SCIENCE

GCE Normal (Academic) Level (2017)

(Syllabus 5105 Science: Physics, Chemistry)
(Syllabus 5106 Science: Physics, Biology)
(Syllabus 5107 Science: Chemistry, Biology)

CONTENTS

Singapore Examinations and Assessment Board

CAMBRIDGE International Examinations

AIMS

These are not listed in order of priority.

The aims are to:

1. provide, through well-designed studies of experimental and practical science, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge to
   - 1.1 become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific importance
   - 1.2 recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life
   - 1.3 be suitably prepared for studies beyond 'Normal' Level which, for many students, will be in science-related courses or another year of study leading to the GCE O Level Science examination
2. develop abilities and skills that
   - 2.1 are relevant to the study and practice of science
   - 2.2 are useful in everyday life
   - 2.3 encourage efficient and safe practice
   - 2.4 encourage effective communication
3. develop attitudes relevant to science such as
   - 3.1 accuracy and precision
   - 3.2 objectivity
   - 3.3 integrity
   - 3.4 inquiry
   - 3.5 initiative
   - 3.6 inventiveness
4. stimulate interest in and care for the local and global environment
5. promote an awareness that
   - 5.1 the study and practice of science are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations
   - 5.2 the applications of science may be both beneficial and detrimental to the individual, the community and the environment
   - 5.3 science transcends national boundaries and that the language of science, correctly and rigorously applied, is universal
   - 5.4 the use of information technology is important for communications, as an aid to experiments and as a tool for the interpretation of experimental and theoretical results.

ASSESSMENT OBJECTIVES

A Knowledge with Understanding

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

1. scientific phenomena, facts, laws, definitions, concepts, theories

2. scientific vocabulary, terminology, conventions (including symbols, quantities and units contained in '*Signs, Symbols and Systematics*', Association for Science Education (2000), and the recommendations on terms, units and symbols in 'Biological Nomenclature 4th Edition (2009)' published by the Institute of Biology, in conjunction with the Association for Science Education)

3. scientific instruments and apparatus, including techniques of operation and aspects of safety

4. scientific quantities and their determination

5. scientific and technological applications with their social, economic and environmental implications.

The subject content defines the factual knowledge that candidates may be required to recall and explain. Questions testing these objectives will often begin with one of the following words: *define, state, describe, explain* or *outline.* (See the *Glossary of Terms.*)

B Handling Information and Solving Problems

Candidates should be able – in words or by using symbolic, graphical and numerical forms of presentation – to:

1. locate, select, organise and present information from a variety of sources

2. translate information from one form to another

3. manipulate numerical and other data

4. use information to identify patterns, report trends and draw inferences

5. present reasoned explanations for phenomena, patterns and relationships

6. make predictions and hypotheses

7. solve problems.

These assessment objectives cannot be precisely specified in the subject content because questions testing such skills may be based on information which is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: *predict, suggest, calculate* or *determine*. (See the *Glossary of Terms.*)

Weighting of Assessment Objectives

Theory Papers (Papers 1, 2, 3, 4, 5 and 6)

A Knowledge with Understanding, approximately 50% of the marks with approximately 20% allocated to recall.

B Handling Information and Solving Problems, approximately 50% of the marks.

SCHEME OF ASSESSMENT

There will be six papers of which candidates will take four as described below.

5105	Science (Physics, Chemistry)	Papers 1, 2, 3, 4
5106	Science (Physics, Biology)	Papers 1, 2, 5, 6
5107	Science (Chemistry, Biology)	Papers 3, 4, 5, 6

The pair of Papers 1 and 2, 3 and 4, 5 and 6 will be taken in one session of 1 hour 15 minutes. Candidates will be advised not to spend more than 30 minutes on each of Papers 1, 3 and 5.

Paper	Type of Paper	Duration	Marks	Weighting
1	Multiple Choice (Physics)	1 hour 15 minutes	20	20%
2	Structured (Physics)		30	30%
3	Multiple Choice (Chemistry)	1 hour 15 minutes	20	20%
4	Structured (Chemistry)		30	30%
5	Multiple Choice (Biology)	1 hour 15 minutes	20	20%
6	Structured (Biology)		30	30%

Theory papers

Paper 1, 3, 5 (20 marks)

Each of these papers consists of 20 compulsory multiple choice questions.

A copy of The Periodic Table of Elements will be printed as part of Paper 3 for syllabuses 5105 and 5107.

Paper 2, 4, 6 (30 marks)

Each of these papers consists of *two* sections.

Section A will carry 14 marks and will contain a small number of compulsory structured questions.

Section B will carry 16 marks and will contain *three* structured questions. Candidates must answer only two out of these three questions.

A copy of The Periodic Table of Elements will be printed as part of Paper 4 for syllabuses 5105 and 5107.

PHYSICS SECTION

INTRODUCTION

The N Level Science (Physics) syllabus provides students with a coherent understanding of energy, matter, and their interrelationships. It focuses on investigating natural phenomena and then applying patterns, models (including mathematical ones), principles, theories and laws to explain the physical behaviour of the universe. The theories and concepts presented in this syllabus belong to a branch of physics commonly referred to as classical physics. Modern physics, developed to explain the quantum properties at the atomic and sub-atomic level, is built on knowledge of these classical theories and concepts.

Students should think of physics in terms of scales. Whereas the classical theories such as Newton's laws of motion apply to common physical systems that are larger than the size of atoms, a more comprehensive theory, quantum theory, is needed to describe systems at the atomic and sub-atomic scales. It is at these scales that physicists are currently making new discoveries and inventing new applications.

It is envisaged that teaching and learning programmes based on this syllabus would feature a wide variety of learning experiences designed to promote acquisition of scientific expertise and understanding, and to develop values and attitudes relevant to science. Teachers are encouraged to use a combination of appropriate strategies to effectively engage and challenge their students. It is expected that students will apply investigative and problem-solving skills, effectively communicate the theoretical concepts covered in this course and appreciate the contribution that physics makes to our understanding of the physical world.

CONTENT STRUCTURE

SECTION	Topics
I. MEASUREMENT	1. Physical Quantities, Units and Measurement
II. NEWTONIAN MECHANICS	2. Kinematics 3. Dynamics 4. Mass, Weight and Density 5. Turning Effect of Forces 6. Pressure 7. Energy, Work and Power
III. THERMAL PHYSICS	8. Kinetic Model of Matter 9. Transfer of Thermal Energy 10. Thermal Properties of Matter
IV. WAVES	11. General Wave Properties 12. Electromagnetic Spectrum 13. Sound
V. ELECTRICITY AND MAGNETISM	14. Current of Electricity 15. D.C. Circuits 16. Practical Electricity

SUBJECT CONTENT

SECTION I: MEASUREMENT

Overview

In order to gain a better understanding of the physical world, scientists use a process of investigation that follows a general cycle of observation, hypothesis, deduction, test and revision, sometimes referred to as the scientific method. Galileo Galilei, one of the earliest architects of this method, believed that the study of science had a strong logical basis that involved precise definitions of terms and physical quantities, and a mathematical structure to express relationships between these physical quantities.

