? What can be done with nuclear wastes?
- What are the health risks from radioactive materials?

Module P4: Explaining Motion

- 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?

Module P5: Electric Circuits

- Electric current – a flow of what?
- What determines the size of the current in an electric circuit?
- How do parallel and series circuits work?
- How is mains electricity produced?
- How much electrical energy do we use at home?

Module P6: The Wave Model of Radiation

- What are waves?
- Why so scientists think that light and sound are waves?
- Do all types of electromagnetic radiation behave in the same way?
- How is information added to a wave?

Module P7: Further Physics - Observing the Universe

- How do astronomers observe the sky?
- How does a telescope work?
- What are the objects we see in the night sky and how far away are they?
- What are stars?
- How do astronomers work together?

3 Content

Layout of Module Content

The specification content of modules P1, P2 and P3 is based on a set of Science Explanations and the Ideas about Science (see Appendices F and G). The presentation of the content of these modules recognises these ideas about science in the presentation of the synopsis page, which has a layout shown here.

Issues for citizens	Questions that science may help to answer
e.g. e.g. Is it safe to use mobile ‘phones?	e.g. e.g. Which types of electromagnetic radiation harm living tissues and why?
Science Explanations	**Ideas about Science**
e.g. e.g. SE 12 Radiation	e.g. IaS 2.1, 2.3 - 2.7 Correlation and cause

The overview identifies:

- issues for citizens which are likely to be uppermost in the minds of citizens 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;
- those Science Explanations and Ideas about Science which are introduced or further developed in the module.

Modules P4, P5, P6 and P7 also begin with a synopsis page, which outlines the content of the module.

Some symbols and fonts are provided to give teachers additional information, expressed in abbreviated form, about the way in which the content is linked to other parts of the specification, and the table below summarises this information.

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

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 learn about the life cycle of a star and its implications for the Sun and Earth. They also explore the scale of the Universe and its past, present and future, and consider whether we are alone or there might be life elsewhere.

Closer to home, candidates consider both long and short term changes in the Earth's crust, and how these changes impact on human life. A theme running through the module is natural disasters: earthquakes, volcanoes and asteroid impact - explaining them, predicting them and coping with or averting them.

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
Is there life elsewhere in the Universe?	What do we know about 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?	How have the Earth's continents moved, and with what consequences?
Could the human race be destroyed by an asteroid colliding with the Earth? What will happen to the Earth and the Sun?	What is known about stars and galaxies?
What do we know about the Universe? Where do the elements of life come from?	How do scientists develop explanations of the Earth and space?
Science Explanations	**Ideas about Science**
SE14 a, b The Earth SE15 The Solar System SE16 The Universe	IaS3 Developing explanations IaS4 The scientific community

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- computer modelling of galaxies in collision;
- processing data on movements of the Earth's lithosphere (to confirm the theory of plate tectonics);
- creating a 3D model of the large-scale structure of the Universe from individual galaxy observations.

Use of ICT in teaching and learning can include:

- animations to illustrate continental drift and movement at tectonic plate margins;
- internet to research particular geohazard.

MODULE P1: THE EARTH IN THE UNIVERSE

P1.1 What do we know about the Earth and space?

1. recall that rocks provide evidence for changes in the Earth (erosion and sedimentation, fossils, folding, radioactive dating, craters);
2. understand that continents would be worn down to sea level, if mountains were not being continuously formed;
3. understand that the rock processes seen today can account for past changes;
4. understand that the Earth must be older than its oldest rocks, **which are about 4 thousand million years old**;
5. label on a given diagram of the Earth its crust, mantle and core;
6. recall that the solar system was formed over very long periods from clouds of gases and dust in space, **about 5 thousand million years ago**;
7. distinguish between planets, moons, the Sun, comets, asteroids and be aware of their relative sizes and motions;
8. recall that fusion of hydrogen **nuclei** is the source of the Sun's energy;
9. understand that all chemical elements larger than helium were made in earlier stars;
10. discuss the probability and possible consequences of an asteroid colliding with the Earth, including the extinction of the dinosaurs;
11. in relation to the above, or when provided with relevant additional information:
    - can identify statements which are data and statements which are (all or part of) an explanation;
    - can recognise data or observations that are accounted for by (or conflict with) an explanation;
    - can identify imagination and creativity in the development of explanations;
    - can justify accepting or rejecting a proposed explanation on the grounds that it:
        - accounts for observations;
        - **and/or provides an explanation that links things previously thought to be unrelated;**
        - **and/or leads to predictions that are subsequently confirmed;**
12. recall that light travels at a high but finite speed, **300 000 km/s;**
13. understand that the speed of light means distant objects are observed as younger than they are now;
14. recall a light-year is the distance travelled by light in a year;
15. compare the relative ages of the Earth, the Sun, and the Universe;
16. compare the relative diameters of the Earth, the Sun and the Milky Way;
17. relate uncertainty in the distance of stars and galaxies to the difficulty of observations.

MODULE P1: THE EARTH IN THE UNIVERSE

P1.2 How have the Earth’s continents moved, and with what consequences?

1. recall Wegener’s theory of continental drift and his evidence for it (geometric fit of continents and their matching fossils, mountain chains, and rocks);
2. understand how Wegener’s theory accounted for mountain building;
3. recall reasons for the rejection of Wegener’s theory by geologists of his time (movement of continents not detectable, Wegener an outsider to the community of geologists, too big an idea from limited evidence, simpler explanations of the same evidence);
4. understand that seafloor spreading is a consequence of movement of the solid mantle;
5. **recall that seafloors spread by about 10 cm a year;**
6. **understand how seafloor spreading produces a pattern in the magnetism recorded in ocean floors, limited to reversals of the Earth’s magnetic field and solidification of molten magma at oceanic ridges;**
7. recall that earthquakes, volcanoes and mountain building generally occur at the edges of tectonic plates;
8. **understand how the movement of tectonic plates causes earthquakes, volcanoes, mountain building and contributes to the rock cycle;**
9. recall some actions that public authorities can take to reduce damage caused by geohazards.

MODULE P1: THE EARTH IN THE UNIVERSE

P1.3 What is known about stars and galaxies?

1. understand that what we know about distant stars and galaxies comes only from the radiation astronomers can detect;
2. understand that distance to stars can be measured using the relative brightness of stars or parallax (qualitative idea only);
3. understand that light pollution interferes with observations of the night sky;
4. recall that the Sun is a star 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 make up the Universe;
6. recall that all stars have a life cycle;
7. recall that astronomers have detected planets around some nearby stars;
8. 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;
9. recall that no evidence of alien life (at present or in the past) has so far been detected;
10. recall that distant galaxies are moving away from us;
11. **relate the distance of galaxies to the speed at which they are moving away; (Hubble's law, but not redshift);**
12. **understand why the motions of galaxies suggests that Space itself is expanding;**
13. recall that the Universe began with a 'big bang' about 14 thousand million years ago;
14. understand why the ultimate fate of the Universe is difficult to predict.

MODULE P1: THE EARTH IN THE UNIVERSE

P1.4 How do scientists develop explanations of the Earth and Space?

