Singapore Examinations and Assessment Board

Cambridge Assessment International Education

Singapore–Cambridge General Certificate of Education Advanced Level Higher 1 (2025)

Physics
(Syllabus 8867)

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INTRODUCTION

The syllabus has been designed to build on and extend the content coverage at O-Level. Candidates will be assumed to have knowledge and understanding of Physics at O-Level, either as a single subject or as part of a balanced science course.

AIMS

The aims of a course based on this syllabus should be to:

1. provide students with an experience that develops their interest in physics and builds the knowledge, skills and attitudes necessary for them to become scientifically literate citizens who are well-prepared for the challenges of the 21st century.

2. develop in students the understanding, skills, ethics and attitudes relevant to the *Practices of Science,* including the following:

   2.1 understanding the nature of scientific knowledge

   2.2 demonstrating science inquiry skills

   2.3 relating science and society

3. develop in students an understanding that a small number of basic principles and core ideas can be applied to explain, analyse and solve problems in a variety of systems in the physical world.

PRACTICES OF SCIENCE

Science as a discipline is more than the acquisition of a body of knowledge (e.g. scientific facts, concepts, laws, and theories) it is a way of knowing and doing. It includes an understanding of the nature of scientific knowledge and how this knowledge is generated, established and communicated. Scientists rely on a set of established procedures and practices associated with scientific inquiry to gather evidence and test their ideas on how the natural world works. However, there is no single method and the real process of science is often complex and iterative, following many different paths. While science is powerful, generating knowledge that forms the basis for many technological feats and innovations, it has limitations.

The Practices of Science are explicitly articulated in this syllabus to allow teachers to embed them as learning objectives in their lessons. Students' understanding of the nature and the limitations of science and scientific inquiry are developed effectively when the practices are taught in the context of relevant science content. Attitudes relevant to science such as *inquisitiveness*, *concern for accuracy* and *precision*, *objectivity*, *integrity* and *perseverance* should be emphasised in the teaching of these practices where appropriate. For example, students learning science should be introduced to the use of technology as an aid in practical work or as a tool for the interpretation of experimental and theoretical results.

The Practices of Science comprise three components:

1. Understanding the Nature of Scientific Knowledge

1.1 Understand that science is an evidence-based, model-building enterprise concerned with the natural world

1.2 Understand that the use of both logic and creativity is required in the generation of scientific knowledge

1.3 Recognise that scientific knowledge is generated from consensus within the community of scientists through a process of critical debate and peer review

1.4 Understand that scientific knowledge is reliable and durable, yet subject to revision in the light of new evidence

2. Demonstrating Science Inquiry Skills

2.1. Identify scientific problems, observe phenomena and pose scientific questions/hypotheses

2.2 Plan and conduct investigations by selecting appropriate experimental procedures, apparatus and materials, with due regard for accuracy, precision and safety

2.3 Obtain, organise and represent data in an appropriate manner

2.4 Analyse and interpret data

2.5 Construct explanations based on evidence and justify these explanations through reasoning and logical argument

2.6 Use appropriate models[1] to explain concepts, solve problems and make predictions

2.7 Make decisions based on evaluation of evidence, processes, claims and conclusions

2.8 Communicate scientific findings and information using appropriate language and terminology

3. Relating Science and Society

3.1. Recognise that the application of scientific knowledge to problem solving could be influenced by other considerations such as economic, social, environmental and ethical factors

3.2 Demonstrate an understanding of the benefits and risks associated with the application of science to society

3.3 Use scientific principles and reasoning to understand, analyse and evaluate real-world systems as well as to generate solutions for problem solving

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[1] *A model is a representation of an idea, an object, a process or a system that is used to describe and explain phenomena that cannot be experienced directly. Models exist in different forms from the concrete, such as physical, scale models to abstract representations, such as diagrams or mathematical expressions. The use of models involves the understanding that all models contain approximations and assumptions limiting their validity and predictive power.*

CORE IDEAS IN PHYSICS

- Physics encompasses the study of systems spanning a wide scale of distances and times: from 10^{-15} m (e.g. sub-atomic particles) to larger than 10^{30} m (e.g. galaxies), from near-instantaneous events such as current flow with a flick of a switch to slow-evolving phenomenon such as the birth and death of a star.
- A small number of basic principles and laws can be applied in the study and interpretation of this wide variety of simple and complex systems. Similarly, a few core ideas that cut across traditional content boundaries can be introduced in the curriculum to provide students with a broader way of thinking about the physical world.
- These *Core Ideas* are fundamental in the study of physics and help students integrate knowledge and link concepts across different topics. They provide powerful analytical tools which can explain phenomena and solve problems.