In this section, we study a set of base physical quantities and units that can be used to derive all other physical quantities. These precisely defined quantities and units, with accompanying order-of-ten prefixes (e.g. milli, centi and kilo) can then be used to describe the interactions between objects in systems that range from celestial objects in space to sub-atomic particles.

1. Physical Quantities, Units and Measurement

Content

- Physical quantities
- SI units
- Prefixes
- Scalars and vectors
- Measurement of length and time

Learning Outcomes

Candidates should be able to:

(a) show understanding that all physical quantities consist of a numerical magnitude and a unit

(b) recall the following base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K)

(c) use the following prefixes and their symbols to indicate decimal sub-multiples and multiples of the SI units: nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G)

(d) show an understanding of the orders of magnitude of the sizes of common objects ranging from a typical atom to the Earth

(e) state what is meant by *scalar* and *vector* quantities and give common examples of each

(f) describe how to measure a variety of lengths with appropriate accuracy by means of tapes, rules, micrometers and calipers, using a vernier scale as necessary

(g) describe how to measure a short interval of time including the period of a simple pendulum with appropriate accuracy using stopwatches or appropriate instruments

SECTION II: NEWTONIAN MECHANICS

Overview

Mechanics is the branch of physics that deals with the study of motion and its causes. Through a careful process of observation and experimentation, Galileo Galilei used experiments to overturn Aristotle's ideas of the motion of objects, for example the flawed idea that heavy objects fall faster than lighter ones, which dominated physics for about 2000 years.

The greatest contribution to the development of mechanics is by one of the greatest physicists of all time, Isaac Newton. By extending Galileo's methods and understanding of motion and gravitation, Newton developed the three laws of motion and his law of universal gravitation, and successfully applied them to both terrestrial and celestial systems to predict and explain phenomena. He showed that nature is governed by a few special rules or laws that can be expressed in mathematical formulae. Newton's combination of logical experimentation and mathematical analysis shaped the way science has been done ever since.

In this section, we begin by examining kinematics, which is a study of motion without regard for the cause. After which, we study the conditions required for an object to be accelerated and introduce the concept of forces through Newton's Laws. Subsequently, concepts of moments and pressure are introduced as consequences of a force. This section concludes by leading the discussion from force to work and energy, and the use of the principle of conservation of energy to explain interactions between bodies.

2. Kinematics

Content

- Speed, velocity and acceleration
- Graphical analysis of motion
- Free fall

Learning Outcomes

Candidates should be able to:

(a) state what is meant by speed and velocity

(b) calculate average speed using *distance travelled / time taken*

(c) state what is meant by uniform acceleration and calculate the value of an acceleration using *change in velocity / time taken*

(d) interpret given examples of non-uniform acceleration

(e) plot and interpret a distance-time graph and a speed-time graph

(f) deduce from the shape of a distance-time graph when a body is:

  (i) at rest

  (ii) moving with uniform speed

  (iii) moving with non-uniform speed

(g) deduce from the shape of a speed-time graph when a body is:
   (i) at rest
   (ii) moving with uniform speed
   (iii) moving with uniform acceleration
   (iv) moving with non-uniform acceleration

(h) calculate the area under a speed-time graph to determine the distance travelled for motion with uniform speed or uniform acceleration

(i) state that the acceleration of free fall for a body near to the Earth is constant and is approximately $10\,m/s^2$

3. Dynamics

Content

- Balanced and unbalanced forces
- Free-body diagram
- Friction

Learning Outcomes

Candidates should be able to:

(a) apply Newton's Laws to:
   (i) describe the effect of balanced and unbalanced forces on a body
   (ii) describe the ways in which a force may change the motion of a body
   (stating of Newton's Laws is not required)

(b) identify forces acting on an object and draw free-body diagram(s) representing the forces acting on the object (only for cases involving forces acting in 1 dimension)

(c) recall and apply the relationship *resultant force = mass* × *acceleration* to new situations or to solve related problems

(d) explain the effects of friction on the motion of a body

4. Mass, Weight and Density

Content

- Mass and weight
- Gravitational field and field strength
- Density

Learning Outcomes

Candidates should be able to:

(a) state that mass is a measure of the amount of substance in a body

(b) state that mass of a body resists a change in the state of rest or motion of the body (inertia)

(c) state that a gravitational field is a region in which a mass experiences a force due to gravitational attraction

(d) define gravitational field strength, *g*, as *gravitational force per unit mass*

(e) recall and apply the relationship *weight = mass × gravitational field strength* to new situations or to solve related problems

(f) distinguish between mass and weight

(g) recall and apply the relationship *density = mass / volume* to new situations or to solve related problems

5. Turning Effect of Forces

Content

- Moments
- Centre of gravity
- Stability

Learning Outcomes

Candidates should be able to:

(a) describe the moment of a force in terms of its turning effect and relate this to everyday examples

(b) recall and apply the relationship *moment of a force (or torque) = force × perpendicular distance from the pivot* to new situations or to solve related problems

(c) state the principle of moments for a body in equilibrium

(d) apply the principle of moments to new situations or to solve related problems

(e) show understanding that the weight of a body may be taken as acting at a single point known as its centre of gravity

(f) describe qualitatively the effect of the position of the centre of gravity on the stability of objects

6. Pressure

Content

- Pressure

Learning Outcomes

Candidates should be able to:

(a) define the term pressure in terms of force and area

(b) recall and apply the relationship *pressure = force / area* to new situations or to solve related problems

7. Energy, Work and Power

Content

- Energy conversion and conservation
- Work
- Power

Learning Outcomes

Candidates should be able to:

(a) show understanding that kinetic energy, potential energy (chemical, gravitational, elastic), light energy, thermal energy, electrical energy and nuclear energy are examples of different forms of energy

(b) state the principle of the conservation of energy and apply the principle to new situations or to solve related problems

(c) state that kinetic energy $E_k = \frac{1}{2} mv^2$ and gravitational potential energy $E_p = mgh$ (for potential energy changes near the Earth's surface)

(d) apply the relationships for kinetic energy and potential energy to new situations or to solve related problems

(e) recall and apply the relationship *work done* = *force* × *distance moved in the direction of the force* to new situations or to solve related problems

(f) recall and apply the relationship *power* = *work done* / *time taken* to new situations or to solve related problems

SECTION III: THERMAL PHYSICS

Overview

Among the early scientists, heat was thought to be some kind of invisible, massless fluid called 'caloric'. Certain objects that released heat upon combustion were thought to be able to 'store' the fluid. However, this explanation failed to explain why friction was able to produce heat. In the 1840s, James Prescott Joule used a falling weight to drive an electrical generator that heated a wire immersed in water. This experiment demonstrated that work done by a falling object could be converted to heat.

In the previous section, we studied about energy and its conversion. Many energy conversion processes which involve friction will have heat as a product. This section begins with the introduction of the kinetic model of matter. This model is then used to explain and predict the physical properties and changes of matter at the molecular level in relation to heat or thermal energy transfer.

