Syllabus

Cambridge IGCSE Co-ordinated Sciences (Double Award)

Syllabus code 0654

For examination in June and November 2011

UNIVERSITY of CAMBRIDGE
International Examinations

Note for Exams Officers: Before making Final Entries, please check availability of the codes for the components and options in the E3 booklet (titled "Procedures for the Submission of Entries") relevant to the exam session. Please note that component and option codes are subject to change.

Contents

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1. Introduction

1.1 Why choose Cambridge?

University of Cambridge International Examinations (CIE) is the world's largest provider of international qualifications. Around 1.5 million students from 150 countries enter Cambridge examinations every year. What makes educators around the world choose Cambridge?

Recognition

Cambridge IGCSE is internationally recognised by schools, universities and employers as equivalent to UK GCSE. Cambridge IGCSE is excellent preparation for A/AS Level, the Advanced International Certificate of Education (AICE), US Advanced Placement Programme and the International Baccalaureate (IB) Diploma. Learn more at **www.cie.org.uk/recognition**.

Support

CIE provides a world-class support service for teachers and exams officers. We offer a wide range of teacher materials to Centres, plus teacher training (online and face-to-face) and student support materials. Exams officers can trust in reliable, efficient administration of exams entry and excellent, personal support from CIE Customer Services. Learn more at **www.cie.org.uk/teachers**.

Excellence in education

Cambridge qualifications develop successful students. They not only build understanding and knowledge required for progression, but also learning and thinking skills that help students become independent learners and equip them for life.

Not-for-profit, part of the University of Cambridge

CIE is part of Cambridge Assessment, a not-for-profit organisation and part of the University of Cambridge. The needs of teachers and learners are at the core of what we do. CIE invests constantly in improving its qualifications and services. We draw upon education research in developing our qualifications.

1.2 Why choose Cambridge IGCSE Co-ordinated Sciences (Double Award)?

A double award, IGCSE Co-ordinated Sciences gives candidates the opportunity to study biology, chemistry and physics within a cross-referenced, scientifically coherent syllabus. Candidates learn about the basic principles of each subject through a mix of theoretical and practical studies, while also developing an understanding of the scientific skills essential for further study.

Candidates learn how science is studied and practised, and become aware that the results of scientific research can have both good and bad effects on individuals, communities and the environment. As well as focusing on the individual sciences, the syllabus enables candidates to better understand the technological world they live in, and take an informed interest in science and scientific developments.

The syllabus is aimed at candidates across a very wide range of attainments, and will allow them to show success over the full range of grades from A*A* to GG.

1.3 Cambridge International Certificate of Education (ICE)

Cambridge ICE is the group award of the International General Certificate of Secondary Education (IGCSE). It requires the study of subjects drawn from the five different IGCSE subject groups. It gives schools the opportunity to benefit from offering a broad and balanced curriculum by recognising the achievements of students who pass examinations in at least seven subjects, including two languages, and one subject from each of the other subject groups.

The Cambridge portfolio of IGCSE qualifications provides a solid foundation for higher level courses such as GCE A and AS Levels and the International Baccalaureate Diploma as well as excellent preparation for employment.

A wide range of IGCSE subjects is available and these are grouped into five curriculum areas. Co-ordinated Sciences (Double Award) falls into Group III, Science.

Learn more about ICE at **www.cie.org.uk/qualifications/academic/middlesec/ice**.

1.4 How can I find out more?

If you are already a Cambridge Centre

You can make entries for this qualification through your usual channels, e.g. CIE Direct. If you have any queries, please contact us at **international@cie.org.uk**.

If you are not a Cambridge Centre

You can find out how your organisation can become a Cambridge Centre. Email us at **international@cie.org.uk**. Learn more about the benefits of becoming a Cambridge Centre at **www.cie.org.uk**.

Acknowledgement

This International syllabus draws its inspiration from the UK GCSE Nuffield Co-ordinated Sciences syllabus, and has been developed with the kind permission of the Nuffield-Chelsea Curriculum Trust.

2. Assessment at a glance

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Syllabus code 0654

<table>
<tr><th colspan="2">Candidates take:</th></tr>
<tr><td colspan="2">Paper 1 (30% of total marks)
(45 minutes)
A multiple-choice paper consisting of 40 items of the four-choice type.</td></tr>
<tr><th>and either:</th><th>or:</th></tr>
<tr><td>Paper 2 (50% of total marks)
(2 hours)
Core curriculum – Grades C to G available
Core theory paper consisting of short-answer and structured questions, based on the core curriculum.</td><td>Paper 3 (50% of total marks)
(2 hours)
Extended curriculum – Grades A* to G available
Extended theory paper consisting of short-answer and structured questions. A quarter of the marks available will be based on core material and the remainder on the supplement.</td></tr>
<tr><th colspan="2">and:</th></tr>
<tr><td colspan="2">Practical assessment (20% of total marks)
either: Paper 4 Coursework
or: Paper 5 Practical test (2 hours)
or: Paper 6 Alternative to practical (1 hour)</td></tr>
</table>

3. Syllabus aims and assessment

3.1 Aims

The aims of the syllabus below are not listed in order of priority.

The aims are to:

1. provide a worthwhile educational experience for all candidates, through well-designed studies of experimental and practical science, whether or not they go on to study science beyond this level. In particular, candidates' studies should enable them to acquire understanding and knowledge of the concepts, principles and applications of biology, chemistry and physics and, where appropriate, other related sciences so that they may
   - become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific importance
   - recognise the usefulness, and limitations, of scientific method and appreciate its applicability in other disciplines and in everyday life
   - be suitably prepared to embark upon certain post-16 science-dependent vocational courses and studies in any of the pure sciences and applied sciences
2. develop abilities and skills that
   - are relevant to the study and practice of science
   - are useful in everyday life
   - encourage safe practice
   - encourage effective communication
3. stimulate
   - curiosity, interest and enjoyment in science and its methods of enquiry
   - interest in, and care for, the environment
4. promote an awareness that
   - the study and practice of science are co-operative and cumulative activities subject to social, economic, technological, ethical and cultural influences and limitations
   - the applications of science may be both beneficial and detrimental to the individual, the community and the environment
   - the concepts of science are of a developing and sometimes transient nature
   - science transcends national boundaries and that the language of science is universal

3. Syllabus aims and assessment

In addition to these general aims, IGCSE Co-ordinated Sciences seeks to:

5. emphasise that some principles and concepts are common to all science, while others are more particular to the separate sciences of biology, chemistry and physics
6. promote interdisciplinary enquiry through practical investigations and through the co-ordination of the subject matter of the three separate sciences
7. introduce candidates to the methods used by scientists and to the ways in which scientific discoveries are made

3.2 Assessment objectives

The three assessment objectives in Co-ordinated Sciences are

A Knowledge with understanding

B Handling information and problem solving

C Experimental skills and investigations

A description of each assessment objective follows.

A Knowledge with understanding

Students should be able to demonstrate knowledge and understanding in relation to:

- scientific phenomena, facts, laws, definitions, concepts and theories
- scientific vocabulary, terminology and conventions (including symbols, quantities and units)
- scientific instruments and apparatus, including techniques of operation and aspects of safety
- scientific quantities and their determination
- scientific and technological applications with their social, economic and environmental implications.

The curriculum content defines the factual material that candidates may be required to recall and explain. Questions testing this will often begin with one of the following words: *define, state, describe, explain* or *outline*.

B Handling information and problem solving

Students should be able, using words or other written forms of presentation (i.e. symbolic, graphical and numerical), to

- locate, select, organise and present information from a variety of sources
- translate information from one form to another
- manipulate numerical and other data

- use information to identify patterns, report trends and draw inferences
- present reasoned explanations for phenomena, patterns and relationships
- make predictions and hypotheses
- solve problems.

These skills cannot be precisely specified in the curriculum content, because questions testing such skills are often based on information which is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts in the syllabus and apply them in a logical, deductive manner to a new situation. Questions testing these skills will often begin with one of the following words: *discuss, predict, suggest, calculate* or *determine*.

C Experimental skills and investigations

Students should be able to

- use techniques, apparatus and materials (including the following of a sequence of instructions where appropriate)
- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data
- plan investigations and/or evaluate methods, and suggest possible improvements (including the selection of techniques, apparatus and materials).

Specification grid

The approximate weightings allocated to each of the assessment objectives in the assessment model are summarised in the table below.

Assessment objective	Weighting
A Knowledge with understanding	50% (not more than 25% recall)
B Handling information and problem solving	30%
C Experimental skills and investigations	20%

3. Syllabus aims and assessment

3.3 Scheme of assessment

All candidates must enter for three papers: Paper 1; *either* Paper 2 *or* Paper 3; *one from* Papers 4, 5 or 6.
Candidates who have only studied the core curriculum or who are expected to achieve a grade D or below should normally be entered for Paper 2.
Candidates who have studied the extended curriculum, and who are expected to achieve a grade C or above, should be entered for Paper 3.

Candidates take:

Paper 1 **(30% of total marks)**
(45 minutes)

A multiple-choice paper consisting of 40 items of the four-choice type.

The questions will be based on the core curriculum, will be of a difficulty appropriate to grades C to G, and will test skills mainly in Assessment objectives A and B.

and either:	**or:**
Paper 2 **(50% of total marks)** (2 hours) *Core curriculum – Grades C to G available* Core theory paper consisting of short-answer and structured questions, based on the core curriculum. The questions will be of a difficulty appropriate to grades C to G and will test skills mainly in Assessment objectives A and B.	**Paper 3** **(50% of total marks)** (2 hours) *Extended curriculum – Grades A* to G available* Extended theory paper consisting of short-answer and structured questions. A quarter of the marks available will be based on core material and the remainder on the supplement. The questions will be of a difficulty appropriate to the higher grades and will test skills mainly in Assessment objectives A and B.

and:

Practical assessment * **(20% of total marks)**

either:	Paper 4	Coursework – a school-based assessment of practical skills **
or:	Paper 5	Practical test (2 hours) – with questions covering experimental and observational skills
or:	Paper 6	Alternative to Practical (1 hour) – a written paper designed to test familiarity with laboratory based procedures

3. Syllabus aims and assessment

* Scientific subjects are, by their nature, experimental. So, it is important that an assessment of a candidate's knowledge and understanding of science should contain a component relating to practical work and experimental skills (see Assessment objective C). Because schools and colleges have different circumstances – such as the availability of resources – three different means of assessment are provided: school-based assessment, a formal practical test and an 'alternative to practical' paper.

** Teachers may not undertake school-based assessment without the written approval of CIE. This will only be given to teachers who satisfy CIE requirements concerning moderation and they will have to undergo special training in assessment before entering candidates. CIE offers schools in-service training in the form of occasional face-to-face courses held in countries where there is a need, and also through the IGCSE Coursework Training Handbook, available from CIE Publications.

N.B. The data sheet (Periodic Table) will be included in Papers 1, 2 and 3.

3.4 Exam combinations

Candidates can combine this syllabus in an exam session with any other CIE syllabus, except:

- syllabuses with the same title at the same level
- 0610 Biology
- 0620 Chemistry
- 0625 Physics
- 0652 Physical Science
- 0653 Combined Science
- 5054 Physics
- 5070 Chemistry
- 5090 Biology
- 5096 Human and Social Biology
- 5124 Science (Physics, Chemistry)
- 5125 Science (Physics, Biology)
- 5126 Science (Chemistry, Biology)
- 5129 Combined Science
- 5130 Additional Combined Science

Please note that IGCSE, Cambridge International Level 1/Level 2 Certificates and O Level syllabuses are at the same level.

3.5 Notes

Conventions (e.g. signs, symbols, terminology and nomenclature)

Syllabuses and question papers will conform with generally accepted international practice.
In particular, attention is drawn to the following documents, published in the UK, which will be used as guidelines.

(a) Reports produced by the Association for Science Education (ASE):

- *SI Units, Signs, Symbols and Abbreviations* (1981)
- *Chemical Nomenclature, Symbols and Terminology for use in school science* (1985)
- *Signs, Symbols and Systematics: The ASE Companion to 16–19 Science* (2000)

(b) Reports produced by the Institute of Biology (in association with the ASE):

- *Biological Nomenclature, Recommendations on Terms, Units and Symbols* (1997)

It is intended that, in order to avoid difficulties arising out of the use of l for the symbol for litre, usage of dm^3 in place of l or litre will be made.

The concept of co-ordinated sciences

The syllabus has been designed to set the content, ideas, skills, processes and applications of science in the broadest possible contexts. It sets out to make teachers and candidates continuously aware of the inter-relationships between the main areas of science, while allowing Centres to retain the separate identities of biology, chemistry and physics. This co-ordination is the feature that distinguishes this syllabus from independent, self-supporting syllabuses in the separate sciences on the one hand, and integrated science on the other.

This syllabus has been developed from the GCSE Nuffield Co-ordinated Sciences syllabus. It has been modified to:

- be appropriate to the wide range of teaching environments in IGCSE Centres
- encourage the consideration of science within an international context
- be relevant to the differing backgrounds and experiences of students throughout the world.

Significance

The syllabus provides topics through which candidates can discuss issues that arise from the interaction of science, technology and society. These serve to remind candidates that matters of science are also matters of the everyday world. At the same time the science studied should have immediate significance for the candidate in terms of its intrinsic interest and its applications to candidates' individual lives and preoccupations. Correlation between what is taught in the classroom and issues of worldwide significance is a continual theme of this syllabus.

Experimental work

Experimental work is an essential component of all science. Experimental work within science education

- gives candidates first-hand experience of phenomena
- enables candidates to acquire practical skills
- provides candidates with the opportunity to plan and carry out investigations into practical problems.

This can be achieved by individual or group experimental work, or by demonstrations which actively involve the candidates.

Duration of course

Centres will obviously make their own decisions about the length of time taken to teach this course, though it is assumed that most Centres will attempt to cover it in two years. We suggest that Centres should allocate 6 × 40 minute lessons to science each week, over at least 52 full teaching weeks. On this basis, a possible time allowance has been allocated to each topic (see Figure 1 on page 15).

4. Co-ordination

Co-ordination of the content and development of the separate sciences is the feature that distinguishes this syllabus from independent, self-supporting syllabuses in biology, chemistry and physics on the one hand, and integrated science syllabuses on the other.

There are two aspects to co-ordination:

- it is a process that has taken place in devising and writing the syllabus
- it is an essential process that takes place within a Science Department teaching this syllabus.

Co-ordination in the planning and writing of the syllabus has taken place in two ways:

- **co-ordination of content** – ideas developed in one science are taken up in another, so that duplication of teaching can be avoided
- **co-ordination of ideas** – ideas that are common to two or more sciences (e.g. energy) are developed according to a common policy.

Co-ordination of content

If the topics in the separate syllabuses for biology, chemistry and physics are taught in the order given in the syllabus, then it should prove possible to co-ordinate the content of the three sciences.

Figure 1: Topic sequence (page 15) shows how the content of one science is related in time to the content of another. For example: work on chemicals from plants, in chemistry, starts just after corresponding work on photosynthesis in biology; when work in physics is concerned with electric currents, work in chemistry is concerned with ions and electrolysis.

There are also ways that one science takes up ideas already developed in another. For example:

- work on cells and batteries in **C15** of the chemistry syllabus assumes an acquaintance with work on energy and electricity in **P8** of the physics syllabus
- work on temperature control in an organism, in **B11** of the biology syllabus, relies on understanding the relationship between evaporation and energy transfer in **P2** of the physics syllabus
- the study of digestion in **B9** makes more sense in the light of work on carbohydrate molecules in **C4**.

If schools devise alternative pathways through the material, they will need to bear in mind the way the development of some major ideas has been co-ordinated across the sciences. For example, it is necessary to ensure that introductory work on energy in physics precedes the development of topics using energy in biology and chemistry. Important priorities are made clear in the charts, which show the development of ideas about energy and particles.

4. Co-ordination

Other ways the content of the three sciences can be linked to each other and to other areas of study are cross-reference and application. For example:

- work on chemicals from plants in **C4** of the chemistry syllabus looks *forward* to the use that will be made of this in future work in biology
- work on optical fibres in physics (**P9**) reminds candidates of earlier work on glass in chemistry (**C5**) but does not explicitly use ideas from that section.

Co-ordination of concepts and ideas

A common policy needs to be adopted in the development of any idea that occurs in more than one science. In this syllabus, particular policies have been adopted towards the concept of energy and the use of the word 'particle'.

(i) Energy

There is often confusion in candidates' minds over the scientist's 'book-keeping' view of conservation of energy and the everyday idea that energy is somehow being used up.

A change (e.g. of position, motion, temperature, chemical nature) almost invariably accompanies the transfer of energy. There is an 'energy cost' involved in bringing about any desirable change. This idea is introduced prior to any consideration of energy conservation.

Later, candidates learn that energy is conserved (i.e. not lost). Energy is transferred to the surroundings, warming them up. This energy is not lost, but, spread out, it cannot all be re-used. This can be compared with the 'loss' of material resources by their wide dispersal.

Figure 2: Energy co-ordination (page 16) shows the way ideas about energy are inter-related in the three sciences.

(ii) Particles

It is common to use the word 'particle' in physics as a general term for atom, molecule or even ion since, in many cases (e.g. when developing ideas of the kinetic theory), it is inconvenient and unnecessary to draw any distinction between them. In chemistry, on the other hand, it is usual to distinguish between atoms and molecules. The distinction is often an important one as, for example, when comparing the strong forces which bind atoms into molecules with the much weaker forces which may bind molecules into solids or liquids.

The word 'particle' is also used in chemistry (and in physics) to mean 'small specks of matter'. It is used in this way when talking of colloidal particles or smoke particles.

There seems no way of avoiding the use of these terms in any of the ways listed above.

Figure 3: Particle co-ordination (page 17) shows the way the ideas about particles are taken up in all three sciences. Not surprisingly, the concept is central to work in chemistry.

