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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Secondary Education

Physics 4451
2010

Special Features

- Objective tests for Physics 1 are available as on-screen tests

Material accompanying this Specification

- The Teacher's Guide

SPECIFICATION

This specification will be published annually on the AQA Website (www.aqa.org.uk). If there are any changes to the specification centres will be notified in print as well as on the Website. The version on the Website is the definitive version of the specification.

Vertical black lines indicate a significant change to the previous version of this specification.

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Background Information

1 Revision of GCSE Sciences – an Outcome of the DfES 14–19 Strategy

Following the publication of the DfES '14–19: opportunity and excellence' policy document, changes to the key stage 4 National Curriculum for England have been announced. One change is a new programme of study for KS4 Science (published autumn 2004), and the consequent rewriting by QCA of the GCSE Criteria for Science. Further details of this are given in Section 1.1. Another change relevant to GCSE Science is a requirement to provide work-related learning for all students. This is described in the QCA document 'Changes to the key stage 4 curriculum – guidance for implementation from September 2004', and is discussed in Section 1.2. These changes have together necessitated the redevelopment of GCSE Science specifications by all awarding bodies for first teaching from September 2006.

1.1 Changes to the GCSE Criteria for Science

The new programme of study has been incorporated by QCA into the GCSE Criteria for Science. The revised Criteria outline the common characteristics and subject content for science GCSEs developed by all awarding bodies for first teaching from September 2006. The main points are as follows.

- Importance is attached to the knowledge, skills and understanding of how science works in the world at large, as well as in the laboratory (referred to as the procedural content in the specification).
- This is set in the context of knowing and understanding a body of scientific facts (referred to as the substantive content).
- In the programme of study, procedural and substantive content are given equal emphasis.
- There is a new single award GCSE Science incorporating all of the content in the programme of study.
- There is a new single award GCSE Additional Science, which together with GCSE Science allows progression to post-16 science courses.
- Alternative progression routes are available in the form of single award separate sciences (GCSE Biology, GCSE Chemistry and GCSE Physics), and an applied science route leading to a new single award GCSE Additional Applied Science.

- There is provision for students wishing to follow an applied route from the outset of KS4 through a revised double award GCSE Applied Science.
- Taken together, the three separate sciences cover the requirement to teach the new programme of study, as does the revised double award GCSE Applied Science.
- Through these new specifications the opportunity exists for candidates to study GCSE Science and one or more of the separate science GCSE courses.

In parallel with the GCSE developments, a new Entry Level Certificate specification for science is being produced. This covers the breadth of the programme of study but in less depth than required for GCSE Science.

Further details of the suite of specifications developed by AQA to meet these requirements are given in Section 4.2.

1.2 Changes to the KS4 Curriculum

Requirement to teach programme of study

The revised programme of study for KS4 Science has been designed by QCA as a small core of content relevant to all students. It is a statutory requirement to teach the programme of study to all students at maintained schools. Since the start of teaching of the new specifications (September 2006), it has no longer been possible to disapply KS4 students from this requirement for the purposes of extended work-related learning.

Work-related learning

The removal of the provision for disapplication is linked to the statutory requirement for work-related learning for all students which was introduced in September 2004. With the greater emphasis in the revised programme of study on 'How Science Works', science teachers are enabled, if they wish, to make a larger contribution to work-related learning through the teaching of science.

1.3 Other Regulatory Requirements

Key Skills

All GCSE specifications must identify, as appropriate to the subject, opportunities for generating evidence for the Key Skills of Application of Number, Communication, Information and Communication Technology, Working with Others, Improving own Learning and Performance, and Problem Solving. Details for this specification are given in Section 14.

ICT

The subject content of all GCSEs must require candidates to make effective use of ICT and provide, where appropriate, assessment opportunities for ICT. In science in the wider world, ICT plays a crucial role, and teaching and learning in the GCSE Sciences should reflect this. Details of how the teaching of this specification can encourage the application and development of ICT skills are given in Section 9.3. However, ICT skills are not assessed by any component of this specification.

Communication

All GCSE specifications must ensure that the assessment arrangements require that, when they produce extended written material, candidates have 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.

Further details for this specification are given in Section 7.4.

Citizenship

Since 2002, students in England have been required to study Citizenship as a National Curriculum subject. Each GCSE specification must signpost, where appropriate, opportunities for developing citizenship knowledge, skills and understanding. Further details for this specification are given in Section 15.5.

Other issues

All specifications must identify ways in which the study of the subject can contribute to developing understanding of spiritual, moral, ethical, social and cultural issues, European developments, environmental issues, and health and safety. Further details for this specification are given in Sections 15.1, 15.2, 15.3 and 15.4.

Wales and Northern Ireland

There is no longer any additional material that centres in Wales or Northern Ireland have to teach in order to meet the different requirements of the National Curriculum in these countries.

Therefore, centres may offer any of the AQA specifications without the need to supplement the teaching required in order to meet additional statutory orders applying to students outside England.

2

Specification at a Glance

Physics

This specification is one of a suite of GCSE Science specifications offered by AQA. The specification leads to a single award GCSE Physics. The award has four or five assessment units.

There are two tiers of assessment: Foundation (G–C) and Higher (D–A *). The centre-assessed unit is not tiered.

The objective tests are available as paper-based and on-screen tests in centres.

On-screen tests are undertaken by candidates sitting at a computer and keying their responses.

GCSE Physics	
Physics 1 Written paper 25% 45 minutes 45 marks	
or	
Physics 1a Matching/multiple choice questions Objective test 12.5% 30 minutes 36 marks	**Physics 1b** Matching/multiple choice questions Objective test 12.5% 30 minutes 36 marks
Physics 2 Written paper 25% 45 minutes 45 marks	
Physics 3 Written paper 25% 45 minutes 45 marks	
Physics Centre-Assessed Unit (P1, P2 or P3) based on normal class practical work 25% 40 marks Investigative Skills Assignment (an externally set, internally assessed test taking 45 minutes) + Practical Skills Assessment (a holistic skills assessment)	

GCSE Physics
4451

3 Availability of Assessment Units and Entry Details

3.1 Availability of Assessment Units and Subject Awards

Examinations based on this specification are available as follows.

	Physics 1	Physics 1a Physics 1b	Physics 2 Physics 3	Physics Centre-Assessed Unit	Subject Award
November		✓			✓
January	✓		✓		✓
March		✓			✓
June	✓	✓	✓	✓	✓

3.2 Entry Codes

Normal entry requirements apply, but the following information should be noted.

Each assessment unit has a separate unit entry code, as follows:

Physics 1	PHY1F or PHY1H
or	
Paper-based Objective Tests	
Physics 1a	PHY1AP
Physics 1b	PHY1BP
or	
On-screen Objective Tests	
Physics 1a	PH1ASF or PH1ASH
Physics 1b	PH1BSF or PH1BSH
Physics 2	PHY2F or PHY2H
Physics 3	PHY3F or PHY3H
Physics centre-assessed unit	PHYC

For Physics 1, Physics 2 and Physics 3 the entry code determines the tier taken. See section 3.3 for Physics 1a and Physics 1b.

The units which contribute to the subject award GCSE Physics are: Physics 1 or (Physics 1a and Physics 1b), Physics 2, Physics 3 and the Physics centre-assessed unit.

The Subject Code for entry to the GCSE Physics award is 4451.

3.3 Entry Restrictions

Each specification is assigned to a national classification code, indicating the subject area to which it belongs. Centres should be aware that candidates who enter for more than one GCSE qualification with the same classification code will have only one grade (the highest) counted for the purpose of the School and College Performance Tables.

The classification code for this specification is 1210.

The subject award GCSE Physics has common units with other specifications in the AQA GCSE Sciences suite. Physics 1 is common to GCSE Physics and GCSE Science B, and it has exactly the same content as Physics 1a and Physics 1b together. Physics 2 is common to GCSE Physics and GCSE Additional Science.

The Objective Tests for Physics 1a and Physics 1b are tiered, but the questions for both tiers are contained within the same question paper. Candidates choose at the time of the examination which tier to take. For on-screen tests, a tiered entry should be made.

It is **not** a requirement to take the same tier for every Objective Test or written paper. Candidates can opt to take different tiers for the different tests / written paper and can choose to resit a test / written paper at a different tier.

3.4 Private Candidates

This specification is available for private candidates. Private candidates should write to AQA for a copy of *Supplementary Guidance for Private Candidates*.

3.5 Access Arrangements and Special Consideration

AQA pays due regard to the provisions of the Disability Discrimination Act 1995 in its administration of this specification.

Arrangements may be made to enable candidates with disabilities or other difficulties to access the assessment. An example of an access arrangement is the production of a Braille paper for a candidate with a visual impairment. Special consideration may be requested for candidates whose work has been affected by illness or other exceptional circumstances.

Further details can be found in the Joint Council for Qualifications (JCQ) document:
Access Arrangements and Special Consideration
Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations
GCE, AEA, VCE, GCSE, GNVQ, Entry Level & Key Skills
This document can be viewed via the AQA website (www.aqa.org.uk)

Applications for access arrangements and special consideration should be submitted to AQA by the Examinations Officer at the centre.

3.6 Language of Examinations

All assessment will be through the medium of English. Assessment materials will not be provided in Welsh or Gaeilge.

Scheme of Assessment

4 Introduction

4.1 National Criteria

This GCSE Physics specification complies with the following:

- the Statutory Regulation of External Qualifications in England, Wales and Northern Ireland 2004, including the common criteria for all qualifications and the additional criteria for GCSE
- the GCSE Criteria for Science
- the GCSE, GCE, VCE, GNVQ and AEA Code of Practice April 2008.

4.2 Background

This GCSE Physics specification is part of the AQA GCSE Science suite, which comprises:

GCSE Science A
GCSE Science B
GCSE Additional Science
GCSE Additional Applied Science
GCSE Biology
GCSE Chemistry
GCSE Physics (this specification)
GCSE Applied Science (Double Award)

A matching Entry Level Certificate specification for Science is also available.

The suite enables centres to offer a range of flexible progression routes from KS3 through KS4 Science to further studies.

As noted in Section 1.1, the GCSE Criteria for Science require a greater emphasis on 'How Science Works' in these new specifications. AQA is grateful to staff in the School of Education of the University of Durham for assistance in addressing this requirement. The procedural content of this specification draws substantially on pioneering work conducted at the University of Durham on 'Concepts of Evidence', using a subset of these concepts which are appropriate to GCSE Sciences. For more information about this work visit: www.dur.ac.uk/richard.gott/Evidence/cofev.htm

University staff have also assisted AQA senior examiners in developing the assessment of the procedural content in relation to the substantive content, in both the written papers and the centre-assessed unit. Initial pilot work by the University has helped significantly in designing assessments which are accessible to students at KS4. AQA acknowledges this indebtedness.

Rationale

The rationale of the six general science specifications (GCSE Science A, GCSE Science B, GCSE Additional Science, GCSE Biology, GCSE Chemistry and GCSE Physics) is the appropriate exploration of 'How Science Works' in contexts which are relevant to the role of science in society and which are able to serve as a foundation for progression to further learning. A body of content has been identified which underpins the knowledge and understanding of 'How Science Works' at all levels. This 'procedural content' relates to the processes of scientific activity. The 'substantive content' comprises the Biology, Chemistry, Physics or other science content. In these specifications the procedural content and the substantive content are presented in separate sections in order to ensure that there is a coherent and consistent understanding of what candidates are required to know, understand and be able to do. However, it is expected that delivery of the procedural content will be integrated.

Integrating 'How Science Works' (procedural content)

Although the procedural content is presented in a separate section in the general science specifications, it is not expected that it is taught separately from the substantive content. Teachers might teach a topic of substantive content (eg reflex action, fractional distillation, or features of electromagnetic waves) or of procedural content (eg methods of collecting scientific data) but often they will deliver a blend of procedural and substantive content (eg when teaching about the greenhouse effect and global warming).

In order to reflect this approach, each sub-section of substantive content has details of activities which enable candidates to develop their skills, knowledge and understanding of how science works (the procedural content), then details are given of the substantive contexts that need to be known and understood in order to undertake the activities. This is supplemented by signposting which highlights opportunities to develop the skills, knowledge and understanding of the investigative aspects of the procedural content, and opportunities to encourage knowledge and understanding of how scientific evidence is used. Further details about integrating the procedural content are given in Section 9.1.

Assessment in the written papers will also reflect this approach. Parts of questions may address procedural content, substantive content or a blend of both. Candidates will be expected to apply their procedural knowledge, understanding and skills in a wide range of substantive contexts.

Each of the specifications has particular features and these are described in the following paragraphs.

GCSE Science A and GCSE Science B

Students can begin KS4 with a general science course based on either GCSE Science A or GCSE Science B. These are both single award qualifications. They cover all aspects of a good science education: evaluating evidence and the implications of science for society, explaining, theorising and modelling in science, and procedural and technical knowledge of science practice, though with an emphasis on the first aspect, namely, evaluating evidence and the implications of science for society. The weighting given to the procedural content in these specifications is higher than in the other general science specifications, and the substantive contexts lend themselves to engagement with the societal implications of scientific knowledge at a level which is appropriate to key stage 4. Both these specifications therefore provide the opportunity for all students to develop the science knowledge, understanding and skills needed for adult life, but they also give a good basis for further study of science.

These specifications have identical content, covering the whole programme of study for KS4 Science, with the subject areas of Biology, Chemistry and Physics presented separately so that they can be taught by subject specialists if this suits the staffing and/or teaching strategy in the centre. The assessment styles for Science A and Science B are different, though they share a common model for centre assessment. Students who are successful in GCSE Science could study a level 3 science qualification such as AS Science for Public Understanding, but would find progression to GCE Biology, Chemistry, Physics and Applied Science difficult without further preparation. Many will undertake a level 2 course such as GCSE Additional Science or GCSE Additional Applied Science before continuing to level 3 courses.

GCSE Science A

The specific feature of this specification is that external assessment is available through 'bite size' objective tests. Each of the three units, Biology 1, Chemistry 1 and Physics 1, is divided into two equal sections and each section is examined in a separate 30 minute test. The tests are available in November, March and June. The objective tests are available as paper-based and on-screen tests in centres.

GCSE Science B

In contrast, GCSE Science B does not offer assessment through the 'bite-size' test route but has 45 minute written papers with structured questions. There is one paper for each of Biology 1, Chemistry 1 and Physics 1, available in January and June.

GCSE Applied Science (Double Award)

Alternatively, students embarking on KS4 and wishing from the outset to specialise in a vocational approach to science can be offered GCSE Double Award Applied Science. This is a qualification which has been developed from the previous GCSE Applied Science specification but unlike its predecessor it covers the whole programme of study for KS4 Science, enabling the requirement to teach the programme to be met (see Section 1.2). The assessment comprises four units; three portfolio units and one unit which is externally assessed.

ELC Science

Candidates who may not be ready to take GCSE Science at the same time as their contemporaries can study for the Entry Level Certificate in Science. This has the same breadth of content as GCSE Science, but less depth. Teaching for ELC Science can enable the requirement to teach the programme of study for KS4 Science to be met (see Section 1.2) and students can be taught alongside students preparing for GCSE Science (if they cannot be taught separately). Students who have succeeded in ELC Science can progress to GCSE Science. Assessment is through the completion of units of content with the success criteria being clearly focussed on skills rather than depth of knowledge.

GCSE Additional Science

This is a single award GCSE, separate from and taken after or at the same time as GCSE Science A or B. This award together with an award in GCSE Science provides the nearest equivalent to the previous GCSE Science: Double Award. The content follows on from that of GCSE Science, and the centre assessment follows the same model as used for Science A and Science B. However, the emphasis of this specification, and the three separate sciences, GCSE Biology, Chemistry and Physics, is somewhat different. Whereas GCSE Science A and B emphasise evaluating evidence and the implications of science for society, these specifications have a greater emphasis on explaining, theorising and modelling in science.