1. Systems and Interactions

1.1. Defining the *systems* under study (by specifying their *boundaries* and making explicit a *models* of the systems) provides tools for understanding and testing ideas that are applicable throughout physics.

1.2. *Objects* can be treated as having no *internal structure* or an internal structure that can be ignored. A *system*, on the other hand, is a collection of objects with an internal structure which may need to be taken into account.

1.3. Physical events and phenomena can be understood by studying the *interactions* between objects in a system and with the environment.

1.4. Students should be able to identify *causal relationships* when analysing interactions and *changes* in a system.

1.5. Interactions between objects in a system can be modelled using *forces* (e.g. a system of forces being applied to move a mass; a system of two masses colliding; a system of the moon orbiting around the earth; a system of electrical charges; a system of current in a straight wire placed in a magnetic field).

1.6. Fields existing in space are used to explain interactions between objects that are not in contact. Forces at a distance are explained by fields that can transfer *energy* and can be described in terms of the arrangement and properties of the interacting objects. These forces can be used to describe the relationship between electrical and magnetic fields.

1.7. *Equilibrium* is a unique state where the relevant physical properties of a system are balanced (e.g. equilibrium in a single particle arises if there is no resultant force acting on it, a rigid body is considered to be in equilibrium if, in addition, there is no resultant moment about any point).

1.8. Simplified *microscopic* models can explain *macroscopic* properties observed in systems with complex and random interactions between a large number of objects:

1.8.1. Microscopic models are applied in the study of electricity. Macroscopic properties (e.g. current) are used to investigate interactions and changes in these systems.

1.8.2. These macroscopic properties can be linked to complex interactions at the microscopic level, for example: the half-life of unstable nuclei decaying randomly.

1.8.3. Such complex systems may also be better characterised by *statistical averages* (e.g. half life) as these quantities may be more meaningful than the properties and behaviours of individual components (e.g. which unstable nuclei is decaying and when).

2. Models and Representations

2.1. *Models* use reasonable *approximations* to simplify real-world phenomena in order to arrive at useful ways to explain or analyse systems.

2.2. The awareness of the approximations used in a proposed model allows one to estimate the *validity* and *reliability* of that model.

2.3. Models are tested through observations and experiments and should be *consistent with available evidence*; models can evolve and be refined in the light of new evidence.

2.4. The assumptions made in defining a system will determine how interactions are described and analysed. Understanding the limits of these assumptions is a fundamental aspect of modelling.

2.5. The use of *representations* is inherent in the process of constructing a model. Examples of representations are pictures, motion diagrams, graphs, energy bar charts and mathematical equations.

2.6. Mathematics is an important tool in physics. It is used as a *language* to describe the relationships between different physical quantities and to solve numerical problems.

2.7. Representations and models help in analysing phenomena, solving problems, making predictions and communicating ideas.

3. Conservation Laws

3.1. *Conservation laws* are fundamental among the principles in physics used to understand the physical world.

3.2. When analysing physical events or phenomena, the choice of system and associated conservation laws provides a powerful set of tools to use to predict the possible outcome of an interaction.

3.3. Conservation laws *constrain* the possible behaviours of objects in a system, or the outcome of an interaction or process.

3.4. Associated with every conservation law in classical physics is a physical quantity, a scalar or a vector, which characterises a system.

3.5. In a *closed* system, the associated physical quantity has a constant value independent of interactions between objects in the system. In an *open* system, the changes of the associated physical quantity are always equal to the transfer of that quantity to or from the system by interactions with other systems.

3.6. In physics, charge, momentum, mass-energy and angular momentum are conserved.

3.7. Examples of how conservation laws are used in our syllabus:

3.7.1. conservation of momentum in collisions and explosions allowing prediction of subsequent motion of the objects or particles.

3.7.2. conservation of energy to calculate change in total energy in systems that are open to energy transfer due to external forces (work is done).

3.7.3. conservation of mass-energy, charge and nucleon number in nuclear reactions to enable the calculation of relevant binding energies and identification of the resulting nuclides.

CURRICULUM FRAMEWORK

The *Practices of Science, Core Ideas* in physics and *Learning Experiences* are put together in a framework (**Fig. 1**) to guide the development of the H1 Physics curriculum.