1. in relation to movements of the Earth's continents (P1.2) or what is known about stars and galaxies (P1.3), or when provided with relevant additional information:
    - can identify statements which are data and statements which are (all or part of) an explanation;
    - can recognise data and observations that are accounted for by, (or conflict with), a given explanation;
    - can identify imagination and creativity in the development of an explanation;
    - can describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists;
    - can recognise that new scientific claims which have not yet been evaluated by the scientific community are less reliable than well established ones;
2. in relation to movements of the Earth's continents (P1.2), or when provided with relevant additional information:
    - can justify accepting or rejecting a proposed explanation on the grounds that it:
        - accounts for observations;
        - **and/or provides an explanation that links things previously thought to be unrelated;**
        - **and/or leads to predictions that are subsequently confirmed;**
    - can draw valid conclusions about the implications of given data for a given explanation, e.g.
        - recognises that an observation that agrees with a prediction (derived from an explanation) increases confidence in the explanation **but does not prove it is correct**;
        - recognises that an observation that disagrees with a prediction (derived from an explanation) indicates that either the observation or the prediction is wrong, **and that this may decrease our confidence in the explanation;**
    - can identify a scientific question for which there is not yet an agreed answer, **and suggest a reason why**;
    - can identify absence of replication as a reason for questioning a scientific claim;
    - **can explain why scientists regard it as important that a scientific claim can be replicated by other scientists;**
    - can suggest plausible reasons why scientists involved in a scientific event or issue disagree(d);
    - **can suggest reasons for scientists' reluctance to give up an accepted explanation when new data appear to conflict with it.**

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. 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. 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. Finally, candidates study evidence of global warming and its relationship to the carbon cycle. Possible consequences and preventative actions are explored.

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

Science Explanations	Ideas about Science
SE 12 Radiation SE 5a The chemical cycles of life SE14c The Earth	IaS 2.1, 2.3 - 2.7 Correlation and cause IaS 5 Risk

ICT Opportunities

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.

Use of ICT in teaching and learning can include:

- PowerPoint slides to illustrate evidence of climate change;
- video clip to illustrate infra red imaging;
- animation to model Sun’s radiation and greenhouse effect
- animation to model effect of carbon dioxide levels on global temperature
- computer climate models

MODULE P2: RADIATION AND LIFE

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

1. recall that light is one of a family of radiations, the electromagnetic spectrum;
2. understand that a beam of electromagnetic radiation delivers energy in ‘packets’ called photons
3. list the electromagnetic radiations in order of the energy delivered by each photon – radio waves, microwaves, infrared, ^{red} light ^{violet}, ultraviolet, X-rays, gamma rays;
4. interpret a situation in which one object affects another some distance away in terms of the general model of electromagnetic radiation:
   - one object (a source) emits radiation;
   - the radiation travels from the source and can be reflected, transmitted or absorbed by materials on its journey;
   - radiation may absorbed by another object (a detector) some distance away;
5. understand that the energy deposited by a beam of electromagnetic radiation depends on both the number of photons arriving and the energy that each photon delivers;
6. recall that intensity of electromagnetic radiation is the energy arriving at a surface each second;
7. understand that the intensity of a beam of electromagnetic radiation decreases with distance **and be able to explain why;**
8. understand that ionising radiation is able to break molecules into bits (called ions), **which can then take part in other chemical reactions;**
9. recall that ionising radiation includes:
   - ultraviolet radiation;
   - X-rays;
   - gamma rays;
10. understand that microwaves heat materials containing particles that the microwaves can vibrate;
11. relate the heating effect of non-ionising radiation to its intensity **and duration;**
12. recall an example of the way in which each of infrared, microwaves and radio waves are used for transmitting information.

MODULE P2: RADIATION AND LIFE

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

1. recall that the heating effect of absorbed radiation can damage living cells;
2. recall that low intensity microwave radiation, for example from mobile phone hand sets and masts, may be a health risk, but this is disputed;
3. recall that ionising radiation can damage living cells;
4. recall examples of how exposure to different amounts of ionising radiation can affect living cells;
5 recall that the metal cases and door screens of microwave ovens protect users from the radiation;
6. recall that physical barriers protect people from ionising radiation, for example, sun-screens and clothing can be used to absorb most of the ultraviolet radiation from the Sun.

P2.3 How does electromagnetic radiation make life on Earth possible?

1. recall that the Earth is surrounded by an atmosphere which allows light radiated from the Sun to pass through;
2. recall that this radiation:
   - provides the energy for photosynthesis;
   - warms the Earth's surface;
3. recall that photosynthesis removes carbon dioxide from the atmosphere and adds oxygen, and that this reverses the effect of respiration;
4. understand that the Earth emits electromagnetic radiation that is absorbed by some gases in the atmosphere, so keeping the Earth warmer than it would otherwise be. This is called the greenhouse effect;
5. understand that the ozone layer absorbs ultraviolet radiation, **producing reversible chemical changes in that part of the atmosphere;**
6. understand that the ozone layer protects living organisms, especially animals, from the harmful effects ultraviolet radiation.

MODULE P2: RADIATION AND LIFE

P2.4 What is the evidence for global warming, why might it be occurring, and how serious a threat is it?

1. recall that one of the greenhouse gases in the Earth's atmosphere is carbon dioxide, present in small amounts;
2. **recall that other greenhouse gases include methane, present in trace amounts, and water vapour;**
3. interpret simple diagrams representing the carbon cycle;
4. use the carbon cycle to explain:
   - why for thousands of years the amount of carbon dioxide in the Earth's atmosphere was approximately constant;
   - how decomposers play an important part in the recycling of carbon;
   - that during the past two hundred years, the amount of carbon dioxide in the atmosphere has been steadily rising;
   - that the rise in atmospheric carbon dioxide is largely the result of:
     - burning increased amounts of fossil fuels as an energy source;
     - burning forests to clear land;
5. **understand that computer climate models provide evidence that human activities are causing global warming;**
6. understand that global warming could result in:
   - climate change and how this could make it impossible to continue growing some food crops in particular regions;
   - extreme weather conditions in some regions;
   - rising sea levels, due to melting continental ice and expansion of water in the oceans, which would cause flooding of low-lying land.

MODULE P2: RADIATION AND LIFE

P2.5 What ideas do citizens and scientists have about risk?

1. when provided with necessary additional information about alleged health risks due to radiation (P2.2) or global warming (P2.4) can:
    - identify examples of risk which arise from new scientific or technological advances;
    - suggest ways of reducing specific risks;
    - interpret and discuss information on the size of risks, presented in different ways;
    - **discuss a given risk, taking account of both the chance of it occurring and the consequences if it did;**
    - **identify, or propose, an argument based on the precautionary principle;**
    - use the ideas of correlation and cause appropriately when discussing historical events or topical issues in science;
    - **explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and give an example to illustrate this;**
    - suggest factors that might increase the chance of an outcome, but not invariably lead to it;
    - explain that individual cases do not provide convincing evidence for or against a correlation;
    - **use data to develop an argument that a factor does/does not increase the chance of an outcome;**
    - **identify the presence (or absence) of a plausible mechanism as significant for the acceptance (or rejection) of a claimed causal link.**

2. When provided with necessary additional information about alleged health risks due to radiation emitted from technological devices, or ultraviolet radiation from the Sun (P2.2), can:
    - explain why it is impossible for anything to be completely safe;
    - suggest benefits of activities with known risk;
    - offer reasons for peoples willingness (or reluctance) to accept the risk of a given activity;
    - discuss personal and social choices in terms of a balance of risk and benefit;
    - **distinguish between actual and perceived risk, when discussing personal and social choices;**
    - **suggest reasons for given examples of differences between actual and perceived risk;**
    - **explain what the ALARA (as low as reasonably achievable) principle means, and how it applies in a given situation;**
    - identify the outcome and the factors that may affect it;
    - suggest how an outcome might be affected when a factor is changed;
    - give an example from everyday life of a correlation between a factor and an outcome;
    - evaluate the design for a study to test whether or not a factor increases the chance of an outcome, by commenting on sample size and how well the samples are matched.

MODULE P3: 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.

Through the use of radioactive materials in the health sector, candidates learn about the nature of radioactivity, 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.