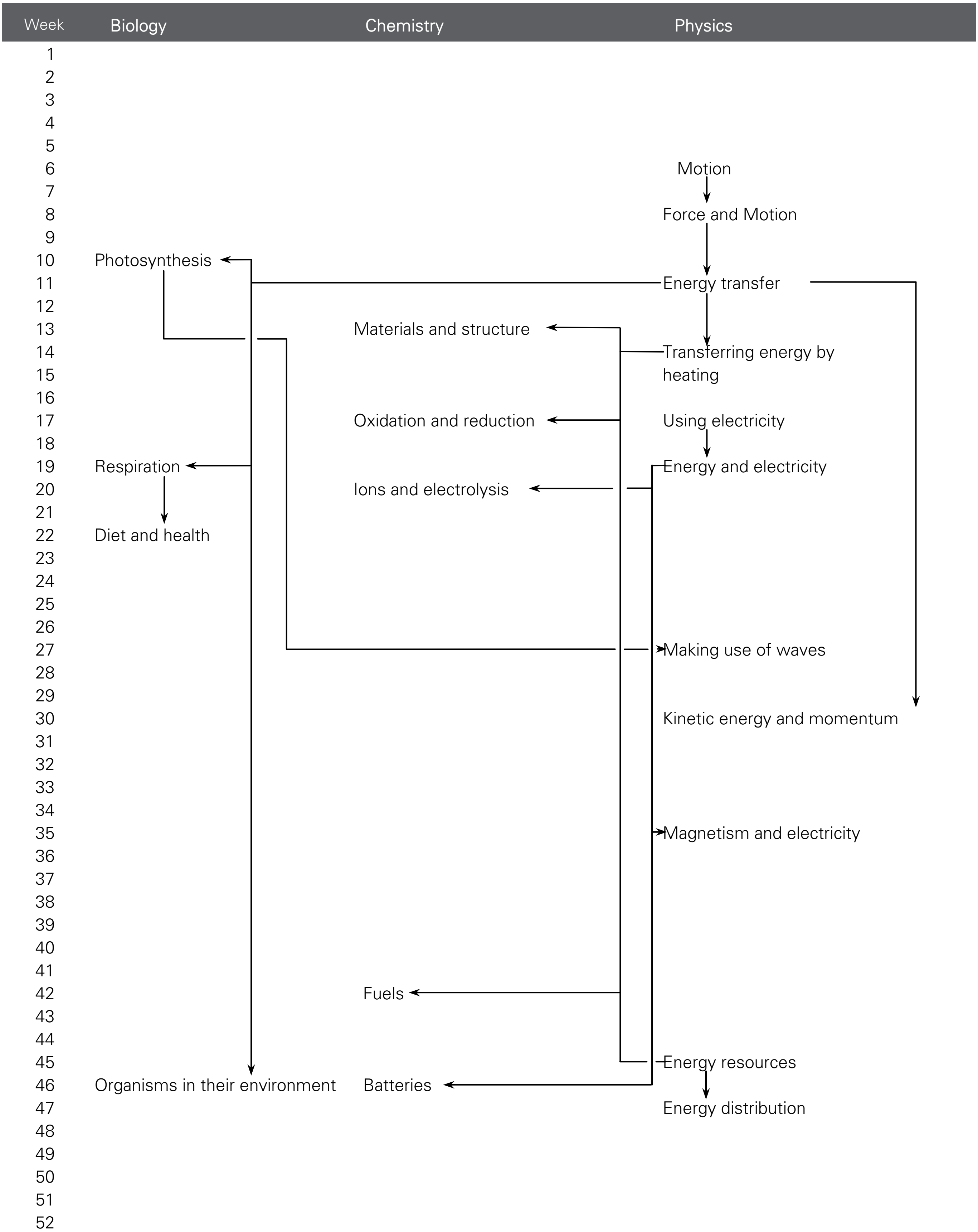
4. Co-ordination

Figure 1: Topic sequence

Week	Biology	Chemistry	Physics
1	Biological classification	The elements of chemistry	The strength of solids
2			
3		Classifying elements	Particles in motion
4	Cellular organisation		
5			
6		Petrochemicals	Motion
7			
8	Support and movement		Force and motion
9			
10	Photosynthesis		
11		Chemicals from plants	Energy transfer
12			
13	Gaseous exchange in animals	Materials and structures	
14			Transferring energy by heating
15			
16	Transport systems		
17		Oxidation and reduction	Using electricity
18			
19	Respiration		Energy and electricity
20		Ions and electrolysis	
21			
22	Diet and health		Light and sound
23		Solvents and solutions	
24			Making waves
25			
26	Digestion		
27		Acids and alkalis	Making use of waves
28			
29			
30	Responding to the environment	Soil, rocks and rates	Kinetic energy and momentum
31			
32			
33	Homeostasis		Gravity
34		Fertilisers	
35	Reproduction		Magnetism and electricity
36			
37		Dyes and drugs	
38	Human reproduction		Communications
39			
40		Colloids	Electrons
41	Inheritance		
42		Fuels	Radioactivity
43			
44	Evolution		
45			Energy resources
46	Organisms in their environment	Batteries	
47			Energy distribution
48			
49	Cycles and the effects of	Metals and alloys	
50	humans on the environment		Electronics
51		Atoms, bonding and the	
52		Periodic Table	

4. Co-ordination

Figure 2: Energy co-ordination



4. Co-ordination

Figure 3: Particle co-ordination

Week	Biology	Chemistry	Physics
1		The elements of chemistry	The strengths of solids
2			
3		Classifying elements	Particles in motion
4	Cellular organisation		
5			
6		Petrochemicals	
7			
8			
9			
10			
11		Chemicals from plants	
12			
13	Gaseous exchange in animals	Materials and structures	
14			Transferring energy
15			
16			
17			
18			
19			
20		Ions and electrolysis	
21			
22			
23		Solvents and solutions	
24			
25			
26	Digestion		
27		Acids and alkalis	
28			
29			
30			
31			
32			
33	Homeostasis		
34			
35			
36			
37			
38			
39			
40		Colloids	Electrons
41			
42			Radioactivity
43			
44			
45			
46		Batteries	
47			
48			
49		Metals and alloys	
50			
51		Atoms, bonding and the	
52		Periodic Table	

5. Curriculum content

The curriculum content that follows is divided into three sections: biology (B1–B17), chemistry (C1–C17) and physics (P1–P20). **Candidates must study all three sections.**

Candidates can follow either the core curriculum only, or they can follow the extended curriculum which includes both the core and the supplement. Candidates aiming for grades A*A* to CC should follow the extended curriculum.

Note:

1. The curriculum content is designed to provide guidance to teachers as to what will be assessed in the overall evaluation of the candidate. It is not meant to limit, in any way, the teaching programme of any particular school or college.
2. The content is set out in topic areas within biology, chemistry and physics. Each topic is framed within a context, outlined beneath the topic title. The left-hand column provides amplification of the core content, which all candidates must study. The centre column outlines the supplementary content, which should be studied by candidates following the extended curriculum. The right-hand column gives some suggested approaches which teachers may adopt in teaching each topic. At the bottom of each page are opportunities for co-ordination linking the topic to other topics within the syllabus.

5. Curriculum content

B1: THE PRINCIPLES OF BIOLOGICAL CLASSIFICATION AND THE DIVERSITY OF ORGANISMS

Context: Opportunity should be given to observe a variety of animals and plants, giving emphasis to locally occurring ones. All organisms within a group show certain common characteristics that have been used to place them in that group. Organisms have a large number of different characteristics, many of which enable them to survive in the ecosystem in which they live. The principles of biological classification, including the definition of species, rules for naming and the hierarchical structure of the classification system, can be presented using a wide range of organisms as examples.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate why organisms are classified into groups		Opportunities should be given to observe a variety of organisms occurring locally. Similarities and differences between them can be noted and diagnostic characteristics used to sort them into groups.
• be able to use the binomial system of naming organisms, and know the binomial names for two different organisms • appreciate that organisms belong to different species, which are discrete breeding groups		Simple keys can be used to identify locally occurring organisms. Candidates aiming for higher grades should design a key to enable identification of five or six organisms (e.g. trees from characteristics of their leaves).
• be able to use a simple dichotomous identification key	• be able to construct a simple dichotomous key to enable identification of organisms	The idea of the species can be discussed and also the international benefits of using the binomial system.
• know the main features of the five main classes of vertebrates (fish, amphibians, reptiles, birds, mammals)	• know the main features of three classes of arthropods (insects, crustaceans and arachnids only)	

Opportunities for co-ordination: The concept of classification is also dealt with in **C2**, where the classification of the elements is covered. Towards the end of the course, in **B15** and **B16**, candidates can develop ideas of differences and similarities between organisms with regard to their adaptations to the pressures imposed on them by their environment and to their evolutionary relationships.

5. Curriculum content

B2: Cellular organisation and function

Context: This section looks at the cell as the basic unit from which most living organisms are constructed. The parts of a cell are identified and their functions considered. Differences between plant and animal cells and between cells performing different functions within a plant or animal are discussed. The particular role of the cell membrane in the uptake or loss of water is examined.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate that all living organisms are made up of cells		Candidates should observe light micrographs of a variety of animal and plant cells. Human cheek cells and leaf mesophyll cells could be used as examples of 'typical' animal and plant cells.
• know the structure of a typical animal cell and a typical plant cell (cell membrane, cytoplasm, nucleus, cell wall, vacuole, chloroplast only) • understand the functions of the parts of animal and plant cells (as listed above) • understand the significance of the differences in structure between animal and plant cells • appreciate that different types of cells perform different functions, and that their structure is related to their function • know that cells are arranged in groups to form tissues • know that osmosis is the diffusion of water molecules through a partially permeable membrane, and be able to relate this to the effects of solutions of different concentrations on animal and plant cells	• be able to interpret light micrographs and simple electron micrographs of plant and animal cells	If possible, temporary mounts can be observed using light microscopes. Onion epidermis cells and filamentous algae are particularly suitable. Osmosis should be considered as a type of diffusion in which water molecules, but not soluble molecules, can pass through a partially permeable membrane. This can be illustrated using sucrose solution separated from water by Visking tubing. Possible practical work involving osmosis and cells includes: the effects of soaking raisins in water; de-shelled raw eggs in concentrated and dilute salt solutions; potato chips in a range of concentrations of salt solutions. Photographs of red blood cells in solutions of different concentrations could be observed.

Opportunities for co-ordination: An understanding of osmosis can be developed by building on the study of particles in motion in **P2**. There are also strong links with **C4**, where the use of a partially permeable membrane to separate large molecules from small ones is covered. This topic provides a basis for much of the further study of living organisms. The importance of turgor in support, covered in **B3**, and the uptake of water by osmosis in plant roots, covered in **B6**, both make use of a knowledge of osmosis in plant cells. The importance of water concentration to animal cells is further developed in **B11**. **B4** and **B12** provide opportunities to consider how individual types of animal and plant cells are adapted to perform particular functions.

B3: SUPPORT AND MOVEMENT

Context: This section develops ideas about how organisms support themselves. Plant stems are strong and flexible and the importance of lignin and turgidity in supporting cells are considered.

The functions of skeletons and muscles in animal movement are developed. An understanding of joints and muscles can be used to discuss sports injuries, athletic training and diseases such as arthritis.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
		The need for strong supporting structures in terrestrial organisms should be discussed.
• understand the importance of lignin in supporting woody parts of plants, and turgid cells in supporting non-woody parts of plants		Observation of a wilted plant with a woody stem can be used to illustrate that the support provided by lignin in stems and veins is unaffected by lack of water, while leaf cells normally supported by turgor become flaccid.
• know that the skeleton of a mammal is made of bone and cartilage, and appreciate the differences in properties of these substances • know the structure of the skeleton and muscles of the human arm (ulna, radius, humerus, scapula, tendons, biceps and triceps only), and understand how the antagonistic muscles and bones act together to flex or extend the arm • know that a joint occurs where two bones meet • know that a synovial joint allows the movement of two bones, and that cartilage and synovial fluid reduce friction between the bones	• be able to appreciate that the contraction of the biceps produces a turning effect, with the elbow joint as pivot • understand that the small distance between the attachment of the biceps and the pivot means that a large force is required to produce a large effect, and be able to relate this to the ability of muscles to produce large forces and their inability to contract over large distances	Models of skeletons and X-rays of bones could be observed. Candidates aiming for higher grades could investigate the turning effect of the biceps muscle. A simple model can be used, in which lengths of wood or plastic to represent the ulna and the humerus are joined at the 'elbow' in such a way as to allow movement. A newton meter can be hooked on to the 'ulna' at varying distances from the 'elbow' and the force needed to lift a mass hanging on the end of the 'ulna' measured. Injuries and diseases such as sprains, breakage of bones, torn tendons and arthritis could be discussed.

Opportunities for co-ordination: This topic builds on ideas introduced in **P1**, where the strength of solids, stability, design of structures to provide support and the turning effects of forces are covered. The effects of friction are considered in **P4**. Osmosis and turgor will have been met in **B2**. There is also a possible link with **C4**, in which the use of wood in making paper and building is considered.

B4: PHOTOSYNTHESIS

Context: This section examines the physiology of photosynthesis and how it relates to agriculture and food production. The value of photosynthesis as an oxygen-producing process is examined and related to the maintenance of the composition of the atmosphere.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the significance of photosynthesis in making food • appreciate that photosynthesis transfers energy from sunlight into energy in chemicals, such as glucose and starch		The absorption of red and blue light by chlorophyll could be demonstrated. Candidates could examine microscope slides, transparencies or micrographs of transverse sections through a leaf, and consider how the leaf is adapted as a 'food factory'.
• understand the significance of chlorophyll as a light-absorbing molecule • understand the requirements for photosynthesis; the nature of the products formed; the effects of altering the conditions on the rate of photosynthesis • know the word equation for photosynthesis • appreciate how the structure of a leaf enables photosynthesis to occur effectively	• appreciate the variety of factors that limit the rate of photosynthesis, and ways of overcoming the limitations when growing plants for food or other uses	The production of oxygen by a water plant can be investigated. Data from such an investigation, or data provided by the teacher, could be used to plot graphs relating rate of photosynthesis to light intensity, light wavelengths or carbon dioxide concentration. Candidates aiming for higher grades could relate such data to increasing the rate of growth of crop plants, concentrating on those crops grown locally, if appropriate.
• be able to perform starch tests on leaves • understand how photosynthesis affects the concentrations of carbon dioxide and oxygen in water or the atmosphere • understand that plants need nitrate ions for making proteins, and that they may absorb these from the soil		Experiments can be performed to investigate the production of starch by leaves with and without light, carbon dioxide or chlorophyll. Hydrogencarbonate indicator solution can be used to investigate the consumption and production of carbon dioxide by an aquatic plant in the light and in the dark.

Opportunities for co-ordination: The concepts of energy transfer are introduced in **P5**. **C4** further develops ideas about the molecular structure of sugars, starch and cellulose and also provides an opportunity to investigate the composition of chlorophylls, using paper chromatography. The importance of photosynthesis in ecosystems, in terms of both energy transfer and the cycling of carbon, is further developed in **B16** and **B17**.

B5: GASEOUS EXCHANGE IN ANIMALS

Context: This section provides the opportunity for investigating how the human breathing system allows the exchange of gases between the alveoli and the blood capillaries. The effects of cigarette smoke on health are considered.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know the structure of the mammalian breathing system (larynx, trachea, epiglottis, bronchi, bronchioles, alveoli, pleural membranes, diaphragm and intercostal muscles)		Candidates may be given the opportunity to observe the structure of mammalian lungs, for example sheep's lungs.
• understand how the structure of the alveoli and blood capillaries enable gaseous exchange to occur and the importance of diffusion in gaseous exchange across the alveoli	• understand how movements of the intercostal muscles and diaphragm enable inhalation and exhalation to occur through changes in pressure in the thorax	Candidates aiming for higher grades could use models to illustrate how movements of the intercostal muscles and diaphragm can cause volume or pressure changes in the thorax.
• understand the role of goblet cells and cilia in keeping the lungs free from infection		The composition of cigarette smoke can be demonstrated, and its effects on the breathing system discussed.
• understand the effects of smoke and air pollution on the breathing system	• be able to discuss the effects of cigarette smoke on health, and the reasons why people smoke	The relative amounts of carbon dioxide in inspired and expired air can be investigated using hydrogencarbonate indicator solution or limewater. The relative amounts of oxygen in inspired and expired air can be investigated by timing the burning of a candle in a gas jar of air.
• know that air breathed out contains more carbon dioxide and less oxygen than air breathed in	• be able to state the percentage composition of inspired and expired air, and explain the reasons for the differences	

Opportunities for co-ordination: This topic links closely with **B6**, where the transport of oxygen within the mammalian body is considered, and with **B7**, which deals with the use of oxygen by living cells. The production of sulfur dioxide, and its possible polluting effects, is dealt with in **C14** and **B17** and this can be related to the effects of this pollutant on the breathing system. A knowledge of the relationship between pressure and volume changes, covered in **P2**, will help candidates to understand the effects of breathing movements.

B6: TRANSPORT SYSTEMS

Context: This section allows transport systems to be examined. The need for transport systems in large organisms is considered, together with the ways in which the major transport systems of plants and mammals function.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that plants take up water and inorganic ions through root hairs		The movement of dye through a celery stalk can be used to demonstrate the movement of water through xylem vessels.
• know that xylem transports water and inorganic ions and that phloem transports the products of photosynthesis		Detail of the structure of xylem vessels or phloem sieve tubes is **not** required.
• know that transpiration provides a 'pull' which draws water through xylem vessels • know that red blood cells carry oxygen, attached to haemoglobin, around the body of a mammal	• understand how environmental conditions may alter the transpiration rate and thus the rate of water uptake by a plant	Candidates aiming for higher grades could use simple potometers, or data provided by the teacher, to investigate the effects of varying environmental conditions on the rate of water uptake.
• know that white blood cells prevent infection becoming established • know that platelets help in clotting, and that plasma transports glucose, carbon dioxide, hormones and urea	• appreciate the roles of phagocytes and antibodies in destroying invading micro-organisms	The structure of a mammalian heart could be examined.
• understand that arteries carry blood away from the heart; veins carry blood towards the heart; capillaries link arteries with veins, and are the sites of exchange with the tissues	• be able to relate the structure of arteries, veins and capillaries to their functions	Candidates aiming for higher grades could examine microscope slides, transparencies or photographs of sections of blood vessels.

B6: TRANSPORT SYSTEMS continues on the next page

B6: TRANSPORT SYSTEMS (continued)

• know the external and internal structure of the mammalian heart, and understand its function • be able to explain the events leading to a heart attack and a stroke, and appreciate how life-style may affect the risk of heart attacks or strokes		

Opportunities for co-ordination: B2 introduces the idea of osmosis, which is used here to explain the uptake of water by root hairs. The importance of transpiration in the water cycle is covered in **B17**. The possible links between diet and heart disease can be further developed in **B8**.

B7: RESPIRATION

Context: This section introduces respiration as a process for transferring energy from food (e.g. glucose) to the cells of an organism. Oxygen is normally required for respiration and carbon dioxide is produced as a waste product.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand that aerobic respiration involves transferring energy from glucose to a cell; oxygen is needed and carbon dioxide is produced		A burning nut can be used to heat a tube of water. Parallels can be drawn between the release of energy from the nut and its transfer into the water, with the release of energy from glucose in respiration and its transfer into the cell.
• be able to state the word equation for aerobic respiration		Candidates aiming for higher grades could attempt a quantitative investigation into the amount of energy released from a burning nut.
• appreciate the uses of transferred energy to organisms (e.g. movement, growth and warming the body) • understand that anaerobic respiration can occur in human muscles, and that lactic acid is produced and must later be removed with the use of oxygen		The effects of exercise on breathing rate can be investigated. Data can then be plotted on a graph and the reasons for the increase of breathing rate with exercise, and the delayed return to normal after exercise stops, can be discussed.
• appreciate that respiration occurs in all living cells		Candidates interested in sport might like to discuss the effects of training on the efficiency of oxygen supply to muscles and their tolerance to lactic acid accumulation.

Opportunities for co-ordination: The concept of energy transfer is introduced in **P5**. **P6** further develops the idea of transferring energy by heating. Links can be made between the oxidation of glucose in cells and the burning of fossil fuels, covered in **C14**. **B17** considers the importance of respiration in the cycling of carbon within an ecosystem.