8. Kinetic Model of Matter

Content

- States of matter
- Kinetic model

Learning Outcomes

Candidates should be able to:

(a) compare the properties of solids, liquids and gases

(b) describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces and distances between molecules and to the motion of the molecules

(c) describe the relationship between the motion of molecules and temperature

9. Transfer of Thermal Energy

Content

- Conduction
- Convection
- Radiation

Learning Outcomes

Candidates should be able to:

(a) show understanding that thermal energy is transferred from a region of higher temperature to a region of lower temperature

(b) describe, in molecular terms, how energy transfer occurs in solids

(c) describe, in terms of density changes, convection in fluids

(d) explain that energy transfer of a body by radiation does not require a material medium and the rate of energy transfer is affected by:
   (i) colour and texture of the surface
   (ii) surface temperature
   (iii) surface area

(e) apply the concept of thermal energy transfer to everyday applications

10. Thermal Properties of Matter

Content

- Internal energy
- Melting, boiling and evaporation

Learning Outcomes

Candidates should be able to:

(a) describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy)

(b) describe melting/solidification and boiling/condensation as processes of energy transfer without a change in temperature

(c) explain the difference between boiling and evaporation

SECTION IV: WAVES

Overview

Waves are inherent in our everyday lives. Much of our understanding of wave phenomena has been accumulated over the centuries through the study of light (optics) and sound (acoustics). The nature of oscillations in light was only understood when James Clerk Maxwell, in his unification of electricity, magnetism and electromagnetic waves, stated that all electromagnetic fields spread in the form of waves. Using a mathematical model (Maxwell's equations), he calculated the speed of electromagnetic waves and found it to be close to the speed of light, leading him to make a bold but correct inference that light consists of propagating electromagnetic disturbances. This gave the very nature of electromagnetic waves, and hence its name.

In this section, we examine the nature of waves in terms of the coordinated movement of particles. The discussion moves on to wave propagation and its uses by studying the properties of light, electromagnetic waves and sound, as well as their applications in wireless communication, home appliances, medicine and industry.

11. General Wave Properties

Content

- Describing wave motion
- Wave terms
- Longitudinal and transverse waves

Learning Outcomes

Candidates should be able to:

(a) describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by waves in a ripple tank

(b) show understanding that waves transfer energy without transferring matter

(c) define *speed, frequency, wavelength, period* and *amplitude*

(d) state what is meant by the term *wavefront*

(e) recall and apply the relationship *velocity = frequency* × *wavelength* to new situations or to solve related problems

(f) compare transverse and longitudinal waves and give suitable examples of each

12. Electromagnetic Spectrum

Content

- Properties of electromagnetic waves
- Applications of electromagnetic waves

Learning Outcomes

Candidates should be able to:

(a) state that all electromagnetic waves are transverse waves that travel with the same speed in vacuum and state the magnitude of this speed

(b) describe the main components of the electromagnetic spectrum

(c) state examples of the use of the following components:

- (i) radiowaves (e.g. radio and television communication)
- (ii) microwaves (e.g. microwave oven and satellite television)
- (iii) infra-red (e.g. infra-red remote controllers and intruder alarms)
- (iv) light (e.g. optical fibres for medical uses and telecommunications)
- (v) ultra-violet (e.g. sunbeds and sterilisation)
- (vi) X-rays (e.g. radiological and engineering applications)
- (vii) gamma rays (e.g. medical treatment)

13. Sound

Content

- Sound waves
- Speed of sound
- Echo

Learning Outcomes

Candidates should be able to:

(a) describe the production of sound by vibrating sources

(b) describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction

(c) explain that a medium is required in order to transmit sound waves and the speed of sound differs in air, liquids and solids

(d) relate loudness of a sound wave to its amplitude and pitch to its frequency

(e) describe how the reflection of sound may produce an echo, and how this may be used for measuring distances

SECTION V: ELECTRICITY

Overview

The investigation of electric currents was triggered by a chance observation of an Italian biologist, Luigi Galvani. Frog legs that he was preparing twitched when touched by a charged scalpel. This led to his discovery of the role of electricity in living systems. It was only after the physicist, Alessandro Volta, invented the first type of battery that the understanding of electricity developed rapidly. Perhaps the greatest achievements in this area came from a German school teacher, Georg Simon Ohm. Ohm introduced the important quantities of voltage, current, and resistance and discovered the relationship between them.

The section begins with a discussion of electric charges that are static, i.e. not moving. Next, we study the phenomena associated with moving charges and the concepts of current, voltage and resistance. We also study how these concepts are applied to simple circuits and household electricity.

14. Current of Electricity

Content

- Electric charges
- Conventional current and electron flow
- Electromotive force
- Potential difference
- Resistance

Learning Outcomes

Candidates should be able to:

(a) state that there are positive and negative charges and that charge is measured in coulombs

(b) state that current is a rate of flow of charge and that it is measured in amperes

(c) distinguish between conventional current and electron flow

(d) recall and apply the relationship *charge* = *current* × *time* to new situations or to solve related problems

(e) define electromotive force (e.m.f.) as the work done by a source in driving a unit charge around a complete circuit

(f) state that the e.m.f. of a source and the potential difference (p.d.) across a circuit component is measured in volts

(g) define the p.d. across a component in a circuit as the work done to drive a unit charge through the component

(h) state the definition that *resistance = p.d. / current*

(i) apply the relationship $R = V / I$ to new situations or to solve related problems

(j) describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations

(k) recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems

(l) recall and apply the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems

15. D.C. Circuits

Content

- Current and potential difference in circuits
- Series and parallel circuits

Learning Outcomes

Candidates should be able to:

(a) draw circuit diagrams with power sources (cell or battery), switches, lamps, resistors (fixed and variable), fuses, ammeters and voltmeters

(b) state that the current at every point in a series circuit is the same and apply the principle to new situations or to solve related problems

(c) state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and apply the principle to new situations or to solve related problems

(d) state that the current from the source is the sum of the currents in the separate branches of a parallel circuit and apply the principle to new situations or to solve related problems

(e) state that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems

(f) recall and apply the relevant relationships, including $R = V/I$ and those for current, potential differences and resistors in series and in parallel circuits, in calculations involving a whole circuit

16. Practical Electricity

Content

- Electric power and energy
- Dangers of electricity
- Safe use of electricity in the home

Learning Outcomes

Candidates should be able to:

(a) describe the use of the heating effect of electricity in appliances such as electric kettles, ovens and heaters

(b) recall and apply the relationships $P = VI$ and $E = VIt$ to new situations or to solve related problems

(c) calculate the cost of using electrical appliances where the energy unit is the kW h

(d) state the hazards of using electricity in the following situations:

   (i) damaged insulation

   (ii) overheating of cables

   (iii) damp conditions

(e) explain the use of fuses and circuit breakers in electrical circuits and of fuse ratings

(f) explain the need for earthing metal cases and for double insulation

(g) state the meaning of the terms *live, neutral* and *earth*

(h) describe the wiring in a mains plug

(i) explain why switches, fuses, and circuit breakers are wired into the live conductor

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

Students should be able to state the symbols for the following physical quantities and, where indicated, state the units in which they are measured. Students should be able to define those items indicated by an asterisk (*).