The UK Government may soon consult with the public about building new nuclear power stations. A key argument is that generating electricity from nuclear fission does not produce carbon dioxide. On the other hand, there is still no solution to the long-term problem of disposing of nuclear wastes. Renewable energy sources may not generate sufficient electricity to replace existing nuclear stations when these reach the end of their lifetimes.

Candidates consider different ways that electricity could be generated and different ways that nuclear wastes could be disposed of. These case studies illustrate that public decisions must be made by weighing up benefits against costs. Factors to consider include both technical feasibility and likely social and environment impact, now and in the future.

Issues for citizens	Questions that science may help to answer
What does ‘radioactive’ mean?	Why are some materials radioactive?
If radiation from radioactive materials is dangerous, how can it help to cure cancer?	What are the health risks from radioactive materials? How can radioactive materials be used and handled safely, including wastes?
Do we need nuclear power?	How can electricity be generated? What can done with nuclear waste?

Science Explanations	Ideas about Science
SE 11a,b,e Energy sources and uses SE 13 Radioactivity	IaS 5 Risk IaS 6.1-6.3, 6.7 Making decisions about science and technology

ICT Opportunities

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:

- datalogging 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 P3: RADIOACTIVE MATERIALS

P3.1 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, emitting background radiation;
3. recognise, in given text, the terms electron, proton, neutron and nucleus;
4. **understand that an atom has a nucleus, made of protons and neutrons;**
5. **understand that every atom of any element has the same number of protons but the number of neutrons may differ;**
6. understand that the behaviour of radioactive materials cannot be changed by chemical or physical processes;
7. recall three types of ionising radiation (alpha, beta and gamma) emitted by radioactive materials;
8. recall the penetration properties of each type of radiation;
9. **describe radioactive materials in terms of the instability of the nucleus, radiation emitted and the element left behind;**
10. understand that, over time, the activity of radioactive sources decreases;
11. understand the meaning of the term half-life;
12. understand that radioactive elements have a wide range of half-life values;
13. **carry out simple calculations involving half-life.**

MODULE P3: RADIOACTIVE MATERIALS

P3.2 How can radioactive materials be used and handled safely, including wastes?

1. understand that ionising radiation can damage living cells;
2. understand that ionising radiation is able to break molecules into bits (called ions), **which can then take part in other chemical reactions;**
3. understand that when ionising radiation strikes living cells these may be killed or may become cancerous;
4. recall how ionising radiation can be used to:
   - treat cancer;
   - sterilise surgical instruments;
   - sterilise food;
5. recall that radiation dose (in sievert) (based on both amount and type of radiation) is a measure of the possible harm done to your body;
6. interpret given data on risk related to radiation dose;
7. understand that radioactive materials expose people to risk by irradiation and contamination;
8. recall that we are irradiated and contaminated all the time and name some sources of this background radiation;
9. relate ideas about half life and background radiation to the time taken for a radioactive source to become safe;
10. recall categories of people who are regularly exposed to risk of radiation and that their exposure is carefully monitored.

MODULE P3: RADIOACTIVE MATERIALS

P3.3 How can electricity be generated? What can be done with nuclear wastes?

1. understand why electricity is called a secondary energy source;
2. understand that electricity is convenient because it is easily transmitted over distances and can be used in many ways;
3. label a block diagram showing the basic steps by which electricity is generated;
4. interpret a Sankey diagram of electricity generation and distribution to include the efficiency of energy transfers;
5. recall two examples to show that we can use renewable energy sources instead of fuels to generate electricity;
6. recall that power stations which burn carbon fuels will produce carbon dioxide;
7. understand that a nuclear fuel is one where energy is released from changes in the nucleus;
8. **know that in nuclear fission a neutron splits a large and unstable nucleus (limited to uranium) into two smaller parts, roughly equal in size, releasing more neutrons;**
9. **compare the amount of energy released during nuclear fission with that released in a chemical reaction;**
10. **understand how the nuclear fission process in nuclear power stations is controlled, and use the terms chain reaction, fuel rod, control rod and coolant;**
11. understand that nuclear power stations produce radioactive waste;
12. understand that nuclear wastes are categorised as high level, intermediate level and low level, and relate this to disposal methods;
13. Interpret and evaluate information about different energy sources for generating electricity, considering efficiency, economic and environmental costs, **power output and lifetime.**

MODULE P3: RADIOACTIVE MATERIALS

P3.4 What are the health risks from radioactive materials?

1. when provided with additional information on the health risks associated with radioactive materials, and the steps taken to limit these:
   - can explain why it is impossible for anything to be completely safe;
   - can identify examples of risks which arise from new scientific or technological advances;
   - can suggest ways of reducing specific risks;
   - can interpret and discuss information on the size of risks, presented in different ways;
   - **can discuss a given risk, taking account of both the chance of it occurring and the consequences if it did;**
   - can suggest benefits of activities with known risk;
   - can offer reasons for people's willingness (or reluctance) to accept the risk of a given activity;
   - can discuss personal and social choices in terms of a balance of risk and benefit;
   - **can identify, or propose, an argument based on the 'precautionary principle';**
   - **can distinguish between actual risk and perceived risk, when discussing personal and social choices;**
   - **can suggest reasons for given examples of differences between actual and perceived risk;**
   - **can explain what the ALARA (as low as reasonably achievable) principle means and how it applies to the issue in question;**
2. in the context of health risks associated with radioactive materials:
   - can identify the groups affected and the main benefits and costs of a course of action for each group;
   - can explain the idea of sustainable development, and apply it to specific situations;
   - shows awareness that scientific research and applications are subject to official regulations and laws;
   - **can distinguish what can be done (technical feasibility), from what should be done (values);**
   - **can explain why different courses of action may be taken in different social and economic contexts.**

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 equipments 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 fourth and final topic considers the idea of work done by a force, gravitational potential energy and kinetic energy.

Topics
P4.1 How can we describe motion?
Calculation of speed; velocity; 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; KE; losses due to air resistance and friction.

ICT Opportunities

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

P4.1 How can we describe motion?

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

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

ⓘ Candidates should be able to apply the above equation to situations where an average speed is involved.

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 distances measured in one direction are positive, and in the other, negative;

ⓘ Candidates are not expected to recall or use the term 'displacement'.

4. draw and interpret the shape of a distance-time graph for an object that is:
   - stationary;
   - moving at constant speed;
   - **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. recall that the velocity of an object at any instant is its speed plus an indication of the direction;
8. 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;
9. draw and interpret the shape of a velocity-time graph for an object that is:
   - stationary;
   - moving in a straight line with constant speed;
   - moving in a straight line with steadily increasing or decreasing speed;
10. relate these ideas about recording motion to applications such as lorry tachographs.

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 one object exerts a force on another, it always experiences a force in return;
3. in simple everyday situations:
   - identify forces arising from an interaction between two objects.
   - identify the ‘partner’ of a given force (i.e. the other force of the interaction pair);
   - specify, for each force, the object which exerts it, and the object on which it acts;
   - 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. recall that some forces (such as friction, reaction of a surface) arise in response to the action of an applied force;
6. describe the interaction between an object and a surface it is resting on: the object pushes down on the surface; the surface pushes up on the object with an equal force; this is called the reaction of the surface;
7. describe the interaction between two surfaces which slide (or tend to slide) relative to each other: each surface experiences a force in the direction which prevents (or tends to prevent) relative movement; this interaction is called friction;

ⓘ Candidates should be able to apply these ideas to explain situations such as walking, or the driving force on vehicles.

8. be able to use the idea of a pair of equal and opposite forces to explain in outline how rockets and jet engines work.