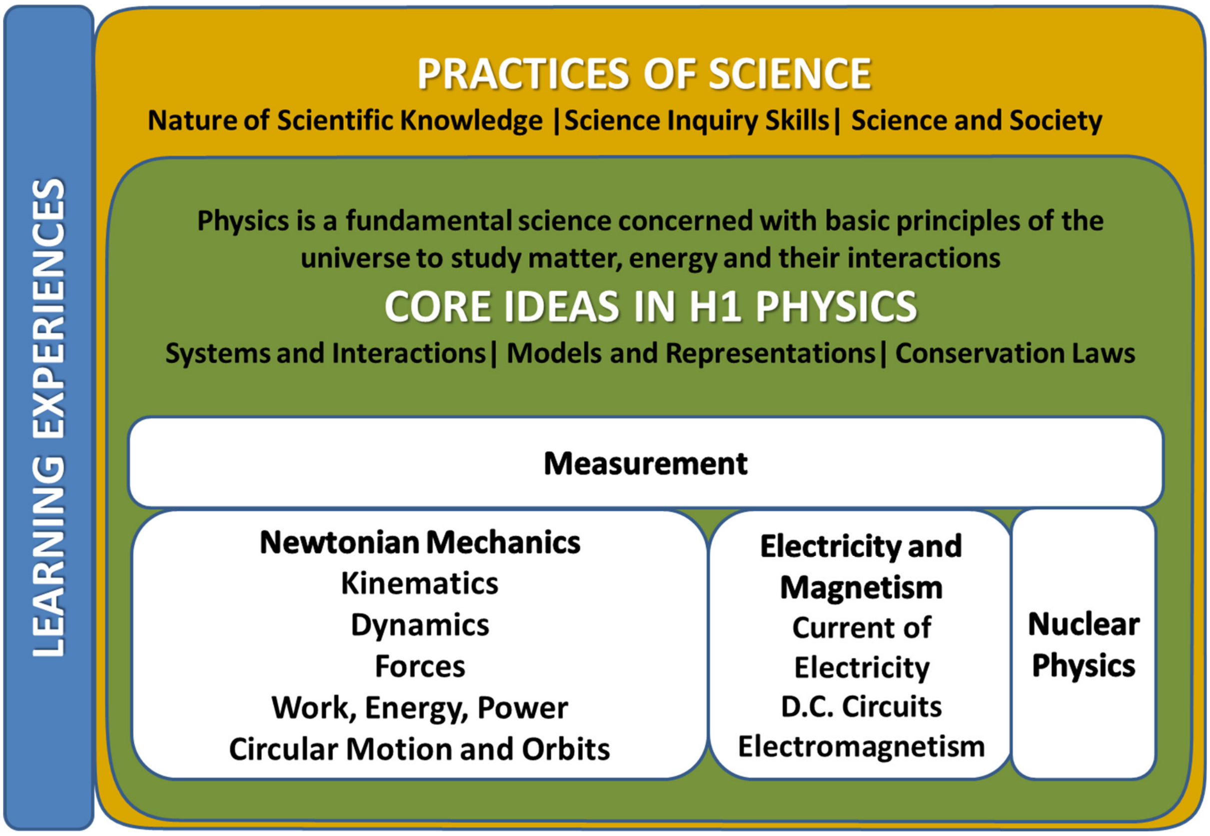

Fig. 1: H1 Physics Curriculum Framework

The *Practices of Science* are common to the natural sciences of physics, chemistry and biology. These practices highlight the ways of thinking and doing that are inherent in the scientific approach, with the aim of equipping students with the understanding, skills, and attitudes shared by the scientific disciplines, including an appropriate approach to ethical issues. The *Core Ideas* help students to integrate knowledge and link concepts across different topics, and highlight important themes that recur throughout the curriculum. The syllabus content is organised into sections according to the main branches and knowledge areas of physics, i.e. *Newtonian Mechanics*, *Electricity and Magnetism*, and *Nuclear Physics* to allow for a focused, systematic and in-depth treatment of topics within each section.

The *Learning Experiences*[2] refer to a range of learning opportunities selected by teachers to link the physics content with the *Core Ideas* and the *Practices of Science* to enhance students' learning of the concepts. Rather than being mandatory, teachers are encouraged to incorporate *Learning Experiences* that match the interests and abilities of their students and provide opportunities to illustrate and exemplify the *Practices of Science*, where appropriate. Real-world contexts can help illustrate the concepts in physics and their applications. Experimental activities and ICT tools can also be used to build students' understanding.

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[2] The *Learning Experiences* can be found in the Teaching and Learning Syllabus.

ASSESSMENT OBJECTIVES

The assessment objectives listed below reflect those parts of the *aims* and *Practices of Science* that will be assessed in the examination.

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)
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 syllabus 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* or *explain*. (See the glossary of terms).

