version 1.0

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Secondary Education

Science: Double Award *Specification A* (Modular) 2005

This specification should be read in conjunction with:

Specimen and Past Papers and Mark Schemes
Specimen and Past Module Tests and Mark Schemes
Examiners' Reports
Teachers' Guide

AQA GCSE 3468

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.

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Kathleen Tattersall, Director General.

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Background Information

1 The Revised General Certificate of Secondary Education

Following a review of the National Curriculum requirements, and the establishment of the National Qualifications Framework, all the unitary awarding bodies have revised their GCSE syllabuses for examination in 2003.

1.1 National Qualifications Framework

GCSE has the following broad equivalence to General National Vocational Qualifications (GNVQ).

GCSE		GCSE Vocational Subjects		GNVQ	
Two GCSE	Grades D-G	One (Double Award)	DD-GG		
	Grades A*-C	One (Double Award)	A*A*-CC		
Four GCSE	Grades D-G	Two (Double Award)	DD-GG	One 6-Unit GNVQ	Foundation ††
	Grades A*-C	Two (Double Award)	A*A*-CC		

†† only available until 2005

1.2 Changes at GCSE

Key Skills

All GCSE specifications must identify, as appropriate, opportunities for generating evidence on which candidates may be assessed in the "main" Key Skills of communication, application of number and information technology at the appropriate level(s). Also, where appropriate, they must identify opportunities for developing and generating evidence for addressing the "wider" Key Skills of working with others, improving own learning and performance and problem solving.

Spiritual, moral, ethical, social, cultural, environmental, health and safety and European Issues

All specifications must identify ways in which the study of the subject can contribute to an awareness and understanding of these issues.

ICT

The national curriculum requires that students should be given opportunities to apply and develop their ICT capacity through the use of ICT tools to support their learning. In each specification candidates will be required to make effective use of ICT in ways appropriate to the needs of the subject.

Tiering

In most subjects the scheme of assessment must include question papers, targeted at two tiers of grades, i.e. A* - D and C - G.

A safety net of an allowed Grade E will be provided for candidates entered for the higher tier who just fail to achieve Grade D. The questions will still be targeted at A* - D.

Citizenship

From 2002, students in England will be required to study Citizenship as a national curriculum subject. Each GCSE specification must signpost, where appropriate, opportunities for developing citizenship knowledge, skills and understanding.

1.3 Changes to the Science Criteria

Changes made to the GCSE Criteria for Science (including Biology, Chemistry and Physics), which this specification is designed to meet, reflect the changes made to Science in the National Curriculum as part of the National Curriculum review.

2 Specification at a Glance

Science: Double Award A (Modular)

This specification is one of a suite of GCSE Science framework specifications offered by AQA. The framework includes specifications for double science, single science and the separate sciences.

There are two tiers of assessment: Foundation (G-C) and Higher (D-A*).

GCSE Science: Double Award A (Modular)
Paper 1 **Written Paper** — 25% of total marks Foundation Tier 1½ hours. Structured questions including extended writing. Higher Tier 1½ hours. Structured questions including extended writing. Covers Sc2 Life processes and living things, Sc3 Materials and their properties and Sc4 Physical processes, including ideas and evidence in science.
Paper 2 **Written Paper** — 25% of total marks Foundation Tier 1½ hours. Structured questions including extended writing. Higher Tier 1½ hours. Structured questions including extended writing. Covers Sc2 Life processes and living things, Sc3 Materials and their properties and Sc4 Physical processes, including ideas and evidence in science.
Module Tests **Module Tests** — 30% of total marks Foundation Tier 6 x ½ hour objective tests. Ten objective questions of different types. Higher Tier 6 x ½ hour objective tests. Ten objective questions of different types. Covers Sc2 Life processes and living things, Sc3 Materials and their properties and Sc4 Physical processes.
Coursework **Coursework** — 20% of total marks Internal assessment of investigative skills associated with Sc1 scientific enquiry.

Foundation Tier
3468F
Higher Tier
3468H

Centres in Wales and Northern Ireland must refer to the statement in Section 9 and Appendix F.

3 Availability of Assessment Units and Entry Details

3.1 Availability of Assessment Units

Terminal examinations based on this Specification are available in the June examination series only.

Specific dates and times for module test sessions will be announced separately. Six test sessions will be available for candidates over a two year course as follows:

Late November/Early December	Year 10
Early March	Year 10
Mid/Late June	Year 10
Late November/Early December	Year 11
Early March	Year 11
Mid/Late June	Year 11

For each test session, tests on each of the 6 tested modules will be available. The year 11 sessions will be the same as the year 10 sessions and will use common tests. Candidates following a shorter course must use the relevant available sessions.

3.2 Entry Codes

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

The **Subject Code** for entry to the GCSE award is 3468.

3.3 Prohibited Combinations

Candidates entering for this examination are prohibited from entering any other GCSE Science: Double Award or Science: Single Award specification or GCSE Biology, Chemistry, Physics or Biology (Human) specification in the same examination series.

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 1370.

3.4 Private Candidates

This specification is **not** available for private candidates.

3.5 Special Consideration

Special consideration may be requested for candidates whose work has been affected by illness or other exceptional circumstances. The appropriate form and all relevant information should be forwarded to the AQA office which deals with such matters for the centre concerned. Special arrangements may be provided for candidates with special needs.

Details are available from AQA and centres should ask for a copy of *Regulations and Guidance relating to Candidates with Particular Requirements.*

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 AQA GCSE in Science: Double Award Specification A complies with the following:

- The GCSE Subject Criteria for Science;
- The GCSE and GCE A/AS Code of Practice;
- The GCSE Qualification Specific Criteria;
- The Arrangements for the Statutory Regulation of External Qualifications in England, Wales and Northern Ireland: Common Criteria.

4.2 Rationale

This specification is part of the AQA GCSE Science framework which comprises the following range of specifications:

Science: Double Award A (Modular)
Science: Single Award A (Modular)
Science: Double Award B (Co-ordinated)
Science: Single Award B (Co-ordinated)
Biology A (Modular)
Chemistry A (Modular)
Physics A (Modular)
Biology B
Biology (Human)
Chemistry B
Physics B

The framework has been developed from the key stage 4 requirements of Science in the National Curriculum. It provides a coherent suite of specifications, each of which can stand alone. Common content developed from National Curriculum Science is used throughout, together with a common coursework assessment scheme.

The common content of the specification has been developed in such a way that maximum use has been made of content in previous AQA (NEAB) and AQA (SEG) syllabuses. The content is presented as a clear, coherent and detailed specification of the knowledge, skills and understanding expected of candidates. It is organised in a way that reflects teaching and assessment approaches as follows.

Modular: Where the content is organised into a range of modules providing for a modular approach to course construction and for specialist teaching, and where some modules are assessed via module tests and others via the terminal examination.

Co-ordinated: Where the separate areas of science are clear and can be taught by specialist teachers, and where the assessment of the content is entirely terminal.

Modular Biology/Chemistry/Physics: Where the National Curriculum content relevant to each separate science is supplemented and the content is organised into modules providing for a modular approach to course construction. Some modules are assessed via module tests and others via the terminal examination. Some of the module tests are common with Double Award (Modular).

Biology/Biology (Human)/Chemistry/Physics: Where the National Curriculum content relevant to each separate science is supplemented and arranged to reflect the distinctive nature of each subject. The specifications have been prepared as a linked set to meet the National Curriculum requirements. However each can be offered separately to candidates for whom National Curriculum requirements do not apply.

Continuity for centres

These approaches reflect the style of previous AQA (NEAB) and AQA (SEG) syllabuses, providing continuity for centres wherever possible. They are illustrative; centres are free to organise the material to form a scheme of work in any suitable way. The framework can be used by teachers to devise courses which meet their needs, and to adapt their courses as their needs change. It provides as much continuity as possible in the changeover to the new specifications in order to conserve the extensive financial and professional resources already invested in the organisation of teaching and assessment, and, in its flexibility, for continued development of the quality of schemes of work in centres.

The importance of Science

Science stimulates and excites candidates' curiosity about phenomena and events in the world around them. It also satisfies this curiosity with knowledge. Because science links direct practical experience with ideas, it can engage learners at many levels. Scientific method is about developing and evaluating explanations through experimental evidence and modelling. This is a spur to critical and creative thought. Through science, candidates understand how major scientific ideas contribute to technological change – impacting on industry, business and medicine and improving quality of life. Candidates recognise the cultural significance of science and trace its world-wide development. They learn to question and discuss science-based issues that may affect their own lives, the direction of society and the future of the world.

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 key stage 3 programme of study for 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. The Subject Content sections of this specification provide details of relevant key stage 3 science material.

4.4 Progression

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

This specification lays an appropriate foundation for further study of science subjects post-16. These may include AS/A level in Biology/Human Biology, Chemistry, Electronics, Environmental Science and Physics, AS level in Science for Public Understanding, and GNVQ in Science.

In addition it provides a worthwhile course for candidates of various ages and from diverse backgrounds in terms of general education and lifelong learning.

5 Aims

A course based on this specification should encourage candidates to:

a. acquire a systematic body of scientific knowledge, and the skills needed to apply this in new and changing situations in a range of domestic, industrial and environmental contexts;

b. acquire an understanding of scientific ideas, how they develop, the factors which may affect their development and their power and limitations;

c. plan and carry out a range of investigations, considering and evaluating critically their own data and that obtained from other sources, using ICT where appropriate;

d. evaluate in terms of their scientific knowledge and understanding, the benefits and drawbacks of scientific and technological developments, including those related to the environment, personal health and quality of life, and considering ethical issues;

e. select, organise and present information clearly and logically, using appropriate scientific terms and conventions, using ICT where appropriate.

6 Assessment Objectives

The scheme of assessment will require candidates to demonstrate their ability to:

6.1 Knowledge and Understanding (AO1)

- recognise, recall and show understanding of specific scientific facts, terminology, principles, concepts and practical techniques;
- demonstrate understanding of the power and limitations of scientific ideas and factors affecting how these ideas develop;
- draw on existing knowledge to show understanding of the benefits and drawbacks of applications of science;
- select, organise and present relevant information;

6.2 Application of Knowledge and Understanding, Analysis and Evaluation (AO2)

- describe, explain and interpret phenomena, effects and ideas in terms of scientific principles and concepts, presenting arguments and ideas clearly and logically;
- interpret and translate, from one form into another, data presented as continuous prose or in tables, diagrams and graphs;
- carry out relevant calculations;
- apply principles and concepts to unfamiliar situations, including those related to applications of science in a range of domestic, industrial and environmental contexts;
- evaluate scientific information and make informed judgements from it;

6.3 Investigative Skills (AO3)

- devise and plan investigations, drawing on scientific knowledge and understanding in selecting appropriate strategies;
- demonstrate appropriate investigative methods, including safe and skilful practical techniques, obtaining data which are sufficient and of appropriate precision, recording these methodically;
- interpret data to draw conclusions which are consistent with the evidence, using scientific knowledge and understanding, whenever possible, in explaining their findings;
- evaluate data and methods.

6.4 Quality of Written Communication

Where candidates are required to produce extended written material in English, they will be assessed on the quality of written communication. Candidates will be required to:

- present relevant information in a form that suits its purposes;
- ensure that text is legible and that spelling, punctuation and grammar are accurate, so that meaning is clear.

Quality of written communication will be assessed in the written papers and coursework. This assessment is therefore included in all three assessment objectives.

7 Scheme of Assessment

7.1 Assessment Units

In the Double Award, candidates follow 12 modules. 6 of the modules are assessed by module tests and 6 in the terminal examination.

The complete Scheme of Assessment comprises four components.

Paper 1	1½ hours
25% of the marks	90 marks

This paper will assess the content specified in modules: 04 Inheritance and Selection, 08 Structures and Bonding, 12 Waves and Radiation, including ideas and evidence. It will also assess aspects of the content from modules: 01 Humans as Organisms, 02 Maintenance of Life and 05 Metals. It will comprise compulsory structured questions of different lengths, incorporating calculations and data-response, and will provide the opportunity for answers written in continuous prose. The marking of candidates' continuous prose answers will take into account the quality of written communication. A Data Sheet will be provided. Candidates may use a calculator.

Paper 2	1½ hours
25% of the marks	90 marks

This paper will assess the content specified in modules: 03 Environment, 07 Patterns of Chemical Change, 11 Forces, including ideas and evidence. It will also assess aspects of the Content from modules: 06 Earth Materials, 09 Energy and 10 Electricity. It will comprise compulsory structured questions of different lengths, incorporating calculations and data-response, and will provide the opportunity for answers written in continuous prose. The marking of candidates' continuous prose answers will take into account the quality of written communication. A Data Sheet will be provided. Candidates may use a calculator.

Module Tests

30% of the marks

Six module tests will assess the content specified in modules: 01 Humans as Organisms, 02 Maintenance of Life, 05 Metals, 06 Earth Materials, 09 Energy and 10 Electricity. Each test consists of ten compulsory objective questions of different types.

Coursework

20% of the marks — **60 marks**

Assessments will be submitted in each of four skill areas from assessments made during normal coursework. The four skill areas are:

P. Planning
O. Obtaining evidence
A. Analysing and considering evidence
E. Evaluating.

Detailed instructions are provided later in this specification.

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	Component Weightings (%)				Overall Weighting of AOs (%)
	Paper 1	Paper 2	Module Tests	Course work	
AO1	15	15	20	-	50
AO2	10	10	10	-	30
AO3	-	-	-	20	20
Overall Weighting (%)	25	25	30	20	**100**

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

The structure of the scheme of assessment ensures that the content of the four main sections of the National Curriculum programme of study, (i.e. Sc1 Scientific Enquiry, Sc2 Life Processes and Living Things, Sc3 Materials and their Properties, and Sc4 Physical Processes) is weighted equally with 25% allocated to each.

7.3 Terminal Examination Requirements

Applications and ideas and evidence

Questions concerning the applications of science and ideas and evidence in science will make a significant contribution to the assessment. Examination questions will present stimulating material in realistic contexts, incorporating knowledge and understanding of the appropriate science. Candidates will therefore be expected to be able to apply this knowledge and understanding in unfamiliar contexts. Contexts from any of the modules in the scheme for the award, including those previously tested, may be used for such questions.

Assessment of ideas and evidence in science will contribute 5% overall and will be included in the terminal examination papers.

Data Sheet

A Data Sheet will be provided for use by candidates in Papers 1 and 2. The sheet will include specific information that candidates are not expected to recall. It is expected that candidates will be familiar with the sheet before the examination. A copy of the sheet is included in Appendix D.

Formulae

Candidates will be expected to recall the formulae for quantitative relationships specified for Sc4 Physical Processes in modules 09, 10, 11 and 12. A list of formulae is provided in Appendix E.

7.4 Module Tests

In the Double Award candidates are required to take 6 module tests. The tests are taken on examination sessions specified by AQA (see section 3.1), and are set and marked externally by AQA.

Each module test will be in two tiers, Foundation (F) and Higher (H). Each candidate must take one tier only in a module as follows; it is not necessary for the same tier to be taken for each module.

Tier F	Grades G-C	30 minutes
Tier H	Grades D-A*	30 minutes

The tier taken for a module should be appropriate to the candidate's expected attainment in that module. It is important to realise that grades are not awarded for individual modules, but for the subject as a whole.

Candidates must take tests on the following modules. A candidate may resit each module once only.

01 Humans as Organisms
02 Maintenance of Life
05 Metals
06 Earth Materials
09 Energy
10 Electricity

All tests will consist of ten compulsory objective questions of different types. Candidates will complete a separate answer sheet for each test, which will be machine marked by AQA. The types of questions used will involve recognition, completion and more in-depth tasks, designed to assess candidates' ability to recall, understand, use and apply the content of the module. Further details are to be found in the separate booklet of specimen module tests.

A candidate for the Double Award must take 6 module tests across the six available sessions (see section 3.1). The number of tests taken by a candidate in any session will depend on a centre's course structure; there is no restriction on the number of tests which may be taken, and candidates may take no tests in any session. Separate instructions will be given by AQA concerning registration of candidates, provision of module tests, security arrangements, procedures for their conduct, marking arrangements and problems with individual candidates. Module tests will be subject to the same conditions of control as terminal examinations, although the instructions regarding session times will provide for a variable length of session according to the number of tests being taken by candidates.

7.5 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 the use of language which is inappropriately complex or 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 applications of common measures of rate
- Averages/means and the purposes for which they are used
- Substitution of numbers for words and letters in formulae (without transformation of simple formulae)

....

HT

(N.B. In addition to the requirements listed above for the Foundation and Higher Tiers.)

- 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 generally conform to the recommendations contained in the following.

- *Biological Nomenclature*. Institute of Biology, Third Edition, 2000.
- *Chemical Nomenclature, Symbols and Terminology for Use in School Science*. Association for Science Education (ASE), Third Edition, 1985.
- *Graphical Symbols for Use in Schools and Colleges*. British Standards Institution (BSI), PP7307, 1989 incorporates a selection of electrical and electronic symbols for BS3939, 1985.
- *Signs, Symbols and Systematics*. Association for Science Education (ASE), 1995. ISBN 086 357 232 4

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

Subject Content

8

Summary of Subject Content

10. Module 01 – Humans as Organisms

10.1 What are human bodies built from?
10.2 What is the job of the digestive system and how does it do that job?
10.3 What is the job of the breathing system and why is it important?
10.4 How are substances transported around the body?
10.5 What causes disease and how do our bodies defend themselves against it?
10.6 How do dissolved substances get across boundaries in our bodies?

11. Module 02 – Maintenance of Life

11.1 Are plant cells just the same as animal cells?
11.2 How do plants obtain the food they need to live and grow?
11.3 How do the substances the plants need get inside plants and how are they transported once they are inside?
11.4 How do plants respond to their surroundings?
11.5 How do humans respond to their surroundings?
11.6 How do bodies maintain the conditions inside them that they need to work properly?
11.7 How do drugs affect our bodies?

12. Module 03 – Environment

12.1 What determines where particular species live and how many of them there are?
12.2 What happens to energy and biomass at each stage in a food chain?
12.3 What happens to the waste material produced by plants and animals?
12.4 How do humans affect the environment?

13. Module 04 – Inheritance and Selection

13.1 Why are individuals of the same species different from each other?
13.2 How can we breed plants and animals with the characteristics we prefer?
13.3 Why have some species of plants and animals died out? How do new species of plants and animals develop?
13.4 Which human characteristics show a simple pattern of inheritance?
13.5 How can women control their fertility?

14. Module 05 – Metals

14.1 Where do metals fit into a table of the elements?
14.2 How are metals extracted from their ores?
14.3 How can metals be prevented from reverting to their oxides?
14.4 How can metal compounds be made?

15. Module 06 – Earth Materials

15.1 Why is limestone a useful material?
15.2 How can so many useful products be made from crude oil?
15.3 How was the Earth's atmosphere formed?
15.4 Why have all mountains on Earth not worn away by now?

16. Module 07 – Patterns of Chemical Change

16.1 How can we speed up or slow down chemical reactions?
16.2 How can we use living things to do our chemistry for us?
16.3 Do chemical reactions always release energy?
16.4 How do chemicals produce the fertiliser we need to grow food?
16.5 How do we know how much of each reactant to use in a chemical reaction?

17. Module 08 – Structures and Bonding

17.1 What happens when elements react?
17.2 How can we explain the different properties of different types of substances?
17.3 How can chemical elements be grouped into families?
17.4 How can the similarities between elements in the same group be explained?
17.5 How do metal halogen compounds compare with the elements from which they are made? What use are these compounds?
17.6 What do all these chemical symbols, formulae and equations mean?

18. Module 09 – Energy

18.1 How is heat (thermal energy) transferred and how can we reduce heat transfer?
18.2 Why are electrical appliances so useful and what does it cost to use them?
18.3 How efficient are the appliances we use?
18.4 How should we generate the electricity we need?

19. Module 10 – Electricity

19.1 What does the current through an electrical circuit depend on?
19.2 How can electricity be used to make things move?
19.3 What is static electricity, how can it be used, and what is the connection between static electricity and electric currents?
19.4 What is mains electricity and how can it be used safely?
19.5 Why do we need to know the power of electrical appliances?
19.6 How do generators and transformers work?

20. Module 11 – Forces

20.1 How can we describe the way things move?
20.2 How do we make things speed up or slow down?
20.3 What happens to the movement energy when things speed up or slow down?
20.4 How do planets and artificial satellites stay in orbit?
20.5 What do we know about the origins of the Universe and the life histories of stars?

21. Module 12 – Waves and Radiation

21.1 Why do scientists talk about light and sound as waves?
21.2 Is there radiation we cannot see beyond the ends of the spectrum?
21.3 What do we know about the radiation from radioactive substances?
21.4 What happens to radioactive substances when they decay or are used in nuclear reactors?
21.5 What is ultrasound and how can it be used?
21.6 What do the shock waves from Earthquakes tell us about the Earth?

22. Aspects of Content for Terminal Examination

9 Introduction to Subject Content

9.1 Introduction

The content in this specification provides a modular approach in which topics in each of the three main areas of subject are grouped to form a number of coherent modules. It is envisaged that these may well be taught by different teachers. The arrangement of the modules facilitates this, and enables cross-referencing so that different teachers can work together where concepts interrelate or where topics might be transferred for teaching purposes.

The arrangement and numbering of modules is not intended to imply a teaching sequence beyond that necessary to match the timing of module tests. Centres are free to organise the teaching of modules into a suitable pattern, perhaps according to the preferences and expertise of the teachers involved. No attempt has been made to do this as there are many possible ways of arranging the modules. It is important to note that some of the modules are assessed by module tests and others by the terminal examination.

9.2 Breadth of Study

Reference must be made to the teaching requirements for breadth of study which are included in the key stage 4 programme of study and which are important when designing schemes of work. These identify contexts in which science should be taught, make clear that technological applications should be studied, and identify what should be taught about communication and health and safety in science.

Teaching of knowledge, skills and understanding

During the key stage, candidates should be taught the knowledge, skills and understanding through:

a. a range of domestic, industrial and environmental contexts;

b. considering ways in which science is applied in technological developments;

c. considering and evaluating the benefits and drawbacks of scientific and technological developments, including those related to the environment, personal health and quality of life, and those raising ethical issues;

d. using a range of sources of information, including ICT-based sources;

e. using first-hand and secondary data to carry out a range of scientific investigations, including complete investigations;

f. using quantitative approaches, where appropriate, including calculations based on relationships between physical quantities.

During the key stage, candidates should be taught to:

Communication

a. use a wide range of scientific, technical and mathematical language, symbols and conventions, including SI units, balanced chemical equations and a standard form to communicate ideas and develop an argument;

Health and Safety

b. recognise that there are hazards in living things, materials and physical processes, and assess risks and take action to reduce risks to themselves and others.

9.3 Ideas and Evidence in Science

The requirements of the ideas and evidence section of Sc1 Scientific Enquiry need to be met through the teaching of the subject content in this specification.

The subject content includes historical and contemporary contexts selected as being appropriate for the teaching/learning and assessment of ideas and evidence in science. These contexts may also be used to assess knowledge and understanding of relevant scientific ideas from the subject content.

All of the above contexts are indicated by a .

Through these contexts **candidates should be able** to apply the following ideas appropriately to information they are given about historically important scientific discoveries and to currently controversial scientific and technological issues:

a. that scientists report their findings to other scientists in special journals. The reports are not published unless other scientists feel the scientific research is of good quality and the findings are not usually accepted unless they can be repeated by other scientists;

b. that members of the public depend on the mass media (TV, newspapers, radio etc.) to keep them informed about issues involving science and technology. These may be biased but have a big influence on
- the issues that are discussed
- the points of view people take on these issues
- decisions about what research should be funded;

c. that to explain their findings scientists need to use their imaginations, so there can be more than one explanation of the same findings;

d. that scientists, like other people
- are reluctant to give up explanations that have served them well in the past
- have scientific, moral, religious and social views that are influenced by the prevailing views in the society in which they live;

e. that a new explanation is more likely to be accepted if it can be used to make predictions which are then tested and observed to be correct;

f. that scientists may be uncertain about whether or not a factor increases the chance of a particular outcome. This is especially likely
- in complex situations
- when the evidence is based on a small number of cases
- if it is difficult to explain how the factor could cause the outcome;

g. that science-based technology provides people with many of the things they most value in life but can also, usually unintentionally, harm people and the environment so that benefits always need to be weighed against costs (economic, environmental and social);

h. that even when there is full scientific agreement about the likely effects of some technological process, there may be a further (moral) question about whether, on balance, it should be allowed.

Assessment

Questions designed to assess ideas and evidence through the contexts in the subject content will be included in the terminal examination papers and will contribute 5% to the overall award. Information needed by candidates to answer these questions, in addition to that which is included in the subject content, will be provided in the questions.

9.4 Presentation of the Subject Content

Each module includes an introductory section, outlining its theme and the main topics included. The content is then presented under a series of questions and accompanying comments designed to provide structure for the module and to encourage an enquiring, investigative approach. Should teachers wish to organise the content of a module in some other suitable way, there is nothing to prevent this.

Detail

The detailed content inevitably seems quite long. However, it is important to realise that it represents an explicit specification of the knowledge, skills and understanding expected of candidates. It is the maximum an examiner will require, presented in clear, unambiguous language. Candidates will, however, be expected to demonstrate understanding by applying principles and concepts in the subject content to unfamiliar situations.

"Candidates should be able..."

The phrase "**Candidates should be able**…" is used to describe skills which candidates will need to display or where examples are expected. The use of the phrase varies across areas of the subject according to the nature of the material involved. Content which relates to ideas and evidence in science is often presented in this way.

Content tiering and key stage 3

The presentation of the content makes clear the material to be covered in the two examination tiers. It also makes clear the knowledge, skills and understanding expected of candidates from key stage 3 which are particularly relevant. This is done by sub-dividing each topic using lines and indicating material as follows.

KS3 — Content which is particularly relevant from key stage 3.

FT and HT — Content included in **both** Foundation and Higher tiers.

HT — Content included **only** in the Higher tier.

Examination questions in both tiers will assume that candidates have mastery of key stage 3 content, but the key stage 3 content will **not** be directly assessed.

Previously tested modules

The aspects of the content of previously tested modules required in the terminal examination are listed at the end of the modules.

9.5 Use in Wales and Northern Ireland

This GCSE specification has been written against the key stage 4 programme of study for England. Candidates entering for this GCSE in Wales and Northern Ireland must be taught all the material required by the National Curriculum in their own country.

Some material in the key stage 4 programmes of study for Wales and Northern Ireland is additional to the key stage 4 programme of study for England. This includes some material that was previously in key stage 4 in England and is now in key stage 3, but which remains in key stage 4 in Wales.

The presentation of the detailed subject content in this specification includes relevant material from key stage 3 for England. By teaching some of this material in key stage 4 where it is necessary to do so, teachers will partly meet the statutory curriculum requirements in their country.

There is, though, some remaining additional material in the key stage 4 programmes of study in Wales and Northern Ireland which does not feature in key stage 4 in England. For convenience, an outline is given in Appendix F of the additional material which needs to be taught by teachers in Wales and Northern Ireland to meet fully the statutory curriculum requirements in their country. This additional material will **not** be assessed in the examination on this specification.

10 Module 01 – Humans as Organisms

This module includes the following:

Considering the similarities between the cells that make up the human body and the differences between them which enable them to do different jobs.

Exploring some human organ systems in relation to the life processes they serve:

- *the digestive system which enables nutrients from food to enter the bloodstream;*
- *the breathing system which takes into the body the oxygen cells needed for respiration and removes from the body the carbon dioxide released by this process;*
- *the circulation system which transports materials around the body.*

Examining the ways in which the body defends itself against infection.

Module 02 Maintenance of Life provides complementary studies of how the cells, tissues and organs of living things serve their life processes.

10.1 What are human bodies built from?

All living things are made up of cells. Different types of cells do different jobs.