MODULE P4: EXPLAINING MOTION

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

1. be able to interpret situations in which several forces act on an object;
2. recall that the resultant force on an object is the sum of all the individual forces acting on it, taking their directions into account;
3. recall 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 is related to the size of the resultant force and the time for which it acts in the following way:
   - change of momentum = resultant force x 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. recall that for a moving object, if the driving force is:
   - greater than the counter force, the vehicle will speed up;
   - equal to the counter force, the vehicle will move at constant speed in a straight line;
   - 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 this idea to discuss and explain the action of road safety measures, such as car seat-belts, crumple zones, air bags, cycle and motorcycle helmets;
10. 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 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 kinetic energy ;
2. recall that as an object falls, its gravitational potential energy decreases;
3. recall that when a force causes movement of an object, work is done;
4. use the equation:
   - work done by a force = force × distance moved by the force
     (joule, J) (newton, N) (metre, m)
5. understand that when work is done on an object, the energy of the object increases and when work is done by an object, the energy of the object decreases according to the relationship:
   - change in energy = work done;
     (joule, J) (joule, J)
6. understand that when an object is lifted to a higher position above the ground, work is done by the lifting force against the gravitational force acting on the object (its weight); this increases the object's gravitational potential energy (GPE);
7. use the equation:
   - change in GPE = weight × vertical height difference
     (joule, J) (newton, N) (metre, 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 more kinetic energy it has;
10. use the equation:
    - kinetic energy = ½ × mass × $[\text{velocity}]^2$
      (joule, J) (kilogram, kg) $(\text{metre per second, m/s})^2$
11. explain that if friction and air resistance can be ignored, an object's kinetic energy increases 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, because some energy is dissipated through heating;
13. recall that energy is always conserved;
14. calculate the gain in kinetic energy, **and the speed**, of an object that has fallen through a given height.

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.

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?
Voltage; current and resistance; series and parallel circuits; working out resistance.	
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 a parallel circuit.	
P5.4	How is mains electricity produced?
Including voltages and currents; how generators work; ac and dc.	
P5.5	How much electrical energy do we use at home?
The relationship between power, voltage and current; calculating the energy transferred and the efficiency of the transfer.	

ICT Opportunities

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

P5.1 Electric current - a flow of what?

1. explain that when two objects are rubbed together and become charged, electrons are transferred from one object to the other;
2. recall that there are repulsive forces between objects with similar charges, and attractive forces between objects with opposite charges;
3. explain simple electrostatic effects in terms of attraction and repulsion between 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 components and wires are full of 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;
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?

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. recall that resistors get hotter when electric current passes through them, **and that this heating effect is caused by collisions between the moving charges and stationary atoms in the wire;**
6. recall that this heating effect makes a lamp filament hot enough to glow;
7. describe how the resistance of an LDR varies with light intensity;
8. describe how the resistance of a thermistor (ntc only) varies with temperature;
9. recognise and use the electrical symbols for a cell, power supply, filament lamp, switch, LDR, fixed and variable resistor, thermistor, ammeter and voltmeter;
10. explain that two (or more) resistors in series have more resistance than one on its own, because the battery has to push charges through both of them;
11. explain that two (or more) resistors in parallel provide more paths for charges to flow along than one resistor on its own, so the total resistance is less and the current is bigger;
12. use the equation:
    - $$\text{resistance (ohm, }\Omega\text{)} = \frac{\text{voltage (volt, V)}}{\text{current (ampere, A)}}$$

ⓘ **Rearrangement of the equation is expected only on higher tier.**

13. describe in words, or using a sketch graph, how the current varies with voltage in components whose 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 of 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 energy transferred to, or from, a given amount of charge as it moves between these points;
5. describe the effect on voltage and current of adding further batteries in series **and in parallel** with original one;
6. understand that when several components are connected in series to a battery:
   - the current through each component is the same;
   - the potential differences across the components add up to the potential difference across the battery **(because the total energy transferred to each unit of charge by the battery must equal the amount transferred from it to other components);**
   - the potential difference is largest across the component with the greatest resistance, **because more energy is transferred by the charge passing through a large resistance than through a small one;**
7. recall that when several components are connected in parallel directly to a battery:
   - **the potential difference (voltage) across each component is equal to the potential difference of the battery;**
   - **the current through each component is the same as if it were the only component present;**
   - the total current from (and back to) the battery is the sum of the currents through each of the parallel components;
   - the current is largest through the component with the smallest resistance, **because the same battery voltage causes more current to flow through a smaller resistance than a bigger one.**

MODULE P5: ELECTRIC CIRCUITS

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

Candidates will be assessed on their ability to:

1. recall that mains electricity is produced by generators;
2. recall that generators produce a voltage by a process called electromagnetic induction;
3. recall that when a magnet is moving into a coil of wire a voltage is induced across the ends of the coil;
4. recognise that if the ends of the coil are connected to make a closed circuit, a current will flow round the circuit;
5. recall 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.
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. recall that a transformer can change the size of an alternating voltage;
9. **be able to use the equation**:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

10. 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;
11. understand that the size of this induced voltage can be increased by:
    - increasing the speed of rotation of the magnet or electromagnet;
    - increasing the strength of its magnetic field;
    - increasing the number of turns on the coil;
    - placing an iron core inside the coil;
12. **describe how the induced voltage across the coil of a generator changes during each revolution of the magnet or electromagnet and explain that the current produced in an external circuit is an alternating current (a.c.);**
13. understand that the current from a battery is always in the same direction: it is a direct current (d.c.);
14. recall that mains electricity is an a.c. supply;
15. **explain that a.c. is used because it is easier to generate than d.c., and can be distributed more efficiently;**
16. recall that the mains supply voltage to our homes is 230 volts.

MODULE P5: ELECTRIC CIRCUITS

P5.5 How much electrical energy do we use at home?

1. explain that when electric charge flows through a component (or device), energy is transferred to the component;
2. recall that the power (in watt, W) is a measure of the rate at which an appliance or device transfers energy;
3. use the following equation to calculate energy transfer in joules and kilowatt-hours:
   - energy transferred = power × time
     (joule, J) (watt, W) (second, s)
     (kilowatt hour, kWh) (kilowatt, kW) (hour, h)
4. use the equation:
   - power = potential difference (voltage) × current
     (watt, W) (volt, V) (ampere, A)

ⓘ **Transformation of these equations is only required on the higher tier.**

5. know that a joule is a very small amount of energy, so a domestic electricity meter measures the energy transfer in kilowatt hours;
6. calculate the cost of electrical energy given the power, the time and the cost per kilowatt hour;
7. use the following equation in the context of different electrical appliances:

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

MODULE P6: THE WAVE MODEL OF RADIATION – OVERVIEW

Wave behaviour explains a great many phenomena, both natural and artificial, for all waves have properties in common.

The first topic introduces a basic vocabulary for describing waves. Reflections and refractions of water serve as models for the behaviour of light and sound in the second topic. The third topic explores the electromagnetic spectrum, giving examples of properties and contemporary uses of different waves.

The final topic is a first step towards an understanding of modern communications systems.

Topics	
P6.1	What are waves?
Transverse and longitudinal waves; frequency, wavelength, amplitude, wave speed.	
P6.2	Why do scientists think that light and sound are waves?
Reflection; refraction; effect of the medium; behaviour of water waves related to sound and light waves.	
P6.3	Do all types of electromagnetic radiation behave in the same way?
Wavelength and frequency of the parts of the electromagnetic spectrum; properties and uses of each part of the electromagnetic spectrum.	
P6.4	How is information added to a wave?
Analogue and digital signals to carry information; the quality of each type of signal.	

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- simulating the shape of wavefronts and interference effects in a variety of engineering applications;
- analysing wave reflections in seismic explorations.

Use of ICT in teaching and learning can include:

- 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;
- spreadsheets to model features of analogue and digital communications systems;
- sound files, which can be listened to, displayed graphically and modified to illustrate AM and FM modulation and the effects of noise.