B8: DIET AND HEALTH

Context: This section allows ideas of healthy eating to be discussed in terms of the biological requirements of a balanced diet. Sensible eating patterns should be discussed.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that a balanced diet contains protein, fat, carbohydrate, vitamins, minerals (inorganic ions), roughage (fibre) and water		Candidates should be given the opportunity to carry out food tests on a variety of foods.
• be able to perform tests for starch (iodine solution), reducing sugar (Benedict's reagent), protein (biuret test) and fat (ethanol test)		They should analyse their own diet, identify any problems, and suggest how it might be improved.
• know that energy input should approximately equal energy output, and that fat and carbohydrate provide most of the energy input of a balanced diet		The variation in dietary needs from person to person could be considered. Energy needs can be plotted on a bar chart.
• know that protein is an essential body-building food	• understand that proteins have a wide variety of roles in the human body, and be able to describe a range of these roles	The problem of world food supplies can be discussed.
• understand the uses in the human body of iron, calcium, vitamin C and vitamin D		
• know examples of foods which are good sources of each of the components of a balanced diet		
• appreciate local dietary problems (for example too much fat, insufficient protein), and how these may affect health	• be able to discuss the problems and possible solutions of inadequate diet in one or more parts of the world	

Opportunities for co-ordination: The use of food as a fuel will have been introduced in B7. C3 introduces the idea of polymers, while C4 gives opportunity for a consideration of the structure of carbohydrates and proteins.

5. Curriculum content

B9: DIGESTION

Context: Digestion is presented as a means of transforming complex food substances into smaller molecules prior to absorption into the body. The functions of the human digestive systems are examined. This section also provides an opportunity to explore the role of enzymes as catalysts.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand that digestion breaks large molecules of food into small ones, which can then pass through the wall of the gut into the blood		A 'model gut' of Visking tubing, containing a glucose and starch solution, can be used to demonstrate that glucose can be absorbed but starch cannot; the need for digestion can then be discussed.
• appreciate that the gut is a coiled tube, and is the site of digestion and absorption • know the internal structure of a human tooth, and how the different types of human teeth are used when eating		Candidates can examine their own teeth, using a mirror. If tooth decay is a problem locally, data can be collected on numbers of decayed teeth of different types, and strategies for limiting the occurrence of decay discussed.
• understand the role of bacteria forming acids in the mouth leading to tooth decay		Photographs or models of the alimentary canal could be examined.
• be able to identify the gross structure of the alimentary canal and its associated organs (mouth, oesophagus, stomach, small and large intestine, rectum, anus, pancreas and liver) • appreciate that food is moved along the gut by peristalsis		Potato or liver could be used to investigate the action of the enzyme catalase on hydrogen peroxide. This gives an opportunity to emphasise the fact that not all enzymes are digestive enzymes.
• appreciate that digestion is brought about by enzymes, acting as catalysts	• appreciate that enzymes are used in many industrial processes and products • understand how the rate of an enzyme reaction can be affected by temperature and pH	Candidates aiming for higher grades could investigate the effects of temperature or pH on the rate of digestion of starch by amylase, or of casein in milk powder by trypsin, or of egg white by pepsin.

B9: DIGESTION continues on the next page

B9: DIGESTION (continued)

• know the functions of amylase, protease and lipase	• know the sites of production and action of amylase, protease and lipase in the human alimentary canal	
• know that the small intestine is the site of absorption of the products of digestion • know that indigestible food, such as fibre, is removed through the anus by the process of egestion	• know that villi in the small intestine increase surface area for absorption, and that absorbed products are taken in the hepatic portal vein to the liver	

Opportunities for co-ordination: A knowledge of the structure of carbohydrates and proteins and of the movement of molecules of different sizes through membranes, both covered in **C4**, will help in understanding the processes of digestion and absorption. The use of catalysts for increasing reaction rate is introduced in **C3**. The way in which temperature affects the rate of enzyme-controlled reactions can be linked to the ideas in **C10**.

B10: RESPONDING TO CHANGES IN THE ENVIRONMENT

Context: All organisms respond to changes in their environments and this section explores some of the ways in which they do this. The human eye is studied as an example of a receptor organ.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate that external stimuli can be detected by organisms, and may result in responses which may increase the chances of the organisms' survival	• know the structure of a motor neurone, and appreciate how its structure is related to its function	A range of stimuli and responses to them can be discussed, using a wide range of animals and plants as examples. The ideas of receptor, communication system and effector can be introduced.
• know that the human nervous system is made up of the central nervous system (brain and spinal cord) and many nerves which carry messages from receptors or to effectors	• understand a spinal reflex arc, and appreciate the value of rapid, automatic responses (reflexes) to an organism	Transparencies or photographs of the human central nervous system and nerves could be observed.
• know the structure of the human eye, and understand how light is focused onto the retina	• understand *accommodation*; know the functions of rods and cones, and their distribution in the human retina	Reflexes could be investigated (e.g. knee jerk, blinking, pupil dilation and contraction), and their survival value discussed. Speed of reflexes can be investigated by catching a dropped ruler.
• appreciate that receptors, such as those in the retina of the eye, convert a stimulus into an impulse in a nerve fibre which is carried to the central nervous system, which may then send an impulse to an effector		A flask of fluorescein can be used to show how diverging or parallel light rays can be focused onto the retina, using a converging lens.
• know that the shoot of a plant grows towards the light, and appreciate that there must be a receptor and an effector involved in this response	• be able to suggest a possible method by which auxin could be involved in the growth of shoots towards the light	The response of seedlings to darkness, unidirectional and uniform light can be investigated and interpreted.

Opportunities for co-ordination: The properties of light, including refraction and the formation of a real image by a lens, are covered in P9. Ideas concerning colour vision are further developed in **P11**.

B11: HOMEOSTASIS

Context: In this section, homeostasis is defined as the maintenance of constant internal conditions within organisms. The principles can be developed in a wide variety of contexts, including the maintenance of balanced water levels in the blood, the regulation of body temperature in mammals, the regulation of blood glucose levels and the removal of excretory products, such as urea.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate that cells function most efficiently under particular conditions of temperature, water and glucose concentration, and know that the maintenance of the internal environment is called homeostasis		The advantages of a constant internal environment could be discussed, relating this to knowledge of osmosis, respiration and enzyme function.
• know that mammals maintain a constant internal body temperature, despite fluctuations in environmental temperature	• understand how sweating, vasodilation and vasoconstriction help in regulating body temperature	Candidates could investigate how rate of heat loss is affected by one or more of surface area, insulation or evaporation, using tubes of hot water to represent animals.
• know that mammals regulate the concentration of glucose in the blood • understand that the secretion of insulin by the pancreas reduces high blood glucose levels and that failure of this mechanism may lead to diabetes		Data relating to blood glucose concentrations before and after a meal could be plotted and analysed, perhaps with reference to diabetes. Detail of urea formation is **not** required.
• know that urea is a nitrogenous waste product formed in the liver from excess proteins, and is excreted by the kidneys in urine	• know the position of the kidneys in the mammalian body and their relationship to the renal artery, renal vein, ureter, bladder and urethra	Candidates aiming for higher grades could observe the macroscopic structure of a mammalian kidney. Only a simple outline of filtration and reabsorption is required, with no detail of the structure of the nephron wall. Knowledge of ADH is **not** required.

B11: HOMEOSTASIS continues on the next page

B11: HOMEOSTASIS (continued)

	• know that the kidneys remove excess water and urea from the blood plasma, and that urine is produced and stored in the bladder. • understand that the amount of water in urine can be varied by the kidney, in response to changes in the water content of the blood	

Opportunities for co-ordination: This section draws on many areas of biology such as the effects of solutions of different concentrations on cells in **B2**, the role of glucose in respiration in **B7**, and the importance of enzymes in metabolism in **B9**. The effects of temperature on reaction rate are discussed in **C10**.

5. Curriculum content

B12: REPRODUCTION

Context: This section introduces the biological aspects of reproduction in organisms. Asexual reproduction is contrasted with sexual reproduction.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that asexual reproduction produces offspring that are identical to the parent		Examples of asexually-reproducing animals or plants could be observed.
• understand that sexual reproduction involves a mobile male gamete (e.g. sperm) fusing with a stationary female gamete (e.g. egg)	• appreciate the significance of the differences between internal and external fertilisation in animals	Photographs or diagrams of egg and sperm could be observed, and the way in which their structure is adapted to their functions discussed.
• know the reproductive parts of an insect-pollinated flower, and understand their functioning • understand the differences between pollination and fertilisation in flowering plants	• understand the differences in structure between insect- and wind-pollinated flowers • be able to describe the growth of the pollen tube from style to ovule, and the passage of the male nucleus along it, before fusion with the female nucleus to form a zygote	An insect-pollinated flower could be examined, the parts identified and their functions described. Candidates aiming for higher grades could also investigate the structure of a wind-pollinated flower, and draw up a comparison chart between the two types.
• understand the formation of seed and fruit from ovule and ovary • understand the importance of seed dispersal, and describe examples of animal- and wind-dispersed seeds or fruits		The changes in a flower after successful pollination and fertilisation can be observed, leading to an appreciation of the development of seeds inside fruits. Animal- and wind-dispersed fruits can be observed, and their structures related to the method of dispersal.
• know the structure of a bean seed (testa, micropyle, cotyledons, plumule and radicle only) • understand the conditions needed for germination of seeds		A bean seed can be examined. Conditions necessary for germination of beans or other seeds (moisture, suitable temperature and oxygen) can be investigated experimentally.

Opportunities for co-ordination: This section introduces the basic ideas concerning the processes of reproduction in living organisms, which are further developed with respect to humans in **B13**. The role of sexual reproduction in introducing variation into populations and the possibilities of cloning are looked at in **B14**.

B13: HUMAN REPRODUCTION

Context: This section deals with the facts of human reproduction and considers the importance of AIDS as a sexually transmitted disease. The problems of a growing world population are considered.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know the structure and function of the male and female reproductive systems • know that adolescence is controlled by hormones produced by the testes or ovaries; that the male sex hormone is testosterone, while the female sex hormones are oestrogen and progesterone • appreciate the changes in the ovary and uterus throughout the menstrual cycle • understand the biological aspects of sexual intercourse, fertilisation and implantation • appreciate the protection given to the embryo by the amnion, and the role of the placenta in allowing transfer of materials to and from the fetus • understand the process of birth • understand the methods of transmission of the HIV virus, and how the spread of AIDS may be limited • appreciate that the world population of humans is growing rapidly and that birth control can help to limit this growth		The structure and function of the human reproductive system, fertilisation, development of the embryo and birth can be approached through a combination of observation of diagrams and photographs and discussion. Data on the spread of AIDS in different parts of the world may be analysed and interpreted. Strategies for limiting its spread could be discussed. The growth of the human population in various parts of the world could be plotted as line graphs. Age pyramids for growing and stable populations could be plotted and compared. The problems of the growing world population could be discussed, together with possible solutions.

Opportunities for co-ordination: Links here are mainly with other biology topics, such as the significance of sexual reproduction in **B12** and the role of white cells in fighting disease in **B6**. The way in which environmental factors can limit population growth is considered in **B16**. The effects of the growing human population and its increasing demand on the world's resources are also considered in **C3**, **C6** and **C14**.

B14: INHERITANCE

Context: This section develops the ideas of genetics. The effects of heredity and the environment on the expression of characteristics are considered. The inherited nature of some human conditions is explained and the value of genetic counselling can be discussed.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate that variation shown by organisms is partly inherited and partly results from environmental influences	• understand the differences between continuous and discontinuous variation, and be able to describe one example of each in humans	Candidates could observe variation amongst themselves, and discuss the relative importance of inheritance and the environment in producing these variations.
• know that chromosomes are found in the nucleus, and that genes are carried on chromosomes • know that genes are 'coded instructions' for making proteins, and that DNA is the chemical which stores the coded instructions		Candidates aiming for higher grades could make measurements of one type of continuous variation, make tally charts and plot bar charts.
• appreciate that gametes contain half the normal number of chromosomes, and that fertilisation restores the normal number		Simple genetic crosses should be shown by means of genetic diagrams, including the inheritance of a disease caused by a recessive gene (e.g. cystic fibrosis, thalassaemia or sickle-cell anaemia). The role of genetic counsellors could be discussed.
• understand the meaning of the terms *dominant*, *recessive*, *phenotype*, *genotype*, *allele*, *homozygote*, *heterozygote* and *mutation*	• appreciate that mutation may occur naturally, but that the chances of mutation are increased by exposure to ionising radiation	The success of tissue culture techniques in cloning oil palms, or a locally important crop, could be considered.

B14: INHERITANCE continues on the next page

B14: INHERITANCE (continued)

• be able to calculate and predict the results of a simple cross involving 1 : 1 or 3 : 1 ratios	• understand that mutation in a body cell is likely to be harmless unless it leads to uncontrolled division of the cell (cancer), but that a mutation in a gamete-forming cell may be passed on to offspring	
• know one example of an inherited disease (e.g. cystic fibrosis, thalassaemia or sickle-cell anaemia) • understand that modern cloning techniques, such as tissue culture, enable the production of plants with identical genes • appreciate that this can have benefits to agriculture	• appreciate that genetic engineering may involve the transfer of desirable genes into crop plants or animals farmed for food, and be able to discuss some of the possible problems associated with genetic engineering (details of the techniques or processes involved are **not** required)	Candidates aiming for higher grades should investigate one example of genetic engineering as applied to a crop plant or animal. Environmental, social or economic issues arising from the use of genetic engineering could be discussed.

Opportunities for co-ordination: The use of plant products is covered in **C4** and links can be made here with the use of cloning techniques and genetic engineering. The nature of ionising radiation and its possible effects on living organisms is dealt with in **P17**.

B15: EVOLUTION

Context: Evolution is considered as a change, over time, in the characteristics of a population of organisms. The important role of natural selection in this process is considered. There are opportunities to relate evolutionary processes to the development of plants and animals for food production and to the problems of antibiotic resistance in bacteria.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
	• understand that organisms vary, and that some variations give advantages over others in the 'struggle for existence'	The theory of natural selection should be discussed. A real or imagined example could be used to show how different selection pressures can produce change in a population.
	• understand that variations caused by genes can be passed on to offspring, and that genes conferring advantageous adaptations are more likely to be passed on than others • know the term *natural selection*	Candidates may like to consider the evidence, such as fossils and homologies, that present-day organisms have evolved from older ones.
	• understand that, if the environment changes, different genes may become advantageous, so leading to a change in the characteristics of a population or organisms	The evolution of antibiotic resistance in bacteria could be discussed. The effects of natural selection on the prevalence of the sickle-cell anaemia allele in some parts of the world could be considered.
	• know one example of natural selection (e.g. peppered moths in Britain) • understand artificial selection, with reference to one type of crop plant or animal	Artificial selection of one locally important crop plant or animal should be considered.

Opportunities for co-ordination: This section builds on an understanding of inheritance, developed in **B14**. The effects of environmental pressures on organisms are further considered in **B16**. **B17** considers the use of pesticides and links may be made here to the development of crop varieties resistant to pests and diseases and also to the evolution of pesticide resistance in pest populations.

B16: ORGANISMS IN THEIR ENVIRONMENT

Context: This section looks at the place of an organism in its environment. The idea of the ecosystem is introduced and feeding relationships of organisms within a community are considered. There is an opportunity to look at energy loss along food chains and the implications of this for human populations.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that the ecosystem is the habitat and the community considered together • know that organisms are adapted to their environment		Candidates could be given the opportunity to observe a community of plants and animals in a particular habitat. The ways in which particular animals and plants are adapted to this habitat could be considered.
• know that the growth of a population of organisms may be limited by environmental factors such as food supply or predation	• be able to interpret population growth curves with respect to one or more limiting environmental factors	Sigmoid population growth curves could be plotted, using data supplied by the teacher. Candidates aiming for higher grades could discuss possible reasons for the shape of the curve.
• understand that energy enters an ecosystem in sunlight, which is transferred to energy in plants by photosynthesis, and that this energy is then passed along food chains		A food chain or food web could be built up, possibly from candidates' own observations of the organisms in a particular habitat. The idea of energy losses along a food chain should be considered.
• know the role of producers, consumers and decomposers in food chains and webs • understand that energy losses occur along a food chain	• be able to interpret pyramids of numbers and biomass, and relate these to the loss of energy along food chains • be able to discuss the advantages of eating plant products rather than animal products, in terms of the amounts of energy available in a food chain	Candidates aiming for higher grades could consider the implication of food shortages in many parts of the world and discuss the advantages, both in terms of energy efficiency and general health, of eating plant products rather than animal products.

Opportunities for co-ordination: This section draws on ideas covered in many other biology sections, especially **B1**, **B4**, **B8** and **B13**. Energy transfer will have been introduced in **P5**.

B17: CYCLES AND THE EFFECTS OF HUMANS ON THE ENVIRONMENT

Context: This section looks at the carbon, nitrogen and water cycles. The ways in which agricultural and industrial activities may affect these cycles are considered, together with some examples of pollution. An understanding of the need for conservation and ways in which this can be achieved can help to give candidates a positive approach to their environment.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the carbon cycle • understand how deforestation and the burning of fossil fuels can increase the amount of carbon dioxide in the atmosphere, and appreciate that this may lead to global warming		The way in which the cycling of carbon, nitrogen and water maintains a balance can be discussed, together with the ways in which human activities may disrupt this balance.
• understand the nitrogen cycle, including nitrogen fixation, the importance of soil nitrates and denitrification, and why farmers may use nitrogen fertilisers	• be able to discuss the advantages and disadvantages of using nitrogen fertilisers • understand how leaching of excess nitrogen fertilisers may damage aquatic ecosystems, and suggest alternatives to the use of nitrogen fertilisers	Details of the micro-organisms involved in these cycles are **not** required, although candidates should appreciate the important roles of decomposers.
• understand the water cycle and how it may be affected by deforestation • appreciate that farmers may need to use pesticides, but that this may endanger other living organisms	• be able to discuss the advantages and disadvantages of using pesticides • know the harmful effects of one pesticide on other living organisms, and be able to discuss alternative methods of pest control, with reference to one example	The need to use fertilisers and pesticides in order to produce plentiful, cheap food should be considered, with emphasis on local examples, if appropriate. Possible harmful effects on the environment can be discussed, together with possible solutions. Emphasis should be given to the problems faced by countries where adequate food production is difficult to achieve.

B17: CYCLES AND THE EFFECTS OF HUMANS ON THE ENVIRONMENT continues on the next page

B17: CYCLES AND THE EFFECTS OF HUMANS ON THE ENVIRONMENT (continued)

• know that sulfur dioxide is produced by burning fossil fuels • understand the harmful effects of sulfur dioxide on living organisms, including the effects of acid rain		Candidates aiming for higher grades could investigate alternatives to nitrogen fertilisers and pesticides in more detail. Local examples should be used if appropriate.
• appreciate the need to conserve endangered species and their natural habitats		It may be possible for candidates to be given the opportunity to observe the conservation of a local habitat, and to consider how active management may be an essential part of conservation.