There are three 45 minute written papers with structured questions, one paper for each of Biology 2, Chemistry 2 and Physics 2, available in January and June. Courses based on this specification form a firm basis for level 3 courses in the sciences, such as AS and A Level Biology, Chemistry and Physics.

GCSE Additional Applied Science

This is another single award GCSE, which could be taken after or at the same time as GCSE Science A or B. It emphasises the procedural and technical knowledge of science practice, so is suitable for students who want to learn more about vocational contexts which are relevant to the modern world. The subject content is set in three vocational contexts: sports science, food science and forensic science. Together with GCSE Science, it would form a firm basis for level 3 courses in the sciences, such as GCE Applied Science.

GCSE Biology, Chemistry, Physics

Each of these single award GCSEs would provide the basis for the study of the corresponding GCE science. Like GCSE additional science, they emphasise explaining, theorising and modelling in science. Taken together, they include the whole programme of study for KS4 Science, enabling the statutory requirement to be met. Students could take courses based on these specifications directly after KS3 Science. Alternatively, some students may prefer to take GCSE Science to provide a general background in KS4 Science, then specialise in one or more separate science(s).

Centre-Assessed Unit

The general science GCSEs (Science A, Science B, Additional Science, Biology, Chemistry and Physics) share a common approach to centre assessment. This is based on the belief that assessment should encourage practical activity in science, and that practical activity should encompass a broad range of types of activity. The previous model of practical assessment based on ‘investigations’ has become a straightjacket to practical activity in the classroom, and it is the intention that the model adopted will avoid this.

The centre-assessed unit is a combination of practical skills assessment (a holistic assessment on a 6 point scale) and a written test. Before taking a test, candidates undertake practical work relating to a topic under normal class conditions and, during their work, they collect data. They bring their data to the test. The written test is taken in a subsequent lesson but under examination conditions. Tests are externally set, but internally marked, using marking guidance provided by AQA. Each test will have questions relating to the candidate's data and questions which relate to additional data provided in the question paper. Several tests relevant to each unit will be available at any one time, and the tests can be taken at times chosen by the teacher. Further details are given in Sections 16-18.

4.3 Prior Level of Attainment and Recommended Prior Learning

This key stage 4 GCSE specification builds on the knowledge, understanding and skills set out in the National Curriculum programme of study for KS3 Science. While there is no specific prior level of attainment required for candidates to undertake a course of study based on this specification, a level of scientific, literacy and numeracy skills commensurate with having followed a programme of study at key stage 3 is expected.

4.4 Progression

This qualification is a recognised part of the National Qualifications Framework. As such, GCSE is a level 2 qualification and provides progression from key stage 3 to post-16 studies.

A course based on this specification provides a worthwhile course for candidates of various ages and from diverse backgrounds in terms of general education and lifelong learning. It will follow naturally from a course based on the programme of study for KS3 Science. From a GCSE Physics course, students could progress to GCE Physics. Alternatively, students could progress to AS Science for Public Understanding.

5 Aims

A course based on this specification should encourage candidates to:

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

6 Assessment Objectives

6.1

The scheme of assessment will require candidates to demonstrate the abilities detailed under assessment objectives below in the context of the subject content in Sections 10-13.

6.2 Assessment Objective 1 (AO1)

Knowledge and understanding of science and how science works

Candidates should be able to:

a) demonstrate knowledge and understanding of the scientific facts, concepts, techniques and terminology in the specification

b) show understanding of how scientific evidence is collected and its relationship with scientific explanations and theories

c) show understanding of how scientific knowledge and ideas change over time and how these changes are validated.

6.3 Assessment Objective 2 (AO2)

Application of skills, knowledge and understanding

Candidates should be able to:

a) apply concepts, develop arguments or draw conclusions related to familiar and unfamiliar situations

b) plan a scientific task, such as a practical procedure, testing an idea, answering a question or solving a problem

c) show understanding of how decisions about science and technology are made in different situations, including contemporary situations and those raising ethical issues

d) evaluate the impact of scientific developments or processes on individuals, communities or the environment.

6.4 Assessment Objective 3 (AO3)

Practical, enquiry and data handling skills

Candidates should be able to:

a) carry out practical tasks safely and skilfully

b) evaluate the methods they use when collecting first-hand and secondary data

c) analyse and interpret qualitative and quantitative data from different sources

d) consider the validity and reliability of data in presenting and justifying conclusions.

7 Scheme of Assessment

7.1 Assessment Units

The Scheme of Assessment comprises four or five units: Physics 1, or (Physics 1a and Physics 1b), Physics 2, Physics 3, and the Physics centre–assessed unit.

The objective tests are available as paper-based and on-screen tests in centres.

Physics 1	Written Paper	45 minutes
25% of the marks		45 marks

The unit comprises a written paper with short answer questions. The questions assess the subject content in Sections 10 (up to 9 marks) and 11 (at least 36 marks). The paper is available at Foundation and Higher Tier. All questions are compulsory.

Either Physics 1 or (Physics 1a and Physics 1b) should be taken.

Physics 1a	Objective Test	30 minutes
12.5% of the marks		36 marks

The unit comprises an objective test with matching and multiple choice questions. The questions assess the content in Sections 10 (at least 7 marks) and 11a (up to 29 marks). The test is available at Foundation and Higher Tier. All questions are compulsory.

Physics 1b	Objective Test	30 minutes
12.5% of the marks		36 marks

The unit comprises an objective test with matching and multiple choice questions. The questions assess the content in Sections 10 (at least 7 marks) and 11b (up to 29 marks). The test is available at Foundation and Higher Tier. All questions are compulsory.

Physics 2	Written Paper	45 minutes
25% of the marks		45 marks

The unit comprises a written paper with short answer questions. The questions assess the subject content in Sections 10 (up to 9 marks) and 12 (at least 36 marks). The paper is available at Foundation and Higher Tier. All questions are compulsory.

Physics 3	Written Paper	45 minutes
25% of the marks		45 marks

The unit comprises a written paper with short answer questions. The questions assess the subject content in Sections 10 (up to 9 marks) and 13 (at least 36 marks). The paper is available at Foundation and Higher Tier. All questions are compulsory.

Physics Centre-Assessed Unit	
25% of the marks	40 marks

The unit comprises an Investigative Skills Assignment, which is normal class practical work followed by an externally set, internally assessed test taking 45 minutes, and a Practical Skills Assessment which is a holistic practical skills assessment. The unit assesses parts of the content in Section 10 (these are detailed in Section 17).

7.2 Weighting of Assessment Objectives

The approximate relationship between the relative percentage weighting of the Assessment Objectives (AOs) and the overall Scheme of Assessment is shown in the following table:

Assessment Objectives	**Unit Weightings (%)**				**Overall Weighting of AOs (%)**
	Physics 1	**Physics 2**	**Physics 3**	**Physics Centre-Assessed Unit**	
AO1	12	12	12	-	36
AO2	13	13	13	5	44
AO3	-	-	-	20	20
Overall Weighting (%)	25	25	25	25	**100**

Candidates' marks for each assessment unit are scaled to achieve the correct weightings.

7.3 Tiering and Assessment

The centre-assessed unit is not tiered. In the other assessments for this specification, the papers are tiered, with Foundation Tier being aimed at grades C–G and Higher Tier being aimed at grades A*–D. Questions for the Higher Tier will be more demanding, requiring higher level skills, allowing candidates to access the higher grades. See Section 9.4 for information about tiering and subject content. Different tiers can be taken for different papers.

In Physics 1a and Physics 1b the questions for both tiers are contained within the same paper. Candidates choose at the time of the examination which tier to take.

The level of demand of questions depends on factors such as the nature of the underlying scientific concepts being tested, amount of cueing provided, including the plausibility of distractors, the context/application in which the question is contained, whether the response required is directed or open, and the extent to which reference material must be used in order to respond. Consideration of such factors allows GCSE science questions to be allocated to one of three levels of demand (low, standard and high). Foundation Tier papers contain low and standard demand questions, while Higher Tier papers contain standard and high demand questions.

7.4 Mathematical and Other Requirements

The knowledge and skills in mathematics which are relevant to science and which are given below will not be exceeded in making assessments in this specification. Candidates will not be prevented from demonstrating achievement in science by mathematics which is excessively demanding.

FT and HT

- The four rules applied to whole numbers and decimals
- Use of tables and charts
- Interpretation and use of graphs
- Drawing graphs from given data
- Reading, interpreting and drawing simple inferences from tables
- Vulgar and decimal fractions and percentages
- Scales
- Elementary ideas and application of common measures of rate
- Averages/means and the purpose for which they are used
- Substitution of numbers for words and letters in formulae (without transformation of simple formulae)

HT only

(in addition to the requirements listed above)

- Square and square root
- Conversion between vulgar and decimal fractions and percentages
- The four rules applied to improper (and mixed) fractions
- Expression of one quantity as a percentage of another; percentage change
- Drawing and interpreting of related graphs
- Idea of gradient
- Transformation of formulae
- Simple linear equations with one unknown
- Elementary ideas and applications of direct and inverse proportion.

Units, symbols and nomenclature

Units, symbols and nomenclature used in examination papers will normally conform to the recommendations contained in the following.

- *Signs, Symbols and Systematics – the ASE companion to 16-19 Science.* Association for Science Education (ASE), 2000. ISBN 0 86357 312 6
- *Signs, Symbols and Systematics – the ASE companion to 5-16 Science.* Association for Science Education (ASE), 1995. ISBN 0 86357 232 4

Any generally accepted alternatives used by candidates will be given appropriate credit.

Formulae list

For the Physics written papers, when a formula is required to answer a question, the formula or formulae will be given in that question. However, candidates may be asked to identify the units.

Communication skills

AQA takes care that candidates are not prevented from demonstrating achievement in science by the use of language in question papers which is inappropriately complex and hinders comprehension. Similarly, while the assessment of communication is not a primary function of this specification, candidates are required to demonstrate scientific communication skills. These are described in Section 9.2.

Scientific communication skills are specifically targeted by questions in the Investigative Skills Assignment (ISA) part of the centre-assessed unit. The externally set test for every ISA has a question in which the scoring of marks is in part dependent on skills such as presenting information, developing an argument and drawing a conclusion.

In addition, candidates will have difficulty in scoring the marks for science in any of the written assessments if they do not:

- 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.

In presenting their answers, they will also need to use scientific conventions (including chemical equations) and mathematical language (including formulae) accurately and appropriately to score all the available marks.

Subject Content

8 Summary of Subject Content

8.1	How Science Works	10.1	The thinking behind the doing
		10.2	Fundamental ideas
		10.3	Observation as a stimulus to investigation
		10.4	Designing an investigation
		10.5	Making measurements
		10.6	Presenting data
		10.7	Using data to draw conclusions
		10.8	Societal aspects of scientific evidence
		10.9	Limitations of scientific evidence
8.2	Physics 1 Physics 1a	11.1	How is heat (thermal energy) transferred and what factors affect the rate at which heat is transferred?
		11.2	What is meant by the efficient use of energy?
		11.3	Why are electrical devices so useful?
		11.4	How should we generate the electricity we need?
	Physics 1b	11.5	What are the uses and hazards of the waves that form the electromagnetic spectrum?
		11.6	What are the uses and dangers of emissions from radioactive substances?
		11.7	What do we know about the origins of the Universe and how it continues to change?
8.3	Physics 2	12.1	How can we describe the way things move?
		12.2	How do we make things speed up or slow down?
		12.3	What happens to the movement energy when things speed up or slow down?
		12.4	What is momentum?
		12.5	What is static electricity, how can it be used and what is the connection between static electricity and electric currents?
		12.6	What does the current through an electrical circuit depend on?
		12.7	What is mains electricity and how can it be used safely?
		12.8	Why do we need to know the power of electrical appliances?
		12.9	What happens to radioactive substances when they decay?
		12.10	What are nuclear fission and nuclear fusion?

8.4 Physics 3

13.1 How do forces have a turning effect?

13.2 What keeps bodies moving in a circle?

13.3 What provides the centripetal force for planets and satellites?

13.4 What do mirrors and lenses do to light?

13.5 What is sound?

13.6 What is ultrasound and how can it be used?

13.7 How can electricity be used to make things move?

13.8 How do generators work?

13.9 How do transformers work?

13.10 What is the life history of stars?

9 Introduction to Subject Content

9.1 Integrating the Procedural Content

The subject content of this specification is presented in four sections: the procedural content ('How Science Works'), and three sections of substantive content, Physics 1, Physics 2 and Physics 3. To aid understanding of the changes that have been introduced in the teaching, learning and assessment of science at key stage 4, the procedural content is stated separately in Section 10 from the Physics content in Sections 11–13. However, it is intended that the procedural content is integrated and delivered in the context of the content in Physics 1, Physics 2 and Physics 3.

The organisation of each sub-section of the substantive content is designed to facilitate this approach. Each of the sub-sections in Physics 1, Physics 2 and Physics 3 starts with the statement: 'Candidates should use their skills, knowledge and understanding of how science works (to)'. This introduces a number of activities, for example:

- comparing and contrasting the advantages and disadvantages of using different energy sources to generate electricity.

These are intended to enable candidates to develop many aspects of the skills, knowledge and understanding of how science works. In general, the activities address using scientific evidence. Other aspects of the skills, knowledge and understanding of how science works, particularly obtaining scientific evidence, will be better developed through investigative work, and it is expected that teachers will want to adopt a practical approach to the teaching of many topics.

In each sub-section, the contexts for the activities and associated practical work are introduced by the statement: 'Their skills, knowledge and understanding of how science works should be set in these substantive contexts'. Sentences such as this follow:

- Electricity can be produced directly from the Sun's radiation using solar cells.

These sentences define the scope of the Physics content.

In order to assist teachers in identifying sections of the content which lend themselves to the delivery of the procedural content, two symbols have been used.

The first, shown here, identifies parts of the content which lend themselves to extended investigative work of the type needed to explore Sections 10.3–10.7 of the procedural content. These sections are about obtaining valid and reliable scientific evidence. These parts of the content may form the contexts for Investigative Skills Assignments (see also Section 18.2).

? The second, shown here, identifies parts of the content which lend themselves to activities which allow Sections 10.2 and 10.8 – 10.9 to be considered. These sections are about using scientific evidence, for example, how scientific evidence can contribute to decision making and how scientific evidence is limited.

Further guidance about the delivery of 'How Science Works' in the context of the substantive content is being prepared for publication in the Teacher's Guide for this specification.

In the written papers, questions will be set which examine the procedural content in the context of the substantive content. Candidates will be required to use their knowledge, understanding and skills in both the procedural and substantive content to respond to questions. In some cases it is anticipated that candidates will use additional information which is given to them, and demonstrate their understanding by applying the principles and concepts in the substantive content to unfamiliar situations.

To compensate for the additional teaching time that will be involved in delivering 'How Science Works', the substantive content sections (Physics 1, Physics 2 and Physics 3) have been substantially reduced compared with the previous specifications.

9.2 Communication Skills

Throughout their GCSE Science course, candidates should be encouraged to develop and improve their scientific communication skills.

These include:

- recalling, analysing, interpreting, applying and questioning scientific information or ideas
- using both qualitative and quantitative approaches
- presenting information, developing an argument and drawing a conclusion, using scientific, technical and mathematical language, conventions and symbols and ICT tools.

These skills will be developed through the activities that candidates undertake during their course, including those required for this specification by the statements at the beginning of each section of the substantive content. Appropriate use of these skills will enable candidates to be successful in the written assessments for this specification.

