



Syllabus

Cambridge IGCSE™

Co-ordinated Sciences (Double Award)

0654

Use this syllabus for exams in 2022.

Exams are available in the June and November series.

Exams are also available in the March series in India only.



Why choose Cambridge International?

Cambridge International prepares school students for life, helping them develop an informed curiosity and a lasting passion for learning. We are part of the University of Cambridge.

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Our mission is to provide educational benefit through provision of international programmes and qualifications for school education and to be the world leader in this field. Together with schools, we develop Cambridge learners who are confident, responsible, reflective, innovative and engaged – equipped for success in the modern world.

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'We think the Cambridge curriculum is superb preparation for university.'

Christoph Guttentag, Dean of Undergraduate Admissions, Duke University, USA



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Contents

1 Why choose this syllabus?	3
2 Syllabus overview	6
Aims	6
Content overview	7
Assessment overview	9
Assessment objectives	10
3 Subject content	12
Biology	12
Chemistry	33
Physics	48
4 Details of the assessment	65
Core assessment	65
Extended assessment	65
Practical assessment	66
Glossary of terms used in science papers	71
5 Appendix	72
Electrical symbols	72
Symbols and units for physical quantities	73
Notes for use in qualitative analysis	75
The Periodic Table	76
Safety in the laboratory	77
Mathematical requirements	77
Presentation of data	78
ICT opportunities	79
Conventions (e.g. signs, symbols, terminology and nomenclature)	79

6 What else you need to know	80
Before you start	80
Making entries	81
After the exam	82
How students and teachers can use the grades	82
Grade descriptions	82
Changes to this syllabus for 2022	83

Changes to this syllabus

For information about changes to this syllabus for 2022, go to page 83.

The latest syllabus is version 1, published September 2019.

Any textbooks endorsed to support the syllabus for examination from 2019 are still suitable for use with this syllabus.



1 Why choose this syllabus?

Key benefits

Cambridge IGCSE is the world's most popular international qualification for 14 to 16 year olds, although it can be taken by students of other ages. It is tried, tested and trusted.

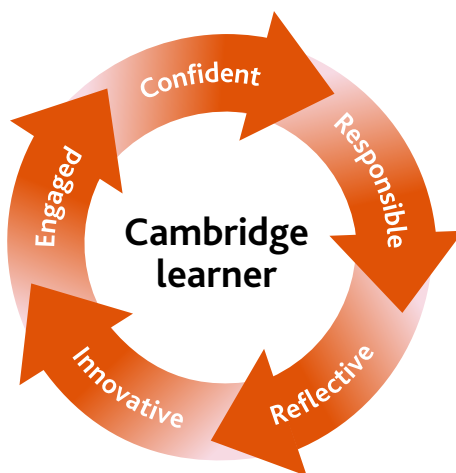
Students can choose from 70 subjects in any combination – it is taught by over 4700 schools in 150 countries.

Our programmes balance a thorough knowledge and understanding of a subject and help to develop the skills learners need for their next steps in education or employment.

Cambridge IGCSE Co-ordinated Sciences (Double Award) enables learners to:

- increase their understanding of the technological world
- take an informed interest in scientific matters
- recognise the usefulness (and limitations) of scientific method, and how to apply this to other disciplines and in everyday life
- develop relevant attitudes, such as a concern for accuracy and precision, objectivity, integrity, enquiry, initiative and inventiveness
- develop an interest in, and care for, the environment
- better understand the influence and limitations placed on scientific study by society, economy, technology, ethics, the community and the environment
- develop an understanding of the scientific skills essential for both further study and everyday life.

Our approach encourages learners to be:



'The strength of Cambridge IGCSE qualifications is internationally recognised and has provided an international pathway for our students to continue their studies around the world.'

Gary Tan, Head of Schools and CEO, Raffles International Group of Schools, Indonesia

International recognition and acceptance

Our expertise in curriculum, teaching and learning, and assessment is the basis for the recognition of our programmes and qualifications around the world. The combination of knowledge and skills in Cambridge IGCSE Co-ordinated Sciences (Double Award) gives learners a solid foundation for further study. Candidates who achieve grades A*A* to CC are well prepared to follow a wide range of courses including Cambridge International AS & A Level science subjects.

Cambridge IGCSEs are accepted and valued by leading universities and employers around the world as evidence of academic achievement. Many universities require a combination of Cambridge International AS & A Levels and Cambridge IGCSEs or equivalent to meet their entry requirements.

UK NARIC, the national agency in the UK for the recognition and comparison of international qualifications and skills, has carried out an independent benchmarking study of Cambridge IGCSE and found it to be comparable to the standard of GCSE in the UK. This means students can be confident that their Cambridge IGCSE qualifications are accepted as equivalent to UK GCSEs by leading universities worldwide.

Learn more at www.cambridgeinternational.org/recognition



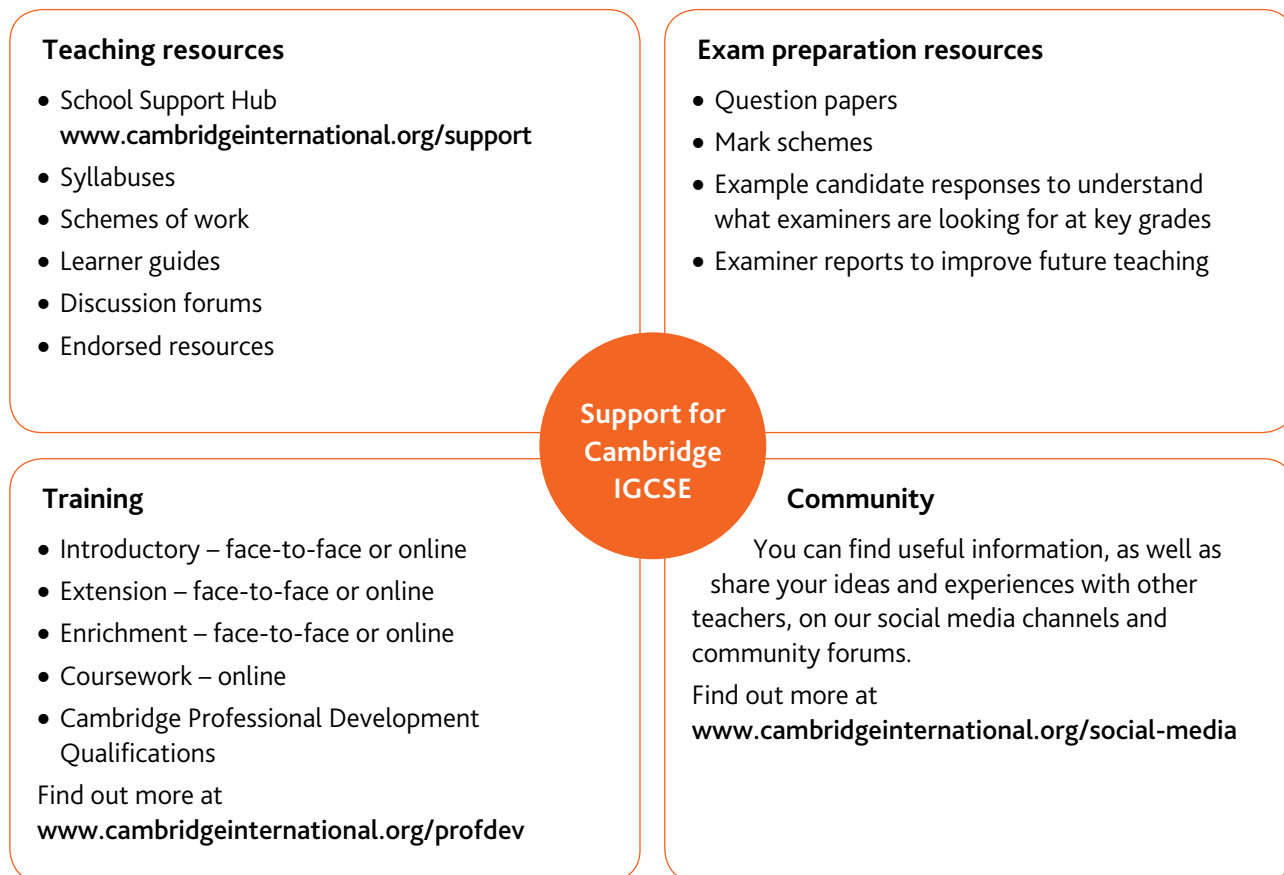
Cambridge Assessment International Education is an education organisation and politically neutral. The content of this syllabus, examination papers and associated materials do not endorse any political view. We endeavour to treat all aspects of the exam process neutrally.

'Cambridge IGCSE is one of the most sought-after and recognised qualifications in the world. It is very popular in Egypt because it provides the perfect preparation for success at advanced level programmes.'

Managing Director of British School in Egypt BSE

Supporting teachers

We provide a wide range of practical resources, detailed guidance, and innovative training and professional development so that you can give your students the best possible preparation for Cambridge IGCSE.



2 Syllabus overview

Aims

The aims describe the purposes of a course based on this syllabus.

You can deliver some of the aims using suitable local, international or historical examples and applications, or through collaborative experimental work.

The aims are to:

- provide an enjoyable and worthwhile educational experience for all learners, whether or not they go on to study science beyond this level
- enable learners to acquire sufficient knowledge and understanding to:
 - become confident citizens in a technological world and develop an informed interest in scientific matters
 - be suitably prepared for studies beyond Cambridge IGCSE
- allow learners to recognise that science is evidence-based and understand the usefulness, and the limitations, of scientific method
- develop skills that:
 - are relevant to the study and practice of science
 - are useful in everyday life
 - encourage a systematic approach to problem-solving
 - encourage efficient and safe practice
 - encourage effective communication through the language of science
- develop attitudes relevant to science such as:
 - concern for accuracy and precision
 - objectivity
 - integrity
 - enquiry
 - initiative
 - inventiveness
- enable learners to appreciate that:
 - science is 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.



Support for Cambridge IGCSE Co-ordinated Sciences (Double Award)

The School Support Hub is our secure online site for Cambridge teachers where you can find the resources you need to deliver our programmes, including schemes of work, past papers, mark schemes and examiner reports. You can also keep up to date with your subject and the global Cambridge community through our online discussion forums.

www.cambridgeinternational.org/support

Content overview

The subject content is divided into three sections: Biology (B1–B13), Chemistry (C1–C14) and Physics (P1–P8).

Candidates must study all three sections.

Biology

- B1 Characteristics of living organisms
- B2 Cells
- B3 Biological molecules
- B4 Enzymes
- B5 Plant nutrition
- B6 Animal nutrition
- B7 Transport
- B8 Gas exchange and respiration
- B9 Coordination and response
- B10 Reproduction
- B11 Inheritance
- B12 Organisms and their environment
- B13 Human influences on ecosystems

Chemistry

- C1 The particulate nature of matter
- C2 Experimental techniques
- C3 Atoms, elements and compounds
- C4 Stoichiometry
- C5 Electricity and chemistry
- C6 Energy changes in chemical reactions
- C7 Chemical reactions
- C8 Acids, bases and salts
- C9 The Periodic Table
- C10 Metals
- C11 Air and water
- C12 Sulfur
- C13 Carbonates
- C14 Organic chemistry

Physics

- P1 Motion
- P2 Work, energy and power
- P3 Thermal physics
- P4 Properties of waves, including light and sound
- P5 Electricity and magnetism
- P6 Electric circuits
- P7 Electromagnetic effects
- P8 Atomic physics

Assessment overview

All candidates take three papers.

Candidates who have studied the Core subject content, or who are expected to achieve a grade DD or below, should be entered for Paper 1, Paper 3 and either Paper 5 or Paper 6. These candidates will be eligible for grades CC to GG.

Candidates who have studied the Extended subject content (Core and Supplement), and who are expected to achieve a grade CC or above, should be entered for Paper 2, Paper 4 and either Paper 5 or Paper 6. These candidates will be eligible for grades A*A* to GG.

Core candidates take:

Paper 1 45 minutes
Multiple Choice (Core) 30%
40 marks
40 four-option multiple-choice questions
Questions will be based on the Core subject content.
Externally assessed

Extended candidates take:

Paper 2 45 minutes
Multiple Choice (Extended) 30%
40 marks
40 four-option multiple-choice questions
Questions will be based on the Extended subject content (Core and Supplement).
Externally assessed

and Core candidates take:

Paper 3 2 hours
Theory (Core) 50%
120 marks
Short-answer and structured questions
Questions will be based on the Core subject content.
Externally assessed

and Extended candidates take:

Paper 4 2 hours
Theory (Extended) 50%
120 marks
Short-answer and structured questions
Questions will be based on the Extended subject content (Core and Supplement).
Externally assessed

All candidates take either:

Paper 5 2 hours
Practical Test 20%
60 marks
Questions will be based on the experimental skills in section 4.
Externally assessed

or:

Paper 6 1 hour 30 minutes
Alternative to Practical 20%
60 marks
Questions will be based on the experimental skills in section 4.
Externally assessed

Information on availability is in the **Before you start** section.

Assessment objectives

The assessment objectives (AOs) are:

AO1 Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

- 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 and technological applications with their social, economic and environmental implications.

Subject content defines the factual material that candidates may be required to recall and explain. Candidates will also be asked questions which require them to apply this material to unfamiliar contexts and to apply knowledge from one area of the syllabus to another.

Questions testing this assessment objective will often begin with one of the following words: *define, state, describe, explain (using your knowledge and understanding) or outline (see the Glossary of terms used in science papers)*.

AO2 Handling information and problem-solving

Candidates should be able, in words or using 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, including some of a quantitative nature.