KS3

(prior learning)
All animals and plants are made up of cells.

Cells may be specialised to carry out a particular function. A group of cells with similar structure and a particular function is called a tissue.

Organs are made out of tissues. Different organs are combined to form organ systems. Each system in the body carries out a particular function or range of functions.

FT and HT

Most human cells like most other animal cells have the following parts:

- a nucleus which controls the activities of the cell;
- cytoplasm in which most of the chemical reactions take place;
- a cell membrane which controls the passage of substances in and out of the cell.

Candidates should be able, when provided with appropriate information, to relate the structure of different types of human cells to their function in a tissue, an organ or the whole organism.

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HT The chemical reactions inside cells are controlled by enzymes.

The cytoplasm contains structures called mitochondria, which is where most energy is released in respiration.

10.2 What is the job of the digestive system and how does it do that job?

The job of the digestive system is to convert food into soluble substances and then to absorb it into the bloodstream.

KS3 (prior learning)
The human diet includes carbohydrates, proteins and fats.

The digestive system breaks down food and absorbs it into the bloodstream.
The digestive system includes the gullet, stomach, liver, pancreas, small intestine and large intestine.

FT and HT Starch (a carbohydrate), proteins and fats are insoluble. They are broken down into soluble substances so that they can be absorbed into the bloodstream in the wall of the small intestine. In the large intestine much of the water is absorbed into the bloodstream. The indigestible food which remains makes up the bulk of the faeces. Faeces leave the body via the anus.

The breakdown of large molecules into smaller molecules is speeded up (catalysed) by enzymes.

The enzyme amylase is produced in the salivary glands, the pancreas and the small intestine. This enzyme catalyses the breakdown of starch into sugars.

Protease enzymes are produced by the stomach, the pancreas and the small intestine. These enzymes catalyse the breakdown of protein into amino acids.

Lipase enzymes are produced by the pancreas and small intestine. These enzymes catalyse the breakdown of lipids (fats and oils) into fatty acids and glycerol.

The stomach also produces hydrochloric acid. The acid kills most of the bacteria taken in with food. The enzymes in the stomach work most effectively in these acid conditions.

The liver produces bile which is stored in the gall bladder before being released into the small intestine. Bile neutralises the acid that was added to food in the stomach. This provides alkaline conditions in which enzymes in the small intestine work most effectively. Bile also emulsifies fats (breaks large drops of fats into smaller droplets). This increases the surface area of fats for lipase enzymes to act upon.

10.3 What is the job of the breathing system and why is it important?

The cells in our bodies all need oxygen to be able to release energy for the jobs they do. They all produce carbon dioxide as a waste product. The job of the breathing system is to take oxygen into the body and to get rid of carbon dioxide from the body.

KS3 (prior learning)
The breathing system includes ribs, rib muscles, diaphragm, lungs, trachea, bronchi, bronchioles and alveoli.

The windpipe (trachea) splits into two branches called bronchi, one going to each lung. The bronchi divide repeatedly into smaller branches called bronchioles which end in a very large number of alveoli.

Breathing is necessary because all living cells in the body respire. During aerobic respiration (respiration which uses oxygen) chemical reactions occur which:

- use glucose (a sugar) and oxygen;
- release energy;
- produce carbon dioxide and water.

FT and HT The breathing system takes air into and out of the body so that oxygen from the air can diffuse into the bloodstream and carbon dioxide can diffuse out of the bloodstream into the air. The lungs are in the upper part of the body (thorax), protected by the ribcage and separated from the lower part of the body (abdomen) by the diaphragm.

To make air move in to the lungs the ribcage moves out and the diaphragm becomes flatter. These changes are then reversed to make air move out of the lungs. The movement of air into and out of the lungs is called ventilation.

Aerobic respiration is summarised by the equation :

glucose + oxygen ⟶ carbon dioxide + water [+energy]

During vigorous exercise, muscle cells may be short of oxygen. When there is a shortage of oxygen, cells may carry out anaerobic respiration for a short time. This releases waste lactic acid. Muscle cells can then obtain energy from glucose by anaerobic respiration (respiration which does not use oxygen).

The body then needs oxygen to break down this waste product, lactic acid. The oxygen that is needed is called an oxygen debt.

The energy that is released during respiration is used:

- to build up larger molecules using smaller ones;
- to enable muscles to contract;
- to maintain a steady body temperature in colder surroundings;

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HT

- in the active transport of materials across boundaries.

Aerobic respiration inside cells occurs in mitochondria.

If muscles are subjected to long periods of vigorous activity, they become fatigued, i.e. they stop contracting efficiently. If insufficient oxygen is reaching the muscles they use anaerobic respiration to obtain energy.

This is the incomplete breakdown of glucose and produces lactic acid. Because the breakdown of glucose is incomplete, much less energy is released than during aerobic respiration. Anaerobic respiration results in an oxygen debt that has to be repaid in order to oxidise lactic acid to carbon dioxide and water.

To inhale:

- muscles between the ribs contract, pulling the ribcage upwards;
- at the same time the diaphragm muscles contract causing the diaphragm to flatten;
- these two movements cause an increase in the volume of the thorax;
- the consequent decrease in pressure results in atmospheric air entering the lungs.

The alveoli provide a very large, moist surface, richly supplied with blood capillaries so that gases can readily diffuse into and out of the blood.

10.4 How are substances transported around the body?

Substances are transported around the body, for example from where they are taken into the body to cells; or from cells to where they are removed from the body, by the circulation system, the heart, the blood vessels and the blood.

FT and HT

The circulation system transports substances around the body. The heart pumps blood around the body. Much of the wall of the heart is made from muscle fibres.

Blood enters an atrium of the heart. The atrium contracts and forces blood into a ventricle. The ventricle contracts and forces blood out of the heart. Valves in the heart ensure that blood flows in the correct direction.

Blood flows from the heart to the organs through arteries and returns through veins. There are two separate circulation systems, one to the lungs and one to all other organs of the body.

Arteries have thick walls containing muscle and elastic fibres. Veins have thinner walls and often have valves to prevent the back-flow of blood.

In the organs, blood flows through very narrow, thin-walled, blood vessels called capillaries. Substances needed by the cells in body tissues pass out of the blood, and substances produced by the cells pass into the blood through the walls of the capillaries.

Blood consists of a fluid called plasma in which are suspended white blood cells, platelets and red blood cells.
Plasma transports:

- carbon dioxide from the organs to the lungs;
- soluble products of digestion from the small intestine to other organs;
- urea from the liver to the kidneys.

White blood cells have a nucleus. They form part of the body's defence system against microorganisms.

Platelets are small fragments of cells. They have no nucleus. Platelets help blood clot at the site of a wound.

Red blood cells transport oxygen from the lungs to the organs.

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HT — Red blood cells have no nucleus. They are packed with a red pigment called haemoglobin. In the lungs haemoglobin combines with oxygen to form oxyhaemoglobin. In other organs oxyhaemoglobin splits up into haemoglobin and oxygen.

10.5 What causes disease and how do our bodies defend themselves against it?

Our bodies provide an excellent environment for many microbes which can make us ill once they are inside. Our bodies need to stop most microbes from getting in and deal with any microbes which do get in.

KS3 — (prior learning)
Bacteria and viruses may reproduce rapidly inside the body and may produce poisons (toxins) which make us feel ill. Viruses damage the cells in which they reproduce.

Vaccination is used to protect us against bacteria and viruses.

FT and HT — Diseases can be caused when microorganisms such as certain bacteria and viruses enter the body:

- a bacterial cell consists of cytoplasm and a membrane surrounded by a cell wall; the genes are not in a distinct nucleus;
- viruses are smaller than bacteria; they consist of only a protein coat surrounding a few genes; they can only reproduce inside living cells.

Diseases are more likely to occur if large numbers of microorganisms enter the body as a result of unhygienic conditions or contact with infected people.

The body has several methods of defending itself against the entry of microorganisms:

- the skin acts as a barrier;
- the breathing organs produce a sticky liquid mucus which covers the lining of these organs and traps microorganisms;
- the blood produces clots that seal cuts.

White blood cells help to defend against infective microorganisms:

- by ingesting microorganisms;
- by producing antibodies which destroy particular bacteria or viruses;
- by producing antitoxins which counteract the toxins (poisons) released by microorganisms.

When people are vaccinated they are immunised against disease by introducing a mild, or dead, form of the infecting organism into their bodies. The white blood cells respond by producing antibodies. If the infective organism enters the body, antibodies are rapidly produced to destroy it.

Once they have produced antibodies against a particular bacterium or virus, white blood cells can quickly produce them again so that the person is immune to that disease.

Candidates should be able, when provided with appropriate information, to evaluate evidence relating living conditions and lifestyle to the spread of disease.

10.6 How do dissolved substances get across boundaries in our bodies?

When passing into our bodies dissolved substances need to cross the surfaces of organs. To get into or out of cells, dissolved substances have to cross the cell membranes.

FT and HT

Diffusion is the spreading of the particles of a gas, or of any substance in solution, resulting in a net movement from a region where they are at a higher concentration to a region where they are at a lower concentration. The greater the difference in concentration, the faster the rate of diffusion. Oxygen required for respiration passes through cell membranes and through gas exchange surfaces, such as alveoli in the lungs, by diffusion.

Other substances such as sugar and ions, can also pass through cell membranes.

Many organ systems are specialised for exchanging materials.
In humans the surface area of the lungs is increased by the alveoli, and that of the small intestine by villi.

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HT

Candidates should be able, when provided with appropriate information, to explain how other gas and solute exchange surfaces in humans and other organisms are adapted to maximise effectiveness.

11 Module 02 – Maintenance of Life

This module includes the following:

Investigating how plants:

- *obtain the water, nutrients and carbon dioxide they need;*
- *make food via the process of photosynthesis;*
- *transport materials to where they are needed;*
- *respond to their surroundings.*

Exploring how humans:

- *coordinate their behaviour in response to stimuli from their environment;*
- *maintain a stable internal environment.*

Examining the effects of drugs on the human body.

Module 01 Humans as Organisms complements this module by examining a different range of examples of the ways in which cells, tissues, organs and organ systems enable living things to carry out life processes.

11.1 Are plant cells just the same as animal cells?

Like animals, green plants are made up of cells. These cells are similar to animal cells in some ways but different from them in other ways.

KS3

(prior learning)
All plants are made up of cells. Cells may be specialised to carry out a particular function. A group of cells with similar structure and a particular function is called a tissue. Organs are made of tissues.

FT and HT

Most plant cells, like animal cells, have the following parts:

- a nucleus which controls the activities of the cell;
- cytoplasm in which most of the chemical reactions take place;
- a cell membrane which controls the passage of substance in and out of the cell.

Plant cells also have:

- a cell wall which strengthens the cell;

and often have:

- chloroplasts which absorb light energy to make food;
- a permanent vacuole filled with cell sap.

Candidates should be able, when provided with appropriate information, to relate the structure of different types of plant cells to their function in a tissue or an organ.

11.2 How do plants obtain the food they need to live and grow?

Green plants use light energy to make their own food. They obtain the raw materials they need to make this food from the air and the soil.

KS3 (prior learning)
Green plants photosynthesise when it is light.

FT and HT Photosynthesis is summarised by the equation:
carbon dioxide + water [+ light energy] $\longrightarrow$ glucose + oxygen

During photosynthesis:

- light energy is absorbed by a green substance called chlorophyll which is found in chloroplasts in some plant cells;
- this energy is used by converting carbon dioxide and water into sugar (glucose);
- oxygen is released as a by-product.

The rate of photosynthesis may be limited by:

- low temperature;
- shortage of carbon dioxide;
- shortage of light.

The glucose produced in photosynthesis may be converted into insoluble starch for storage.

Plant cells use some of the glucose produced during photosynthesis for respiration.

Plant roots absorb mineral salts including nitrate needed for healthy growth.

Light, temperature and the availability of carbon dioxide interact and in practice any one of them may be the factor that limits photosynthesis.

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HT The energy released by plants during respiration is used to build up smaller molecules into larger molecules:

- sugars into starch;
- sugars into cellulose for cell walls;
- sugars, nitrates and other nutrients into amino acids which are then built up into proteins;
- sugars into lipids (fats or oils) for storage in seeds.

For healthy growth plants also need mineral ions including:

- nitrate – for the synthesis of proteins;
- phosphate – which has an important role in the reactions involved in photosynthesis and respiration;
- potassium – which helps enzymes involved in photosynthesis and respiration to work.

The symptoms shown by plants growing in conditions where mineral ions are deficient include:

- stunted growth and yellow older leaves if nitrate ions are deficient;
- poor root growth and purple younger leaves if phosphate ions are deficient;
- yellow leaves with dead spots if potassium ions are deficient.

11.3 How do the substances plants need get inside plants and how are they transported once they are inside?

The leaves of plants have to take in the carbon dioxide the plants need and their roots have to take in the minerals and water the plants need. Inside plants, materials have to be transported to where they are needed.

KS3

(prior learning)
Most of the water and minerals which enter a plant root are absorbed by root hair cells.

FT and HT

Carbon dioxide enters leaves and leaf cells by diffusion, i.e. simply by spreading from a higher to a lower concentration.

Plants lose water vapour from the surface of their leaves. This loss of water vapour is called transpiration. Transpiration is more rapid in hot, dry and windy conditions. Most plants have a waxy layer (cuticle) on their leaves which stops them losing too much water. Plants living in dry conditions have a thicker cuticle.

Most of the transpiration is through tiny holes called stomata. Plants need stomata to obtain carbon dioxide from the atmosphere.
The size of stomata is controlled by guard cells which surround them. If plants lose water faster than it is replaced by the roots, the stomata can close to prevent wilting.

The water inside plant cells gives support for young plants. This is the main method of support and the plant wilts if the cells are short of water.

Flowering plants have separate transport systems for water and nutrients:

- xylem tissue transports water and minerals from the roots to the stem and leaves;
- phloem tissue carries nutrients such as sugars from the leaves to the rest of the plant including the growing regions and the storage organs.

Water often moves across boundaries by osmosis.

Osmosis is the diffusion of water from a dilute to a more concentrated solution through a partially permeable membrane that allows the passage of water molecules but not solute molecules.

In plants, the surface area of the roots is increased by root hairs, and the surface area of leaves by the flattened shape and internal air spaces.

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HT Substances are sometimes absorbed against a concentration gradient. This requires the use of energy from respiration. The process is called active transport. It enables plants to absorb ions from very dilute solutions.

When water moves into plant cells by osmosis it increases the pressure inside the cell. The cell walls are sufficiently strong to withstand the pressure. It is this pressure which keeps the cells rigid (maintains their turgor) and hence provides support.

Candidates should be able, when provided with appropriate information, to explain how the gas and solute exchange surfaces in plants are adapted to maximise effectiveness.

11.4 How do plants respond to their surroundings?

Plants need to be able to detect the directions of gravity, of greatest moisture and of greatest light intensity so that their roots and shoots can grow in the directions which give the plant the best chance of surviving.

FT and HT Plants are sensitive to light, moisture and gravity:

- their shoots grow towards light and against the force of gravity;
- their roots grow towards moisture and in the direction of the force of gravity.

Plants produce hormones to coordinate and control growth.

The responses of plant roots and shoots to light, gravity and moisture are the result of unequal distribution of hormones, causing unequal growth rates.

The hormones which control the processes of growth and reproduction in plants can be used by humans to:

- produce large numbers of plants quickly by stimulating the growth of roots from cuttings;
- regulate the ripening of fruits on the plant and during transport to customers;
- kill weeds by disrupting their normal growth patterns.

11.5 How do humans respond to their surroundings?

We detect features of the world around us using our senses. Processing this information and coordinating the actions which we make in response to it, is the job of our nervous system.

FT and HT

The nervous system enables humans to react to their surroundings and coordinate their behaviour. Cells called receptors detect stimuli (changes in the environment). These include:

- receptors in the eyes which are sensitive to light;
- receptors in the ears which are sensitive to sound;
- receptors in the ears which are sensitive to changes in position and enable us to keep our balance;
- receptors on the tongue and in the nose which are sensitive to chemicals and enable us to taste and smell;
- receptors in the skin that are sensitive to touch and pressure and temperature changes.

Information from receptors passes along cells (neurones) in nerves to the brain. The brain coordinates the response.

Some responses to stimuli are automatic and rapid and are called reflex actions.

In a simple reflex action, electrical impulses pass from a receptor along a sensory neurone to the spinal cord or brain, then along a motor neurone to a muscle or gland. The muscle or gland brings about the response.

The eye includes: sclera, cornea, iris, pupil, lens, ciliary muscle, suspensory ligament, retina and optic nerve.

In the eye:

- the tough outer sclera has a transparent region at the front called the cornea;
- the muscular iris controls the size of the pupil and hence the amount of light reaching the retina;
- the lens is held in position by suspensory ligaments and ciliary muscles;
- the retina contains the receptor cells which are sensitive to light.

Light from an object enters the eye through the cornea. The curved cornea and the lens produce an image on the retina. The receptor cells in the retina send impulses to the brain along sensory neurones in the optic nerve.

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HT

The shape of the lens can be altered, by contraction or relaxation of the ciliary muscles, to focus near or distant objects respectively.

Electrical impulses transmit information from receptor cells along sensory neurones to the central nervous system that includes the brain and the spinal cord.

Reflex actions often involve three neurones called sensory, relay and motor neurones. In such a reflex action:

- impulses from a receptor pass along a sensory neurone to the central nervous system;
- at a junction (synapse) between a sensory neurone and a relay neurone in the central nervous system, a chemical is released which causes an impulse to be sent along a relay neurone;
- a chemical is then released at the synapse between a relay neurone and a motor neurone in the central nervous system, causing impulses to be sent along a motor neurone to the organ (the effector) which brings about the response;
- the effector is either a muscle or a gland;
- a muscle responds by contracting, a gland by releasing (secreting) chemical substances.

Candidates should be able, when provided with appropriate information, to analyse a reflex action in terms of:

stimulus ⟶ receptor ⟶ coordinator ⟶ effector ⟶ response

11.6 How do bodies maintain the conditions inside them that they need to work properly?

To survive our bodies must keep themselves at just the right temperature, have just the right amount of water and sugar in the bloodstream etc. The body has automatic systems which constantly monitor and control these things.

FT and HT

Humans need to remove waste products from their bodies and to keep their internal environment relatively constant.

Waste products which have to be removed from the body include:

- carbon dioxide produced by respiration - most of this leaves the body via the lungs when we breathe out;
- urea produced in the liver by the breakdown of excess amino acids - this is removed by the kidneys in the urine, which is temporarily stored in the bladder.

Internal conditions which are controlled include:

- the water content of the body - water leaves the body via the lungs when we breathe out and via the skin when we sweat, and excess water is lost via the kidneys in the urine;
- the ion content of the body - ions are lost via the skin when we sweat and excess ions are lost via the kidneys in the urine;
- temperature - to maintain the temperature at which enzymes work best.

Sweating helps to cool the body. More water is lost when it is hot, and more water has to be taken as drink or in food to balance this loss.

Many processes within the body are coordinated by chemical substances called hormones. Hormones are secreted by glands and are transported to their target organs by the bloodstream.

The blood glucose concentration is controlled by the hormones insulin and glucagon which are released (secreted) by the pancreas.

Diabetes is a disease in which a person's blood glucose concentration may rise to a fatally high level because the pancreas does not produce enough of the hormone insulin. Diabetes may be treated by careful attention to diet and by injecting insulin into the blood.

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HT The kidneys help to maintain the internal environment by:

- first filtering the blood;
- re-absorbing all the sugar;
- re-absorbing the dissolved ions needed by the body;
- re-absorbing as much water as the body needs;
- releasing urea, excess ions and excess water as urine.

The kidneys produce dilute urine if there is too much water in the blood or concentrated urine if there is too little water in the blood. If the water content of the blood is too low, the pituitary gland releases a hormone called ADH into the blood. This causes the kidneys to re-absorb more water and results in a more concentrated urine. If the water content of the blood is too high, less ADH is released into the blood. Less water is re-absorbed in the kidneys resulting in a more dilute urine.

Sugar and dissolved ions may each be actively absorbed from the kidney tubules against a concentration gradient.

Body temperature is monitored and controlled by the thermoregulatory centre in the brain. This centre has receptors sensitive to the temperature of blood flowing through the brain. Also temperature receptors in the skin send impulses to the centre giving information about skin temperature.

If the core body temperature is too high:

- blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more heat is lost;
- sweat glands release more sweat which cools the body as it evaporates.

If the core body temperature is too low:

- blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries;
- muscles may 'shiver' - their contraction needs respiration which releases some energy as heat.

The blood glucose concentration of the body is monitored and controlled by the pancreas.

If the blood glucose concentration is too high, the pancreas secretes insulin into the blood. This causes the liver to convert glucose into insoluble glycogen and store it.

If the blood glucose concentration is too low, the pancreas secretes glucagon which causes the liver to convert glycogen into glucose and release it into the blood.

11.7 How do drugs affect our bodies?

Even very common drugs such as alcohol and tobacco which may be used legally by people over a certain age harm our bodies. People cannot make sensible decisions about drugs unless they know the dangers involved.

KS3 (prior learning)
Solvents, alcohol, tobacco and other drugs may harm the body.

FT and HT Solvents:

- affect behaviour;
- may cause damage to the lungs, liver and brain.

Alcohol:

- affects the nervous system by slowing down reactions and may lead to lack of self-control, unconsciousness or even coma;
- may cause damage to the liver and brain.

Drugs change the chemical processes in people's bodies so that they may become dependent or addicted to them and suffer withdrawal symptoms without them. Nicotine is the addictive substance in tobacco.

Tobacco smoke contains substances which can help to cause:

- lung cancer;
- other lung diseases such as bronchitis and emphysema;
- disease of the heart and blood vessels.

Tobacco smoke also contains carbon monoxide which reduces the oxygen-carrying capacity of the blood. In pregnant women this can deprive a fetus of oxygen and lead to a low birth mass.

Candidates should be able, when provided with appropriate information, to explain how the link between smoking tobacco and lung cancer gradually became accepted.

HT Carbon monoxide combines irreversibly with the haemoglobin in red blood cells.

12 Module 03 – Environment

This module includes the following:

Examining how various organisms are adapted to survive in their normal environment and the factors which govern the population of a species in a particular location.

Investigating the transfer along food chains and webs of energy, nutrients and biomass.

Exploring the role of microbes in the decomposition of waste organic material and hence recycling it. This includes a detailed study of the carbon cycle and, for the higher tier only, of the nitrogen cycle.

Considering the ways in which human activities can disrupt ecosystems which would otherwise be sustained in a relatively stable condition by the biological and geo-chemical cycling of materials.

12.1 What determines where particular species live and how many of them there are?

Animals and plants are normally well adapted to survive in their normal environment. Their population depends on many factors including competition for the things they need, being eaten for food and being infected by disease.

KS3

(prior learning)
Physical factors which may affect organisms include:

- temperature;
- amount of light;
- availability of water;
- the availability of oxygen and carbon dioxide.

These factors may vary according to the time of day and the time of year.

Organisms live, grow and reproduce in places where, and at times when, conditions are suitable.

This helps to explain why the types of organisms vary from place to place and from time to time.

FT and HT

Organisms have features (adaptations) which enable them to survive in the conditions in which they normally live.

Candidates should be able, when provided with appropriate information, to:

- explain how animals are adapted for survival in arctic and desert environments in terms of:
  - body size and surface area
  - thickness of insulating coat
  - amount of body fat
  - camouflage;
- explain how plants are adapted to survive in arid conditions;
- suggest how other organisms are adapted to the conditions in which they live.

Plants often compete with each other for space, and for water and nutrients from the soil.

Animals often compete with each other for space, food and water.

Candidates should be able, when provided with appropriate information, to suggest the factors for which organisms are competing in a given habitat.

Animals which kill and eat other animals are called predators; the animals they eat are called prey.

In a community:

- the number of animals of a particular species (its population) is usually limited by the amount of food available;
- if the population of prey increases, more food is available for its predators and their population may also increase;
- if the population of predators increases, more food is needed and the population of prey will decrease.

The size of a population may be affected by:

- the total amount of food or nutrients available;
- competition for food or nutrients;
- competition for light;
- predation or grazing;
- disease.

12.2 What happens to energy and biomass at each stage in a food chain?

By observing the numbers and sizes of the organisms in food chains we can find out what happens to energy and biomass as it passes along a food chain.

KS3 (prior learning)
Food chains show which organisms eat other organisms.

In a food chain, A⟶B⟶C means that B eats A and C eats B.

Food chains always begin with green plants (producers) which provide food for other organisms (consumers).

Food chains are often interconnected to form food webs.

Food chains and food webs show the transfer of energy and material from one type of organism to another.

The number of organisms at each stage of a food chain can be shown as a pyramid of numbers.

FT and HT

Radiation from the Sun is the source of energy for all communities of living organisms. Green plants capture a small part of the solar energy which reaches them. This energy is stored in the substances which make up the cells of the plants.

The mass of living material (biomass) at each stage in a food chain is less than it was at the previous stage. The biomass at each stage can be drawn to scale and shown as a pyramid of biomass.

Candidates should be able to interpret pyramids of biomass **and** construct them from appropriate information.

At each stage in a food chain, less material and less energy are contained in the biomass of the organisms. This means that the efficiency of food production can be improved by reducing the number of stages in food chains.

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HT

The amounts of material and energy contained in the biomass of organisms is reduced at each successive stage in a food chain because:

- some materials and energy are always lost in the organisms' waste materials;
- respiration supplies all the energy needs for living processes, including movement; much of this energy is eventually lost as heat to the surroundings; these losses are especially large in mammals and birds whose bodies must be kept at a constant temperature which is usually higher than that of their surroundings.

The efficiency of food production can also be improved by:

- restricting energy loss from food animals by limiting their movement and by controlling the temperature of their surroundings;
- using hormones to regulate the ripening of fruit on the plant and during transport to consumers.

Candidates should be able to evaluate the positive and negative effects of managing food production and distribution and able to recognise that practical solutions to human needs may require compromise between competing priorities.

12.3 What happens to the waste material produced by plants and animals?

Many trees shed their leaves each year and most animals produce droppings at least once a day. All plants and animals also eventually die. Microbes play an important part in decomposing this material so that it can be used again by plants. The same material is recycled over and over again.

FT and HT

Living things remove materials from the environment for growth and other processes. These materials are returned to the environment either in waste materials or when living things die and decay.

Materials decay because they are broken down (digested) by microorganisms.

Microorganisms digest materials faster in warm, moist conditions. Many microorganisms are also more active when there is plenty of oxygen.

Microorganisms are used:
- at sewage works to break down waste from humans;
- in compost heaps to break down waste plant materials.

The decay process releases substances which plants need to grow.

In a stable community, the processes which remove materials are balanced by processes which return materials. The materials are constantly cycled.

The constant cycling of carbon is called the carbon cycle.
In the carbon cycle:
- carbon dioxide is removed from the environment by green plants for photosynthesis; the carbon from the carbon dioxide is used to make carbohydrates, fats and proteins which make up the body of plants;
- some of the carbon dioxide is returned to the atmosphere when green plants respire;
- when green plants are eaten by animals and these animals are eaten by other animals, some of the carbon becomes part of the fats and proteins which make up their bodies;
- when animals respire some of this carbon becomes carbon dioxide and is released into the atmosphere;
- when plants and animals die, some animals and microorganisms feed on their bodies; carbon is released into the atmosphere as carbon dioxide when these organisms respire.

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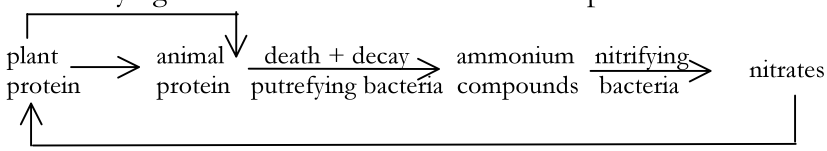
HT

The constant cycling of nitrogen is called the nitrogen cycle.