There is further information in Section 7.4 about scientific communication in assessments, including the use of scientific, technical and mathematical language, conventions and symbols.

9.3 ICT Skills

In undertaking activities to develop their knowledge and understanding of how science works, candidates should be given opportunities to:

- collect data from primary and secondary sources, using ICT sources and tools
- present information, develop arguments and draw conclusions using ICT tools.

Opportunities to use ICT sources and tools occur throughout the content of this specification. They are signposted in Sections 11–13 by the symbol shown, and are listed below under four headings.

- Use the internet (and other primary and secondary sources) to find information or data about:
  - transfer of heat into and out of bodies (Section 11.1)
  - information about efficiency of energy transfers in devices (Section 11.2)
  - comparing different energy sources for electricity generation (Section 11.3)
  - environmental impact of using different energy sources (Section 11.4)
  - hazards of using electromagnetic radiation (Section 11.5)
  - communication using electromagnetic radiation (Section 11.5)
  - reducing exposure to nuclear radiations (Section 11.6)
  - use of radioactive sources as tracers (Section 11.6)
  - using telescopes to observe the universe (Section 11.7)
  - stopping distance of vehicles (Section 12.2)
  - safe discharge of static electricity (Section 12.5)
  - uses of static electricity (Section 12.5)
  - orbital movement of planets and satellites (Section 13.3)
  - use of ultrasound for pre-natal scanning (Section 13.6)
  - uses of transformer (Section 13.9)
- Use sensors and dataloggers to capture data in practical work
  - heat transfer (Section 11.1)
  - describing movement of a body moving in a straight line (Sections 12.1 and 12.2)
  - finding kinetic energy of moving bodies (Section 12.3)
  - potential differences in d.c. and a.c. supplies from oscilloscope traces (Section 12.7)

- Use spreadsheets or databases for data analysis, for modelling or to explore patterns
  - cost effectiveness of methods used to reduce energy consumption (Section 11.2)
- Use electronic resources e.g. software simulations, video clips
  - decay of radioactive materials and half-life (Section 11.6)
  - Doppler effect and red shift in light from distant galaxies (Section 11.7)
  - describing movement of a body in a straight line (Section 12.1 and 12.2)
  - resultant forces (Section 12.2)
  - terminal velocity (Section 12.2)
  - using idea of momentum to explain safety features (Section 12.4)
  - development of nuclear model of atom (Section 12.9)
  - radioactive decay (Section 12.9)
  - chain reactions (Sections 12.10)
  - stability of bodies and toppling (Section 13.1)
  - circular motion and magnitude of centripetal forces (Section 13.2)
  - pitch, loudness and quality of sound (Section 13.5)
  - induced p.d. in coils (Section 13.8)
  - formation and life cycle of stars (Section 13.10)

9.4 Tiering and Subject Content

In this specification there is additional content needed for Higher Tier candidates. Questions in the Higher Tier papers will also be more demanding, allowing candidates to access the higher grades.

HT ❖ Shown like this, HT indicates the additional material needed only by Higher Tier candidates.

10 How Science Works – the Procedural Content

This section contains a statement of the procedural content that candidates need to know and understand in order to be successful in any of the assessment units of this specification. It should be read in conjunction with Sections 11–13, where cross-references to this section have been included to show activities in the context of physics which can be used to develop candidates' skills, knowledge and understanding of how science works.

Candidates should be encouraged to carry out practical work throughout the course and to collect their own data carefully. They should work individually and in groups and should always consider the safety aspects of experimental work.

10.1 The thinking behind the doing

Science attempts to explain the world in which we live. It provides technologies that have had a great impact on our society and the environment. Scientists try to explain phenomena and solve problems using evidence. The data to be used as evidence must be reliable and valid, as only then can appropriate conclusions be made.

A scientifically literate citizen should, amongst other things, be equipped to question, and engage in debate on, the evidence used in decision-making.

The reliability of evidence refers to how much we trust the data. The validity of evidence depends on the reliability of the data, as well as whether the research answers the question. If the data is not reliable the research cannot be valid.

To ensure reliability and validity in evidence, scientists consider a range of ideas which relate to:

- how we observe the world
- designing investigations so that patterns and relationships between variables may be identified
- making measurements by selecting and using instruments effectively
- presenting and representing data
- identifying patterns, relationships and making suitable conclusions.

These ideas inform decisions and are central to science education. They constitute the 'thinking behind the doing' that is a necessary complement to the subject content of biology, chemistry and physics.

The sections below introduce the key ideas relating to evidence that underpin scientific practice.

10.2 Fundamental ideas

Evidence must be approached with a critical eye. It is necessary to look closely at how measurements have been made and what links have been established. Scientific evidence provides a powerful means of forming opinions. These ideas pervade all of 'How Science Works'.

Candidates should know and understand

- It is necessary to distinguish between opinion based on valid and reliable evidence and opinion based on non-scientific ideas (prejudices, whim or hearsay).
- Continuous variables (any numerical values, eg weight, length or force) give more information than ordered variables (eg small, medium or large lumps) which are more informative than categoric variables (eg names of metals). A variable may also be discrete, that is, restricted to whole numbers (eg the number of layers of insulation).
- Scientific investigations often seek to identify links between two or more variables. These links may be:
  - causal, in that a change in one variable causes a change in another
  - due to association, in that changes in one variable and a second variable are linked by a third variable (eg an association noted between soil acidity and crop growth may be the effect of a third variable, fertiliser type and quantity, on both)
  - due to chance occurrence (eg increase in the early 20th century in radio use was accompanied by an increase in mental illness).
- Evidence must be looked at carefully to make sure that it is:
  - reliable, ie it can be reproduced by others
  - valid, ie it is reliable *and* answers the original question.

10.3 Observation as a stimulus to investigation

Observation is the link between the real world and scientific ideas. When we observe objects, organisms or events we do so using existing knowledge. Observations may suggest hypotheses and lead to predictions that can be tested.

Candidates should know and understand

- Observing phenomena can lead to the start of an investigation, experiment or survey. Existing theories and models can be used creatively to suggest explanations for phenomena (hypotheses). Careful observation is necessary before deciding which are the most important variables. Hypotheses can then be used to make predictions that can be tested. An example is the observation that shrimp only occur in parts of a stream. Knowledge about shrimp and water flow leads to a hypothesis relating the distribution to the stream flow rate. A prediction leads to a survey that looks at both variables.
- Data from testing a prediction can support or refute the hypothesis or lead to a new hypothesis. For example, the data from the shrimp survey could suggest that, at slow flow rates, oxygen availability might determine abundance.
- If the theories and models we have available to us do not completely match our data or observations, we need to check the validity of our observations or data, or amend the theories or models.

10.4 Designing an investigation

An investigation is an attempt to determine whether or not there is a relationship between variables. Therefore it is necessary to identify and understand the variables in an investigation. The design of an investigation should be scrutinised when evaluating the validity of the evidence it has produced.

Candidates should know and understand

- An independent variable is one that is changed or selected by the investigator. The dependent variable is measured for each change in the independent variable.
- Any measurement must be valid in that it measures only the appropriate variable, for instance colour change in a pH indicator to measure respiration in woodlice could be affected by their excretion.

Fair Test

- It is important to isolate the effects of the independent variable on the dependent variable. This may be achieved more easily in a laboratory environment than in the field, where it is harder to control all variables.
- A fair test is one in which only the independent variable affects the dependent variable, as all other variables are kept the same.
- In field investigations it is necessary to ensure that variables that change their value do so in the same way for all measurements of the dependent variable (eg in a tomato growth trial, all plants are subject to the same weather conditions).
- When using large-scale survey results, it is necessary to select data from conditions that are similar (eg if a study is to survey the effect of age on blood pressure, a group of people with approximately the same diet or weight could be used).
- Control groups are often used in biological and medical research to ensure that observed effects are due to changes in the independent variable alone (eg in drug experiments, a placebo drug is used as a control).

Choosing values of a variable

- Care is needed in selecting values of variables to be recorded in an investigation. A trial run will help identify appropriate values to be recorded, such as the number of repeated readings needed and their range and interval. For example, in an investigation of the effect of temperature on enzyme activity it is necessary to:
  - use a sufficient amount of enzyme so that its activity can be detected
  - use a sensible range of temperatures
  - have readings ‘closer together’ (at smaller intervals) where a change in pattern is detected.

Accuracy and precision.

- Readings should be repeated to improve the reliability of the data. An accurate measurement is one which is close to the true value.
- The design of an investigation must provide data with sufficient accuracy. For example, measures of blood alcohol levels must be accurate enough to be able to determine whether the person is legally fit to drive.
- The design of an investigation must provide data with sufficient precision to form a valid conclusion. For example, in an investigation into the bounce of different balls, less precision is needed to tell if a tennis ball bounces higher than a squash ball than if you wanted to distinguish between the bounce of two very similar tennis balls.

10.5 Making measurements

When making measurements we must consider such issues as inherent variation due to variables that have not been controlled, human error and the characteristics of the instruments used. Evidence should be evaluated with the reliability and validity of the measurements that have been made in mind.

A single measurement

- There will always be some variation in the actual value of a variable no matter how hard we try to repeat an event. For instance, if a ball is dropped and doesn't land on exactly the same point on its surface there will be a slight difference in the rebound height.
- When selecting an instrument, it is necessary to consider the accuracy inherent in the instrument and the way it has to be used. For example, expensive thermometers are likely to give a reading nearer to the true reading and to be more accurately calibrated.
- The sensitivity of an instrument refers to the smallest change in a value that can be detected. For example, bathroom scales are not sensitive enough to detect the weekly changes in the mass of a baby, whereas scales used by a midwife are sensitive enough to permit a growth chart to be plotted.
- Even when an instrument is used correctly, human error may occur which could produce random differences in repeated readings or a systematic shift from the true value which could, for instance, occur due to incorrect use or poor calibration.
- Random error can result from inconsistent application of a technique. Systematic error can result from consistent misapplication of a technique.
- Any anomalous values should be examined to try and identify the cause and, if a product of a poor measurement, ignored.

10.6 Presenting data

To explain the relationship between two or more variables, data may be presented in such a way as to make the patterns more evident. There is a link between the type of graph used and the type of variable represented. The choice of graphical representation depends upon the type of variable they represent.

Candidates should know and understand

- The range of the data refers to the maximum and minimum values.
- The mean (or average) of the data refers to the sum of all the measurements divided by the number of measurements taken.
- Tables are an effective means of displaying data but are limited in how they portray the design of an investigation,
- Bar charts can be used to display data in which the independent variable is categoric and the dependent variable continuous.
- Line graphs can be used to display data in which both the independent and dependent variables are continuous.
- Scattergrams can be used to show an association between two variables (eg water content of soil and height of plants).

10.7 Using data to draw conclusions

The patterns and relationships observed in data represent the behaviour of the variables in an investigation. However, it is necessary to look at patterns and relationships between variables with the limitations of the data in mind in order to draw conclusions.

Candidates should know and understand

- Patterns in tables and graphs can be used to identify anomalous data that require further consideration.
- A line of best fit can be used to illustrate the underlying relationship between variables.
- The relationships that exist between variables can be linear (positive or negative, eg height of wax remaining in a candle and time it has been burning) or directly proportional (eg extension of a spring and applied force). On a graph, the relationship could show as a curve (eg velocity against time for a falling object).
- Conclusions must be limited by the data available and not go beyond them. For example, the beneficial effects of a new drug may be limited to the sample used in the tests (younger men perhaps) and not the entire population.

Evaluation

- In evaluating a whole investigation the reliability and validity of the data obtained must be considered. The reliability of an investigation can be increased by looking at data obtained from secondary sources, through using an alternative method as a check and by requiring that the results are reproducible by others.

10.8 Societal aspects of scientific evidence

A judgement or decision relating to social-scientific issues may not be based on evidence alone, as other societal factors may be relevant.

Candidates should know and understand

- The credibility of the evidence is increased if a balanced account of the data is used rather than a selection from it which supports a particular pre-determined stance.
- Evidence must be scrutinised for any potential bias of the experimenter, such as funding sources or allegiances.
- Evidence can be accorded undue weight, or dismissed too lightly, simply because of its political significance. If the consequences of the evidence might provoke public or political disquiet, the evidence may be downplayed.
- The status of the experimenter may influence the weight placed on evidence; for instance, academic or professional status, experience and authority. It is more likely that the advice of an eminent scientist will be sought to help provide a solution to a problem than that of a scientist with less experience.
- Scientific knowledge gained through investigations can be the basis for technological developments.
- Scientific and technological developments offer different opportunities for exploitation to different groups of people.
- The uses of science and technology developments can raise ethical, social, economic and environmental issues.
- Decisions are made by individuals and by society on issues relating to science and technology.

10.9 Limitations of scientific evidence

Science can help us in many ways but it cannot supply all the answers.

We are still finding out about things and developing our scientific knowledge. There are some questions that we cannot answer, maybe because we do not have enough reliable and valid evidence. For example, it is generally accepted that the extra carbon dioxide in the air (from burning fossil fuels) is linked to global warming, but some scientists think there is not sufficient evidence and that there are other factors involved.

And there are some questions that science cannot answer at all. These tend to be questions where beliefs and opinions are important or where we cannot collect reliable and valid scientific evidence. For example, science may be able to answer questions that start 'How can we ..' such as 'How can we clone babies?' but questions starting 'Should we ..' such as 'Should we clone babies?' are for society to answer.

11 Unit Physics 1

At the beginning of each sub-section, activities are stated which develop candidates' skills, knowledge and understanding of how science works. Details are then given of the substantive contexts in which these skills, knowledge and understanding should be set. It is expected that, where appropriate, teachers will adopt a practical approach enabling candidates to develop skills in addition to procedural knowledge and understanding.

Note that objective test Physics 1a examines Sections 11.1 – 11.4 and objective test Physics 1b examines Sections 11.5 – 11.7.

11.1 How is heat (thermal energy) transferred and what factors affect the rate at which heat is transferred?

Sometimes we want to transfer heat effectively from one place to another. At other times we want to reduce the rate of heat loss as much as we can. To be able to do either of these things we need to know how heat is transferred and which methods of heat transfer are most important in particular cases.

Candidates should use their skills, knowledge and understanding of how science works:

- to evaluate ways in which heat is transferred in and out of bodies and ways in which the rates of these transfers can be reduced.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Thermal (infra red) radiation is the transfer of energy by electromagnetic waves.
- All bodies emit and absorb thermal radiation.
- The hotter a body is the more energy it radiates.
- Dark, matt surfaces are good absorbers and good emitters of radiation.
- Light, shiny surfaces are poor absorbers and poor emitters of radiation.
- The transfer of energy by conduction and convection involves particles and how this transfer takes place.
- Under similar conditions different materials transfer heat at different rates.
- The shape and dimensions of a body affect the rate at which it transfers heat.
- The bigger the temperature difference between a body and its surroundings, the faster the rate at which heat is transferred.

11.2 What is meant by the efficient use of energy?

Many devices take in input energy in one form and transform (change) it to output energy in another form. They never transform all of the input energy to the output form we want or transfer (move) it all to the place we want. We need to know how efficient devices are so that we can choose between them and try to improve them.

Candidates should use their skills, knowledge and understanding of how science works:

- to describe the intended energy transfers/transformations and the main energy wastages that occur with a range of devices
- to calculate the efficiency of a device using:

$$\text{efficiency} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}$$

- to evaluate the effectiveness and cost effectiveness of methods used to reduce energy consumption.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Energy cannot be created or destroyed. It can only be transformed from one form to another form.
- When energy is transferred and/or transformed only part of it may be usefully transferred/transformed.
- Energy which is not transferred/transformed in a useful way is 'wasted.'
- Both wasted energy and the energy which is usefully transferred/transformed are eventually transferred to their surroundings which become warmer.
- Energy becomes increasingly spread out and becomes increasingly more difficult to use for further energy transformations.
- The greater the percentage of the energy that is usefully transformed in a device, the more efficient the device is.