Questions testing these skills may be based on information that is unfamiliar to candidates, requiring them to apply the principles and concepts from the syllabus to a new situation, in a logical, deductive way.

Questions testing these skills will often begin with one of the following words: *predict, suggest, calculate or determine (see the Glossary of terms used in science papers)*.

AO3 Experimental skills and investigations

Candidates should be able to:

- demonstrate knowledge of how to safely use techniques, apparatus and materials (including following a sequence of instructions where appropriate)
- plan experiments and investigations
- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data
- evaluate methods and suggest possible improvements.

Weighting for assessment objectives

The approximate weightings allocated to each of the assessment objectives (AOs) are summarised below.

Assessment objectives as a percentage of the qualification

Assessment objective	Weighting in IGCSE %
AO1 Knowledge with understanding	50
AO2 Handling information and problem-solving	30
AO3 Experimental skills and investigations	20
Total	100

Assessment objectives as a percentage of each component

Assessment objective	Weighting in components %		
	Papers 1 and 2	Papers 3 and 4	Papers 5 and 6
AO1 Knowledge with understanding	63	63	0
AO2 Handling information and problem-solving	37	37	0
AO3 Experimental skills and investigations	0	0	100
Total	100	100	100

3 Subject content

The subject content that follows is divided into three sections: Biology (B1–B13), Chemistry (C1–C14) and Physics (P1–P8). **Candidates must study all three sections.**

All candidates should be taught the Core subject content. Candidates who are only taught the Core subject content can achieve a maximum of grade CC. Candidates aiming for grades A*A* to CC should be taught the Extended subject content. The Extended subject content includes both the Core and the Supplement.

This syllabus gives you the flexibility to design a course that will interest, challenge and engage your learners. Where appropriate you are responsible for selecting suitable subject contexts, resources and examples to support your learners' study. These should be appropriate for the learners' age, cultural background and learning context as well as complying with your school policies and local legal requirements.

Scientific subjects are, by their nature, experimental. Learners should pursue a fully integrated course which allows them to develop their practical skills by carrying out practical work and investigations within all of the topics listed.

Biology

B1 Characteristics of living organisms

B1.1 Characteristics of living organisms

Core

- 1 Describe the characteristics of living organisms by defining the terms:
 - *movement* as an action by an organism causing a change of position or place
 - *respiration* as the chemical reactions in cells that break down nutrient molecules and release energy
 - *sensitivity* as the ability to detect and respond to changes in the environment
 - *growth* as a permanent increase in size
 - *reproduction* as the processes that make more of the same kind of organism
 - *excretion* as removal from organisms of toxic materials and substances in excess of requirements
 - *nutrition* as taking in of materials for energy, growth and development

Supplement

- 2 Define the terms:
 - *movement* as an action by an organism or part of an organism causing a change of position or place
 - *respiration* as the chemical reactions in cells that break down nutrient molecules and release energy for metabolism
 - *sensitivity* as the ability to detect or sense stimuli in the internal or external environment and to make appropriate responses
 - *growth* as a permanent increase in size and dry mass by an increase in cell number or cell size or both
 - *excretion* as removal from organisms of the waste products of metabolism (chemical reactions in cells including respiration), toxic materials, and substances in excess of requirements
 - *nutrition* as taking in of materials for energy, growth and development; plants require light, carbon dioxide, water and ions; animals need organic compounds and ions and usually need water

0654 Biology

B2 Cells

B2.1 Cell structure

Core

- 1 State that living organisms are made of cells
- 2 Describe and compare the structure of a plant cell with an animal cell, as seen under a light microscope, limited to cell wall, nucleus, cytoplasm, chloroplasts, vacuoles and location of the cell membrane
- 3 State the functions of the structures seen under the light microscope in the plant cell and in the animal cell
- 5 Calculate magnification and size of biological specimens using millimetres as units

Supplement

- 4 Relate the structure of the following to their functions:
 - ciliated cells – movement of mucus in the trachea and bronchi
 - root hair cells – absorption
 - palisade mesophyll cells – photosynthesis
 - red blood cells – transport of oxygen
 - sperm and egg cells – reproduction

B2.2 Movement in and out of cells

Core

- 1 Define *diffusion* as the net movement of particles from a region of their higher concentration to a region of their lower concentration down a concentration gradient, as a result of their random movement
- 3 State that substances move into and out of cells by diffusion through the cell membrane
- 4 State that water diffuses through partially permeable membranes by osmosis
- 5 State that water moves in and out of cells by osmosis through the cell membrane
- 7 Investigate and describe the effects on plant tissues of immersing them in solutions of different concentrations

Supplement

- 2 Investigate the factors that influence diffusion, limited to surface area, temperature, concentration gradients and diffusion distance
- 6 Define *osmosis* as the net movement of water molecules from a region of higher water potential (dilute solution) to a region of lower water potential (concentrated solution), through a partially permeable membrane
- 8 Explain the effects on plant tissues of immersing them in solutions of different concentrations by using the terms turgid, turgor pressure, plasmolysis and flaccid
- 9 Explain the importance of water potential and osmosis in the uptake of water by plants
- 10 Explain the importance of water potential and osmosis on animal cells and tissues

0654 Biology**B3 Biological molecules****B3.1 Biological molecules**

Core

- 1 List the chemical elements that make up:
 - carbohydrates
 - fats
 - proteins
- 2 State that large molecules are made from smaller molecules, limited to:
 - starch and glycogen from glucose
 - proteins from amino acids
 - fats and oils from fatty acids and glycerol
- 3 Describe the use of:
 - iodine solution to test for starch
 - Benedict's solution to test for reducing sugars
 - biuret test for proteins
 - ethanol emulsion test for fats and oils
- 4 State that water is important as a solvent

B4 Enzymes**B4.1 Enzymes**

Core

- 1 Define *enzymes* as proteins that function as biological catalysts
- 3 Investigate and describe the effect of changes in temperature and pH on enzyme activity

Supplement

- 2 Explain enzyme action with reference to the complementary shape of the active site of an enzyme and its substrate and the formation of a product
- 4 Explain the effect of changes in temperature on enzyme activity in terms of kinetic energy, shape and fit, frequency of effective collisions and denaturation
- 5 Explain the effect of changes in pH on enzyme activity in terms of shape and fit and denaturation

0654 Biology

B5 Plant nutrition

B5.1 Plant nutrition

Core

- 1 Define *photosynthesis* as the process by which plants manufacture carbohydrates from raw materials using energy from light
- 2 State the word equation for photosynthesis: carbon dioxide + water → glucose + oxygen, in the presence of light and chlorophyll
- 6 Investigate the necessity for chlorophyll, light and carbon dioxide for photosynthesis, using appropriate controls
- 8 Identify chloroplasts, cuticle, guard cells and stomata, upper and lower epidermis, palisade mesophyll, spongy mesophyll, vascular bundles, xylem and phloem in leaves of a dicotyledonous plant
- 10 Describe the importance of:
 - nitrate ions for making amino acids
 - magnesium ions for making chlorophyll

Supplement

- 3 State the balanced equation for photosynthesis

$$6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow[\text{chlorophyll}]{\text{light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$
- 4 Explain that chlorophyll transfers light energy into chemical energy in molecules, for the synthesis of carbohydrates
- 5 Outline the subsequent use and storage of the carbohydrates made in photosynthesis
- 7 Investigate and describe the effect of varying light intensity and temperature on the rate of photosynthesis (e.g. in submerged aquatic plants)
- 9 Describe the significance of the features of a leaf in terms of functions, to include:
 - palisade mesophyll and distribution of chloroplasts – photosynthesis
 - stomata, spongy mesophyll cells and guard cells – gas exchange
 - xylem for transport and support
 - phloem for transport
- 11 Explain the effects of nitrate ion and magnesium ion deficiency on plant growth

0654 Biology**B6 Animal nutrition****B6.1 Diet**

Core

- 1 State what is meant by the term *balanced diet* for humans
- 2 List the principal sources of, and describe the dietary importance of:
 - carbohydrates
 - fats
 - proteins
 - vitamins, limited to C and D
 - mineral salts, limited to calcium and iron
 - fibre (roughage)
 - water

Supplement

- 3 Explain how age, gender and activity affect the dietary needs of humans including during pregnancy and while breast-feeding
- 4 Describe the effects of malnutrition in relation to starvation, constipation, coronary heart disease, obesity and scurvy
- 5 Explain the causes and effects of vitamin D and iron deficiencies
- 6 Explain the causes and effects of protein-energy malnutrition, e.g. kwashiorkor and marasmus

0654 Biology

B6.2 Alimentary canal

Core

- 1 Define *ingestion* as the taking of substances, e.g. food and drink, into the body through the mouth
- 2 Define *digestion* as the breakdown of large, insoluble food molecules into small, water-soluble molecules using mechanical and chemical processes
- 5 Define *absorption* as movement of digested food molecules through the wall of the intestine into the blood
- 6 Define *assimilation* as the movement of digested food molecules into the cells of the body where they are used, becoming part of the cells
- 7 Define *egestion* as passing out of food that has not been digested, as faeces, through the anus
- 8 Identify the main regions of the alimentary canal and associated organs, including mouth, salivary glands, oesophagus, stomach, small intestine, pancreas, liver, gall bladder, large intestine and anus
- 9 Describe the functions of the regions of the alimentary canal listed above, in relation to ingestion, digestion, absorption, assimilation and egestion of food

Supplement

- 3 Define *mechanical digestion* as the breakdown of food into smaller pieces without chemical change to the food molecules
- 4 Define *chemical digestion* as the breakdown of large, insoluble molecules into small, soluble molecules

0654 Biology

B6.3 Digestion

Core

- 1 Identify the types of human teeth (incisors, canines, premolars and molars)
- 2 Describe the structure of human teeth, limited to enamel, dentine, pulp, nerves and cement, as well as the gums
- 3 Describe the functions of the types of human teeth in mechanical digestion of food
- 4 Describe the proper care of teeth in terms of diet and regular brushing
- 6 State the significance of chemical digestion in the alimentary canal in producing small, soluble molecules that can be absorbed

Supplement

- 5 State the causes of dental decay in terms of a coating of bacteria and food on teeth, the bacteria respiring sugars in the food, producing acid which dissolves the enamel and dentine
- 7 State the functions of enzymes as follows:
 - amylase breaks down starch to simpler sugars
 - protease breaks down protein to amino acids
 - lipase breaks down fats to fatty acids and glycerol
- 8 State where, in the alimentary canal, amylase, protease and lipase are secreted
- 9 State the functions of the hydrochloric acid in gastric juice, limited to killing bacteria in food and giving an acid pH for enzymes
- 10 Explain the functions of the hydrochloric acid in gastric juice, limited to the low pH:
 - denaturing enzymes in harmful microorganisms in food
 - giving the optimum pH for protease activity
- 11 Outline the role of bile in neutralising the acidic mixture of food and gastric juices entering the duodenum from the stomach, to provide a suitable pH for enzyme action
- 12 Outline the role of bile in emulsifying fats to increase the surface area for the chemical digestion of fat to fatty acids and glycerol by lipase
- 13 Explain the significance of villi in increasing the internal surface area of the small intestine
- 14 Describe the structure of a villus
- 15 Describe the roles of capillaries and lacteals in villi

0654 Biology**B7 Transport****B7.1 Transport in plants****Core**

- 1 State the functions of xylem and phloem
- 2 Identify the position of xylem as seen in sections of roots, stems and leaves, limited to non-woody dicotyledonous plants
- 3 Identify root hair cells, as seen under the light microscope, and state their functions
- 5 State the pathway taken by water through root, stem and leaf as root hair cells, root cortex cells, xylem and mesophyll cells
- 6 Investigate, using a suitable stain, the pathway of water through the above-ground parts of a plant
- 7 State that water is transported from the roots to leaves through the xylem vessels
- 8 Define *transpiration* as loss of water vapour from plant leaves by evaporation of water at the surfaces of the mesophyll cells followed by diffusion of water vapour through the stomata
- 10 Investigate and describe the effects of variation of temperature and humidity on transpiration rate

Supplement

- 4 Explain that the large surface area of root hairs increases the rate of absorption of water and ions
- 9 Explain the mechanism by which water moves upwards in the xylem in terms of a transpiration pull, helping to create a water potential gradient that draws up a column of water molecules, held together by cohesion
- 11 Explain the effects of variation of temperature and humidity on transpiration rate
- 12 Define *translocation* in terms of the movement of sucrose and amino acids in phloem:
 - from regions of production (source)
 - to regions of storage OR to regions where they are used in respiration or growth (sink)

0654 Biology

B7.2 Transport in mammals

Core

- 1 Describe the circulatory system as a system of blood vessels with a pump and valves to ensure one-way flow of blood
- 4 Name and identify the structures of the mammalian heart, limited to the muscular wall, the septum, the left and right ventricles and atria, one-way valves and coronary arteries
- 5 State that blood is pumped away from the heart into arteries and returns to the heart in veins
- 7 Name the main blood vessels to and from the:
 - heart, limited to vena cava, aorta, pulmonary artery and pulmonary vein
 - lungs, limited to the pulmonary artery and pulmonary vein
 - kidney, limited to the renal artery and renal vein
- 9 Investigate and state the effect of physical activity on pulse rate
- 11 Describe the structure and functions of arteries, veins and capillaries
- 13 List the components of blood as red blood cells, white blood cells, platelets and plasma
- 14 Identify red and white blood cells, as seen under the light microscope, on prepared slides and in diagrams and photomicrographs
- 15 State the functions of the following components of blood:
 - red blood cells in transporting oxygen, including the role of haemoglobin
 - white blood cells in phagocytosis and antibody production
 - platelets in clotting (details are **not** required)
 - plasma in the transport of blood cells, ions, soluble nutrients, hormones and carbon dioxide