In the nitrogen cycle:
- green plants absorb nitrates from the soil;
- they use the nitrogen in these nitrates to make proteins;
- when green plants are eaten by animals and these animals are eaten by other animals, some of the nitrogen then becomes part of the proteins in their bodies;
- when putrefying (decay) bacteria and fungi break down the waste products of animals and the protein from dead animals and plants, ammonium compounds are produced;
- nitrifying bacteria convert ammonium compounds to nitrates.



By the time the microorganisms and detritus feeders have broken down the waste products and dead bodies of organisms in ecosystems and cycled the materials as plant nutrients, all the energy originally captured by green plants has been transferred.

12.4 How do humans affect the environment?

Humans often upset the balance of different populations in natural ecosystems, or change the environment so that some species find it difficult to survive. With so many people in the world, there is a serious danger of causing permanent damage not just to local environments but also to the global environment.

FT and HT

Humans reduce the amount of land available for other animals and plants by:

- building;
- quarrying;
- farming;
- dumping waste.

Human activities may pollute:

- water – with sewage, fertiliser or toxic chemicals;
- air – with smoke and gases such as sulphur dioxide;
- land – with toxic chemicals, such as pesticides and herbicides, which may be washed from land into water.

When fossil fuels are burned carbon dioxide is released into the atmosphere.

Sulphur dioxide and nitrogen oxides may also be released. These gases dissolve in rain and make it more acidic. Acid rain may damage trees directly. If the water in rivers and lakes becomes too acidic, plants and animals cannot survive.

When the Earth's human population was much smaller, the effects of human activity were usually small and local.

Rapid growth in the human population and an increase in the standard of living means that:

- raw materials, including non-renewable energy resources, are rapidly being used up;
- increasingly more waste is produced;
- unless waste is properly handled more pollution will be caused.

Large scale deforestation in tropical areas, for timber and to provide land for agriculture, has:

- increased the release of carbon dioxide into the atmosphere (because of burning and the activities of microorganisms);
- reduced the rate at which carbon dioxide is removed from the atmosphere and 'locked-up' for many years as wood.

Increases in the numbers of cattle and rice fields have increased the amount of methane released into the atmosphere.

The levels of carbon dioxide and methane in the atmosphere are slowly rising. Increasing levels of these gases may be causing global warming by increasing the 'greenhouse effect'.

An increase in the Earth's temperature of only a few degrees Celsius:

- may cause quite big changes in the Earth's climate;
- may cause a rise in sea level.

Candidates should be able, when supplied with appropriate information, to use their scientific knowledge, weigh evidence and form balanced judgements about some of the major environmental issues facing society, including the importance of sustainable development.

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HT Farmers add fertilisers to soil to replace the nutrients which crops remove. Excess fertilisers may be washed into lakes and rivers.

Pollution of water by fertilisers may cause eutrophication. The stages in this process are:

- the rapid growth of water plants;
- death of some of these due to competition, e.g. for light;
- an increase in the number of microorganisms which feed on dead organisms;
- the increased use of oxygen from the water by these microorganisms for their respiration;
- the resultant death, due to oxygen shortage, of fish and other aquatic animals.

Untreated sewage provides food for microorganisms. This has the same effect (eutrophication) in water as dead vegetation.

Carbon dioxide and methane in the atmosphere absorb most of the energy radiated by the Earth. Some of this energy is re-radiated back to the Earth and so keeps the Earth warmer than it would otherwise be.

13 Module 04 – Inheritance and Selection

This module includes the following:

Investigating the variation between individuals of the same species and interpreting this in terms of both heredity and environmental factors.

Explaining inheritance in terms of information carried on chromosomes and, at the higher tier only, developing this explanation further in terms of cell division by mitosis and meiosis.

Exploring the use of selective breeding, cloning and genetic engineering, to produce plants and animals with preferred characteristics.

Considering how natural selection has resulted in the evolution of some species and the extinction of others, and examining the role of mutation in this process.

Studying a selection of simple patterns of inheritance in humans:
- *the determination of sex;*
- *the inheritance both of diseases caused by dominant alleles and diseases caused by recessive alleles.*

Examining and evaluating the hormonal control of fertility in human females.

13.1 Why are individuals of the same species different from each other?

There are not only differences between different species of plants and animals, but also between individuals of the same species. These differences are due partly to the information in the cells they have inherited from their parents and partly to the different environments in which the individuals live and grow.

FT and HT

Young plants and animals resemble their parents (have similar characteristics) because of information passed on to them in the sex cells (gametes) from which they developed.

This information is carried by genes. Different genes control the development of different characteristics.

Candidates should be able, when provided with appropriate information, to explain:
- why Mendel proposed the idea of separately inherited factors that we now call genes;
- why the importance of Mendel's discovery was not recognised until after his death.

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Differences in the characteristics of different individuals of the same kind (species) may be due to differences in:
- the genes they have inherited (genetic causes);

- the conditions in which they have developed (environmental causes);

or a combination of both.

The nucleus of a cell contains chromosomes. Chromosomes carry genes that control the characteristics of the body. Each chromosome carries a large number of genes.

Many genes have different forms called alleles, which may produce different characteristics.

In body cells the chromosomes are normally found in pairs. Body cells divide to produce additional cells during growth or to produce replacement cells.

There are two forms of reproduction:

- sexual reproduction - which involves the joining (fusion) of male and female gametes;
- asexual reproduction - where there is no fusion of cells and only one individual is needed as the single parent.

Asexual reproduction gives rise to individuals whose genetic information is identical with that of the parent. These genetically identical individuals are known as a clone.

Sexual reproduction results in individuals that have a mixture of the genetic information from two parents. These individuals show more variation than offspring from asexual reproduction.

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HT Before each cell division, a copy of each chromosome is made so that each body cell has exactly the same genetic information. This type of cell division is called mitosis.

Cells in reproductive organs - testes and ovaries in humans - divide to form sex cells (gametes). When a cell divides to form gametes:

- copies of the chromosomes are made;
- then the cell divides twice to form four gametes, each with a single set of chromosomes.

This type of cell division is called meiosis.

When gametes join at fertilisation, a single body cell with new pairs of chromosomes is formed. A new individual then develops by this cell repeatedly dividing by mitosis.

The cells of the offspring produced by asexual reproduction are produced by mitosis from the parental cells. They contain the same genes as the parents.

Sexual reproduction gives rise to variation because:

- the gametes are produced from the parental cells by meiosis;
- when gametes fuse, one of each pair of alleles comes from each parent;
- the alleles in a pair may vary and therefore produce different characteristics.

13.2 How can we breed plants and animals with the characteristics we prefer?

By selecting only preferred plants and animals for sexual reproduction we can gradually breed animals and plants with desired characteristics. Non-sexual reproduction can be used to produce individuals exactly like their parents. [Scientists can now add, remove or change genes to produce the plants and animals they want.]

KS3 (prior learning)
Selective breeding in agriculture has resulted in varieties of plants and breeds of animals that have increased yields.

FT and HT

New plants can be produced quickly and cheaply by taking cuttings from older plants. These new plants are genetically identical to the parent plant.
Cuttings are most likely to grow successfully if they are grown in a damp atmosphere until roots develop.

We can use artificial selection to produce new varieties of organisms. We do this by choosing individuals which have characteristics useful to us and breeding from them.

Selective breeding greatly reduces the number of alleles in a population. Widespread use of clones in agriculture also reduces the number of alleles available for further selective breeding. Selective breeding to produce new varieties for changed conditions may not then be possible.

Modern cloning techniques include:

- tissue culture - using small groups of cells from part of a plant;
- embryo transplants - splitting apart cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers.

Genes from the chromosomes of humans and other organisms can be 'cut out' using enzymes and transferred to bacterial cells. The transferred gene continues to make the same protein in a bacterial cell. By culturing the genetically engineered bacteria on a large scale, commercial quantities of the protein can be produced. This process is used in the manufacture of drugs and hormones, including human insulin.

Genes can also be transferred to the cells of animals or plants at an early stage in their development so that they develop with desired characteristics.

Candidates should be able to make informed judgements about the economic, social, and ethical issues concerning cloning and genetic engineering that they have studied or from information that is presented to them.

13.3 Why have some species of plants and animals died out? How do new species of plants and animals develop?

Changes in the environments of plants and animals may cause them to die out. Particular genes, or accidental changes in the genes of plants or animals may give them characteristics which enable them to survive better. Over a period this may result in entirely new species.

FT and HT

Fossils are the 'remains' of plants or animals from many years ago which are found in rocks.
Fossils may be formed in various ways including:

- from the hard parts of animals which do not decay easily;
- from parts of animals or plants which have not decayed because one or more of the conditions needed for decay are absent;
- when parts of the plant or animal are replaced by other materials as they decay;
- as preserved traces of animals or plants, e.g. footprints, burrows or rootlet traces.

We can learn from fossils how much (or how little) different organisms have changed since life developed on Earth.

The theory of evolution states that all species of living things which exist today - and many more which are now extinct - have evolved from simple life-forms which first developed more than three billion years ago.

Evolution occurs via natural selection:

- individual organisms within a particular species may show a wide range of variation because of differences in their genes;
- predation, disease and competition cause large numbers of individuals to die;
- individuals with characteristics most suited to the environment are more likely to survive to breed successfully;
- the genes which have enabled these individuals to survive are then passed on to the next generation.

Candidates should be able to:

- explain how fossils provide evidence for the theory of evolution;
- explain how over-use of antibiotics can lead to the evolution of resistant bacteria.

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Candidates should be able, when provided with additional information, to interpret evidence relating to evolutionary theory.

The environment that species need to be able to survive may change or successful new predators, new diseases or new competitors may arise. Unless evolution occurs and species become better adapted to survive these changes they may become extinct.

New forms of genes result from changes (mutations) in existing genes.

Mutations occur naturally. The chance of mutations occurring is increased by:

- exposure to ionising radiations, including ultraviolet light, X-rays and radiation from radioactive substances; the greater the dose of radiation, the greater the chance of mutation;
- certain chemicals.

Candidates should be able, when provided with appropriate information, to:

- suggest reasons why Darwin's theory of natural selection was only gradually accepted;

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HT

- identify the differences between Darwin's theory of evolution and conflicting theories, e.g. Lamarck's;
- suggest reasons for the different theories.

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Most mutations are harmful:

- if mutations occur in reproductive cells, young may develop abnormally or die at an early stage of their development;
- if mutations occur in body cells, these may start to multiply in an uncontrolled way and invade other parts of the body; this is cancer.

Some mutations are neutral in their effects and, in rare cases, a mutation may increase the chances of survival of an organism and any offspring which inherit the mutant gene.

13.4 Which human characteristics show a simple pattern of inheritance?

What sex human beings are, and whether or not they inherit certain diseases, show a very simple pattern of inheritance. Chromosomes have long molecules of a substance called DNA. Genes are sections of DNA molecules.

FT and HT

In human body cells, one of the 23 pairs of chromosomes carries the genes which determines sex. In females the sex chromosomes are the same (XX); in males the sex chromosomes are different (XY).

Chromosomes have long molecules of a substance called DNA. A gene is a section of a DNA molecule.

For certain characteristics, the characteristic is controlled by one gene. Some genes have two different forms called alleles.

An allele which controls the development of a characteristic when it is present on only one of the chromosomes is a dominant allele.

An allele which controls the development of characteristics only if the dominant allele is not present is a recessive allele.

Some disorders are inherited:
[Attention is drawn to the potential sensitivity needed in teaching about inherited disorders.]

- Huntington's disease - a disorder of the nervous system - is caused by a dominant allele of a gene and can therefore be passed on by only one parent who has the disorder;
- cystic fibrosis - a disorder of cell membranes - must be inherited from both parents. The parents may be carriers of the disorder without actually having the disorder themselves. It is caused by a recessive allele of a gene and can therefore be passed on by parents, neither of whom has the disorder;
- sickle-cell anaemia – a disorder of the red blood cells which reduces the oxygen-carrying capacity of the blood. Being a carrier of the allele can be advantageous in countries where malaria is prevalent.

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HT If both chromosomes in a pair contain the same allele of a gene, the individual is homozygous for that gene.

If the chromosomes in a pair contain different alleles of a gene, the individual is heterozygous for that gene.

Candidates should be able, when provided with appropriate information:

- to predict and/or explain the outcomes of crosses between individuals for each possible combination of dominant and recessive alleles of the same gene;
- to construct and/or interpret genetic diagrams.

DNA contains coded information that determines inherited characteristics. DNA is made of very long strands which have four different compounds called bases. A sequence of three bases is the code for a particular amino acid.

The order of bases controls the order in which amino acids are assembled to produce a particular protein.

[Candidates are not expected to know the names of all the four bases or how complementary pairs of bases enable DNA replication to take place.]

13.5 How can women control their fertility?

The monthly cycle which controls the release of eggs by a woman's ovaries is controlled by hormones. These hormones can be deliberately used to increase or reduce fertility.

FT and HT

The monthly release of an egg from a woman's ovaries and the changes in the thickness of the lining of her womb are controlled by hormones secreted by the pituitary gland and by the ovaries.
Fertility in women can be controlled by giving:

- hormones that stimulate the release of eggs from the ovaries (fertility drugs);
- hormones that prevent the release of eggs from the ovaries (oral contraception).

Candidates should be able to evaluate the benefits of, and the problems that may arise from, the use of hormones to control fertility.

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HT

Several hormones are involved in the menstrual cycle of a woman. Those hormones involved in promoting the release of an egg include:

- FSH which is secreted by the pituitary gland and causes an egg to mature in one of the ovaries, and also stimulates the ovaries to produce hormones including oestrogen;
- oestrogen which is secreted by the ovaries and inhibits the further production of FSH as well as stimulating the pituitary gland to produce a hormone called LH;
- LH which is secreted by the pituitary gland and stimulates the release of the egg about the middle of the menstrual cycle.

The uses of hormones in controlling fertility include:

- giving FSH as a 'fertility drug' to a woman whose own level of FSH is too low to stimulate eggs to mature;
- giving oral contraceptives which contain oestrogen, to inhibit FSH production so that no eggs mature.

14 Module 05 – Metals

This module includes the following:

Examining how common metals are, and where they are, in a periodic table of the elements. (N.B. For the purposes of this module, the periodic table is regarded as comprising the elements in order of their relative atomic masses. The periodic table in order of their proton (atomic) numbers is considered in Module 08 in the context of atomic structure.)

Comparing the properties of alkali metals with the properties of transition metals and relating this to the greater usefulness of the latter or structural materials.

Explaining how metals are extracted from their ores and relating this to their reactivities.

Considering how structural metals can be prevented from reverting to their oxides (i.e. corroding).

Investigating how metal compounds (salts) can be prepared.

N.B. It is anticipated that candidates' abilities:

- to represent chemical substances by formulae;
- to interpret chemical equations in which reactants and products are represented by formulae;

and at the higher tier:

- to represent chemical reactions by balanced equations;
- to calculate reacting masses and volumes from balanced equations;

will be progressively developed throughout the modules associated with Materials and their Properties.

The assessment of these abilities will, however, be incorporated into the assessment, via the terminal examination, of those modules where they are explicitly specified, i.e. "Patterns of Chemical Change" and "Structure of Bonding".

Candidates should be able to write word equations for all reactions referred to in the tier of this module for which they are entered.

14.1 Where do metals fit into a table of the elements?

Chemists have for more than 150 years arranged elements into a table so that they form Groups with similar properties. There are several groups of metals in such a periodic table.

FT and HT

The chemical elements can be arranged in order of the relative atomic masses of their elements. This list can then be arranged in rows so that elements with similar properties are in the same columns, known as Groups. The resulting table is known as the periodic table.

Although most elements are in appropriate Groups, a few are not. Argon atoms, for example, have a greater relative atomic mass than potassium atoms but argon is better placed before the potassium in the periodic table so that it is in Group 0 and potassium is in Group 1.

More than three-quarters of the elements are metals.
In the periodic table metals are mainly found:

- in the two left hand columns (Group 1 and Group 2);
- in the central block (transition elements).

The elements in Group 1 of the periodic table (known as the alkali metals):

- are metals with low density (the first three in the Group are less dense than, and therefore float on, water);
- react with non-metals to form ionic compounds. The compounds are white solids which dissolve in water to form colourless solutions;
- react with water releasing hydrogen;

form hydroxides which dissolve in water to give alkaline solutions.

In the centre of the periodic table is a block of metallic elements. These elements, which include iron and copper, are known as transition metals.

Like other metals, transition metals are good conductors of heat and electricity and can easily be bent or hammered into shape.
Compared to alkali metals:

- they have high melting points (except for mercury, which is a liquid at room temperature);
- they are hard, tough and strong;
- they are much less reactive and so do not react (corrode) so quickly with oxygen and/or water.

These properties make transition metals very useful as structural materials (e.g. iron, usually in the form of steel) and for making things which must allow heat or electricity to pass through them easily (e.g. copper for electrical cables).

Most transition metals form coloured compounds.
These can be seen:

- in pottery glazes of various colours;
- in weathered copper (green).

Many transition metals, including iron and platinum, are used as catalysts.

14.2 How are metals extracted from their ores?

How a metal is extracted from its ore depends on how reactive the metal is. Because aluminium is more reactive than iron it has to be extracted from its oxide in a different way.

KS3 (prior learning)
Some metals are more reactive than others.

By observing whether or not various metals react:

- with air, to produce metal oxides;
- with water (cold, hot or as steam) to produce metal hydroxides (or oxides) and hydrogen;
- with dilute acids, to produce metal salts and hydrogen;

and by observing how vigorous any of these reactions are, a reactivity series can be determined.

FT and HT

The Earth's crust contains metals and metal compounds. These are always found mixed with other substances. In ores, the metal or metal compound is concentrated enough to make it economic to extract the metal.

Gold, an unreactive metal, is found in the Earth as the metal itself. Chemical separation is not needed.

The reactivity series of metals lists metals in order of their reactivity, the most reactive metal being placed at the top of the list and the least reactive at the bottom. A more reactive metal can displace a less reactive metal from its compounds.

The non-metal elements carbon and hydrogen will also displace less reactive metals from oxides of those metals.

Candidates should be able to use the position of a metal in the reactivity series to predict how the metal could be extracted from a compound.

[See Data Sheet for a reactivity series of metals, which also includes carbon and hydrogen.]

Often an ore contains a metal oxide or a substance which can easily be changed into a metal oxide. To extract the metal, the oxygen must be removed from the metal oxide. This is called reduction. How a metal is extracted from its ore depends on how reactive the metal is.

A metal such as iron, which is less reactive than carbon, can be extracted from its ore using carbon.

The solid raw materials used in the blast furnace are iron ore (haematite), coke and limestone. Hot air is blown into the furnace and this causes the coke to burn forming carbon dioxide and releasing energy. At the high temperatures in the furnace the carbon dioxide reacts with coke to form carbon monoxide. The carbon monoxide reduces the iron oxide in the iron ore into molten iron which flows to the bottom of the furnace. The carbon monoxide combines with the oxygen from the iron ore to produce carbon dioxide. This is called oxidation. Limestone is added to remove acidic impurities forming a molten slag that floats on the surface of the molten iron.

Reactive metals such as aluminium are extracted by electrolysis.

When substances which are made of ions are dissolved in water, or melted, they can be broken down (decomposed) into simpler substances by passing an electric current through them. This process is called electrolysis.

When an ionic substance is melted or dissolved in water the ions are free to move about.

During electrolysis, positively charged ions – for example, metal ions – move to the negative electrode, and negatively charged ions move to the positive electrode.

During electrolysis, gases may be given off, or metals deposited at the electrodes.

The raw material for producing aluminium is aluminium oxide, purified from aluminium ore (bauxite). Because aluminium oxide has a very high melting point it is dissolved in a molten aluminium compound called cryolite at a much lower temperature. The electrodes are made of carbon. The aluminium forms at the negative electrode and oxygen forms at the positive electrodes. This makes the positive electrodes burn away quickly so that they frequently have to be replaced.

Copper can be purified by electrolysis using a positive electrode made of the impure copper and a negative electrode of pure copper in a solution containing copper ions.

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HT

At the negative electrode positively charged ions gain electrons (reduction).
At the positive electrode negatively charged ions lose electrons (oxidation).

In a chemical reaction if oxidation occurs reduction also occurs. These reactions are called redox reactions.

14.3 How can metals be prevented from reverting to their oxides?

When we use metals as structural materials we don't want them to corrode (oxidise) back to their oxides. There are various ways of preventing this.

FT and HT

Iron (or steel) corrodes more quickly than most other transition metals. This corrosion can be prevented by connecting iron to a more reactive metal (e.g. zinc or magnesium) (sacrificial protection) or by mixing in other metals (e.g. chromium) to make non-rusting alloys called stainless steel.

Aluminium does not oxidise (corrode) as quickly as its reactivity would suggest. Once a thin oxide layer has formed on the surface, it forms a barrier to oxygen and water and so prevents further corrosion. Aluminium is a useful structural metal. It can be made harder, stronger and stiffer by mixing it with small amounts of other metals (e.g. magnesium) to make alloys.

14.4 How can metal compounds be made?

Metal compounds called salts can be prepared by reacting metal hydroxides or metal oxides with acids.

KS3

(prior learning)
When a substance dissolves in water it forms an aqueous solution which may be acidic, alkaline or neutral.
Water itself is neutral.
Indicators can be used to show whether a solution is acidic, alkaline or neutral by the way their colours change.

The pH scale is used to show how acidic or alkaline a solution is:

0 ⟵ 7 ⟶ 14

increasing acidity — neutral — increasing alkalinity

FT and HT

Compounds of alkali metals called salts can be made by reacting solutions of their hydroxides, which are alkaline, with acids. In these neutralisation reactions:

acid + alkaline hydroxide solution ⟶ a neutral salt solution + water

The particular salt produced in any reaction between an acid and an alkali depends on:

- the acid used;
- the metal in the alkali.

Neutralising hydrochloric acid produces chlorides.
Neutralising nitric acid produces nitrates.
Neutralising sulphuric acid produces sulphates.

Ammonia also dissolves in water to produce an alkaline solution. This can be neutralised with acids to produce ammonium salts.

An indicator can be used to show when acidic and alkaline solutions have completely reacted to produce a neutral salt solution.

Salts of transition metals, as with salts of some other metals, can be made by reacting their oxides or hydroxides with acids. Transition metal oxides and hydroxides do not dissolve in water and are called bases. To produce a solution of a soluble transition metal salt, the metal oxide (or hydroxide) is added to an acid until no more will react. The excess metal oxide (or hydroxide) can then be filtered off.

Hydrogen ions $H^+(aq)$ make solutions acidic.
Hydroxide ions $OH^-(aq)$ make solutions alkaline.

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HT

In neutralisation reactions:

$$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$$

15 Module 06 – Earth Materials

This module includes the following:

Investigating the uses of limestone both as a building material and as a raw material for producing a range of other useful materials.

Studying the fractionation and cracking of crude oil to produce a range of useful materials, including plastics via the process of polymerisation.

Considering the origins of the Earth's atmosphere.

Extending the concept of global changes via a consideration of tectonics.

N.B. It is anticipated that candidates' abilities:

- to represent chemical substances by formulae;
- to interpret chemical equations in which reactants and products are represented by formulae;

and at the higher tier:

- to represent chemical reactions by balanced equations;
- to calculate reacting masses and volumes from balanced equations;

will be progressively developed throughout the modules associated with Materials and their Properties.

The assessment of these abilities will, however, be incorporated into the assessment, via the terminal examination, of those modules where they are explicitly specified, i.e. "Patterns of Chemical Change" and "Structure of Bonding".

Candidates should be able to write word equations for all reactions referred to in the tier of this module for which they are entered.

15.1 Why is limestone such a useful material?

Limestone is a commonly occurring rock which can be used not only for building but also for making many other useful materials including lime, cement and glass.

FT and HT

Limestone, which is mainly calcium carbonate, can be quarried and used as a building material. Powdered limestone can be used to neutralise acidity in lakes and soils.

When limestone is heated in a kiln it breaks down into quicklime (calcium oxide) and carbon dioxide. This type of reaction is called thermal decomposition (other carbonates behave in a similar way). Quicklime reacts with water to produce slaked lime (calcium hydroxide) which is used to reduce the acidity of soil.

Cement is produced by roasting powdered limestone with powdered clay in a rotary kiln. When cement is mixed with water, sand and crushed rock, a slow chemical reaction produces a hard, stone-like building material called concrete.

Glass is made by heating a mixture of limestone, sand and soda (sodium carbonate).

15.2 How can so many useful products be made from crude oil?

Crude oil is found inside the Earth's crust. Many useful products can be obtained from crude oil by separating the many different substances it contains and by using some of these in chemical reactions to make new substances, for example plastics.

KS3

(prior learning)
Crude oil is obtained from the Earth's crust.
It was formed from the remains of organisms which lived millions of years ago.
It is a fossil fuel.

The fossil fuels coal, oil and natural gas have resulted from the action of heat and pressure over millions of years, in the absence of oxygen, on material from animals and plants (organic material) which has been covered by layers of sedimentary rock.

FT and HT

Crude oil is a mixture of a very large number of compounds.

A mixture consists of two or more elements or compounds not chemically combined together. The chemical properties of each substance in the mixture are unchanged. This makes it possible to separate the substances in a mixture by physical methods including distillation.

Most of the compounds in crude oil consist of molecules made up of hydrogen and carbon atoms only (hydrocarbons).

The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by evaporating the oil and allowing it to condense at a number of different temperatures. This process is fractional distillation.

The hydrocarbon molecules in crude oil vary in size.

The larger the molecules (the greater the number of carbon atoms) in a hydrocarbon:

- the higher its boiling point;
- the less volatile it is;
- the less easily it flows (the more viscous it is);
- the less easily it ignites (the less flammable it is).

This limits the usefulness of hydrocarbons with large molecules as fuels.

Large hydrocarbon molecules can be broken down (cracked) to produce smaller, more useful molecules. This process involves heating the hydrocarbons to vaporise them and passing the vapours over a hot catalyst. A thermal decomposition reaction then occurs.

Some of the products of cracking are useful as fuels.

Most fuels contain carbon and/or hydrogen and may also contain some sulphur. The gases released into the atmosphere when a fuel burns may include:

- carbon dioxide;
- water (vapour), which is an oxide of hydrogen;
- sulphur dioxide.

Other products of cracking can be used to make plastics (polymers) such as poly(ethene) and poly(propene). Poly(ethene) is used for making plastic bags and bottles. Poly(propene) is used for making crates and ropes.

Most plastics, including poly(ethene) and poly(propene), are not broken down by microorganisms. They are not biodegradable. This can lead to problems with waste disposal.

Candidates should be able, when provided with appropriate information, to evaluate the impact on the environment of burning hydrocarbon fuels and of plastic waste disposal.

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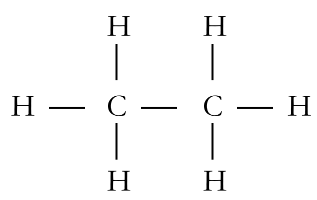
HT Carbon atoms form the spine of hydrocarbon molecules.

When the carbon atoms are joined by single covalent carbon carbon bonds (when the hydrocarbons are saturated) they are known as alkanes.

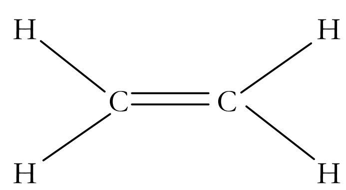
Candidates should be able to represent and to interpret saturated hydrocarbon molecules in the following form:



Other hydrocarbons have carbon carbon double covalent bonds (they are unsaturated) and are known as alkenes.

A simple laboratory test for an unsaturated hydrocarbon is to use bromine water. The yellow-brown bromine water becomes colourless as the bromine reacts with the hydrocarbon.