Opportunities for co-ordination: This topic brings together ideas from many other areas of the syllabus. Photosynthesis in **B4**, respiration in **B7**, the burning of fossil fuels in **C14** and the use of various energy resources in **P18**, are all relevant to the carbon cycle. Links with the nitrogen cycle will be seen in **B4**, **C10** and **C11**. **C8** considers water purification and pollution, which may be linked to a knowledge of the water cycle. Use of pesticides can be linked to **B16**. The production of sulfur dioxide from fossil fuels is dealt with in **C14** and **B5** considers possible effects of pollutants such as sulfur dioxide on the breathing system. Conservation of species and their habitats has obvious links with the extraction of metal ores from the Earth, the use of chemicals from plants, the extraction and use of petrochemicals and the use of alternative energy resources, covered in **C6**, **C4**, **C3** and **P18** respectively.

5. Curriculum content

C1: THE ELEMENTS OF CHEMISTRY

Context: The basic language of chemistry is introduced including symbols and equations. Candidates following the supplementary syllabus are also introduced to simple calculations.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate the distinction between the three states of matter, and explain how they can be interconverted in terms of the kinetic theory		The state of matter may be introduced by experiments involving heating and cooling suitable substances.
• understand the terms *element*, *compound*, *mixture*, *atom* and *molecule* • know that each element has a particular chemical symbol • be able to use symbols of elements to write formulae of simple compounds when given a list of symbols and combining powers	• know that 'amount of substance' is measured in moles • know quantitatively that 'amount of substance' has a precise meaning in chemistry	Candidates should be given the opportunity to use chemical symbols and develop word equations with state symbols for reactions involving the formation of compounds from elements. Where possible, this should be developed from experimental work (e.g. the formation of FeS or MgO). Candidates aiming for higher grades should be able to carry out calculations in moles for elements and simple compounds.
• know the relative charge and the approximate relative mass of a proton, a neutron and an electron • understand the meaning of *nucleon number* and *proton number*		

Opportunities for co-ordination: The particulate nature of matter and the kinetic theory model, which are discussed in **P2**, need to be closely co-ordinated with this topic. Many biology topics assume that candidates understand the concept of molecules and the difference between elements and compounds. The electron is taken up again in **P16** whilst details of atomic structure are in **C17**.

C2: CLASSIFYING THE ELEMENTS

Context: The idea of grouping elements according to their physical and chemical properties is introduced. The arrangement of the Periodic Table is then discussed as a way of organising the elements to make useful comparisons and predictions.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know the distinction between *metals* and *non-metals* on the basis of their physical properties, in particular, density, malleability, electrical and thermal conductivity		Throughout this section, further opportunities should be provided in the use of chemical symbols and simple word equations.
• know that elements can be arranged in groups with similar chemical properties, and may form compounds with similar chemical properties • be able to describe the trends in physical properties of the alkali metals, in particular, density, hardness and melting point • know that the reactivity of the alkali metals increases down Group I • be able to describe the trends in physical properties of the halogens, in particular, colour, physical state, density and melting point • know that the reactivity of the halogens decreases down Group VII	• be able to predict the properties of elements from their position in the Periodic Table, given relevant information, and to identify trends in other groups of elements	Patterns of physical and chemical data of elements should, as far as possible, be based on direct observation/ experimentation. Candidates aiming for higher grades could study other groups of elements (e.g. Groups III and VI and their oxides) and appreciate the differences in the elements of Group IV, as well as making predictions based on the Periodic Table.

C2: CLASSIFYING THE ELEMENTS continues on the next page

C2: CLASSIFYING THE ELEMENTS (continued)

• know that in the Periodic Table, the elements are arranged in order of proton number, and understand the terms *group* and *period* • know that some metals form oxides by reaction with oxygen • know that some metals form basic oxides, and some non-metals form acidic oxides	• understand what is meant by a *periodic pattern*, exemplified by electronic structure of atoms and melting point of elements (qualitative treatment only required)	The term *oxidation* may be introduced at this stage, and the concept of acids, alkalis and pH introduced during a discussion of acidic and basic oxides and the reaction of the alkali metals with water.

Opportunities for co-ordination: The idea of biological classification built up in topic **B1** forms a link with the grouping of elements in the Periodic Table. In **C2**, candidates may use a simple electrical circuit to test for electrical conductivity. This precedes work on electricity in **P7**. The Periodic Table is taken up in more detail in **C17** where the electronic structure of the atom is considered.

5. Curriculum content

C3: PETROCHEMICALS

Context: The topic provides opportunities to explore the importance of the petrochemical industry and introduces the ideas of distillation, polymerisation and catalysis as well as a consideration of how the properties of different sorts of molecules may be related to their size.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that crude oil (petroleum) is a mixture of hydrocarbons • know that in molecules containing carbon, the carbon atoms may be joined in chains, branched chains or rings	• understand the meaning of the terms *molecular formula* and *graphical formula* • understand how the melting and boiling points, viscosity and flammability of hydrocarbons depend on molecular size	Candidates are not expected to remember chemical formulae but they should be able to extract them from tables of data and work out a simple graphical formula of an alkane. Models can be used to represent the molecules and chemical changes in this section. Candidates should use graphs to examine how the boiling point of alkanes changes with their length.
• understand the difference between *saturated* and *unsaturated* hydrocarbons	• know that aqueous bromine can be used to distinguish between a saturated and an unsaturated hydrocarbon	
• know that alkanes are unreactive, but that alkenes have distinct chemical reactions	• know that alkanes and alkenes are members of homologous series of compounds, each member of such a series having similar properties	
• be aware of the wide range of uses of petroleum fractions for fuels, lubricants, waxes and in the synthesis of other chemicals • know the meaning of the terms *fractional distillation*, *cracking*, *polymerisation*, *polymer*, *monomer* and *catalyst* • appreciate the importance of catalysts in the petrochemical industry	• know that alkenes may be manufactured by the cracking of petroleum • know that ethanol may be formed by the catalytic addition of steam to ethene	The fractional distillation of a suitable mixture of chemicals may be demonstrated and related to the difference in boiling points of the various components. Polymerisation may be approached by using simplified models, perhaps using the linking of beads or paper clips. Experiments involving the cracking of paraffin using a catalyst of aluminium oxide could serve as an introduction to catalysis.

C3: PETROCHEMICALS continues on the next page

C3: PETROCHEMICALS (continued)

	• understand the difference between *addition* and *condensation polymerisation*, using simplified models	A demonstration of making nylon will emphasise that care needs to be taken when working with dangerous chemicals.
• know the meaning of the term *plastic*, and know how thermoplastics and thermosets behave on heating	• understand the difference between *thermoplastics* and *thermosets* in terms of weak 'between molecule' forces and cross linking	Plastics may be identified with the aid of keys, and candidates could be given the opportunity to investigate the strength or permeability of plastics. A survey of plastics may give candidates an opportunity to retrieve and present information.

Opportunities for co-ordination: Candidates are introduced to the idea of simple molecules and polymers before they cover photosynthesis in **B4** and digestion in **B9**. Catalysis is also introduced early on so that the idea can be applied to enzymes in **B9**. The identification of plastics using keys forms a link with **B1** and distillation can be linked with **P2** and the energy transfer in changing state with **P6**. There is also a link between **P18** and the refining of petroleum to form fuels.

C4: CHEMICALS FROM PLANTS

Context: The work in **C3** is extended here to include biological polymers and their simple monomers. The wide range of plant products is discussed.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that sugars, starch and cellulose are carbohydrates		For many candidates a simple bead model for polysaccharides and proteins should be sufficient, but candidates aiming for higher grades should make more complex models.
• know that carbohydrates are compounds of carbon, hydrogen and oxygen	• appreciate that bonding in carbohydrate molecules is essentially the same as in simpler carbon compounds	
• know that starch and cellulose are polymers of glucose • know that protein molecules consist of long chains of amino acids • know that amino acids are compounds of nitrogen, carbon, hydrogen and oxygen, and that some also contain sulfur		Simple tests for starch and reducing sugars allow candidates to observe changes. A knowledge of carbohydrate molecules allows candidates to interpret results of experiments to study the diffusion of molecules through membranes.
• know that cellulose and rubber are important natural polymers, and be able to name some common uses of these substances • appreciate the use of wood and other plant materials in making paper and in building, and understand the need to conserve such resources	• understand how large molecules can be separated from smaller ones by a partially permeable membrane	The properties of different types of paper could be related to its structure as seen under the microscope.

Opportunities for co-ordination: Candidates are introduced to biological polymers and their simple units early on to help with the understanding of the processes of photosynthesis in **B4**, respiration in **B7**, diet and health in **B8** and digestion in **B9**. Tests for starch and reducing sugars are linked with work in **B4**, **B8** and **B9** and dialysis has links with the function of the kidney in **B11** and the movement of molecules in **P2**. The use of wood as a resource is relevant to the conservation of species in **B17** and to the strength of solids in **B3**.

C5: MATERIALS AND STRUCTURES

Context: This section shows how the properties of materials are related to their use and how such properties can be explained in terms of structure and bonding. Molecular and covalently bonded giant structures are considered and ionic giant structures are also introduced in simple terms.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand some of the vocabulary used to describe the properties of materials (e.g. strength, elasticity, hardness, transparency, porosity, electrical and thermal conductivity and biodegradability) and the opposites of these words		Testing materials for hardness and electrical conductivity and observations of changes of state during heating provide a practical basis for understanding how properties of substances are related to their known structures.
	• appreciate that the forces holding atoms together in molecules are stronger than the forces between the molecules	Candidates should be able to determine the physical state of substances with the aid of data on melting and boiling points.
	• understand why ionic compounds only conduct when molten or when in solution • understand the distinction between molecular structures and giant structures, with the help of a limited range of examples such as water, carbon dioxide, oxygen, graphite, diamond and silicon(IV) oxide	Symbols for ions should be introduced and candidates aiming for higher grades should work out the formulae of simple salts given a table of ions. The conduction of a melt such as molten lead(II) bromide may be compared with the non-conduction of the solid.
• know that an ion is a charged particle, and many compounds of metals with non-metals are ionic giant structures • know that glass is made from silicon(IV) oxide combined with some metal oxides	• be able to deduce the formula of simple ionic compounds from the charges on their ions	Practical work involving glasses and ceramics might include moulding and working these materials. The uses of different kinds of glasses and ceramics could be discussed.
• know that common ceramic objects are made from fired clay	• understand that glass has a giant structure with a disordered arrangement of atoms	Candidates aiming for higher grades should be able to solve simple quantitative problems based on formulae and equations.
• know some advantages and disadvantages of recycling glass	• know how to carry out calculations in moles for molecules and giant structures	

Opportunities for co-ordination: The study of different materials may be linked to **P1**, where the strength of solids is discussed. The kinetic theory model developed in **P2** can be used in the supplementary syllabus to explain why ions conduct electricity in a melt. The idea of ions is introduced and the concept of charge is taken up in more detail in **P7**. Recycling of materials is also relevant to **B17**.

C6: OXIDATION AND REDUCTION

Context: Simple ideas of oxidation and reduction are developed and the importance of using a suitable reducing agent for the extraction of some metals is considered.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the terms *oxidation* and *reduction* in terms of the addition and removal of oxygen	• be able to write simple equations to describe oxidation and reduction, using both words and symbols	The heating of metals in air or oxygen and the reduction of some metal oxides could be investigated.
• know that rocks are an important source of chemicals, including metals		Locally occurring minerals could be studied, but candidates are not expected to remember names and formulae of minerals.
• understand that some minerals are relatively pure compounds • understand the names and formulae of minerals given in tables of data		Smelting of copper ore could be investigated as an introduction to the extraction of zinc or iron from their ores by the use of a reducing agent. The importance of limestone in the extraction of iron should be mentioned.
• appreciate the role of carbon in the extraction of metals from their ores	• understand that the ease of obtaining a metal from its ore is related to its position in the reactivity series	The thermite reaction may be demonstrated, to show that a more reactive element may remove oxygen from the oxide of a less reactive element.
• appreciate that economic, social and environmental issues may be involved when minerals are mined		Those aiming for higher grades could be set calculations to find the percentage of metal in an ore. Discussion of the issues involved in the responsible exploitation of resources such as limestone and iron and copper ores provides opportunities for candidates to argue the case based on technical information.

Opportunities for co-ordination: The oxidation of glucose in cells in **B7** is more complex than the simple oxidation reactions considered in this topic although the overall equation shows that the carbon in glucose has been oxidised. Energy cost in manufacture is taken up in discussion of energy resources in **P18**. The importance of the reactivity series is developed further in **C15** and the effect of quarrying on the environment forms a link with **B17** where conservation of habitat is considered.

C7: IONS AND ELECTROLYSIS

Context: Electrolysis is introduced as a method of splitting up compounds and extracting reactive elements. Some more ionic compounds are introduced and the economic importance of chemicals made from salt discussed.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that electrolysis can be used to split up compounds • know the meaning of the terms *electrode*, *electrolyte*, *anode* and *cathode*	• know that reactive metals are extracted by electrolysis	The case of aluminium could be used as an example of a metal extracted by electrolysis.
• be able to describe the effect of chlorine on damp litmus paper (see also *Notes for use in Qualitative Analysis*) • be able to test for hydrogen (lighted splint) and oxygen (glowing splint)	• know that metals or hydrogen are produced at the cathode, and non-metals other than hydrogen are produced at the anode, during electrolysis of concentrated solutions of ionic compounds • understand the need for ionic mobility in electrolysis	Candidates should be given the opportunity to observe changes during electrolysis, and to test for hydrogen and oxygen during the electrolysis of acidified water, and for chlorine during the electrolysis of concentrated salt solution. The results of electrolysis experiments provide opportunities to look for patterns and make predictions.
• understand the economic importance of salt, and be aware of the need for alkali, chlorine and hydrogen made from this raw material		Diagrams and photographs could be used to show the manufacture of sodium hydroxide, sodium carbonate and chlorine. Candidates should be given the opportunity to make a sample of pure salt from rock salt using techniques of dissolving, filtration and evaporation.
• know that electrolysis can be used to purify metals		An article could be plated with copper or another metal by electrolysis.

Opportunities for co-ordination: The idea of ions as electrically charged atoms builds upon the understanding of electric charge developed in **P7** and on the simple ideas of ionic giant structures in **C5**. The importance of ions for plant growth is considered in **B17** and in relation to fertilisers in **C11**. Ionising radiation is mentioned in **P17**. The energy cost of manufacturing aluminium forms a link with energy resources in **P18** and using electricity in **P7**.

C8: SOLVENTS AND SOLUTIONS

Context: Water treatment and a study of hard water is used to amplify the chemistry of solutions. The use of detergents and non-aqueous solvents for cleaning leads to a general discussion of water pollution.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the problems involved in obtaining an adequate supply of pure water		The problem of supply of pure water should be put in its local context.
• understand the processes involved in purifying water, in terms of filtration and chlorination • know that some substances are more soluble in water than others • know the test for chloride ions using acidified silver nitrate solution • know the test for sulfate ions using acidified barium nitrate solution	• understand the measurement of concentrations in moles per dm^3	This section provides practice in the use of chemical symbols and equations. Those aiming for higher grades should be able to use symbols for ions to explain what happens during precipitation reactions in terms of the solubility of substances (e.g. the addition of OH^- ions to aqueous salt solutions). The concept of amount of substance should be extended to cover the measurement of concentrations in moles per dm^3 for those aiming for higher grades.
• know that hardness is caused by the presence of dissolved calcium or magnesium compounds, and be familiar with the behaviour of soap in hard and soft water	• understand equations which describe hard water, scale formation and water softening processes	
• understand how boiling and scale removers help to soften water • know that non-aqueous solvents may be used in cleaning	• understand how the process of ion exchange can be used to soften water • know that ionic compounds dissolve in water and molecular compounds usually dissolve in non-aqueous solvents	Candidates should have the opportunity to plan and carry out experiments on hard and soft water, and perhaps compare the efficiency of different methods of cleaning.
• know that detergents are needed to help get things clean • know some of the domestic, industrial and agricultural sources of water pollution	• understand a simple molecular explanation of the action of detergents	The idea of specific analytical tests could be developed by using test sticks to analyse water in the locality (e.g. testing for nitrates).

Opportunities for co-ordination: The topic of solubility and solutions occurs frequently in biology. Diffusion in **B2**, transport systems in **B6**, digestion in **B9** and homeostasis in **B11** all require a background appreciation of solubility. The water cycle is considered in **B17** and aspects of water pollution considered in **C8** are also relevant to this topic. The use of detergents provides a link between this section and colloids in **C13**. Problems of scale due to hard water may be linked to the efficiency of energy transfer in **P18**.

C9: ACIDS AND ALKALIS

Context: The general properties of acids are considered and the process of salt formation by reaction of an acid with a base developed. Wherever possible, this is put in an everyday context with which the candidates may be familiar. The idea that energy changes may be involved when chemicals react is introduced.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know the properties of acids with regard to their reactions with metals, bases and carbonates • know the test for carbonate ions using dilute hydrochloric acid and limewater		This section could be developed in the context of acids and alkalis in everyday use (e.g. lime, vinegar and antacid tablets).
• be able to describe solutions as acidic, alkaline or neutral in terms of the pH scale	• be able to suggest a method of making a named salt from suitable starting materials	A comparative investigation of the reactions of acids should enable candidates to draw out chemical patterns.
• know that salts are formed when acids are neutralised by alkalis • know the meaning of the term *exothermic reaction*, and that when acids react with alkalis the temperature of the solution increases	• understand that during neutralisation reactions, hydrogen ions combine with hydroxide ions to form water molecules • be able to write simple balanced equations for salt formation, and appreciate that it is possible to calculate the amount of alkali required to neutralise an acid using the mole concept	Candidates should gain experience of the preparative techniques of filtration, evaporation and crystallisation by making a salt. The technique of titration using simple apparatus provides an opportunity for candidates to learn to measure masses and volumes accurately.
• know the meaning of the word *antacid*		For higher grades, calculations based on reactions involved in salt formation provide further practice in using symbols and equations.
• know that lime can be used to neutralise industrial waste		Energy changes occurring on neutralisation could be measured using a suitably insulated vessel. For higher grades, the results could be calculated per mole of acid.

Opportunities for co-ordination: The hydrogencarbonate indicator used in **B4** and **B5** in gas exchange reactions forms a link with the acid/base indicators used in titrations. The concept of acidity is used in the discussion of acid rain in **B17** and for candidates following the extended curriculum, the effect of pH on enzyme activity is considered in **B9**. Mineral salts are mentioned in B6 and the effect of pH on the availability of ions for plant growth developed in **C10**.

C10: SOIL, ROCKS AND RATES

Context: A consideration of the natural processes leading to soil formation leads to a discussion of the factors which affect the rate of reaction, including catalysts. The importance of limestone products is considered and the effect of pH on the availability of ions for plant growth investigated.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that rocks may be classified as sedimentary, igneous or metamorphic • know that geological time scales are very long compared to human lifetimes • know that weathering of rocks is the result of both physical and chemical changes, and that soil is formed from both rocks and organic material • be able to describe at least one example in each case of physical, biological and chemical weathering of rock		Keys could be used to classify rocks and minerals. Wherever possible the samples used should be those found in the locality. The weathering of rocks could be developed by investigations involving heating, cooling and abrasion. Candidates could undertake a survey of local soils, using a simple soil test kit, and a sedimentation test could be used to compare the composition of different soils.
• know that lime can be manufactured by the decomposition of limestone, and can be used to treat acidic soils • know that weathering of rock releases salts into the soil which plants need for growth • understand the importance of controlling soil acidity • understand that concentration, temperature and surface area are factors which affect the speeds of chemical reactions • be able to describe tests for oxygen, hydrogen and carbon dioxide	• understand the role of limestone in the extraction of iron • be able to interpret data from reaction rate experiments • understand the factors affecting reaction rate in terms of the frequency of reactive collision between particles	Photographs and diagrams could help in discussing the manufacture of products obtained from limestone. This section also provides further opportunities to use equations and for practical work involving neutralisation of acids with lime. The reaction of marble chips with acid could be used to introduce techniques for studying the speed of a reaction. Candidates could plan their own investigations into the factors affecting speeds of reaction. The effect of a catalyst on speed of reaction could be developed, by demonstrating the effect of MnO_2 on the decomposition of aqueous hydrogen peroxide. (*Notes for use in Qualitative Analysis* are reproduced in the question paper for the Practical Test.)