Supplement

- 2 Describe double circulation in terms of circulation to the lungs and circulation to the body tissues in mammals
- 3 Explain the advantages of a double circulation
- 6 Describe the functioning of the heart in terms of the contraction of muscles of the atria and ventricles and the action of the valves
- 8 Describe coronary heart disease in terms of the blockage of coronary arteries and state the possible risk factors as diet, stress, smoking, genetic predisposition, age and gender
- 10 Explain the effect of physical activity on the heart rate
- 12 Explain how the structures of arteries, veins and capillaries are adapted for their function

0654 Biology**B8 Gas exchange and respiration****B8.1 Gas exchange****Core**

- 1 Name and identify the lungs, diaphragm, ribs, intercostal muscles, larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries
- 3 State the differences in composition between inspired and expired air limited to oxygen, carbon dioxide and water vapour
- 5 Use limewater as a test for carbon dioxide to investigate the differences in composition between inspired and expired air
- 6 Investigate and describe the effects of physical activity on rate and depth of breathing

Supplement

- 2 List the features of gas exchange surfaces in humans, limited to large surface area, thin surface, good blood supply and good ventilation with air
- 4 Explain the differences in composition between inspired and expired air
- 7 Explain the effects of physical activity on rate and depth of breathing in terms of the increased carbon dioxide concentration in the blood, causing an increased rate of breathing
- 8 Explain the role of goblet cells, mucus and ciliated cells in protecting the gas exchange system from pathogens and particles
- 9 State that tobacco smoking can cause chronic obstructive pulmonary disease (COPD), lung cancer and coronary heart disease
- 10 Describe the effects on the gas exchange system of tobacco smoke and its major toxic components, limited to carbon monoxide, nicotine and tar

0654 Biology

B8.2 Respiration

Core

- 1 State the uses of energy in the body of humans limited to: muscle contraction, protein synthesis, cell division, growth and the maintenance of a constant body temperature
- 3 State the word equation for aerobic respiration as glucose + oxygen → carbon dioxide + water

Supplement

- 2 Define *aerobic respiration* as the chemical reactions in cells that use oxygen to break down nutrient molecules to release energy
- 4 State the balanced chemical equation for aerobic respiration as
$$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$$
- 5 Define *anaerobic respiration* as the chemical reactions in cells that break down nutrient molecules to release energy without using oxygen
- 6 State the word equation for anaerobic respiration in muscles during vigorous exercise (glucose → lactic acid)
- 7 State that lactic acid builds up in muscles and blood during vigorous exercise causing an oxygen debt
- 8 State the word equation for anaerobic respiration in microorganism yeast (glucose → alcohol + carbon dioxide)
- 9 Describe the role of anaerobic respiration in yeast during bread-making
- 10 State that anaerobic respiration releases much less energy per glucose molecule than aerobic respiration

0654 Biology**B9 Coordination and response****B9.1 Nervous control in humans****Core**

- 1 Describe a nerve impulse as an electrical signal that passes along nerve cells called neurones
- 2 Describe the human nervous system in terms of:
 - the central nervous system consisting of brain and spinal cord
 - the peripheral nervous system
 - coordination and regulation of body functions
- 4 Identify motor (effector), relay (connector) and sensory neurones from diagrams
- 5 Describe a simple reflex arc in terms of receptor, sensory neurone, relay neurone, motor neurones and effector
- 6 Describe a reflex action as a means of automatically and rapidly integrating and coordinating stimuli with the responses of effectors (muscles and glands)

Supplement

- 3 Distinguish between voluntary and involuntary actions

B9.2 Sense organs**Supplement**

- 1 Identify the structures of the eye, limited to cornea, iris, pupil, lens, retina, optic nerve, ciliary muscles, suspensory ligaments and blind spot
- 2 Describe the function of each part of the eye, limited to:
 - cornea – refracts light
 - iris – controls how much light enters pupil
 - lens – focuses light onto retina
 - retina – contains light receptors, some sensitive to light of different colours
 - optic nerve – carries impulses to the brain
- 3 Explain the pupil reflex in terms of light intensity and antagonistic action of circular and radial muscles in the iris
- 4 Explain accommodation to view near and distant objects in terms of the contraction and relaxation of the ciliary muscles, tension in the suspensory ligaments, shape of the lens and refraction of light

0654 Biology**B9.3 Hormones**

Core

- 1 Define a *hormone* as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs
- 2 Describe adrenaline as the hormone secreted in 'fight or flight' situations and its effects, limited to increased breathing and pulse rate and widened pupils
- 3 Give examples of situations in which adrenaline secretion increases

Supplement

- 4 Discuss the role of the hormone adrenaline in the chemical control of metabolic activity, including increasing the blood glucose concentration and pulse rate
- 5 Compare nervous and hormonal control systems in terms of speed and longevity of action

B9.4 Homeostasis

Core

- 1 Define *homeostasis* as the maintenance of a constant internal environment
- 5 Name and identify on a diagram of the skin: hairs, hair erector muscles, sweat glands, receptors, sensory neurones, blood vessels and fatty tissue
- 6 Describe the maintenance of a constant internal body temperature in humans in terms of insulation, sweating, shivering and the role of the brain (limited to blood temperature receptors and coordination)

Supplement

- 2 Explain that homeostasis is the control of internal conditions within set limits
- 3 Explain the concept of control by negative feedback
- 4 Describe the control of the glucose content of the blood by the liver and the roles of insulin and glucagon from the pancreas
- 7 Describe the maintenance of a constant internal body temperature in humans in terms of vasodilation and vasoconstriction of arterioles supplying skin surface capillaries

0654 Biology**B9.5 Tropic responses**

Core

- 1 Define *gravitropism* as a response in which parts of a plant grow towards or away from gravity
- 2 Define *phototropism* as a response in which parts of a plant grow towards or away from the direction from which light is coming
- 4 Investigate gravitropism and phototropism in shoots and roots

Supplement

- 3 Explain phototropism and gravitropism of a shoot as examples of the chemical control of plant growth
- 5 Explain the role of auxin in controlling shoot growth, limited to:
 - auxin made in shoot tip (only)
 - auxin spreads through the plant from the shoot tip
 - auxin is unequally distributed in response to light and gravity
 - auxin stimulates cell elongation

B10 Reproduction**B10.1 Asexual and sexual reproduction**

Core

- 1 Define *asexual reproduction* as a process resulting in the production of genetically identical offspring from one parent
- 3 Identify examples of asexual reproduction from information provided
- 4 Define *sexual reproduction* as a process involving the fusion of the nuclei of two gametes (sex cells) to form a zygote and the production of offspring that are genetically different from each other

Supplement

- 2 Discuss the advantages and disadvantages of asexual reproduction to a population of a species in the wild
- 5 State that the nuclei of gametes are haploid and that the nucleus of a zygote is diploid
- 6 Discuss the advantages and disadvantages of sexual reproduction to a population of a species in the wild

0654 Biology**B10.2 Sexual reproduction in plants****Core**

- 1 Identify and draw, using a hand lens if necessary, the sepals, petals, stamens, filaments and anthers, carpels, style, stigma, ovary and ovules, of an insect-pollinated flower
- 3 State the functions of the sepals, petals, anthers, stigmas and ovaries
- 5 Define *pollination* as the transfer of pollen grains from the anther to the stigma
- 6 Name the agents of pollination
- 7 State that fertilisation occurs when a pollen nucleus fuses with a nucleus in an ovule
- 9 Investigate and state the environmental conditions that affect germination of seeds, limited to the requirement for water, oxygen and a suitable temperature

Supplement

- 2 Use a hand lens to identify and describe the anthers and stigmas of a wind-pollinated flower
- 4 Distinguish between the pollen grains of insect-pollinated and wind-pollinated flowers
- 8 Describe the structural adaptations of insect-pollinated and wind-pollinated flowers

0654 Biology

B10.3 Sexual reproduction in humans

Core

- 1 Identify and name on diagrams of the male reproductive system: the testes, scrotum, sperm ducts, prostate gland, urethra and penis
- 2 State the function of the parts of the male reproductive system limited to:
 - testes – production of male gametes (sperm)
 - scrotum – sac that holds the testes outside the body
 - sperm ducts – transfer sperm to the urethra
 - prostate gland – secrete fluids for sperm to swim in forming semen
 - urethra – carries urine and semen out of the body
 - penis – transfers semen to vagina during sexual intercourse
- 3 Identify and name on diagrams of the female reproductive system: the ovaries, oviducts, uterus, cervix and vagina
- 4 State the function of the parts of the female reproductive system limited to:
 - ovaries – release of female gametes (eggs)
 - oviducts – transfers egg to uterus and the site of fertilisation
 - uterus – where the fetus develops
 - cervix – ring of muscle at the opening of the uterus
 - vagina – receives penis during sexual intercourse
- 5 Describe fertilisation as the fusion of the nuclei from a male gamete (sperm) and a female gamete (egg cell/ovum)
- 9 Describe the menstrual cycle in terms of changes in the uterus and ovaries (knowledge of sex hormones is **not** required)

Supplement

- 6 Compare male and female gametes in terms of size, structure, motility and numbers
- 7 State the adaptive features of sperm, limited to flagellum and the presence of enzymes
- 8 State the adaptive features of egg cells, limited to energy stores and a jelly coating that changes after fertilisation

continued

0654 Biology

B10.3 Sexual reproduction in humans continued

Core

- 10 State that in early development, the zygote forms an embryo which is a ball of cells that implants into the wall of the uterus
- 13 State that human immunodeficiency virus (HIV) infection may lead to acquired immune deficiency syndrome (AIDS)
- 14 Describe the methods of transmission of HIV
- 15 Explain how the spread of sexually transmitted infections (STIs) is controlled

Supplement

- 11 State the functions of the umbilical cord, placenta, amniotic sac and amniotic fluid
- 12 Describe the function of the placenta and umbilical cord in relation to exchange of dissolved nutrients, gases and excretory products and providing a barrier to toxins (structural details are **not** required)

B11 Inheritance

B11.1 Chromosomes and genes

Core

- 1 Define *inheritance* as the transmission of genetic information from generation to generation
- 2 Define *chromosome* as a thread-like structure of DNA, carrying genetic information in the form of genes
- 3 Define *gene* as a length of DNA that codes for a protein
- 4 Define *allele* as a version of a gene
- 5 Describe the inheritance of sex in humans with reference to XX and XY chromosomes

Supplement

- 6 Define a *haploid nucleus* as a nucleus containing a single set of unpaired chromosomes, e.g. in gametes
- 7 Define a *diploid nucleus* as a nucleus containing two sets of chromosomes, e.g. in body cells
- 8 State that in a diploid cell, chromosomes are arranged in pairs and in a human diploid cell there are 23 pairs

0654 Biology

B11.2 Cell division

Supplement

- 1 Define *mitosis* as nuclear division giving rise to genetically identical cells (details of stages are **not** required)
- 2 State that the exact duplication of chromosomes occurs before mitosis
- 3 State the role of mitosis in growth, repair of damaged tissues, replacement of cells and asexual reproduction
- 4 Define *meiosis* as reduction division in which the chromosome number is halved from diploid to haploid resulting in genetically different cells (details of stages are **not** required)
- 5 State that meiosis is involved in the production of gametes

B11.3 Monohybrid inheritance

Core

- 1 Define *genotype* as the genetic make-up of an organism in terms of the alleles present
- 2 Define *phenotype* as the observable features of an organism
- 3 Define *homozygous* as having two identical alleles of a particular gene
- 4 State that two identical homozygous individuals that breed together will be pure-breeding
- 5 Define *heterozygous* as having two different alleles of a particular gene
- 6 State that a heterozygous individual will not be pure-breeding
- 7 Define *dominant* as an allele that is expressed if it is present
- 8 Define *recessive* as an allele that is only expressed when there is no dominant allele of the gene present
- 9 Use genetic diagrams to predict the results of monohybrid crosses and calculate phenotypic ratios, limited to 1:1 and 3:1 ratios
- 10 Use Punnett squares in crosses which result in more than one genotype to work out and show the possible different genotypes

Supplement

- 11 Interpret pedigree diagrams for the inheritance of a given characteristic

0654 Biology

B11.4 Variation and selection

Core

- 1 Define *variation* as differences between individuals of the same species
- 2 Distinguish between phenotypic variation and genetic variation
- 4 State that continuous variation results in a range of phenotypes between two extremes, e.g. height in humans
- 6 State that discontinuous variation results in a limited number of phenotypes with no intermediates, e.g. tongue rolling
- 7 Record and present the results of investigations into continuous and discontinuous variation
- 10 Describe natural selection with reference to:
 - variation within populations
 - production of many offspring
 - competition for resources
 - struggle for survival
 - reproduction by individuals that are better adapted to the environment than others
 - passing on of their alleles to the next generation
- 14 Describe selective breeding with reference to:
 - selection by humans of individuals with desirable features
 - crossing these individuals to produce the next generation
 - selection of offspring showing the desirable features

Supplement

- 3 State that phenotypic variation is caused by both genetic and environmental factors
- 5 State that discontinuous variation is mostly caused by genes alone, e.g. A, B, AB and O blood groups in humans
- 8 Define *mutation* as a change in a gene or chromosome
- 9 State that ionising radiation and some chemicals increase the rate of mutation
- 11 Describe evolution as the change in adaptive features of a population over time as the result of natural selection
- 12 Define the process of *adaptation* as the process, resulting from natural selection, by which populations become more suited to their environment over many generations
- 13 Describe the development of strains of antibiotic resistant bacteria as an example of evolution by natural selection
- 15 State the differences between natural and artificial selection
- 16 Outline how selective breeding by artificial selection is carried out over many generations to improve crop plants and domesticated animals