Quantity	***Symbol***	***Unit***
length	*l, h . . .*	km, m, cm, mm
area	*A*	m^2, cm^2
volume	*V*	m^3, cm^3
weight	*W*	N*
mass	*m, M*	kg, g, mg
time	*t*	h, min, s, ms
period*	*T*	s
density*	ρ	g/cm^3, kg/m^3
speed*	*u, v*	km/h, m/s, cm/s
acceleration*	*a*	m/s^2
acceleration of free fall	*g*	m/s^2, N/kg
force*	*F, f*	N
moment of force*		N m
work done*	*W, E*	J*
energy	*E*	J, kW h*
power*	*P*	W*
temperature	θ, *T*	°C, K
frequency*	*f*	Hz
wavelength*	λ	m, cm
potential difference*/voltage	*V*	V*, mV
current*	*I*	A, mA
charge	*q, Q*	C, A s
e.m.f.*	*E*	V
resistance	*R*	Ω

PRACTICAL GUIDELINES

Scientific subjects are, by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to support and facilitate the learning of this subject. A list of suggested practical work is provided below.

- Measurements of length, time interval, temperature, volume, mass and weight using the appropriate instruments
- Determination of the density of solids and liquids
- Determination of the value of free fall
- Investigation of the effects of balanced and unbalanced forces
- Verification and application of the principle of moments
- Determination of the position of the centre of gravity of a plane lamina
- Investigation of the factors affecting thermal energy transfer
- Measurements of current and voltage by using appropriate ammeters and voltmeters
- Determination of the resistance of a circuit element using appropriate instruments

This is not intended to be an exhaustive list. Reference may be made to the techniques used in these experiments in the theory papers but no detailed description of the experimental procedures will be required.

CHEMISTRY SECTION

INTRODUCTION

This syllabus is designed to place less emphasis on factual materials and greater emphasis on the understanding and application of scientific concepts and principles. This approach has been adapted in recognition of the need for students to develop skills that will be of long-term value in an increasingly technological world rather than focusing on large quantities of factual materials, which may have only short-term relevance.

It is important that, throughout the course, attention should be drawn to:

(i) the finite life of the world's resources and hence the need for recycling and conservation

(ii) economic considerations in the chemical industry, such as the availability and cost of raw materials and energy

(iii) the social, environmental, health and safety issues relating to the chemical industry

(iv) the importance of chemicals in industry and in everyday life.

It is envisaged that teaching and learning programmes based on this syllabus will feature a wide variety of learning experiences designed to promote acquisition of expertise and understanding. Teachers are encouraged to use a combination of appropriate strategies including developing appropriate practical work for their students to facilitate a greater understanding of the subject.

CONTENT STRUCTURE

SECTION	Topics
I. EXPERIMENTAL CHEMISTRY	1. Experimental Chemistry
II. ATOMIC STRUCTURE AND THE MOLE CONCEPT	2. The Particulate Nature of Matter 3. Formulae and the Mole Concept
III. CHEMISTRY OF REACTIONS	4. Acids, Bases and Salts
IV. PERIODICITY	5. The Periodic Table 6. Metals
V. ATMOSPHERE	7. Air
VI. ORGANIC CHEMISTRY	8. Organic Chemistry

SUBJECT CONTENT

SECTION I: EXPERIMENTAL CHEMISTRY

Overview

Chemistry is typically an experimental science and relies primarily on practical work. It is important for students to learn the techniques of handling laboratory apparatus and to pay special attention to safety while working in the laboratory. Accidents happened even to German chemist, Robert Bunsen, while working in the laboratory. Robert Bunsen spent most of his time doing experiments in the laboratory and, at the age of 25, he lost an eye in a laboratory explosion due to the lack of proper eye protection.

In this section, students examine the appropriate use of simple apparatus and chemicals, and the experimental techniques. Students need to be aware of the importance of purity in the electronic, pharmaceutical, food and beverage industries, and be allowed to try out different methods of purification and analysis in school science laboratories. Students should be able to appreciate the need for precision and accuracy in making readings and also value the need for safe handling and disposing of chemicals.

1. Experimental Chemistry

Content

1.1 Experimental design

1.2 Methods of purification and analysis

1.3 Identification of gases

Learning Outcomes

Candidates should be able to:

1.1 Experimental design

(a) name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes, measuring cylinders and gas syringes

(b) suggest suitable apparatus, given relevant information, for a variety of simple experiments, including collection of gases

1.2 Methods of purification and analysis

(a) describe methods of separation and purification for the components of mixtures, to include:

- (i) use of a suitable solvent, filtration and crystallisation or evaporation
- (ii) distillation and fractional distillation (see also **8.1**(b))
- (iii) paper chromatography

(b) suggest suitable separation and purification methods, given information about the substances involved in the following types of mixtures:

- (i) solid-solid
- (ii) solid-liquid
- (iii) liquid-liquid (miscible)

(c) interpret paper chromatograms (the use of R_f values is **not** required)

(d) deduce from the given melting point and boiling point the identities of substances and their purity

1.3 Identification of gases

(a) describe tests to identify the following gases: carbon dioxide (using limewater), hydrogen (using a burning splint), oxygen (using a glowing splint)

SECTION II: ATOMIC STRUCTURE AND MOLE CONCEPT

Overview

For over 2000 years, people have wondered about the fundamental building blocks of matter. As far back as 440 BC, the Greek Leucippus and his pupil Democritus coined the term *atomos* to describe the smallest particle of matter. It translates to mean something that is indivisible. In the eighteenth century, chemist, John Dalton, revived the term when he suggested that each element was made up of unique atoms and the atoms of an element are all the same. At that time, there were about 35 known elements. This simple model could explain the millions of different materials around us.

Differences between atoms give elements their different chemical properties. Atoms of one or more substances (reactants) undergo some ‘rearrangements’ during a chemical change (reaction). These rearrangements form new and different substances (products). After the chemical reaction, all the atoms of the reactants are still present in the products. Balanced chemical equations can be written because of the *law of conservation of mass*. These equations make it possible to predict the masses of reactants and products involved in chemical reactions.

In this section, the idea of atoms and chemical bonding being the most important fundamental concept in chemistry is introduced. The knowledge of atomic structure opens the door for students to understand the world of chemical reactions. Students are also introduced to the use of models and theories in the study of the structures of atoms, molecules and ions, and the bonding in elements and compounds.

2. The Particulate Nature of Matter

Content

2.1 Kinetic particle theory

2.2 Atomic structure

2.3 Structure and properties of materials

2.4 Ionic bonding

2.5 Covalent bonding

Learning Outcomes

Candidates should be able to:

2.1 Kinetic particle theory

(a) describe the solid, liquid and gaseous states of matter and explain their interconversion in terms of the kinetic particle theory and of the energy changes involved

2.2 Atomic structure

(a) state the relative charges and approximate relative masses of a proton, a neutron and an electron

(b) describe, with the aid of diagrams, the structure of an atom as containing protons and neutrons (nucleons) in the nucleus and electrons arranged in shells (energy levels)

(Knowledge of s, p, d and f classification is **not** required; a copy of The Periodic Table of the Elements will be available in the examination.)