B *Handling, applying and evaluating information*

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. handle information, distinguishing the relevant from the extraneous
3. manipulate numerical and other data and translate information from one form to another
4. use information to identify patterns, report trends, draw inferences and report conclusions
5. present reasoned explanations for phenomena, patterns and relationships
6. make predictions and put forward hypotheses
7. apply knowledge, including principles, to novel situations
8. bring together knowledge, principles and concepts from different areas of physics, and apply them in a particular context
9. evaluate information and hypotheses
10. demonstrate an awareness of the limitations of physical theories and models.

These assessment objectives cannot be precisely specified in the syllabus content because questions testing such skills may be based on information that 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, reasoned or deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: *predict*, *suggest*, *deduce*, *calculate* or *determine*. (See the glossary of terms)

SCHEME OF ASSESSMENT

All candidates are required to enter for Papers 1 and 2.

Paper	Type of Paper	Duration	Marks	Weighting (%)
1	**Multiple Choice**	1 h	30	33
2	**Structured Questions**	2 h	80	67

Paper 1 (1 h, 30 marks)

This paper will consist of 30 multiple-choice questions. All questions will be of the direct choice type with 4 options.

Paper 2 (2 h, 80 marks)

This paper will consist of 2 sections. All answers will be written in spaces provided on the Question Paper.

Section A (60 marks)
This section will consist of a variable number of structured questions including one or two data-based questions, all compulsory. The data-based question(s) will constitute 15–20 marks.

Section B (20 marks)
This section will consist of two 20-mark questions of which candidates will answer one. The questions will require candidates to integrate knowledge and understanding from different areas of the syllabus.

Weighting of Assessment Objectives

Assessment Objectives		Weighting (%)	Assessment Components
A	**Knowledge with understanding**	40	Papers 1, 2
B	**Handling, applying and evaluating information**	60	Papers 1, 2

ADDITIONAL INFORMATION

Mathematical Requirements

The mathematical requirements are given on pages 20 and 21.

Data and Formulae

Data and Formulae, as printed on page 26, will appear as page 2 in *Papers 1* and *2.*

Symbols, Signs and Abbreviations

Symbols, signs and abbreviations used in examination papers will follow the recommendations made in the Association for Science Education publication Signs, Symbols and Systematics (The ASE Companion to 16–19 Science, 2000). The units kWh, atmosphere, eV and unified atomic mass unit (u) may be used in examination papers without further explanation.

Geometrical Instruments

Candidates should have geometrical instruments with them for Paper 1 and Paper 2.

Disallowed Subject Combinations

Candidates may not simultaneously offer Physics at H1 and H2 levels.

SUBJECT CONTENT

SECTION I MEASUREMENT

1 Measurement

Content

- Physical quantities and SI units
- Scalars and vectors
- Errors and uncertainties

Learning Outcomes
Candidates should be able to:

(a) recall the following base quantities and their SI units: mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol)

(b) state that one mole of any substance contains 6.02×10^{23} particles and use the Avogadro number $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

(c) express derived units as products or quotients of the base units and use the named units listed in 'Summary of Key Quantities, Symbols and Units' as appropriate

(d) use SI base units to check the homogeneity of physical equations

(e) show an understanding of and use the conventions for labelling graph axes and table columns as set out in the ASE publication *Signs, Symbols and Systematics (The ASE Companion to 16–19 Science, 2000)*

(f) use the following prefixes and their symbols to indicate decimal sub-multiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)

(g) make reasonable estimates of physical quantities included within the syllabus

(h) distinguish between scalar and vector quantities, and give examples of each

(i) add and subtract coplanar vectors

(j) represent a vector as two perpendicular components

(k) show an understanding of the distinction between systematic errors (including zero error) and random errors

(l) show an understanding of the distinction between precision and accuracy

(m) assess the uncertainty in a derived quantity by addition of actual, fractional, percentage uncertainties or by numerical substitution (a rigorous statistical treatment is not required).

SECTION II NEWTONIAN MECHANICS

2 Kinematics

Content

- Rectilinear motion
- Non-linear motion

Learning Outcomes

Candidates should be able to:

(a) show an understanding of and use the terms distance, displacement, speed, velocity and acceleration

(b) use graphical methods to represent distance, displacement, speed, velocity and acceleration

(c) identify and use the physical quantities from the gradients of displacement-time graphs and areas under and gradients of velocity-time graphs, including cases of non-uniform acceleration

(d) derive, from the definitions of velocity and acceleration, equations which represent uniformly accelerated motion in a straight line

(e) solve problems using equations which represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitational field without air resistance

(f) describe qualitatively the motion of bodies falling in a uniform gravitational field with air resistance

(g) describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction.