Opportunities for co-ordination: The classification of minerals forms a link with the classification process carried out in **B1**. The uptake of minerals by plants is considered in **B6** and there are also links with soil nitrates/denitrification in **B17**. Solubility of salts relates back to work on solutions in **C8**. The effect of temperature and catalysts on rates of reaction forms a link with **B9** where the effect of temperature on enzyme catalysed reactions is considered.

C11: FERTILISERS

Context: The value of fertilisers in agriculture and some of the chemistry of their manufacture is considered. The topic should be placed not only in the context of the social and environmental issues involved with the use of fertilisers but also in terms of the scientific and engineering problems associated with their manufacture.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that ammonia is an alkaline gas • know the effect of ammonia on damp litmus paper (see *Notes for use in Qualitative Analysis*)	• be able to distinguish between ammonia and ammonium salts	This section allows candidates to interpret information presented in the form of tables and charts, and provides further experience in the use of formulae. The properties of ammonia (solubility, alkaline character and reaction with acids) may be demonstrated. A practical approach may be adopted by allowing candidates to make a fertiliser, such as ammonium phosphate or ammonium nitrate, and to cost the process. This gives further experience of the techniques of filtration, evaporation, etc.
• know that fertilisers contain inorganic ions which supply plants with elements they need, including nitrogen, phosphorus and potassium • know the test for the ammonium ion by warming with sodium hydroxide solution • know the test for the nitrate ion by reduction with aluminium	• understand equations which describe the chemical changes involved in the manufacture of ammonia, nitric acid and sulfuric acid	
• know the meaning of the term *nitrogen fixation*, and appreciate that the chemical basis of the nitrogen problem is the inert nature of gaseous nitrogen	• understand the effect of catalysts in the synthesis of ammonia, nitric and sulfuric acids	
	• know that leaching of nitrates from the soil is a problem, while leaching of phosphates and potassium salts is not	Candidates should be able to interpret graphs and tables related to the manufacture of ammonia and nitric acid. For higher grades, candidates should be encouraged to apply their chemical knowledge of catalysis and rates of reaction to these processes. The relative insolubility of phosphate salts, compared with the solubility of nitrates, could be investigated with references to simple precipitation reactions.

Opportunities for co-ordination: This topic complements **B17** where nitrogen fixation, denitrification and the effect of fertilisers are investigated. There is also a link with salt formation in **C9** and solubility in **C8**.

C12: DYES AND DRUGS

Context: Dyes and drugs are selected as two examples of the wide range of useful products which can be obtained from plants. This topic is used as a vehicle for practical investigations and an appreciation of how chemicals or chemical processes can be modified to make them more effective.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that many natural dyes may be obtained from plants, and that modern dyes are synthetic • know that natural colouring matter, such as chlorophyll, may be separated by the technique of paper chromatography • know the meaning of the terms *drug*, *analgesic* and *chemotherapy* • know that drugs are often discovered as a result of studying chemicals from plants • know the importance of purity in food and drugs	• know that the melting and the boiling point of a substance are affected by impurities	Investigations into the dyeing of fabrics could be based on locally available plant materials. Dyeing with indigo brings in ideas of oxidation and reduction. Fastness of dyes could be discussed as well as mordanting. Opportunities could be provided for candidates to carry out experiments to test for fastness. Paper chromatography could be used to separate mixtures of dyes, including plant pigments. Aspirin could be used as an example to show how drugs can be discovered in plants and modified to make them more effective. Problems of drug abuse could also be mentioned. For higher grades, candidates could investigate the effect of salt on the freezing point of water.

Opportunities for co-ordination: The manufacture of products derived from plants forms a link with the use of cloning techniques and genetic engineering in **B14**. Chlorophyll, mentioned in relation to photosynthesis in **B4**, can be separated from other plant pigments using the method of paper chromatography.

C13: COLLOIDS

Context: This topic focuses on a variety of colloidal systems and stresses their importance in everyday life.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that a colloid consists of one substance finely dispersed in another, and know the meaning of the words *sol*, *gel* and *emulsion*		Investigations on light scattering, Brownian motion and (for higher grades) the effect of adding ions to coagulate colloidal particles should give candidates a chance to observe the behaviour of colloids.
• know that colloidal systems are not transparent	• understand that colloidal systems are not transparent because they scatter light rays	Examples of the colloidal states which are familiar to candidates should be chosen wherever possible (e.g. smoke, mist, paint, milk, creams).
• appreciate the purpose of emulsifiers	• understand, in simple terms, the action of emulsifiers	Making an emulsion such as a cream used as a base for cosmetics or medical preparations introduces one of the practical techniques used to prepare colloids.

Opportunities for co-ordination: The word particle, first encountered in **P2**, is used here to indicate a speck of matter rather than an atom or a molecule. Other areas of co-ordination with **P2** concern the properties of mists and other colloidal material where particles are in motion and an explanation of Brownian motion using the kinetic theory model. Other areas involving materials with colloidal properties include cigarette smoke in **B5**, blood plasma in **B6** and **B11** and enzymes in **B9**.

C14: FUELS

Context: This topic describes the importance of fossil fuels and the products of burning and includes aspects of energy transfer. This leads on to a discussion of the impact that burning fuels has on the environment and the ways of controlling different classes of fires.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand burning in terms of the fire triangle, and know that carbon dioxide and water are among the products of burning hydrocarbon fuels	• know that some finely powdered substances may explode when ignited because their high surface area causes very high reaction rate	Candidates could investigate the products formed when fuels burn.
• be aware of the use of oxygen in welding and in medicine • understand what is meant by the term *fossil fuel*		This section provides practice in the skill of interpreting information presented in the form of graphs and tables, including those related to world and local fuel reserves.
• know some examples of solid, liquid and gaseous fuels, and be able to give examples of their use • know that methane obtained by decay of waste materials may be used as a fuel • know the terms *exothermic reaction* and *endothermic reaction*		By measuring the energy transferred when fuels burn, candidates can be given the opportunity to comment critically on the apparatus used. A comparison of the properties of fuels should bring out the criteria for judging a fuel, including its cost.
• know that carbon monoxide and lead compounds are also atmospheric pollutants		Pollution caused by burning fuels should be discussed, using local examples wherever possible.
• know that the oxides of some nonmetals, such as sulfur and nitrogen, are acidic and may cause pollution • know some of the environmental issues that arise from the use of fossil fuels, such as the adverse effect on buildings, trees and health	• appreciate that there are ways of reducing the emission of pollutants • understand that pollutants in the exhaust gas from vehicles may be cut down by the use of catalytic converters	

Opportunities for co-ordination: The importance of fats and carbohydrates as fuels in the body is considered in B8 and there are obvious links with respiration in **B7**. The carbon cycle and the environmental effect of burning fuels are taken up again in **B17**. The measurement of energy transfer from fuels and specific heat capacity first developed in **P6** is further extended here. There are also links back to P5 where transferring energy to do useful jobs is considered and forward to P18 where energy resources are dealt with on a global scale.

C15: BATTERIES

Context: The reactivity series is used as an introduction to electrochemical cells. The study is widened to encompass a variety of cells including fuel cells. Corrosion and its prevention are also investigated.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that metals can be placed in order of their reactivity by reference to reaction with water/steam or dilute acid • know that a cell consists of two different electrodes dipping into an electrolyte solution	• know that the reactivity of metals is related to the ease with which they form ions	Investigation on the reactivity of metals with acids and the displacement of metals from their salts involves candidates in pattern searching exercises.
• know that changing the electrodes changes the cell voltage • understand that there is a limit to the life of a simple cell, because one or more of the reactants is eventually used up	• know that the voltage of a cell with two metal electrodes can be related to the position of the metals in the activity series	Investigations with cells provide candidates with a practical opportunity to use voltmeters and set up circuits. Candidates could design a suitable cell for themselves, and take into account factors such as cost, convenience etc.
• appreciate some of the cost and convenience factors which dictate the choice of cells for particular purposes	• understand, in principle, the differences between simple cells, rechargeable cells and fuel cells	
• know that rusting involves a reaction of iron with air and water • be able to give an account of methods of rust prevention, and appreciate the advantages and disadvantages of alternative methods of rust prevention		Investigation into rusting and suggested methods of preventing corrosion requires accurate observations of the changes in corrosion indicators. It also provides opportunities to plan investigations. Anodizing of aluminium could be used as an example of preventing corrosion of this metal.

Opportunities for co-ordination: This topic examines the way that electrochemical cells are constructed. The transfer of electricity consequent of the chemical reaction is dealt with in terms of energy transfer in **P8** and in terms of electrons in **P16**. Batteries may be considered to be ways of distributing small amounts of energy and in this context form a link with **P18**.

C16: METALS AND ALLOYS

Context: This section seeks to explain the connection between the properties of metals and alloys and their uses, by making use of a simplified model of a metal giant structure.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know some of the properties of common metals and alloys	• be able to describe the metallic bond using the 'sea of electrons' model to account for malleability and electrical conductivity of metals	Studying a model of a metal crystal provides opportunities to work out what the model can explain and to examine its limitations.
• understand that metals have giant structures		Candidates should be encouraged to look for patterns in the properties of metals, and to explore the connection between these properties and the use of the metal.
• know that the transition elements are metals with high densities and high boiling points which form coloured compounds • know that alloys are mixtures of metals	• understand, in terms of the difference in atomic size, why the malleability of an alloy of two metals is different from either of the pure metals used to make it	The ability of transition metals or their ions to act as catalysts forms a link with **C11**. An investigation of the action of metal ions on the decomposition of hydrogen peroxide gives candidates practical experience of collecting and measuring gases.
• know that alloys are made by mixing molten metals • know that alloys may also contain non-metals, as exemplified by carbon in most types of steel know that some metal cations can be identified by characteristic flame colours, and this can be used as a basis for chemical analysis • know the characteristic flame colours for sodium, copper, calcium and potassium • know the tests for aqueous copper(II), iron(II), iron(III) and zinc, using aqueous sodium hydroxide and aqueous ammonia	• be able to use the mole concept to describe the amounts of metals in an alloy	

Opportunities for co-ordination: An appreciation of the relative strength of different metals links this topic with **P1** where the strength of solids is considered. Electrical conductivity of metals refers back to **C2** and **P7** whereas the production of electrons from a heated wire has already been dealt with in **P16**. Flame tests may also be related to work on spectra in **P11**. The catalysis of the decomposition of hydrogen peroxide by transition metal ions has analogies with the action of catalase in **B9**.

5. Curriculum content

C17: ATOMS, BONDING AND THE PERIODIC TABLE

Context: This section draws together ideas from many sections of the syllabus and develops further the Periodic Table to give an indication of the ways chemists use theories to rationalise their knowledge. Ideas are developed about atoms, molecules and ions by consideration of their electronic structure. Much of the work on electronic structure is for candidates following the extended curriculum.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that there is a relationship between the group number and the number of outer electrons	• know that the electrons in an atom are arranged in a series of shells • understand how the arrangement of elements in the Periodic Table can be explained in terms of atomic structure • understand the significance of the noble gas electronic structure	This section provides an opportunity for candidates to draw together their knowledge of the structures of simple compounds and relate them to the position of the elements in the Periodic Table. There are opportunities to analyse patterns related to the Periodic Table by reference to tables of data (e.g. melting and boiling points).
• know that ions are formed by gain or loss of electrons		
• know that the term *covalent bond* refers to a shared pair of electrons between two atoms	• understand the meaning of the term *isotopes* in terms of atomic structure • know that molecules are formed by sharing pairs of electrons, and appreciate that the number of bonds formed by an atom in a molecule can be explained in terms of atomic structure	In addition, for higher grades, candidates should represent atomic structures with symbols showing nucleon number and proton number and, with the aid of relevant data, use dot and cross diagrams to describe what happens when atoms bond together.
	• understand, with reference to simple examples, how atoms turn into ions and ions into atoms during electrolysis	Candidates will benefit from understanding the problems faced by Mendeleev and other scientists involved in classifying and arranging elements.

Opportunities for co-ordination: This section builds on the ideas about the simplified structure of the atom established in **C1** and links with work on electrons and ions in **P16** and **P17**. The term 'isotopes' is also relevant to **P17**.

5. Curriculum content

P1: THE STRENGTH OF SOLIDS

Context: This section is centred around an investigation into any local, familiar structures, such as bridges. The investigation leads on to a study of forces in equilibrium, the behaviour of springs and ideas about stiffness. Candidates who follow the extended curriculum also investigate the vector nature of forces.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that there is a relationship between the extension of a spring and the force applied to it • understand that the strength of solids derives from the forces between their constituent atoms and molecules	• be able to calculate the turning effect (moment) of a force	The relationship between forces and spring extension and the turning effect of forces provide good opportunities for individual practical work. The relationship between force and spring extension also provides an opportunity for developing skills in plotting graphs.
• appreciate the spring-like nature of these forces by comparing the behaviour of materials under tension and compression with the behaviour of springs		The turning effect of forces is introduced in this section. It again forms a good opportunity for individual practical work, using simple equipment. The turning effect of forces will be used again in **P5** when machines are investigated.
• understand that equal and opposite forces acting on the same body may have a turning effect • appreciate that the choice of materials for a particular use depends upon the materials' properties	• know that for a body in equilibrium both forces and their turning effects must balance • understand the difference between vector and scalar quantities • be able to add two vector quantities by graphical representation to produce a resultant	

Opportunities for co-ordination: The study of materials is taken up again in **C5**. Plants and animals rely on the stiffness of tubular structures and the elasticity of muscles and this is taken up in **B3**. The turning effect of forces is also of importance in the study of support and movement in **B3**.

5. Curriculum content

P2: PARTICLES IN MOTION

Context: The kinetic theory and the assumption that there are forces between atoms and molecules, together present a theory which enables many of the properties of liquids and gases to be understood, as well as the operation of aerosol sprays, refrigerators and diesel engines.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the meaning of the phrase *kinetic theory of matter* as describing a model for matter in terms of particles (atoms and molecules) in motion • appreciate that there is a connection between the temperature of an object and the movement of its particles • appreciate that the three states of matter can be understood in terms of inter-molecular and inter-atomic forces and the motion of the atoms and molecules	• know the relationship between pressure and temperature for a gas, and understand how this leads to the Kelvin scale of temperature	It is helpful, if at all possible, to develop work on the kinetic theory as a solution to a problem that candidates can understand. In the original (Nuffield) course, this was the problem of how a pressure cooker can cook food more quickly. However, such an application might be quite unreal to many candidates, so some other choice might be better. The aim is to make the kinetic theory a necessity in order to solve a readily understood problem, rather than a seemingly abstract theory with no application.
• be able to describe an experiment to determine the density of a liquid and of a regularly shaped solid and know that *density = mass/volume*	• be able to use and describe the displacement method to find the density of an irregularly shaped solid	

P2: PARTICLES IN MOTION continues on the next page

P2: PARTICLES IN MOTION (continued)

• be able to describe the process of evaporation in terms of the kinetic theory • know the relationship between the pressure and volume of a gas, and understand how the relationship may be predicted by the kinetic theory • be able to describe qualitatively the effect of a change in temperature on the volume of a gas		Experimental work is difficult to carry out without specifically designed equipment. Apparatus manufacturers produce equipment that can be used to demonstrate the way the pressure of a gas changes with volume and temperature. However, the basic ideas behind the kinetic theory can be easily understood using nothing more than a tray and some marbles. If the equipment is available, experiments in this section give useful opportunities for graph plotting. Even if equipment is not available, candidates can plot graphs of pressure against volume and pressure against temperature using 'second-hand' readings. The kinetic theory is one of the few opportunities candidates have in elementary physics to explore a theory and see how it can explain a large number of observable events.

Opportunities for co-ordination: The treatment of atoms and molecules (often referred to as 'particles' in physics) needs to be closely co-ordinated with work in chemistry. The distinction between atoms and molecules is important in chemistry and the distinction between the two is made in **C1**. However, the properties of solids, liquids and gases do not require this distinction to be made. A term covering both 'atom' and 'molecule' is needed and for this reason the commonly used word 'particle' has been retained. The same word is also used to mean a 'speck of matter', as in the phrase 'smoke particle'. It is also used in chemistry in this sense when dealing with colloids (see **C3**).

Other areas of co-ordination are the properties of mists and foams in **C13** and evaporation and cooling in **B11**. The kinetic theory is further refined in **P6**, when ideas of energy transfer are explicitly introduced.

P3: MOTION

Context: Work on speed and acceleration can be made relevant by applying the ideas to transport, for example cars. In so doing, candidates can be encouraged to discuss aspects of safety in relation to high speeds and high accelerations.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the meaning of the terms *speed* and *acceleration* • appreciate the existence of errors in measurements, and understand how these may be reduced by taking the average of a number of readings	• understand how distances travelled can be derived from the area under a speed-time graph	The measurement of time is one of the main themes of this section of work. Candidates can use hand-held clocks and automatic timing devices. An interesting task is for candidates to try to make their own timing device using whatever material is to hand.
• understand the relationships between distance, time, speed and acceleration, and appreciate how graphs may be used to display these relationships	• know and be able to use the relationships $v = at$ and $s = ½ at^2$ when applied to an object accelerating uniformly from rest	Candidates should be given opportunities to measure speeds for themselves, by timing a moving object over a measured distance. Laboratory measurements invariably involve short time intervals, so automatic-timing techniques can be introduced.
• appreciate how the ideas of speed and acceleration can be applied to transport (e.g. road, rail etc.)	• understand the difference between *speed* and *velocity* • appreciate that a body may accelerate by change in velocity, but without a change in speed	Using hand-held clocks, there will be quite a lot of variation within the results obtained by a group of candidates timing the same moving object. This can lead to the importance of repeated readings, and the way that many results can be averaged to produce a more accurate answer. Candidates following the extended curriculum can use the formula $s = ½ at^2$ to measure the acceleration of a trolley (small wheeled vehicle) running down a sloping board (runway). They can investigate the way the acceleration varies with the slope of the runway. Work on distance, time, speed and acceleration gives many opportunities for graph plotting and for learning to interpret graphs.

Opportunities for co-ordination: There are few links in this section with work in biology and chemistry, but it is a useful section for learning to make accurate measurements – something of importance to all science. There are also several opportunities to link with mathematics – particularly in the use and plotting of graphs.