11.3 Why are electrical devices so useful?

We often use electrical devices because they transform electrical energy to whatever form of energy we need at the flick of a switch.

Candidates should use their skills, knowledge and understanding of how science works:

- to compare and contrast the particular advantages and disadvantages of using different electrical devices for a particular application
- to calculate the amount of energy transferred from the mains using:

$$\underset{\text{(kilowatt-hour, kWh)}}{\text{energy transferred}} = \underset{\text{(kilowatt, kW)}}{\text{power}} \times \underset{\text{(hour, h)}}{\text{time}}$$

- to calculate the cost of energy transferred from the mains using:

$$\text{total cost} = \text{number of kilowatt-hours} \times \text{cost per kilowatt-hour}$$

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Examples of energy transformations that everyday electrical devices are designed to bring about.
- Examples of everyday electrical devices designed to bring about particular energy transformations.

- The amount of electrical energy a device transforms depends on how long the appliance is switched on and the rate at which the device transforms energy.
- The power of an appliance is measured in watts (W) or kilowatts (kW).
- Energy is normally measured in joules (J).
- Electricity is transferred from power station to consumers along the National Grid.
- The uses of step-up and step-down transformers in the National Grid.
- Increasing voltage (potential difference) reduces current, and hence reduces energy losses in the cables.

11.4 How should we generate the electricity we need?

Various energy sources can be used to generate the electricity we need. We must carefully consider the advantages and disadvantages of using each energy source before deciding which energy source(s) it would be best to use in any particular situation.

Candidates should use their skills, knowledge and understanding of how science works:

- to compare and contrast the particular advantages and disadvantages of using different energy sources to generate electricity.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- In most power stations an energy source is used to heat water. The steam produced drives a turbine which is coupled to an electrical generator.
- Common energy sources include coal, oil and gas, which are burned to produce heat and uranium/plutonium, in which nuclear fission produces heat.
- Energy from renewable energy sources can be used to drive turbines directly.
- Renewable energy sources used in this way include wind, the rise and fall of water due to waves and tides, and the falling of water in hydroelectric schemes.
- Electricity can be produced directly from the Sun's radiation using solar cells.
- In some volcanic areas hot water and steam rise to the surface. The steam can be tapped and used to drive turbines. This is known as geothermal energy.
- Using different energy resources has different effects on the environment. These effects include the release of substances into the atmosphere, noise and visual pollution, and the destruction of wildlife habitats.

- The advantages and disadvantages of using fossil fuels, nuclear fuels and renewable energy sources to generate electricity. These include the cost of building power stations, the start-up time of power stations, the reliability of the energy source, the relative cost of energy generated and the location in which the energy is needed.

11.5 What are the uses and hazards of the waves that form the electromagnetic spectrum?

Electromagnetic radiations are disturbances in an electric field. They travel as waves and move energy from one place to another. They can all travel through a vacuum and do so at the same speed. The waves cover a continuous range of wavelengths called the electromagnetic spectrum. The uses and hazards of the radiations in different parts of the electromagnetic spectrum depend on their wavelength and frequency.

Candidates should use their skills, knowledge and understanding of how science works:

- to evaluate the possible hazards associated with the use of different types of electromagnetic radiation
- to evaluate methods to reduce exposure to different types of electromagnetic radiation.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Electromagnetic radiation travels as waves and moves energy from one place to another.
- All types of electromagnetic waves travel at the same speed through a vacuum (space).
- The electromagnetic spectrum is continuous but the wavelengths within it can be grouped into types of increasing wavelength and decreasing frequency:
  - gamma rays, X-rays, ultraviolet rays, visible light, infra red rays, microwaves and radio waves.
- Different wavelengths of electromagnetic radiation are reflected, absorbed or transmitted differently by different substances and types of surface.
- When radiation is absorbed the energy it carries makes the substance which absorbs it hotter and may create an alternating current with the same frequency as the radiation itself.
- Different wavelengths of electromagnetic radiation have different effects on living cells. Some radiations mostly pass through soft tissue without being absorbed, some produce heat, some may cause cancerous changes and some may kill cells. These effects depend on the type of radiation and the size of the dose.
- The uses and the hazards associated with the use of each type of radiation in the electromagnetic spectrum.
- Radio waves, microwaves, infra red and visible light can be used for communication.
- Microwaves can pass through the Earth's atmosphere and are used to send information to and from satellites and within mobile phone networks.

- Infra red and visible light can be used to send signals along optical fibres and so travel in curved paths.
- Communication signals may be analogue (continuously varying) or digital (discrete values only, generally on and off). Digital signals are less prone to interference than analogue and can be easily processed by computers.
- Electromagnetic waves obey the wave formula:

wave speed (metre/second, m/s)	=	frequency (hertz, Hz)	×	wavelength (metre, m)

11.6 What are the uses and dangers of emissions from radioactive substances?

Radioactive substances emit radiation from the nuclei of their atoms all the time. These nuclear radiations can be very useful but may also be very dangerous. It is important to understand the properties of different types of nuclear radiation.

Candidates should use their skills, knowledge and understanding of how science works:

- to evaluate the possible hazards associated with the use of different types of nuclear radiation
- to evaluate measures that can be taken to reduce exposure to nuclear radiations
- to evaluate the appropriateness of radioactive sources for particular uses, including as tracers, in terms of the type(s) of radiation emitted and their half-lives.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The basic structure of an atom is a small central nucleus composed of protons and neutrons surrounded by electrons.
- The atoms of an element always have the same number of protons, but have a different number of neutrons for each isotope.
- Some substances give out radiation from the nuclei of their atoms all the time, whatever is done to them. These substances are said to be radioactive.
- Identification of an alpha particle as a helium nucleus, a beta particle as an electron from the nucleus and gamma radiation as electromagnetic radiation.
- Properties of the alpha, beta and gamma radiations limited to their relative ionising power, their penetration through materials and their range in air.
- Alpha and beta radiations are deflected by both electric and magnetic fields but gamma radiation is not.
- The uses of and the dangers associated with each type of nuclear radiation.
- The half-life of a radioactive isotope is defined as the time it takes for the number of nuclei of the isotope in a sample to halve or the time it takes for the count rate from a sample containing the isotope to fall to half its initial level.

11.7 What do we know about the origins of the Universe and how it continues to change?

Current evidence suggests that the universe is expanding and that matter and space expanded violently and rapidly from a very small initial 'point' i.e. the universe began with a 'big bang'.

Candidates should use their skills, knowledge and understanding of how science works:

- to compare and contrast the particular advantages and disadvantages of using different types of telescope on Earth and in space to make observations on and deductions about the universe.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- If a wave source is moving relative to an observer there will be a change in the observed wavelength and frequency.
- There is a red-shift in light observed from most distant galaxies. The further away galaxies are the bigger the red-shift.
- How the observed red-shift provides evidence that the universe is expanding and supports the 'big bang' theory (that the universe began from a very small initial point).
- Observations of the solar system and the galaxies in the universe can be carried out on the Earth or from space.
- Observations are made with telescopes that may detect visible light or other electromagnetic radiations such as radio waves or X-rays.

12 Unit Physics 2

At the beginning of each sub-section, activities are stated which develop candidates' skills, knowledge and understanding of how science works. Details are then given of the substantive contexts in which these skills, knowledge and understanding should be set. It is expected that, where appropriate, teachers will adopt a practical approach enabling candidates to develop skills in addition to procedural knowledge and understanding.

12.1 How can we describe the way things move?

Even when things are moving in a straight line, describing their movement is not easy. They can move with different speeds and can also change their speed and/or direction (accelerate). Graphs can help us to describe the movement of the body. These may be distance-time graphs or velocity-time graphs.

Candidates should use their skills, knowledge and understanding of how science works:

- to construct distance-time graphs for a body moving in a straight line when the body is stationary or moving with a constant speed
- to construct velocity-time graphs for a body moving with a constant velocity or a constant acceleration
- HT ❖ to calculate the speed of a body from the slope of a distance-time graph
- HT ❖ to calculate the acceleration of a body from the slope of a velocity-time graph
- HT ❖ to calculate the distance travelled by a body from a velocity-time graph.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The slope of a distance-time graph represents speed.
- The velocity of a body is its speed in a given direction.
- The acceleration of a body is given by:

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

- The slope of a velocity-time graph represents acceleration.
- The area under a velocity-time graph represents distance travelled.

12.2 How do we make things speed up or slow down?

To change the speed of a body an unbalanced force must act on it.

Candidates should use their skills, knowledge and understanding of how science works:

- to draw and interpret velocity-time graphs for bodies that reach terminal velocity, including a consideration of the forces acting on the body
- to calculate the weight of a body using:

$$\underset{(\text{newton, N})}{\text{weight}} = \underset{(\text{kilogram, kg})}{\text{mass}} \times \underset{(\text{newton/kilogram, N/kg})}{\text{gravitational field strength}}$$

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Whenever two bodies interact, the forces they exert on each other are equal and opposite.
- A number of forces acting on a body may be replaced by a single force which has the same effect on the body as the original forces all acting together. The force is called the resultant force.
- If the resultant force acting on a stationary body is zero the body will remain stationary.
- If the resultant force acting on a stationary body is not zero the body will accelerate in the direction of the resultant force.
- If the resultant force acting on a moving body is zero the body will continue to move at the same speed and in the same direction.
- If the resultant force acting on a moving body is not zero the body will accelerate in the direction of the resultant force.
- Force, mass and acceleration are related by the equation:

resultant force	=	mass	×	acceleration
(newton, N)		(kilogram, kg)		(metre/second^2, m/s^2)

- When a vehicle travels at a steady speed the frictional forces balance the driving force.
- The greater the speed of a vehicle the greater the braking force needed to stop it in a certain distance.
- The stopping distance of a vehicle depends on the distance the vehicle travels during the driver's reaction time and the distance it travels under the braking force.
- A driver's reaction time can be affected by tiredness, drugs and alcohol.
- A vehicle's braking distance can be affected by adverse road and weather conditions and poor condition of the vehicle.
- The faster a body moves through a fluid the greater the frictional force which acts on it.
- A body falling through a fluid will initially accelerate due to the force of gravity. Eventually the resultant force on the body will be zero and it will fall at its terminal velocity.

12.3 What happens to the movement energy when things speed up or slow down?

When a body speeds up or slows down, its kinetic energy increases or decreases. The forces which cause the change in speed do so by transferring energy to, or from, the body.

Candidates should use their skills, knowledge and understanding of how science works:

- to discuss the transformation of kinetic energy to other forms of energy in particular situations.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- When a force causes a body to move through a distance, energy is transferred and work is done.
- Work done = energy transferred.
- The amount of work done, force and distance are related by the equation:

work done (joule, J) = force applied (newton, N) × distance moved in direction of force (metre, m)

- Work done against frictional forces is mainly transformed into heat.
- For an object that is able to recover its original shape, elastic potential is the energy stored in the object when work is done on the object to change its shape.
- The kinetic energy of a body depends on its mass and its speed.

HT ❖ Calculate the kinetic energy of a body using the equation:

kinetic energy (joule, J) = ½ × mass (kilogram, kg) × speed^2 ((metre/second)^2, (m/s)^2)

12.4 What is momentum?

The faster a body is moving the more kinetic energy it has. It also has momentum. When working out what happens to bodies as a result of explosions or collisions it is more useful to think in terms of momentum than in terms of energy.

Candidates should use their skills, knowledge and understanding of how science works:

- to use the conservation of momentum (in one dimension) to calculate the mass, velocity or momentum of a body involved in a collision or explosion
- to use the ideas of momentum to explain safety features.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Momentum, mass and velocity are related by the equation:

momentum (kilogram metre/second, kg m/s) = mass (kilogram, kg) × velocity (metre/second, m/s)

- Momentum has both magnitude and direction.
- When a force acts on a body that is moving, or able to move, a change in momentum occurs.
- Momentum is conserved in any collision/explosion provided no external forces act on the colliding/exploding bodies.

HT ❖ Force, change in momentum and time taken for the change are related by the equation:

$$\text{force (newton, N)} = \frac{\text{change in momentum (kilogram metre/second, kg(m/s))}}{\text{time taken for the change (second, s)}}$$

12.5 What is static electricity, how can it be used and what is the connection between static electricity and electric currents?

Static electricity can be explained in terms of electrical charges. When electrical charges move we get an electric current.

Candidates should use their skills, knowledge and understanding of how science works:

- to explain why static electricity is dangerous in some situations and how precautions can be taken to ensure that the electrostatic charge is discharged safely
- to explain how static electricity can be useful.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- When certain insulating materials are rubbed against each other they become electrically charged. Negatively charged electrons are rubbed off one material onto the other.
- The material that gains electrons becomes negatively charged. The material that loses electrons is left with an equal positive charge.
- When two electrically charged bodies are brought together they exert a force on each other.
- Two bodies that carry the same type of charge repel. Two bodies that carry different types of charge attract.
- Electrical charges can move easily through some substances, eg metals.
- The rate of flow of electrical charge is called the current.
- A charged body can be discharged by connecting it to earth with a conductor. Charge then flows through the conductor.

HT ❖ The greater the charge on an isolated body the greater the potential difference between the body and earth. If the potential difference becomes high enough a spark may jump across the gap between the body and any earthed conductor which is brought near it.

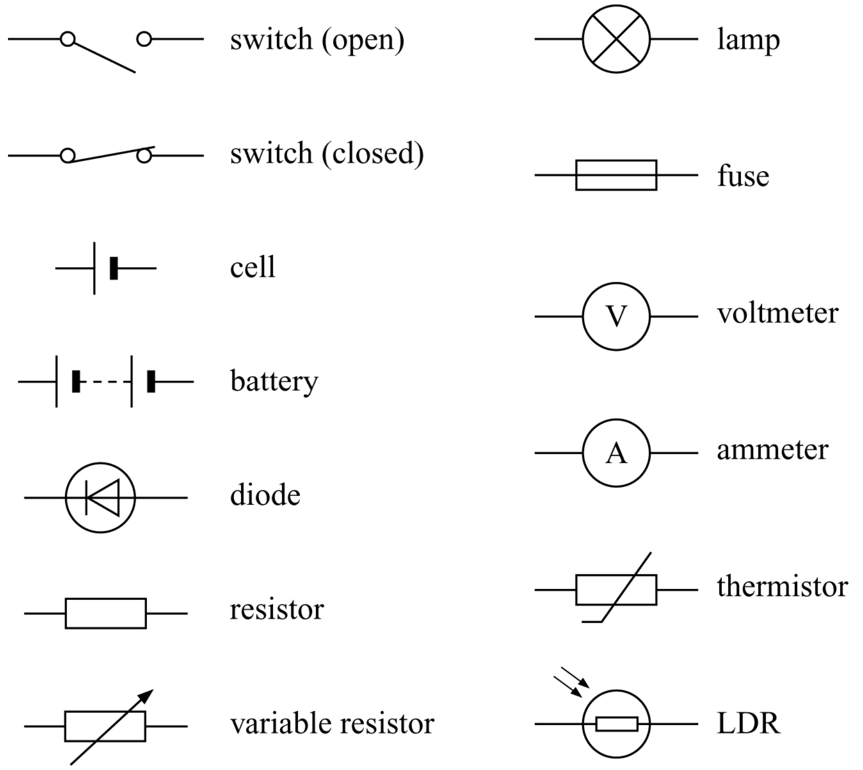
- Electrostatic charges can be useful, for example in photocopiers and smoke precipitators and the basic operation of these devices.