0654 Biology

B12 Organisms and their environment

B12.1 Organisms and their environment

Core

- 1 State that the Sun is the principal source of energy input to biological systems
- 2 Define the terms:
 - *food chain* as showing the transfer of energy from one organism to the next, beginning with a producer
 - *food web* as a network of interconnected food chains
 - *producer* as an organism that makes its own organic nutrients, usually using energy from sunlight, through photosynthesis
 - *consumer* as an organism that gets its energy by feeding on other organisms
 - *herbivore* as an animal that gets its energy by eating plants
 - *carnivore* as an animal that gets its energy by eating other animals
 - *decomposer* as an organism that gets its energy from dead or waste organic matter
- 6 Construct simple food chains
- 7 Interpret food chains and food webs in terms of identifying producers and consumers
- 8 State that consumers may be classed as primary, secondary and tertiary according to their position in a food chain

Supplement

- 3 Define the terms:
 - *ecosystem* as a unit containing all of the organisms and their environment, interacting together, in a given area, e.g. a lake
 - *trophic level* as the position of an organism in a food chain or food web
- 4 Describe how energy is transferred between trophic levels
- 5 Explain why food chains usually have fewer than five trophic levels
- 9 Identify producers, primary consumers, secondary consumers, tertiary consumers and quaternary consumers as the trophic levels in food webs and food chains

0654 Biology**B13 Human influences on ecosystems****B13.1 Human influences on ecosystems****Core**

- 1 Describe the carbon cycle, limited to photosynthesis, respiration, feeding, decomposition, fossilisation and combustion
- 3 List the undesirable effects of deforestation as an example of habitat destruction, to include extinction, loss of soil, flooding and increase of carbon dioxide in the atmosphere
- 5 State the sources and effects of pollution of water (rivers, lakes and the sea) by chemical waste, discarded rubbish, untreated sewage and fertilisers

Supplement

- 2 Discuss the effects of the combustion of fossil fuels and the cutting down of forests on the oxygen and carbon dioxide concentrations in the atmosphere
- 4 Explain the undesirable effects of deforestation on the environment
- 6 Explain the process of eutrophication of water in terms of:
 - increased availability of nitrate and other ions
 - increased growth of producers
 - increased decomposition after death of producers
 - increased aerobic respiration by decomposers
 - reduction in dissolved oxygen
 - death of organisms requiring dissolved oxygen in water

Chemistry

C1 The particulate nature of matter

C1.1 The particulate nature of matter

Core

- 1 State the distinguishing properties of solids, liquids and gases
- 2 Describe the structure of solids, liquids and gases in terms of particle separation, arrangement and types of motion
- 3 Describe the changes of state in terms of melting, boiling, evaporation, freezing and condensation
- 4 Demonstrate understanding of the terms *atom*, *molecule* and *ion*
- 6 Describe and explain diffusion in terms of the movement of particles (atoms, molecules or ions)

Supplement

- 5 Explain changes of state in terms of particle theory and the energy changes involved
- 7 Describe and explain dependence of rate of diffusion on molecular mass

C2 Experimental techniques

C2.1 Measurement

Core

- 1 Name and suggest appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes and measuring cylinders

C2.2 Criteria of purity

Core

- 1 Demonstrate knowledge and understanding of paper chromatography
- 2 Interpret simple chromatograms
- 4 Understand the importance of purity in substances for use in everyday life, e.g. in the manufacture of compounds to use in drugs and food additives
- 5 Recognise that mixtures melt and boil over a range of temperatures

Supplement

- 3 Interpret simple chromatograms, including the use of R_f values
- 6 Identify substances and assess their purity from melting point and boiling point information

0654 Chemistry

C2.3 Methods of purification

Core

- 1 Describe and explain methods of separation and purification by the use of a suitable solvent, filtration, crystallisation, distillation, fractional distillation and paper chromatography
- 2 Suggest suitable separation and purification techniques, given information about the substances involved

C3 Atoms, elements and compounds

C3.1 Physical and chemical changes

Core

- 1 Identify physical and chemical changes, and understand the differences between them

Supplement

- 2 Understand that some chemical reactions can be reversed by changing the reaction conditions (Limited to the effects of heat and water on hydrated and anhydrous copper(II) sulfate and cobalt(II) chloride.) (Concept of equilibrium is **not** required.)

C3.2 Elements, compounds and mixtures

Core

- 1 Describe the differences between elements, mixtures and compounds, and between metals and non-metals
- 2 Define the terms *solvent*, *solute*, *solution* and *concentration*

0654 Chemistry

C3.3 Atomic structure and the Periodic Table

Core

- Describe the structure of an atom in terms of a central nucleus, containing protons and neutrons, and 'shells' of electrons
- Describe the build-up of electrons in 'shells' and understand the significance of the noble gas electronic structures and of the outer-shell electrons
(The ideas of the distribution of electrons in s and p orbitals and in d-block elements are **not** required.)
- State the charges and approximate relative masses of protons, neutrons and electrons
- Define and use *proton number* (atomic number) as the number of protons in the nucleus of an atom
- Define and use *nucleon number* (mass number) as the total number of protons and neutrons in the nucleus of an atom
- Use proton number and the simple structure of atoms to explain the basis of the Periodic Table, with special reference to the elements of proton numbers 1 to 20
- Define *isotopes* as atoms of the same element which have the same proton number but a different nucleon number

Supplement

- Understand that isotopes have the same properties because they have the same number of electrons in their outer shell

Note: a copy of the Periodic Table, as shown in the Appendix, will be provided in Papers 1, 2, 3 and 4.

C3.4 Ions and ionic bonds

Core

- Describe the formation of ions by electron loss or gain
- Use dot-and-cross diagrams to describe the formation of ionic bonds between Group I and Group VII

Supplement

- Describe the formation of ionic bonds between metallic and non-metallic elements to include the strong attraction between ions because of their opposite electrical charges
- Describe the lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions, exemplified by the sodium chloride structure

0654 Chemistry

C3.5 Molecules and covalent bonds

Core

- 1 State that non-metallic elements form simple molecules with covalent bonds between atoms
- 2 Describe the formation of single covalent bonds in H_2 , Cl_2 , H_2O , CH_4 , NH_3 and HCl as the sharing of pairs of electrons leading to the noble gas configuration including the use of dot-and-cross diagrams
- 4 Describe the differences in volatility, solubility and electrical conductivity between ionic and covalent compounds

Supplement

- 3 Use and draw dot-and-cross diagrams to represent the bonding in the more complex covalent molecules such as N_2 , C_2H_4 , CH_3OH , and CO_2
- 5 Explain the differences in melting point and boiling point of ionic and covalent compounds in terms of attractive forces

C3.6 Macromolecules

Core

- 1 State that there are several different forms of carbon, including diamond and graphite
- 2 Describe the giant covalent structures of graphite and diamond

Supplement

- 3 Relate the structures of diamond and graphite to their uses, e.g. graphite as a lubricant and a conductor and diamond in cutting tools
- 4 Describe the macromolecular structure of silicon(IV) oxide (silicon dioxide, SiO_2)

C4 Stoichiometry

C4.1 Stoichiometry

Core

- 1 Use the symbols of the elements and write the formulae of simple compounds
- 3 Deduce the formula of a simple compound from the relative numbers of atoms present
- 4 Deduce the formula of a simple compound from a model or a diagrammatic representation
- 5 Construct and use word equations
- 6 Interpret and balance simple symbol equations

Supplement

- 2 Determine the formula of an ionic compound from the charges on the ions present
- 7 Construct and use symbol equations, with state symbols, including ionic equations
- 8 Deduce the balanced equation for a chemical reaction, given relevant information
- 9 Define *relative atomic mass*, A_r , as the average mass of naturally occurring atoms of an element on a scale where the ^{12}C atom has a mass of exactly 12 units
- 10 Define *relative molecular mass*, M_r , as the sum of the relative atomic masses (*relative formula mass* or M_r will be used for ionic compounds)

0654 Chemistry

C4.2 The mole

Supplement

- 1 Define the *mole* in terms of a specific number of particles called Avogadro's constant
- 2 Use the molar gas volume, taken as 24 dm^3 at room temperature and pressure
- 3 Calculate stoichiometric reacting masses, volumes of gases and solutions, and concentrations of solutions expressed in g/dm^3 and mol/dm^3 . (Calculations involving the idea of limiting reactants may be set.)

C5 Electricity and chemistry

C5.1 Electricity and chemistry

Core

- 1 Define *electrolysis* as the breakdown of an ionic compound when molten or in aqueous solution by the passage of electricity
- 2 Use the terms *inert electrode*, *electrolyte*, *anode* and *cathode*
- 4 Describe the electrode products and the observations made, using inert electrodes (platinum or carbon), in the electrolysis of:
 - molten lead(II) bromide
 - concentrated aqueous sodium chloride
 - dilute sulfuric acid
- 8 Describe electroplating with copper

Supplement

- 3 Describe electrolysis in terms of the ions present and the reactions at the electrodes, in terms of gain of electrons by cations and loss of electrons by anions to form atoms
- 5 State the general principle that metals or hydrogen are formed at the negative electrode (cathode), and that non-metals (other than hydrogen) are formed at the positive electrode (anode)
- 6 Relate the products of electrolysis to the electrolyte and electrodes used, exemplified by the specific examples in the Core together with aqueous copper(II) sulfate using carbon electrodes and using copper electrodes (as used in the refining of copper)
- 7 Construct simple ionic half-equations for the formation of elements at the cathode
- 9 Predict the products of the electrolysis of a specified molten binary compound
- 10 Describe, in outline, the chemistry of the manufacture of:
 - aluminium from pure aluminium oxide in molten cryolite
 - chlorine, hydrogen and sodium hydroxide from concentrated aqueous sodium chloride
 (Starting materials and essential conditions should be given but not technical details or diagrams.)

0654 Chemistry**C6 Energy changes in chemical reactions****C6.1 Energy changes in chemical reactions****Core**

- 1 Describe the meaning of *exothermic* and *endothermic* reactions

Supplement

- 2 Describe bond breaking as an endothermic process and bond forming as an exothermic process
- 3 Draw and label energy level diagrams for exothermic and endothermic reactions using data provided
- 4 Interpret energy level diagrams showing exothermic and endothermic reactions and the activation energy of a reaction

C7 Chemical reactions**C7.1 Rate (speed) of reaction****Core**

- 1 Describe practical methods for investigating the rate of a reaction which produces a gas
- 2 Interpret data obtained from experiments concerned with rate of reaction
- 4 Describe the effect of concentration, particle size, catalysts and temperature on the rate of reactions
- 7 Describe how concentration, temperature and surface area create a danger of explosive combustion with fine powders (e.g. flour mills) and gases (e.g. methane in mines)

Supplement

- 3 Suggest suitable apparatus, given information, for experiments, including collection of gases and measurement of rates of reaction
- 5 Describe and explain the effect of changing concentration in terms of frequency of collisions between reacting particles
- 6 Describe and explain the effect of changing temperature in terms of the frequency of collisions between reacting particles and more colliding particles possessing the minimum energy (activation energy) to react

Note: Candidates should be encouraged to use the term *rate* rather than *speed*.

0654 Chemistry

C7.2 Redox

Core

- 1 Describe oxidation and reduction in chemical reactions in terms of oxygen loss / gain (Oxidation state limited to its use to name ions, e.g. iron(II), iron(III), copper(II).)

Supplement

- 2 Define *redox* in terms of electron transfer, and identify such reactions from given information, which could include simple equations
- 3 Define and identify an *oxidising agent* as a substance which oxidises another substance during a redox reaction and a *reducing agent* as a substance which reduces another substance during a redox reaction

C8 Acids, bases and salts

C8.1 The characteristic properties of acids and bases

Core

- 1 Describe neutrality and relative acidity and alkalinity in terms of pH (whole numbers only) measured using universal indicator
- 2 Describe the characteristic properties of acids (exemplified by dilute hydrochloric acid and dilute sulfuric acid) including their effect on litmus paper and their reactions with metals, bases and carbonates
- 3 Describe the characteristic properties of bases including their effect on litmus paper and their reactions with acids and ammonium salts
- 4 Describe and explain the importance of controlling acidity in soil

Supplement

- 5 Define *acids* and *bases* in terms of proton (H^+) transfer, limited to aqueous solutions

C8.2 Types of oxides

Core

- 1 Classify oxides as either acidic or basic, related to metallic and non-metallic character

Supplement

- 2 Further classify other oxides as neutral or amphoteric

C8.3 Preparation of salts

Core

- 1 Describe the preparation, separation and purification of salts using techniques specified in Section C2 and the reactions specified in Section C8.1

Supplement

- 2 Suggest a method of making a given salt from suitable starting material, given appropriate information, including precipitation

0654 Chemistry

C8.4 Identification of ions and gases

Core

- 1 Describe and use the following tests to identify:

aqueous cations:

ammonium, calcium, copper(II), iron(II), iron(III) and zinc, using aqueous sodium hydroxide and aqueous ammonia as appropriate (formulae of complex ions are **not** required)

cations:

flame tests to identify lithium, sodium, potassium and copper(II)

anions:

carbonate (by reaction with dilute acid and then limewater), chloride and bromide (by reaction under acidic conditions with aqueous silver nitrate), nitrate (by reduction with aluminium) and sulfate (by reaction under acidic conditions with aqueous barium ions)

gases:

ammonia (using damp red litmus paper), carbon dioxide (using limewater), chlorine (using damp litmus paper), hydrogen (using a lighted splint), oxygen (using a glowing splint)

