PHYSICS
Ordinary Level
(Syllabus 5058)

CONTENTS

NOTES

Nomenclature

The proposals in 'Signs, Symbols and Systematics (The Association for Science Education Companion to 16-19 Science, 2000)' will generally be adopted.

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.

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

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

INTRODUCTION

The 'O' level physics syllabus provides candidates 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.

Candidates 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 that are very small, at the atomic and sub-atomic scales. It is at this atomic and sub-atomic scale 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 candidates will apply investigative and problem-solving skills, effectively communicate the theoretical concepts covered in this course and appreciate the contribution physics makes to our understanding of the physical world.

AIMS

These are not listed in order of priority.

The aims are to:

1. provide, through well-designed studies of experimental and practical Physics, a worthwhile educational experience for all candidates, 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 and stimulated for studies beyond Ordinary level in Physics, in applied sciences or in science-dependent vocational courses

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 concern for accuracy and precision
   - 3.2 objectivity
   - 3.3 integrity
   - 3.4 enquiry
   - 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 sciences 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 (IT) 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 16-19*', Association for Science Education, 2000)
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 those 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 propose 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, reasoned or 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.)

C Experimental Skills and Investigations

Candidates should be able to:

1. follow a sequence of instructions
2. use techniques, apparatus and materials
3. make and record observations, measurements and estimates
4. interpret and evaluate observations and experimental results
5. plan investigations, select techniques, apparatus and materials
6. evaluate methods and suggest possible improvements

Weighting of Assessment Objectives

Theory Papers (Papers 1 and 2)

A Knowledge with Understanding, approximately 55% of the marks with approximately 20% allocated to recall.

B Handling Information and Solving Problems, approximately 45% of the marks.

School-Based Science Practical Assessment (SPA) (Paper 3)

C Experimental Skills and Investigations, 100% of the marks.

SCHEME OF ASSESSMENT

Candidates are required to enter for Papers 1, 2 and 3.

Paper	Type of Paper	Duration	Marks	Weighting
1	Multiple Choice	1 hour	40	30%
2	Structured and Free Response	1 hour 45 minutes	80	50%
3	School-based Science Practical Assessment (SPA)	--	96	20%

Theory papers

Paper 1 (1 hour, 40 marks), consisting of 40 compulsory multiple choice items of the direct choice type.

Paper 2 (1 hour 45 minutes, 80 marks), consisting of two sections.

Section A will carry 50 marks and will consist of a variable number of compulsory structured questions.

Section B will carry 30 marks and will consist of three questions. The first two questions are compulsory questions, one of which will be a data-based question requiring candidates to interpret, evaluate or solve problems using a stem of information. This question will carry 8–12 marks. The last question will be presented in an either/or form and will carry 10 marks.

School-based Science Practical Assessment (SPA)

Paper 3 (96 marks)

The School-based Science Practical Assessment (SPA) will be conducted to assess appropriate aspects of objectives *C1* to *C6*. SPA will take place over an appropriate period that the candidates are offering the subject. The assessment of science practical skills is grouped into 3 skill sets:

Skill set 1 – Performing and Observing

Skill set 2 – Analysing

Skill set 3 – Planning

Each candidate is to be assessed only **twice** for each of skill sets 1 and 2 and only **once** for skill set 3.

Weighting and Marks Computation of the 3 Skill Sets

The overall level of performance of each skill set (skill sets 1, 2 and 3) is the sum total of the level of performance of each strand within the skill set.

The weighting and marks computation of the skill sets are as follows:

Skill Set	No. of Assessments (a)	Max Marks per Assessment (b)	Weight (c)	Sub-total ($a \times b \times c$)	Weighting
1	2	6	4	$2 \times 6 \times 4 = 48$	50%
2	2	4	3	$2 \times 4 \times 3 = 24$	25%
3	1	4	6	$1 \times 4 \times 6 = 24$	25%
Total Marks for SPA				96	

Please refer to the SPA Information Booklet for more detailed information on the conduct of SPA.