P4: FORCE AND MOTION

Context: This section is centred around the problem of changing and maintaining motion. Everyday observations seem to point to the fact that both changing and maintaining motion need a force. Experiments show however that only changing motion requires a force to act. Forces are used to maintain motion in everyday life because of the need to overcome friction. Candidates studying the extended curriculum go on to investigate the relationship between force, mass and acceleration, summarised in Newton's Second Law of Motion.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that force is measured in newtons • understand that unbalanced forces change motion and that, in the absence of an unbalanced force, an object will either remain at rest or travel with a constant velocity	• know the relationship between force, mass and acceleration given by the equation $F = ma$ • be able to use the relationship $F = ma$ in simple problems	Work on the relationship between force and motion gives a good opportunity for an experimental investigation by candidates using simple equipment. The effects of friction can be investigated with little more than blocks of wood and some means of measuring a pulling force on them. More sophisticated equipment is needed (such as linear air track) if friction-free motion is to be demonstrated.
• appreciate that friction often provides an opposing force acting on moving bodies • appreciate qualitatively that the acceleration of a body depends both on its mass and on the size of the unbalanced force acting on it		More advanced candidates may benefit from hearing about (and seeing) Galileo's original argument using inclined planes to support his view that in the absence of friction, motion, once started, continues indefinitely. This is also a good opportunity for exploring alternative theories in physics; does steady motion need a force or will motion continue unchanged if no force acts? Candidates following the extended curriculum will also benefit from doing experiments to show the way the acceleration of an object depends on its mass and the size of the force acting.

Opportunities for co-ordination: The study of friction and the factors which affect its size have some direct application in biology. **B3** is concerned with support and movement and gives some attention to reducing friction in joints.

P5: ENERGY TRANSFER

Context: The concepts of energy, power and efficiency are developed within the context of everyday usage. Machines are seen as devices which make energy transfers easier to carry out, while engines are devices for transferring the energy locked up in fuels and other natural sources of energy.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate that when change takes place, energy is transferred • know that work, measured as *force × distance moved*, is a measure of energy transfer	• appreciate that heat engines cannot function without transferring substantial amounts of energy to the surroundings	The underlying approach to energy adopted in this syllabus is described in *Figure 2: Energy co-ordination*. Work is introduced as a means of measuring an energy transfer.
• understand that liquids can be used to send forces where they are required • know that pressure is related to the size of the force and the area over which the force acts • know and be able to use the relationship *pressure = force/area* • understand that power is the rate at which energy is transferred	• know that hydraulic systems are force multipliers, and describe everyday applications of hydraulic systems (car braking systems and hydraulic jacks)	
• appreciate that there is an energy cost in making this happen • appreciate that machines are devices enabling the transfer of energy, but that the energy cost of doing a job is still at least the same as if the job were to be done without the help of a machine (and will certainly be greater than that) • understand that engines are devices for transferring energy from fuels to enable force-using jobs to be done • appreciate that the use of machines and engines always means some wastage of energy		No attempt is made in this section to suggest that energy is conserved. Instead, it builds on the everyday view that energy is used up – it is the 'cost' of getting things done. Machines are ways of making the transfer of energy easier – but nearly always at a greater energy cost. The lever, thought of as a machine, recalls ideas about the turning effect of forces (see **P1**). Engines are devices that can transfer energy from fuels to do other things. In both cases, energy is wasted heating up the surroundings. Candidates will gain much greater familiarity with these ideas if they can get practical experience in measuring energy and power transfers, and get experience of a range of different machines and engines.

Opportunities for co-ordination: Ideas about energy, established in this section, are used throughout work in biology and chemistry as well as in later work in physics. Use of fuels as an energy resource is taken up in **C4**.

The idea that the human body can in some ways be treated as an engine is developed fully in **B7**.

P6: TRANSFERRING ENERGY BY HEATING

Context: The relationship between 'heating things' and energy transfer is fundamental to the concept of energy conservation. Once it is understood that rise in temperature and change of state are simply a sign of an energy transfer then the idea that energy is conserved when transferred can be understood.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand that 'heating' is a mode of energy transfer • know the meaning of the terms *conduction*, *convection* and *radiation* • appreciate that, unlike work, heating as a mode of energy transfer is not measured directly, but in terms of the rise in temperature it can produce • appreciate that energy may be transferred to a substance in changing it from solid to liquid or liquid to gas without raising its temperature		Candidates will already be aware how rise in temperature and change of state can be understood in terms of the kinetic theory (**P2**). Rise in temperature can now be revised in terms of the increasing energy of motion of the particles that make up matter. Change of state, on the other hand, can be understood in terms of the work that must be done to overcome the attractive forces between the particles.
• understand the meaning of the term *specific heat capacity*	• know and be able to make simple calculations using the relationship: *energy transferred (J) = mass (kg) × specific heat capacity (J/kg °C) × temperature rise (°C)*	Experimental work using the particle models of **P2** will help establish many of the ideas in this section.
• understand the meaning and implications of the phrase *conservation of energy*	• be able to apply the concept of energy conservation in a variety of energy transfer processes	Simple laboratory equipment also exists for transferring mechanical work to warm up an object. Measurements of the work done and consequent rise in temperature enable the specific heat capacity (in joules/kg °C) to be determined. The relationship between energy transferred, mass, specific heat capacity and temperature rise can be established easily using small electric heaters, water and a thermometer.

Opportunities for co-ordination: The relationship between energy transfer and rise in temperature is of importance throughout biology (see **B7** and **B11**). Chemistry also makes use of the relationship between rise in temperature and energy transfer. It can be used explicitly in **C4** to measure the energy that can be transferred from fuels.

5. Curriculum content

P7: USING ELECTRICITY

Context: This first section on electricity is concerned with the concept of electric current and the way it can be used to transfer energy. Ideas about electric circuits and electric charge arise from this. The work is developed within the context of the safe use of electricity in the home.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate the need for a complete circuit when making use of electricity • appreciate that energy can be transferred by an electric current, and that the current can be read by an ammeter • be able to explain how ammeters are used in circuits and what they measure • be aware of the dangers of electricity and state the hazards of poor insulation, overloading and damp conditions • know that an electric current is a flow of electric charge • know that electric charge is measured in coulombs, and that a flow rate of one coulomb per second is called one ampere • appreciate that electric charge produced by friction is the same charge which, moving around a circuit, produces an electric current	• understand that the readings on ammeters in simple and branching circuits conform to the idea that the behaviour of electricity in a circuit is analogous to the behaviour of, for example, currents of liquids in pipes	The approach adopted depends very much on the background of the candidates. If the use of electrical appliances in the home is commonplace, one approach is to make a study of the labels attached to such appliances. These labels almost always carry information about the power of the appliance. Measurement of the current passed by appliances of different power but the same voltage will show that the higher the power, the higher the ammeter reading. This can be interpreted as a faster flow of electric charge (higher current) and so a faster transfer of energy. Candidates not so familiar with domestic appliances may benefit from experiments with simple circuits, measuring currents using ammeters, before discussing just what it is that the ammeters are measuring. Either approach will lead on to electric current as a flow of charge and some simple electrostatics. The work can end by linking electrostatic charge to the charge flowing round an electric circuit. Candidates following the extended curriculum can add to their understanding by carrying out experiments with branching circuits.

Opportunities for co-ordination: An understanding of the properties of electric charge is important for understanding the special properties of ions as electrically charged atoms in chemistry (see **C7**). The concept of ions and of ionisation is picked up again in **P17** 'Radioactivity'.

P8: ENERGY AND ELECTRICITY

Context: This section considers the energy which an electric current can transfer. The context is again the vast range of electrical machinery – both industrial and domestic. Once the concept of 'voltage' (electric potential difference) has been established, electric resistance is introduced as the link between current and voltage.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• be able to apply the idea of voltage numerically to circuits containing more than one component, and apply correctly the term *potential difference*	• know that a potential difference of one volt is equivalent to an energy difference of one joule per coulomb of charge	Two lamps – one designed for a high voltage ('mains') supply and the other designed for a dry cell – may pass the same current, but will differ in their brightness and power.
• understand that the 'voltage' of an electrical supply is a measure of the energy it can transfer from an electrical supply elsewhere, and that it can be measured with a voltmeter		Such an observation can serve as the basis for an understanding of 'voltage' as the joules per coulomb available from the source of electric power.
• be able to explain how voltmeters are used in circuits and what they measure • know and be able to use the relationship *power = voltage × current*		The term 'electric potential difference' is more readily applied to the energy transfer per coulomb by a particular circuit component (lamp, resistor, etc.).
• understand the meaning of the term *electrical resistance* and know that *the resistance of a component (in ohms) = voltage across component/current through component*	• appreciate the experimental evidence leading to Ohm's Law	
• be able to work out the combined resistance of two resistors in series	• be able to work out the combined resistance of two resistors in parallel	Such a development of concepts will be helped by practical experience in the measurement of electric potential difference in a variety of circuits, using voltmeters.

P8: ENERGY AND ELECTRICITY continues on the next page

P8: ENERGY AND ELECTRICITY (continued)

• appreciate the factors affecting the resistance of a component: length of wire, temperature of wire and cross section of wire		Electric resistance is introduced as a property of a conductor, regardless of whether or not the current through it is proportional to the p.d. across it. The work in this section can be further enhanced by some investigations into the behaviour of electrical devices. Candidates could, for example, carry out an investigation into the efficiency of a small electrical motor, by measuring its input and output power under different conditions They could also investigate the design of an electrical appliance, such as an electric fire, working out the resistance and consequent dimensions of the wire.

Opportunities for co-ordination: The work on energy and electricity is continued in C15 'Batteries'. This section examines the way electric cells are constructed so that they can transfer electricity as a consequence of chemical reactions.

5. Curriculum content

P9: WAVES

Context: This section provides the necessary background for interpreting light and sound as a wave motion.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand that a wave is a means of transferring energy without transferring matter • understand that energy is transferred in the direction in which the wave travels	• know the meaning of the term *wavefront*	The basic properties of wave motion can most easily be established by doing experiments with long springs (often called 'slinkies'). In the absence of these, long rubber tubing filled with sand, or even a heavy rope, make a suitable substitute.
• know the meaning of the terms *wavelength*, *amplitude*, *frequency* and *wave speed*	• know and be able to use the equation *wave speed* = *wavelength* × *frequency* in simple applications	The difference between transverse and longitudinal waves can only be shown using springs.
• be able to distinguish between *transverse* and *longitudinal waves*, and appreciate the circumstances in which either or both might occur		The properties of refraction and reflection off plane barriers are best demonstrated using water waves in a ripple tank. Even better, candidates can do the experiments for themselves.
• appreciate the way a wave can be reflected off a plane barrier • appreciate the way in which a wave can change direction as its speed changes		

Opportunities for co-ordination: Care may be needed in the use of the term 'pulse' in this section. 'Wave pulse' is the term applied to a single up-and-down (or to-and-fro) motion of the wave travelling along the medium. The term 'pulse' is also used in biology (e.g. **B6** 'Transport Systems'). While superficially the two uses may appear to be the same, a wave pulse is simply a transfer of energy, with no transfer of matter. A heart pulse actually pushes blood around the body (i.e. matter is transferred).

P10: LIGHT AND SOUND

Context: The basic properties of light and sound are likely to have been covered before candidates start on this IGCSE Co-ordinated Sciences syllabus. The two applications of optical fibres and noise give a context within which the basic properties of light and sound can be applied and thus revised. Optical fibres are becoming increasingly important in applications ranging from medicine to communications.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the basic properties of reflection and refraction, as they apply to light and sound		The way light can be uniformly reflected from a mirror and refracted when passing into another, transparent, medium such as glass can easily be investigated experimentally.
• understand how the refraction of light by a lens can lead to the formation of real images • appreciate how reflection and refraction properties can be applied to understand the transmission of light down an optical fibre • appreciate how sound levels can be measured, and appreciate the desirability of reducing noise levels yet recognise the problems involved in doing this		The formation of an image by a lens is a consequence of the refraction of light, but it can be established empirically using experiments such as those devised by the Nuffield Physics project. In those experiments, candidates first explore the behaviour of a pinhole camera with one, then many, pinholes. The multiple overlapping pinhole pictures can be collected into one by placing a lens in front of the camera – this is what a lens does. It collects together all the light rays falling on it from an object and bends them so that they pass through another place where the image is.
• know that there is limited range of frequencies over which hearing takes place • appreciate the importance of communication systems in the modern world	• be able to state the approximate frequencies over which human hearing takes place	The reflection and refraction of sound are harder to demonstrate experimentally, although a balloon filled with carbon dioxide gas can be made to act as a 'sound lens'. Work with optical fibres can lead to some introductory work on communications. Candidates who live in urban areas will undoubtedly understand noise as an increasing environmental problem – something that can be usefully investigated.

Opportunities for co-ordination: Sound and light are closely related to our senses of hearing and sight. Sight is developed in **B10** 'Responding to Changes in the Environment'. Optical fibres make use of transparent materials. Such materials may be made from materials like glass and plastic. Glasses are dealt with in **C5** and plastics in **C3** 'Petrochemicals'. Ideas about communication are picked up again in **P15**.

P11: MAKING USE OF WAVES

Context: Light and sound are recognised, from their properties, to travel as waves. Light itself is seen in the context of the family of electromagnetic waves with a wide range of applications. Waves can transfer energy selectively – something that has application from radio to photosynthesis.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand that wave motion is a useful way of describing and explaining the behaviour of light and sound	• understand that diffraction and the speed of light in glass, in relation to that in air, are some evidence for the wave nature of light	This section provides an opportunity for 'model building' in physics. The wave nature of light and sound can only be established by critically comparing their properties as waves.
• understand how a prism can be used to split white light into its component colours	• appreciate how energy can be transferred from waves, and how it is possible to be selective in making that transfer	Apart from associating colour with wave frequency, the work on colour vision is not related to the properties of light as a wave. Primary and secondary colours are ways of describing how we see colours, and many interesting experiments are possible if a well-darkened room is available.
• appreciate the nature of colour vision in terms of primary and secondary colours • be able to identify wavelength with colour in light • appreciate that light is a part of a wide band of wavelengths called the electromagnetic spectrum	• appreciate that earthquakes involve the passage of waves through the Earth	The electromagnetic spectrum is important for the wealth of applications that it provides. As many as possible of these applications should be within the candidates' experience. The relationship between the loudness and pitch of sound and the amplitude and frequency of the sound wave is easily demonstrated if a signal generator loudspeaker and cathode ray oscilloscope are available. Range of hearing can be tested here if it is not covered in biology.

P11: MAKING USE OF WAVES continues on the next page

P11: MAKING USE OF WAVES (continued)

• be able to associate the terms *radio*, *microwave*, *infra-red*, *ultraviolet* and *X-rays* with the appropriate parts of the electromagnetic spectrum, and know some of the uses to which these parts of the spectrum are put • know how sound can be transmitted through air as a wave		The selective transfer of energy by waves ('resonance') is a topic of everyday importance in radio and television. It is easily demonstrated using a dynamics trolley held in place by springs attached to each end. The trolley can be set in motion by a wave sent down a long piece of sand-filled rubber tubing, attached to the trolley, but only if the wave frequency is equal to the natural frequency of the spring-coupled trolley.
• be able to relate the loudness and pitch of a sound to the amplitude and frequency of the sound wave		Earthquakes are an important example of wave motion, and the damage they can do often depends on resonance between building and wave. This will be a matter of real experience of candidates in many parts of the world.

Opportunities for co-ordination: The work on colour is complemented by **C12** 'Dyes and Drugs'. Flame tests, introduced in **C16** 'Metals and Alloys' are also related to potential work in this section. Colour is also important in the use of indicators in chemistry (**C9** 'Acids and Alkalis' and **C10** 'Soil, Rocks and Rates'). The selective absorption of colours is fundamental to work on 'Photosynthesis' (**B4**). The use of X-rays for finding the structure of solid materials may have been mentioned in **C5** 'Materials and Structures'. The use of waves for communication is taken up again in **P15** 'Communication'. Work on earthquakes will have indirect links with the study of rocks, which forms a part of **C10** 'Soil, Rocks and Rates'.

P12: KINETIC ENERGY AND MOMENTUM

Context: The concepts of kinetic energy and momentum give an easier way of understanding many everyday problems involving forces than does an application of Newton's Laws of Motion. If appropriate to the candidates' environment, road safety provides a good context for developing an understanding and an application for both concepts.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the meaning of the terms *kinetic energy* and *momentum*	• be able to use kinetic energy and momentum to solve simple, quantitative problems involving force, motion and recoil	It is suggested that this section be separated from the earlier work on force and motion, since it requires the more mature approach to physics that candidates may have gained by the later stages of the course.
• be able to find both the kinetic energy and momentum of a moving body from a knowledge of its mass and velocity • be able to use kinetic energy to solve simple, qualitative problems involving force and motion • be able to use momentum in simple, qualitative problems involving recoil	• appreciate that, in collisions between objects, their total momentum is unchanged ('conservation of momentum')	Kinetic energy should be seen as an extension of earlier work on energy transfer, with the added ability of being able to calculate its size from a simple formula. The important feature of kinetic energy is the way it increases with the square of an object's speed.
• understand the way the concepts of kinetic energy and momentum can be applied in simple everyday situations		'Recoil' is the most usual example of the effect of momentum and its transfer, in the everyday world. The effect of recoil can be demonstrated using spring-loaded dynamics trolleys and a simple 'Law of recoil' (*momentum lost by one object = momentum gained by the other*) is established.
• appreciate the relationship between the transfer of energy to a gas by heating and the rise in its temperature and the increase in the kinetic energy of its particles		This can be applied to many everyday observations such as stepping off a small boat. Candidates may also be interested in the way it can be applied to understand rocket and jet propulsion. Car safety belts, vehicle brakes, braking distances and road crash barriers all provide a context for thinking about kinetic energy and momentum, if a 'road safety' theme is chosen.

Opportunities for co-ordination: The concept of kinetic energy is important in the kinetic theory of matter and is thus of relevance to both biology and chemistry when that theory is being used. Examples include diffusion and osmosis in biology (**B2** 'Cellular Organisation and Function') and chemical reactions in chemistry (**C10** 'Soil, Rocks and Rates').

P13: GRAVITY

Context: Gravitational force provides candidates with their first insight into 'forces which act at a distance'. The study leads on to a brief look at artificial Earth satellites and air resistance as a counterbalancing force acting on falling objects.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate that gravity is a force which acts between bodies, even though they are not in contact • know that the Earth is the source of a gravitational field • understand the part air resistance plays in the way objects fall when close to the Earth's surface • appreciate the distinction between *mass* and *weight*	• appreciate why it is possible for objects to orbit the Earth without falling to its surface	The acceleration of a freely falling body can be easily explored using a 'ticker-timer' of the sort commonly used in dynamics experiments. The analysis of the tape attached to a falling object readily shows: (i) that the object falls with a uniform acceleration of about $10\ m / s^2$ (ii) that objects of different mass fall with the same acceleration. These two observations show that a force acts on all bodies close to the Earth which is proportional in size to their mass. Newton's treatment of falling bodies, in which he showed if a body was projected at a fast enough speed horizontally it would 'fall' round the Earth without ever returning to the surface, gives an elementary approach to Earth satellites. This can even be turned into a scale diagram to work out the necessary speed of projection. The everyday observation that an object falling some distance never achieves a falling speed expected from the gravitational force leads on to air resistance, and the way this is utilised in safe parachuting.