Candidates should be able to represent and to interpret unsaturated hydrocarbon molecules in the following form:



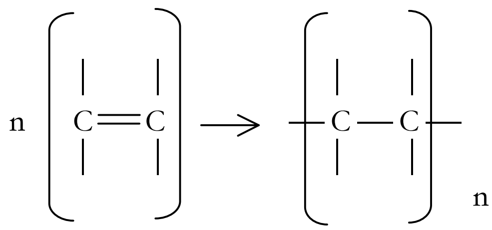
These unsaturated hydrocarbons are reactive and so are useful for making many other substances including polymers. Polymers have very large molecules. They are formed when many small molecules, of substances called monomers, join together. This process is called polymerisation.

When unsaturated monomers join together to form a polymer with no other substance being produced in the reaction, the process is called addition polymerisation.

Plastics are polymers and are made by polymerisation. For example, poly(ethene) (often called polythene) is made by polymerising the simplest alkene, ethene.

Candidates should be able:

- to interpret diagrammatic representations of addition polymerisation;
- to represent the formation of a simple addition polymer in the following form:



15.3 How was the Earth's atmosphere formed?

The Earth's atmosphere has been much the same for millions of years. Before that it was very different from what it is today.

FT and HT

For 200 million years the proportions of different gases in the atmosphere have been much the same as they are today:

- about four-fifths (80%) nitrogen;
- about one-fifth (20%) oxygen;
- small proportions of various other gases, including carbon dioxide, water vapour and noble gases.

During the first billion years of the Earth's existence there was intense volcanic activity. This activity released the gases which then formed the early atmosphere and water vapour which condensed to form the oceans.

During this period the Earth's atmosphere was probably mainly carbon dioxide and there would have been little or no oxygen gas (like the atmospheres of Mars and Venus today).

There would also have been water vapour and small proportions of methane and ammonia.

When plants evolved and successfully colonised most of the Earth's surface:

- the atmosphere gradually became more and more "polluted" with oxygen. This meant that, gradually, there were fewer habitats suitable for microorganisms which could not tolerate oxygen;
- most of the carbon from the carbon dioxide in the air gradually became locked up in sedimentary rocks as carbonates and fossil fuels;
- the methane and ammonia in the atmosphere reacted with the oxygen;

....

HT

- nitrogen gas was released into the air, partly from the reaction between oxygen and ammonia, but mainly from living organisms, including denitrifying bacteria;
- the oxygen in the atmosphere resulted in the development of an ozone layer. This filters out harmful ultraviolet radiation from the Sun allowing the evolution of new living organisms.

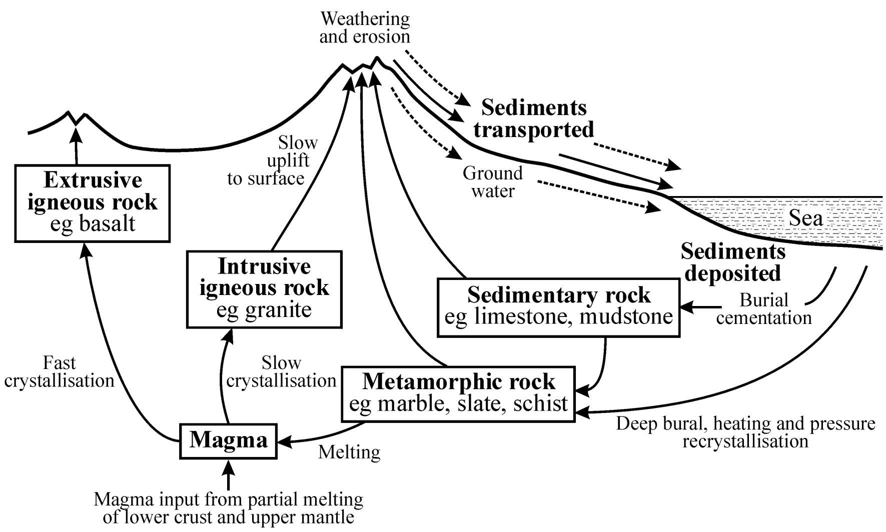
Carbonate rocks are sometimes moved deep into the Earth by geological activity. They may then release carbon dioxide back into the atmosphere via volcanoes.

The release of carbon dioxide by burning the carbon locked up over hundreds of millions of years in fossil fuels increases the level of carbon dioxide in the atmosphere. Though the reaction between carbon dioxide and sea-water also increases, producing insoluble (mainly calcium) carbonates which are deposited as sediment and soluble hydrogencarbonates (mainly calcium and magnesium), this does not wholly absorb the additional carbon dioxide released into the atmosphere.

15.4 Why have all mountains on Earth not worn away by now?

Though the land masses on Earth seem to us to be very fixed they are, in fact, slowly moving about. This movement causes parts of the Earth's crust to rise and so form mountains.

KS3 (prior learning)



FT and HT The Earth is nearly spherical and has a layered structure comprising:

- a thin crust;
- a mantle extending almost halfway to the Earth's centre which has all the properties of a solid except that it can flow very slowly;
- a core, with just over half of the Earth's radius, made of nickel and iron, the outer part of which is liquid and the inner part of which is solid.

The overall density of the Earth is much greater than the mean densities of the rocks which form the crust. This indicates that the interior of the Earth is made of material different from, and denser than, that of the crust.

At the surface of the Earth younger sedimentary rocks usually lie on top of older rocks. Sediments contain evidence for how they were deposited (e.g. layers formed by discontinuous deposition, ripple marks formed by currents or waves). Sedimentary rock layers are often found tilted, folded, fractured (faulted) and sometimes even turned upside down. This shows that the Earth's crust is unstable and has been subjected to very large forces.

Large scale movements of the Earth's crust can cause mountain ranges to form very slowly over millions of years. These replace older mountain ranges worn down by weathering and erosion.

Metamorphic rocks are associated with the Earth movements (tectonic activity) which created present-day and ancient mountain belts. They are evidence of the high temperatures and pressure created by these mountain-building processes.

The edges of land masses (continents) which are separated by thousands of kilometres of ocean (e.g. the east coast of South America and the west coast of Africa):

- have shapes which fit quite closely;
- have similar patterns of rocks and fossils.

This suggests that they were once part of a single land mass which has split and been moved apart.

The Earth's lithosphere (the crust and the upper part of the mantle) is cracked into a number of large pieces (tectonic plates) which are constantly moving at relative speeds of a few centimetres per year as a result of convection currents within the Earth's mantle driven by heat released by natural radioactive processes.

Earthquakes and/or volcanic eruptions occur at the boundaries between tectonic plates.

Candidates should be able, when provided with information about the complex probable causes of earthquakes and volcanic eruptions and the difficulty of making measurements of many of the factors involved, to explain why scientists cannot yet accurately predict when they will occur.

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At one time it was believed that the major features of the Earth's surface were the result of the shrinking of the crust as the Earth cooled down following its formation.

Candidates should be able, when provided with appropriate additional information, to explain why Wegener's theory of crustal movement (continental drift) was not generally accepted until more than 50 years after it was proposed.

HT Tectonic plates:

- may slide past each other. This is happening along the Californian coast giving rise to earthquakes;
- may move towards each other. As this happens, a thinner, denser oceanic plate can be driven down (subducted) beneath a thicker granitic continental plate where it partially melts. The continental crust is compressed, causing folding and metamorphism. Earthquakes are produced and magma may rise through the continental crust to form volcanoes. This is happening along the western side of South America (the Andes);
- may move away from each other. This causes fractures which are filled by magma producing new, basaltic, oceanic crust. This is known as sea floor spreading and is happening along oceanic ridges, including the mid-Atlantic ridge. The iron-rich minerals in the magma record the direction of the Earth's magnetic field at the time when the rising magma solidified. Magnetic reversal patterns in oceanic crust occur in stripes parallel to oceanic ridges, matching the periodic reversals of the Earth's magnetic field and so supporting the concept of sea floor spreading.

16 Module 07 – Patterns of Chemical Change

This module includes the following:

Exploring the various factors affecting the rates of chemical reactions and explaining these in terms of collisions between particles.

Investigating the activities of biological catalysts i.e. enzymes.

Examining the energy changes which occur in chemical reactions and the idea of reversible reactions.

Applying many of the above ideas in a detailed consideration of the various stages involved in the production of ammonium nitrate fertiliser including, for the higher tier only, a consideration of the factors which affect reversible reactions.

It is anticipated that candidates' abilities:

- to represent chemical substances by formulae;
- to interpret chemical equations in which reactants and products are represented by formulae;

and at the higher tier

- to represent chemical reactions by balanced equations;
- to calculate reacting masses and volumes from balanced equations;

will be progressively developed throughout the modules associated with Materials and their Properties.

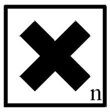
The assessment of the relevant abilities explicitly specified in section 16.5 of this module i.e. "How do we know how much of each reactant to use in a chemical reaction?" will, however, be incorporated into the assessment of this module via the final examination.

Candidates should be able to write word equations for all reactions referred to in the tier of this module for which they are entered.

FT and HT

Candidates should be able to recognise, and explain the significance of, the following hazard symbols.

Oxidising
These substances provide oxygen which allows other materials to burn more fiercely.

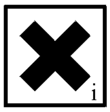


Harmful
These substances are similar to toxic substances but less dangerous.

Highly flammable
These substances easily catch fire.

Corrosive
These substances attack and destroy living tissues, including eyes and skin.

Toxic
These substances can cause death. They may have their effects when swallowed or breathed in or absorbed through the skin.



Irritant
These substances are not corrosive but can cause reddening or blistering of the skin.

Candidates should be able to use information in the Data Sheet, where appropriate, in answering examination questions.

16.1 How can we speed up or slow down chemical reactions?

Being able to control the speed of chemical reactions is important both in everyday life (for example in cooking) and when making new materials on an industrial scale.

FT and HT

The speed (rate) of a chemical reaction increases:

- if the temperature increases;
- if the concentration of dissolved reactants or the pressure of gases increases;
- if solid reactants are in smaller pieces (greater surface area);
- if a catalyst is used.

A catalyst increases the rate of a chemical reaction but it is not used up during the reaction. It is used over and over again to speed up the conversion of reactants to products. Different reactions need different catalysts.

Increasing the rates of chemical reactions is important in industry because it helps to reduce costs.

The rate of a chemical reaction can be followed by measuring the rate at which the products are formed or the rate at which the reactants are used up. This allows a comparison to be made of the changing rate of a chemical reaction under different conditions.

Candidates should be able to interpret graphs showing the amount of product formed (or reactant used up) with time in terms of the above principles.

Chemical reactions can only occur when reacting particles collide with each other and with sufficient energy. The minimum amount of energy particles must have to react is the activation energy.

Increasing the temperature increases the speed of the reacting particles so that they collide more frequently and more energetically. This increases the rate of reaction.

Increasing the concentration of reactants in solutions and increasing the pressure of reacting gases also increases the frequency of collisions and so increases the rate of reaction.

16.2 How can we use living things to do our chemistry for us?

Living things produce catalysts called enzymes which allow chemical reactions to occur quite quickly at ordinary temperatures and pressures. Enzymes are widely used in the food industry and are being used more and more to manufacture many other chemicals.

FT and HT

Living cells use chemical reactions to produce new materials.

Yeast cells convert sugar into carbon dioxide and alcohol.
This process is called fermentation and is used:

- to produce the alcohol in beer and wine;
- to produce the bubbles of carbon dioxide which make bread dough rise.

A simple laboratory test for carbon dioxide is that it turns limewater milky.

Bacteria are used to produce yoghurt from milk. The bacteria convert the sugar in milk (lactose) to lactic acid.

The chemical reactions brought about by living cells are quite fast in conditions that are warm rather than hot. This is because the cells use catalysts called enzymes. Enzymes are protein molecules which are usually damaged by temperatures above about 45 °C. Different enzymes work best at different pH values.

Enzymes are involved in the following processes:

in the home:

- biological detergents may contain protein-digesting and fat-digesting enzymes (proteases and lipases);

in industry:

- proteases are used to 'pre-digest' the protein in some baby foods;
- carbohydrases are used to convert starch syrup into sugar syrup;
- isomerase is used to convert glucose syrup into fructose syrup, which is much sweeter and therefore can be used in smaller quantities in slimming foods.

In industry, enzymes are used to bring about reactions at normal temperatures and pressures that would otherwise require expensive, energy demanding equipment.

Candidates should be able, when provided with appropriate information, to evaluate the advantages and disadvantages of using microorganisms and enzymes to bring about chemical reactions.

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HT Successful industrial processes depending on enzymes usually:

- stabilise the organism to keep it functioning for a long period;
- immobilise the enzyme by trapping it in an inert solid support or carrier such as alginate beads;
- allow a continuous process rather than a batch process.

16.3 Do chemical reactions always release energy?

Chemical reactions, like anything else that happens, involve energy transfers. Many chemical reactions involve the release of energy. For other chemical reactions to occur energy must be supplied. [Even chemical reactions which release energy sometimes need to be supplied with energy to get them started.]
Some chemical reactions are reversible.

KS3 (prior learning)
When fuels burn energy is released as heat.

FT and HT Whenever chemical reactions occur, energy is usually transferred to or from the surroundings.

An exothermic reaction is one which transfers energy, often as heat, to the surroundings.

An endothermic reaction is one which takes in energy, often as heat, from the surroundings.

If a reversible reaction is exothermic in one direction it is endothermic in the opposite direction. The same amount of energy is transferred in each case. For example:

$$\underset{\text{(blue)}}{\text{hydrated copper sulphate}} \quad [\text{+heat energy}] \rightleftharpoons \underset{\text{(white)}}{\text{anhydrous copper sulphate}} + \text{water}$$

The reverse reaction can be used as a test for water.

In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented:

$$A + B \rightleftharpoons C + D$$

For example:

$$\underset{\text{(white solid)}}{\text{ammonium chloride}} \rightleftharpoons \underset{\text{(colourless gases)}}{\text{ammonia + hydrogen chloride}}$$

…………………………………………………………………………..

HT During a chemical reaction:

- energy must be supplied to break bonds;
- energy is released when bonds are formed.

In an exothermic reaction, the energy released from forming new bonds is greater than the energy needed to break existing bonds.

In an endothermic reaction, the energy needed to break existing bonds is greater than the energy released from forming new bonds.

Candidates should be able to:

- interpret simple energy level diagrams in terms of bond breaking and bond formation (including the idea of activation energy and the effect on this of catalysts);
- calculate the nett energy transfer in reactions, using simple energy level diagrams or supplied bond energies.

16.4 How do chemicals produce the fertiliser we need to grow food?

Chemists use nitrogen from air to make nitrogen fertiliser. The processes they use to do this involve several types of chemical reaction and many important chemical ideas.

FT and HT Air is almost 80% nitrogen.

The nitrogen can be used to manufacture several important chemicals, including nitrogen-based fertilisers. Nitrogen-based fertilisers are important in agriculture for increasing the yields of crops. Nitrates can, however, create problems if they find their way into streams, rivers or groundwater and so contaminate our drinking water.

Candidates should be able, when provided with appropriate information, to reach balanced judgements concerning the benefits of using nitrate fertilisers and the contamination of drinking water they can cause.

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Ammonia is manufactured in the Haber process. The raw materials are nitrogen from the air and hydrogen obtained from natural gas. The purified gases are passed over a catalyst of iron at a high temperature (about 450 °C) and a high pressure (about 200 atmospheres). Some of the hydrogen and nitrogen reacts to form ammonia. The reaction is reversible. This means that ammonia also breaks back down again into nitrogen and hydrogen:

$$\text{nitrogen} + \text{hydrogen} \rightleftharpoons \text{ammonia}$$

The reaction conditions are chosen to produce a reasonable yield of ammonia quickly. On cooling the ammonia liquefies and is removed. The remaining hydrogen and nitrogen is re-cycled.

Ammonia can be oxidised to produce nitric acid. Ammonia gas reacts with oxygen in air in the presence of a hot platinum catalyst. This oxidation reaction forms nitrogen monoxide which is then cooled and reacted with water and more oxygen to form nitric acid.

Ammonium nitrate fertiliser is made by the neutralisation reaction between ammonia and nitric acid.

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HT **Candidates should be able** to outline and evaluate the economic factors associated with the conditions under which the Haber process is normally carried out.

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Candidates should be able to explain the details of these processes in terms of chemical principles from this specification including:

- energy transfers during the reaction;
- the rates of the reactions;
- equilibrium conditions in reversible reactions.

When a reversible reaction occurs in a closed system, an equilibrium is reached when the reactions occur at exactly the same rate in each direction.

The relative amounts of all the reacting substances at equilibrium depend on the conditions of the reaction.

If the forward reaction is endothermic, and the temperature is increased, the yield of products is increased; if the temperature is decreased, the yield of products is decreased.

If the forward reaction is exothermic, and the temperature is increased, the yield of products is decreased; if the temperature is decreased, the yield of products is increased.

In gaseous reactions, an increase in pressure will favour the reaction which produces the least number of molecules as shown by the symbol equation for that reaction.

These factors, together with reaction rates, are important when determining the optimum conditions in industrial processes, including the Haber process.

16.5 How do we know how much of each reactant to use in a chemical reaction?

If we know the formula of a chemical compound and the relative masses of all the atoms involved we can calculate the formula mass of the compound and the percentage of each element in the compound. [If we also know the symbol equation for a chemical reaction we can calculate how much of each reactant we need to produce a certain amount of product. From the masses of reactants and products we can also calculate the empirical formulae of chemical compounds.]

FT and HT

Atoms of different elements have different masses.

To be able to work out exactly what is happening in chemical reactions we need to know how the masses of atoms compare with each other, i.e. their relative atomic masses (A_r).

Candidates should be able to:

- calculate the relative formula mass (M_r) of compounds whose formulae are supplied;
- calculate the percentage of an element in a compound whose formula is supplied.

[See Data Sheet for A_r of elements.]

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HT

Candidates should be able to use supplied balanced symbol equations and supplied data about the masses/volumes of some reactants/products:

- to calculate the masses/volumes of other reactants/products; *[Candidates may use moles in their calculations but are not required to do so. The volume of the M_r in grams, of a gas, will be given.]*
- to determine the ratios of atoms in compounds from supplied masses or percentage composition (empirical formulae).

Candidates should be able to use given half equations for reactions occurring at the electrodes and given data about the mass/volume of one of the products to calculate the mass/volume of the other product.

17 Module 08 – Structures and Bonding

This module includes the following:

Extending basic particle theory to include atomic structure and using this to explain:

- *what happens when elements react;*
- *the properties of different types of substance.*

Exploring the similarities between elements in the same group of the periodic table and the trends in those properties within groups.

Explaining in terms of atomic structure:

- *the similarities between elements in the same group;*
- *the differences between elements in different groups;*

and, for the higher tier only;

- *the trends within groups.*

Investigating some reactions and uses of the metal-halogen compounds sodium chloride and silver halides.

N.B. It is anticipated that candidates' abilities:

- to represent chemical substances by formulae;
- to interpret chemical equations in which reactants and products are represented by formulae;

and at the higher tier

- to represent chemical reactions by balanced equations;
- to calculate reacting masses and volumes from balanced equations;

will be progressively developed throughout the modules associated with Materials and their Properties.

The assessment of the relevant abilities explicitly specified in section 17.6 of this module, i.e. "What do all these chemical symbols, formulae and equations mean?" will, however, be incorporated into the assessment of this module via the terminal examination.

Candidates should be able to write word equations for all reactions referred to in the tier of this module for which they are entered.

Candidates should be able to use information in the Data Sheet, where appropriate, in answering examination questions.

17.1 What happens when elements react?

Scientists believe that when elements react, their atoms are joining together or bonding. To understand the ways in which this can happen we need to know how atoms themselves are constructed.

KS3 (prior learning)
When the particles of a substance gain or lose energy, the substance may change its state.

If energy is supplied to a solid, its particles vibrate more violently; they may separate from each other and become free to move. This is melting. The temperature at which a solid melts is called its melting point. Heating a liquid makes its particles move around more quickly. Particles which have enough energy may overcome attractive forces and escape from the liquid and become a gas. This is evaporation. When the temperature is higher, more particles have enough energy to escape so evaporation is faster. If the temperature is high enough, a liquid will boil. The temperature at which a liquid boils is called its boiling point.

FT and HT All substances are made of atoms. There are about 100 different sorts of atoms. A substance which contains only one sort of atom is called an element.

Candidates should be able, when provided with appropriate information, to explain why the idea of atoms only became generally accepted by scientists after Dalton re-introduced the idea about 200 years ago.

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Atoms have a small central nucleus made up of protons and neutrons around which there are electrons.

The relative masses of protons, neutrons and electrons, and their relative electric charges are as shown:

	Mass	Charge
proton	1	+1
neutron	1	0
electron	negligible	–1

In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.

All atoms of a particular element have the same number of protons. Atoms of different elements have different numbers of protons.

The number of protons in an atom is called its atomic number (proton number). The total number of protons and neutrons in an atom is called its mass number.

Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes of that element.

Candidates should be able to represent and interpret atoms as shown:

$$^{23}_{11}\mathrm{Na}$$

mass number 23

atomic number 11

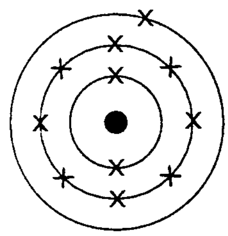
Electrons occupy particular energy levels.

Each electron in an atom is at a particular energy level (in a particular shell). The electrons in an atom occupy the lowest available energy levels (innermost available shells).

[N.B. Though only energy levels are referred to throughout this specification, candidates may answer in terms of shells if they prefer.]

Candidates should be able to represent the electronic structure of the first twenty elements of the periodic table in the following forms:

for sodium



and 2,8,1

Compounds are substances in which atoms of two, or more, elements are not just mixed together but chemically combined.

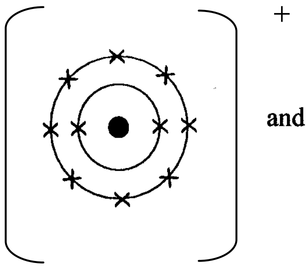
Chemical reactions between elements involve either the giving and taking, or sharing, of electrons in the highest occupied energy levels of atoms.

When atoms form chemical bonds by gaining and losing electrons they form electrically charged atoms called ions. Atoms can also form bonds by sharing electrons.

The atoms which lose electrons become positively charged ions and the atoms which gain electrons become negatively charged ions. These ions now have the electronic structure of a noble gas.

Candidates should be able to represent the electronic structure of the ions in sodium chloride, magnesium oxide and calcium chloride in the following forms:

for sodium ion (Na^+)



and $[2,8]^+$

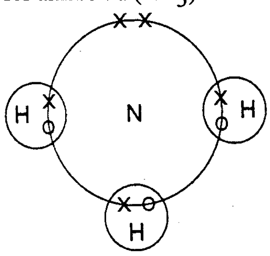
An ionic compound is a giant structure of ions. Substances with giant structures have high melting points and boiling points.

Ionic compounds are held together by strong forces of attraction between oppositely charged ions. This is the ionic bond.

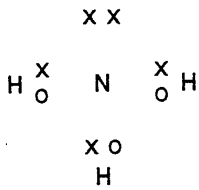
Atoms which share electrons often form molecules. The atoms in molecules are held together because they share pairs of electrons. The strong bonds between the atoms are called covalent bonds.

Candidates should be able to represent the covalent bonds in water, ammonia, hydrogen, hydrogen chloride, methane and oxygen in the following forms:

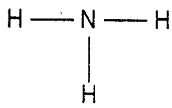
for ammonia (NH_3)



and/or



and/or



Substances which are made of molecules have low melting points and boiling points.

17.2 How can we explain the different properties of different types of substances?

Different types of substances have different properties because of differences in the forces between the particles from which they are made.

HT Simple molecular compounds are gases, liquids or solids which have relatively low melting points and boiling points and do not conduct electricity. This is because:

- the forces between the molecules (intermolecular forces) are weak;
- the molecules do not carry an overall electric charge.

Atoms which share electrons can also form giant structures. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are giant covalent structures (lattices) of atoms. Because of the large number of covalent bonds in their structures, they have very high melting points.

In diamond each carbon atom forms four covalent bonds in a rigid, giant covalent structure.

In graphite each carbon atom forms three covalent bonds and the carbon atoms form layers which are free to slide over each other. In graphite there are free electrons which allow graphite to conduct electricity.

Ionic compounds form regular structures (giant ionic lattices) in which the strong forces between oppositely charged ions result in these compounds having high melting points and high boiling points. When they are melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move.

Metals consist of giant structures in which the electrons from the highest occupied (outer) energy levels of metal atoms are free to move through the whole structure. These free electrons:

- hold the atoms together in a regular structure;
- allow the atoms to slide over each other;
- allow the metal to conduct heat and electricity.

17.3 How can chemical elements be grouped into families?

It is easier to remember the properties of more than 90 naturally occurring elements if we can group them into families of elements with similar properties. Chemists arrange these family groups of elements in a special way which is known as the periodic table.

FT and HT

The chemical elements can be arranged in order of their relative atomic masses. This list can then be arranged in rows so that elements with similar properties are in the same columns, known as Groups. The resulting table is known as the periodic table.

Although most elements are in appropriate Groups, a few are not. Argon atoms, for example, have a greater relative atomic mass than potassium atoms but argon is better placed before the potassium in the periodic table so that it is in Group 0 and potassium is in Group 1.

In the modern periodic table elements are arranged in order of their atomic (proton) number. All elements are then in the appropriate Group.

The periodic table can be seen as an arrangement of the elements in terms of their electronic structure. From left to right, across each horizontal row (period) of the periodic table, a particular energy level is gradually filled up with electrons; in the next period, the next energy level is filled with electrons.

The similarities and differences between the properties of elements in the same group of the periodic table can be explained by the electronic structure of their atoms.

Candidates should be able, when provided with appropriate additional information, to explain:

- how attempts to classify elements in a systematic way, including those of Newlands and Mendeleev, have led through the growth of chemical knowledge to the modern periodic table;
- why scientists regarded a periodic table of the elements first as a curiosity, then as a useful tool and finally as an important summary of the structure of atoms.

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The elements in Group 1 of the periodic table are known as alkali metals because they form hydroxides which dissolve in water to give alkaline solutions. They react with non-metals to form ionic compounds in which the metal ion carries a charge of +1.

Fewer than one quarter of the elements are non-metals. Non-metal elements are found in the Groups at the right hand side of the periodic table.

The elements in Group 7 and Group 0 have the typical properties of non-metals:

- they have low melting points and boiling points (at room temperature all the Group 0 elements are gases, the first two Group 7 elements are gases and the third, bromine, is a liquid);
- they are brittle and crumbly when solid;
- they are poor conductors of heat and electricity even when solid or liquid.

The elements in Group 7 of the periodic table (known as halogens):

- have coloured vapours;
- consist of molecules which are made up of pairs of atoms;
- form ionic salts with metals in which the chloride, bromide or iodide ion (halide ions) carries a charge of –1;
- form molecule compounds with other non-metallic elements.

The elements in Group 0 of the periodic table (known as noble gases);

- are all chemically very unreactive gases;
- exist as individual atoms rather than as diatomic gases like other gaseous elements;
- are used as inert gases in filament lamps and in electrical discharge tubes.

The first element in the Group, helium, is much less dense than air and is used in balloons.

In Group 1, the further down the group an element is:

- the more reactive the element;
- the lower its melting point and boiling point.

When a piece of lithium, sodium or potassium is placed in cold water the metal floats, may melt and moves around the surface of the water. The metal reacts with the water to form a metal hydroxide solution and hydrogen gas. The more reactive the metal, the more vigorous is the reaction with water.

A simple laboratory test for hydrogen is that when a test tube of hydrogen is held to a flame the hydrogen burns in the air with a squeaky explosion.

In Group 7, the further down the group an element is:

- the less reactive the element;
- the higher its melting point and boiling point.

A more reactive halogen can displace a less reactive halogen from an aqueous solution of its salt.