(c) define *proton (atomic) number* and *nucleon (mass) number*

(d) interpret and use symbols such as ${}^{12}_{6}C$

(e) define the term *isotopes*

(f) deduce the numbers of protons, neutrons and electrons in atoms and ions given proton and nucleon numbers

2.3 Structure and properties of materials

(a) describe the differences between elements, compounds and mixtures

2.4 Ionic bonding

(a) describe the formation of ions by electron loss/gain in order to obtain the electronic configuration of a noble gas

(b) describe the formation of ionic bonds between metals and non-metals, e.g. $NaCl$; $MgCl_2$

(c) relate the physical properties (including electrical property) of ionic compounds to their lattice structure

2.5 Covalent bonding

(a) describe the formation of a covalent bond by the sharing of a pair of electrons in order to gain the electronic configuration of a noble gas

(b) describe, using 'dot and cross' diagrams, the formation of covalent bonds between non-metallic elements, e.g. H_2; O_2; H_2O; CH_4 and CO_2

(c) deduce the arrangement of electrons in other covalent molecules

(d) relate the physical properties (including electrical property) of covalent substances to their structure and bonding

3. Formulae and Mole Concept

Learning Outcomes

Candidates should be able to:

(a) state the symbols of the elements and formulae of the compounds mentioned in the syllabus

(b) deduce the formulae of simple compounds from the relative numbers of atoms present and vice versa

(c) deduce the formulae of ionic compounds from the charges on the ions present and vice versa

(d) interpret chemical equations with state symbols

(e) construct chemical equations, with state symbols, including ionic equations

(f) define *relative atomic mass*, A_r

(g) define *relative molecular mass*, M_r, and calculate relative molecular mass (and relative formula mass) as the sum of relative atomic masses

(h) perform calculations involving the relationship between the amount of substance in moles, mass and molar mass (calculations of stoichiometric reacting masses and volumes of gases are **not** required)

SECTION III: CHEMISTRY OF REACTIONS

Overview

Chemists like Svante Arrhenius played an important role in providing a comprehensive understanding of what happens in chemical reactions. In 1887, the Swedish chemist Svante Arrhenius proposed the theory that acids, bases, and salts in water are composed of ions. He also proposed a simple yet beautiful model of neutralisation – the combination of hydrogen and hydroxyl ions to form water.

In this section, candidates examine the chemical characteristic properties of acids, bases and salts, and also their reactions with substances. Candidates should be able to value the knowledge of the hazardous nature of acids/alkalis and the safe handling, storing and disposing of chemicals.

4. Acids, Bases and Salts

Content

4.1 Acids and bases

4.2 Salts

Learning Outcomes

Candidates should be able to:

4.1 Acids and bases

(a) describe the meanings of the terms *acid* and *alkali* in terms of the ions they produce in aqueous solution and their effects on Universal Indicator

(b) describe how to test hydrogen ion concentration and hence relative acidity using Universal Indicator and the pH scale

(c) describe the characteristic properties of acids as in reactions with metals, bases and carbonates

(d) describe the reaction between hydrogen ions and hydroxide ions to produce water, $H^+ + OH^- \rightarrow H_2O$ as neutralisation

(e) describe the importance of controlling the pH in soils and how excess acidity can be treated using calcium hydroxide

(f) describe the characteristic properties of bases as in reactions with acids and with ammonium salts

(g) classify oxides as acidic, basic, amphoteric or neutral based on metallic/non-metallic character

4.2 Salts

(a) describe the techniques used in the preparation, separation and purification of salts as examples of some of the techniques specified in Sections **1.2**(a)

(Methods for preparation should include precipitation and titration, together with reactions of acids with metals, insoluble bases and insoluble carbonates.)

(b) suggest a method of preparing a given salt from suitable starting materials, given appropriate information

SECTION IV: PERIODICITY

Overview

The development of the Periodic Table started in the 1800s as chemists began to recognise similarities in the properties of various elements and place them in families. The most famous and successful classification, widely accepted by chemists, was published in 1869 by Dmitri Mendeleev, a Russian chemist. His periodic table arranged the elements known at that time, in order of increasing atomic masses.

The International Union of Pure and Applied Chemistry (IUPAC) is the gatekeeper of elements and it oversees the Periodic Table of elements. Until 2007, the Periodic Table consisted of 111 officially named elements. However, in 2009 it was reported that Element 112, with an atomic number of 112 and about 277 times heavier than hydrogen, was discovered by Sigurd Hoffmann and his team of 21 scientists from Germany, Finland, Russia and Slovakia. It is currently the heaviest element in the Periodic Table.

In this section, students examine the periodic trends and group properties of elements, occurrence of metals, their properties, reactivity and uses. Students should be able to appreciate the development of the Periodic Table and hence to envisage that scientific knowledge changes and accumulates over time, and also the need for conserving some of the finite resources.

5. The Periodic Table

Content

5.1 Periodic trends

5.2 Group properties

Learning Outcomes

Candidates should be able to:

5.1 Periodic trends

(a) describe the Periodic Table as an arrangement of the elements in the order of increasing proton (atomic) number

(b) describe how the position of an element in the Periodic Table is related to proton number and electronic structure

(c) explain the similarities between the elements in the same group of the Periodic Table in terms of their electronic structure

(d) describe the change from metallic to non-metallic character from left to right across a period of the Periodic Table

(e) describe the relationship between group number, number of valency electrons and metallic/non-metallic character

(f) predict the properties of elements in Group I and Group VII using the Periodic Table

5.2 Group properties

(a) describe lithium, sodium and potassium in Group I (the alkali metals) as a collection of relatively soft, low density metals showing a trend in melting point and in their reaction with water

(b) describe chlorine, bromine and iodine in Group VII (the halogens) as a collection of diatomic non-metals showing a trend in colour, state and their displacement reactions with solutions of other halide ions

(c) describe the lack of reactivity of the elements in Group 0 (the noble gases) in terms of their electronic structures

6. Metals

Content

6.1 Properties of metals

6.2 Reactivity series

6.3 Extraction of metals

6.4 Recycling of metals

6.5 Iron

Learning Outcomes

Candidates should be able to:

6.1 Properties of metals

(a) describe the general physical properties of metals as solids having high melting and boiling points, being malleable and good conductors of heat and electricity

(b) describe alloys as a mixture of a metal with another element, e.g. brass; stainless steel

(c) identify representations of metals and alloys from diagrams of structures

6.2 Reactivity series

(a) place in order of reactivity, calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc, by reference to the reactions, if any, of the metals with water, steam and dilute hydrochloric acid

(b) deduce the order of reactivity from a given set of experimental results

6.3 Extraction of metals

(a) describe the ease of obtaining metals from their ores by relating the elements to their positions in the reactivity series

6.4 Recycling of metals

(a) describe metal ores as a finite resource and hence the need to recycle metals, e.g. the recycling of iron

(b) discuss the social, economic and environmental issues of recycling metals

6.5 Iron

(a) describe and explain the essential reactions in the extraction of iron using haematite, limestone and coke in the blast furnace

(b) describe the essential conditions for the corrosion (rusting) of iron as the presence of oxygen and water; prevention of rusting can be achieved by placing a barrier around the metal, e.g. painting; greasing; plastic coating

SECTION V: ATMOSPHERE

Overview

Our atmosphere has been taken for granted in the past. In the last few decades, scientists and the general public began to realise the adverse effects of pollutants on the air we breathe. It is now recognised that pollutants such as sulfur dioxide, oxides of nitrogen, carbon monoxide and particulates released into the atmosphere as a result of energy generation and increased use of motor vehicles, have serious health and environmental consequences.