3 Dynamics

Content

- Newton's laws of motion
- Linear momentum and its conservation

Learning Outcomes

Candidates should be able to:

(a) state and apply each of Newton's laws of motion

(b) show an understanding that mass is the property of a body which resists change in motion (inertia)

(c) describe and use the concept of weight as the force experienced by a mass in a gravitational field

(d) define and use linear momentum as the product of mass and velocity

(e) define and use impulse as the product of force and time of impact

(f) relate resultant force to the rate of change of momentum

(g) recall and solve problems using the relationship $F = ma$, appreciating that resultant force and acceleration are always in the same direction

(h) state the principle of conservation of momentum

(i) apply the principle of conservation of momentum to solve simple problems including inelastic and (perfectly) elastic interactions between two bodies in one dimension (Knowledge of the concept of coefficient of restitution is not required)

(j) show an understanding that, for a (perfectly) elastic collision between two bodies, the relative speed of approach is equal to the relative speed of separation

(k) show an understanding that, whilst the momentum of a closed system is always conserved in interactions between bodies, some change in kinetic energy usually takes place.

4 Forces

Content

- Types of force
- Centre of gravity
- Turning effects of forces
- Equilibrium of forces

Learning Outcomes

Candidates should be able to:

(a) recall and apply Hooke's law ($F = kx$, where k is the force constant) to new situations or to solve related problems

(b) describe the forces on a mass, charge and current-carrying conductor in gravitational, electric and magnetic fields, as appropriate

(c) show a qualitative understanding of normal contact forces, frictional forces and viscous forces including air resistance (No treatment of the coefficients of friction and viscosity is required)

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

(e) define and apply the moment of a force and the torque of a couple

(f) show an understanding that a couple is a pair of forces which tends to produce rotation only

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

(h) show an understanding that, when there is no resultant force and no resultant torque, a system is in equilibrium

(i) use a vector triangle to represent forces in equilibrium.

5 Work, Energy and Power

Content

- Work
- Energy conversion and conservation
- Efficiency
- Potential energy and kinetic energy
- Power

Learning Outcomes

Candidates should be able to:

(a) define and use work done by a force as the product of the force and displacement in the direction of the force

(b) calculate the work done in a number of situations

(c) give examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation

(d) show an appreciation for the implications of energy losses in practical devices and use the concept of efficiency to solve problems

(e) derive, from the equations for uniformly accelerated motion in a straight line, the equation $E_k = \frac{1}{2}mv^2$

(f) recall and use the equation $E_k = \frac{1}{2}mv^2$

(g) distinguish between gravitational potential energy, electric potential energy and elastic potential energy

(h) deduce that the elastic potential energy in a deformed material is related to the area under the force-extension graph

(i) show an understanding of and use the relationship between force and potential energy in a uniform field to solve problems

(j) derive, from the definition of work done by a force, the equation $E_p = mgh$ for gravitational potential energy changes near the Earth's surface

(k) recall and use the equation $E_p = mgh$ for gravitational potential energy changes near the Earth's surface

(l) define power as work done per unit time and derive power as the product of a force and velocity in the direction of the force.

6 Motion in a Circle and Orbits

Content

- Kinematics of uniform circular motion
- Centripetal acceleration
- Centripetal force
- Gravitational force between point masses
- Circular orbits

Learning Outcomes

Candidates should be able to:

(a) express angular displacement in radians

(b) show an understanding of and use the concept of angular velocity to solve problems

(c) recall and use $v = r\omega$ to solve problems

(d) describe qualitatively motion in a curved path due to a perpendicular force, and understand the centripetal acceleration in the case of uniform motion in a circle

(e) recall and use centripetal acceleration $a = r\omega^2$, and $a = v^2/r$ to solve problems

(f) recall and use centripetal force $F = mr\omega^2$, and $F = mv^2/r$ to solve problems

(g) recall and use Newton's law of gravitation in the form $F = \frac{Gm_1m_2}{r^2}$

(h) analyse circular orbits in inverse square law fields by relating the gravitational force to the centripetal acceleration it causes

(i) show an understanding of geostationary orbits and their application.