12.6 What does the current through an electrical circuit depend on?

The size of the current in a circuit depends on how hard the supply tries to push charge through the circuit and how hard the circuit resists having charge pushed through it.

Candidates should use their skills, knowledge and understanding of how science works:

- to interpret and draw circuit diagrams using standard symbols. The following standard symbols should be known:

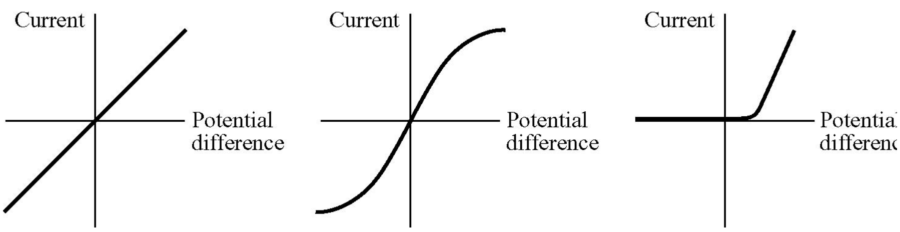


- to apply the principles of basic electrical circuits to practical situations.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Current-potential difference graphs are used to show how the current through a component varies with the potential difference across it.

A resistor at constant temperature | A filament lamp | A diode



- The current through a resistor (at a constant temperature) is directly proportional to the potential difference across the resistor.
- Potential difference, current and resistance are related by the equation:

potential difference (volt, V) = current (ampere, A) × resistance (ohm, Ω)

- The resistance of a component can be found by measuring the current through, and potential difference across, the component.

- The resistance of a filament lamp increases as the temperature of the filament increases.
- The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction.
- The resistance of a light-dependent resistor (LDR) decreases as light intensity increases.
- The resistance of a thermistor decreases as the temperature increases (ie knowledge of negative temperature coefficient thermistor only is required).
- The current through a component depends on its resistance. The greater the resistance the smaller the current for a given potential difference across the component.
- The potential difference provided by cells connected in series is the sum of the potential difference of each cell (depending on the direction in which they are connected).
- For components connected in series:
  - the total resistance is the sum of the resistance of each component
  - there is the same current through each component
  - the total potential difference of the supply is shared between the components.
- For components connected in parallel:
  - the potential difference across each component is the same
  - the total current through the whole circuit is the sum of the currents through the separate components.

12.7 What is mains electricity and how can it be used safely?

Mains electricity is useful but can be very dangerous. It is important to know how to use it safely.

Candidates should use their skills, knowledge and understanding of how science works:

- to recognise errors in the wiring of a three-pin plug
- to recognise dangerous practice in the use of mains electricity
- to compare potential differences of d.c. supplies and the peak potential differences of a.c. supplies from diagrams of oscilloscope traces

HT ❖ to determine the period and hence the frequency of a supply from diagrams of oscilloscope traces.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Cells and batteries supply current which always passes in the same direction. This is called direct current (d.c.).
- An alternating current (a.c.) is one which is constantly changing direction. Mains electricity is an a.c. supply. In the UK it has a frequency of 50 cycles per second (50 hertz).
- UK mains supply is about 230 volts.
- Most electrical appliances are connected to the mains using cable and a three-pin plug.

- The structure of electrical cable.
- The structure of a three-pin plug.
- Correct wiring of a three-pin plug.
- If an electrical fault causes too great a current the circuit should be switched off by a fuse or a circuit breaker.
- When the current in a fuse wire exceeds the rating of the fuse it will melt, breaking the circuit.
- Appliances with metal cases are usually earthed.
- The earth wire and fuse together protect the appliance and the user.

HT ❖ The live terminal of the mains supply alternates between positive and negative potential with respect to the neutral terminal.

HT ❖ The neutral terminal stays at a potential close to zero with respect to earth.

12.8 Why do we need to know the power of electrical appliances?

Electrical appliances transform energy. The power of an electrical appliance is the rate at which it transforms energy. Most appliances have their power and the potential difference of the supply they need printed on them. From this we calculate their current and the fuse they need.

Candidates should use their skills, knowledge and understanding of how science works:

- to calculate the current through an appliance from its power and the potential difference of the supply and from this determine the size of fuse needed.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Electric current is the rate of flow of charge.
- When an electrical charge flows through a resistor, electrical energy is transformed into heat energy.
- The rate at which energy is transformed in a device is called the power.

$$\underset{\text{(watt, W)}}{\text{power}} = \frac{\text{energy transformed (joule, J)}}{\text{time (second, s)}}$$

- Power, potential difference and current are related by the equation:

$$\underset{\text{(watt, W)}}{\text{power}} = \underset{\text{(ampere, A)}}{\text{current}} \times \underset{\text{(volt, V)}}{\text{potential difference}}$$

HT ❖ Energy transformed, potential difference and charge are related by the equation:

$$\underset{\text{(joule, J)}}{\text{energy transformed}} = \underset{\text{(volt, V)}}{\text{potential difference}} \times \underset{\text{(coulomb, C)}}{\text{charge}}$$

HT ❖ The amount of electrical charge that flows is related to current and time by the equation:

$$\underset{\text{(coulomb, C)}}{\text{charge}} = \underset{\text{(ampere, A)}}{\text{current}} \times \underset{\text{(second, s)}}{\text{time}}$$

12.9 What happens to radioactive substances when they decay?

To understand what happens to radioactive substances when they decay we need to understand the structure of the atoms from which they are made.

Candidates should use their skills, knowledge and understanding of how science works: HT

❖ to explain how the Rutherford and Marsden scattering experiment led to the 'plum pudding' model of the atom being replaced by the nuclear model.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The relative masses and relative electric charges of protons, neutrons and electrons.
- In an atom the number of electrons is equal to the number of protons in the nucleus. The atom has no net electrical charge.
- Atoms may lose or gain electrons to form charged particles called ions.
- All atoms of a particular element have the same number of protons.
- Atoms of different elements have different numbers of protons.
- Atoms of the same element which have different numbers of neutrons are called isotopes.
- The total number of protons in an atom is called its atomic number.
- The total number of protons and neutrons in an atom is called its mass number.
- The effect of alpha and beta decay on radioactive nuclei.
- The origins of background radiation.

12.10 What are nuclear fission and nuclear fusion?

Nuclear fission is the splitting of atomic nuclei and is used in nuclear reactors as a source of heat energy which can be transformed to electrical energy. Nuclear fusion is the joining together of atomic nuclei and is the process by which energy is released in stars.

Candidates should use their skills, knowledge and understanding of how science works:

- to sketch a labelled diagram to illustrate how a chain reaction may occur.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- There are two fissionable substances in common use in nuclear reactors, uranium 235 and plutonium 239.
- Nuclear fission is the splitting of an atomic nucleus.
- For fission to occur the uranium 235 or plutonium 239 nucleus must first absorb a neutron
- The nucleus undergoing fission splits into two smaller nuclei and 2 or 3 neutrons and energy is released.
- The neutrons may go on to start a chain reaction.
- Nuclear fusion is the joining of two atomic nuclei to form a larger one.
- Nuclear fusion is the process by which energy is released in stars.

13 Unit Physics 3

At the beginning of each sub-section, activities are stated which develop candidates' skills, knowledge and understanding of how science works. Details are then given of the substantive contexts in which these skills, knowledge and understanding should be set. It is expected that, where appropriate, teachers will adopt a practical approach enabling candidates to develop skills in addition to procedural knowledge and understanding.

13.1 How do forces have a turning effect?

Even if the forces acting on a body are balanced in the sense that they do not cause the body to change speed, they can still make the body turn.

Candidates should use their skills, knowledge and understanding of how science works:

- to describe how to find the centre of mass of a thin sheet of a material
- HT ❖ to calculate the size of a force, or its distance from an axis of rotation, acting on a body that is balanced
- HT ❖ to analyse the stability of bodies by considering their tendency to topple.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The turning effect of a force is called the moment.
- The size of the moment is given by the equation:

moment (newton metre, Nm) = force (newton, N) × perpendicular distance from the line of action of the force to the axis of rotation (metre, m)

- The centre of mass of a body is that point at which the mass of the body may be thought to be concentrated.
- If suspended, a body will come to rest with its centre of mass directly below the point of suspension.
- The centre of mass of a symmetrical body is along the axis of symmetry.
- HT ❖ If a body is not turning, the total clockwise moment must be exactly balanced by the total anticlockwise moment about any axis.
- HT ❖ Recognise the factors that affect the stability of a body.
- HT ❖ If the line of action of the weight of a body lies outside the base of the body there will be a resultant moment and the body will tend to topple.

13.2 What keeps bodies moving in a circle?

A body remains stationary, or keeps moving at the same speed in a straight line, unless an unbalanced force acts upon it. If a body moves in a circular path there must be an unbalanced force acting upon it all the time.

Candidates should use their skills, knowledge and understanding of how science works:

- to identify which force(s) provide(s) the centripetal force in a given situation
- to interpret data on bodies moving in circular paths.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- When a body moves in a circle it continuously accelerates towards the centre of the circle. This acceleration changes the direction of motion of the body, not its speed.
- The resultant force causing this acceleration is called the centripetal force.
- The direction of the centripetal force is always towards the centre of the circle.
- The centripetal force needed to make a body perform circular motion increases as:
  - the mass of the body increases;
  - the speed of the body increases;
  - the radius of the circle decreases.

13.3 What provides the centripetal force for planets and satellites?

The planets, like the Earth, orbit the Sun. Artificial satellites, which are used for communications and monitoring, orbit the Earth. Gravitational force provides the centripetal force that allows all of these bodies to orbit.

Candidates should use their skills, knowledge and understanding of how science works:

- to interpret data on planets and satellites moving in orbits that approximate to circular paths.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The Earth, Sun, Moon and all other bodies attract each other with a force called gravity.
- The bigger the masses of the bodies the bigger the force of gravity between them.
- As the distance between two bodies increases the force of gravity between them decreases.
- The orbit of any planet is an ellipse (slightly squashed circle), with the Sun at one focus.
- Gravitational force provides the centripetal force that allows planets and satellites to maintain their circular orbits.
- The further away an orbiting body is the longer it takes to make a complete orbit.
- To stay in orbit at a particular distance, smaller bodies, including planets and satellites, must move at a particular speed around larger bodies.
- Communications satellites are usually put into a geostationary orbit above the equator.

- Monitoring satellites are usually put into a low polar orbit.

13.4 What do mirrors and lenses do to light?

Mirrors and lenses can be used to form images in optical devices such as cameras and magnifying glasses. The most commonly used mirrors and lenses have surfaces with a uniform curvature and these are the only ones which need to be considered. All objects and images will be located vertically on the principal axis.

Candidates should use their skills, knowledge and understanding of how science works:

- to construct ray diagrams to show the formation of images by plane, convex and concave mirrors
- to construct ray diagrams to show the formation of images by diverging lenses and converging lenses
- to explain the use of a converging lens as a magnifying glass and in a camera
- to calculate the magnification produced by a lens or mirror using the formula:

$$\text{magnification} = \frac{\text{image height}}{\text{object height}}$$

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The normal is a construction-line perpendicular to the reflecting/refracting surface at the point of incidence.
- The angle of incidence is equal to the angle of reflection.
- The nature of an image is defined by its size relative to the object, whether it is upright or inverted relative to the object and whether it is real or virtual.
- The nature of the image produced by a plane mirror.
- The nature of the image produced by a convex mirror.
- The nature of the image produced by a concave mirror for an object placed at different distances from the mirror.
- Refraction at an interface.
- Refraction by a prism.
- The nature of the image produced by a diverging lens.
- The nature of the image produced by a converging lens for an object placed at different distances from the lens.
- The use of a converging lens in a camera to produce an image of an object on a detecting device (eg film).

13.5 What is sound?

Sounds are mechanical vibrations that can be detected by the human ear. This means they are in the frequency range 20-20 000 Hz.

Candidates should use their skills, knowledge and understanding of how science works:

- to compare the amplitudes and frequencies of sounds from diagrams of oscilloscope traces.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Sound is caused by mechanical vibrations and travels as a wave.
- Sounds in the range 20-20 000 Hz can be detected by the human ear.
- Sound cannot travel through a vacuum.
- The pitch of a note increases as the frequency increases.
- The loudness of a note increases as the amplitude of the wave increases.
- The quality of a note depends upon the waveform.
- Sound waves can be reflected and refracted.

13.6 What is ultrasound and how can it be used?

Just as there is electromagnetic radiation with frequencies we cannot see, there are "sound" waves with frequencies we cannot hear. These ultrasound waves have several important uses.

Candidates should use their skills, knowledge and understanding of how science works:

- to compare the amplitudes and frequencies of ultrasounds from diagrams of oscilloscope traces

HT ❖ to determine the distance between interfaces in various media from diagrams of oscilloscope traces.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Electronic systems can be used to produce ultrasound waves which have a frequency higher than the upper limit of hearing for humans.
- Ultrasound waves are partially reflected when they meet a boundary between two different media. The time taken for the reflections to reach a detector is a measure of how far away such a boundary is.
- Ultrasound waves can be used in industry for cleaning and quality control.
- Ultrasound waves can be used in medicine for pre-natal scanning.

13.7 How can electricity be used to make things move?

Electric currents produce magnetic fields. Forces produced in magnetic fields can be used to make things move. This is called the motor effect and is how devices such as the electric motor create movement.

Candidates should use their skills, knowledge and understanding of how science works:

- to explain how the motor effect is used in simple devices.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- When a conductor carrying an electric current is placed in a magnetic field, it may experience a force.
- The size of the force can be increased by:
  - increasing the strength of the magnetic field
  - increasing the size of the current.

- The conductor will not experience a force if it is parallel to the magnetic field.
- The direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed.

13.8 How do generators work?

If an electrical conductor 'cuts' through magnetic field lines, an electrical potential difference is induced across the ends of the conductor. This is called the generator effect and is used in generators to produce electricity.

Candidates should use their skills, knowledge and understanding of how science works: HT

❖ to explain from a diagram how an a.c. generator works, including the purpose of the slip rings and brushes.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- If an electrical conductor 'cuts' through magnetic field lines, an electrical potential difference is induced across the ends of the conductor.
- If a magnet is moved into a coil of wire, an electrical potential difference is induced across the ends of the coil.
- If the wire is part of a complete circuit, a current is induced in the wire.
- If the direction of motion, or the polarity of the magnet, is reversed, the direction of the induced potential difference and the induced current is reversed.
- The generator effect also occurs if the magnetic field is stationary and the coil is moved.
- The size of the induced potential difference increases when:
  - the speed of the movement increases
  - the strength of the magnetic field increases
  - the number of turns on the coil increases
  - the area of the coil is greater.

13.9 How do transformers work?

Transformers are used to step-up (increase) or step-down (decrease) a.c. potential differences.

Candidates should use their skills, knowledge and understanding of how science works:

- to determine which type of transformer should be used for a particular application.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The basic structure of the transformer.
- An alternating current in the primary coil produces a changing magnetic field in the iron core and hence in the secondary coil. This induces an alternating potential difference across the ends of the secondary coil.

HT ❖ The potential difference (p.d.) across the primary and secondary coils of a transformer are related by the equation:

$$\frac{\text{p.d. across primary}}{\text{p.d. across secondary}} = \frac{\text{number of turns on primary}}{\text{number of turns on secondary}}$$

- In a step-up transformer the potential difference across the secondary coil is greater than the potential difference across the primary coil.
- In a step-down transformer the potential difference across the secondary coil is less than the potential difference across the primary coil.
- The uses of step-up and step-down transformers in the National Grid.

13.10 What is the life history of stars?

Astronomers believe that gravitational forces are responsible for the formation of galaxies of stars, and for stars like the Sun having a long stable period.