In this section, the sources of air pollutants and their effects are examined. Students should be able to value the knowledge of the hazardous nature of pollutants and the environmental issues related to air pollution.

7. Air

Learning Outcomes

Candidates should be able to:

(a) describe the volume composition of gases present in dry air as being approximately 78% nitrogen, 21% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide

(b) name some common atmospheric pollutants, e.g. carbon monoxide; methane; nitrogen oxides (NO and NO_2); ozone; sulfur dioxide; unburned hydrocarbons

(c) state the sources of these pollutants as:

- (i) carbon monoxide from incomplete combustion of carbon-containing substances
- (ii) nitrogen oxides from lightning activity and internal combustion engines
- (iii) sulfur dioxide from volcanoes and combustion of fossil fuels

(d) discuss some of the effects of these pollutants on health and on the environment:

- (i) the poisonous nature of carbon monoxide
- (ii) the role of nitrogen dioxide and sulfur dioxide in the formation of ‘acid rain’ and its effects on respiration and buildings

SECTION VI: ORGANIC CHEMISTRY

Overview

In the nineteenth century, chemists believed that organic chemicals originated in tissues of living organisms. Friedrich Wohler, in 1828, changed this belief and synthesised the organic compound, urea, a compound found in urine, under laboratory conditions. His work led other chemists to attempt synthesis of other organic compounds.

In this section, students examine the sources of fuels, some basic concepts of organic chemistry such as homologous series, functional group, general formula and structural formula. Students should be able to identify and name unbranched alkanes and alkenes.

8. Organic Chemistry

Content

8.1 Fuels and crude oil

8.2 Alkanes

8.3 Alkenes

Learning Outcomes

Candidates should be able to:

8.1 Fuels and crude oil

(a) name natural gas, mainly methane, and petroleum as sources of energy

(b) describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation (see also **1.2**(a))

(c) name the following fractions and state their uses:

- (i) petrol (gasoline) as a fuel in cars
- (ii) naphtha as the feedstock for the petrochemical industry
- (iii) paraffin (kerosene) as a fuel for heating and cooking and for aircraft engines
- (iv) diesel as a fuel for diesel engines
- (v) lubricating oils as lubricants and as a source of polishes and waxes
- (vi) bitumen for making road surfaces

8.2 Alkanes

(a) describe an homologous series as a group of compounds with a general formula, similar chemical properties and showing a gradation in physical properties as a result of increase in the size and mass of the molecules, e.g. melting and boiling points; viscosity; flammability

(b) describe the alkanes as an homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}

(c) draw the structures of unbranched alkanes, C_1 to C_3 and name the unbranched alkanes, methane to propane

(d) describe the properties of alkanes (exemplified by methane) as being generally unreactive except in terms of combustion and substitution by chlorine

8.3 Alkenes

(a) describe the alkenes as an homologous series of unsaturated hydrocarbons with the general formula C_nH_{2n}

(b) draw the structures of unbranched alkenes, C_2 to C_3 and name the unbranched alkenes, ethene to propene

(c) describe the manufacture of alkenes and hydrogen by cracking hydrocarbons and recognise that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process

(d) describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine

(e) describe the properties of alkenes (exemplified by ethene) in terms of combustion and the addition reactions with bromine and hydrogen

(f) state the meaning of *polyunsaturated* when applied to food products

(g) describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The list below is intended as a guide to the more important quantities which might be encountered in teaching and used in question papers. The list is not exhaustive.

Quantity	Symbol	Unit
Base quantities		
mass	m	g, kg, tonne
length	l	cm, m
time	t	s, min
amount of substance	n	mol
Other quantities		
temperature	θ, t	°C
volume	V, v	cm^3, m^3, dm^3
density	ρ	g/cm^3, kg/m^3
atomic mass	m_a	g
relative { atomic / isotopic } mass	A_r	–
molecular mass	m	g
relative molecular mass	M_r	–
molar mass	M	g/mol
nucleon number	A	–
proton number	Z	–
neutron number	N	–
enthalpy change of reaction	ΔH	J, kJ
bond energy	-	kJ/mol
concentration	c	mol/dm^3, g/dm^3
pH	pH	–

PRACTICAL GUIDELINES

Scientific subjects are, by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to facilitate the learning of this subject. A list of suggested practicals is provided.

1. Separation techniques including filtration, simple paper chromatography and distillation
2. Measurements of temperature based on thermometers with 1 °C graduation
3. Determination of melting point and boiling point
4. Experiments involving the preparation of salts
5. Experiments involving the solubility of salts
6. Acid/alkali titration involving the use of a pipette, burette and a suitable given indicator
7. Identification of gases as specified in the syllabus
8. Experiments involving displacement reactions

This is not intended to be an exhaustive list. Candidates may be asked to carry out other practical work and appropriate guidance will be provided where unfamiliar experiments are involved.

NOTES FOR QUALITATIVE ANALYSIS

Test for gases

gas	***test and test result***
carbon dioxide (CO_2)	gives white ppt. with limewater (ppt. dissolves with excess CO_2)
hydrogen (H_2)	‘pops’ with a lighted splint
oxygen (O_2)	relights a glowing splint

The Periodic Table of Elements

Group

I	II											III	IV	V	VI	VII	0
							1 **H** Hydrogen 1										4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	64 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	**Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La** Lanthanum 57 *	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	209 **Po** Polonium 84	210 **At** Astatine 85	222 **Rn** Radon 86
223 **Fr** Francium 87	226 **Ra** Radium 88	227 **Ac** Actinium 89 †															

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

140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	147 **Pm** Promethium 61	150 **Sm** Samarium 62	152 **Eu** Europium 63	157 **Gd** Gadolinium 64	159 **Tb** Terbium 65	162 **Dy** Dysprosium 66	165 **Ho** Holmium 67	167 **Er** Erbium 68	169 **Tm** Thulium 69	173 **Yb** Ytterbium 70	175 **Lu** Lutetium 71
232 **Th** Thorium 90	231 **Pa** Protactinium 91	238 **U** Uranium 92	237 **Np** Neptunium 93	244 **Pu** Plutonium 94	243 **Am** Americium 95	247 **Cm** Curium 96	247 **Bk** Berkelium 97	251 **Cf** Californium 98	252 **Es** Einsteinium 99	257 **Fm** Fermium 100	258 **Md** Mendelevium 101	259 **No** Nobelium 102	260 **Lr** Lawrencium 103

Key

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

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

BIOLOGY SECTION

INTRODUCTION

This syllabus is designed to have less emphasis on factual materials, but a much greater emphasis on the understanding and application of scientific concepts and principles. This approach has been adopted in recognition of the need for students to develop skills that will be of long-term value in an increasingly technological world, rather than focusing on large quantities of factual material, which may have only short-term relevance.