Opportunities for co-ordination: There are only indirect links between the work of this section of the syllabus and work in biology and chemistry.

P14: MAGNETISM AND ELECTRICITY

Context: An introductory study of the advantages of electrically powered vehicles introduces the electric motor and the force which can act on a current-carrying wire in a magnetic field. This, in turn, leads to a more detailed investigation into how electric motors work and into electromagnets and relays. Dynamos are introduced as 'electric motors in reverse'. This leads on to electromagnetic induction, alternating currents and power station generators.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• know that magnetic materials have the ability to attract some materials, but to attract and repel each other	• understand that an electric current can be induced in a wire moving relative to a magnetic field	A study of the possibility of using electric power for vehicles is a good way of introducing electromagnetism.
• understand the meaning of the term *magnetic field*, and know that the Earth is surrounded by one • know that forces can act on an electric current when in a magnetic field	• be able to apply this idea to understand the working of dynamos and alternators	Either prior to, or just after this, candidates will need to explore some of the properties of the magnetic field surrounding permanent magnets – a second example of 'action at a distance'. They will need to know that the same type of field can be generated by a current-carrying wire.
• know that the force on an electric current in a magnetic field is at right angles to the direction of the current and the field		The electric motor works by using the force acting on a current-carrying wire in an electric field. A series of demonstrations will show both the effect and also the relative directions of field, current and force.
• be able to apply these ideas in understanding how an electric motor works • appreciate that an electric current itself has a magnetic field, and that this can be applied to the design of electromagnets and relays		Candidates will benefit by trying to construct their own simple d.c. motor. Ideas about magnetic fields can be applied to electromagnets and relays. These same motors, run in reverse, can be shown to generate a voltage – a process referred to as electromagnetic induction. Candidates following the extended curriculum can carry out a series of investigations into the factors which affect the strength of an induced current. This work should lead to some understanding of the working of dynamos, alternators and power station generators.

Opportunities for co-ordination: There are no direct links between this section of the syllabus and other sections in biology and chemistry.

P15: COMMUNICATION

Context: Ideas about electricity, magnetism and wave motion are used to explore the ways in which communication systems have developed over the years. The electric telegraph, microphones, loudspeakers and the telephone system are explored. Radio transmission is investigated and its advantages discussed. The advantages of digital coding of signals over analogue transmission can lead to fibre optics, satellites for transmission of information and compact disc players.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand how, historically, the use of light greatly increased the speed of communication, but that this required the use of a code	• understand the difference between analogue signals and digital signals, and recognise that the latter require an extension of the idea of a code for transmitting information	The workings of microphones, loudspeakers and telephones can be explored practically. The emphasis throughout is on the application of ideas already learnt.
• understand how the use of electrical signals has improved long-distance, high speed communication even further	• understand the benefits of digital coding for transmitting information	The speed and distance of communication possible with electromagnetic waves is shown by the use of radio.
• be able to describe the operation of the microphone and earphone, and relate their operation to basic physical principles	• be able to compare the operation of the telephone system with radio communication, including the need for modulation of a carrier wave	Digital coding of information can be likened to the earlier use of Morse code – the messages transmitted are far less likely to be corrupted.

Opportunities for co-ordination: B10 'Responding to the Environment' is partly concerned with the transmission of information within an organism. There are links to be made between a national telephone network and our own nervous system. This section of the syllabus also looks back at earlier work on optical fibres (**P9**) and satellites (**P13**).

P16: ELECTRONS

Context: The investigation into electron beams can be set in the context of understanding how television sets work. This, in turn, leads to the cathode-ray oscilloscope and its many uses.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate that the behaviour of the thermionic diode can be interpreted in terms of negatively-charged particles given off from a heated tungsten wire	• appreciate that a flow of negatively charged particles (electrons) is the best solution in explaining the behaviour of a thermionic diode	This section of the syllabus can be presented in two ways. For candidates who are also following the extended curriculum, much of the work can be presented as a problem-solving activity:
• recognise that the electron, as a basic component of the atom, could be the particle carrying an electric current in a thermionic diode and also the particle responsible for carrying charge round an electric circuit	• understand how charges produced by friction can be understood in terms of an electron transfer	(i) solving the problem of how a television receiver can produce pictures, (ii) solving the problem presented by electron tubes which can apparently conduct an electric current through a vacuum.
• understand how the production of electrons from a heated wire has led to the cathode-ray oscilloscope and the possibility of television		Even if equipment to demonstrate (ii) is not available, the observations can be described, or shown on video or film.
		For candidates following only the core curriculum, it is probably sufficient to describe or demonstrate experiments with electron beam tubes. These observations can then be used to explain the inner workings of a television receiver.
		Candidates following the extended curriculum can use the model of atoms which can gain or lose electrons to explain electrostatic phenomena encountered in P7. This model can also help candidates to understand the nature of positive and negative ions.

Opportunities for co-ordination: The concept of ions as charged atoms is used extensively in chemistry and in P17. However, the fact that ions are formed by atoms gaining or losing electrons is not taken up in the chemistry syllabus until **C17** 'Atoms, Bonding and the Periodic Table'. This is the last section of the chemistry syllabus and it can be understood as a development of earlier chemical ideas and the model established in **P16** and **P17**. The syllabus order has been constructed with this progression in mind.

P17: RADIOACTIVITY

Context: The study of radioactivity is developed within the context of the uses and hazards associated with the radioactive substances. This leads to an understanding of the ionising power of the radiations and the concept of half-life. For candidates following the extended curriculum, some attention is also given to the structure of the atomic nucleus and how this can be related to radioactivity.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• appreciate that radiations from radioactive materials are capable of breaking up other atoms and molecules • understand the meaning of the term *ionising radiation*	• appreciate the link between ionisation and electric charge	Understanding the nature of radioactivity is made difficult by its invisibility and the indirect nature of its effects. Added to this is the fact that the effects radioactivity can produce will not be within a candidate's normal experience.
• know how radioactivity may be detected and measured • understand the meaning of the term *background radiation*	• be able to relate radioactivity to the structure of an atom	This syllabus links radioactivity firmly to its *ionising* property. This is in fact almost the only property that makes radioactivity impinge upon our consciousness. It is its ability to ionise matter through which it passes that makes it both hazardous and underpins most of its applications.
• appreciate why radioactivity can be dangerous to living things, but be able to put these hazards into perspective • appreciate the differences between alpha, beta, and gamma radiations		Understanding the extent and consequences of this ionisation, and also understanding the concept of half-life, are necessary if the hazards are to be put in proper perspective and the many applications understood.
• appreciate how radioactivity changes with time and understand the concept of *half-life*	• appreciate the idea of randomness in the decay process, and relate this to half-life	Wherever possible, experiments should be demonstrated to show the sorts of detectors that are used to measure radioactivity, and also to show how it may be absorbed and how it decays.

P17: RADIOACTIVITY continues on the next page

P17: RADIOACTIVITY (continued)

• appreciate some of the uses to which radioactivity has been put		Radioactive decay gives an opportunity for more graph plotting and recognition of the need to draw trend lines through points. Candidates following the extended curriculum can explore the random nature of radioactivity and see how it leads to the law of radioactive decay. Experiments throwing dice can give a good simulation of the decay process.

Opportunities for co-ordination: The concept of ions and ionisation is required in this section. This need mean no more than understanding that atoms and groups of atoms can carry electrical charge. However, candidates will have learnt in **P16** that atoms and molecules can be ionised by gaining or losing electrons. Ideas about ions as charged atoms will first have been encountered in **C7** 'Ions and Electrolysis'. The concept of ions recurs throughout chemistry and particularly so in **C17** 'Atoms, Bonding and the Periodic Table'. The use of radioactive materials as tracers may be referred to in biology.

P18: ENERGY RESOURCES

Context: This section is devoted to a study of the world's energy resources. In addition to the use of fossil fuels, nuclear power is discussed – both fission and (for the future?) fusion. Renewable energy sources are considered and the benefits of increasing the efficiency of energy transfer are discussed.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand the meaning of the term *efficiency* when it is applied to energy transfer processes		This section of work builds directly on **P5** and **P6**. There are few, if any, opportunities for practical work here, but immense scope for candidate involvement through discussions.
• appreciate the necessity of finding an alternative to fossil fuels in the near future • understand how energy may be released from the nuclei of atoms by both nuclear fission and nuclear fusion • appreciate some of the problems involved in the use of nuclear fission as an energy resource		A variety of video or film material can be used to support work on using fossil fuels and nuclear power and prime energy sources. Renewable energy resources – such as hydroelectric power, solar power, etc. – are also the subject of many videos and films. However, many candidates may live in areas where renewable sources are being exploited. If this is so, then a visit to the appropriate power stations could be of great benefit, as well as building on candidates' local knowledge.
• understand that there are alternative (renewable) energy resources, but understand that no single renewable energy source is likely to act as a total replacement for present energy resources		The very large savings which are possible by the more efficient use of current energy resources should be discussed.
• appreciate that greater efficiency in the use of energy can be as helpful as finding alternative sources		This section of work will form a useful revision, not only of earlier work on energy, but also of electricity generation and radioactivity.

Opportunities for co-ordination: The human body, as an engine which needs fuel, is treated in detail in **B7** 'Respiration'. Photosynthesis, as the means by which the Sun's energy is trapped by and thus transferred to fossil fuels, is covered in **B4**.

The refining of crude oil (petroleum) to produce fuels is the subject of **C3** 'Petrochemicals'. Energy from fossil fuels is dealt with in detail in **C14** 'Fuels'. There are also links with **C4** 'Chemicals from Plants'.

P19: ENERGY DISTRIBUTION

Context: This section is concerned with the problem of getting energy to the places where it is needed. The work concentrates on the use of electricity as the most convenient means of energy distribution, but shows that all distribution systems involve an additional energy 'cost'. Candidates following the extended curriculum have the opportunity for considering other means of energy distribution such as belt drives and hydraulics.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand that energy can be transferred from fuels to electricity by dynamos • appreciate the problems involved in the electrical transmission of energy		A worthwhile introduction to this section is to consider the distribution of energy from a prime source such as coal. The coal could be burnt in a power station and the energy released distributed via electricity. Alternatively, the coal could be delivered to where it is needed and then burnt to release its energy. Both methods have an energy 'cost'; which is the lesser?
• understand the importance of transformers in the electrical transmission of energy	• be able to describe the work of a transformer in terms of the currents induced by changing magnetic fields • know and be able to use the equation $V_p / V_s = N_p / N_s$ • appreciate the possible advantages of other methods of distributing energy, including the use of petrol for cars and the use of hydraulics	The distribution of energy using electricity could have a very high energy cost if it were not for the use of alternating current and transformers. The operation of transformers can be investigated practically. Candidates who are only following the core curriculum will not have covered electromagnetic induction in **P14**. They will need a simplified approach here if the rest of the work is to make sense: for example, 'if electric current + magnetic field can produce motion of a wire, then perhaps motion of wire in a magnetic field can produce an electric current'. Only candidates aiming for higher grades should treat the transformer in any detail.

Opportunities for co-ordination: For candidates following the extended curriculum, this section of work is clearly closely linked with **P14** 'Magnetism and Electricity'. There are few direct links with biology and chemistry, although electric batteries and alternative ways of distributing small quantities of energy are covered in **C15**. Hydrogen is another potential source for storing and distributing energy. This can be linked in with a number of chemical ideas.

The work on hydraulics links back to work in **P5**.

P20: ELECTRONICS

Context: This final section is concerned with controlling the use of energy. 'Control' is not used here in the sense that it is used in B11 'Homeostasis'. In the latter case, control means maintaining a given situation – a particular temperature, for example. In the case of this physics unit, control means making things happen as you want them to happen. Electronics is often used to bring about control *automatically*.

Core	Supplement	Suggested approaches
All candidates should:	*In addition to what is required in the core, candidates following the extended curriculum should:*	
• understand that electronics is an extension of the study of electricity • appreciate that a knowledge of changes in resistance can be used to produce detectors which can respond to changes in the environment • understand how a reed relay can be used to operate devices which need larger currents than detectors can pass • appreciate how electronics can be used to solve simple problems in everyday life	• appreciate that integrated circuits, called microprocessors, are the control units of many devices in everyday use • appreciate how AND, NOT and OR gates are used	Although there are other means of maintaining control than by the use of electronic circuits, electronics is now used so much for this purpose that it overshadows all other methods. This section also helps to place electricity in a context which, increasingly, is the most familiar one a candidate meets. The intention is that this section of work should be almost entirely practical. As such, it tries not to be too specific about the sort of electronic circuits a candidate might make. The electromagnetic relay is used to introduce the concept of the electronic gate. A reed relay is only a small-scale version of larger relays, using small currents and voltages. A larger one could be used instead. Its essential purpose is to show how a controlling circuit can be separated from, and yet control, the operating circuit. Once this is understood, the relay can be replaced by an electronic gate (NOR gates are simplest to use). Electronic gates have the virtue of requiring very small currents and voltages to operate. This leads to the use of sensors (devices that respond to changes in the environment) to provide the controlling signals. Finally, candidates should have the opportunity to see how control circuits can be combined to carry out quite complex operations – whether domestically or industrially.

Opportunities for co-ordination: Using sensors for control is an integral part of the behaviour of living organisms. The ear, eye and sense of touch all rely on sensors that change external stimuli into electrical signals which are processed by the organism. **B10** is concerned with how an organism responds to its environment. The electromagnetic relay, on which this section depends, is introduced in **P14**.

6. Practical assessment

Practical assessment: Papers 4, 5 or 6

Scientific subjects are, by their nature, experimental. It is therefore important that an assessment of a student's knowledge and understanding of Science should contain a component relating to practical work and experimental skills (as identified by assessment objective C). To accommodate, within IGCSE, differing circumstances – such as the availability of resources – CIE provides three different means of assessing assessment objective C objective: School-based assessment (see below), a formal Practical Test and an Alternative to Practical Paper.

6.1 Paper 4: Coursework (School-based assessment of practical skills)

The experimental skills and abilities to be assessed are:

C1 Using and organising techniques, apparatus and materials

C2 Observing, measuring and recording

C3 Handling experimental observations and data

C4 Planning, carrying out and evaluating investigations

The four skills carry equal weighting.

All assessments must be based upon experimental work carried out by the candidates.

The teaching and assessment of experimental skills and abilities should take place throughout the course.

Teachers must ensure that they can make available to CIE evidence of two assessments for each skill for each candidate. For skills C1 to C4 inclusive, information about the tasks set and how the marks were awarded will be required. For skills C2, C3 and C4, the candidate's written work will also be required.

The final assessment scores for each skill must represent the candidate's best performances.

For candidates who miss the assessment of a given skill through no fault of their own, for example because of illness, and who cannot be assessed on another occasion, CIE's procedure for special consideration should be followed. However, candidates who for no good reason absent themselves from an assessment of a given skill should be given a mark of zero for that assessment.

6. Practical assessment

Criteria for assessment of experimental skills and abilities

Each skill must be assessed on a six-point scale, level 6 being the highest level of achievement. Each of the skills is defined in terms of three levels of achievement at scores of 2, 4, and 6.

A score of 0 is available if there is no evidence of positive achievement for a skill.

For candidates who do not meet the criteria for a score of 2, a score of 1 is available if there is some evidence of positive achievement.

A score of 3 is available for candidates who go beyond the level defined for 2, but who do not meet fully the criteria for 4.

Similarly, a score of 5 is available for those who go beyond the level defined for 4, but do not meet fully the criteria for 6.

Score	Skill C1: Using and organising techniques, apparatus and materials
0	No evidence of positive achievement for this skill.
1	Some evidence of positive achievement, but the criteria for a score of 2 are not met.
2	Follows written, diagrammatic or oral instructions to perform a single practical operation. Uses familiar apparatus and materials adequately, needing reminders on points of safety.
3	Is beyond the level defined for 2, but does not meet fully the criteria for 4.
4	Follows written, diagrammatic or oral instructions to perform an experiment involving a series of step-by-step practical operations. Uses familiar apparatus, materials and techniques adequately and safely.
5	Is beyond the level defined for 4, but does not meet fully the criteria for 6.
6	Follows written, diagrammatic or oral instructions to perform an experiment involving a series of practical operations where there may be a need to modify or adjust one step in the light of the effect of a previous step. Uses familiar apparatus, materials and techniques safely, correctly and methodically.

6. Practical assessment

Score	Skill C2: Observing, measuring and recording
0	No evidence of positive achievement for this skill.
1	Some evidence of positive achievement, but the criteria for a score of 2 are not met.
2	Makes observations or readings given detailed instructions. Records results in an appropriate manner given a detailed format.
3	Is beyond the level defined for 2, but does not meet fully the criteria for 4.
4	Makes relevant observations, measurements or estimates given an outline format or brief guidelines. Records results in an appropriate manner given an outline format.
5	Is beyond the level defined for 4, but does not meet fully the criteria for 6.
6	Makes relevant observations, measurements or estimates to a degree of accuracy appropriate to the instruments or techniques used. Records results in an appropriate manner given no format.

Score	Skill C3: Handling experimental observations and data
0	No evidence of positive achievement for this skill.
1	Some evidence of positive achievement, but the criteria for a score of 2 are not met.
2	Processes results in an appropriate manner given a detailed format. Draws an obvious qualitative conclusion from the results of an experiment.
3	Is beyond the level defined for 2, but does not meet fully the criteria for 4.
4	Processes results in an appropriate manner given an outline format. Recognises and comments on anomalous results. Draws qualitative conclusions which are consistent with obtained results and deduces patterns in data.
5	Is beyond the level defined for 4, but does not meet fully the criteria for 6.
6	Processes results in an appropriate manner given no format. Deals appropriately with anomalous or inconsistent results. Recognises and comments on possible sources of experimental error. Expresses conclusions as generalisations or patterns where appropriate.

Score	Skill C4: Planning, carrying out and evaluating investigations
0	No evidence of positive achievement for this skill.
1	Some evidence of positive achievement, but the criteria for a score of 2 are not met.
2	Suggests a simple experimental strategy to investigate a given practical problem. Attempts ‘trial and error’ modification in the light of the experimental work carried out.
3	Is beyond the level defined for 2, but does not meet fully the criteria for 4.
4	Specifies a sequence of activities to investigate a given practical problem. In a situation where there are two variables, recognises the need to keep one of them constant while the other is being changed. Comments critically on the original plan, and implements appropriate changes in the light of the experimental work carried out.
5	Is beyond the level defined for 4, but does not meet fully the criteria for 6.
6	Analyses a practical problem systematically and produces a logical plan for an investigation. In a given situation, recognises that there are a number of variables and attempts to control them. Evaluates chosen procedures, suggests/implements modifications where appropriate and shows a systematic approach in dealing with unexpected results.

Notes for guidance

The following notes are intended to help teachers to make valid and reliable assessments of the skills and abilities of their candidates.

The assessments should be based on the principle of positive achievement: candidates should be given opportunities to demonstrate what they understand and can do.

It is expected that candidates will have had opportunities to acquire a given skill before assessment takes place.

It is not expected that all of the practical work undertaken by a candidate will be assessed.