17.4 How can the similarities between elements in the same group be explained?

Once again, these similarities and differences can be explained in terms of the atomic structure of the atoms concerned.

HT

Elements in the same group have similar properties because they have the same number of electrons in the highest occupied (outer) energy level.

The higher the energy level:

- the more easily electrons are lost;
- the less easily electrons are gained.

These ideas explain the trends in the reactivity of elements in Groups 1 and 7 of the periodic table.

Group 0 elements (noble gases) are unreactive and monatomic because their highest occupied energy level is full so that atoms have no tendency to gain, to lose or to share electrons.

17.5 How do metal halogen compounds compare with the elements from which they are made? What use are these compounds?

Compounds of metals and halogens have very different properties than the elements from which they are made. The use we make of these compounds depends on these different properties.

FT and HT

Sodium chloride (common salt) is a compound of an alkali metal and a halogen. It is found in large quantities in the sea and in underground deposits.

The electrolysis of sodium chloride solution (brine) is an important industrial process. Chlorine gas is formed at the positive electrode and hydrogen gas at the negative electrode. A solution of sodium hydroxide is also formed. Each of these products can be used to make other useful materials:

- chlorine is used to kill bacteria in drinking water and in swimming pools, and to manufacture hydrochloric acid, disinfectants, bleach and the plastic (polymer) known as PVC;

- hydrogen is used in the manufacture of ammonia and margarine;
- sodium hydroxide is used in the manufacture of soap, paper and ceramics.

A simple laboratory test for chlorine is that it bleaches damp litmus paper.

Silver chloride, silver bromide and silver iodide (silver halides) are reduced to silver by the action of light, X-rays and the radiation from radioactive substances. They are used to make photographic film and photographic paper.

Hydrogen halides are gases which dissolve in water to produce acidic solutions.

17.6 What do all these chemical symbols, formulae and equations mean?

Once you understand them, chemical symbols, formulae and equations are a very convenient way of describing what elements chemical compounds contain and what is happening in chemical reactions.

KS3

(prior learning)
Each element is represented by a different symbol. The chemical formula for a compound shows which elements are in the compound.

A chemical reaction can be described using a word equation:

$$\text{reactants} \longrightarrow \text{products}$$

FT and HT

Candidates should be able to write word equations for all reactions referred to in the tier of the specification for which they are entered.

The symbols for elements are used to write chemical formulae for compounds which show the ratios of atoms from different elements which are combined to form the compounds.

Candidates should be able to write down the correct formulae for simple ionic compounds.

[See Data Sheet for the formulae of, and charges on, common ions.]

Candidates should be able to recall the formulae of all simple covalent compounds referred to in the relevant tier of the specification.

Candidates should be able to interpret chemical formulae or symbolic representations of molecules in terms of the elements present and the ratios of their atoms.

Chemical reactions can be represented using the chemical formulae for the reactants and the products.

Candidates should be able to interpret supplied symbol equations, which may include the state symbols (s), (l), (g) and (aq).

The total mass of the product(s) of a chemical reaction is always equal to the total mass of the reactant(s).
This is because the products of a chemical reaction are made up from exactly the same atoms as the reactants.

Symbol chemical equations must, therefore, always be balanced. The total number of atoms of each element on the reactants side of the equation must be equal to the total number of atoms of the same element on the products side of the equation.

Candidates should be able to :

- balance supplied symbol equations;
- write a balanced symbol equation from a supplied word equation.

……………………………………………………………………..

HT During electrolysis, ions gain or lose electrons at the electrodes. Electrically neutral atoms or molecules are released.

Candidates should be able to complete and balance supplied half equations for the reactions occurring at the electrodes during electrolysis.

The supplied equations will include information about the charge of the ion and the atomic or molecular nature of the product.

For example, when supplied with

$$Cl^- - e^- \longrightarrow Cl_2$$

***Candidates should be able** to produce*

$$2Cl^- - 2e^- \longrightarrow Cl_2$$

18 Module 09 – Energy

This module includes the following:

Investigations of thermal energy transfer by means of radiation – and of how all types of thermal energy transfer can be reduced when necessary.

For the higher tier only, explaining how thermal energy transfers by means of conduction and convection occur.

Calculating:

- *the energy transferred by appliances from their power and the length of time they are used;*
- *the cost of using electrical appliances;*

and at the higher tier only;

- *the energy transferred to bodies by lifting them i.e. gravitational potential energy.*

An examination of the idea of efficiency in relation to energy transfer.

A detailed study of the advantages and disadvantages, from various points of view, of a range of renewable and non-renewable energy resources.

18.1 How is heat (thermal energy) transferred and how can we reduce heat transfer?

Sometimes we want to transfer heat effectively from one place to another. At other times we want to reduce heat losses 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.

KS3 (prior learning)

When different parts of a substance are at different temperatures, energy is transferred by the substance from places where the temperature is higher to places where the temperature is lower.

Transfer of energy by a substance, without the substance itself moving, is called conduction. Metals are very good conductors. Non-metals are usually poor conductors (insulators). Gases are very poor conductors.

Liquids and gases can flow and so can transfer energy from places where the temperature is higher to places where the temperature is lower.

Transfer of energy by liquids or gases moving in this way is called convection.

Energy is continually being transferred to and from all objects by radiation, even through empty space (a vacuum).

FT and HT

Hot bodies emit mainly infra red radiation.

The hotter an object is, the more energy it radiates. Dark, matt surfaces emit more radiation than light, shiny surfaces at the same temperature. Particles of matter are not involved.

Dark, matt surfaces are good absorbers (poor reflectors) of radiation. Light, shiny surfaces are good reflectors (poor absorbers) of radiation.

Candidates should be able:

- to describe various ways in which heat energy is transferred from buildings;
- to describe and explain ways in which the rates of these energy transfers can be reduced.

Candidates should be able, when given appropriate information, to evaluate the effectiveness and cost-effectiveness of methods used to reduce energy consumption in buildings.

………………………………………………………………………..

HT

Conduction occurs in metals because the hotter the metal is the more kinetic energy the vibrating ions in the metal structure have. This energy is transferred to cooler parts of a piece of metal by free electrons as they diffuse through the metal and collide with ions and with other electrons.

Convection currents occur in liquids and gases because their particles move faster when they are hot causing the liquid or gas to expand. Warm regions are then less dense than cold regions. The warm regions rise up through the colder regions and colder regions replace the warmer regions.

Thermal radiation transfer is the transfer of energy by waves.

18.2 Why are electrical appliances so useful and what does it cost to use them?

We often use electrical appliances because they transfer electrical energy as whatever form of energy we need at the flick of a switch. What we pay for when we use an electrical appliance is the energy it transfers. Some appliances transfer energy faster than others and so cost more to use.

FT and HT

Much of the energy transferred in homes and industry is electrical energy. This is because electrical energy is readily transferred as:

- heat (thermal energy);
- light;
- sound;
- movement (kinetic energy).

Candidates should be able:

- to specify the energy transfers everyday electrical devices are designed to bring about;
- to give examples of everyday electrical devices designed to bring about particular energy transfers.

FT and HT

Electrical energy may also be transferred as gravitational potential energy.

Gravitational potential energy is the energy stored in an object because of the height to which the object has been lifted against the force of gravity.

How much electrical energy an appliance transfers depends on:

- how long the appliance is switched on;
- how fast the appliance transfers energy (its power).

The power of an appliance is measured in watts (W) or kilowatts (1 kW = 1000 W).

The amount of energy transferred from the mains is measured in kilowatt-hours, called Units:

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

Candidates should be able, when provided with suitable diagrams of a digital domestic electricity meter, to calculate the number of Units used.

The cost of this energy can be calculated using:

$$\text{total cost} = \text{number of Units} \times \text{cost per Unit}$$

Energy is normally measured in joules (J).

Power is a measure of how fast energy is transferred. The greater the power, the more energy is transferred in a given time.

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

1 watt is the transfer of 1 J of energy in 1 s.

The total amount of energy, in joules, transferred by an electrical device can be calculated as follows:

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

....

HT

$$\underset{\text{(joule, J)}}{\text{change in gravitational potential energy}} = \underset{\text{(newton, N)}}{\text{weight}} \times \underset{\text{(metre, m)}}{\text{change in vertical height}}$$

18.3 How efficient are the appliances we use?

The electrical appliances and all the other energy transferring devices we use are never perfect; they never transfer all the energy we supply as the energy form we want to the place where we want it. We need to know how efficient different energy-transferring devices are so that we can choose between them and try to improve them.

FT and HT

Whenever energy is transferred, only part of it is transferred to where it is wanted and in the form it is wanted (usefully transferred). The rest of the energy is transferred in some non-useful way and so wasted.

Candidates should be able to describe the intended energy transfers and the main energy wastages which occur when using a range of everyday devices.

The energy which is 'wasted' during energy transfers and the energy which is usefully transferred both end up being transferred to the surroundings which become warmer.

The energy becomes increasingly spread out and becomes increasingly more difficult to use for further useful energy transfers.

The more of the energy supplied to a device that is usefully transferred, the more efficient we say the device is.

Candidates should be able, when provided with appropriate information, to evaluate methods of reducing wasteful transfers of energy.

The efficiency of a device can be calculated using:

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

18.4 How should we generate the electricity we need?

Electricity is what is called a secondary energy source; some other energy resource is needed to generate it. 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 source(s) it would be best to use in any particular situation.

KS3

(prior learning)
Coal, oil, gas and wood are all fuels. They release energy when they are burned.

The Earth's supply of the fossil fuels (coal, oil and gas) and of nuclear fuels is limited . They are often called non-renewable energy resources. It will take millions of years to replace the fossil fuels we have used. Most of the energy used by humans comes from non-renewable fuels, mainly from fossil fuels. The more economical people are with these fuels, the longer they will last.

More trees can be grown to replace trees that are cut down to provide wood for fuel. Wood is a renewable energy resource.

Renewable energy resources include sunlight, the wind, the waves, running water and the tides. These energy resources will not run out.

Electricity is a very convenient and widely used energy source. It is generated in power stations using some other energy resource.

FT and HT

In most power stations, energy from fuel is used to heat water. In Britain, many power stations burn fossil fuels. Other power stations use nuclear fuel, mainly uranium and plutonium. The steam which is produced is used to drive turbines. The turbines then drive generators which produce electricity.

Electricity can also be generated from renewable energy resources. Energy from renewable resources can be used to drive turbines directly. The resources used in this way include:

- the wind;
- the rise and fall of water due to waves;
- the flow of water from a higher level to a lower level from behind tidal barrages or the dams of hydroelectric schemes.

In some volcanic areas, hot water and steam rise to the surface. The steam can be tapped and used to drive turbines producing geothermal energy supplies. The energy released in volcanic areas originally came from the decay of radioactive elements, including uranium, within the Earth.

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

Using different energy resources has different effects on the environment.

- Burning fossil fuels releases carbon dioxide, a gas which increases the greenhouse effect and causes increased global warming. For the same amount of energy released, coal produces more carbon dioxide than oil and oil produces more carbon dioxide than natural gas. There is no feasible way of preventing the very large amounts of carbon dioxide involved from entering the atmosphere. Burning most types of coal and oil also releases sulphur dioxide, a gas that helps to produce acid rain. The sulphur can be removed from these fuels before they are burnt or the sulphur dioxide removed from the waste gases before they enter the atmosphere, though this increases the cost of the electricity that is generated.
- Nuclear fuels do not produce gases which increase the greenhouse effect or which help to produce acid rain. When nuclear power stations are running normally, very little radiation or radioactive material escapes into the surroundings. If there is an accident, however, large amounts of very dangerous radioactive material may be released over a wide area. Nuclear power stations also produce waste, some of which stays dangerously radioactive for thousands of years and which has to be stored safely.

- Groups of large wind generators (wind farms) are usually sited on hills and/or coasts and are considered unsightly by some people. They can also be noisy for people living nearby. Wind farms cause visual pollution and noise pollution.
- Using energy from tides involves building barrages across river estuaries. This destroys the habitat of many organisms, e.g. wading birds and the mud-living organisms on which they feed.
- Hydroelectricity schemes involve damming upland river valleys. This means flooding land that may have previously been used for farming or forestry.

Energy sources also differ in when they are available for generating electricity.

- Power stations which use fuels can produce electricity at any time (of the day or of the year); they are reliable energy sources. The time it takes to start them up varies considerably:

nuclear	longest time ↑
coal	↕
oil	
natural gas	↓ shortest time

- The amount of electricity produced by wind generators depends on the strength of the wind which varies considerably.
  The amount of electricity produced by tidal barrages depends on the state of the tide, which varies during each day, and the height of the tide, which varies both on a monthly and yearly cycle.
  The amount of electricity produced by solar cells depends on the intensity of light that falls on them.
  Each of these energy sources can generate electricity only at certain times; they are all to some extent unreliable.
- Hydroelectric schemes are generally very reliable. They can also be started up very quickly to meet sudden increases in the demand for electricity. They can also be operated in reverse using surplus electricity from other power stations to pump water from a lower reservoir to a higher one. This means that most of the energy from the surplus electricity is stored rather than being wasted.

Solar cells have a very high cost per Unit of electricity produced over their lifetime compared to all other sources of electricity except non-rechargeable batteries. Despite their cost, they are often the best energy source for producing electricity in remote locations (e.g. on satellites) or where only small amounts of electricity are needed (e.g. for watches or calculators).

Candidates should be able to compare and contrast the particular advantages and disadvantages of using different energy sources to generate electricity.

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HT **Candidates should be able** to identify and evaluate the financial and environmental costs of using various energy resources to generate electricity and to evaluate these costs against the benefits to society, taking into consideration:

- the factors listed above;
- that though there are no fuel costs with renewables, the energy is dilute so that the capital cost of the generating equipment is high;
- that though the fuel costs for nuclear power stations are low, the cost of building the power stations, and of de-commissioning them at the end of their useful life, is high;
- the need to match supply and demand;
- any additional information, including quantitative information, with which they are provided.

19 Module 10 – Electricity

This module includes the following:

Exploring the relationship between the three key variables, potential difference, resistance and current and applying it to a range of devices.

Examining uses of the magnetic effects of electrical currents including the transfer of electrical energy as movement in electric motors and circuit breakers.

Using the concept of electrical charge:

- *in the context of static electricity, its uses and the problems it causes;*
- *to explain electric currents and electrolysis.*

Considering the nature of mains electricity and its safe use.

Calculating:

- *power, in terms of p.d. and current (and hence of appropriate fuses for appliances of given power);*

and, at the higher tier:

- *energy transfer in terms of p.d. and charge;*
- *charge in terms of current and time.*

Investigating electromagnetic induction and its use in generators and transformers.

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

How large a current flows depends on how hard the supply is trying to push a current through a circuit and how hard the circuit resists having a current pushed through it.

KS3 (prior learning)

A current will flow through an electrical component (or device) only if there is a voltage or potential difference (p.d.) across its ends. The bigger the potential difference across a component, the bigger the current that flows through it.

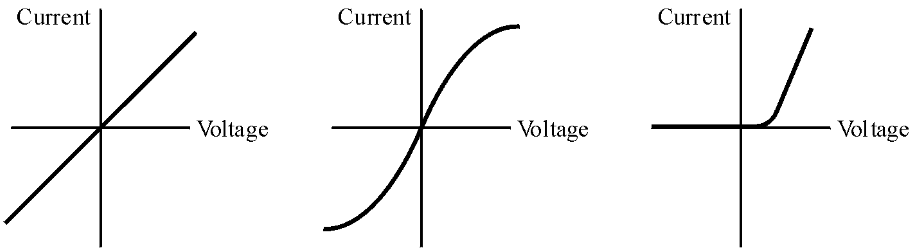
Components resist a current flowing through them. The bigger their resistance, the smaller the current produced by a particular voltage, or the bigger the voltage needed to produce a particular current.

The p.d. across a component in a circuit is measured in volts (V) using a voltmeter connected across (in parallel with) the component.

The current flowing through a component in a circuit is measured in amperes (A) using an ammeter connected in series with the component.

FT and HT Current-voltage graphs are used to show how the current through a component varies with the voltage across it.

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



When components are connected in series:

- their total resistance is the sum of their separate resistances;
- the same current flows through each component;
- the total potential difference of the supply is shared between them.

When components are connected in parallel:

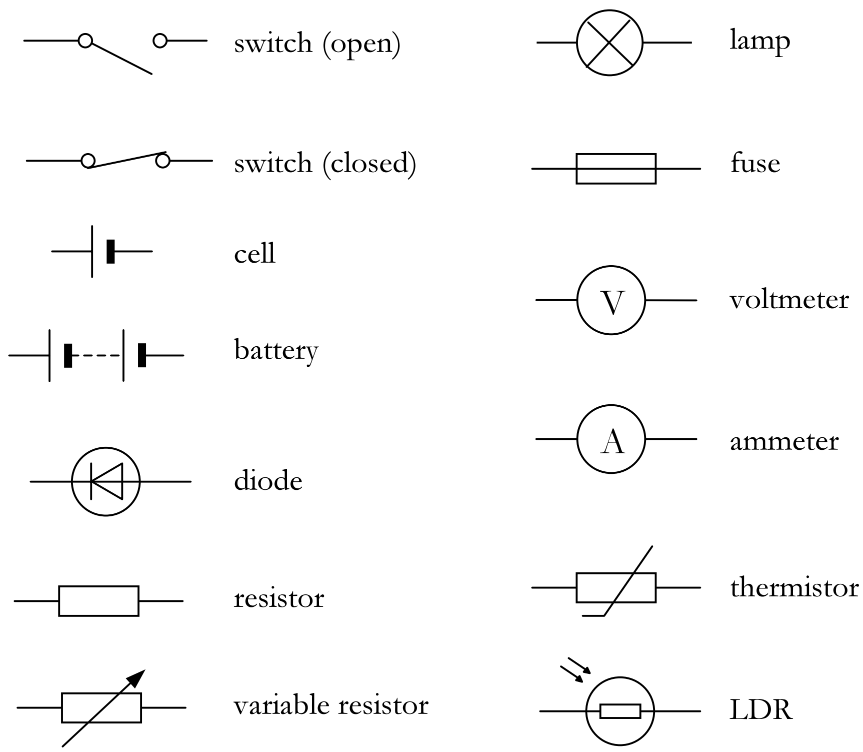
- there is the same potential difference across each component;
- the total current through the whole circuit is the sum of the currents through the separate components.

The potential difference provided by cells connected in series is the sum of the potential difference of each cell separately (bearing in mind the direction in which they are connected).

The current through a component depends on its resistance. The greater the resistance the smaller the current.

Resistance is measured in ohms (Ω).

Candidates should be able to interpret and/or draw circuit diagrams using standard symbols. The following standard symbols should be known.



Potential difference, current and resistance are related as shown:

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

The current through a resistor (at a constant temperature) is directly proportional to the voltage across the resistor.

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 decreases as the light intensity increases.

The resistance of a thermistor decreases as the temperature increases [*i.e. knowledge of negative temperature coefficient thermistor only is required*].

19.2 How can electricity be used to make things move?

Electric currents produce magnetic fields. These can be used to make things move, for example, electric motors and circuit breakers.

KS3 (prior learning)

A magnet exerts a force on any piece of magnetic material including iron and steel, or another magnet which is placed near it. (There is a magnetic field around the magnet.)

A coil of wire acts like a bar magnet when an electric current flows through it.
One end becomes a north-seeking pole and the other end a south-seeking pole.
This is called an electromagnet.

Reversing the current in an electromagnet reverses the poles of the electromagnet.

FT and HT

When a wire 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 direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed.

Candidates should be able - when provided with diagrams and/or other appropriate information – to explain how electromagnetic effects are used in simple d.c. motors and circuit breakers.

[Details of the split ring for reversing the current of a d.c. motor each half turn will not be required.]

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

Static electricity – the things it does and the problems it causes – can be explained in terms of electrical charges. When electrical charges move we get an electric current.

FT and HT

When certain different insulating materials are rubbed against each other they become electrically charged. Electrically charged objects attract small objects placed near them.

When two electrically charged objects are brought close together, they exert a force on each other. Two charged objects may either pull towards each other (attract) or push each other away (repel).

These observations can be explained in terms of two types of charge called positive (+) and negative (–). Two objects which have the same type of charge repel. Two objects which have different types of charge attract.

When two different materials are rubbed against each other, electrons, which have a negative charge, are rubbed off one material on to the other. The material which gains electrons becomes negatively charged; the material which loses electrons is left with an equal positive charge.

Electrostatic charges can be useful in everyday life.
For example in photocopiers:

- a copying plate is electronically charged;
- an image of the page you want to copy is projected on to the plate;
- where light falls on the plate, the electrical charges leak away;
- the parts of the plate that are still charged attract bits of black powder;
- the black powder is transferred from the plate to a sheet of paper;
- the paper is heated to make the black powder stick;
- there is now a copy of the original page.

Burning fuel, such as coal, pollutes the atmosphere not only with waste gases but also with smoke. Smoke consists of tiny particles of solid material. The smoke can be removed from the waste gases before they pass into the atmosphere by using a smoke precipitator:

- the waste gases pass by a charged metal grid;
- the smoke particles pick up an electrical charge as they pass by the grid;
- the smoke particles are repelled by the similar charge on the grid;
- the large collecting plates in the precipitator are given an opposite charge to that on the grid;
- the smoke particles are attracted to the oppositely charged plates and stick to them (hence they are precipitated);
- the collecting plates are knocked regularly so the smoke particles fall down and can be removed;
- the waste gases are then free of smoke particles.

A charged conductor can be discharged by connecting it to earth with a conductor.

Candidates should be able, when provided with the appropriate information about a situation in which static electricity is dangerous, to explain why it is dangerous and how precautions can be taken to ensure that the electrostatic charge is discharged safely.

In solid conductors, an electric current is a flow of electrons.

When some chemical compounds are melted or dissolved in water they conduct electricity. These compounds are made up of electrically charged particles called ions. The current is due to negatively charged ions moving to the positive terminal (electrode) and the positively charged ions moving to the negative electrode. Simpler substances are released at the terminals (electrodes). This process is called electrolysis.

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

Metals are good conductors of electricity because some of the electrons from their atoms can move freely throughout the metal structure.

During electrolysis the mass and/or volume of the substance deposited or released at the electrode increases in proportion to:

- the current;
- the time for which the current flows.

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

Mains electricity is very useful but it is also very dangerous. It is important for everyone to know how to use it safely.

FT and HT The UK mains supply is about 230 volts. Mains electricity can kill if it is not used safely.

Most electrical appliances are connected to the mains using cable and a 3-pin plug. To make them safe to use:

cable comprises:

- two or three inner cores of copper, because copper is a good conductor;
- outer layers of flexible plastic, because plastic is a good insulator.

a plug has:

- a plastic or rubber case, because plastic and rubber are good insulators;
- pins made from brass, because brass is a good conductor;
- a fuse;
- an earth pin;
- a cable grip.

The fuse in a plug should always be the same as the one recommended by the manufacturer of the appliance. Appliances with metal cases are usually earthed.

When connecting an appliance to a 3-pin plug:

- the blue wire is connected to the neutral terminal;
- the brown wire is connected via a fuse to the live terminal;
- the green/yellow wire (when fitted) is connected to the earth terminal;
- the cable should be secured in the plug by the cable grip;
- a fuse of the correct value (rating) should be in place.

Candidates should be able, when provided with appropriate diagrams:

- to recognise errors in the wiring of a mains (3-pin) plug;
- to recognise dangerous practice in the use of mains electricity.

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 or 50 hertz (Hz) which means that it changes direction and back again 50 times each second.

Cells and batteries supply a current which always flows in the same direction. This is called a direct current (d.c.).

Candidates should be able to compare the voltages of d.c. supplies and the frequencies and peak voltages of a.c. supplies from diagrams of oscilloscope traces.

If a fault in an electrical circuit or an appliance causes too great a current to flow, the circuit is switched off by a fuse or a circuit breaker.

The fuse should have a value higher than, but as close as possible to, the current through the appliance when it is working normally.

When the current through a fuse wire exceeds the current rating of the fuse the wire becomes hot and will (eventually) melt breaking the circuit and switching off the current.

Candidates should be able, when provided with appropriate information, to explain how a circuit breaker works.

Appliances with metal cases need to be earthed. The earth pin is connected to the case via the yellow/green wire. If a fault in the appliance connects the case to the live wire, and the supply is switched on, a very large current flows to earth and overloads the fuse.

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HT The live terminal of the mains supply alternates between a positive and negative voltage with respect to the neutral terminal. The neutral terminal stays at a voltage close to zero with respect to earth.

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

Electrical appliances transfer energy. The power of an electrical appliance is the rate at which it transfers energy. Most appliances have their power (in watts) and the voltage of the supply they need printed on them. From this we can calculate their current and so the fuse they need. [In fact, potential difference is defined in terms of the energy released per unit of charge transferred.]

KS3 (prior learning)
As an electric current flows through a circuit, energy is transferred from the battery or power supply to the components in the electrical circuit.

FT and HT

An electric current is a flow of charge.

When electrical charge flows through a resistor, electrical energy is transferred as heat.

The rate of energy transfer (power) is given by:

power (watt, W)	=	potential difference (volt, V)	x	current (ampere, A)

1 watt is the transfer of 1 J of energy in 1 s.

……………………………………………………………………………..

HT

The higher the voltage of a supply, the greater the amount of energy transferred for a given amount of charge which flows.

energy transferred (joule, J)	=	potential difference (volt, V)	x	charge (coulomb, C)

The amount of electrical charge which flows is related to current and time as follows:

charge (coulomb, C)	=	current (ampere, A)	x	time (second, s)

19.6 How do generators and transformers work?

Just as electric currents can be used to produce magnetic fields, so magnetic fields can be used to produce electric currents. This idea is used in generators to produce electricity and in transformers to increase or decrease voltage.

FT and HT

If a magnet is moved into a coil of wire which is part of a complete circuit a current is produced (induced) in the wire.

If the magnet is moved out of the coil, or the other pole of the magnet is moved into the coil, the direction of the induced current is reversed.

Transformers are used to change the voltage of an a.c. supply. At power stations, transformers are used to produce very high voltages before the electricity is transmitted to where it is needed through power lines (National Grid). Local transformers reduce the voltage to safer levels before the electricity is supplied to consumers.

Electricity can be generated by rotating a coil of wire in a magnetic field or by rotating a magnet inside a coil of wire. This is how a generator works.

If a wire, or coil of wire 'cuts through' a magnetic field, or vice-versa, a voltage (potential difference) is produced between the ends of the wire. This induced voltage causes a current to flow if the wire is part of a complete circuit.

The size of the induced voltage increases when:

- the speed of the movement increases;
- the strength of the magnetic field is increased;
- the number of turns on the coil is increased;
- the area of the coil is greater.

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HT **Candidates should be able**, when provided with a diagram, to explain how an a.c. generator works, including the purposes of the slip rings and brushes.

A changing magnetic field will also produce an induced voltage in a coil. This is how a transformer works.

The higher the voltage, the smaller the current needed to transmit energy at the same rate. Less energy is wasted by heating up the power lines.

A transformer consists of two separate coils wound around an iron core. When an alternating voltage is applied across one coil (the primary) an alternating voltage is produced across the other coil (secondary).

The voltages across the primary and secondary coils of a transformer are related as shown:

$$\frac{\text{voltage across primary (volt, V)}}{\text{voltage across secondary (volt, V)}} = \frac{\text{number of turns on primary}}{\text{number of turns on secondary}}$$

20 Module 11 – Forces

This module includes the following:

Interpreting graphical representations of speed and acceleration.

Examining the effects of forces on motion i.e.
- *unbalanced forces which produce accelerations as expressed in their relationship F=ma;*
- *frictional forces which oppose motion and which are not only important for slowing down and stopping vehicles but are also responsible for steady driving forces eventually resulting in steady speeds.*

Calculating:
- *the work done by forces which act on bodies to affect their movement;*
- *the kinetic energy of a moving body.*

Exploring the role of gravitational forces:
- *in keeping satellites in orbit;*
- *in maintaining the stability of the solar system;*
- *in the life histories of stars.*

Considering, at the higher tier only, the implications of the estimated speeds of distant galaxies for the origins of the Universe.