SECTION III ELECTRICITY AND MAGNETISM

7 Current of Electricity

Content

- Electric current
- Potential difference
- Resistance and resistivity
- Electromotive force

Learning Outcomes

Candidates should be able to:

(a) show an understanding that electric current is the rate of flow of charge

(b) recall and solve problems using the equation $Q = It$

(c) recall and solve problems using the equation $V = W/Q$

(d) recall and solve problems using the equations $P = VI$, $P = I^2R$ and $P = V^2/R$

(e) define the resistance of a circuit component as the ratio of the potential difference across the component to the current passing through it, and solve problems using the equation $V = IR$

(f) sketch and explain the I–V characteristics of various electrical components such as an ohmic resistor, a semiconductor diode, a filament lamp and a negative temperature coefficient (NTC) thermistor

(g) sketch the resistance-temperature characteristic of an NTC thermistor

(h) recall and solve problems using the equation $R = \rho l/A$

(i) distinguish between electromotive force (e.m.f.) and potential difference (p.d.) using energy considerations

(j) show an understanding of the effects of the internal resistance of a source of e.m.f. on the terminal potential difference and output power.

8 D.C. Circuits

Content

- Circuit symbols and diagrams
- Series and parallel arrangements
- Potential divider

Learning Outcomes

Candidates should be able to:

(a) recall and use appropriate circuit symbols as set out in the ASE publication *Signs, Symbols and Systematics (The ASE Companion to 16–19 Science, 2000)*

(b) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus

(c) solve problems using the formula for the combined resistance of two or more resistors in series

(d) solve problems using the formula for the combined resistance of two or more resistors in parallel

(e) solve problems involving series and parallel circuits for one source of e.m.f.

(f) show an understanding of the use of a potential divider circuit as a source of variable p.d.

(g) explain the use of thermistors and light-dependent resistors in potential divider circuits to provide a potential difference which is dependent on temperature and illumination respectively.

9 Electromagnetism

Content

- Concept of an electric field
- Concept of a magnetic field
- Magnetic fields due to currents
- Force on a current-carrying conductor
- Force between current-carrying conductors
- Force on a charge

Learning Outcomes

Candidates should be able to:

(a) show an understanding of the concept of an electric field as an example of a field of force and define electric field strength at a point as the electric force exerted per unit positive charge placed at that point

(b) represent an electric field by means of field lines

(c) show an understanding that a magnetic field is an example of a field of force produced either by current-carrying conductors or by permanent magnets

(d) sketch flux patterns due to currents in a long straight wire, a flat circular coil and a long solenoid

(e) show an understanding that the magnetic field due to a solenoid may be influenced by the presence of a ferrous core

(f) show an understanding that a current-carrying conductor placed in a magnetic field might experience a force

(g) recall and solve problems using the equation $F = BIl\sin\theta$, with directions as interpreted by Fleming's left-hand rule

(h) define magnetic flux density

(i) show an understanding of how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field using a current balance

(j) explain the forces between current-carrying conductors and predict the direction of the forces

(k) predict the direction of the force on a charge moving in a magnetic field

(l) recall and solve problems using the equation $F = BQv \sin \theta$

(m) calculate the forces on charges in uniform electric fields using the equation $F = Eq$

(n) describe the effect of a uniform electric field on the motion of charged particles.

SECTION IV NUCLEAR PHYSICS

10 Nuclear Physics

Content

- The nucleus
- Isotopes
- Nuclear processes
- Mass defect and nuclear binding energy
- Radioactive decay
- Biological effects of radiation

Learning Outcomes

Candidates should be able to:

(a) infer from the results of the Rutherford α-particle scattering experiment the existence and small size of the atomic nucleus

(b) distinguish between nucleon number (mass number) and proton number (atomic number)

(c) show an understanding that an element can exist in various isotopic forms each with a different number of neutrons in the nucleus

(d) use the usual notation for the representation of nuclides and represent simple nuclear reactions by nuclear equations of the form ${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$

(e) state and apply to problem solving the concept that nucleon number, charge and mass-energy are all conserved in nuclear processes

(f) show an understanding of the concept of mass defect

(g) recall and apply the equivalence between energy and mass as represented by $E = mc^2$ to solve problems

(h) show an understanding of the concept of nuclear binding energy and its relation to mass defect

(i) sketch the variation of binding energy per nucleon with nucleon number

(j) explain the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission

(k) show an understanding of the spontaneous and random nature of nuclear decay, and use the term activity

(l) infer the random nature of radioactive decay from the fluctuations in count rate

(m) show an understanding of the origin and significance of background radiation

(n) show an understanding of the nature of α, β and γ

(o) define half-life as the time taken for a quantity x to reduce to half its initial value and use the term to solve problems which might involve information in tables or decay curves

(p) discuss qualitatively the effects, both direct and indirect, of ionising radiation on living tissues and cells.