Assessments can be carried out at any time during the course. However, at whatever stage assessments are done, the standards applied must be those expected at the end of the course as exemplified in the criteria for the skills.

6. Practical assessment

Assessments should normally be made by the person responsible for teaching the candidates.

It is recognised that a given practical task is unlikely to provide opportunities for all aspects of the criteria at a given level for a particular skill to be satisfied, for example, there may not be any anomalous results (Skill C3). However, by using a range of practical work, teachers should ensure that opportunities are provided for all aspects of the criteria to be satisfied during the course.

The educational value of extended experimental investigations is widely recognised. Where such investigations are used for assessment purposes, teachers should make sure that candidates have ample opportunity for displaying the skills and abilities required by the scheme of assessment.

It is not necessary for all candidates in a Centre, or in a teaching group within a Centre, to be assessed on exactly the same practical work, although teachers may well wish to make use of work that is undertaken by all of their candidates.

When an assessment is carried out on group work the teacher must ensure that the individual contribution of each candidate can be assessed.

Skill C1 may not generate a written product from the candidates. It will often be assessed by watching the candidates carrying out practical work.

Skills C2, C3 and C4 will usually generate a written product from the candidates. This product will provide evidence for moderation.

Raw scores for individual practical assessments should be recorded on the Individual Candidate Record Card. The final, internally-moderated, total score should be recorded on the Coursework Assessment Summary Form. Examples of both forms are provided at the end of this syllabus.

Raw scores for individual practical assessments may be given to candidates as part of the normal feedback from the teacher. The final, internally-moderated, total score, which is submitted to CIE should not be given to the candidate.

6. Practical assessment

Moderation

(a) Internal moderation

When several teachers in a Centre are involved in internal assessments, arrangements must be made within the Centre for all candidates to be assessed to a common standard.

It is essential that within each Centre the marks for each skill assigned within different teaching groups (e.g. different classes) are moderated internally for the whole Centre entry. The Centre assessments will then be subject to external moderation.

(b) External moderation

External moderation of internal assessment will be carried out by CIE.

The internally moderated marks for all candidates must be received at CIE by 30 April for the June examination and 31 October for the November examination. These marks may be submitted either by using MS1 mark sheets or by using Cameo as described in the Handbook for Centres.

Once CIE has received the marks, CIE will select a sample of candidates whose work should be submitted for external moderation. CIE will communicate the list of candidates to the Centre, and the Centre should despatch the coursework of these candidates to CIE immediately. For each candidate on the list, every piece of work which has contributed to the final mark should be sent to CIE. Individual Candidate Record Cards and Coursework Assessment Summary Forms (copies of which may be found at the back of this syllabus booklet) must be enclosed with the coursework.

Further information about external moderation may be found in the Handbook for Centres and the Administrative Guide for Centres.

A further sample may be required. All records and supporting written work should be retained until after publication of results. Centres may find it convenient to use loose-leaf A4 file paper for assessed written work. This is because samples will be sent through the post for moderation and postage bills are likely to be large if whole exercise books are sent. Authenticated photocopies of the sample required would be acceptable.

The individual pieces of work should **not** be stapled together. Each piece of work should be labelled with the skill being assessed, the Centre number and candidate name and number, title of the experiment, a copy of the mark scheme used, and the mark awarded. This information should be attached securely, mindful that adhesive labels tend to peel off some plastic surfaces.

6.2 Paper 5: Practical test

Biology

Candidates should be able to:

- follow instructions and handle apparatus and materials safely and correctly
- observe and measure biological material or a biological experiment, using appropriate equipment/characters/units
- record observations and measurements by drawing biological material or by recording experimental data in a variety of ways and using appropriate scales, intervals and axes
- interpret and evaluate observational and experimental data from specimens or from experiments
- comment on an experimental method used and suggest possible improvements.

Chemistry

Candidates may be asked to carry out exercises involving:

- simple quantitative experiments involving the measurement of volumes
- speeds of reactions
- measurement of temperature based on a thermometer with 1 °C graduations
- problems of an investigatory nature, possibly including suitable organic compounds
- simple paper chromotography
- filtration
- identification of ions and gases as specified in the core curriculum (*Notes for Use in Qualitative Analysis* will be provided in the question paper).

Physics

Candidates should be able to:

- follow written instructions for the assembly and use of provided apparatus (e.g. for using ray-tracing equipment, for wiring up simple electrical circuits)
- select, from given items, the measuring device suitable for the task
- carry out the specified manipulation of the apparatus (e.g. when determining a (derived) quantity such as the extension per unit load for a spring, when testing/identifying the relationship between two variables, such as between the p.d. across a wire and its length, when comparing physical quantities such as the thermal capacity of two metals)
- take readings from a measuring device, including
  - reading a scale with appropriate precision/accuracy
  - consistent use of significant figures

  - interpolating between scale and divisions
  - allowing for zero errors, where appropriate
  - taking repeated measurements to obtain an average value
- record their observations systematically, with appropriate units
- process their data, as required
- present their data graphically, using suitable axes and scales (appropriately labelled) and plotting the points accurately
- take readings from a graph by interpolation and extrapolation
- determine a gradient, intercept or intersection on a graph
- draw and report a conclusion or result clearly
- indicate how they carried out a required instruction
- describe precautions taken in carrying out a procedure
- give reasons for making a choice of items of apparatus
- comment on a procedure used in an experiment and suggest an improvement.

Note:

The examination will **not** require the use of textbooks, nor will candidates need to have access to their own records of laboratory work made during their course.
Candidates will be expected to carry out the experiments from the instructions given in the paper.

6.3 Paper 6: Alternative to practical

This paper is designed to test candidates' familiarity with laboratory practical procedures.

Questions may be set requesting candidates to:

- describe in simple terms how they would carry out practical procedures
- explain and/or comment critically on described procedures or points of practical detail
- follow instructions for drawing diagrams
- draw, complete and/or label diagrams of apparatus
- take readings from their own diagrams, drawn as instructed, and/or from printed diagrams including
  - reading a scale with appropriate precision/accuracy with consistent use of significant figures and with appropriate units
  - interpolating between scale divisions,
  - taking repeat measurements to obtain an average value
- process data as required, complete tables of data
- present data graphically, using suitable axes and scales (appropriately labelled) and plotting the points accurately
- take readings from a graph by interpolation and extrapolation
- determine a gradient, intercept or intersection on a graph
- draw and report a conclusion or result clearly
- identify and/or select, with reasons, items of apparatus to be used for carrying out practical procedures
- explain, suggest and/or comment critically on precautions taken and/or possible improvements to techniques and procedures
- describe, from memory, tests for gases and ions, and/or draw conclusions from such tests (*Notes for Use in Qualitative Analysis*, will **not** be provided in the question paper)

7. Appendix

7.1 Symbols, units and definitions of physical quantities

Candidates should be able to state the symbols for the following physical quantities and, where indicated, state the units in which they are measured. Candidates should be able to define those items indicated by an asterisk (*). The list for the extended curriculum includes both the core and the supplement.

Core			**Supplement**		
Quantity	***Symbol***	***Unit***	***Quantity***	***Symbol***	***Unit***
length	*l*, *h* ...	km, m, cm, mm			
area	*A*	m^2, cm^2			
volume	*V*	m^3, dm^3, cm^3			
weight	*W*	N			N*
mass	*m*, *M*	kg, g			mg
time	*t*	h, min, s			ms
density*	*d*, ρ	kg/m^3, g/cm^3			
speed*	*u*, *v*	km/h, m/s, cm/s	velocity*		km/h, m/s, cm/s
acceleration	*a*		acceleration*		m/s^2
acceleration of free fall	*g*				
force	*F*, *P* ...	N	force*		N*
			moment of a force*		N m
work done*	*W*, *E*	J	work done by a force*		J*
energy	*E*	J			J*, kW h*
power	*P*	W	power*		W*
pressure	*P*	Pa			
temperature	*t*	°C		*T*	K
specific heat capacity	*c*	J/(kg °C)	specific heat capacity*		
frequency*	*f*	Hz			Hz*
wavelength*	λ	m, cm			
focal length	*f*	cm, mm			
angle of incidence	*i*	degree (°)			
angle of reflection, refraction	*r*	degree (°)			
critical angle	*c*	degree (°)			
potential difference/ voltage	*V*	V, mV	potential difference*		V*
current	*I*	A*, mA	current*		
charge		C, A s			
e.m.f.	*E*	V	e.m.f.*		
resistance	*R*	Ω			

7. Appendix

7.2 Notes for use in qualitative analysis

Tests for anions

anion	test	test result
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify with dilute nitric acid, then add aqueous barium nitrate	white ppt.

Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
ammonium (NH_4^+)	ammonia produced on warming	-
copper(II) (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

Tests for gases

gas	test and test result
ammonia (NH_3)	turns damp red litmus paper blue
carbon dioxide (CO_2)	turns lime water milky
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	'pops' with a lighted splint
oxygen (O_2)	relights a glowing splint

7.3 Data sheet

Group																	
I	II											III	IV	V	VI	VII	0
							1 H Hydrogen 1										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 Phosphorus 15	32 S Sulfur 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	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 †															

*58-71 Lanthanoid series
†90-103 Actinoid series

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	163 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	Pa Protactinium 91	238 U Uranium 92	Np Neptunium 93	Pu Plutonium 94	Am Americium 95	Cm Curium 96	Bk Berkelium 97	Cf Californium 98	Es Einsteinium 99	Fm Fermium 100	Md Mendelevium 101	No Nobelium 102	Lr Lawrencium 103

Key

a **X** b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

7. Appendix

7.4 Grade descriptions

The scheme of assessment is intended to encourage positive achievement by all candidates. Mastery of the core curriculum is required for further academic study.

A **Grade A** candidate must show mastery of the core curriculum and the extended curriculum.

A **Grade C** candidate must show mastery of the core curriculum plus some ability to answer questions which are pitched at a higher level.

A **Grade F** candidate must show competence in the core curriculum.

A **Grade A** candidate is likely to

- relate facts to principles and theories and vice versa
- state why particular techniques are preferred for a procedure or operation
- select and collate information from a number of sources and present it in a clear logical form
- solve problems in situations which may involve a wide range of variables
- process data from a number of sources to identify any patterns or trends
- generate an hypothesis to explain facts, or find facts to support an hypothesis.

A **Grade C** candidate is likely to

- link facts to situations not specified in the syllabus
- describe the correct procedure(s) for a multi-stage operation
- select a range of information from a given source and present it in a clear logical form
- identify patterns or trends in given information
- solve problems involving more than one step, but with a limited range of variables
- generate an hypothesis to explain a given set of facts or data.

A **Grade F** candidate is likely to

- recall facts contained in the syllabus
- indicate the correct procedure for a single operation
- select and present a single piece of information from a given source
- solve a problem involving one step, or more than one step if structured help is given
- identify a pattern or trend where only a minor manipulation of data is needed
- recognise which of two given hypotheses explains a set of facts or data.

7.5 Mathematical requirements

Calculators may be used in all parts of the assessment.

Candidates should be able to:

- add, subtract, multiply and divide
- understand and use *averages, decimals, fractions, percentages, ratios* and *reciprocals*
- recognise and use standard notation
- use direct and inverse proportion
- use positive, whole number indices
- draw charts and graphs from given data
- interpret charts and graphs
- select suitable scales and axes for graphs
- make approximate evaluations of numerical expressions
- recognise and use the relationship between length, surface area and volume and their units on metric scales
- use usual mathematical instruments (ruler, compasses, protractor, set square)
- understand the meaning of *angle, curve, circle, radius, diameter, square, parallelogram, rectangle* and *diagonal*
- solve equations of the form $x = yz$ for any one term when the other two are known
- recognise and use points of the compass (N, S, E, W)

7.6 Glossary of terms used in science papers

It is hoped that the glossary (which is relevant only to Science subjects) will prove helpful to candidates as a guide (e.g. it is neither exhaustive nor definitive). The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend, in part, on its context.

1. *Define* (the term(s) ...) is intended literally, only a formal statement or equivalent paraphrase being required.
2. *What do you understand by/What is meant by* (the term (s) ...) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.
3. *State* implies a concise answer with little or no supporting argument (e.g. a numerical answer that can readily be obtained 'by inspection').
4. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified this should not be exceeded.
5. *Explain* may imply reasoning or some reference to theory, depending on the context.
6. *Describe* requires the candidate to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena.

   In other contexts, *describe* should be interpreted more generally (i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer). *Describe and explain* may be coupled, as may *state and explain*.
7. *Discuss* requires the candidate to give a critical account of the points involved in the topic.
8. *Outline* implies brevity (i.e. restricting the answer to giving essentials).
9. *Predict* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question.

   Predict also implies a concise answer with no supporting statement required.
10. *Deduce* is used in a similar way to *predict* except that some supporting statement is required (e.g. reference to a law, principle, or the necessary reasoning is to be included in the answer).
11. *Suggest* is used in two main contexts (i.e. either to imply that there is no unique answer (e.g. in Chemistry, two or more substances may satisfy the given conditions describing an 'unknown'), or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus').
12. *Find* is a general term that may variously be interpreted as *calculate, measure, determine*, etc.

13. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.
14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument (e.g. length, using a rule, or mass, using a balance).
15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula (e.g. resistance, the formula of an ionic compound).
16. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.
17. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, **but** candidates should be aware that, depending on the context, some quantitative aspects may be looked for (e.g. passing through the origin, having an intercept).

    In diagrams, *sketch* implies that simple, freehand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.

7.7 Forms

The following pages contain:

- Individual Candidate Record Card
- Instructions for completing individual candidate record cards
- Coursework Assessment Summary Form
- Instructions for completing coursework assessment summary forms
- Sciences Experiment Form
- Instructions for completing sciences experiment forms

CO-ORDINATED SCIENCES
Individual Candidate Record Card

IGCSE 2011

Please read the instructions printed overleaf and the General Coursework Regulations before completing this form.

Centre number						Centre name		June/November	**2**	**0**	**1**	**1**
Candidate number						Candidate name		Teaching group/set				

Date of assessment	Experiment number from Sciences Experiment Form	Assess at least twice: ring highest two marks for each skill (Max 6 each assessment)				Relevant comments (for example, if help was given)
		C1	C2	C3	C4	
Marks to be transferred to Coursework Assessment Summary Form		(max 12)	(max 12)	(max 12)	(max 12)	TOTAL (max 48)

Instructions for completing individual candidate record cards

1. Complete the information at the head of the form.
2. Mark each item of Coursework for each candidate, according to instructions given in the Syllabus and Training Manual.
3. Enter marks and total marks in the appropriate spaces. Complete any other sections of the form required.
4. Ensure that the addition of marks is independently checked.
5. **It is essential that the marks of candidates from different teaching groups within each Centre are moderated internally.** This means that the marks awarded to all candidates within a Centre must be brought to a common standard by the teacher responsible for co-ordinating the internal assessment (i.e. the internal moderator), and a single valid and reliable set of marks should be produced which reflects the relative attainment of all the candidates in the Coursework component at the Centre.
6. Transfer the marks to the Coursework Assessment Summary Form, in accordance with the instructions given on that document.
7. Retain all Individual Candidate Record Cards and Coursework, **which will be required for external moderation**. Further detailed instructions about external moderation will be sent in late March of the year of the June examination, and early October of the year of the November examination. See also the instructions on the Coursework Assessment Summary Form.

Note:

These Record Cards are to be used by teachers only for students who have undertaken Coursework as part of the IGCSE.

IGCSE/SCIENCES/CW/I/11

Please read the instructions printed overleaf and the General Coursework Regulations before completing this form.

Centre number					Centre name		June/November	2	0	1	1
Syllabus code	0	6	5	4	Syllabus title	**CO-ORDINATED SCIENCE**	Component number	0	4	Component title	**COURSEWORK**

Candidate number	Candidate name	Teaching group/ set	C1 (max 12)	C2 (max 12)	C3 (max 12)	C4 (max 12)	Total mark (max 48)	Internally moderated mark (max 48)

Name of teacher completing this form		Signature		Date
Name of internal moderator		Signature		Date

A. Instructions for completing coursework assessment summary forms

1. Complete the information at the head of the form.
2. List the candidates in an order which will allow ease of transfer of information to a computer-printed Coursework mark sheet MS1 at a later stage (i.e. in candidate index number order, where this is known; see item B.1 below). Show the teaching group or set for each candidate. The initials of the teacher may be used to indicate group or set.
3. Transfer each candidate's marks from his or her Individual Candidate Record Card to this form as follows:
   (a) Where there are columns for individual skills or assignments, enter the marks initially awarded (i.e. before internal moderation took place).
   (b) In the column headed 'Total mark', enter the total mark awarded before internal moderation took place.
   (c) In the column headed 'Internally moderated mark', enter the total mark awarded *after* internal moderation took place.
4. Both the teacher completing the form and the internal moderator (or moderators) should check the form and complete and sign the bottom portion.

B. Procedures for external moderation

1. University of Cambridge International Examinations (CIE) sends a computer-printed Coursework mark sheet MS1 to each Centre (in late March for the June examination, and in early October for the November examination), showing the names and index numbers of each candidate. Transfer the total internally moderated mark for each candidate from the Coursework Assessment Summary Form to the computer-printed Coursework mark sheet MS1.
2. The top copy of the computer-printed Coursework mark sheet MS1 must be despatched in the specially provided envelope to arrive at CIE as soon as possible, but no later than 30 April for the June examination and 31 October for the November examination.
3. CIE will select a list of candidates whose work is required for external moderation. As soon as this list is received, send candidates' work to CIE, with the corresponding Individual Candidate Record Cards, this summary form and the second copy of MS1.
4. Experiment Forms, Work Sheets and Marking Schemes must be included for each task **that has contributed to the final mark of these candidates**.
5. Photocopies of the samples may be sent **but** candidates' original work, with marks and comments from the teacher, is preferred.
6. (a) The pieces of work for each skill should **not** be stapled together, nor should individual sheets be enclosed in plastic wallets.
   (b) Each piece of work should be clearly labelled with the skill being assessed, Centre name, candidate name and index number and the mark awarded. For each task, supply the information requested in B.4 above.
7. CIE reserves the right to ask for further samples of Coursework.

SCIENCES
Experiment Form
IGCSE 2011

Please read the instructions printed overleaf.

Centre number						Centre name	
Syllabus code						Syllabus title	
Component number	**0**		**4**			Component title	**Coursework**
November	**2**	**0**	**1**	**1**			

Experiment number	Experiment	Skill(s) assessed

UNIVERSITY of CAMBRIDGE
International Examinations

WMS340 **IGCSE/SCIENCES/CW/EX/11**

Instructions for completing sciences experiment form

1. Complete the information at the head of the form.
2. Use a separate form for each Syllabus.
3. Give a brief description of each of the experiments your students performed for assessment in the IGCSE Science Syllabus indicated. Use additional sheets as necessary.
4. Copies of the experiment forms and the corresponding worksheets/instructions and marking schemes will be required for each assessed task sampled, for each of Skills C1 to C4 inclusive.

IGCSE/SCIENCES/CW/EX/11

University of Cambridge International Examinations
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
Tel: +44 (0)1223 553554 Fax: +44 (0)1223 553558
Email: international@cie.org.uk Website: www.cie.org.uk

PART OF THE
CAMBRIDGE ASSESSMENT
GROUP