Candidates should use their skills, knowledge and understanding of how science works:

- to explain how stars are able to maintain their energy output for millions of years

HT ❖ to explain why the early Universe contained only hydrogen but now contains a large variety of different elements.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Our Sun is one of the many billions of stars in the Milky Way galaxy.
- The Universe is made up of billions of galaxies.
- Stars form when enough dust and gas from space is pulled together by gravitational attraction. Smaller masses may also form and be attracted by a larger mass to become planets.
- Gravitational forces balance radiation pressure to make a star stable.
- A star goes through a life cycle (limited to the life cycle of stars of similar size to the Sun and stars much larger than the Sun).

HT ❖ Fusion processes in stars produce all naturally occurring elements. These elements may be distributed throughout the Universe by the explosion of a star (supernova) at the end of its life.

Key Skills and Other Issues

14 Key Skills – Teaching, Developing and Providing Opportunities for Generating Evidence

14.1 Introduction

The Key Skills Qualification requires candidates to demonstrate levels of achievement in the Key Skills of *Application of Number, Communication* and *Information and Communication Technology*.

The units for the 'wider' Key Skills of *Improving own Learning and Performance, Working with Others* and *Problem-Solving* are also available. The acquisition and demonstration of ability in these 'wider' Key Skills is deemed highly desirable for all candidates, but they do not form part of the Key Skills Qualification.

Copies of the Key Skills units may be downloaded from the QCA web site (http://www.qca.org.uk/keyskills).

Copies of the Key Skills specification may be downloaded from the AQA website (www.aqa.org.uk).

14.2 Teaching, Developing and Providing Opportunities for Generating Evidence

Areas of study and learning that can be used to encourage the acquisition and use of Key Skills, and to provide opportunities to generate evidence, are signposted in the tables below. Key Skills signposting indicates naturally occurring opportunities for the development of Key Skills during teaching, learning and assessment. Candidates will not necessarily achieve the signposted Key Skill through the related evidence.

Application of Number Level 1

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Physics Centre-Assessed Unit	**Physics 1**	**Physics 2**	**Physics 3**
N1.1 Interpret information from **two** different sources. At least **one** source must include a table, chart, graph or diagram.	✓	✓	✓	✓
N1.2 Carry out and check calculations to do with: a. amounts or sizes b. scales or proportion c. handling statistics.	✓	✓	✓	✓
N1.3 Interpret results of your calculations and present your findings – in **two** different ways using charts or diagrams.	✓	✓	✓	✓

Application of Number Level 2

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Physics Centre-Assessed Unit	**Physics 1**	**Physics 2**	**Physics 3**
N2.1 Interpret information from a suitable source.	✓	✓	✓	✓
N2.2 Use your information to carry out calculations to do with: a. amounts or sizes b. scales or proportions c. handling statistics d. using formulae.	✓	✓	✓	✓
N2.3 Interpret the results of your calculations and present your findings.	✓	✓	✓	✓

Communication Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Physics Centre-Assessed Unit	Physics 1	Physics 2	Physics 3
C1.1 Take part in either a **one-to-one** discussion or a **group** discussion.	✓	✓	✓	✓
C1.2 Read and obtain information from at least **one** document.	✓	✓	✓	✓
C1.3 Write **two** different types of documents.	✓	✓	✓	✓

Communication Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Physics Centre-Assessed Unit	Physics 1	Physics 2	Physics 3
C2.1a Take part in a group discussion.	✓	✓	✓	✓
C2.1b Give a talk of at least four minutes.	✓	✓	✓	✓
C2.2 Read and summarise information from at least **two** documents about the same subject. Each document must be a minimum of 500 words long.	✓	✓	✓	✓
C2.3 Write **two** different types of documents each one giving different information. One document must be at least 500 words long.	✓	✓	✓	✓

Information and Communication Technology Level 1

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Physics Centre-Assessed Unit	**Physics 1**	**Physics 2**	**Physics 3**
ICT1.1 Find and select relevant information.	✓	✓	✓	✓
ICT1.2 Enter and develop information to suit the task.	✓	✓	✓	✓
ICT1.3 Develop the presentation so that the final output is accurate and fit for purpose.	✓	✓	✓	✓

Information and Communication Technology Level 2

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Physics Centre-Assessed Unit	**Physics 1**	**Physics 2**	**Physics 3**
ICT2.1 Search for and select information to meet your needs. Use different information sources for each task and multiple search criteria in at least one case.	✓	✓	✓	✓
ICT2.2 Explore and develop the information to suit the task and derive new information.	✓	✓	✓	✓
ICT2.3 Present combined information such as text with image, text with number, image with number.	✓	✓	✓	✓

Improving own Learning and Performance Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Physics Centre-Assessed Unit	Physics 1	Physics 2	Physics 3
LP1.1 Confirm your targets and plan how to meet these with the person setting them.	✓	✓	✓	✓
LP1.2 Follow your plan, to help meet targets and improve your performance.	✓	✓	✓	✓
LP1.3 Review your progress and achievements in meeting targets, with an appropriate person.	✓	✓	✓	✓

Improving own Learning and Performance Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Physics Centre-Assessed Unit	Physics 1	Physics 2	Physics 3
LP2.1 Help set targets with an appropriate person and plan how these will be met.	✓	✓	✓	✓
LP2.2 Take responsibility for some decisions about your learning, using your plan to help meet targets to improve your performance.	✓	✓	✓	✓
LP2.3 Review progress with an appropriate person and provide evidence of your achievements.	✓	✓	✓	✓

Working with Others Level 1

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Physics Centre-Assessed Unit	**Physics 1**	**Physics 2**	**Physics 3**
WO1.1 Confirm you understand the given objectives, and plan for working together.	✓	✓	✓	✓
WO1.2 Work with others towards achieving the given objectives.	✓	✓	✓	✓
WO1.3 Identify ways you helped to achieve things and how to improve your work with others.	✓	✓	✓	✓

Working with Others Level 2

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Physics Centre-Assessed Unit	**Physics 1**	**Physics 2**	**Physics 3**
WO2.1 Plan work with others.	✓	✓	✓	✓
WO2.2 Work co-operatively towards achieving identified objectives.	✓	✓	✓	✓
WO2.3 Review your contributions and agree ways to improve work with others	✓	✓	✓	✓

Problem Solving Level 1

What you must do ...	Signposting of Opportunities for Generating Evidence in Subject Content			
	Physics Centre-Assessed Unit	Physics 1	Physics 2	Physics 3
PS1.1 Confirm with an appropriate person that you understand the given problem and identify different ways of tackling it.	✓	✓	✓	✓
PS1.2 Confirm with an appropriate person what you will do and follow your plan for solving the problem.	✓	✓	✓	✓
PS1.3 Check with an appropriate person if the problem has been solved and how to improve your problem solving skills.	✓	✓	✓	✓

Problem Solving Level 2

What you must do ...	Signposting of Opportunities for Generating Evidence in Subject Content			
	Physics Centre-Assessed Unit	Physics 1	Physics 2	Physics 3
PS2.1 Identify a problem, with help from an appropriate person, and identify different ways of tackling it.	✓	✓	✓	✓
PS2.2 Plan and try out at least one way of solving the problem.	✓	✓	✓	✓
PS2.3 Check if the problem has been solved and identify ways to improve problem solving skills.	✓	✓	✓	✓

15 Spiritual, Moral, Ethical, Social, Cultural and Other Issues

15.1 Spiritual, Moral, Ethical, Social and Cultural Issues

The study of science can contribute to an understanding of spiritual, moral, ethical, social and cultural issues. The following are examples of opportunities to promote candidates' development through the teaching of science.

Spiritual

Through candidates sensing the natural, material and physical world they live in, reflecting on their part in it, exploring questions such as the formation of galaxies, and experiencing a sense of awe and wonder at the natural world. Sections 11.7, 12.9, 13.10 are relevant.

Moral and ethical

Through helping candidates see the need to draw conclusions using observation and evidence, rather than preconception or prejudice, and through discussion of the implications of the uses of scientific knowledge, including the recognition that such uses can have both beneficial and harmful effects. Exploration of values and ethics relating to applications of science and technology is possible. Sections 10.7, 11.4, 11.5, 11.6 and 12.10 are relevant.

Social

Through helping candidates recognise how the formation of opinion and the justification of decisions can be informed by experimental evidence, and drawing attention to how different interpretations of scientific evidence can be used in discussing social issues. Sections 10.8, 11.4, 11.5, 11.7, 12.2, 12.9 and 13.3 are relevant.

Cultural

Through helping candidates recognise how scientific discoveries and ideas have affected the way people think, feel, create, behave and live, and drawing attention to how cultural differences can influence the extent to which scientific ideas are accepted, used and valued. Sections 10.2, 10.8, 11.4, 12.4 and 12.10 are relevant.

15.2 European Dimension

AQA has taken account of the 1988 Resolution of the Council of the European Community in preparing this specification and associated specimen papers.

There are opportunities in this specification to relate the study of topics to wider European or global contexts. In particular, a broader European context could be used in relation to Sections 11.4, 11.6, 12.7 and 12.10.

15.3 Environmental Issues

AQA has taken account of the 1988 Resolution of the Council of the European Community and the Report *"Environmental Responsibility: An Agenda for Further and Higher Education"* 1993 in preparing this specification and associated specimen papers.

This specification allows responsible attitudes to environmental issues to be fostered. In particular, environmental issues can be considered in relation to Sections 11.4, 11.6 and 12.10.

15.4 Health and Safety

Teaching about health and safety during practical science forms part of the teaching requirements for this specification (see section 18.3). However, more general teaching requirements about health and safety are as applicable to science as to other subjects. Examples can be found in Sections 11.5, 11.6, 12.1, 12.2, 12.4, 12.5, 12.6, 12.7, 12.8, 12.9, 13.1, 13.4, 13.5, 13.6, 13.7, 13.8 and 13.9.

When working with equipment and materials, in practical activities and in different environments, including those that are unfamiliar, candidates should be taught:

- about hazards, risks and risk control
- to recognise hazards, assess consequent risks and take steps to control the risks to themselves and others
- to use information to assess the immediate and cumulative risks
- to manage their environment to ensure the health and safety of themselves and others
- to explain the steps they take to control risks.

Centres are reminded of requirements to make their own risk assessments under COSHH regulations in relation to the many materials and processes involved in the teaching of this subject.

15.5 Citizenship

This specification allows treatment of aspects of citizenship through the contribution made to candidates' moral, ethical, social and cultural development (see Section 15.1), through opportunities to teach about the European dimension (see Section 15.2) and through opportunities to promote an understanding of, and responsible attitudes towards, environmental issues (see Section 15.3).

15.6 Avoidance of Bias

AQA has taken great care in the preparation of this specification and associated specimen papers to avoid bias of any kind.

15.7 Use of Organisms

Nothing in this specification requires candidates or teachers to kill animals. Live animals brought into the laboratory for study should be kept unstressed in suitable conditions and should, wherever possible, be returned unharmed to their habitats. Studies of animals and plants in their habitats should aim at minimal disturbance.

Centre-Assessed Unit

16 Nature of the Centre-Assessed Unit

Candidates should be encouraged to carry out practical and investigational work throughout the course. They should work safely and accurately, both individually and in groups. This work should cover the skills and knowledge in Section 10: fundamental ideas, observation, investigation design, measurement, data presentation, identifying patterns in relationships and any social aspects of scientific evidence.

AQA identifies some areas of the specification suitable for investigational work and provides ISAs (Investigative Skills Assignments) in the form of written tests relating to these areas of the specification. Candidates are required to carry out practical work beforehand and bring their own data with them. Teachers use their judgement and the marking guidance from AQA to mark each ISA. Teachers are also required to make a holistic assessment of the general practical and safety skills of each candidate. The best ISA mark and the general practical and safety skills assessment are needed for the mark for this unit. It counts for 25% of the total marks for the award.

17 Investigative Knowledge and Skills for Centre-Assessed Unit

17.1 Introduction

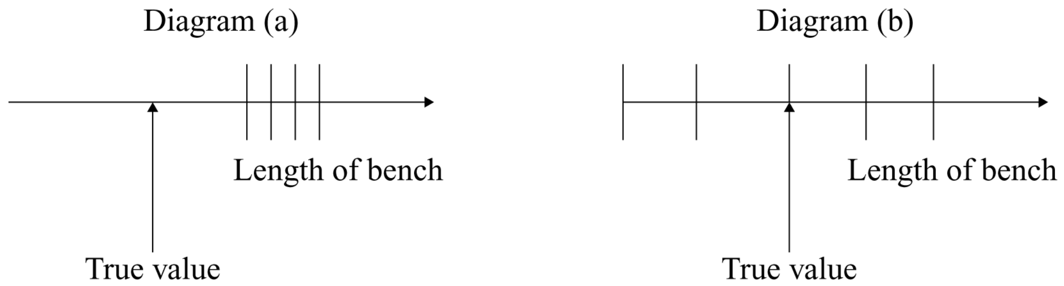
The knowledge and understanding which are assessed by the centre-assessed unit are detailed in full in Section 10. The following is a summary of the Procedural Content which teachers and candidates may find useful in preparing for this unit. It contains the following sections:

- Fundamental ideas
- Observation
- Designing an investigation
- Making measurements
- Presenting data
- Identifying patterns and relationships in data
- Societal aspects of scientific evidence
- Limitations of scientific evidence

A Glossary of Terms relating to 'How Science Works' is provided in Appendix D.

17.2	Fundamental ideas	Candidates should be able to understand what is meant by scientific evidence and thus be able to distinguish between opinions based on scientific facts and opinions based on hearsay evidence or bias.
17.3	Observation	Candidates should be able to recognise key features and make observations in a rational and unbiased manner. They should realise that observations are often the starting point of investigations and may be used as a basis for classification. They should realise that observations can lead to hypotheses and predictions, and that data from observations may support, refute or lead to new hypotheses.
17.4	Designing an Investigation	
	Design of investigations: Variable structure	Candidates should be able to distinguish between the dependent and the independent variable. They should also know the difference between categoric and continuous variables.
	Design: Validity, 'fair tests' and controls	Candidates should be able to describe the attributes of a 'fair test', ie one in which only the chosen independent variable has been allowed to influence the dependent variable. They should also be able to identify other key variables that must either be controlled or, if that is not possible, at least monitored. They should appreciate that in field investigations and surveys there are particular requirements to ensure a fair test, and that control groups are often appropriate to ensure that changes are due to the independent variable.
	Design: Choosing values	Candidates should be able to specify the range of, and interval between, readings to be taken and to appreciate that these can often be determined by means of a preliminary trial run. They should also be able to specify the number of readings to be taken.
	Design: Accuracy and precision	Candidates should be able to explain how an investigation can be designed so that it will render data which is sufficiently accurate and precise as to enable a sensible conclusion to be drawn.
	Reliability and validity of the design	Candidates should be able to evaluate the design of an experiment or investigation by commenting on the ways in which the experimenter did or did not achieve reliability and validity.
17.5	Making Measurements	
	Measurement	Candidates should be able to identify situations in which natural inherent variation in a measurement has been caused by uncontrolled variables, human error or the characteristics of the instrument used.
	Instruments: Underlying relationships	Candidates should be able to explain how a measuring instrument can utilise the relationship between two variables, eg that the length of the mercury column in a thermometer is related directly to the temperature.