C9 The Periodic Table

C9.1 The Periodic Table

Core

- 1 Describe the Periodic Table as a method of classifying elements and its use to predict properties of elements

C9.2 Periodic trends

Core

- 1 Describe the change from metallic to non-metallic character across a period

Supplement

- 2 Describe the relationship between group number, number of outer-shell electrons and metallic/non-metallic character

0654 Chemistry

C9.3 Group properties

Core

- 1 Describe lithium, sodium and potassium in Group I as a collection of relatively soft metals showing a trend in melting point, density and reaction with water
- 3 Describe the halogens, chlorine, bromine and iodine in Group VII, as a collection of diatomic non-metals showing a trend in colour and physical state

Supplement

- 2 Predict the properties of other elements in Group I, given data, where appropriate
- 4 State the reaction of chlorine, bromine and iodine with other halide ions
- 5 Predict the properties of other elements in Group VII, given data where appropriate
- 6 Identify trends in other groups, given data about the elements concerned

C9.4 Transition elements

Core

- 1 Describe the transition elements as a collection of metals having high densities, high melting points and forming coloured compounds, and which, as elements and compounds, often act as catalysts

C9.5 Noble gases

Core

- 1 Describe the noble gases, in Group VIII or 0, as being unreactive, monoatomic gases and explain this in terms of electronic structure
- 2 State the uses of the noble gases in providing an inert atmosphere, i.e. argon in lamps, helium for filling balloons

0654 Chemistry**C10 Metals****C10.1 Properties of metals****Core**

- Describe the general physical properties of metals as solids with high melting and boiling points, malleable and good conductors of heat and electricity
- Describe alloys, such as brass, as mixtures of a metal with other elements
- Explain in terms of their properties why alloys are used instead of pure metals

Supplement

- Describe metallic bonding as a lattice of positive ions in a 'sea of electrons' and use this to describe the electrical conductivity and malleability of metals
- Describe how the properties of iron are changed by the controlled use of additives to form steel alloys, such as mild steel and stainless steel
- Identify representations of alloys from diagrams of structure

C10.2 Reactivity series**Core**

- Place in order of reactivity: potassium, sodium, calcium, magnesium, aluminium, (carbon), zinc, iron, (hydrogen) and copper, by reference to the reactions, if any, of the elements with:
 - water or steam
 - dilute hydrochloric acid
 - reduction of their oxides with carbon
- Deduce an order of reactivity from a given set of experimental results

Supplement

- Describe the reactivity series in terms of the tendency of a metal to form its positive ion, illustrated by its reaction, if any, with:
 - aqueous ions of other listed metals
 - the oxides of other listed metals

C10.3 Extraction of metals from their ores**Core**

- Describe the use of carbon in the extraction of some metals from their ores
- Know that aluminium is extracted from the ore bauxite by electrolysis
- Describe metal ores as a finite resource and hence the need to recycle metals

Supplement

- Describe and explain the essential reactions in the extraction of iron from hematite in the blast furnace, including the removal of acidic impurities as slag

$$\text{C} + \text{O}_2 \rightarrow \text{CO}_2$$

$$\text{C} + \text{CO}_2 \rightarrow 2\text{CO}$$

$$\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$$

$$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$$

$$\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$$
- Relate the method of extraction of a metal from its ore to its position in the reactivity series for the metals listed in section C10.2 and for other metals, given information

0654 Chemistry

C10.4 Uses of metals

Core

- 1 Describe the uses of aluminium:
 - in aircraft parts because of its strength and low density
 - in food containers because of its resistance to corrosion
- 3 State the uses of mild steel (car bodies and machinery) and stainless steel (chemical plant and cutlery)

Supplement

- 2 Describe and explain the apparent unreactivity of aluminium in terms of the oxide layer which adheres to the metal
- 4 Explain the uses of zinc for galvanising steel and for making brass

C11 Air and water

C11.1 Water

Core

- 1 Describe a chemical test for water using copper(II) sulfate and cobalt(II) chloride
- 2 Describe, in outline, the treatment of the water supply in terms of filtration and chlorination

0654 Chemistry

C11.2 Air

Core

- 1 State the composition of clean air as being a mixture of 78% nitrogen, 21% oxygen and small quantities of noble gases, water vapour and carbon dioxide
- 2 Name the common pollutants in air as being carbon monoxide, sulfur dioxide and oxides of nitrogen
- 3 State the adverse effect of these common air pollutants on buildings and on health
- 4 State the source of each of these pollutants:
 - carbon monoxide from the incomplete combustion of carbon-containing substances
 - sulfur dioxide from the combustion of fossil fuels which contain sulfur compounds (leading to acid rain)
 - oxides of nitrogen from car engines
- 7 State the conditions required for the rusting of iron (presence of oxygen and water)
- 8 Describe and explain barrier methods of rust prevention, including paint and other coatings

Supplement

- 5 Describe some approaches to reducing emissions of sulfur dioxide, including the use of low sulfur petrol and flue gas desulfurisation by calcium oxide
- 6 Describe, in outline, how a catalytic converter removes nitrogen monoxide and carbon monoxide from exhaust emissions by reaction over a hot catalyst

$$2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$$

$$2\text{NO} + 2\text{CO} \rightarrow \text{N}_2 + 2\text{CO}_2$$

$$2\text{NO} \rightarrow \text{N}_2 + \text{O}_2$$
- 9 Describe and explain sacrificial protection in terms of the reactivity series of metals and galvanising as a method of rust prevention

C11.3 Carbon dioxide and methane

Core

- 1 State the formation of carbon dioxide:
 - as a product of complete combustion of carbon-containing substances
 - as a product of respiration
 - as a product of the reaction between an acid and a carbonate
 - as a product of thermal decomposition of calcium carbonate
- 2 State that carbon dioxide and methane are greenhouse gases

Supplement

- 3 State that increased concentrations of greenhouse gases cause an enhanced greenhouse effect, which may contribute to climate change

0654 Chemistry

C11.4 Nitrogen and fertilisers

Core

- 1 Describe the need for nitrogen-, phosphorus- and potassium-containing fertilisers
- 2 Describe the displacement of ammonia from its salts

Supplement

- 3 Describe and explain the essential conditions for the manufacture of ammonia by the Haber process including the sources of the hydrogen (reaction of methane/natural gas with steam) and nitrogen (from the air)

C12 Sulfur

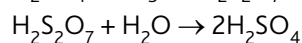
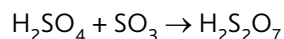
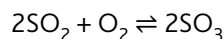
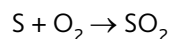
C12.1 Sulfur

Core

- 1 Name the use of sulfur in the manufacture of sulfuric acid

Supplement

- 2 Describe the manufacture of sulfuric acid by the Contact process, including essential conditions and reactions



C13 Carbonates

C13.1 Carbonates

Core

- 1 Describe the manufacture of lime (calcium oxide) from limestone (calcium carbonate) in terms of the chemical reactions involved, and the use of limestone in treating acidic soil and neutralising acidic industrial waste products
- 2 Describe the thermal decomposition of calcium carbonate (limestone)

C14 Organic chemistry

C14.1 Names of compounds

Core

- 1 Name and draw the structures of methane, ethane, ethene and ethanol
- 2 State the type of compound present, given a chemical name ending in *-ane*, *-ene* and *-ol*, or a molecular structure

Supplement

- 3 Name and draw the structures of the unbranched alkanes and alkenes (**not** *cis-trans*), containing up to four carbon atoms per molecule

0654 Chemistry

C14.2 Fuels

Core

- 1 State that coal, natural gas and petroleum are fossil fuels that produce carbon dioxide on combustion
- 2 Name methane as the main constituent of natural gas
- 3 Describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation
- 5 Name the uses of the fractions as:
 - refinery gas for bottled gas for heating and cooking
 - gasoline fraction for fuel (petrol) in cars
 - naphtha fraction as a feedstock for making chemicals
 - diesel oil / gas oil for fuel in diesel engines
 - bitumen for road surfaces

Supplement

- 4 Describe the properties of molecules within a fraction

C14.3 Homologous series

Supplement

- 1 Describe the homologous series of alkanes and alkenes as families of compounds with the same general formula and similar chemical properties

C14.4 Alkanes

Core

- 1 Describe alkanes as saturated hydrocarbons whose molecules contain only single covalent bonds
- 2 Describe the properties of alkanes (exemplified by methane) as being generally unreactive, except in terms of burning
- 3 Describe the complete combustion of hydrocarbons to give carbon dioxide and water

0654 Chemistry

C14.5 Alkenes

Core

- 1 Describe alkenes as unsaturated hydrocarbons whose molecules contain one double covalent bond
- 2 State that cracking is a reaction that produces alkenes
- 4 Recognise saturated and unsaturated hydrocarbons:
 - from molecular structures
 - by their reaction with aqueous bromine

Supplement

- 3 Describe the formation of smaller alkanes, alkenes and hydrogen by the cracking of larger alkane molecules and state the conditions required for cracking
- 5 Describe the properties of alkenes in terms of addition reactions with bromine, hydrogen and steam, exemplified by ethene

C14.6 Alcohols

Core

- 1 State that ethanol may be formed by fermentation and by reaction between ethene and steam
- 3 Describe the complete combustion of ethanol to give carbon dioxide and water
- 4 State the uses of ethanol as a solvent and as a fuel

Supplement

- 2 Describe the formation of ethanol by fermentation and the catalytic addition of steam to ethene

C14.7 Polymers

Core

- 1 Define *polymers* as long chain molecules formed from small units (monomers)

Supplement

- 2 Understand that different polymers have different monomer units and/or different linkages

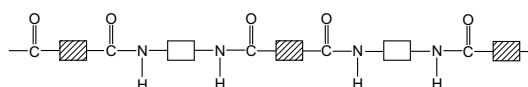
C14.8 Synthetic polymers

Core

- 1 Describe the formation of poly(ethene) as an example of addition polymerisation of monomer units

Supplement

- 2 Deduce the structure of the polymer product from a given alkene and *vice versa*
- 3 Explain the differences between addition and condensation polymerisation
- 4 Describe the formation of a simple condensation polymer exemplified by nylon, the structure of nylon being represented as:



Physics

P1 Motion

P1.1 Length and time

Core

- 1 Use and describe the use of rules and measuring cylinders to find a length or a volume
- 3 Use and describe the use of clocks and devices, both analogue and digital, for measuring an interval of time
- 4 Obtain an average value for a small distance and for a short interval of time by measuring multiples (including the period of a pendulum)

Supplement

- 2 Understand that a micrometer screw gauge is used to measure very small distances

P1.2 Motion

Core

- 1 Define *speed* and calculate average speed from
$$\frac{\text{total distance}}{\text{total time}}$$
- 4 Plot and interpret a speed–time graph and a distance–time graph
- 6 Recognise from the shape of a speed–time graph when a body is:
 - at rest
 - moving with constant speed
 - moving with changing speed
- 8 Calculate the area under a speed–time graph to work out the distance travelled for motion with constant acceleration
- 10 Demonstrate an understanding that acceleration and deceleration are related to changing speed including qualitative analysis of the gradient of a speed–time graph
- 11 State that the acceleration of free fall g for a body near to the Earth is constant

Supplement

- 2 Distinguish between *speed* and *velocity*
- 3 Define and calculate *acceleration* using
$$\frac{\text{change of velocity}}{\text{total time}}$$
- 5 Calculate acceleration from the gradient of a speed–time graph
- 7 Recognise linear motion for which the acceleration is constant and calculate the acceleration
- 9 Recognise motion for which the acceleration is not constant

0654 Physics

P1.3 Mass and weight

Core

- 1 Distinguish between *mass* and *weight*
- 2 Know that the Earth is the source of a gravitational field
- 4 Recognise that g is the gravitational force on unit mass and is measured in N/kg
- 5 Recall and use the equation $W = mg$
- 6 Demonstrate understanding that weights (and hence masses) may be compared using a balance

Supplement

- 3 Describe, and use the concept of, weight as the effect of a gravitational field on a mass

P1.4 Density

Core

- 1 Recall and use the equation $\rho = \frac{m}{V}$
- 2 Describe an experiment to determine the density of a liquid and of a regularly-shaped solid and make the necessary calculation

Supplement

- 3 Describe the determination of the density of an irregularly shaped solid by the method of displacement and make the necessary calculation

P1.5 Forces

P1.5.1 Effects of forces

Core

- 1 Describe how forces may change the size, shape and motion of a body
- 6 Understand friction as the force between two surfaces which impedes motion and results in heating
- 7 Recognise air resistance as a form of friction
- 8 Find the resultant of two or more forces acting along the same line
- 9 Recognise that if there is no resultant force on a body it either remains at rest or continues at constant speed in a straight line

Supplement

- 2 Plot and interpret extension–load graphs and describe the associated experimental procedure
- 3 State Hooke's law and recall and use the expression $F = kx$, where k is the spring constant
- 4 Recognise the significance of the term *limit of proportionality* for an extension–load graph
- 5 Recall and use the relationship between resultant force, mass and acceleration, $F = ma$

0654 Physics**P1.5 Forces continued**

P1.5.2 Turning effect

Core

- 1 Describe the moment of a force as a measure of its turning effect, and give everyday examples
- 2 Calculate moment using the product force \times perpendicular distance from the pivot
- 3 Recognise that, when there is no resultant force and no resultant turning effect, a system is in equilibrium

Supplement

- 4 Apply the principle of moments to the balancing of a weightless beam about a pivot
- 5 Apply the principle of moments to different situations

P1.5.3 Centre of mass

Core

- 1 Perform and describe an experiment to determine the position of the centre of mass of a plane lamina
- 2 Describe qualitatively the effect of the position of the centre of mass on the stability of simple objects