It is envisaged that teaching and learning programmes based on this syllabus will feature a wide variety of learning experiences designed to promote inquiry. Teachers are encouraged to use a combination of appropriate strategies in teaching topics in this syllabus. The assessment will be specifically intended to test skills, comprehension and insight in familiar and unfamiliar contexts.

CONTENT STRUCTURE

SECTION	Topics
I. PRINCIPLES OF BIOLOGY	1. Cell Structure and Organisation 2. Movement of Substances 3. Biological Molecules
II. MAINTENANCE AND REGULATION OF LIFE PROCESSES	4. Nutrition in Humans 5. Nutrition in Plants 6. Transport in Flowering Plants 7. Transport in Humans 8. Respiration in Humans
III. CONTINUITY OF LIFE	9. Reproduction

SUBJECT CONTENT

SECTION I: PRINCIPLES OF BIOLOGY

Overview

A basic characteristic of life is the hierarchy of structural order within the organism. Robert Hooke (1635–1703), one of the first scientists to use a microscope to examine pond water, cork and other things, was the first to refer to the cavities he saw in cork as ‘cells’, Latin for chambers. Subsequent scientists developed Hooke’s discovery of the cell into the Cell Theory on which modern biology is built. The Cell Theory states that all organisms are composed of one or more cells, and that those cells have arisen from pre-existing cells.

In this section, we study two key principles of biology. The first principle is the correlation of structure to function. This is illustrated by how each part of the cell is suited for its intended function. The second principle is that specialisation results in the division of labour which enables the cell to effectively carry out a number of vital life processes. A strong foundation in the principles of biology will pave the way for students to master the content in the subsequent topics.

1. Cell Structure and Organisation

Content

- Plant and animal cells
- Specialised cells, tissues and organs

Learning Outcomes

Candidates should be able to:

(a) identify cell structures (including organelles) of typical plant and animal cells from diagrams, photomicrographs and as seen under the light microscope using prepared slides and fresh material treated with an appropriate temporary staining technique:
- chloroplasts
- cell membrane
- cell wall
- cytoplasm
- cell vacuoles (large, sap-filled in plant cells, small, temporary in animal cells)
- nucleus

(b) identify the following organelles from diagrams and electronmicrographs:
- mitochondria
- ribosomes

(c) state the functions of the organelles identified above

(d) compare the structure of typical animal and plant cells

(e) state, in simple terms, the relationship between cell function and cell structure for the following:
- absorption – root hair cells
- conduction and support – xylem vessels
- transport of oxygen – red blood cells

(f) differentiate cell, tissue, organ and organ system

Use the knowledge gained in this section in new situations or to solve related problems.

2. Movement of Substances

Content

- Diffusion
- Osmosis

Learning Outcomes

Candidates should be able to:

(a) define diffusion and describe its role in nutrient uptake and gaseous exchange in plants and humans

(b) define osmosis and describe the effects of osmosis on plant and animal tissues

Use the knowledge gained in this section in new situations or to solve related problems.

3. Biological Molecules

Content

- Water and living organisms
- Carbohydrates, fats and proteins
- Enzymes

Learning Outcomes

Candidates should be able to:

(a) state the roles of water in living organisms

(b) describe and carry out tests for:

- starch (iodine in potassium iodide solution)
- reducing sugars (Benedict's solution)
- protein (biuret test)
- fats (ethanol emulsion)

(c) state that large molecules are synthesised from smaller basic units

- glycogen from glucose
- polypeptides and proteins from amino acids
- fats from glycerol and fatty acids

(d) explain enzyme action in terms of the 'lock and key' hypothesis (explain the mode of action of enzymes in terms of an active site, enzyme-substrate complex and enzyme specificity)

(e) investigate and explain the effects of temperature and pH on the rate of enzyme-catalysed reactions

Use the knowledge gained in this section in new situations or to solve related problems.

SECTION II: MAINTENANCE AND REGULATION OF LIFE PROCESSES

Overview

Life is sustained through the integrated organisation of the whole organism. In humans, the maintenance and regulation of life processes include nutrition, transport, respiration, excretion, homeostasis and co-ordination and response. The key overarching theme in the study of the organ systems is the correlation between form and function.

4. Nutrition in Humans

Content

- Human alimentary canal
- Chemical digestion
- Absorption and assimilation

Learning Outcomes

Candidates should be able to:

(a) describe the functions of main regions of the alimentary canal and the associated organs: mouth, salivary glands, oesophagus, stomach, duodenum, pancreas, gall bladder, liver, ileum, colon, rectum, anus, in relation to ingestion, digestion, absorption, assimilation and egestion of food, as appropriate

(b) describe the functions of enzymes (e.g. amylase, maltase, protease, lipase) in digestion, listing the substrates and end-products

(c) state the function of the hepatic portal vein in the transport of blood rich in absorbed nutrients from the small intestine to the liver

(d) state the role of the liver in

- the metabolism of glucose
- the metabolism of amino acids and the formation of urea
- the breakdown of alcohol

Use the knowledge gained in this section in new situations or to solve related problems.

5. Nutrition in Plants

Content

- Leaf structure
- Photosynthesis

Learning Outcomes

Candidates should be able to:

(a) identify the cellular and tissue structure of a dicotyledonous leaf, as seen in cross-section under the microscope and state their functions:

- distribution of chloroplasts – photosynthesis
- stomata and mesophyll cells – gaseous exchange
- vascular bundles – transport

(b) state the equation, in words only, for photosynthesis

(c) outline the intake of carbon dioxide and water by plants

(d) state that chlorophyll traps light energy and converts it into chemical energy for the formation of carbohydrates and their subsequent uses

(e) investigate and state the effect of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis, e.g. in submerged aquatic plants

(f) briefly explain why most forms of life are completely dependent on photosynthesis

Use the knowledge gained in this section in new situations or to solve related problems.

6. Transport in Flowering Plants

Content

- Water and ion uptake
- Transpiration and translocation

Learning Outcomes

Candidates should be able to:

(a) identify the positions of xylem vessels and phloem in sections of a typical dicotyledonous stem and leaf, under the light microscope, and state their functions

(b) relate the structure and functions of root hairs to their surface area, and to water and ion uptake

(c) state that transpiration is the loss of water vapour from the stomata

(d) briefly explain the movement of water through the stem in terms of transpiration pull

(e) describe

- the effects of variation of air movement, temperature, humidity and light intensity on transpiration rate
- how wilting occurs

(f) define the term translocation as the transport of food in the phloem tissue

Use the knowledge gained in this section in new situations or to solve related problems.