Instruments: Calibration and error	Candidates should be able to explain that a measuring instrument is calibrated before use, eg a scale is marked on it by using some known, fixed points. They should know that a measuring instrument may have a zero error and that the smallest scale divisions must be smaller than the value that they are trying to measure. They should realise that the sensitivity of the instrument should be taken into account. They should realise that random errors can result from an inconsistent technique.
Reliability and validity of a single measurement	Candidates should know that the reliability of a measurement may be improved by data from secondary sources, by others repeating the investigation or by using another instrument as a crosscheck. They should understand that for a measurement to be valid the instrument or technique must be actually measuring that which is intended.
The choice of an instrument for measuring a datum	Candidates should be able to distinguish between precision and accuracy. An accurate measurement is one which is close to the true value . Precision is related to the smallest scale division on the measuring instrument that you are using. In the examples below, measurements were taken of the length of a laboratory bench. Each vertical line on the scale represents a reading. Diagram (a) shows a set of results which is very precise but not very accurate. Diagram (b) shows a set of results which is very accurate but not very precise.



Sampling a datum	Candidates should be able to determine the optimum number of measurements and repeats to be made, and to identify any anomalous results.
Statistical treatment of measurements of data	Candidates should be able to state the range of the measurements that have been made, quoting the maximum and minimum values and to calculate the mean.
Reliability and validity of a datum	Candidates should be able to ascertain whether a measurement or observation is (a) reliable, ie has it been crosschecked and (b) valid, ie has the appropriate variable been measured?

17.6 Presenting Data

Tables	Candidates should be able to draw up a results table such that data can be presented in a meaningful and easy to understand way.
Data presentation	Candidates should be able to decide upon the most appropriate method of presenting and analysing data. Such methods include tables, bar charts, line graphs, scattergrams, histograms and pie charts.

17.7 Identifying Patterns and Relationships in Data

Patterns and relationships in data	Candidates should be able to recognise and describe patterns in data and draw conclusions from them. Such patterns include linear and proportional relationships, curves and empirical relationships. They should be capable of drawing and interpreting lines of best fit. They should also be aware that anomalous data may need to be excluded before such a pattern is identified.
Reliability and validity of the data in the whole investigation	Candidates should be able to explain why further evidence may be needed in order to draw a firm conclusion and how this extra evidence may be obtained.

17.8 Societal Aspects of Scientific Evidence

Relevant societal aspects	Candidates should be able to explain how the consequences of scientific experiments may impinge upon society. They should understand that the credibility of scientific research may suffer as the result of any bias by the experimenters. They should also be aware of the consequences of scientific research and understand that acceptability is influenced by a range of other factors, such as ethical, social, economic and environmental issues.

17.9 Limitations of Scientific Evidence

Candidates should realise that it is sometimes difficult to collect sufficient evidence to answer a question. There are also questions that cannot be answered by looking at scientific evidence alone, for example, questions where moral judgements are involved.

18 Guidance on Managing the Centre-Assessed Unit

18.1 Outline

The total marks for this unit are derived in two ways.

Investigative Skills Assignment (ISA)

During the course, candidates carry out practical work on any aspect of science relevant to the specification. When the candidate has carried out practical work on one of the topics listed by AQA as being available for assessment, the teacher may assess the candidate on investigative skills. In a normal timetabled lesson, but under controlled conditions, the candidate is provided with an ISA, supplied by AQA. The maximum time allowed for each ISA is 45 minutes. The candidate must be provided in this session with the data that he or she has collected during the practical work. The ISA is in two parts.

(a) Section 1

This consists of a number of questions relating directly to the candidate's own data. This data must be stapled to the answer sheet.

The number of marks allocated to this section is between 14 and 20.

(b) Section 2

At the start of this section, candidates are supplied with another set of data, relating to the same topic from the specification in which the candidate has conducted his or her practical work. A number of questions relating to the analysis and evaluation of this data then follow. Candidates are expected to make appropriate comparisons between their own and the presented data.

The number of marks allocated to this section is between 14 and 20.

Candidates may attempt any number of the ISAs supplied by AQA, in any of the contexts of Physics 1, Physics 2 or Physics 3 and the best mark obtained is submitted.

Practical Skills Assessment (PSA)

Candidates are assessed throughout the course on the implementation of practical work, using a scale from 0 to 6.

The mark submitted for practical skills should be judged by the teacher over the duration of the course. Teachers may wish to use this section for formative assessment and keep an ongoing record of each candidate's performance, but the mark submitted should represent the candidate's practical abilities over the whole course.

Work to be submitted

The work to be submitted for each candidate consists of their best Investigative Skills Assignment (ISA) and a Candidate Record Form showing the marks for this ISA and the Practical Skills Assessment (PSA).

18.2 Investigative Skills Assignments (ISA)

Candidates will be expected to carry out practical work within certain specified areas of the content of the Specification for Physics 1, Physics 2 or Physics 3. AQA will provide assignments and marking guidance on topics from the specification such as:

Suitable topics

Unit Physics 1

- Evaluate ways in which heat is transferred in and out of bodies and ways in which the rates of these transfers can be reduced.

  Typical investigation: Investigate the rate of loss of heat from various containers.

- The greater the percentage of the energy that is usefully transformed in a device, the more efficient the device is.

  Typical investigation: Investigate the efficiency of an electrical device such as a heater.

- Electricity can be produced directly from the Sun's radiation using solar cells.

  Typical investigation: Find out how the surface area of a solar cell determines the p.d. that can be produced.

Unit Physics 2

- A body falling through a fluid will initially accelerate due to the force of gravity. Eventually the resultant force on the body will be zero and it will fall at its terminal velocity.

  Typical investigation: Measuring the terminal velocity of different parachutes.

- To use the conservation of momentum (in one dimension) to calculate the mass, velocity or momentum of a body involved in a collision or explosion.

  Typical investigation: Measurement of momentum changes when trolleys collide.

- The resistance of a filament lamp increases as the temperature of the filament increases.

  Typical investigation: Investigating how resistance changes as the lamp increases in brightness with increased current.

Unit Physics 3

- Calculate the magnification produced by a lens or mirror using the formula

$$\text{magnification} = \frac{\text{image height}}{\text{object height}}$$

  Typical investigation: Comparing the magnification produced by different lenses.

- To compare the amplitudes and frequencies of sounds from diagrams of oscilloscope traces.

  Typical investigation: Using an oscilloscope to compare the change of frequency when the tension in a stretched string is altered.

- The size of the induced potential difference increases when:
  - the speed of the movement increases
  - the strength of the magnetic field increases
  - the number of turns on the coil increases
  - the area of the coil is greater.

  Typical investigation: Using a small d.c. motor as a generator connected to a voltmeter, to investigate one or more of the factors above.

In Sections 11– 13 this symbol is used to identify topics which are suitable for extended investigative work. These topics, in addition to those listed, may form the basis for future ISAs. However, the list and the signposted topics are not intended to be exhaustive – both are provided for illustrative purposes only. Nonetheless, practical work in these areas will provide a good preparation for formal assessment in the centre-assessed unit including the ISAs.

Getting started

A suitable strategy would be to teach the knowledge that underlies Section 10 and the skills that provide for the gathering of data. Candidates should gain an understanding of the application of these concepts by applying them to supported practical studies and practice tests. Candidates should then be assessed when they apply these abilities in the formal ISA situation.

The proposed task should allow for candidates to work individually to obtain data suitable for analysis or, if working in groups, allow the contribution of individual candidates to be identified and assessed.

Candidates may include supportive second-hand data and whole-class data. It is important, however, that the candidate identifies the data that has been collected under his or her direction. Whilst some practical situations can only be effectively conducted in groups, each candidate must have completed a set of data that has been derived under their own direction. Candidates should keep an independent record of the raw data collected in preparation for the ISA.

The assignments, setting guidance and marking guidance are made available to centres at the beginning of each year. They should be kept locked away securely until used. If they are to be used on more than one occasion, then centres must ensure security between sessions. AQA is issuing two tests in the first year that each centre-assessed unit for a specification is available. At least one extra test is issued each year so that centres have a choice of which test to offer. Each test is available for two years.

Using the assignments

Whilst carrying out the practical work, candidates are expected to make and record detailed observations in a suitable way. Measurements should be made with an appropriate level of precision and accuracy and the data recorded logically in an appropriately constructed table. Candidates should use ICT where appropriate.

Candidates should be supplied with an outline method and asked to make their own results table. The outline method and instructions should not be too prescriptive. Centres are provided with setting guidance which will detail any particular requirements. As far as possible AQA does not put any restriction on the method to be used in the investigation.

Candidates must present, while the work is in progress, the data collected in a suitable table. They should not be assessed using evidence from formal reports written after the completion of the practical work. For certain ISAs, candidates are also required to process the data into a graph or chart. Where this is the case, teachers are notified in the setting guidance. Teachers should collect the table of data (and graphs or charts if appropriate) from each candidate at the end of the practical session and store it in readiness for the ISA.

The ISA should be taken as soon as possible after completion of the practical work, in a suitable timetabled lesson. Candidates should work on their own and in silence. Each candidate is provided with an ISA to which the teacher has stapled the candidate's own data record.

Section 1 of the ISA contains questions concerning the candidate's own data. Section 2 provides the candidate with additional data on the same topic which the candidate is required to analyse, evaluate and comment upon. Answers to both sections are written on the question paper. At the end of 45 minutes, the papers are collected from the candidates. Teachers are required to mark these papers, using a set of marking guidelines provided by AQA.

Candidates absent for the preliminary practical work

If a candidate is absent for the practical work, the teacher may supply the candidate with some data to use in Section 1 and the teacher can mark it, but the mark for Section 1 cannot be submitted. However, a mark for Section 2 on its own may be submitted.

Security of assignments

When teachers have marked the ISAs, they may tell candidates their marks but they may not return the papers. Completed ISAs should be treated like examination papers and kept under secure conditions while the ISA is valid.

Practice ISAs from specimen or training material can be used to teach candidates the skills required, feeding back their marks as formative assessment. However, ISAs which are currently valid cannot be given back to the candidates. Candidates may sit any number of ISAs and the best mark can be submitted for certification.

18.3 Practical Skills Assessment (PSA)

This assessment may be made at any time during the course of a candidate's normal practical work.

The nature of the assessment

Since the skills in this section involve implementation, they must be assessed while the candidate is carrying out practical work. In order to provide appropriate opportunities to demonstrate the necessary skills, instructions provided must not be too prescriptive but should allow candidates to make decisions for themselves, particularly concerning the conduct of practical work, their organisation and the manner in which equipment is used.

Centres should bear in mind that a high performance should reflect the ability to work methodically and safely, demonstrating competence in the required manipulative skills and efficiency of managing time.

The assessment criteria

Candidates should:

- use apparatus and materials in an appropriate and careful way
- carry out work in a methodical and organised way
- work with due regard for safety and with appropriate consideration for the well-being of living organisms and the environment.

Descriptors are provided for 2, 4 and 6 marks. These descriptors should be used to judge the mark which best describes a candidate's performance.

IMPLEMENTATION OF PRACTICAL WORK	
PERFORMANCE LEVEL	**SKILLS**
2	*Practical work is conducted:* • safely, but with help to work in an organised manner. *The candidate:* • uses the apparatus with assistance.
4	*Practical work is conducted:* • safely and in a reasonably organised manner. *The candidate:* • uses the apparatus skilfully and without the need for assistance.
6	*Practical work is conducted:* • safely and in a well-organised manner. *The candidate*: • uses the apparatus skilfully in a demanding context.

NB In order to gain 5 or 6 marks, a candidate must:

- demonstrate competence with a range of equipment, some of which is quite complex
- take all measurements to an appropriate level of accuracy
- present, while the work is in progress, the data collected in a suitable table.

Descriptors are designed to be hierarchical so that a description at a particular mark subsumes descriptions at lower marks. Use should be made of intermediate marks (1, 3 and 5) when performance exceeds one description but only partly satisfies the next.

At each of the marks (2, 4 and 6) there are two bullet points. If **neither** of the bullet points for 2 marks is matched, the candidate should be awarded zero marks. If **either** of the bullet points for 2 marks is matched, the candidate will score 1 mark. If **both** bullet points for 2 marks are matched, the candidate will score 2 marks.

Once 2 marks have been awarded, consideration may be given to the two bullet points for 4 marks: matching either one will allow 3 marks to be awarded, both will result in 4 marks. Similarly, once 4 marks have been gained, consideration may be given to the two bullet points for 6 marks, in order to determine whether the candidate should be awarded 5 or 6 marks.

18.4 Further Support

Apart from material published in the specification, support for this unit is provided in a number of ways:

- **A Teacher's Guide** published by AQA includes information and advice from the Principal Moderator. This will be supplemented by further booklets containing examples of work.
- **Centre-Assessed Unit Advisers** are appointed by AQA and are available to give centres advice. Details are sent to the Head of Department at individual centres, or may be obtained from the Subject Department at AQA's Guildford office. Advice will normally be given in response to telephone or e-mail enquiries but will be restricted to:
  - issues relating to the carrying out of assignments for assessment
  - standards of marking
  - administrative issues
  - discussion of feedback from moderators.

  Advisers do not mark work.
- **Annual meetings** will be held on a regional basis, usually at the beginning of the academic year. These meetings discuss aspects of internal assessment which have given rise to concern and provide opportunities to standardise procedures and marking. Attendance in the first year of a new programme of assessment is compulsory, as is attendance by centres where there has been serious misinterpretation of the requirements of the specification. Centres will be informed directly if they are required to attend.

19 Supervision and Authentication

19.1 Supervision of Candidates' Work

The centre-assessed unit comprises an Investigative Skills Assignment (ISA) and a Practical Skills Assessments (PSA) for each candidate. It is expected that the preliminary practical work for the ISAs and the work assessed for the PSA are carried out under normal class conditions, with a degree of supervision of candidates corresponding to those conditions. However, ISAs should be taken under controlled conditions with candidates working in silence. They may sit the ISA in their usual classroom (or laboratory) providing this allows them to be suitably spaced to avoid the possibility of cheating.

19.2 Unfair Practice

At the start of the course, the supervising teacher is responsible for informing candidates of the AQA regulations concerning malpractice. The penalties for malpractice are set out in the AQA regulations. Centres must report suspected malpractice to AQA.

19.3 Authentication of Candidates' Work

Both the candidate and the teacher are required to sign declarations confirming that the work submitted for assessment is the candidate's own. The teacher declares that the work was conducted under the specified conditions, and records details of any additional assistance.

20 Standardisation

20.1 Standardising Meetings

Annual standardising meetings will usually be held in the autumn term. Centres entering candidates for the first time must send a representative to the meetings. Attendance is also mandatory in the following cases:

- where there has been a serious misinterpretation of the specification requirements
- where the management of the centre-assessed unit by a centre has been inappropriate
- where a significant adjustment has been made to a centre's marks in the previous year's examination.

Otherwise attendance is at the discretion of centres. At these meetings support will be provided for centres in the development of appropriate preliminary practical work and assessment procedures.

20.2 Internal Standardisation of Marking

The centre is required to standardise the assessments across different teachers and teaching groups to ensure that all candidates at the centre have been judged against the same standards. If two or more teachers are involved in marking the centre-assessed unit, one teacher must be designated as responsible for internal standardisation. Common pieces of work must be marked on a trial basis and differences between assessments discussed at a training session in which all teachers involved must participate. The teacher responsible for standardising the marking must ensure that the training includes the use of reference and archive materials such as work from a previous year or examples provided by AQA. The centre is required to send to the moderator the Centre Declaration Sheet, duly signed, to confirm that the marking of centre-assessed work at the centre has been standardised. If only one teacher has undertaken the marking, that person must sign this form.

A specimen Centre Declaration Sheet appears in Appendix B.

21 Administrative Procedures

21.1 Recording Assessments

Teachers should keep records of their assessments during the course in a form which facilitates the complete and accurate submission of final centre assessments at the end of the course. Candidates may undertake a number of ISAs. Candidates should complete the details required on the front cover of the ISA in full. The data collected by each candidate in the preliminary practical work should be firmly attached (ie stapled or by treasury tag) to the candidate's ISA script. The candidates' work must be marked according to the marking guidelines provided by AQA, and the marks entered on the front cover. Towards the end of the course, the teacher must select the ISA with the highest mark and must award a mark for the PSA, using the criteria in the grid in Section 18. This mark and the mark for the ISA should be entered on a Candidate Record Form, together with supporting information and details of any additional help given, in the spaces provided. The completed Candidate Record Form for each candidate must be attached to the work and made available to AQA on request.