P1.5.4 Pressure

Core

- 1 Relate qualitatively pressure to force and area, using appropriate examples

Supplement

- 2 Recall and use the equation $p = F/A$

P2 Work, energy and power**P2.1 Work**

Core

- 1 Relate (without calculation) work done to the magnitude of a force and distance moved in the direction of the force

Supplement

- 2 Recall and use $W = Fd = \Delta E$

0654 Physics**P2.2 Energy****Core**

- 1 Demonstrate an understanding that work done = energy transferred
- 2 Demonstrate understanding that an object may have energy due to its motion (kinetic energy, KE) or its position (potential energy, PE) and that energy may be transferred and stored
- 3 Give and identify examples of changes in kinetic, gravitational potential, chemical potential, elastic potential (strain), nuclear, thermal, light, sound and electrical energy that have occurred as a result of an event or process
- 5 Recognise that energy is transferred during events and processes, including examples of transfer by forces (mechanical working), by electric currents (electrical working), by heating and by waves
- 6 Apply the principle of conservation of energy to simple examples
- 7 Show a qualitative understanding of efficiency

Supplement

- 4 Recall and use the expressions $KE = \frac{1}{2}mv^2$ and gravitational potential energy (GPE) = mgh or change in $GPE = mg\Delta h$

P2.3 Power**Core**

- 1 Relate (without calculation) power to work done and time taken, using appropriate examples

Supplement

- 2 Recall and use the equation $P = \Delta E / t$ in simple systems, including electrical circuits

0654 Physics

P2.4 Energy resources

Core

- 1 Distinguish between renewable and non-renewable sources of energy
- 2 Describe how electricity or other useful forms of energy may be obtained from:
 - chemical energy stored in fuel
 - water, including the energy stored in waves, in tides, and in water behind hydroelectric dams
 - geothermal resources
 - nuclear fission
 - heat and light from the Sun (solar cells and panels)
 - wind energy
- 3 Give advantages and disadvantages of each method in terms of renewability, cost, reliability, scale and environmental impact

Supplement

- 4 Understand that the Sun is the source of energy for all our energy resources except geothermal, nuclear and tidal
- 5 Understand that the source of tidal energy is mainly the moon
- 6 Show an understanding that energy is released by nuclear fusion in the Sun
- 7 Recall and use the equations:

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{power input}} \times 100\%$$

0654 Physics

P3 Thermal physics

P3.1 Simple kinetic molecular model of matter

Core

- 1 State the distinguishing properties of solids, liquids and gases
- 3 Describe qualitatively the molecular structure of solids, liquids and gases in terms of the arrangement, separation, and motion of the molecules
- 4 Describe qualitatively the pressure of a gas and the temperature of a gas, liquid or solid in terms of the motion of its particles
- 6 Show an understanding of Brownian motion (the random motion of particles in a suspension) as evidence for the kinetic molecular model of matter
- 8 Use and describe the use of thermometers to measure temperature on the Celsius scale
- 9 Describe *melting* and *boiling* in terms of energy input without a change in temperature
- 10 State the meaning of *melting point* and *boiling point*, and recall the melting and boiling points for water
- 12 Describe condensation and solidification
- 13 Explain evaporation in terms of the escape of more-energetic molecules from the surface of a liquid
- 14 Relate evaporation to the consequent cooling of the liquid

Supplement

- 2 Relate the properties of solids, liquids and gases to the forces and distances between the molecules and to the motion of the molecules
- 5 Describe qualitatively the pressure of a gas in terms of the motion of its molecules and their colliding with the walls creating a force
- 7 Show an appreciation that massive particles may be moved by light, fast-moving molecules
- 11 Distinguish between *boiling* and *evaporation*
- 15 Demonstrate an understanding of how temperature, surface area and draught over a surface influence evaporation

P3.2 Pressure changes

Supplement

- 1 Describe qualitatively, in terms of molecules, the effect on the pressure of a gas of:
 - a change of temperature at constant volume
 - a change of volume at constant temperature

0654 Physics**P3.3 Matter and thermal properties****Core**

- 1 Describe qualitatively the thermal expansion of solids, liquids and gases at constant pressure
- 3 Identify and explain some of the everyday applications and consequences of thermal expansion

Supplement

- 2 Explain in terms of the motion and arrangement of molecules, the relative order of the magnitude of the expansion of solids, liquids and gases

P3.4 Measurement of temperature**Core**

- 1 Describe how a physical property that varies with temperature may be used for the measurement of temperature, and state examples of such properties
- 4 Recognise the need for and identify fixed points
- 6 Describe and explain the structure and action of liquid-in-glass thermometers

Supplement

- 2 Demonstrate understanding of sensitivity, range and linearity
- 3 Describe the structure of a thermocouple and show understanding of its use as a thermometer for measuring high temperatures and those that vary rapidly
- 5 Describe and explain how the structure of a liquid-in-glass thermometer relates to its sensitivity, range and linearity

P3.5 Thermal processes**P3.5.1 Conduction****Core**

- 1 Recognise and name typical good and bad thermal conductors
- 2 Describe experiments to demonstrate the properties of good and bad thermal conductors

Supplement

- 3 Explain conduction in solids in terms of molecular vibrations and transfer by electrons

P3.5.2 Convection**Core**

- 1 Recognise convection as the main method of energy transfer in fluids
- 3 Interpret and describe experiments designed to illustrate convection in liquids and gases (fluids)

Supplement

- 2 Relate convection in fluids to density changes

0654 Physics

P3.5 Thermal processes continued

P3.5.3 Radiation

Core

- 1 Recognise radiation as the method of energy transfer that does not require a medium to travel through
- 2 Identify infrared radiation as the part of the electromagnetic spectrum often involved in energy transfer by radiation

Supplement

- 3 Describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of radiation
- 4 Interpret and describe experiments to investigate the properties of good and bad emitters and good and bad absorbers of infrared radiation

P3.5.4 Consequences of energy transfer

Core

- 1 Identify and explain some of the everyday applications and consequences of conduction, convection and radiation

P4 Properties of waves, including light and sound

P4.1 General wave properties

Core

- 1 Demonstrate understanding that waves transfer energy without transferring matter
- 2 Describe what is meant by *wave motion* as illustrated by vibration in ropes and springs and by experiments using water waves
- 3 Use the term *wavefront*
- 4 State the meaning of *speed*, *frequency*, *wavelength* and *amplitude*
- 6 Describe how waves can undergo:
 - reflection at a plane surface
 - refraction due to a change of speed

Supplement

- 5 Distinguish between transverse and longitudinal waves and give suitable examples
- 7 Recall and use the equation $v = f \lambda$
- 8 Understand that refraction is caused by a change in speed as a wave moves from one medium to another
- 9 Describe how waves can undergo diffraction through a narrow gap
- 10 Describe the use of water waves to demonstrate diffraction

0654 Physics

P4.2 Light

P4.2.1 Reflection of light

Core

- 1 Describe the formation of an optical image by a plane mirror and give its characteristics
- 2 Recall and use the law:
angle of incidence i = angle of reflection r
recognising these angles are measured to the normal
- 3 Perform simple constructions, measurements and calculations for reflection by plane mirrors

P4.2.2 Refraction of light

Core

- 1 Interpret and describe an experimental demonstration of the refraction of light
- 3 Use the terminology for the angle of incidence i and angle of refraction r and describe the passage of light through parallel-sided transparent material

Supplement

- 2 Recall and use the definition of refractive index n in terms of speed
- 4 Recall and use the equation for refractive index
$$\frac{\sin i}{\sin r} = n$$
- 5 Describe internal and total internal reflection using ray diagrams
- 6 Give the meaning of *critical angle*
- 7 Describe and explain the action of optical fibres particularly in medicine and communications technology

P4.2.3 Thin converging lens

Core

- 1 Describe the action of a thin converging lens on a beam of light
- 2 Use the terms *principal focus* and *focal length*
- 3 Draw ray diagrams for the formation of a real image by a single lens
- 4 Describe the nature of an image using the terms enlarged / same size / diminished and upright / inverted

Supplement

- 5 Describe the difference between a *real image* and a *virtual image*
- 6 Use and describe the use of a single lens as a magnifying glass

0654 Physics

P4.3 Electromagnetic spectrum

Core

- 1 Describe the main features of the electromagnetic spectrum in order of frequency, from radio waves to gamma-radiation (γ)
- 2 State that all electromagnetic waves travel with the same high speed in a vacuum and approximately the same in air
- 4 Describe typical properties and uses of radiations in all the different regions of the electromagnetic spectrum including:
 - radio and television communications (radio waves)
 - satellite television and telephones (microwaves)
 - electrical appliances, remote controllers for televisions and intruder alarms (infrared)
 - medicine and security (X-rays)
- 5 Demonstrate an understanding of safety issues regarding the use of microwaves and X-rays
- 6 State the dangers of ultraviolet radiation, from the Sun or from tanning lamps

Supplement

- 3 State that the speed of electromagnetic waves in a vacuum is 3.0×10^8 m/s

P4.4 Sound

Core

- 1 Describe the production of sound by vibrating sources
- 4 State that the approximate range of audible frequencies for a healthy human ear is 20 Hz to 20 000 Hz
- 5 Show an understanding that a medium is needed to transmit sound waves
- 6 Describe and interpret an experiment to determine the speed of sound in air, including calculation
- 8 Relate the loudness and pitch of sound waves to amplitude and frequency
- 9 Describe how the reflection of sound may produce an echo

Supplement

- 2 Describe the longitudinal nature of sound waves
- 3 Describe the transmission of sound waves in air in terms of compressions and rarefactions
- 7 Recognise that sound travels faster in liquids than gases and faster in solids than in liquids

0654 Physics**P5 Electricity and magnetism****P5.1 Simple phenomena of magnetism****Core**

- 1 Describe the forces between magnets, and between magnets and magnetic materials
- 3 Draw and describe the pattern and direction of magnetic field lines around a bar magnet
- 4 Distinguish between the magnetic properties of soft iron and steel
- 5 Distinguish between the design and use of permanent magnets and electromagnets
- 6 Describe methods of magnetisation to include stroking with a magnet, use of direct current (d.c.) in a coil and hammering in a magnetic field

Supplement

- 2 Give an account of induced magnetism

P5.2 Electrical quantities**P5.2.1 Electric charge****Core**

- 1 State that there are positive and negative charges
- 2 State that unlike charges attract and that like charges repel
- 3 Describe and interpret simple experiments to show the production and detection of electrostatic charges by friction
- 4 State that charging a body involves the addition or removal of electrons
- 6 Distinguish between electrical conductors and insulators and give typical examples

Supplement

- 5 Describe an electric field as a region in which an electric charge experiences a force

0654 Physics**P5.2 Electrical quantities continued****P5.2.2 Current, potential difference and electromotive force (e.m.f.)****Core**

- 1 Demonstrate understanding of *current, potential difference, e.m.f. and resistance*
- 2 State that current is related to the flow of charge
- 4 State that current in metals is due to a flow of electrons
- 5 State that the potential difference (p.d.) across a circuit component is measured in volts
- 6 Use and describe the use of an ammeter and a voltmeter, both analogue and digital
- 7 State that the electromotive force (e.m.f) of an electrical source of energy is measured in volts

Supplement

- 3 Show understanding that a current is a rate of flow of charge and recall and use the equation $I = Q/t$
- 8 Show understanding that e.m.f. is defined in terms of energy supplied by a source in driving charge around a complete circuit

P5.2.3 Resistance**Core**

- 1 State that resistance = p.d. / current and understand qualitatively how changes in p.d. or resistance affect current
- 3 Recall and use the equation $R = V/I$

Supplement

- 2 Sketch and explain the current–voltage characteristic of an ohmic resistor and a filament lamp
- 4 Recall and use quantitatively the proportionality between resistance and length, and the inverse proportionality between resistance and cross-sectional area of a wire

P6 Electric circuits**P6.1 Circuit diagrams****Core**

- 1 Draw and interpret circuit diagrams containing sources, switches, resistors (fixed and variable), lamps, ammeters, voltmeters and fuses (Symbols for other common circuit components will be provided in questions.)

0654 Physics**P6.2 Series and parallel circuits****Core**

- 1 Understand that the current at every point in a series circuit is the same
- 2 Calculate the combined resistance of two or more resistors in series
- 4 State that, for a parallel circuit, the current from the source is larger than the current in each branch
- 6 State that the combined resistance of two resistors in parallel is less than that of either resistor by itself
- 8 State the advantages of connecting lamps in parallel in a circuit

Supplement

- 3 Recall and use the fact that the sum of the p.d.s across the components in a series circuit is equal to the total p.d. across the supply
- 5 Recall and use the fact that the current from the source is the sum of the currents in the separate branches of a parallel circuit
- 7 Calculate the combined resistance of two resistors in parallel
- 9 Draw and interpret circuit diagrams containing NTC thermistors and light-dependent resistors (LDRs)
- 10 Describe the action of NTC thermistors and LDRs and show understanding of their use as input transducers

P6.3 Electrical energy**Supplement**

- 1 Recall and use the equations $P = IV$ and $E = IVt$

P6.4 Dangers of electricity**Core**

- 1 Identify electrical hazards including:
 - damaged insulation
 - overheating of cables
 - damp conditions
- 2 State that a fuse protects a circuit
- 3 Explain the use of fuses and choose appropriate fuse ratings

0654 Physics**P7 Electromagnetic effects****P7.1 Magnetic effect of an electric current****Core**

- 1 Describe the pattern of the magnetic field (including direction) due to currents in straight wires and in solenoids

Supplement

- 2 Describe the effect on the magnetic field of changing the magnitude and direction of the current

P7.2 Force on a current-carrying conductor**Core**

- 1 Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing:
 - the current
 - the direction of the field

Supplement

- 2 State and use the relative directions of force, field and current

P7.3 d.c. motor**Core**

- 1 State that a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by:
 - increasing the number of turns on the coil
 - increasing the current
 - increasing the strength of the magnetic field

Supplement

- 2 Relate this turning effect to the action of an electric motor including the action of a split-ring commutator

P7.4 Electromagnetic induction**Supplement**

- 1 Show understanding that a conductor moving across a magnetic field or a changing magnetic field linking with a conductor can induce an e.m.f. in the conductor
- 2 State the factors affecting the magnitude of an induced e.m.f.