MODULE P6: THE WAVE MODEL OF RADIATION

P6.1 What are waves?

1. recall that a wave consists of disturbances that transfer energy in the direction that the wave travels, without transferring matter;
2. describe the differences between a transverse and a longitudinal wave;
3. recall that the frequency of the waves, in hertz (Hz), is the number of waves each second that are made by the source, or that pass through any particular point in the medium;
4. recall that the wavelength of waves is the distance between the same point on two adjacent disturbances;
5. recall the amplitude of waves is the distance from the top of the crest or bottom of the trough to the undisturbed position;
6. draw and interpret diagrams showing the amplitude and the wavelength of waves;
7. use the equation:
   - wave speed = frequency x wavelength
     (metre per second m/s) (hertz, Hz) (metre, m)

ⓘ **Rearrangement of the equation is only expected on higher tier.**

8. recall that the speed of a wave is usually independent of its frequency or amplitude.

MODULE P6: THE WAVE MODEL OF RADIATION

P6.2 Why do scientists think that light and sound are waves?

1. draw and interpret diagrams showing the reflection of plane water waves and narrow beams of sound or light from a plane reflector;
2. recognise that wave speed is affected by what waves are travelling along or through (the medium) and that the speed will change if a wave moves from one medium into another;
3. explain how 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;
4. draw and interpret diagrams showing the refraction of plane water waves, or beams of light or sound, when they cross a boundary between different media, relating the change of direction to the change in wave speed;
5. recall that the refraction of light waves and sound waves can be explained by a change in their speed when they pass into a different medium;
6. recall that light rays for which the angle of refraction would be greater than 90 degrees cannot leave the medium they are in, and are reflected and that this is known as total internal reflection;
7. recall that waves can spread out at a narrow gap and that this is called diffraction;
8. draw and interpret diagrams showing wave diffraction through gaps;
9. recall that light can be diffracted but needs a very small gap, comparable to the wavelength of the wave;
10. recall that where two waves meet, their effects add and that this is called interference;
11. recall that where two waves arrive in step they reinforce and where they arrive out of step they cancel out;
12. recall that two light beams can be shown to produce an interference pattern;
13. explain interference patterns in terms of constructive and destructive interference;
14. explain how the diffraction and interference of light and sound are evidence of their waves natures.

MODULE P6: THE WAVE MODEL OF RADIATION

P6.3 Do all types of electromagnetic radiation behave in the same way?

1. recall that the different colours of light in the spectrum have different frequencies (and therefore wavelengths);
2. list the parts of the whole electromagnetic spectrum in order of frequency or wavelength (radio waves, microwave, infrared , visible light, ultraviolet, X-rays, gamma radiation);
3. recall that the energy delivered by each photon in a beam of electromagnetic radiation increases with the frequency of the electromagnetic waves;
4. understand that the intensity of a beam of electromagnetic radiation (the energy it delivers per second) depends on the number of photons arriving every second and the amount of energy carried by each photon;
5. know that all types of electromagnetic radiation travel at exactly the same, very high, speed through space (a vacuum);
6. recall an important difference between electromagnetic waves and sound waves: electromagnetic waves can travel through empty space, but sound waves can only travel through a substance (solid, liquid or gas);
7. understand that different frequencies of electromagnetic radiation are used for different purposes due to the difference in reflection, absorption, or transmission by different materials to include:
   - radio waves are not strongly absorbed by the atmosphere so can be used to carry information for radio and TV programmes;
   - some microwaves are strongly absorbed by water molecules and so can be used to heat objects containing water;
   - satellite dishes are made of metal because metals reflect microwaves well;
   - 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;
   - light and infrared radiation can be used to carry information along optical fibres because they travel through without becoming significantly weaker.

MODULE P6: THE WAVE MODEL OF RADIATION

P6.4 How is information added to a wave?

1. recall that signals can be carried not only by radio waves and microwaves through the Earth's atmosphere and through space but also by light waves and infrared waves through optical fibres;
2. understand that if a wave is to carry information the waves must be made to vary in amplitude or frequency, and that the information is carried by the pattern of the variation, recall that this process is called modulation;
3. interpret diagrams showing how a sound wave can be used to vary the amplitude or frequency of a radio wave, with a pattern that matches its own frequency;
4. recall that a signal which varies continuously is called an analogue signal;
5. recall that the job of the receiver is to reproduce the original sound from the pattern of the variation;

ⓘ Details of any transmission or receiver systems are not required.

6. recall that sound (or other information) can be transmitted digitally (digital signal);
7. recall that, in digital transmission, the sound is often converted into a digital code made up from just two symbols (0 and 1);
8. recall that this coded information can be used to control the short bursts of waves (pulses) produced by a source (0 = no pulse, 1 = pulse);
9. recall that when the waves are received, the pulses are decoded to produce a copy of the original sound wave;
10. know that an important advantage of digital signals over analogue signals is that they can transmit information with higher quality, i.e. the signal is less affected by the transmission process;
11. understand that all signals, as they travel, decrease in intensity (their amplitude becomes smaller), so they may have to be amplified;
12. know that random additions to the original signal (noise) may be picked up as a signal travels, reducing its quality;
13. know that, when a signal is amplified, any noise it has picked up is also amplified;
14. understand that, with digital signals, 'on' and 'off' states can usually still be recognised despite any noise that is picked up. The signal can therefore be 'cleaned up' to remove the noise and restore the original pattern of 'on's and 'off's;
15. be able to use these ideas to interpret information about analogue and digital transmission **and to explain why information can be transmitted digitally with higher quality.**

MODULE P7: FURTHER PHYSICS OBSERVING THE UNIVERSE – OVERVIEW

More than ever before, Physics in the Twenty First Century has become an example of international cooperation, particularly in the areas of astronomy and cosmology. Astronomers work in a number of different ways. Some design new instruments for detecting photons across the full electromagnetic spectrum, some are involved directly in the planning, construction and operation of large telescopes, and others analyse the information obtained from robotic telescopes across the Earth or in orbit.

The module is in five sections: Observing the sky with the naked eye, Telescopes, Stars and Galaxies, the Birth and Death of Stars, and the Astronomical Community.

This module should emphasise the size and location of telescopes and the way in which astronomers obtain, share and use the information obtained from them. It provides the opportunity for a case study of the working of an astronomy group in the UK or overseas and allows candidates to obtain and discuss astronomical images either by direct observation or using the many images obtained from the websites of major observatories.

The last section incorporates an opportunity for a case study and a closing poster session on an astronomical topic chosen by the candidate. This is used to highlight aspects of Ideas about Science, IaS4: The Scientific Community. Candidates present and debate information that they have researched, as is done in scientific conferences.

Throughout the module candidates have opportunities to employ Ideas about Science from IaS1 Data and its limitations, IaS3 Developing explanations, and IaS4 Scientific community.

Topics	
P7.1	Observing the sky with the naked eye.
Observations of stars, planets and satellites.	
P7.2	How does a telescope work?
Making a real image with a converging lens and the use of a second lens to create a telescope.	
P7.3	What are the objects we see in the night sky and how far are they?
Spectra and brightness of stars; parsec; Cepheid variables; Hubble constant.	
P7.4	What are stars?
Birth and death of stars; nuclear processes.	
P7.5	How do astronomers work together?
Working with telescopes.	

ICT Opportunities

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.

MODULE P7: FURTHER PHYSICS OBSERVING THE UNIVERSE

P7.1 Observing the sky with the naked eye.