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. Temperature 11. Thermal Properties of Matter
IV. WAVES	12. General Wave Properties 13. Light 14. Electromagnetic Spectrum 15. Sound
V. ELECTRICITY AND MAGNETISM	16. Static Electricity 17. Current of Electricity 18. D.C. Circuits 19. Practical Electricity 20. Magnetism 21. Electromagnetism 22. Electromagnetic Induction

SUBJECT CONTENT

SECTION I: MEASUREMENT

Overview

In order to gain a better understanding of the physical world, scientists use a process of investigation commonly known 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 a mathematical structure to express relationships.

In this section, we examine how a small set of base physical quantities and units is used to describe 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), amount of substance (mol)

(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)

(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) add two vectors to determine a resultant by a graphical method

(g) 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

(h) 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 discovered the flaws in Aristotle's ideas of the motion of objects that dominated physics for about 2,000 years. Galileo's approach, which is now a standard procedure in physics, involved studying an idealised system in which complicating factors (like friction) are absent, and then transferring this understanding to a real physical process with its complexities and subtleties. But the greatest contribution to the development of mechanics is from arguably the greatest physicist of all time, Isaac Newton.

Newton's three laws of motion and his law of universal gravitation, developed in the seventeenth century, have been successfully applied to explain and predict motion of terrestrial as well as celestial objects. 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 examine important concepts in mechanics which include speed, velocity, acceleration, force, gravitational field and energy conversion and conservation. Analysis of the motion of an object is performed using free-body and vector diagrams, graphical analysis as well as mathematical formulae. Examples of the effects of forces introduced include the moment of a force and pressure. The law of conservation of energy and two important physical quantities, work and power, are introduced to study and explain the interactions between objects in a system.

2. Kinematics

Content

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

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

(j) describe the motion of bodies with constant weight falling with or without air resistance, including reference to terminal velocity

3. Dynamics

Content

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

Learning Outcomes:

Candidates should be able to:

(a) describe the effect of balanced and unbalanced forces on a body

(b) describe the ways in which a force may change the motion of a body

(c) identify forces acting on an object and draw free body diagram(s) representing the forces acting on the object (for cases involving forces acting in at most 2 dimensions)

(d) solve problems for a static point mass under the action of 3 forces for 2-dimensional cases (a graphical method would suffice)

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

(f) 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 the 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
- Pressure differences
- Pressure measurement

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

(c) describe and explain the transmission of pressure in hydraulic systems with particular reference to the hydraulic press

(d) recall and apply the relationship *pressure due to a liquid column = height of column* × *density of the liquid* × *gravitational field strength* to new situations or to solve related problems

(e) describe how the height of a liquid column may be used to measure the atmospheric pressure

(f) describe the use of a manometer in the measurement of pressure difference

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, elastic potential energy, gravitational potential energy, chemical potential energy and thermal energy are examples of different forms of energy

(b) state the principle of the conservation of energy

(c) apply the principle of the conservation of energy to new situations or to solve related problems

(d) 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)

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

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

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

SECTION III: THERMAL PHYSICS

Overview

Nearly all the energy we use come from the Sun. Solar energy provides an almost infinite source of heat which is essential for plants and animals. Early scientists thought of heat as some kind of invisible, massless fluid called "caloric" that flowed into objects when they are heated. This view, which endured for some time as it was adequate for explaining many thermodynamic phenomena, was eventually proven wrong by the famous Joule experiment. The results of this experiment showed that heat is a form of energy.

In this section, we examine how changes in temperature or state of matter are related to internal energy and heat (or more precisely, thermal energy transfer). The kinetic model of matter is used to explain and predict the physical properties and changes of matter in terms of the microscopic molecular interactions level. The different processes of thermal energy transfer are introduced, together with the thermal properties, such as specific heat capacity and latent heat, of matter.