20.1 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 (accelerate).
Graphs showing how either the distance of a body from its starting point or its speed change over a period of time can help us to describe the movement of the body.

KS3

(prior learning)
For an object moving at a steady speed in a straight line, the distance it travels and the time it takes are related as shown:

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

FT and HT

If an object moves in a straight line, how far it is from a certain point can be represented by a distance-time graph.

Candidates should be able to construct and recognise the shape of a distance-time graph when a body is:
- stationary;
- moving with a steady speed.

The steeper the slope of the graph, the greater the speed it represents. The velocity of an object is its speed in a given direction.

Velocity-time graphs can represent the motion of a body.
Candidates should be able to recognise the shape of the velocity-time graph when a body is moving with:

- constant velocity;
- constant acceleration.

The steeper the slope of the graph, the greater the acceleration it represents.

The acceleration of an object is the rate at which its velocity changes. For objects moving in a straight line with a steady acceleration, the acceleration, the change in velocity and the time taken for the change are related as shown:

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

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HT **Candidates should be able** to calculate the gradient of a distance-time graph.

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

Candidates should be able to calculate:

- the gradient of a velocity-time graph and interpret this as acceleration;
- the area under a velocity-time graph;

for an object moving with constant acceleration.

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

To change the speed of a body an unbalanced force must act on it.
We use the force of friction between two solid surfaces to slow down and stop bicycles and motor vehicles safely.
[Because of friction, a driving force is needed to keep a body moving at a steady speed.]

KS3 (prior learning)
The forces acting on an object may cancel each other out (balance).
When an object rests on a surface:

- the weight of the object exerts a downward force on the surface;
- the surface exerts an upwards force on the object;
- the sizes of the two forces are the same.

A force of friction acts:

- when an object moves through the air or water;
- when solid surfaces slide, or tend to slide, across each other.

The direction of this force of friction is always opposite to the direction in which the object or surface is moving. Friction causes objects to heat up and to wear away at their surfaces.

Without friction, the tyres of a car would not grip the road.

The friction between solid surfaces is used in brakes which slow down and stop moving vehicles.

FT and HT

Whenever two bodies interact, the forces they exert on each other are equal and opposite.

Balanced forces will have no effect on the movement of an object: it will remain stationary or, if it is already moving it will continue to move at the same speed and in the same direction.

If the forces acting on an object do not cancel each other out, an unbalanced force will act on the object.

This unbalanced force will affect the movement of the object. How the movement is affected depends on the direction and the size of the unbalanced force:

- a stationary object will start to move in the direction of the unbalanced force;
- an object moving in the direction of the force will speed up;
- an object moving in the opposite direction to the force will slow it down;
- the greater the size of the unbalanced force, the faster the object will speed up or slow down.

When an unbalanced force acts on an object in a particular direction its speed changes (it accelerates) in that direction. The greater the force, the greater the acceleration. The bigger the mass of an object, the greater the force needed to give the object a particular acceleration.

Falling bodies are accelerated by gravity.
On Earth the gravitational field strength is about 10 N/kg.

weight	=	mass	x	gravitational field strength
(newton, N)		(kilogram, kg)		(newton/kilogram, N/kg)

The greater the speed of a vehicle:

- the greater the braking force needed to stop in a certain time;
- the greater the distance needed to stop it with a certain braking force.

If too great a braking force is applied, friction between a vehicle's tyres and the road surface may not be great enough to prevent skidding.

The stopping distance of a vehicle depends on:

- the distance the vehicle travels during the driver's reaction time;
- the distance the vehicle travels under the braking force.

The overall stopping distance is greater if:

- the vehicle is initially travelling faster;
- the driver's reactions are slower (due to tiredness, drugs, alcohol);
- there are adverse weather conditions (wet/icy roads, poor visibility);
- the vehicle is poorly maintained (e.g. worn brakes/tyres).

The faster an object moves through a gas or a liquid (a fluid) the greater the force of friction which acts on it.

When a body falls:

- initially it accelerates due to the force of gravity;
- frictional forces increase until they balance the gravitational forces;
- the resultant force eventually reaches zero and the body falls at its terminal velocity.

When a vehicle has a steady speed the frictional forces balance the driving force.

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HT One newton is the force needed to give a mass of one kilogram an acceleration of one metre per second squared.

Force, mass and acceleration are related as shown:

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

20.3 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.

FT and HT When a force moves an object, energy is transferred and work is done:

work done = energy transferred

The amount of work done, force and distance are related as shown:

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

Work done against frictional forces is transferred mainly as heat.

Elastic potential energy is the energy stored in an elastic object when work is done on the object to change its shape.

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HT Kinetic energy is the energy an object has because of its movement.

An object has more kinetic energy:

- the greater its mass;
- the greater its speed.

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{speed}^2$$

(joule, J) (kilogram, kg) [(metre/second)^2, (m/s)^2]

20.4 How do planets and artificial satellites stay in orbit?

Astronomers believe that the planets, like Earth, orbit the Sun. Satellites which orbit Earth are used for communications and to monitor events on Earth. All these bodies can remain in orbit only because of gravitational forces.

KS3 (prior learning)
The Earth spins on its own axis once every day (24 hours). The half of the Earth which faces the sun is in daylight; the other half of the Earth is in night.

The Earth moves round (orbits) the Sun once each year (just over 365 days).

The stars in the night sky stay in fixed patterns (called constellations). The planets which are visible to the naked eye look just like stars. They move very slowly across the constellations.

The planets do not give out their own light. Like the Earth, they move in orbits around the Sun. We can see planets because they reflect light from the Sun.
Where we see the planets against the background of the stars depends on exactly where they, and the Earth, are in their orbits round the Sun.

Satellites can be put into orbit around the Earth. They can be used:

- to send information between places which are a long way apart from the Earth;
- to monitor conditions on Earth, including the weather;
- to observe the Universe without the Earth's atmosphere getting in the way.

FT and HT The orbits of the planets are slightly squashed circles (ellipses) with the Sun quite close to the centre.

Comets have orbits which are far from circular. They are very much closer to the Sun at some times than at others. This is when they can be seen.

The Earth, the Sun, the Moon and all other bodies attract each other with a force called gravity. As the distance between two bodies increases, the force of gravity between them decreases more than in proportion to the increase in distance.

A smaller body will stay in orbit around a larger one because of the combination of its high speed and the force of gravity between the bodies.

To stay in orbit at a particular distance, smaller bodies, including planets and satellites, must move at a particular speed around larger bodies.

The further away an orbiting body is the longer it takes to make a complete orbit.

Communication satellites, including those used for television programmes, are usually put into orbit high above the equator so that they move around the Earth in exactly the same time as the Earth spins. This means that they are always in the same position when viewed from Earth (a geostationary orbit). There is space for about only 400 geostationary satellites or they would interfere with each other's signals.

Monitoring satellites are usually put into a low polar orbit so that the Earth spins beneath them and they can scan the whole Earth each day from much closer range than a geostationary satellite.

20.5 What do we know about the origins of the Universe and the life histories of stars?

Astronomers also believe that gravitational forces are responsible for the formation of galaxies of stars and for stars like the Sun having a long stable period. The speed with which other galaxies appear to be moving away from us suggests how the Universe might have begun.

FT and HT

Our Sun is just one of many millions of stars in a galaxy (large group of stars) called the Milky Way.
The stars in a galaxy are often millions of times further away from each other than the planets in the solar system.
The Universe as a whole is made up of at least a billion galaxies.
Galaxies are often millions of times further apart than the stars within a galaxy.

Stars, including the Sun, 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.

If there is, or has been, life on other planets, in our own solar system or around other stars:

- we may be able to observe living organisms (e.g. microbes), or their fossilised remains, directly, for example, by actually going to Mars or Europa (a satellite of Jupiter), by using robots to send back pictures or by using robots to collect samples to bring back to Earth;
- we may be able to detect living organisms by the chemical changes they produce in a closed system (e.g. inside a closed container or in the atmosphere of their planet);
  Because of living organisms, the atmosphere of the Earth is very different from what it would be purely from chemical and geological processes; for example, there is much more oxygen;

- we may be able to receive signals from other species with technologies that are at least as advanced as our own.

The search for extra-terrestrial intelligence (SETI), using radio telescopes to try to find meaningful signals in a narrow band of wavelengths (i.e. not just "noise"), has gone on for more than forty years, so far without success.

Candidates should be able, when provided with appropriate information to evaluate:

- the methods scientists use to discover whether there is life elsewhere in the universe;
- evidence that such life exists.

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Individual stars, including the Sun, do not stay the same for ever.

Stars are very massive so that the force of gravity which tends to draw together the matter from which they are made is very strong. The very high temperatures create forces which tend to make them expand. During the main stable period of a star, which may last for billions of years, these forces are balanced. The Sun is at this stage of its life.

The star then expands to become a red giant. At a later point in its history it contracts under its own gravity to become a white dwarf. The matter from which the star is made may then be millions of times denser than any matter on Earth.
If a red giant is massive enough, it may eventually rapidly contract and then explode (become a supernova) throwing dust and gas into space. The matter that is left behind may form a very dense neutron star.

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HT If enough matter is left behind, this may be so dense, and its gravitational field so strong that nothing can escape from it, not even light or other forms of electromagnetic radiation. It is then called a black hole. We cannot see black holes but we can sometimes observe their effects on their surroundings, for example, the X-rays emitted when gases from a nearby star spiral into a black hole.

During a star's lifetime, nuclei of lighter elements (mainly hydrogen and helium) gradually fuse to produce nuclei of heavier elements. These nuclear fusion reactions release the energy which is radiated by stars.

Nuclei of the heaviest elements are present in the Sun and atoms of these elements are present in the inner planets of the solar system. This suggests that the solar system was formed from the material produced when earlier stars exploded.

Theories of the origin of the Universe have to take into account:

- that light from other galaxies is shifted to the red end of the spectrum;
- that the further away galaxies are, the bigger this 'red-shift'.

The current way of explaining this is:

- that other galaxies are moving away from us very quickly;
- that the further away from us a galaxy is, the faster it is moving away from us.

This suggests that the whole Universe is expanding and that it might have started, billions of years ago, with a huge explosion ('big bang').

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21 Module 12 – Waves and Radiation

This module includes the following:

Comparing the behaviour of waves we can actually see (e.g. water waves) with the behaviour of light and sound. This leads to the suggestion that light and sound might also travel as waves with the same relationship between wave-speed, frequency and wavelength.

Investigating the different types of waves in the electromagnetic spectrum in terms of their wavelengths/frequencies, properties and uses.

Examining the properties, uses and dangers of the radiation emitted by radioactive substances.

Explaining radioactive decay (and, for the higher tier only, nuclear fission) in terms of atomic structure.

Extending the study of sound waves to include:

- *ultrasound and its uses;*
- *what seismic waves reveal about the internal structure of the Earth.*

21.1 Why do scientists talk about light and sound as waves?

Water waves, and other waves that we can see, behave in the same way as light and sound. This suggests that light and sound might also travel as waves.

KS3

(prior learning)
Sounds bounce back (reflect) from hard surfaces. Echoes are sound reflections.

When a ray of light is reflected from a flat, shiny surface (plane mirror) the angle at which it leaves the surface is the same as the angle at which it meets the surface.

Rays of light change direction (are refracted) when they cross the boundary between one transparent substance and another, unless they meet the boundary at right angles (along a normal).

Sounds are also refracted, i.e. their direction is changed when they cross the boundary between two different substances at an angle other than a right angle.

FT and HT

Waves can be produced in ropes and springs and on the surface of water.

When waves travel along ropes or springs or across the surface of water they set up regular patterns of disturbances:

- the maximum disturbance caused by a wave is called its amplitude;
- the distance between a particular point on one disturbance and the same point on the next is called the wavelength;
- the number of waves each second produced by a source (or passing a particular point) is called the frequency, and is measured in hertz (Hz).

Wave speed, wavelength and frequency are related as follows:

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

Waves transfer energy from a source to other places without any matter being transferred.

Waves travelling along a rope or spring, or across the surface of water, can be reflected.
Waves travelling across the surface of water can also be refracted.

The change in the speed of water waves when they cross the boundary between two different depths causes a change in their direction (refraction), unless the direction of travel of the waves is along a normal.

This behaviour of waves suggests that light and sound:

- also travel as waves;
- are refracted because they travel at different speeds in different substances (media).

When light travels from glass, Perspex or water into air, some of the light is reflected from the boundary.

If the angle between the ray and the normal is greater than a certain angle (called the critical angle), all of the light is reflected inside the glass, Perspex or water. This is called total internal reflection.

When light travels down an optical fibre, all the light may stay inside the fibre until it emerges from the other end.

This is because light travels down optical fibres by repeated total internal reflection.

Light can be sent along optical fibres, for example, in endoscopes used by doctors to see inside patients' bodies.

Candidates should be able to describe, using a suitable diagram, a use of total internal reflection.

The waves which travel along ropes and across the surface of water are transverse waves: the disturbances in the substance through which the waves travel is at right angles to the direction in which waves themselves travel.

The waves which travel through springs may also be longitudinal: the disturbances in the spring are along the same direction as that in which the waves themselves travel.

Sound waves travel through solids, liquids and gases as longitudinal waves.
Light waves are transverse waves and can travel through a vacuum, i.e. they do not need a medium.

When a wave moves through a gap, or past an obstacle, it spreads out from the edges. This is called diffraction.

Electromagnetic radiation and sound are also diffracted which supports the idea that they travel as waves.

Because of diffraction:

- sounds can sometimes be heard in the shadow of buildings;
- radio signals can sometimes be received in the shadow of hills.

Waves having a longer wavelength are more strongly diffracted.

21.2 Is there radiation we cannot see beyond the ends of the spectrum?

White light can be split up into a spectrum of different colours. There are many other types of radiation beyond the ends of the visible spectrum. Each type of radiation in this extended spectrum - known as the electromagnetic spectrum – has its own special properties and uses.

KS3 (prior learning)
When rays of light pass through prisms their direction may be changed.

When white light is used, a spectrum is produced.

The spectrum is produced because white light is made up of many different colours. Different colours of light are refracted by different amounts; red light is refracted least and violet light most.

FT and HT Light is one type of electromagnetic radiation.

All types of electromagnetic waves travel at the same speed through space.

The various types of electromagnetic radiation form a continuous spectrum extending far beyond each end of the visible spectrum:

highest frequency ↑		shortest wavelength ↑
	gamma rays X-rays ultraviolet rays light infra red rays microwaves radio waves	
↓ lowest frequency		↓ longest wavelength

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;
- may create an alternating current with the same frequency as the radiation itself.

The uses and effects of different types of radiation depend on these and other properties.

Radio waves are used to transmit radio and TV programmes between different points on the Earth's surface. Longer wavelength radio waves are reflected from an electrically charged layer in the Earth's upper atmosphere. This enables them to be sent between distant points despite the curvature of the Earth's surface.

Microwave radiation of wavelengths which can pass easily through the Earth's atmosphere is used to send information to and from satellites, and within mobile phone networks. Microwave radiation, with wavelengths strongly absorbed by water molecules, is used for cooking.

Infra red radiation is used in grills, toasters and radiant heaters, in optical fibre communication and for the remote control of TV sets and VCRs.

Ultraviolet radiation is used in sunbeds. Special coatings which absorb ultraviolet radiation and emit the energy as light, are used in fluorescent lamps and security coding.

X-radiation is used to produce shadow pictures of materials which X-rays do not easily pass through including bones and metals.

Gamma radiation is used to:
- kill harmful bacteria in food;
- sterilise surgical instruments;
- kill cancer cells.

Different types of radiation have different effects on living cells:
- microwaves are absorbed by the water in cells, which may be damaged or killed by the heat released;
- infra red radiation is absorbed by skin and is felt as heat;
- ultraviolet radiation can pass through skin to deeper tissues. The darker the skin, the more ultraviolet it absorbs and the less reaches into deeper tissues;
- X-radiation and gamma radiation mostly pass through soft tissues, but some is absorbed by the cells.

High doses of ultraviolet radiation, X-radiation and gamma radiation can kill normal cells. Lower doses of these types of ionising radiation can cause normal cells to become cancerous.

Candidates should be able, when provided with appropriate information, to evaluate:
- the dangers, or possible dangers, of exposure to different types of electromagnetic radiation and to radiation from radioactive substances;
- measures that can be taken to reduce such exposure.

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Information such as speech or music can be converted into electrical signals so that they can be sent long distances through cables or using electromagnetic waves as carriers. Information can also be converted into light or infra red signals and sent along optical fibres.

More information can be carried than by sending electrical signals through cables of the same diameter. There is also less weakening of the signal in optical fibres.

Signals which vary continuously in amplitude and/or frequency, in the same way that the sound waves of speech or music do, are called analogue signals.

Signals can also be coded as a series of pulses. The signal then only has two states, on or off. Signals of this type are called digital signals.

The advantages of digital signals are:
- their higher quality – the signals do not change their information during the transmission process;
- their information carrying capacity – more information can be sent in a given time via a given cable, optical fibre or carrier wave than with analogue signals.

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As signals travel they become weaker. Random additions to the signal (noise) may also be picked up.

With analogue signals, different frequencies within the signal may weaken to different extents. Each time the signal is amplified, these differences, and any noise that has been picked up, are also amplified. This means that the signal becomes less and less like the original signal; its quality deteriorates.

With digital signals, even though pulses weaken with distance, they are still recognisable as "on" states, whereas noise is generally of low amplitude and is ignored (i.e. interpreted as "off"). The quality of a digital signal is maintained, therefore, during the transmission process.

21.3 What do we know about the radiation from radioactive substances?

Radioactive substances, which emit radiation all the time, are very useful but also very dangerous. It is important to understand the properties of the different types of radiation they emit.

FT and HT

Some substances give out radiation all the time, whatever is done to them. These substances are said to be radioactive. Radioactivity is a random process.

There are three types of radiation emitted by radioactive sources:
- alpha (α) radiation - which is easily absorbed by a few centimetres of air or a thin sheet of paper;
- beta (β) radiation - which easily passes through air or paper but is mostly absorbed by a few millimetres of metal;
- gamma (γ) radiation - which is very penetrating and requires many centimetres of lead or metres of concrete to absorb most of it.

There are radioactive substances all around us, including in the ground, in the air, in building materials and in food. Radiation also reaches us from space. The radiation from all these sources is called background radiation.
When radiation from radioactive materials collides with neutral atoms or molecules these may become charged (ionised).
When radiation ionises molecules in living cells it can cause damage, including cancer. The larger the dose of radiation the greater the risk of cancer.

Higher doses of ionising radiation can kill cells; they are used to kill cancer cells and harmful microorganisms.

As radiation passes through a material it can be absorbed. The greater the thickness of a material the greater the absorption. The absorption of radiation can be used to monitor/control the thickness of materials.

When sources of radiation are outside the body:
- beta and gamma radiation are the most dangerous because they can reach the cells of organs and may be absorbed by them;
- alpha radiation is least dangerous because it is unlikely to reach living cells.

Workers who are at risk from radiation often wear a radiation badge to monitor the amount of radiation they have been exposed to over a period of time. This is a small packet containing photographic film. The more radiation a worker has been exposed to, the darker the photographic film is when it has been developed.

When sources of radiation are inside the body:

- alpha radiation is the most dangerous because it is so strongly absorbed by cells;
- beta and gamma radiation are less dangerous because cells are less likely to absorb the radiation.

The half-life of a radioactive substance:

- is the time it takes for the number of parent atoms in a sample to halve;
- is the time it takes for the count rate from the original substance to fall to half its initial level.

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HT **Candidates should be able** to evaluate the appropriateness of radioactive sources for particular uses including as tracers, in terms of:

- the type(s) of radiation emitted;
- their half-lives.

21.4 What happens to radioactive substances when they decay or are used in nuclear reactors?

To understand what happens to radioactive substances when they decay, or when we use them in nuclear reactors, we need to understand the structure of the atoms from which they are made.

FT and HT Atoms have a small central nucleus made up of protons and neutrons around which there are electrons.

Candidates should be able, when provided with appropriate information, to:

- explain how the Rutherford and Marsden scattering experiment led to the current model of the atom replacing the earlier "plum pudding" model;
- suggest why the new model very quickly became widely accepted.

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The relative masses of protons, neutrons and electrons and their relative electric charges are as shown:

	Mass	Charge
Proton	1	+1
Neutron	1	0
Electron	negligible	−1

In an atom, the number of electrons is equal to the number of protons in the nucleus. The atom as a whole has no electrical charge.

All atoms of a particular element have the same number of protons. Atoms of different elements have different numbers of protons. The total number of protons and neutrons (nucleons) in an atom is called its mass (nucleon) number.

Atoms of the same element which have different numbers of neutrons are called isotopes.

Radioactivity occurs as a result of changes in the nuclei of atoms (nuclear changes).

Radioactive isotopes (radioisotopes or radionuclides) are atoms with unstable nuclei. When an unstable nucleus splits up (decays):

- it emits radiation;
- a different atom, with different number of protons, is formed.

The older a particular radioactive material, the less radiation it emits. This idea can be used to date materials, including rocks.

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HT Alpha radiation consists of helium nuclei, particles made up of two protons and two neutrons.
Beta radiation consists of high-energy electrons emitted from the nuclei of atoms.
For each electron emitted, a neutron in the nucleus becomes a proton.
Gamma radiation is very short wavelength electromagnetic radiation.

Nuclear reactors use a process called nuclear fission. When an atom with a very large nucleus is bombarded with neutrons:

- the nucleus splits into two smaller nuclei;
- further neutrons are released which may cause further nuclear fission resulting in a chain reaction;
- the new atoms which are formed are themselves radioactive.

[Details of nuclear reactors are not required.]

The energy released by an atom during radioactive decay or nuclear fission is very large compared to the energy released when a chemical bond is made between two atoms.

During one half-life, half of the radioactive atoms initially present in a sample decay. This idea can be used to date materials.

Uranium isotopes, which have a very long half-life, decay via a series of relatively short-lived radioisotopes to produce stable isotopes of lead. The relative proportions of uranium and lead isotopes in a sample of igneous rock can, therefore, be used to date the rock.

The proportions of the radioisotope potassium-40 and its stable decay product argon can also be used to date igneous rocks from which the gaseous argon has been unable to escape.

Candidates should be able to make such calculations when provided with appropriate data.

21.5 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 ultrasounds have several important uses.

KS3 (prior learning)
Sounds are produced when objects vibrate.

The greater the size (amplitude) of vibrations the louder the sound.

The number of complete vibrations each second is called the frequency (hertz, Hz). The higher the frequency of a sound the higher its pitch.

FT and HT **Candidates should be able** to compare the amplitudes and frequencies of sounds from diagrams of oscilloscope traces.

Electronic systems can be used to produce electrical oscillations with any frequency. These electrical oscillations can be used to produce ultrasonic waves which have a frequency higher than the upper limit of the hearing range for humans.

Ultrasonic waves can be used:

- in industry for cleaning and quality control;
- in medicine for pre-natal scanning.

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HT Ultrasonic waves are partly reflected when they meet a boundary between two different media. The time taken for the reflections of ultrasonic pulses to reach a detector (usually placed near to the source) is a measure of how far away such a boundary is. This idea is used in industry to detect flaws in metal castings and in medicine for pre-natal scans. Information about the time taken for reflections to travel is usually processed to produce a visual display.

Ultrasonic waves in liquids can also be used for cleaning delicate mechanisms without having to disassemble them.

21.6 What do the shock waves from Earthquakes tell us about the Earth?

By studying the shock waves from earthquakes scientists have learnt a great deal about the internal structure of the Earth.

FT and HT Our knowledge of the structure of the Earth comes mainly from studying how the shockwaves from earthquakes (seismic waves) travel through it. These waves are detected using seismographs.

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HT Earthquakes produce surface waves that can cause damage. They also produce two types of waves that can travel through the Earth:

- faster travelling P waves, which are longitudinal and travel through liquids as well as solids;
- slower travelling S waves, which are transverse and travel only through solids.

The speed of both types of wave increases with depth through the mantle. The waves travel in curved paths as their speed changes gradually through a material. When the state of the transmitting medium changes abruptly, e.g. when moving from solid to liquid, the wave direction also changes abruptly.

It is by observing the path of these waves that scientists have been able to work out details of the Earth's layered structure.

Candidates should be able to interpret diagrams of the paths of seismic waves inside the Earth in terms of:

- the liquid nature of the Earth's outer core;
- refraction at the boundaries between layers;
- refraction due to changes in speed within a particular layer.

22 Aspects of Content for Terminal Examination

This list identifies aspects of the content of previously tested modules which candidates will be expected to know for the terminal examination. The content is presented using headings to identify the module and section from which it is extracted.

Paper 1 – Double Award

22.1 From Module 01 Humans as Organisms

From Section 10.2 FT and HT

Starch (a carbohydrate), proteins and fats are insoluble. They are broken down into soluble substances so that they can be absorbed into the bloodstream in the wall of the small intestine. In the large intestine much of the water is absorbed into the bloodstream. The indigestible food which remains makes up the bulk of the faeces. Faeces leave the body via the anus.

The breakdown of large molecules into smaller molecules is speeded up (catalysed) by enzymes.

From Section 10.3 FT and HT

The breathing system takes air into and out of the body so that oxygen from the air can diffuse into the bloodstream and carbon dioxide can pass out of the bloodstream into the air.

During vigorous exercise, muscle cells may be short of oxygen. When there is a shortage of oxygen cells may carry out anaerobic respiration for a short time. This releases waste lactic acid. Muscle cells can then obtain energy from glucose by anaerobic respiration (respiration which does not use oxygen).

The body then needs oxygen to break down this waste product, lactic acid. The oxygen that is needed is called an oxygen debt.

The energy that is released during respiration is used:

- to build up larger molecules using smaller ones;
- to enable muscles to contract;
- to maintain a steady body temperature in colder surroundings;

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- in the active transport of materials across boundaries.

Aerobic respiration inside cells occurs in mitochondria.

If muscles are subjected to long periods of vigorous activity, they become fatigued, i.e. they stop contracting efficiently. If insufficient oxygen is reaching the muscles they use anaerobic respiration to obtain energy.

This is the incomplete breakdown of glucose and produces lactic acid. Because the breakdown of glucose is incomplete, much less energy is released than during aerobic respiration. Anaerobic respiration results in an oxygen debt that has to be repaid in order to oxidise lactic acid to carbon dioxide and water.

The alveoli provide a very large, moist surface, richly supplied with blood capillaries so that gases can readily diffuse into and out of the blood.

From Section 10.4 FT and HT

The circulation system transports substances around the body.

Blood consists of a fluid called plasma in which are suspended white blood cells, platelets and red blood cells.
Plasma transports:

- carbon dioxide from the organs to the lungs;
- soluble products of digestion from the small intestine to other organs;
- urea from the liver to the kidneys.

Red blood cells transport oxygen from the lungs to the organs.

From Section 10.5 FT and HT

Candidates should be able, when provided with appropriate information, to evaluate evidence relating living conditions and lifestyle to the spread of disease.

From Section 10.6 FT and HT

Diffusion is the spreading of the particles of a gas, or of any substance in solution, resulting in a net movement from a region where they are at a higher concentration to a region where they are at a lower concentration. The greater the difference in concentration, the faster the rate of diffusion. Oxygen required for respiration passes through cell membranes and through gas exchange surfaces, such as alveoli in the lungs, by diffusion.

Many organ systems are specialised for exchanging materials.
In humans the surface area of the lungs is increased by the alveoli, and that of the small intestine by villi.

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HT

Candidates should be able, when provided with appropriate information, to explain how other gas and solute exchange surfaces in humans and other organisms are adapted to maximise effectiveness.