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 **(23 h 56 min);** that the Moon appears to travel east-west across the sky once in a slightly longer time period **(about 25 hours)**, and that the naked-eye planets (Mercury, Venus, Mars, Jupiter and Saturn) appear to move with the stars but change their positions in complicated patterns;
2. explain the apparent motions of Sun, stars, Moon **and planets** in terms of rotation of the Earth and the orbits of the Earth, Moon **and planets;**
3. explain the phases of the Moon in terms of the relative positions of the Sun, Moon and Earth;
4. explain 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;**
5. explain that the positions of astronomical objects are measured in terms of angles as seen from Earth;
6. 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;**
7. explain why different stars are seen in the night sky at different times of the year, in terms of the movement of the Earth and the sun;
8. recall that planets move in complicated patterns relative to the 'fixed' stars.

MODULE P7: FURTHER PHYSICS OBSERVING THE UNIVERSE

P7.2 How does a telescope work?

1. recall that convex/converging lenses bring parallel light to a focus;
2. recall that more powerful lenses of the same material have more curved surfaces;
3. calculate the power of a lens from:

   $$\underset{\text{(dioptre)}}{\text{power}} = \frac{1}{\underset{\text{(metre)}}{\text{focal length}}}$$

4. draw and interpret diagrams showing the formation of a real image of a distant point source (off the principal axis of a lens) and of a distant extended source;
5. understand that astronomical objects are so distant that light from them is effectively parallel;
6. recall that a simple telescope has two converging lenses of different powers, with the more powerful lens as the eyepiece;
7. **calculate the angular magnification of a telescope from the powers of the two lenses using:**

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

8. recall that most astronomical telescopes have concave mirrors, not convex lenses, as their objectives;
9. understand how concave mirrors bring parallel light to a focus.

MODULE P7: FURTHER PHYSICS OBSERVING THE UNIVERSE

P7.3 What are the objects we see in the night sky and how far away are they?

1. explain how parallax makes some stars seem to move relative to others over the course of a year;
2. define the parallax angle of a star as half the angle moved against a background of 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;
7. recall that typical interstellar distances are a few parsecs;
8. recall that the intrinsic brightness of a star depends on its temperature and its size;
9. explain qualitatively why the observed brightness of a star (as seen on Earth) depends on its intrinsic brightness and its distance from Earth;
10. recall that Cepheid variable stars pulse in brightness, with a period related to their brightness;
11. 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 nebulas as distant galaxies. (IaS 1.3, 1, 4);
13. recall that telescopes revealed that the Milky Way consists of very many 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 nebulae were objects within the Milky Way or separate galaxies outside it;
16. recall that Hubble's observations of Cepheid variables in one nebula indicated that it was much further away than any star in the Milky Way, and hence that this nebula was a separate galaxy;
17. recall that intergalactic distances are typically measured in megaparsecs (Mpc);
18. recall that Cepheid variable data in distant galaxies has given accurate values of the Hubble constant;
19. use the following equation to calculate, given appropriate data, the speed of recession, **the Hubble constant and the distance to distant galaxies:**

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

MODULE P7: FURTHER PHYSICS OBSERVING THE UNIVERSE

P7.4 What are stars?

1. recall that all hot objects (including stars) emit a continuous range of electromagnetic radiation, whose total intensity and peak frequency increases with temperature;
2. recall that the removal of electrons from atoms is called ionisation and that electron movement within atoms produces line spectra;
3. recall that the spectrum of a star also contains some specific spectral lines, and that these 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. recall that when the volume of a gas is reduced its pressure increases and be able to explain this using a molecular model;
6. explain why the pressure or volume of a gas varies with temperature and interpret absolute zero using a molecular model;
7. recall that -273°C is the absolute zero of temperature, and be able to convert temperatures in K to temperatures in °C (and vice versa);
8. explain the formation of a protostar in terms of the effects of gravity compressing a cloud of gas;
9. understand that nuclear processes discovered in the early 20th Century provided a possible answer to the mystery of the Sun’s energy source;
10. explain that compressing the gas, e.g. in a protostar, will raise its temperature;
11. describe the results of the Rutherford-Geiger-Marsden alpha particle scattering experiment as indicating that a gold atom contains a small, massive, positive region (the nucleus);
12. recall that the nucleus contains positive protons and neutral neutrons;
13. explain that protons are held together in the nucleus by a strong force much greater than the repulsive electrical force between them;
14. recall that hydrogen nuclei can fuse into helium nuclei, releasing energy, if brought close together;
15. recall that a star contains: a hotter core, where fusion takes place; a convective zone, where energy is transported to the surface by convection; the photosphere, where energy is radiated into space;
16. understand that all stars change when there is insufficient hydrogen in the core for fusion to continue;
17. recall that small stars like our Sun become red giants when the core hydrogen is depleted, while larger stars become red supergiants;
18. understand that red giants and red supergiants liberate energy by fusing helium into larger nuclei such as carbon, nitrogen and oxygen;
19. explain that red giants lack the mass to compress the core further at the end of the helium fusion, and they then shrink into hot white dwarfs, which gradually cool;

20. explain that fusion in red supergiants continues to larger nuclei due to the higher pressures in the core;
21. recall that fusion in large stars ceases when the core has been largely converted into iron, and the star then explodes in a supernova, leaving a dense neutron star or black hole.

MODULE P7: FURTHER PHYSICS OBSERVING THE UNIVERSE

P7.5 How do astronomers work together?

Candidates will be assessed on their ability to:

1. recall two examples of the location of major astronomical observatories;
2. explain that large telescopes are needed to collect the weak radiation from faint or very distant sources;
3. **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;**
4. describe two ways in which astronomers work with local or remote telescopes;
5. explain the advantages of computer control in remote telescopes;
6. explain the main advantages and disadvantages of using telescopes outside the Earth's atmosphere
   - avoids absorption and refraction effects of atmosphere;
   - can use parts of electromagnetic spectrum that the atmosphere absorbs;
   - cost of setting up, maintaining and repairing;
   - uncertainties of space programme;
7. understand the need for international collaboration in terms of economy and pooling of expertise;
8. describe one example showing how international cooperation is essential for progress in expensive 'big science' projects such as astronomy;
9. describe two astronomical factors that influence the choice of site for major astronomical observatories;
10. understand that non-astronomical factors:
    - cost;
    - environmental and social impact near the observatory;
    - working conditions for employees;

    are important considerations in planning, building, operating, and closing down an observatory.

4 Scheme of Assessment

4.1 Units of Assessment

GCSE Physics (J635)	
Unit 1: Physics A Unit 1 – modules P1, P2, P3 (A331)	
16.7% of the total GCSE marks 40 minutes written paper 42 marks	This question paper: • is offered in Foundation and Higher Tiers; • focuses on modules P1, P2 and P3; • uses objective style questions throughout (there is no choice of questions). • assesses knowledge and understanding of the specification content and application of that knowledge and understanding.
Unit 2: Physics A Unit 2 – modules P4, P5, P6 (A332)	
16.7% of the total GCSE marks 40 minutes written paper 42 marks	This question paper: • is offered in Foundation and Higher Tiers; • focuses on modules P4, P5 and P6; • uses objective questions throughout (there is no choice of questions). • assesses knowledge and understanding of the specification content and application of that knowledge and understanding.
Unit 3: Physics A Unit 3 – Ideas in Context (A333)	
33.3% of the total GCSE marks 60 minutes written paper 55 marks	This question paper: • incorporates pre-release material • assesses knowledge and understanding of the specification content and application of that knowledge and understanding • uses structured questions throughout (there is no choice of questions). • the subject focus of the pre-release material will normally be one or two of modules P1 to P6, the precise focus will be clear from the stimulus material. • the remaining questions will be focused on the content of P7 Further Physics. • includes some marks for communication skills.
Unit 4: Physics A Unit 4 – Practical Data Analysis and Case Study (A339)	
33.3% of the total GCSE marks skills assessment 40 marks (16 + 24)	• This skills assessment unit comprises two elements: the critical analysis of primary data and a case study of a topical (scientific) issue. • Opportunities for both elements should arise naturally during the course. • This unit is assessed by teachers, internally standardised and then externally moderated by OCR.