MATHEMATICAL REQUIREMENTS

Arithmetic

Candidates should be able to:

(a) recognise and use expressions in decimal and standard form (scientific) notation

(b) use appropriate calculating aids (electronic calculator or tables) for addition, subtraction, multiplication and division. Find arithmetic means, powers (including reciprocals and square roots), sines, cosines, tangents (and the inverse functions), exponentials and logarithms (lg and ln)

(c) take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified

(d) make approximate evaluations of numerical expressions (e.g. $\pi^2 \approx 10$) and use such approximations to check the magnitude of machine calculations

Algebra

Candidates should be able to:

(a) change the subject of an equation. Most relevant equations involve only the simpler operations but may include positive and negative indices and square roots

(b) solve simple algebraic equations. Most relevant equations are linear but some may involve inverse and inverse square relationships. Linear simultaneous equations and the use of the formula to obtain the solutions of quadratic equations are included

(c) substitute physical quantities into physical equations using consistent units and check the dimensional consistency of such equations

(d) formulate simple algebraic equations as mathematical models of physical situations, and identify inadequacies of such models

(e) recognise and use the logarithmic forms of expressions like ab, a/b, x^n, e^{kx}; understand the use of logarithms in relation to quantities with values that range over several orders of magnitude

(f) manipulate and solve equations involving logarithmic and exponential functions

(g) express small changes or errors as percentages and *vice versa*

(h) comprehend and use the symbols $<$, $>$, «, », $\approx$, $/$, $\propto$, $\langle x \rangle$ ($= \overline{x}$), Σ, Δx, δx, $\surd$

Geometry and trigonometry

Candidates should be able to:

(a) calculate areas of right-angled and isosceles triangles, circumference and area of circles, areas and volumes of rectangular blocks, cylinders and spheres

(b) use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle

(c) use sines, cosines and tangents (especially for 0°, 30°, 45°, 60°, 90°). Use the trigonometric relationships for triangles:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}; \; a^2 = b^2 + c^2 - 2bc\cos A$$

(d) use $\sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$ for small θ; $\sin^2\theta + \cos^2\theta = 1$

(e) understand the relationship between degrees and radians (defined as arc/radius), translate from one to the other and use the appropriate system in context.

Vectors

Candidates should be able to:

(a) find the resultant of two coplanar vectors, recognising situations where vector addition is appropriate

(b) obtain expressions for components of a vector in perpendicular directions, recognising situations where vector resolution is appropriate.

Graphs

Candidates should be able to:

(a) translate information between graphical, numerical, algebraic and verbal forms

(b) select appropriate variables and scales for graph plotting

(c) for linear graphs, determine the slope, intercept and intersection

(d) choose, by inspection, a straight line which will serve as the line of best fit through a set of data points presented graphically

(e) recall standard linear form $y = mx + c$ and rearrange relationships into linear form where appropriate

(f) sketch and recognise the forms of plots of common simple expressions like $1/x$, x^2, $1/x^2$, $\sin x$, $\cos x$, e^{-x}

(g) use logarithmic plots to test exponential and power law variations

(h) understand, draw and use the slope of a tangent to a curve as a means to obtain the gradient, and use notation in the form dy/dx for a rate of change

(i) understand and use the area below a curve where the area has physical significance.

Any calculator used must be on the Singapore Examinations and Assessment Board list of approved calculators.

Boohan, R (2016). The Language of Mathematics in Science: A Guide for Teachers of 11–16 Science (Association for Science Education). ISBN 9780863574559 www.ase.org.uk/mathsinscience

GLOSSARY OF TERMS USED IN PHYSICS PAPERS

It is hoped that the glossary will prove helpful to candidates as a guide, although it is not exhaustive. 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. They should also note that the number of marks allocated for any part of a question is a guide to the depth of treatment required for the answer.

1. *Define (the term(s) ...)* is intended literally. Only a formal statement or equivalent paraphrase, such as the defining equation with symbols identified, being required.

2. *What is meant by ...* 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. *Explain* may imply reasoning or some reference to theory, depending on the context.

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

5. *List* requires a number of points with no elaboration. Where a given number of points is specified, this should not be exceeded.

6. *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. The amount of description intended should be interpreted in the light of the indicated mark value.

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

8. *Deduce/Predict* implies that candidates are not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question.

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

10. *Calculate* is used when a numerical answer is required. In general, working should be shown.

11. *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.

12. *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.

13. *Show* is used when an algebraic deduction has to be made to prove a given equation. It is important that the terms being used by candidates are stated explicitly.

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

15. *Sketch,* when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct. However, 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, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates clearly indicate what is being plotted on each axis.