P7.5 a.c. generator**Supplement**

- 1 Distinguish between direct current (d.c) and alternating current (a.c)
- 2 Describe and explain the operation of a rotating-coil generator and the use of slip rings
- 3 Sketch a graph of voltage output against time for a simple a.c. generator

0654 Physics

P7.6 Transformer

Supplement

- 1 Describe the construction of a basic transformer with a soft-iron core, as used for voltage transformations
- 2 Describe the principle of operation of a transformer
- 3 Use the terms step-up and step-down
- 4 Recall and use the equation $(V_p / V_s) = (N_p / N_s)$ (for 100% efficiency)
- 5 Describe the use of the transformer in high-voltage transmission of electricity
- 6 Recall and use the equation $I_p V_p = I_s V_s$ (for 100% efficiency)
- 7 Explain why power losses in cables are lower when the voltage is high

P8 Atomic physics

P8.1 The nuclear atom

Core

- 1 Describe the composition of the nucleus in terms of protons and neutrons
- 2 Use the terms *proton number Z* and *nucleon number A*
- 3 Use and explain the term *isotope*
- 4 Use and interpret the term *nuclide* and use the nuclide notation A_ZX

0654 Physics

P8.2 Radioactivity

P8.2.1 Characteristics of the three kinds of emission

Core

- 1 Describe the random nature of radioactive emission
- 2 Identify alpha (α)-, beta (β)- and gamma (γ)-emissions by recalling
 - their nature
 - their relative ionising effects
 - their relative penetrating abilities
 (β^+ are not included: β -particles will be taken to refer to β^-)
- 4 Recognise the general term *ionising radiation* can be used to describe radioactive emissions

Supplement

- 3 Describe the deflection of α -particles, β -particles and γ -rays in electric fields and in magnetic fields
- 5 Describe and explain examples of practical applications of α -, β - and γ -emissions

P8.2.2 Detection of radioactivity

Core

- 1 Demonstrate understanding of background radiation
- 2 Describe the detection of α -particles, β -particles and γ -rays

P8.2.3 Radioactive decay

Core

- 1 State the meaning of *radioactive decay*
- 2 Use word equations to represent changes in the composition of the nucleus when particles are emitted

Supplement

- 3 Use nuclide notation in equations to show α - and β -decay

P8.2.4 Half-life

Core

- 1 Use the term *half-life* in simple calculations which may involve information in tables or decay curves

0654 Physics

P8.2 Radioactivity continued

P8.2.5 Safety precautions

Core

- 1 Recall the effects of ionising radiations on living things
- 2 Describe how radioactive materials are handled, used and stored in a safe way

4 Details of the assessment

All candidates take three papers.

Candidates who have studied the Core subject content, or who are expected to achieve a grade DD or below, should be entered for Paper 1, Paper 3 and either Paper 5 or Paper 6. These candidates will be eligible for grades CC to GG.

Candidates who have studied the Extended subject content (Core and Supplement), and who are expected to achieve a grade CC or above, should be entered for Paper 2, Paper 4 and either Paper 5 or Paper 6. These candidates will be eligible for grades A*A* to GG.

Core assessment

Core candidates take the following papers that have questions based on the Core subject content only:

Paper 1 – Multiple Choice (Core)

45 minutes, 40 marks

Forty compulsory multiple-choice items of the four-option type. This paper tests assessment objectives AO1 and AO2.

Paper 3 – Theory (Core)

2 hours, 120 marks

Short-answer and structured questions testing assessment objectives AO1 and AO2.

Extended assessment

Extended candidates take the following papers that have questions based on the Core and Supplement subject content:

Paper 2 – Multiple Choice (Extended)

45 minutes, 40 marks

Forty compulsory multiple-choice items of the four-option type. This paper tests assessment objectives AO1 and AO2.

Paper 4 – Theory (Extended)

2 hours, 120 marks

Short-answer and structured questions testing assessment objectives AO1 and AO2.

Practical assessment

All candidates take one practical component from a choice of two:

Paper 5 – Practical Test

2 hours, 60 marks

This paper tests assessment objective AO3 in a practical context.

or

Paper 6 – Alternative to Practical

1 hour 30 minutes, 60 marks

This paper tests assessment objective AO3 in a written paper.

Whichever practical paper you choose, please be aware that:

- they test the same assessment objective, AO3
- they require the same experimental skills to be learned and developed
- the same sequence of practical activities is appropriate.

Candidates must not use textbooks or any of their course notes in the practical component.

These papers are based on testing experimental skills. One question on each paper assesses the skill of planning. This question will be based on any one of the sciences, which could be: Biology, Chemistry or Physics.

Questions in the practical papers are structured to assess performance across the full grade range. The information candidates need to answer the questions is in the question paper itself or the experimental context and skills listed below. The questions do not assess specific subject content.

Experimental skills tested in Paper 5 Practical Test and Paper 6 Alternative to Practical

Candidates may be required to do the following:

- carefully follow a sequence of instructions
- describe, explain or comment on experimental arrangements and techniques
- select the most appropriate apparatus or method for a task and justify the choice made
- draw, complete or label diagrams of apparatus
- perform simple arithmetical calculations
- take readings from an appropriate measuring device or from an image of the device (e.g. thermometer, rule, protractor, measuring cylinder, ammeter, stop-watch), including:
 - reading analogue and digital scales with accuracy and appropriate precision
 - interpolating between scale divisions when appropriate
 - correcting for zero errors when appropriate
- plan to take a sufficient number and range of measurements, repeating where appropriate to obtain an average value

- describe or explain precautions taken in carrying out a procedure to ensure safety or the accuracy of observations and data, including the control of variables and repetition of measurements
- identify key variables and describe how, or explain why, certain variables should be controlled
- record observations systematically, for example in a table, using appropriate units and to a consistent and appropriate degree of precision
- process data, using a calculator where necessary
- present and analyse data graphically, including the use of best-fit lines where appropriate, interpolation and extrapolation, and the determination of a gradient, intercept or intersection
- interpret and evaluate observations and experimental data
- draw an appropriate conclusion, justifying it by reference to the data and using an appropriate explanation
- comment critically on a procedure or point of practical detail, and suggest an appropriate improvement
- evaluate the quality of data, identifying and dealing appropriately with any anomalous results
- identify possible causes of uncertainty, in data or in a conclusion
- make estimates or describe outcomes which demonstrate their familiarity with an experiment, procedure or technique
- plan an experiment or investigation, including making reasoned predictions of expected results and suggesting suitable apparatus and techniques.

Biology

Candidates may be asked questions on the following experimental contexts:

- the use of familiar, and unfamiliar, techniques to record observations and data, process them and make deductions from them
- recall of simple chemical tests, e.g. for food substances and the use of limewater, hydrogencarbonate indicator, litmus and universal indicator paper
- recognise, observe, record and measure images of familiar, and unfamiliar, biological specimens
- make a clear line drawing from an image of a specimen, calculating the magnification and adding labels as required.

Chemistry

Candidates may be asked questions on the following experimental contexts:

- simple quantitative experiments involving the measurement of volumes and/or masses
- rates (speeds) of reaction
- measurement of temperature based on a thermometer with 1°C graduations and energetics
- problems of an investigatory nature, possibly including suitable organic compounds
- filtration
- electrolysis
- identification of ions and gases
- metals and the reactivity series
- acids, bases, oxides and preparation of salts
- redox reactions and rusting.

Physics

Candidates may be asked questions on the following experimental contexts:

- measurement of physical quantities such as length or volume or force or density
- cooling and heating
- springs and balances
- timing motion or oscillations
- electric circuits, circuit diagrams and electrical symbols
- optics equipment such as mirrors, prisms and lenses
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate
- use or describe the use of common techniques, apparatus and materials, e.g. ray-tracing equipment or the connection of electric circuits
- explain the manipulation of the apparatus to obtain observations or measurements, 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 two masses, using a balancing method.

Teaching experimental skills

We expect you to look for suitable opportunities to embed practical techniques and investigative work throughout the course.

The best way to prepare candidates for these papers is to integrate practical work fully into the course so that it becomes a normal part of your teaching. Practical work helps candidates to:

- develop a deeper understanding of the syllabus topics
- learn to appreciate the way in which scientific theories are developed and tested
- develop experimental skills and positive scientific attitudes such as objectivity, integrity, cooperation, enquiry and inventiveness.

Note on taking readings

When approximate volumes are used, e.g. about 2 cm^3 , it is expected that candidates will estimate this and not use measuring devices.

A measuring instrument should be used to its full precision. Thermometers may be marked in 1°C intervals but it is often appropriate to interpolate between scale divisions and record a temperature to the nearest 0.0°C or 0.5°C . Measurements using a rule require suitable accuracy of recording, such as 15.0 cm rather than 15 cm ; the use of millimetres when appropriate should be encouraged. Similarly, when measuring current, it is often more appropriate to use milliamperes rather than amperes.

Apparatus list

This list contains the items you are likely to need for teaching the experimental skills needed for both practical papers, as well as the Paper 5 exam. It is not exhaustive and does not include equipment commonly regarded as standard in a science laboratory. The *Confidential Instructions* we send you before the Paper 5 exam will give the detailed requirements for that exam.

- rulers capable of measuring to 1 mm
- metre rule
- mounted needles or seekers or long pins with large heads
- means of cutting biological materials, such as scalpels, solid edged razor blades or knives
- scissors
- forceps
- means of writing on glassware
- beakers, 100 cm³, 250 cm³
- polystyrene or other plastic beakers of approximate capacity 150 cm³
- test-tubes (Pyrex or hard glass), approximately 125 mm × 16 mm
- boiling tubes, approximately 150 mm × 25 mm
- delivery tubes
- conical flasks, within the range 150 cm³ to 250 cm³
- means of measuring small volumes of liquids, such as syringes (with needles removed)
- measuring cylinders, 100 cm³, 50 cm³, 25 cm³, 10 cm³
- dropping pipettes
- white tiles
- spotting tiles
- water-bath
- large containers (e.g. plastic bowl) to hold cold water
- hand lens ×6 magnification
- thermometers, -10 °C to +110 °C with 1 °C graduations
- stop-clocks (or wall-clock or wrist-watch), to measure to an accuracy of 1 s
- Petri dishes
- glass rods
- spatulas
- wooden splints
- chemicals (e.g. for food tests, limewater test)
- indicators (e.g. litmus paper, universal indicator paper, full range universal indicator, hydrogencarbonate indicator)
- burettes, 50 cm³
- pipettes, 25 cm³
- pipette fillers
- filter funnels and filter paper
- wash bottle
- ammeter FSD 1 A, 1.5 A
- voltmeter FSD 1 V, 5 V
- electrical cells (batteries) and holders to enable several cells to be joined

- connecting leads and crocodile clips
- d.c. power supply, variable to 12 V
- low-voltage filament lamps in holders
- various resistors and resistance wire
- switches
- good supply of masses and holders
- 2 cm expendable springs
- clamps and stands
- pendulum bobs
- newton meters
- Plasticine or modelling clay
- wooden boards
- converging lens with $f = 15$ cm
- glass or Perspex block, rectangular and semicircular
- glass or Perspex prism, triangular
- optics pins
- plane mirrors
- ray box




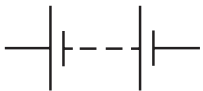
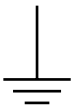










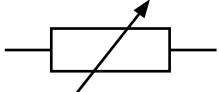
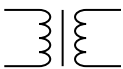
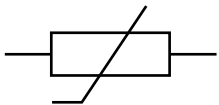
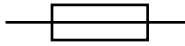
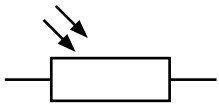

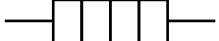
Glossary of terms used in science papers

This glossary (which is relevant only to science subjects) will prove helpful to candidates as a guide, but 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 (a) *Explain* may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to give reasons. The candidate needs to leave the examiner in no doubt why something happens.
(b) *Give a reason / Give reasons* is another way of asking candidates to explain why something happens.
- 6 *Describe* requires the candidate to state in words (using diagrams where appropriate) the main points. *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.
- 8 *Outline* implies brevity (i.e. restricting the answer to giving essentials).
- 9 *Predict* implies that the candidate is expected to make a prediction not by recall but by making a logical connection between other pieces of information.
- 10 *Deduce* 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.
- 11 *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in physics there are several examples of energy resources from which electricity, or other useful forms of energy, may be obtained), or to imply that candidates are expected to apply their general knowledge of the subject to a 'novel' situation, one that may be formally 'not in the syllabus' – many data response and problem-solving questions are of this type.
- 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 from a graph or by calculation.
- 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, free-hand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.

5 Appendix

Electrical symbols

cell		switch	
battery of cells			
or		earth or ground	
power supply		electric bell	
a.c. power supply		motor	
junction of conductors		generator	
lamp		ammeter	
fixed resistor		voltmeter	
variable resistor		transformer	
thermistor		fuse	
light dependent resistor		oscilloscope	
heater			

Symbols and units for physical quantities

Candidates should be able to give the symbols for the following physical quantities and, where indicated, state the units in which they are measured. The list for the Extended syllabus content includes both the Core and the Supplement.