Unit 5: Physics A Unit 5 – Practical Investigation (A340)	
33.3% of the total GCSE marks skills assessment 40 marks	• This unit comprises five strands, which together are used to assess a complete investigative task. • This unit is assessed by teachers, internally standardised and then externally moderated by OCR.

4.2 Unit Options

Candidates take Units 1, 2 and 3 **and** either Unit 4 **or** Unit 5.

4.3 Tiers

Units 1, 2 and 3 are set in one of two tiers: Foundation Tier and Higher Tier. Foundation Tier papers assess Grades G to C and Higher Tier papers assess Grades D to A*. An allowed grade E may be awarded on the Higher Tier components. Candidates are entered for either the Foundation Tier or the Higher Tier using option codes F and H.

Unit 4 and 5 (skills assessment) are not tiered. Candidates enter either A339 Practical Data Analysis task plus a Case Study, or A340 a Practical Investigation.

Candidates may enter Units 1, 2, and 3 at different tiers, so for example, a candidate may take A331F, A332F and A333H.

4.4 Assessment Availability

There are two examination sessions each year, in January and June.

	Unit 1 (A331)	Unit 2 (A332)	Unit 3 (A333)	Unit 4 (A339)	Unit 5 (A340)
January 2007	-	-	-	-	-
June 2007	✓	-	-	-	-
January 2008	✓	✓	-	-	-
June 2008	✓	✓	✓	✓	✓

After June 2008, Units A331 and A332 will be available in the January and June sessions. The Physics Ideas in Context paper, (Unit A333) and skills assessment, (Units A339 and A340), will only be available in the June sessions.

The Foundation and Higher tier papers covering the same unit will be timetabled on the same day, and will commence at the same time. The papers timetabled simultaneously will contain common questions, or part questions, targeting the overlapping grades C and D.

4.5 Assessment Objectives

The Assessment Objectives describe the intellectual and practical skills which candidates should be able to demonstrate, in the context of the prescribed content. Candidates should demonstrate communication skills, including ICT, using scientific conventions (including chemical equations) and mathematical language (including formulae).

Assessment Objective 1 (AO1): Knowledge and understanding of science and how science works

Candidates should be able to:

- demonstrate knowledge and understanding of the scientific facts, concepts techniques and terminology in the specification;
- show understanding of how scientific evidence is collected and its relationship with scientific explanations and theories;
- show understanding of how scientific knowledge and ideas change over time and how these changes are validated.

Assessment Objective 2 (AO2): Application of skills knowledge and understanding

Candidates should be able to:

- apply concepts, develop arguments or draw conclusions related to familiar and unfamiliar situations;
- plan a scientific task, such as a practical procedure, testing an idea, answering a question or solving a problem;
- show understanding of how decisions about science and technology are made in different situations, including contemporary situations and those raising ethical issues;
- evaluate the impact of scientific developments or processes on individuals, communities or the environment.

Assessment Objective 3 (AO3): Practical, enquiry and data-handling skills

Candidates should be able to:

- carry out practical tasks safely and skillfully;
- evaluate the methods they use when collecting first-hand and secondary data;
- analyse and interpret qualitative and quantitative data from different sources;
- consider the validity and reliability of data in presenting and justifying conclusions.

Weighting of Assessment Objectives

All figures given are for guidance only and have a tolerance of ±3%.

Assessment Objectives		Weighting
AO1:	Knowledge and understanding	30.0%
AO2:	Application of knowledge and understanding, analysis and evaluation	40.6%
AO3:	Enquiry	29.3%

The relationship between the components and the assessment objectives of the scheme of assessment is shown in the following grid.

	Weighting of Assessment Objectives by Unit			
	AO1	AO2	AO3	Total
Unit 1 (A331), Unit 2 (A332)	15%	16.3%	2.0%	33.3%
Unit 3 (A333)	13%	18.3%	2.0%	33.3%
Unit 4 (A339) Unit 5 (A340)	2%	6%	25.3%	33.3%
Overall	30%	40.6%	29.3%	100%

4.6 Quality of Written Communication

Candidates are expected to:

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

Candidates quality of written communication will be assessed in the Ideas of Context (A333) and in the Case Study (A339) or Practical Investigation (A340).

5 Skills Assessment

5.1 Nature of Skills Assessment

Rationale

The skills assessment accounts for 33.3% of the marks for this specification. There is some choice of the material that is presented for assessment. However it is hoped that candidates have opportunities to develop their skills in all aspects of the tasks described here and then present the highest scoring piece of work.

Skills assessment should arise naturally out of teaching, so that it can be assessed by teachers, internally standardised and then externally moderated by OCR. Candidates are required to submit work for either Unit 4 (A339) or Unit 5 (A340).

Practical Data Analysis and Case Study (Unit 4, A339)

The Unit 4 skills assessment comprises two elements: the critical analysis of primary data, and a Case Study on a topical (scientific) issue.

First-hand experience of the problems of collecting valid and reliable data can give candidates a better sense of what the difficulties really are, a 'feel' for how great they are in specific cases, and provide a context for beginning to understand how to tackle and perhaps overcome them. Analysis and interpretation of data teaches how scientists use experimental evidence to develop and test theories. Evaluation of procedures and data shows how the reliability of scientific findings can be assessed.

The Case Study is designed to motivate candidates and give them an insight into how science is reported to the public, and how they can explore the validity of underlying research and claims or recommendations based on the research. Centres should note that marks for both elements of Unit 4 (A339) must be submitted in the same examination session.

Element 1: Data Analysis: Marks submitted out of 16

Candidates either singly or collaboratively take part in a practical procedure in order to collect primary data. Candidates are assessed on their ability to analyse and evaluate the data collected and the limitations of the techniques used. It is not essential for candidates to collect all of the data which is to be used in this exercise. Their own first hand data may be supplemented with extra data from other candidates or classes, demonstrations or other sources.

Marks are awarded for two strands, Interpretation (Strand I) and Evaluation (Strand E). The two marks which make up the assessment total for this element of skills assessment must both come from the same activity.

Element 2: Case Study Marks submitted out of 24

This assignment should arise naturally from work on the course or from an issue that arises while candidates are following the course. It should be related to an aspect of science that involves an element of controversy, in terms either of the interpretation of evidence, or of the acceptability of some new development. Topics for study should be selected by candidates in discussion with teachers, and should be seen as an extension or consolidation of studies undertaken as a normal part of the course. The work should be capable of being completed within approximately 4-6 hours over a period of time, for example, one lesson per week for half a term, with some non-contact time.

Practical Investigation (Unit 5, A340)

The use of practical investigations to assess skills in science was based on research in a number of centres, particularly the University of Durham. For more than 10 years, it has formed the basis of coursework assessment for National Curriculum science.

Investigations require the drawing together of skills in planning, collecting data, interpreting data and evaluation. They provide an effective and valid assessment instrument for a course which js seen as a basis for further studies and possible future careers in science. However, the regulations used at Key Stage 4 over the past 5-year cycle have been constructed in a way which has restricted the variety of work attempted and has led to rather mechanical ‘criterion matching’, rather than genuine open-ended work.

For this specification, the basic structure of investigations is retained, but the emphasis on prediction is removed, allowing a much wider range of activities and approaches. A different marking style has been developed, drawing more on the professional judgment of teachers.