16. *Sketch,* when applied to diagrams, implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important details.

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

TEXTBOOKS

Teachers may find reference to the following books helpful.

Practice in Physics (4th Edition), by Akrill et al, published by Hodder Education, ISBN 1-444-12125-1

New Understanding Physics for Advanced Level (4th Edition), by J Breithaupt, published by Nelson Thornes, ISBN 0-748-74314-6

Advanced Physics (5th Edition), by T Duncan, published by Hodder Education, ISBN 0-719-57669-5

Physics for Scientists and Engineers with Modern Physics (9th Edition), by R Serway and J Jewett, published by Brooks/Cole, ISBN 1-133-95399-9

Fundamental of Physics (10th Edition), by R Resnick, D Halliday and J Walker, published by Wiley, ISBN 1-118-23071-X

Physics: Principles with Applications (7th Edition), by D C Giancoli, published by Addison-Wesley, ISBN 0-321-62592-2

College Physics, by P P Urone, published by Brooks/Cole, ISBN 0-534-37688-6

AS/A Level Physics – Essential Word Dictionary by Mike Crundell, ISBN: 0860033775

Advanced Physics by Steve Adams and Jonathan Allday, Oxford University Press, ISBN: 978-0-19-914680-2

Cambridge International AS and A Level Physics Coursebook by Sang, Janoes, Woodside and Chandha, Cambridge University Press, ISBN: 9781107697690

Teachers are encouraged to choose texts for class use that they feel will be of interest to their students and will support their own teaching style.

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The following list illustrates the symbols and units that will be used in question papers.

Quantity	***Usual symbols***	***Usual unit***
Base Quantities		
mass	m	kg
length	l	m
time	t	s
electric current	I	A
thermodynamic temperature	T	K
amount of substance	n	mol
Other Quantities		
distance	d	m
displacement	s, x	m
area	A	m^2
volume	V, v	m^3
density	ρ	$kg\,m^{-3}$
speed	u, v, w, c	$m\,s^{-1}$
velocity	u, v, w, c	$m\,s^{-1}$
acceleration	a	$m\,s^{-2}$
acceleration of free fall	g	$m\,s^{-2}$
force	F	N
weight	W	N
momentum	p	N s
work	w, W	J
energy	E,U,W	J
potential energy	E_p	J
kinetic energy	E_k	J
power	P	W
pressure	p	Pa
torque	T	N m
gravitational constant	G	$N\,kg^{-2}\,m^2$
gravitational field strength	g	$N\,kg^{-1}$
angle	θ	°, rad
angular displacement	θ	°, rad
angular speed	ω	$rad\,s^{-1}$
angular velocity	ω	$rad\,s^{-1}$
period	T	s
frequency	f	Hz
angular frequency	ω	$rad\,s^{-1}$
speed of electromagnetic waves	c	$m\,s^{-1}$
electric charge	Q	C
elementary charge	e	C
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
resistance	R	Ω
resistivity	ρ	Ω m
electric field strength	E	$N\,C^{-1}$, $V\,m^{-1}$
magnetic flux	Φ	Wb
magnetic flux density	B	T
force constant	k	$N\,m^{-1}$
Celsius temperature	θ	°C
Avogadro constant	N_A	mol^{-1}
number	N, n, m	
activity of radioactive source	A	Bq

Quantity	***Usual symbols***	***Usual unit***
half-life	$t_{1/2}$	s
relative atomic mass	A_r	
relative molecular mass	M_r	
atomic mass	m_a	kg, u
electron mass	m_e	kg, u
neutron mass	m_n	kg, u
proton mass	m_p	kg, u
molar mass	M	kg
proton number	Z	
nucleon number	A	
neutron number	N	

DATA AND FORMULAE

Data

speed of light in free space $c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$

elementary charge $e = 1.60 \times 10^{-19}\ \mathrm{C}$

unified atomic mass constant $u = 1.66 \times 10^{-27}\ \mathrm{kg}$

rest mass of electron $m_\mathrm{e} = 9.11 \times 10^{-31}\ \mathrm{kg}$

rest mass of proton $m_\mathrm{p} = 1.67 \times 10^{-27}\ \mathrm{kg}$

the Avogadro constant $N_\mathrm{A} = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$

gravitational constant $G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$

acceleration of free fall $g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion $s = ut + \frac{1}{2}at^{2}$

$v^{2} = u^{2} + 2as$

resistors in series $R = R_1 + R_2 + \ldots$

resistors in parallel $1/R = 1/R_1 + 1/R_2 + \ldots$