Candidate Record Forms are available on the AQA website in the Administration area. They can be accessed via the following link http://www.aqa.org.uk/admin/p_course.php. The exact design may be modified before the operational version is issued and the correct year's Candidate Record Forms should always be used.

21.2 Submitting Marks and Sample Work for Moderation

The total mark for the centre-assessed unit for each candidate must be submitted to AQA on the mark sheets provided or by Electronic Data Interchange (EDI) by the specified date. Centres will be informed which candidates' work is required in the samples to be submitted to the moderator.

An Investigative Skills Assignment (ISA) mark submitted for one centre-assessed unit (SCYC, ASCC, BLYC, CHYC or PHYC) should not be submitted for another centre-assessed unit, even if the ISA is valid for that unit. It is a requirement that new work is submitted for each centre-assessed unit entered.

21.3 Factors Affecting Individual Candidates

Teachers should be able to accommodate the occasional absence of candidates by ensuring that the opportunity is given for them to make up missed assessments.

Special consideration should be requested for candidates whose work has been affected by illness or other exceptional circumstances. Information about the procedure is issued separately.

If work is lost, AQA should be notified immediately of the date of the loss, how it occurred and who was responsible for the loss. AQA will advise on the procedures to be followed in such cases.

Where special help which goes beyond normal learning support is given, AQA must be informed so that such help can be taken into account when assessment and moderation take place.

Candidates who move from one centre to another during the course sometimes present a problem for a scheme of centre assessment. Possible courses of action depend on the stage at which the move takes place. Teachers should note that centre assessment in GCSE Sciences is no longer a common component across all awarding bodies, and therefore there is less flexibility than before in transferring credit for centre assessment undertaken for a specification of an awarding body other than AQA. Centres should contact AQA at the earliest possible stage for advice about appropriate arrangements in individual cases.

21.4 Retaining Evidence

The centre must retain all the work of all candidates, with Candidate Record Forms attached. These must be kept under secure conditions, from the time they are assessed, to allow for the possibility of an enquiry about results. This includes ISAs other than the one with the highest mark. If an enquiry about results is to be made, the work must remain under secure conditions until requested by AQA.

Beyond that time, it is preferred that candidates' work is shredded. In particular, centres must ensure that the security of ISA question papers which are still valid is not compromised.

22 Moderation

22.1 Moderation Procedures

Moderation of the centre-assessed unit is by inspection of a sample of candidates' work, sent by post from the centre to a moderator appointed by AQA. The centre marks must be submitted to AQA and the sample of work must reach the moderator by the specified date in the year in which the qualification is awarded.

Following the re-marking of the sample work, the moderator's marks are compared with the centre marks to determine whether any adjustment is needed in order to bring the centre's assessments into line with standards generally. In some cases it may be necessary for the moderator to call for the work of other candidates. In order to meet this possible request, centres must have available the work and Candidate Record Form of every candidate entered for the examination and be prepared to submit it on demand. Mark adjustments will normally preserve the centre's order of merit, but where major discrepancies are found, AQA reserves the right to alter the order or merit.

22.2 Post-Moderation Procedures

On publication of the GCSE results, the centre is supplied with details of the final marks for the centre-assessed unit.

The candidates' work is returned to the centre after the examination, with a report form from the moderator giving feedback on the accuracy of the assessments made and the reasons for any adjustments to the marks.

Some candidates' work may be retained by AQA for archive purposes.

Awarding and Reporting

23 Grading, Shelf-Life and Re-Sits

23.1 Qualification Titles

The qualification based on this specification has the following title: AQA General Certificate of Secondary Education in Physics.

23.2 Grading System

The qualification will be graded on an 8-point grade Scale A*, A, B, C, D, E, F and G. Candidates who fail to reach the minimum standard for grade G will be recorded as U (unclassified) and will not receive a qualification certificate.

23.3 Grading of Unit Results and Subject Awards

The achievement of each candidate on each unit is reported as a grade on the scale A*–G and as a UMS (Uniform Mark Scale) score.

UMS scores are related to grades as follows:

Range of UMS scores			
Objective test	**Written paper**	**Centre-assessed unit**	**Grade**
45–50	90–100	90–100	A*
40–44	80–89	80–89	A
35–39	70–79	70–79	B
30–34	60–69	60–69	C
25–29	50–59	50–59	D
20–24	40–49	40–49	E
15–19	30–39	30–39	F
10–14	20–29	20–29	G
0–9	0–19	0–19	U

The relationship of raw marks to UMS scores is determined separately for each unit and, where appropriate, for each tier (see Section 23.4), through the awarding procedures for each series. This allows for any variation in the demand of the assessments between series to be taken into consideration. Raw marks which represent the minimum performance to achieve a grade are chosen, and these boundary marks are assigned the minimum UMS score for the grade. Between boundaries interpolation is used to relate raw marks to UMS scores.

When a candidate is entered for a subject award, the grade for the qualification is obtained by adding together the UMS scores for the un its which contribute to the subject award, and using the following relationship between total UMS score and grade:

Range of total UMS score	Grade
360–400	A*
320–359	A
280–319	B
240–279	C
200–-239	D
160–199	E
120–159	F
80–119	G
0–79	U

23.4 Grading and Tiers

The centre-assessed unit is not tiered and the full range of grades A*–G is available to candidates for this unit.

For the other units, candidates take either the Foundation Tier or the Higher Tier. For candidates entered for the Foundation Tier, grades C–G are available. For candidates entered for the Higher Tier, A*-D are available. There is a safety net for candidates entered for the Higher Tier, where an allowed grade E will be awarded if candidates just fail to achieve grade D. Candidates who fail to achieve a grade E on the Higher Tier or grade G on the Foundation Tier will be reported as unclassified.

For these tiered units, candidates cannot obtain a UMS score corresponding to a grade which is above the range for the tier entered. For example the maximum UMS score for candidates on a Foundation Tier written paper, such as Physics 1, is 69. In other words, they cannot achieve a UMS score corresponding to grade B. Candidates who just fail to achieve grade E on the Higher Tier receive the UMS score corresponding to their raw mark i.e. they do not receive a UMS score of zero.

During the awarding procedures the relationship between raw marks and UMS score is decided for each tier separately. Where a grade is available on two tiers, for example grade C, the two raw marks chosen as the boundary for the grade on the two tiers are given the same UMS score. Therefore candidates receive the same UMS score for the same achievement whether this is demonstrated on the Foundation or the Higher Tier assessments.

23.5 Shelf-life of Unit Results

The shelf-life of individual unit results, prior to certification of the qualification, is limited only by the shelf-life of the specification.

23.6 Re-Sits

Each assessment unit may be re-taken an unlimited number of times within the shelf-life of the specification. The best result will count towards the final award. However, marks for individual externally assessed units may be counted once only to a GCSE award.

23.7	Minimum Requirements	Candidates will be graded on the basis of work submitted for assessment.
23.8	Awarding and Reporting	This specification complies with the grading, awarding and certification requirements of the current GCSE, GCE, VCE, GNVQ and AEA Code of Practice April 2008, and will be revised in the light of any subsequent changes in future years.

Appendices

A Grade Descriptions

The following grade descriptions indicate the level of attainment characteristic of the given grade at GCSE. They give a general indication of the required learning outcomes at each specific grade. The descriptions should be interpreted in relation to the content outlined in the specification; they are not designed to define that content.

The grade awarded will depend in practice upon the extent to which the candidate has met the assessment objectives (see Section 6) overall. Shortcomings in some aspects of the examination may be balanced by better performances in others.

Grade A

Candidates demonstrate a detailed knowledge and understanding of science content and how science works, encompassing the principal concepts, techniques and facts across all areas of the specification. They use technical vocabulary and techniques with fluency, clearly demonstrating communication and numerical skills appropriate to a range of situations.

They demonstrate a good understanding of the relationships between data, evidence and scientific explanations and theories. They are aware of areas of uncertainty in scientific knowledge and explain how scientific theories can be changed by new evidence.

Candidates use and apply their knowledge and understanding in a range of tasks and situations. They use this knowledge, together with information from other sources, effectively in planning a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem.

Candidates describe how, and why, decisions about uses of science are made in contexts familiar to them, and apply this knowledge to unfamiliar situations. They demonstrate good understanding of the benefits and risks of scientific advances, and identify ethical issues related to these.

They choose appropriate methods for collecting first-hand and secondary data, interpret and question data skilfully and evaluate the methods they use. They carry out a range of practical tasks safely and skilfully, selecting and using equipment appropriately to make relevant and precise observations.

Candidates select a method of presenting data appropriate to the task. They draw and justify conclusions consistent with the evidence they have collected and suggest improvements to the methods used that would enable them to collect more valid and reliable evidence.

Grade C Candidates demonstrate a good overall knowledge and understanding of science content and how science works, and of the concepts, techniques and facts across most of the specification. They demonstrate knowledge of technical vocabulary and techniques, and use these appropriately. They demonstrate communication and numerical skills appropriate to most situations.

They demonstrate an awareness of how scientific evidence is collected and are aware that scientific knowledge and theories can be changed by new evidence.

Candidates use and apply scientific knowledge and understanding in some general situations. They use this knowledge, together with information from other sources, to help plan a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem.

They describe how, and why, decisions about uses of science are made in some familiar contexts. They demonstrate good understanding of the benefits and risks of scientific advances, and identify ethical issues related to these.

They carry out practical tasks safely and competently, using equipment appropriately and making relevant observations appropriate to the task. They use appropriate methods for collecting first-hand and secondary data, interpret the data appropriately, and undertake some evaluation of their methods.

Candidates present data in ways appropriate to the context. They draw conclusions consistent with the evidence they have collected and evaluate how strongly their evidence supports these conclusions.

Grade F Candidates demonstrate a limited knowledge and understanding of science content and how science works. They use a limited range of the concepts, techniques and facts from the specification, and demonstrate basic communication and numerical skills, with some limited use of technical terms and techniques.

They show some awareness of how scientific information is collected and that science can explain many phenomena.

They use and apply their knowledge and understanding of simple principles and concepts in some specific contexts. With help they plan a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem, using a limited range of information in an uncritical manner. They are aware that decisions have to be made about uses of science and technology and, in simple situations familiar to them, identify some of those responsible for the decisions. They describe some benefits and drawbacks of scientific developments with which they are familiar and issues related to these.

They follow simple instructions for carrying out a practical task and work safely as they do so.

Candidates identify simple patterns in data they gather from first-hand and secondary sources. They present evidence as simple tables, charts and graphs, and draw simple conclusions consistent with the evidence they have collected.

B Record Forms

Candidate Record Forms and Centre Declaration Sheets are available on the AQA website in the Administration area. They can be accessed via the following link http://www.aqa.org.uk/admin/p_course.php

C

Overlaps with other Qualifications

Specifications Covering the Programme of Study

Many of the specifications in the AQA GCSE Sciences suite described in Section 4.2 cover the programme of study for KS4 Science, and there is therefore significant overlap between them. The content in GCSE Science A and GCSE Science B is identical, and all the content in these specifications can be found in GCSE Applied Science (Double Award). In addition, each of the nine units, Biology 1–3, Chemistry 1–3 and Physics 1–3 is identical, regardless of the specification to which it contributes. The procedural content in Section 10 of all the general specifications is the same.

The entry restrictions in Section 3.3 reflect this overlap.

Relationship to Other Subjects

Some of the knowledge, skills and understanding included in this specification may also be encountered by candidates following courses leading towards other subject qualifications. This is a feature of National Curriculum provision and means that the specification can complement other subjects and enable candidates to consolidate their learning. Some overlap exists with the following GCSE subjects:

- Electronics

D

Glossary of Terms

Accuracy
An accurate measurement is one which is close to the true value.

Calibration
This involves fixing known points and then marking a scale on a measuring instrument, between these fixed points.

Data
This refers to a collection of measurements.

For example: Data can be collected for the volume of a gas or the type of rubber.

Datum
The singular of data.

Errors,

- random
These cause readings to be different from the true value. Random errors may be detected and compensated for by taking a large number of readings.

For example: Random errors may be caused by human error, a faulty technique in taking the measurements, or by faulty equipment.

- systematic
These cause readings to be spread about some value other than the true value; in other words, all the readings are shifted one way or the other way from the true value.

For example: A systematic error occurs when using a wrongly calibrated instrument.

- zero
These are a type of systematic error. They are caused by measuring instruments that have a false zero.

For example: A zero error occurs when the needle on an ammeter fails to return to zero when no current flows, or when a top-pan balance shows a reading when there is nothing placed on the pan.

Evidence
This comprises data which have been subjected to some form of validation. It is possible to give a measure of importance to data which has been validated when coming to an overall judgement.

Fair test
A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

For example: A fair test can usually be achieved by keeping all other variables constant.

Precision
The precision of a measurement is determined by the limits of the scale on the instrument being used. Precision is related to the smallest scale division on the measuring instrument that you are using. It may be the case that a set of precise measurements has very little spread about the mean value.

For example, using a ruler with a millimetre scale on it to measure the thickness of a book will give greater precision than using a ruler that is only marked in centimetres.

Reliability
The results of an investigation may be considered reliable if the results can be repeated. If someone else can carry out your investigation and get the same results, then your results are more likely to be reliable. One way of checking reliability is to compare your results with those of others. The reliability of data can be improved by carrying out repeat measurements and calculating a mean.

True Value
This is the accurate value which would be found if the quantity could be measured without any errors at all.

Validity

Data is only valid for use in coming to a conclusion if the measurements taken are affected by a single independent variable only. Data is not valid if for example a fair test is not carried out or there is observer bias.

For example: In an investigation to find the effect on the rate of a reaction when the concentration of the acid is changed, it is important that concentration is the only independent variable. If, during the investigation, the temperature also increased as you increased the concentration, this would also have an effect on your results and the data would no longer be valid.

Variables,

– categoric

A categoric variable has values which are described by labels.

When you present the result of an investigation like this, you should not plot the results on a line graph; you must use a bar chart or pie chart.

For example: If you investigate the effect of acid on different metals, eg copper, zinc and iron, the type of metal you are using is a categoric variable.

– continuous

A continuous variable is one which can have any numerical value.

When you present the result of an investigation like this you should use a line graph.

For example: If you investigate the effect on the resistance of changing the length of a wire, the length of a wire you are using is a continuous variable since it could have any length you choose.

– control

A control variable is one which may, in addition to the independent variable, affect the outcome of the investigation. This means that you should keep these variables constant; otherwise it may not be a fair test. If it is impossible to keep it constant, you should at least monitor it; in this way you will be able to see if it changes and you may be able to decide whether it has affected the outcome of the experiment.

– dependent and independent variables

Often in science we are looking at 'cause' and 'effect'. You can think of the independent variable as being the 'cause' and the dependent variable as being the 'effect'. In other words, the dependent variable is the thing that changes *as a result* of you changing something else.

– dependent

The dependent variable is the variable the value of which you measure for each and every change in the independent variable.

– independent

The independent variable is the variable for which values are changed or selected by the investigator. In other word, this is the thing that *you deliberately change* to see what effect it has.

– discrete

You may sometimes come across this term. It is a type of categoric variable whose values are restricted to whole numbers.

For example, the number of carbon atoms in a chain.

– ordered

You may sometimes come across this term. It is a type of categoric variable that can be ranked.

For example, the size of marble chips could be described as large, medium or small.