Candidates should be familiar with the following multipliers: M mega, k kilo, c centi, m milli.

Core			Supplement		
Quantity	Usual symbol	Usual unit	Quantity	Usual symbol	Usual unit
length	$l, h \dots$	km, m, cm, mm			
area	A	m^2, cm^2			
volume	V	m^3, cm^3			
weight	W	N			
mass	m, M	kg, g	mass	m, M	mg
time	t	h, min, s	time	t	ms
density	ρ	$g/cm^3, kg/m^3$			
speed	u, v	km/h, m/s, cm/s			
acceleration	a		acceleration	a	m/s^2
acceleration of free fall	g		acceleration of free fall	g	m/s^2
force	F	N			
gravitational field strength	g	N/kg			
moment of a force		N m			
work done	W, E	J, kJ, MJ			
energy	E	J, kJ, MJ			
power	P	W, kW, MW			
pressure	p	N/m^2	pressure	p	Pa
temperature	θ, T	$^{\circ}C$			
frequency	f	Hz, kHz			
wavelength	λ	m, cm			
focal length	f	cm			
angle of incidence	i	degree ($^{\circ}$)			

Core			Supplement		
Quantity	Usual symbol	Usual unit	Quantity	Usual symbol	Usual unit
angle of reflection, refraction	r	degree ($^{\circ}$)			
critical angle	c	degree ($^{\circ}$)			
			refractive index	n	
potential difference/voltage	V	V, mV			
current	I	A, mA			
e.m.f.	E	V			
resistance	R	Ω			
			charge	Q	C

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.
bromide (Br^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	cream ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify, 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	–
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt. or very slight white ppt.
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 limewater milky
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	'pops' with a lighted splint
oxygen (O_2)	relights a glowing splint

Flame tests for metal ions

metal ion	flame colour
lithium (Li^+)	red
sodium (Na^+)	yellow
potassium (K^+)	lilac
copper(II) (Cu^{2+})	blue-green

The Periodic Table

		Group														
I	II	III	IV	V	VI	VII	VIII					VIII				
3 Li lithium 7	4 Be beryllium 9	1 H hydrogen 1										2 He helium 4				
11 Na sodium 23	12 Mg magnesium 24	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> Key atomic number atomic symbol name relative atomic mass </div>										10 Ne neon 20				
19 K potassium 39	20 Ca calcium 40	5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40				
37 Rb rubidium 85	38 Sr strontium 88	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	35 Br bromine 80	36 Kr krypton 84			
55 Cs caesium 133	56 Ba barium 137	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131	
87 Fr francium –	88 Ra radium –	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –	
		89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	–	116 Lv livermorium –	–	–	
		57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
		89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm³ at room temperature and pressure (r.t.p.)

Safety in the laboratory

Responsibility for safety matters rests with centres. Further information can be found from the following UK associations, publications and regulations.

Associations

CLEAPSS is an advisory service providing support in practical science and technology.
www.cleapss.org.uk

Publications

CLEAPSS Laboratory Handbook, updated 2009 (available to CLEAPSS members only)
CLEAPSS Hazcards, 2007 update of 1995 edition (available to CLEAPSS members only)

UK regulations

Control of Substances Hazardous to Health Regulations (COSHH) 2002 and subsequent amendment in 2004
www.legislation.gov.uk/uksi/2002/2677/contents/made
www.legislation.gov.uk/uksi/2004/3386/contents/made

A brief guide may be found at
www.hse.gov.uk/pubns/indg136.pdf

Mathematical requirements

Calculators may be used in all parts of the examination.

Candidates should be able to:

- add, subtract, multiply and divide
- use averages, decimals, fractions, percentages, ratios and reciprocals
- use standard notation, including both positive and negative indices
- understand significant figures and use them appropriately
- recognise and use direct and inverse proportion
- use positive, whole number indices in algebraic expressions
- draw charts and graphs from given data
- interpret charts and graphs
- determine the gradient and intercept of a graph
- 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
- recall and use equations for the areas of a rectangle, triangle and circle and the volumes of a rectangular block and a cylinder
- use mathematical instruments (ruler, compasses, protractor and set square)
- understand the meaning of angle, curve, circle, radius, diameter, circumference, square, parallelogram, rectangle and diagonal
- solve equations of the form $x = y + z$ and $x = yz$ for any one term when the other two are known

- recognise and use clockwise and anticlockwise directions
- recognise and use points of the compass (N, S, E, W)
- use sines and inverse sines (Extended candidates only).

Presentation of data

The solidus (/) is to be used for separating the quantity and the unit in tables, graphs and charts, e.g. time /s for time in seconds.

(a) Tables

- Each column of a table should be headed with the physical quantity and the appropriate unit, e.g. time/s.
- The column headings of the table can then be directly transferred to the axes of a constructed graph.

(b) Graphs

- Unless instructed otherwise, the independent variable should be plotted on the x-axis (horizontal axis) and the dependent variable plotted on the y-axis (vertical axis).
- Each axis should be labelled with the physical quantity and the appropriate unit, e.g. time/s.
- The scales for the axes should allow more than half of the graph grid to be used in both directions, and be based on sensible ratios, e.g. 2 cm on the graph grid representing 1, 2 or 5 units of the variable.
- The graph is the whole diagrammatic presentation, including the best-fit line when appropriate. It may have one or more sets of data plotted on it.
- Points on the graph should be clearly marked as crosses (×) or encircled dots (⊙).
- Large 'dots' are penalised. Each data point should be plotted to an accuracy of better than one half of each of the smallest squares on the grid.
- A best-fit line (trend line) should be a single, thin, smooth straight-line or curve. The line does not need to coincide exactly with any of the points; where there is scatter evident in the data, examiners would expect a roughly even distribution of points either side of the line over its entire length. Points that are clearly anomalous should be ignored when drawing the best-fit line.
- The gradient of a straight line should be taken using a triangle whose hypotenuse extends over at least half of the length of the best-fit line, and this triangle should be marked on the graph.

(c) Numerical results

- Data should be recorded so as to reflect the precision of the measuring instrument.
- The number of significant figures given for calculated quantities should be appropriate to the least number of significant figures in the raw data used.

(d) Pie charts

- These should be drawn with the sectors in rank order, largest first, beginning at 'noon' and proceeding clockwise. Pie charts should preferably contain no more than six sectors.

(e) Bar charts

- These should be drawn when one of the variables is not numerical. They should be made up of narrow blocks of equal width that do **not** touch.

(f) Histograms

- These should be drawn when plotting frequency graphs with continuous data. The blocks should be drawn in order of increasing or decreasing magnitude and they **should** touch.

ICT opportunities

In order to play a full part in modern society, candidates need to be confident and effective users of ICT. This syllabus provides candidates with a wide range of opportunities to use ICT in their study of biology, chemistry and physics.

Opportunities for ICT include:

- gathering information from the internet, DVDs and CD-ROMs
- gathering data using sensors linked to data-loggers or directly to computers
- using spreadsheets and other software to process data
- using animations and simulations to visualise scientific ideas
- using software to present ideas and information on paper and on screen.

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

Syllabuses and question papers conform with generally accepted international practice. In particular, the following document, produced by the Association for Science Education (ASE), should be used as a guideline.

- *Signs, Symbols and Systematics: The ASE Companion to 16–19 Science (2000)*

Litre/dm³

To avoid any confusion concerning the symbol for litre, **dm³** will be used in place of *l* or litre.

Decimal markers

In accordance with current ASE convention, decimal markers in examination papers will be a single dot on the line. Candidates are expected to follow this convention in their answers.

Numbers

Numbers from 1000 to 9999 will be printed without commas or spaces. Numbers greater than or equal to 10 000 will be printed without commas. A space will be left between each group of three whole numbers, e.g. 4 256 789.

6 What else you need to know

This section is an overview of other information you need to know about this syllabus. It will help to share the administrative information with your exams officer so they know when you will need their support. Find more information about our administrative processes at www.cambridgeinternational.org/eoguide

Before you start

Previous study

We recommend that learners starting this course should have studied a science curriculum such as the Cambridge Lower Secondary programme or equivalent national educational framework.

Guided learning hours

We design Cambridge IGCSE syllabuses based on learners having about 130 guided learning hours for each subject during the course. As this is a double award, the guided learning hours are about 260 hours but this is for guidance only. The number of hours a learner needs to achieve the qualification may vary according to local practice and their previous experience of the subject.

Availability and timetables

All Cambridge schools are allocated to one of six administrative zones. Each zone has a specific timetable.

You can view the timetable for your administrative zone at www.cambridgeinternational.org/timetables

You can enter candidates in the June and November exam series. If your school is in India, you can also enter your candidates in the March exam series.

Check you are using the syllabus for the year the candidate is taking the exam.

Private candidates can enter for this syllabus.

Combining with other syllabuses

Candidates can take this syllabus alongside other Cambridge International syllabuses in a single exam series. The only exceptions are:

- Cambridge IGCSE Biology (0610)
- Cambridge IGCSE (9–1) Biology (0970)
- Cambridge IGCSE Chemistry (0620)
- Cambridge IGCSE (9–1) Chemistry (0971)
- Cambridge IGCSE Physics (0625)
- Cambridge IGCSE (9–1) Physics (0972)
- Cambridge IGCSE Physical Science (0652)
- Cambridge IGCSE Combined Science (0653)
- Cambridge IGCSE (9–1) Co-ordinated Sciences (Double Award) (0973)
- Cambridge O Level Biology (5090)
- Cambridge O Level Chemistry (5070)

- Cambridge O Level Physics (5054)
- Cambridge O Level Combined Science (5129)
- syllabuses with the same title at the same level.

Cambridge IGCSE, Cambridge IGCSE (9–1) and Cambridge O Level syllabuses are at the same level.

Group awards: Cambridge ICE

Cambridge ICE (International Certificate of Education) is a group award for Cambridge IGCSE. It allows schools to offer a broad and balanced curriculum by recognising the achievements of learners who pass examinations in a range of different subjects.

Learn more about Cambridge ICE at www.cambridgeinternational.org/cambridgeice

Making entries

Exams officers are responsible for submitting entries to Cambridge International. We encourage them to work closely with you to make sure they enter the right number of candidates for the right combination of syllabus components. Entry option codes and instructions for submitting entries are in the *Cambridge Guide to Making Entries*. Your exams officer has a copy of this guide.

Exam administration

To keep our exams secure, we produce question papers for different areas of the world, known as administrative zones. We allocate all Cambridge schools to one administrative zone determined by their location. Each zone has a specific timetable. Some of our syllabuses offer candidates different assessment options. An entry option code is used to identify the components the candidate will take relevant to the administrative zone and the available assessment options.

Support for exams officers

We know how important exams officers are to the successful running of exams. We provide them with the support they need to make your entries on time. Your exams officer will find this support, and guidance for all other phases of the Cambridge Exams Cycle, at www.cambridgeinternational.org/eoguide

Retakes

Candidates can retake the whole qualification as many times as they want to. This is a linear qualification so candidates cannot re-sit individual components.

Equality and inclusion

We have taken great care to avoid bias of any kind in the preparation of this syllabus and related assessment materials. In compliance with the UK Equality Act (2010) we have designed this qualification to avoid any direct and indirect discrimination.

The standard assessment arrangements may present unnecessary barriers for candidates with disabilities or learning difficulties. We can put arrangements in place for these candidates to enable them to access the assessments and receive recognition of their attainment. We do not agree access arrangements if they give candidates an unfair advantage over others or if they compromise the standards being assessed.

Candidates who cannot access the assessment of any component may be able to receive an award based on the parts of the assessment they have completed.

Information on access arrangements is in the *Cambridge Handbook* at www.cambridgeinternational.org/eoguide

Language

This syllabus and the related assessment materials are available in English only.

After the exam

Grading and reporting

Grades A*A*, AA, BB, CC, DD, EE, FF or GG indicate the standard a candidate achieved at Cambridge IGCSE.

A*A* is the highest and GG is the lowest. 'Ungraded' means that the candidate's performance did not meet the standard required for grade GG. 'Ungraded' is reported on the statement of results but not on the certificate. In specific circumstances your candidates may see one of the following letters on their statement of results:

- Q (pending)
- X (no result)
- Y (to be issued).

These letters do not appear on the certificate.

How students and teachers can use the grades

Assessment at Cambridge IGCSE has two purposes:

- to measure learning and achievement
The assessment:
 - confirms achievement and performance in relation to the knowledge, understanding and skills specified in the syllabus, to the levels described in the grade descriptions.
- to show likely future success
The outcomes:
 - help predict which students are well prepared for a particular course or career and/or which students are more likely to be successful
 - help students choose the most suitable course or career.

Grade descriptions

Grade descriptions are provided to give an indication of the standards of achievement candidates awarded particular grades are likely to show. Weakness in one aspect of the examination may be balanced by a better performance in some other aspect.

Grade descriptions for Cambridge IGCSE Co-ordinated Sciences (Double Award) will be published after the first assessment of the syllabus in 2022. Find more information at www.cambridgeinternational.org/igcse

Changes to this syllabus for 2022

We have updated the look and feel of this document. The subject content remains the same.

Minor changes to the wording of some sections have been made to improve clarity.

You are strongly advised to read the whole syllabus before planning your teaching programme.

Any textbooks endorsed to support the syllabus for examination from 2019 are still suitable for use with this syllabus.



'While studying Cambridge IGCSE and Cambridge International A Levels, students broaden their horizons through a global perspective and develop a lasting passion for learning.'

Zhai Xiaoning, Deputy Principal, The High School Affiliated to Renmin University of China

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