22.2 From Module 02 Maintenance of Life

From Section 11.2 FT and HT

Photosynthesis is summarised by the equation:

carbon dioxide + water [+ light energy] $\longrightarrow$ glucose + oxygen

During photosynthesis:

- light energy is absorbed by a green substance called chlorophyll which is found in chloroplasts in some plant cells;
- this energy is used by converting carbon dioxide and water into sugar (glucose);
- oxygen is released as a by-product.

The rate of photosynthesis may be limited by:

- low temperature;
- shortage of carbon dioxide;
- shortage of light.

The glucose produced in photosynthesis may be converted into insoluble starch for storage.

Plant cells use some of the glucose produced during photosynthesis for respiration.

Light, temperature and the availability of carbon dioxide interact and in practice any one of them may be the factor that limits photosynthesis.

From Section 11.3 FT and HT

Carbon dioxide enters leaves and leaf cells by diffusion, i.e. simply spreading from a higher to a lower concentration.

From Section 11.6 FT and HT

Humans need to remove waste products from their bodies and keep their internal environment relatively constant.

Waste products which have to be removed from the body include:

- carbon dioxide produced by respiration - most of this leaves the body via the lungs when we breathe out;
- urea produced in the liver by the breakdown of excess amino acids - this is removed by the kidneys in the urine, which is temporarily stored in the bladder.

Internal conditions which are controlled include:

- the water content of the body - water leaves the body via the lungs when we breathe out and via the skin when we sweat, and excess water is lost via the kidneys in the urine;
- the ion content of the body - ions are lost via the skin when we sweat and excess ions are lost via the kidneys in the urine;
- temperature – to maintain the temperature at which enzymes work best.

Sweating helps to cool the body. More water is lost when it is hot, and more water has to be taken as drink or in food to balance this loss.

Many processes within the body are coordinated by chemical substances called hormones. Hormones are secreted by glands and are transported to their target organs by the bloodstream.

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HT The kidneys help to maintain the internal environment by:

- first filtering the blood;
- re-absorbing all the sugar;
- re-absorbing the dissolved ions needed by the body;
- re-absorbing as much water as the body needs;
- releasing urea, excess ions and excess water as urine.

The kidneys produce dilute urine if there is too much water in the blood or concentrated urine if there is too little water in the blood. If the water content of the blood is too low, the pituitary gland releases a hormone called ADH into the blood. This causes the kidneys to re-absorb more water and results in a more concentrated urine. If the water content of the blood is too high, less ADH is released into the blood. Less water is re-absorbed in the kidneys resulting in a more dilute urine.

Sugar and dissolved ions may each be actively absorbed from the kidney tubules against a concentration gradient.

Body temperature is monitored and controlled by the thermoregulatory centre in the brain. This centre has receptors sensitive to the temperature of blood flowing through the brain. Also temperature receptors in the skin send impulses to the centre giving information about skin temperature.
If the core body temperature is too high:

- blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more heat is lost;
- sweat glands release more sweat which cools the body as it evaporates.

If the core body temperature is too low:

- blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries;
- muscles may 'shiver' - their contraction needs respiration which releases some energy as heat.

From Section 11.7 FT and HT

Candidates should be able, when provided with appropriate information, to explain how the link between smoking tobacco and lung cancer gradually became accepted.

22.3 From Module 05 - Metals

From Section 14.1 FT and HT

More than three-quarters of the elements are metals.
In the periodic table metals are mainly found:

- in the two left hand columns (Group 1 and Group 2);
- in the central block (transition elements).

The elements in Group 1 of the periodic table (known as the alkali metals):

- are metals with a low density (the first three in the Group are less dense than, and therefore float on, water);
- react with non-metals to form ionic compounds. The compounds are white solids which dissolve in water to form colourless solutions;
- react with water releasing hydrogen;
- form hydroxides which dissolve in water to give alkaline solutions.

In the centre of the periodic table is a block of metallic elements. These elements, which include iron and copper, are known as transition metals.

Like all other metals, transition metals are good conductors of heat and electricity and can easily be bent or hammered into shape. Compared to alkali metals:

- they have high melting points (except for mercury, which is a liquid at room temperature);
- they are hard, tough and strong;
- they are much less reactive and so do not react (corrode) so quickly with oxygen and/or water.

These properties make transition metals very useful as structural materials (e.g. iron, usually in the form of steel) and for making things which must allow heat or electricity to pass through them easily (e.g. copper for electrical cables).

Most transition metals form coloured compounds.
These can be seen:

- in pottery glazes of various colours;
- in weathered copper (green).

Many transition metals, including iron and platinum, are used as catalysts.

From Section 14.2 FT and HT

The reactivity series of metals lists metals in order of their reactivity, the most reactive metal being placed at the top of the list and the least reactive at the bottom. A more reactive metal can displace a less reactive metal from its compounds.

How a metal is extracted from its ore depends on how reactive the metal is.

From Section 14.4 FT and HT

Compounds of alkali metals called salts can be made by reacting solutions of their hydroxides which are alkaline with acids. In these neutralisation reactions:

acid + alkaline hydroxide solution $\longrightarrow$ a neutral salt solution + water

The particular salt produced in any reaction between an acid and an alkali depends on:

- the acid used;
- the metal in the alkali.

Paper 2 – Double Award

22.4 From Module 06 Earth Materials

From Section 15.2 FT and HT

Most of the compounds in crude oil consist of molecules made up of hydrogen and carbon atoms only (hydrocarbons).

The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by evaporating the oil and allowing it to condense at a number of different temperatures. This process is fractional distillation.

The hydrocarbon molecules in crude oil vary in size.

The larger the molecules (the greater the number of carbon atoms) in a hydrocarbon:

- the higher its boiling point;
- the less volatile it is.

Large hydrocarbon molecules can be broken down (cracked) to produce smaller more useful molecules. This process involves heating the hydrocarbons to vaporise them and passing the vapours over a hot catalyst. A thermal decomposition reaction then occurs.

Some of the products of cracking are useful as fuels.

Most fuels contain carbon and/or hydrogen and may also contain some sulphur. The gases released into the atmosphere when a fuel burns may include:

- carbon dioxide;
- water (vapour), which is an oxide of hydrogen;
- sulphur dioxide.

Other products of cracking can be used to make plastics (polymers) such as poly(ethene) and poly(propene).

Candidates should be able, when provided with appropriate information, to evaluate the impact on the environment of burning hydrocarbon fuels and of plastic waste disposal.

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HT The cracked hydrocarbon molecules have carbon carbon double covalent bonds (they are unsaturated) and are known as alkenes.

These unsaturated hydrocarbons are reactive and so are useful for making many other substances including polymers. Polymers have very large molecules, and are formed when many small molecules, of substances called monomers, join together. This process is called polymerisation.

From Section 15.3 HT

The release of carbon dioxide by burning the carbon locked up over hundreds of millions of years in fossil fuels increases the level of carbon dioxide in the atmosphere. Though the reaction between carbon dioxide and sea-water also increases, producing insoluble (mainly calcium) carbonates which are deposited as sediment and soluble hydrogencarbonates (mainly calcium and magnesium), this does not wholly absorb the additional carbon dioxide released into the atmosphere.

From Section 15.4 FT and HT

At the surface of the Earth younger sedimentary rocks usually lie on top of older rocks. Sediments contain evidence for how they were deposited (e.g. layers formed by discontinuous deposition, ripple marks formed by currents or waves). Sedimentary rock layers are often found tilted, folded, fractured (faulted) and sometimes even turned upside down. This shows that the Earth's crust is unstable and has been subjected to very large forces.

Candidates should be able, when provided with information about the complex probable causes of earthquakes and volcanic eruptions and the difficulty of making measurements of many of the factors involved, to explain why scientists cannot yet accurately predict when they will occur.

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Candidates should be able, when provided with appropriate additional information, to explain why Wegener's theory of crustal movement (continental drift) was not generally accepted until more than 50 years after it was proposed.

22.5 From Module 09 – Energy

From Section 18.1 FT and HT

Hot bodies emit mainly infra red radiation.

The hotter an object is, the more energy it radiates. Dark, matt surfaces emit more radiation than light, shiny surfaces at the same temperature.

Dark, matt surfaces are good absorbers (poor reflectors) of radiation. Light, shiny surfaces are good reflectors (poor absorbers) of radiation.

Candidates should be able:

- to describe various ways in which heat energy is transferred from buildings;
- to describe and explain ways in which the rates of these energy transfers can be reduced.

Candidates should be able, when given appropriate information, to evaluate the effectiveness and cost-effectiveness of methods used to reduce energy consumption in buildings.

From Section 18.2 FT and HT

Much of the energy transferred in homes and industry is electrical energy. This is because electrical energy is readily transferred as:

- heat (thermal energy);
- light;
- sound;
- movement (kinetic energy).

Candidates should be able:

- to specify the energy transfers everyday electrical devices are designed to bring about;
- to give examples of everyday electrical devices designed to bring about particular energy transfers.

From Section 18.3 FT and HT

Whenever energy is transferred, only part of it is transferred to where it is wanted and in the form it is wanted (usefully transferred). The rest of the energy is transferred in some non-useful way and so wasted.

Candidates should be able to describe the intended energy transfers and the main energy wastages which occur when using a range of everyday devices.

The energy which is 'wasted' during energy transfers and the energy which is usefully transferred both end up being transferred to the surroundings which become warmer.

The energy becomes increasingly spread out and becomes increasingly more difficult to use for further useful energy transfers.

The more of the energy supplied to a device that is usefully transferred, the more efficient we say the device is.

Candidates should be able, when provided with appropriate information, to evaluate methods of reducing wasteful transfers of energy.

The efficiency of a device can be calculated using:

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

From Section18.4 FT and HT

Using different energy resources has different effects on the environment.

- Burning fossil fuels releases carbon dioxide, a gas which increases the greenhouse effect and causes increased global warming. For the same amount of energy released, coal produces more carbon dioxide than oil and oil produces more carbon dioxide than natural gas. There is no feasible way of preventing the very large amounts of carbon dioxide involved from entering the atmosphere. Burning most types of coal and oil also releases sulphur dioxide, a gas that helps to produce acid rain. The sulphur can be removed from these fuels before they are burnt or the sulphur dioxide removed from the waste gases before they enter the atmosphere, though this increases the cost of the electricity that is generated.

- Nuclear fuels do not produce gases which increase the greenhouse effect or which help to produce acid rain. When nuclear power stations are running normally, very little radiation or radioactive material escapes into the surroundings. If there is an accident, however, large amounts of very dangerous radioactive material may be released over a wide area. Nuclear power stations also produce waste, some of which stays dangerously radioactive for thousands of years and which has to be stored safely.
- Groups of large wind generators (wind farms) are usually sited on hills and/or coasts and are considered unsightly by some people. They can also be noisy for people living nearby. Wind farms cause visual pollution and noise pollution.
- Using energy from tides involves building barrages across river estuaries. This destroys the habitat of many living organisms, e.g. wading birds and the mud-living organisms on which they feed.
- Hydroelectricity schemes involve damming upland river valleys. This means flooding land that may have previously been used for farming or forestry.

Energy sources also differ in when they are available for generating electricity.

- Power stations which use fuels can produce electricity at any time (of the day or of the year); they are reliable energy sources. The time it takes to start them up varies considerably:

nuclear	longest time
coal	↑
oil	↓
natural gas	shortest time

- The amount of electricity produced by wind generators depends on the strength of the wind which varies considerably.
  The amount of electricity produced by tidal barrages depends on the state of the tide, which varies during each day, and the height of the tide, which varies both on a monthly and yearly cycle.
  The amount of electricity produced by solar cells depends on the intensity of light that falls on them.
  Each of these energy sources can generate electricity only at certain times; they are all to some extent unreliable.
- Hydroelectric schemes are generally very reliable. They can also be started up very quickly to meet sudden increases in the demand for electricity. They can also be operated in reverse using surplus electricity from other power stations to pump water from a lower reservoir to a higher one. This means that most of the energy from the surplus electricity is stored rather than being wasted.

Solar cells have a very high cost per Unit of electricity produced over their lifetime compared to all other sources of electricity except non-rechargeable batteries. Despite their cost, they are often the best energy source for producing electricity in remote locations (e.g. on satellites) or where only small amounts of electricity are needed (e.g. for watches or calculators).

Candidates should be able to compare and contrast the particular advantages and disadvantages of using different energy sources to generate electricity.

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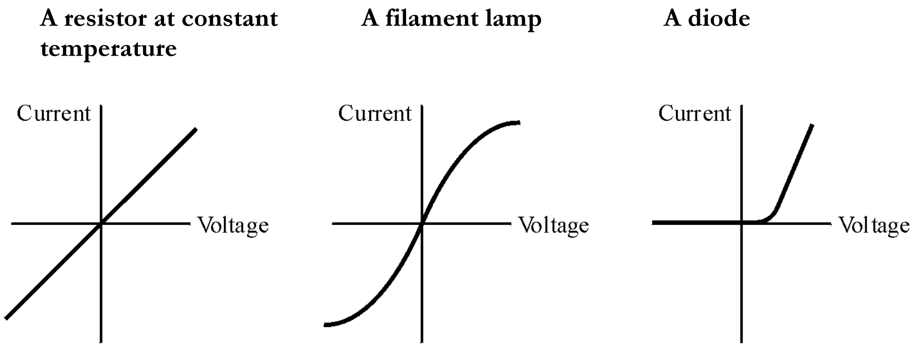
HT **Candidates should be able** to identify and evaluate the financial and environmental costs of using various energy resources to generate electricity and to evaluate these costs against the benefits to society, taking into consideration:

- the factors listed above;
- that though there are no fuel costs with renewables, the energy is dilute so that the capital cost of the generating equipment is high;
- that though the fuel costs for nuclear power stations are low, the cost of building the power stations, and of de-commissioning them at the end of their useful life, is high;
- the need to match supply and demand;
- any additional information, including quantitative information, with which they are provided.

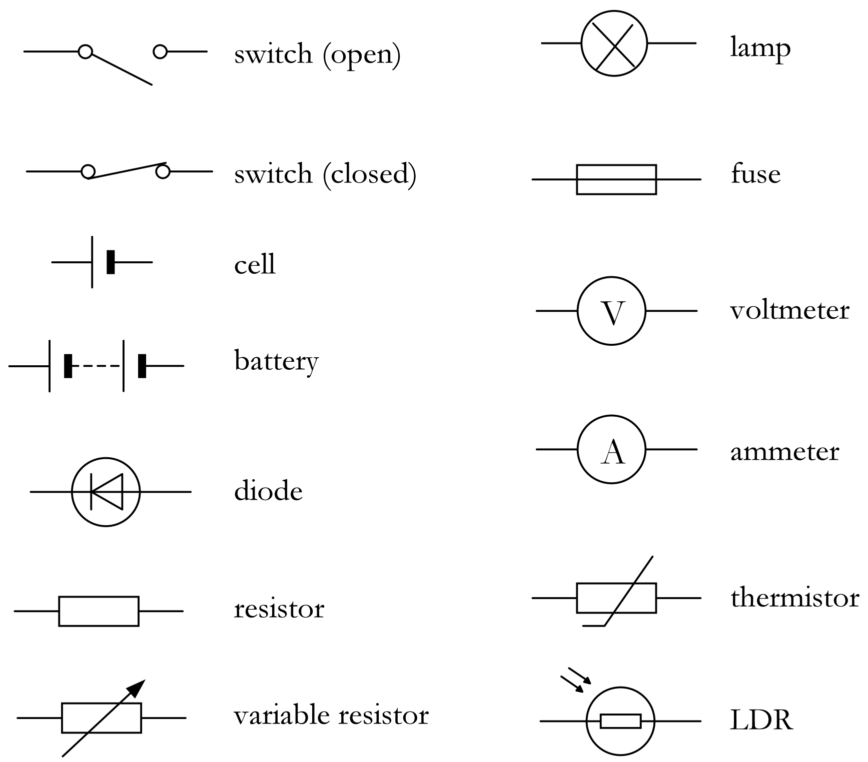
22.6 From Module 10 – Electricity

From Section 19.1 FT and HT

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



Candidates should be able to interpret circuit diagrams using standard symbols. The following standard symbols should be known.



Potential difference, current and resistance, are related as shown:

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

The current through a resistor (at a constant temperature) is proportional to the voltage across the resistor.

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 decreases as the light intensity increases.

The resistance of a thermistor decreases as the temperature increases *[i.e. knowledge of negative temperature coefficient thermistor only is required]*.

From Section 19.2 FT and HT

When a wire 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 direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed.

Candidates should be able - when provided with diagrams and/or other appropriate information – to explain how electromagnetic effects are used in simple d.c. motors and circuit breakers.

[Details of the split ring for reversing the current of a d.c. motor each half turn will not be required.]

From Section 19.6 FT and HT

If a magnet is moved into a coil of wire is part of a complete circuit a current is produced (induced) in the wire.

If the magnet is moved out of the coil, or the other pole of the magnet is moved into the coil, the direction of the induced current is reversed.

Electricity can be generated by rotating a coil of wire in a magnetic field or by rotating a magnet inside a coil of wire. This is how a generator works.

If a wire, or coil of wire 'cuts through' a magnetic field, or vice-versa, a voltage (potential difference) is produced between the ends of the wire. This induced voltage causes a current to flow if the wire is part of a complete circuit.

The size of the induced voltage increases when:

- the speed of the movement increases;
- the strength of the magnetic field is increased;
- the number of turns on the coil is increased;
- the area of the coil is greater.

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HT **Candidates should be able,** when provided with a diagram, to explain how an a.c. generator works, including the purposes of the slip rings and brushes.

Key Skills and Other Issues

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

23.1 Introduction

The Key Skills Qualification requires candidates to demonstrate levels of achievement in the Key Skills of *Application of Number, Communication* and *Information 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 website (www.qca.org.uk/keyskills).

The units for each Key Skill comprise three sections:

A What you need to know.

B What you must do.

C Guidance.

Candidates following a course of study based on this specification for Science can be offered opportunities to develop and generate evidence of attainment in aspects of the Key Skills of *Application of Number, Communication, Information Technology, Improving own Learning and Performance, Working with Others* and *Problem-Solving*. 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 for Part B of the units, are signposted below.

There are numerous Key Skills opportunities in Science and the following tables reflect this. The nature of the subject is such that any aspect of a Key Skill can be covered in the context of any section of the specification if so desired.

23.2 Key Skills Opportunities in Science

Application of Number Level 1

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Sc1 Coursework	**Sc2 Modules**	**Sc3 Modules**	**Sc4 Modules**
N1.1 Interpret information from different sources	✓	✓	✓	✓
N1.2 Carry out calculations	✓	✓	✓	✓
N1.3 Interpret results and present findings	✓	✓	✓	✓

Application of Number Level 2

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Sc1 Coursework	**Sc2 Modules**	**Sc3 Modules**	**Sc4 Modules**
N2.1 Interpret information from different sources	✓	✓	✓	✓
N2.2 Carry out calculations	✓	✓	✓	✓
N2.3 Interpret results and present findings	✓	✓	✓	✓

Communication Level 1

What you must do …	**Signposting of Opportunities for Generating Evidence in Subject Content**			
	Sc1 Coursework	**Sc2 Modules**	**Sc3 Modules**	**Sc4 Modules**
C1.1 Take part in discussions	✓	✓	✓	✓
C1.2 Read and obtain information	✓	✓	✓	✓
C1.3 Write different types of documents	✓	✓	✓	✓

Communication Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
C2.1a Contribute to discussions	✓	✓	✓	✓
C2.1b Give a short talk	✓	✓	✓	✓
C2.2 Read and summarise information	✓	✓	✓	✓
C2.3 Write different types of documents	✓	✓	✓	✓

Information Technology Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
IT1.1 Find, explore and develop information	✓	✓	✓	✓
IT1.2 Present information, including text, numbers and images	✓	✓	✓	✓

Information Technology Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
IT2.1 Search for and select information	✓	✓	✓	✓
IT2.2 Explore and develop information and derive new information	✓	✓	✓	✓
IT2.3 Present combined information, including text, numbers and images	✓	✓	✓	✓

Working with Others Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
WO1.1 Confirm what needs to be done and who is to do it	✓	✓	✓	✓
WO1.2 Work towards agreed objectives	✓	✓	✓	✓
WO1.3 Identify progress and suggest improvements	✓	✓	✓	✓

Working with Others Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
WO2.1 Plan work and confirm working arrangements	✓	✓	✓	✓
WO2.2 Work co-operatively towards achieving identified objectives	✓	✓	✓	✓
WO2.3 Exchange information on progress and agree ways of improving work with others	✓	✓	✓	✓

Improving own Learning and Performance Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
LP1.1 Confirm short-term targets and plan how these will be met	✓	✓	✓	✓
LP1.2 Follow plan to meet targets and improve performance	✓	✓	✓	✓
LP1.3 Review progress and achievements	✓	✓	✓	✓

Improving own Learning and Performance Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
LP2.1 Help set short-term targets and plan how these will be met	✓	✓	✓	✓
LP2.2 Use plan and support from others, to meet targets	✓	✓	✓	✓
LP2.3 Review progress and identify evidence of achievements	✓	✓	✓	✓

Problem Solving Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
PS1.1 Confirm understanding of given problems	✓	✓	✓	✓
PS1.2 Plan and try out ways of solving problems	✓	✓	✓	✓
PS1.3 Check if problems have been solved and describe the results	✓	✓	✓	✓

Problem Solving Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Sc1 Coursework	Sc2 Modules	Sc3 Modules	Sc4 Modules
PS2.1 Identify problems and come up with ways of solving them	✓	✓	✓	✓
PS2.2 Plan and try out options	✓	✓	✓	✓
PS2.3 Apply given methods to check if problems have been solved and describe the results	✓	✓	✓	✓

23.3 Further Guidance

More specific guidance and examples of tasks that can provide evidence of single Key Skills, or composite tasks that can provide evidence of more than one Key Skill are given in the AQA specification support material, particularly the Teachers' Guide.

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

24.1 Spiritual, Moral, Ethical, Social, Cultural and Other 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 when life starts and where life comes from, and experiencing a sense of awe and wonder at the natural world. Sections 10.1, 11.1, 13.3, 15.3, and 20.5 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 10.5, 11.7, 12.4, 13.2, 13.5, 15.2, 16.2, 18.4, 21.2 and 21.3 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 11.7, 12.2, 12.4, 13.2, 15.2, 16.4, 18.1, 18.4 and 27.2 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 13.3, 15.4, 17.3, 20.5 and 21.4 are relevant.

24.2 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.

A study of this specification supports the European dimension in education and contributes to health education and environmental education. There are opportunities to relate the study of topics to wider European or global contexts. In particular, a broader European context could be used in relation to modules 03, 04, 06, 09, 11 and 12.

24.3 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 modules 03, 04, 06, 09, and 12.

24.4 Citizenship

This specification allows treatment of aspects of citizenship through the contribution made to candidates' moral, social and cultural development (see 24.1) and through the opportunities to promote an understanding of, and responsible attitudes towards, environmental issues (see 24.3). In this way, the subject contributes to the development of candidates' social and moral responsibility.

24.5 Avoidance of Bias

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

24.6 Health and Safety

Teaching about health and safety in science forms part of the teaching requirements for breadth of study, as described in section 9.2 of this specification. However, more general teaching requirements about health and safety are applicable to science as well as to other subjects.

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

a. about hazards, risks and risk control;

b. to recognise hazards, assess consequent risks and take steps to control the risks to themselves and others;

c. to use information to assess the immediate and cumulative risks;

d. to manage their environment to ensure the health and safety of themselves and others;

e. 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.

24.7 ICT

Through the teaching of this specification candidates should be given opportunities to apply and develop their ICT capability. Although the scheme of assessment in this specification does not assess directly candidates' effective use of ICT, teaching of the specification can encourage use of ICT. In addition, there are opportunities to generate evidence of attainment in the key skill of information technology.

Candidates should be given opportunities to support their work by being taught to:

a. find things out from a variety of sources, selecting and synthesising the information to meet their needs and developing an ability to question its accuracy, bias and plausibility;

b. develop their ideas using ICT tools to amend and refine their work and enhance its quality and accuracy;

c. exchange and share information, both directly and through electronic media;

d. review, modify and evaluate their work, reflecting critically on its quality, as it progresses.

Examples of opportunities in the subject content for the use of ICT are as follows (see also section 26.2).

Candidates could:

- use multimedia sources to see things that cannot readily be observed first hand (10.3, 11.5);
- use dataloggers in investigations (11.2, 16.1, 19.1);
- use the internet to find information about commercial applications, current developments, products, processes or uses (13.2, 14.1, 14.2, 15.2, 15.4, 16.2, 16.3, 18.4);
- use spreadsheets for modelling or data analysis (12.1, 20.2);
- use software simulations (16.3, 17.1, 20.2, 21.3);
- use databases to explore patterns (14.1, 17.2);
- use CD-ROM software to explore models (20.4, 20.5, 21.1).

24.8 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 Component

25 Nature of the Centre-Assessed Component

Coursework is used to assess the investigative skills section of Sc1 Scientific Enquiry which corresponds to assessment objective AO1. It is allocated 20% of the total marks for the examination.

The coursework scheme is common throughout the framework, irrespective of the specification for which candidates are entered. If candidates from a centre are entered for different specifications within the framework they will be treated as a single overall group in each subject area (i.e. Science/Biology/Chemistry/Physics). Assessments and supporting evidence will be needed separately for each, and moderation will be undertaken using a sample in each.

The skill areas to be assessed in coursework correspond to the four areas of the programme of study for investigative skills at key stage 4. They are as follows:

P. Planning
O. Obtaining evidence
A. Analysing and considering evidence
E. Evaluating evidence

It is a requirement of the programme of study and the GCSE criteria for Science that contexts derived from the three main subject content areas (i.e. Life Processes and Living Things, Materials and their Properties and Physical Processes) are used to teach candidates about investigative skills, and that the whole process of investigating an idea is carried out by candidates themselves on some occasions.

The links between the coursework skills and the knowledge, skills and understanding described in the subject content are therefore fundamental in designing activities which make reasonable demands on candidates. The range of contexts is important as candidates' motivation, interest and attainment inevitably vary from one area of the subject to another. **It is also important to ensure that the requirements for the award of marks can be met** (please refer to section 26.1).

26 Guidance on Setting the Centre-Assessed Component

26.1 Activities and Skill Areas

The internal assessment of candidates' performance in the four skill areas is to be made using normal coursework activities and should be part of the scheme of work. It is a continuous process and not separate or additional. It is important therefore that the scheme of work includes activities designed to develop the skill areas, and that assessment should arise from these activities.

It is important that teachers consider carefully the types of activities which will provide valid evidence of achievement. The activities in which candidates are involved should be designed to make reasonable demands and to enable positive achievement to be demonstrated in relation to the mark descriptions.

The types of activities used must meet the requirements of the programme of study for investigative skills. For convenience, these requirements are listed with the mark descriptions which follow in section 17. The requirements associated with the four skill areas are not a compulsory list to be included in every activity; rather, they describe the abilities which need to be taught and developed through the whole scheme of work.

The scheme of internal assessment is designed to encourage a wide variety of activities. These include those based on collection of first hand evidence and those which depend on secondary evidence. The term "evidence" has been used consistently throughout the assessment scheme to mean observations, measurements or other data.

Teachers will often wish to assess more than one skill area in an activity, particularly in a whole investigation. The mark descriptions allow the four skill areas to be assessed individually, or for them to be assessed together. It is also important to realise that not all candidates need to be assessed on the same activity.

The teacher is free to determine which skill areas are to be assessed in any activity and the stages in the course at which assessments are made. It is important that assessment relates specifically to the skill areas rather than to overall performance on a complete activity. Teachers will find it helpful to refer to the mark descriptions when designing activities.

Where candidates work as a group, it must be possible to identify the individual contribution of each candidate, so that the requirements in the specification are met.