The task aims to motivate candidates and help them to appreciate the importance of having a clear and manageable question, to learn how to choose equipment and use it appropriately, and to design suitable apparatus for making observations and measurements. First-hand experience of the problems of collecting valid and reliable data can give candidates a better sense of what the difficulties really are, and a 'feel' for how great they are in specific cases, and provide a context for beginning to understand how to tackle and perhaps overcome these.

Candidates are required to complete one single practical investigation. The Investigation, accounts for 33% of the marks for this specification. It is assessed by teachers, internally standardised, and then externally moderated.

Within this science suite, investigative work is designed to have a broader and more open definition than in the National Curriculum Programme of Study Sc1.2. In addition to confirming the predicted effect of a variable on a system over a range, the definition also includes more speculative investigation of systems where no clear prediction can be made in advance, e.g. where there is little relevant explanatory theory available in the course, or where the experimental material is likely to be variable, for example in surveys of distribution of species. It also includes tasks which involve determining the consistency of measurements e.g. comparing the characteristics of different artefacts, obtaining evidence for the ‘normal’ variation in respiratory peak flow-rates of an individual, etc.

The initial stimulus for an investigation should arise from class teaching or discussion which ensures that candidates are aware of suitable practical techniques and have some relevant background theoretical knowledge.

This component of the assessment is based on complete, first hand practical investigations. Candidates may complete as many investigations as they wish during the course. The final mark will be the total for the highest-scoring single piece of work assessed. It is not permitted to aggregate together marks taken from different investigations. Where appropriate, first hand data collected by the candidate may be supplemented by secondary data from other sources. In such cases, credit for collecting data should be based on the overall quality of all the data obtained or selected.

Marks are awarded for 5 strands of the investigation, with each strand marked on a scale of 0 – 8.

5.2 Marking Internally Assessed Work

Arrival at Strand Marks

The method of marking the skills assessment is the same across this Science suite.

The award of marks is based on the professional judgement of the science teacher, working within a framework of descriptions of performance. Within each strand, each line in the marking grids represents a different aspect of performance. For each of these, a series of four descriptions of performance illustrates what might be expected for candidates working at different levels.

Marking decisions should be recorded on marking grids. A master copy is provided in the skills assessment guidance booklet. The completed grid serves as a cover-sheet for the work if it is required for moderation.

Candidates may not always report their work in a particular order. So, evidence of achievement in a strand may be located almost anywhere in the work. Thus, it is necessary to look at the whole piece of work for evidence of each strand in turn.

Within any one strand, each aspect should be considered in turn. A tick on the grid should be used to indicate the performance statement that best matches the work.

Where the maximum mark is 8, intermediate marks 1, 3, 5 or 7 can be used where performance exceeds that required by one statement, but does not adequately match that required by the next higher statement (e.g. if the work significantly exceeds what is required for 4 marks, but does not reach the standard for 6, then the tick should be placed on the dividing line between the 4 and 6 mark boxes).

Where a decision is based partly on the teacher' observation of the candidate at work, the work should be annotated to record this at an appropriate point.

In some cases, in order to allow credit for the widest possible variety of activities, an aspect of performance is represented by two (or more) rows of mark descriptors. In such cases, where a row is not relevant or appropriate for a particular activity, it should be left blank and excluded from the 'best-fit' marking judgement and the more appropriate alternative row used.

When each aspect of the performance within a strand have been assessed in this way, the pattern of achievement is interpreted by a 'best-fit' judgement to give a mark for that strand.

This method of marking can be applied even where there is a wide variation between performance in different aspects. Thus, weak performance in one aspect need not depress marks too far if other aspects show better performance.

Recording and submitting marks

Skills Assessment Forms will be provided for centres to record marks submitted for moderation. The final mark should be submitted to OCR on form MS1 by 15th May in the year of entry. These forms are produced and dispatched at the relevant time, based on entry information provided by the Centre.

All assessed work which has contributed to candidates' final totals must be available for moderation.

Unit 4 (A339), Element 1: Practical Data Analysis (13.3%)

Marking Criteria – Practical Data Analysis

There are two strands in this element; Interpreting Data and Evaluation. The descriptors for each strand are identical to those found in Unit 5 Practical Investigation (A340).

Strand I: Interpreting Data

Candidates are expected to be able to:

- present or process a set of data in such a manner as to bring out any 'patterns'[1] that are present (IaS1.4, 2.1, 2.3-4);
- state conclusions based on these patterns (IaS 2.4);
- relate their conclusions to scientific theories or understanding (IaS 3.1, 3.3, 3.4).

Aspect of Performance	Strand I Mark			
	2	4	6	8
a graphical or numerical processing of data	Display limited numbers of results in tables, charts or graphs, using given axes and scales.	Construct simple charts or graphs to display data in an appropriate way, allowing some errors in scaling or plotting.	Correctly select scales and axes and plot data for a graph, including an appropriate line (normally a line of best fit) or construct complex charts or diagrams (e.g. stacked histograms, species distribution maps).	Additionally, indicate the spread of data (e.g. through scatter-graphs or error bars) and give clear keys for displays involving multiple data sets.
	Select individual results as a basis for conclusions.	Carry out simple calculations (e.g. correct calculation of averages from repeated readings).	Use mathematical comparisons between results to support a conclusion.	Use complex processing to reveal patterns in the data (e.g. statistical methods, use of inverse relationships or calculation of gradient of graphs).
b summary of evidence	Note differences between situations/ cases, or compare individual results.	Identify trends or general correlations in the data.	Describe formal or statistical relationships within the cases/situations studied.	Review the extent of, or limitations to, formal conclusions in relation to the scatter evident in the data.
c explanations suggested	Link the outcomes to previous experience or 'common sense'.	Relate the conclusion to scientific ideas/ explanations.	Justify the conclusion by reference to relevant scientific knowledge and understanding.	Use detailed scientific knowledge to explain all aspects of the given conclusion.

[1] 'Patterns' here means similarities, or differences, or the presence or absence of a relationship (e.g. a correlation between a factor and an outcome, or a trend linking two variables)

Strand E: Evaluation

Candidates are expected to be able to look back at the experiment they have carried out, showing what they have learned from doing it and explaining how they would modify it in the light of this, were they to carry it out again. These suggestions may demonstrate understanding of:

- difficulties in collecting valid and reliable data (IaS 1.1-3);
- weaknesses in the design of the data set collected, such as imperfect control of other variables, or the size and matching of samples compared (IaS 2.3, 2.6-7);
- assessing the level of confidence that can be placed in these conclusions (IaS 2.2-3, 2.6-7).

In the following table, each row represents increasing achievement in a different aspect of performance.

Aspect of Performance	Strand E Mark			
	2	4	6	8
a evaluation of procedures	Make a relevant comment about how the data was collected and about safety procedures.	Comment on the limitations to accuracy or range of data imposed by the techniques and equipment, used.	Suggests improvements to apparatus or techniques, or alternative ways to collect the data, but without sufficient practical detail.	Describe in detail improvements to the apparatus or techniques, or alternative ways to collect the data, and explain why they would be an improvement.
b reliability of evidence	Make a claim for accuracy or reliability, but without appropriate reference to the data.	Note the presence or absence of results that are beyond the range of experimental error.	Use the general pattern of results or degree or scatter between repeats as a basis for assessing accuracy and reliability.	Consider critically the reliability of the evidence, accounting for any anomalies.
c reliability of conclusion	Relate judgement of the reliability (or otherwise) of the conclusions only to techniques used, not to data collected.	Link confidence in the conclusion to the apparent reliability of the data collected.	Discuss the precision of apparatus and techniques, the range covered and reliability of data to establish a level of confidence in the conclusions.	Identify weaknesses in the data and give a detailed explanation of what further data would help to make the conclusions more secure.