7. Transport in Humans

Content

- Circulatory system

Learning Outcomes

Candidates should be able to:

(a) name the main blood vessels to and from the heart, lungs, liver and kidney

(b) state the role of blood in transport and defence

- red blood cells – haemoglobin and oxygen transport
- plasma – transport of blood cells, ions, soluble food substances, hormones, carbon dioxide, urea, vitamins, plasma proteins
- white blood cells – phagocytosis, antibody formation and tissue rejection
- platelets – fibrinogen to fibrin, causing clotting

(c) relate the structure of arteries, veins and capillaries to their functions

(d) describe the structure and function of the heart in terms of muscular contraction and the working of valves. (Histology of the heart muscle, names of nerves and transmitter substances are not required)

(e) describe coronary heart disease in terms of the occlusion of coronary arteries and list the possible causes, such as diet, stress, smoking, and the possible preventative measures

Use the knowledge gained in this section in new situations or to solve related problems.

8. Respiration in Humans

Content

- Human gas exchange
- Aerobic respiration
- Anaerobic respiration

Learning Outcomes

Candidates should be able to:

(a) identify on diagrams and name the larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries and state their functions in human gaseous exchange

(b) state the characteristics of, and describe the role of, the exchange surface of the alveoli in gas exchange

(c) describe the effect of tobacco smoke and its major toxic components – nicotine, tar and carbon monoxide, on health

(d) define and state the equation, in words only, for aerobic respiration in humans

(e) define and state the equation, in words only, for anaerobic respiration in humans

(f) describe the effect of lactic acid in muscles during exercise

Use the knowledge gained in this section in new situations or to solve related problems.

SECTION III: CONTINUITY OF LIFE

Overview

The many aspects of form and function that we have examined in this syllabus can be viewed in the widest context as various adaptations aimed at ensuring reproductive success. Reproduction is vital for the survival of species across generations. This section focuses on understanding the processes involved in the continuity of life. These concepts provide the basis for the study of subsequent topics in this section.

9. Reproduction

Content

- Asexual reproduction
- Sexual reproduction in plants
- Sexual reproduction in humans
- Sexually transmitted diseases

Learning Outcomes

Candidates should be able to:

(a) define asexual reproduction as the process resulting in the production of genetically identical offspring from one parent

(b) define sexual reproduction as the process involving the fusion of nuclei to form a zygote and the production of genetically dissimilar offspring

(c) state the functions of the sepals, petals, anthers and carpels

(d) outline the process of pollination

(e) describe the growth of the pollen tube and its entry into the ovule followed by fertilisation (production of endosperm and details of development are **not** required)

(f) identify on diagrams of the male reproductive system and give the functions of: testes, scrotum, sperm ducts, prostate gland, urethra and penis

(g) identify on diagrams of the female reproductive system and give the functions of: ovaries, oviducts, uterus, cervix and vagina

(h) briefly describe the menstrual cycle with reference to the alternation of menstruation and ovulation, the natural variation in its length, and the fertile and infertile phases of the cycle, with reference to the roles of estrogen and progesterone only

(i) briefly describe fertilisation and early development of the zygote simply in terms of the formation of a ball of cells which becomes implanted in the wall of the uterus

(j) discuss the spread of human immunodeficiency virus (HIV) and methods by which it may be controlled

Use the knowledge gained in this section in new situations or to solve related problems.

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The list below is intended as a guide to the more important quantities which might be encountered in teaching and learning. This list is not exhaustive.

Quantity	**Symbol**	**Unit**
length	l	mm, cm, m
area	A	cm^2, m^2
volume	V	cm^3, dm^3, m^3
mass	*m*	mg, g, kg
concentration	*c*	g/dm^3
time	*t*	ms, s, min
pH	pH	–
temperature	*T*	°C
energy	*E*	J

PRACTICAL GUIDELINES

Scientific subjects are, by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to support and facilitate the learning of this subject. A list of suggested practical work is provided below.

1. Preparation of specimens for observation under a light microscope

2. Investigation of the effects of osmosis on plant cells

3. Identification of nutrients (carbohydrates, proteins and fats) in given samples

4. Investigation of the effects of temperature and pH on enzyme action

5. Investigation of the factors affecting photosynthesis

6. Test for the presence of carbon dioxide released during respiration

This is not intended to be an exhaustive list. Reference may be made to the techniques used in these experiments in the theory papers but no detailed description of the experimental procedures will be required.

GLOSSARY OF TERMS USED IN SCIENCE PAPERS

It is hoped that the glossary (which is relevant only to science papers) will prove helpful to candidates as a guide, i.e. 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. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

2. *Classify* requires candidates to group things based on common characteristics.

3. *Comment* is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.

4. *Compare* requires candidates to provide both similarities and differences between things or concepts.

5. *Construct* is often used in relation to chemical equations where a candidate is expected to write a balanced equation, not by factual recall but by analogy or by using information in the question.

6. *Define (the term(s)…)* is intended literally. Only a formal statement or equivalent paraphrase being required.

7. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. In the latter instance the answer may often follow a standard pattern, e.g. Apparatus, Method, Measurement, Results and Precautions.

   In other contexts, describe and give an account of should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. *Describe* and *explain* may be coupled in a similar way to *state* and *explain*.

8. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula.

9. *Discuss* requires candidates to give a critical account of the points involved in the topic.

10. *Estimate* implies a reasoned order magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about the points of principle and about values of quantities not otherwise included in the question.

11. *Explain* may imply reasoning or some reference to theory, depending on the context.

12. *Find* is a general term that may be variously interpreted as calculate, measure, determine, etc.

13. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points are specified, this should not be exceeded.

14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

15. *Outline* implies brevity, i.e. restricting the answer to giving essentials.

16. *Predict* or *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. Such information may be wholly given in the question or may depend on answers extracted from an earlier part of the question. *Predict* also implies a concise answer with no supporting statement required.

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 the intercept, asymptote or discontinuity at a particular value.

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

18. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.

19. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer, or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.

20. *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 light of the indicated mark value.

SPECIAL NOTE

Nomenclature
Candidates will be expected to be familiar with the nomenclature used in the syllabus. The proposals in '*Signs, Symbols and Systematics*' (The Association for Science Education Companion to 16-19 Science, 2000) and the recommendations on terms, units and symbols in 'Biological Nomenclature 4th Edition (2009)' published by the Institute of Biology, in conjunction with the ASE, will generally be adopted although the traditional names sulfate, sulfite, nitrate, nitrite, sulfurous and nitrous acids will be used in question papers. Sulfur (and all compounds of sulfur) will be spelt with f (not with ph) in question papers, however candidates can use either spelling in their answers.

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

In chemistry, full *structural formulae* (*displayed formulae*) in answers should show in detail both the relative placing of atoms and the number of bonds between atoms. Hence, $–CONH_2$ and $–CO_2H$ are not satisfactory as full structural formulae, although either of the usual symbols for the benzene ring is acceptable.

Units, significant figures
Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

Calculators
An approved calculator may be used in all papers.