The AQA will provide a range of guidance and exemplar material to assist teachers in the design of activities and their assessment. This material can be retained for reference purposes throughout the course, and will explain how the mark descriptions are to be applied and give examples of activities. It will also be discussed at teachers' standardising meetings.

An increasing variety of resources is available commercially to teachers which can be used as part of the assessment in this specification. This is encouraging, but care must be taken to ensure that the use of such resources satisfies the scheme's requirements.

26.2 Use of ICT

Through the teaching of investigative skills candidates should be given opportunities to apply and develop their ICT capability. In particular, candidates could:

- use data handling software to analyse data from fieldwork;
- use data handling software to create, analyse and evaluate charts and graphs;
- use dataloggers in investigations;
- use spreadsheets for data analysis;
- use the internet or CD-ROM software as sources of secondary evidence.

26.3 Coursework Advisers

Coursework Advisers will be available to assist centres with any matters relating to coursework. Details will be provided when AQA knows which centres are following the specification.

27 Assessment Criteria

27.1 Introduction

Presentation of Mark Descriptions

Mark descriptions comprising a number of **statements** are provided in each skill area. Activities chosen for assessment should, wherever possible, provide opportunities for all the statements in a mark description to be addressed. It should be noted that some of the statements in the mark descriptions contain a phrase such as "where appropriate" and therefore may not apply to a particular activity.

Descriptions are provided for 2, 4, 6 and 8 marks in skill areas P, O and A and 2, 4 and 6 marks in skill area E. The performance needed to gain 6 marks in skill area E is commensurate with that for 8 marks in the other skill areas.

Whenever assessments are made, the mark descriptions should be used to judge which mark **best fits** the candidate's performance. The statements should not be taken as discrete and literal hurdles, all of which must be fulfilled for a mark to be awarded.

The mark descriptions within a skill area are designed to be hierarchical. This means that, in general, a description at a particular mark subsumes those at lower marks. It is assumed that activities which access higher marks will involve a more sophisticated approach and/or a more complex treatment. Adjacent descriptions should be considered when making judgements and use made of the **intermediate marks** (i.e. 3, 5 and 7) where performance exceeds one description and only partially satisfies the next.

A candidate who fails to meet the requirements for 2 marks, but who has made a creditworthy attempt in a skill area should be given 1 mark for that skill. Zero marks should **only be** awarded for a skill area in the unlikely event of a candidate failing to demonstrate any achievement in that skill.

The **professional judgement** of the teacher in making these judgements is important.

Number of marks

Two marks are required for **each** skill area. Thus **eight** marks are required in total to give a maximum mark of 60.
These marks should be drawn from **not more than four** pieces of work. At least **one** mark must be from a practically based whole investigation.
At least two of the attainment targets must be represented.

In the mark descriptions, the use of terms such as "plan", "communicate", "describe", "record", "identify", "explain", "comment" and "consider" ensure that the quality of written communication will form part of the assessment.

27.2 Mark Descriptions

The mark descriptions for each skill area are on the pages which follow.

Skill Area P: Planning

1 Programme of Study Requirements

Candidates should be taught to:

a. use scientific knowledge and understanding to turn ideas into a form that can be investigated, and to plan an appropriate strategy;

b. decide whether to use evidence from first-hand experience or secondary sources;

c. carry out preliminary work and make predictions, where appropriate;

d. consider key factors that need to be taken into account when collecting evidence, and how evidence can be collected in contexts in which the variables cannot readily be controlled;

e. decide the extent and range of data to be collected, and the techniques, equipment and materials to use.

2 Mark Descriptions

The mark descriptions are designed to be hierarchical.
All work should be assessed in the context of the specification.

Candidates:

Increasing demand of activity ↓

2 marks	P.2a	outline a simple procedure
4 marks	P.4a	plan to collect evidence which will be valid
	P.4b	plan the use of suitable equipment or sources of evidence
6 marks	P.6a	use scientific knowledge and understanding to plan and communicate a procedure, to identify key factors to vary, control or take into account, and to make a prediction where appropriate
	P.6b	decide a suitable extent and range of evidence to be collected
8 marks	P.8a	use detailed scientific knowledge and understanding to plan and communicate an appropriate strategy, taking into account the need to produce precise and reliable evidence, and to justify a prediction, when one has been made
	P.8b	use relevant information from preliminary work, where appropriate, to inform the plan

Skill Area O: Obtaining evidence

1 Programme of Study Requirements

Candidates should be taught to:

f. use a wide range of equipment and materials appropriately, and manage their working environment to ensure the safety of themselves and others;

g. make observations and measurements, including the use of ICT for datalogging to a degree of precision appropriate to the context;

h. make sufficient observations and measurements to reduce error and obtain reliable evidence;

i. judge the level of uncertainty in observations and measurements;

j. represent and communicate qualitative and quantitative data using diagrams, tables, charts, graphs and ICT.

2 Mark Descriptions

The mark descriptions are designed to be hierarchical.
All work should be assessed in the context of the specification.

Candidates:

Increasing demand of activity ↓

2 marks	O.2a	collect some evidence using a simple and safe procedure
4 marks	O.4a	collect appropriate evidence which is adequate for the activity
	O.4b	record the evidence
6 marks	O.6a	collect sufficient systematic and accurate evidence and repeat or check when appropriate
	O.6b	record clearly and accurately the evidence collected
8 marks	O.8a	use a procedure with precision and skill to obtain and record an appropriate range of reliable evidence

Skill Area A: Analysing and considering evidence

1 Programme of Study Requirements

Candidates should be taught to:

k. use diagrams, tables, charts and graphs, and identify and explain patterns or relationships in data;

l. present the results of calculations to an appropriate degree of accuracy;

m. use observations, measurements or other data to draw conclusions;

n. explain to what extent these conclusions support any predictions made, and enable further predictions to be made;

o. use scientific knowledge and understanding to explain and interpret observations, measurements or other data, and conclusions.

2 Mark Descriptions

The mark descriptions are designed to be hierarchical.
All work should be assessed in the context of the specification.

Candidates:

Increasing demand of activity ↓

2 marks	A.2a	state simply what is shown by the evidence
4 marks	A.4a	use simple diagrams, charts or graphs as a basis for explaining the evidence
	A.4b	identify trends and patterns in the evidence
6 marks	A.6a	construct and use suitable diagrams, charts, graphs (with lines of best fit, where appropriate), or use numerical methods, to process evidence for a conclusion
	A.6b	draw a conclusion consistent with the evidence and explain it using scientific knowledge and understanding
8 marks	A.8a	use detailed scientific knowledge and understanding to explain a valid conclusion drawn from processed evidence
	A.8b	explain the extent to which the conclusion supports the prediction if one has been made

Skill Area E: Evaluating

1 Programme of Study Requirements

Candidates should be taught to:

p. consider anomalous data giving reasons for rejecting or accepting them, and consider the reliability of data in terms of uncertainty of measurements and observations;

q. consider whether the evidence collected is sufficient to support any conclusions or interpretations made;

r. suggest improvements to the methods used;

s. suggest further investigations.

2 Mark Descriptions

The mark descriptions are designed to be hierarchical.
All work should be assessed in the context of the specification.

Candidates:

Increasing demand of activity ↓

2 marks	E.2a	make a relevant comment about the procedure used or the evidence obtained
4 marks	E.4a	comment on the quality of the evidence, identifying any anomalies
	E.4b	comment on the suitability of the procedure and, where appropriate, suggest changes to improve it
6 marks	E.6a	consider critically the reliability of the evidence and whether it is sufficient to support the conclusion, accounting for any anomalies
	E.6b	describe, in detail, further work to provide additional relevant evidence

27.3 Evidence to Support the Award of Marks

Teachers should keep records of their assessments during the course, in a form which facilitates the complete and accurate submission of the final assessments at the end of the course.

When the assessments are complete, the marks awarded under each of the assessment criteria must be entered on the Candidate Record Form, with supporting information given in the spaces provided. A specimen Candidate Record Form appears in Appendix B; the exact design may be modified before the operational version is issued and the correct year's Candidate Record Forms should always be used.

28 Supervision and Authentication

28.1 Supervision of Candidates' Work

Candidates' work for assessment must be undertaken under conditions which allow the teacher to supervise the work and enable the work to be authenticated. As much coursework as possible must be conducted in the laboratory/field under the direct supervision of teachers. If it is necessary for some assessed work to be done outside the centre, sufficient work must take place under direct supervision to allow the teacher to authenticate each candidate's whole work with confidence.

28.2 Guidance by the Teacher

The work assessed must be solely that of the candidate concerned. Any assistance given to an individual candidate which is beyond that given to the group as a whole must be recorded on the Candidate Record Form.

It is acceptable for parts of a candidate's coursework to be taken from other sources where these are relevant and appropriate (in some cases this features in the mark descriptions) as long as all such material is fully acknowledged either on the Candidate Record Form or in the supporting evidence. Where phrases, sentences or longer passages are quoted directly from a source, it is important that these are clearly identified.

28.3 Unfair Practice

At the start of the course, the supervising teacher is responsible for informing candidates of the AQA Regulations concerning malpractice. Candidates must not take part in any unfair practice in the preparation of coursework to be submitted for assessment, and must understand that to present material copied directly from books or other sources without acknowledgement will be regarded as deliberate deception. Centres must report suspected malpractice to AQA. The penalties for malpractice are set out in the AQA Regulations.

28.4 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.

29 Standardisation

29.1 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 nature of coursework tasks set by a centre has been inappropriate;
- where a significant adjustment has been made to a centre's marks in the previous year's examination.

After the first year, attendance is at the discretion of centres. At these meetings support will be provided for centres in the development of appropriate coursework tasks and assessment procedures.

29.2 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 a component, 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.

30 Administrative Procedures

30.1 Recording Assessments

The candidates' work must be marked according to the assessment criteria set out in section 27. The marks and supporting information must be recorded in accordance with the instructions in section 27. The completed Candidate Record Form for each candidate must be attached to the work and made available to AQA on request.

30.2 Submitting Marks and Sample Work for Moderation

The total component mark 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.

30.3 Problems with 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 internal assessment. Possible courses of action depend on the stage at which the move takes place. If the move occurs early in the course the new centre should take responsibility for assessment. If it occurs late in the course it may be possible to accept the assessments made at the previous centre. Centres should contact AQA at the earliest possible stage for advice about appropriate arrangements in individual cases.

30.4 Retaining Evidence and Re–Using Marks

The centre must retain the work of all candidates, with Candidate Record Form attached, under secure conditions, from the time it is assessed, to allow for the possibility of an enquiry upon results. The work may be returned to candidates after the issue of results provided that no enquiry upon result is to be made which will include re-moderation of the coursework component. If an enquiry upon result is to be made, the work must remain under secure conditions until requested by AQA.

Candidates repeating the examination may carry forward their moderated mark for the coursework component once only and within a twelve month period.

31 Moderation

31.1 Moderation Procedures

Moderation of the coursework 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 coursework 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.

31.2 Post-Moderation Procedures

On publication of the GCSE results, the centre is supplied with details of the final marks for the coursework component.

The candidates' work is returned to the centre after the examination with a report form from the moderator giving feedback to the centre on the appropriateness of the tasks set, 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

32 Grading, Shelf-Life and Re-Sits

32.1 Qualification Titles

The qualification based on this specification has the following title: AQA GCSE in Science: Double Award.

32.2 Grading System

The qualification will be graded on an 8 point grade Scale A*, A, B, C, D, E, F, 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.

Candidates entered for Science: Double Award will receive double awards certificated as pairs of identical grades.

Candidates must be entered for either the Foundation Tier or 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 where 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.

32.3 Shelf-Life of Module Results

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

32.4 Re-Sits

Candidates may resit each module test once only before GCSE certification. Individual written papers may not be retaken, but candidates may retake the whole qualification more than once.

32.5 Minimum Requirements

Candidates will be graded on the basis of work submitted for assessment.

32.6 Carrying Forward of Centre-Assessed Marks

Candidates repeating the examination may carry forward their moderated coursework marks only once and within a twelve month period.

32.7 Carrying Forward of Module Test marks

Candidates may carry forward their **total** mark for the module tests component. Results from **individual** module tests cannot be carried forward.

32.8 Awarding and Reporting

This specification complies with the grading, awarding and certification requirements of the current GCSE, GCE, VCE and GNVQ Code of Practice, and will be revised in the light of any subsequent changes for future years.

Appendices

A Grade Descriptions

The following grade descriptors 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 descriptors 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 (as in section 6) overall. Shortcomings in some aspects of the examination may be balanced by better performances in others.

Grade A

Candidates recall a wide range of knowledge from all areas of the specification.

Candidates use detailed scientific knowledge and understanding in a range of applications relating to scientific systems or phenomena. For example, they explain how temperature or water content is regulated in humans, routinely use a range of balanced chemical equations, the particle model to explain variations in reaction rates, use a wide range of relationships between physical quantities to carry out calculations effectively. Candidates draw together and communicate knowledge from more than one area, use routinely scientific or mathematical conventions in support of arguments, use a wide range of scientific and technical vocabulary throughout their work.

Candidates explain how scientific theories can be changed by new evidence and identify some areas of uncertainty in science.

Candidates use scientific knowledge and understanding to select an appropriate strategy for a task, identifying the key factors to be considered. They make systematic observations in qualitative work and decide which observations are relevant to the task in hand. When making measurements they decide the level of precision needed and use a range of apparatus with precision and skill to make appropriately precise measurements. They select a method of presenting data appropriate to the task; they use information from a range of sources where it is appropriate to do so. They identify and explain anomalous observations and measurements and the salient features of graphs.

Candidates use scientific knowledge and understanding to identify and explain patterns and draw conclusions from the evidence by combining data of more than one kind or from more than one source. They identify shortcomings in the evidence, use scientific knowledge and understanding to draw conclusions from their evidence and suggest improvements to the methods that would enable them to collect more reliable evidence.

Grade C

Candidates recall a range of scientific information from all areas of the specification. For example, they describe how some organ systems in living things carry out life processes, recall simple chemical symbols and formulae, recall correct units for quantities.

Candidates use and apply scientific knowledge and understanding in some general contexts, for example they describe how a cell is adapted to its functions, use simple balanced equations, use quantitative relationships between physical quantities to perform calculations. Candidates describe links between related phenomena in different contexts, use diagrams, charts and graphs to support arguments, use appropriate scientific and technical vocabulary in a range of contexts.

Candidates describe how evidence is used to test predictions made from scientific theories, and how different people may have different views on some aspects of science.

Candidates use scientific knowledge and understanding to identify an approach to a question, for example, identifying key factors to vary and control. Candidates use a range of apparatus to make careful and precise measurements and systematic observations and recognise when it is necessary to repeat measurements and observations. They present data systematically, in graphs where appropriate, and use lines of best fit. Candidates identify and explain patterns within data and draw conclusions consistent with the evidence. They explain these conclusions using scientific knowledge and understanding and evaluate how strongly their evidence supports the conclusions.

Grade F

Candidates recall a limited range of information. For example, they state the main functions of organs of the human body, describe some defence mechanisms of the body, state some uses of materials obtained from oil, suggest ways in which insulation is used in domestic contexts.

Candidates use and apply knowledge and understanding in some specific everyday contexts. For example, they describe how a reduction in the population of one organism in a habitat can affect another organism, suggest a way of speeding up a particular chemical reaction; explain that fuels are energy resources and that energy is sometimes 'wasted'. Candidates make some use of scientific and technical vocabulary and make simple generalisations from information.

Candidates relate scientific explanations to some experimental evidence and describe simple examples of benefits and drawbacks of scientific development.

Candidates devise fair tests in contexts which involve only a few factors. They use simple apparatus to make measurements appropriate to the task and record observations and measurements in tables and graphs. Candidates obtain information from simple tables, charts and graphs and identify simple patterns in information and observations. They offer explanations consistent with the evidence obtained.

B

Record Forms

Centre-assessed work

Centre Declaration Sheet

Series / Year

Specification Title: .... **Unit Code:** ....

Centre Name: .... **Centre No:**

Authentication

This is to certify that marks have been awarded in accordance with the requirements of the specification and that every reasonable step has been taken to ensure that the work presented is that of the candidates named. Any assistance given to candidates beyond that given to the class as a whole and beyond that described in the specification has been recorded on the Candidate Record Form(s) and has been taken into account. The marks given reflect accurately the unaided achievement of the candidates.

Signature(s) of teacher(s) responsible for assessment

Teacher 1 .... Teacher 2 ....

Teacher 3 .... Teacher 4 ....

Teacher 5 .... Teacher 6 ....

(Continue overleaf if necessary)

Internal Standardisation of Marking

Each centre must standardise the assessments for this unit across different teachers and teaching groups to ensure that all candidates in the centre have been judged against the same standards. If two or more teachers are involved in marking a unit, one of them must be designated as responsible for standardising the marking of all teachers at the centre who mark the unit.

The following declaration must be signed by the teacher responsible for ensuring standardisation. If all the work has been marked by the same person, that person should sign below.

I confirm that:

(a) *I have marked the work of all candidates for this component;
(b) *the procedure described in the specification has been followed at this centre to ensure that the marking is of the same standard for all candidates.

Signed: .... **Date:** ....

Signature of Head of Centre .... **Date:** ....

This form should be completed and sent to the moderator with the sample of centre-assessed work.

AQA
ASSESSMENT and QUALIFICATIONS ALLIANCE

Centre-assessed work

Candidate Record Form

Series / Year

Science: Double Award A and B

Centre Name: .... **Centre No:** | | | | | |

Candidate Name: .... **Candidate No:** | | | | |

This side is to be completed by the candidate

Sources of advice and information

1. Have you received any help or information from anyone other than your subject teacher(s) in the production of this work? .... (Write YES or NO)
2. If you have answered YES, give details below. Continue on a separate sheet if necessary.

   ....

3. If you have used **any** books, information leaflets or other materials (e.g. videos, software packages or information from the Internet) to help you complete this work, you must list these below, unless they are clearly acknowledged in the work itself. To present material copied from books or other sources without acknowledgement will be regarded as deliberate deception.

   ....

   ....

NOTICE TO CANDIDATE

The work you submit for assessment must be your own.

If you copy from someone else or allow another candidate to copy from you, or if you cheat in any other way, you may be disqualified from at least the subject concerned.

Declaration by Candidate

I have read and understood the **Notice to Candidate** (above). I have produced the attached work without any help apart from that which I have stated on this sheet.

Candidate's Signature: .... **Date:** ....

This form should be completed and attached to the candidate's work and retained at the Centre or sent to the moderator as required.

This side is to be completed by the teacher

Marks must be awarded in accordance with the instructions and criteria in Section 27 of the specification.

Supporting information to show how the marks have been awarded should be given in the form of annotations on the candidates' work and in the spaces below.

Please note:

- two marks are required for **each** skill area (thus eight marks to give total out of 60);
- marks to be drawn from **not more than four** pieces of work;
- at least **one** mark from a practically based whole investigation;
- at least **two** of the attainment targets must be represented.

Activity	Sc (2/3/4)	Inv? (✓ or X)	Skill area marks			
			P	O	A	E
	Totals					
	Overall Total (out of 60)					

Details of additional assistance given (if any) Record here details of any assistance given to this candidate which is beyond that given to the class as a whole and beyond that described in the specification. Continue on a separate sheet if necessary.

Teacher's Signature: .... Date: ....

C

Overlaps with other Qualifications

National Curriculum Science

Within the AQA GCSE Science specification framework, there is considerable overlap between Science: Double/Single Award and Biology/Biology(Human)/Chemistry/Physics. This arises from the way in which the specifications are designed to cover the programme of study for double and single science. The prohibited combinations 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 between the following:

GCSE Subjects

- content associated with Sc2 Life Processes and Living Things, and Human Physiology and Health;
- content from all parts of the specification with Environmental Science;
- content associated with Sc4 Physical Processes and Electronics;
- content from all parts of the specification with Applied Science (Double Award);

GNVQ

- content from all parts of the specification with GNVQ Science at Foundation and Intermediate levels.

D Data Sheet

1 Reactivity Series of Metals

Metal	
Potassium	most reactive ↑
Sodium	
Calcium	
Magnesium	
Aluminium	
Carbon	
Zinc	
Iron	
Tin	
Lead	
Hydrogen	
Copper	
Silver	
Gold	
Platinum	least reactive ↓

(elements in italics, though non-metals, have been included for comparison).

2 Formulae of Some Common Ions

Positive ions

Name	Formula
Hydrogen	H^+
Sodium	Na^+
Silver	Ag^+
Potassium	K^+
Lithium	Li^+
Ammonium	NH_4^+
Barium	Ba^{2+}
Calcium	Ca^{2+}
Copper(II)	Cu^{2+}
Magnesium	Mg^{2+}
Zinc	Zn^{2+}
Lead	Pb^{2+}
Iron(II)	Fe^{2+}
Iron(III)	Fe^{3+}
Aluminium	Al^{3+}

Negative ions

Name	Formula
Chloride	Cl^-
Bromide	Br^-
Fluoride	F^-
Iodide	I^-
Hydroxide	OH^-
Nitrate	NO_3^-
Oxide	O^{2-}
Sulphide	S^{2-}
Sulphate	SO_4^{2-}
Carbonate	CO_3^{2-}

3 The Periodic Table of Elements

KEY

Relative atomic mass A_r

Atomic number (Proton number) Z

1 **H** Hydrogen 1

1	2											3	4	5	6	7	0
																	4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorous 15	32 **S** Sulphur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	64 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	99 **Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La** Lanthanum 57	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	**Po** Polonium 84	**At** Astatine 85	**Rn** Radon 86
Fr Francium 87	226 **Ra** Radium 88	227 **Ac** Actinium 89															

Elements 58-71 and 90-103 have been omitted.

E

Formulae List

This list shows the formulae for quantitative relationships in the Physical Processes section of the specification which candidates will be expected to recall (N.B. for convenience, formulae are also given here in symbolic form even though this form is not required by the specification).

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

power = potential difference × current
(watt, W) (volt, V) (ampere, A) $P = VI$

acceleration (metre/second squared, m/s²) = $\frac{\text{change in velocity (metre/second, m/s)}}{\text{time taken for change (seconds, s)}}$ $a = \frac{v - u}{t}$

wave speed = frequency × wavelength
(metre/second, m/s) (hertz, Hz) (metre, m) $v = f\lambda$

work done = energy transferred

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

weight = mass × gravitational field strength
(newton, N) (kilogram, kg) (newton/kilogram, N/kg) $w = mg$

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HT

change in gravitational potential energy (joule, J) = weight (newton, N) × change in vertical height (metre, m) $gpe = mg\Delta h$

kinetic energy (joule, J) = $\frac{1}{2}$ × mass (kilogram, kg) × speed² [(metre/second)², (m/s)²] $ke = \frac{1}{2}mv^2$

energy transferred (joule, J) = potential difference (volt, V) × charge (coulomb, C) $E = VQ$

charge (coulomb, C) = current (ampere, A) × time (second, s) $Q = It$

force (newton, N) = mass (kilogram, kg) × acceleration (metre/second square, m/s²) $F = ma$

$$\frac{\text{voltage across primary (volt, V)}}{\text{voltage across secondary (volt, V)}} = \frac{\text{number of turns on primary}}{\text{number of turns on secondary}} \qquad \frac{V_p}{V_s} = \frac{N_p}{N_s}$$

F Additional Material for Wales and Northern Ireland

1 Additional Material for Wales

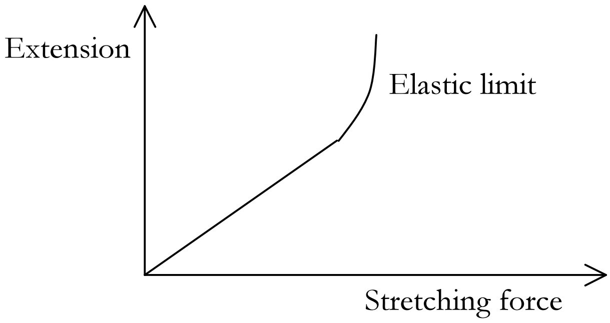
There is some additional material in the programme of study in Wales which does not feature in Key Stage 4 in England. Teachers in Wales are advised to check the following sections of the programme of study in Wales and ensure that teaching fully meets the statutory requirements in their country.

- Nutrition (food tests)
- Health (HIV and hepatitis)
- Adaptation and competition (conservation, biodiversity in Wales)
- Force and pressure on materials (see details below)
- Force and rotation (see details below)

Detailed content for the last two of these sections was previously included in GCSE syllabuses. For the convenience of teachers reviewing schemes of work, this content follows here.

Force and Pressure on Materials

The greater the stretching force which is applied to a metal wire or a spring the greater the extension (stretch) it produces. Provided the elastic limit is not exceeded they return to their original shape and size when the force is removed i.e. they are elastic. If the elastic limit is exceeded they remain permanently deformed.



The greater the force which acts on a certain area, the greater the pressure. The greater the area over which a force acts, the smaller the pressure.

Pressure, force and area are related as shown:

$$\text{pressure (pascal, Pa)} = \frac{\text{force (newton, N)}}{\text{area (metre squared, m}^2\text{)}}$$

A pressure of 1Pa is exerted by a force of 1N acting at right angles to an area of $1m^2$.

Liquids can be used to send forces to where they are needed. A force is applied to the liquid using a master piston. This puts the liquid under pressure. The liquid then presses on a slave piston which exerts a force where it is needed.

At any point in a liquid or gas(fluid), the same pressure acts equally in all directions. The pressure in a fluid increases with depth.

In hydraulic systems, liquids are used to send forces where they are wanted and to make them act in the required direction. Hydraulic systems can be used as force multipliers.
Candidates should be able:

- to describe one everyday application of hydraulic systems;
- to explain how hydraulic systems can be used as force multipliers;
- to calculate how many times a given hydraulic system multiplies forces.

When the pressure on a gas increases and its temperature stays the same, its volume decreases. For a mixed mass of gas at constant temperature the volume is inversely proportional to the pressure.

The pressure and volume of a fixed mass of gas at constant temperature are related as shown:

initial pressure x initial volume = final pressure x final volume

Force and Rotation

The weight of a pivoted object can have a turning effect. If the pivot passes through its centre of mass, the object does not turn, clockwise or anticlockwise.

If suspended, an object will come to rest with its centre of mass directly below the point of suspension.

The centre of mass of a symmetrical object is along the axis of symmetry.

Candidates should be able to describe how to find the centre of mass of a thin sheet of material.

If a force is applied at a distance from the pivot it has a turning effect (moment).

A force has a greater turning effect (moment):

- the greater the size of the force;
- the greater the perpendicular distance between the line of action of the force and the pivot.

How big a turning effect a force has (its moment) can be calculated as shown:

moment (newton metre, Nm) = force (newton, N) × perpendicular distance between line of action and pivot (metre, m)

If an object is not turning, the total moments of forces tending to turn it in the clockwise direction must be exactly balanced by the total moments of forces tending to turn it in the anticlockwise direction.

Candidates should be able to use the law of moments to calculate the size of a force or its distance from the pivot, when an object is balanced under the turning effects of:

- two forces (for an object with a pivot through its centre of mass);
- the weight of the object and one other force (for an object with a pivot not passing through its centre of mass).

If the line of action of the weight of an object lies outside the base of the object, a turning effect will result and the object will tend to fall over.

Candidates should be able to apply this idea to the stability of objects.

2 Additional Material for Northern Ireland

There is some additional material in the programme of study in Northern Ireland which does not feature in Key Stage 4 in England. Teachers in Northern Ireland are advised to check the following sections of the programme of study in Northern Ireland and ensure that teaching fully meets the statutory requirements in their country.

- Living organisms – transport (names of blood vessels), reproduction (all parts), excretion (dialysis), nervous system (antagonistic muscle action, adrenaline)
- Properties and uses (composites)
- Chemical reactions – chemical change (water hardness)
- Forces – linear (momentum), turning (centre of mass – see Force and Rotation in 1 above), circular (circular motion), effects (extension)
- Sound (echoes, resonance)
- Earth in space (space travel)