8. Kinetic Model of Matter

Content

- States of matter
- Brownian motion
- 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) infer from Brownian motion experiments the evidence for the movement of molecules

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

(e) explain the pressure of a gas in terms of the motion of its molecules

(f) recall and explain the following relationships using the kinetic model (stating of the corresponding gas laws is not required):
  (i) a change in pressure of a fixed mass of gas at constant volume is caused by a change in temperature of the gas
  (ii) a change in volume occupied by a fixed mass of gas at constant pressure is caused by a change in temperature of the gas
  (iii) a change in pressure of a fixed mass of gas at constant temperature is caused by a change in volume of the gas

(g) use the relationships in (f) in related situations and to solve problems (a qualitative treatment would suffice)

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. Temperature

Content

- Principles of thermometry
- Thermocouple thermometers

Learning Outcomes:

Candidates should be able to:

(a) explain how a physical property which varies with temperature may be used to define temperature scales and state examples of such properties

(b) explain the need for fixed points and state what is meant by *ice point* and *steam point*

(c) discuss the action of a thermocouple thermometer, showing an understanding of its use for measuring high temperatures and temperatures which vary rapidly (knowledge of the Seebeck effect is not required)

11. Thermal Properties of Matter

Content

- Internal energy
- Specific heat capacity
- Melting, boiling and evaporation
- Specific latent heat

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) define the terms *heat capacity* and *specific heat capacity*

(c) recall and apply the relationship *thermal energy = mass* × *specific heat capacity* × *change in temperature* to new situations or to solve related problems

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

(e) explain the difference between boiling and evaporation

(f) define the terms *latent heat* and *specific latent heat*

(g) recall and apply the relationship *thermal energy = mass* × *specific latent heat* to new situations or to solve related problems

(h) explain latent heat in terms of molecular behaviour

(i) sketch and interpret a cooling curve

SECTION IV: WAVES

Overview

Waves are inherent in our everyday lives. How we hear, see and communicate is due to the way waves travel and transfer energy. Much of our understanding of wave phenomena has been accumulated over the centuries through the study of light (optics) and sound (acoustics).
In this section, we examine the nature of waves and wave propagation and its uses by studying the properties of light, electromagnetic waves and sound, and their applications in communication, home appliances, and medical and industrial use.

12. 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

13. Light

Content

- Reflection of light
- Refraction of light
- Thin lenses

Learning Outcomes:

Candidates should be able to:

(a) recall and use the terms for reflection, including *normal*, *angle of incidence* and *angle of reflection*

(b) state that, for reflection, the angle of incidence is equal to the angle of reflection and use this principle in constructions, measurements and calculations

(c) recall and use the terms for refraction, including *normal*, *angle of incidence* and *angle of refraction*

(d) recall and apply the relationship $\sin i / \sin r$ = constant to new situations or to solve related problems

(e) define *refractive index* of a medium in terms of the ratio of speed of light in vacuum and in the medium

(f) explain the terms *critical angle* and *total internal reflection*

(g) identify the main ideas in total internal reflection and apply them to the use of optical fibres in telecommunication and state the advantages of their use

(h) describe the action of a thin lens (both converging and diverging) on a beam of light

(i) define the term *focal length* for a converging lens

(j) draw ray diagrams to illustrate the formation of real and virtual images of an object by a thin converging lens

14. Electromagnetic Spectrum

Content

- Properties of electromagnetic waves
- Applications of electromagnetic waves
- Effects of electromagnetic waves on cells and tissue

Learning Outcomes:

Candidates should be able to:

(a) state that all electromagnetic waves are transverse waves that travel with the same speed in vacuo 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) radio waves (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)

(d) describe the effects of absorbing electromagnetic waves, e.g. heating, ionisation and damage to living cells and tissue

15. Sound

Content

- Sound waves
- Speed of sound
- Echo
- Ultrasound

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) describe a direct method for the determination of the speed of sound in air and make the necessary calculation

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

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

(g) define *ultrasound* and describe one use of ultrasound, e.g. quality control and pre-natal scanning

SECTION V: ELECTRICITY AND MAGNETISM

Overview

For a long time, electricity and magnetism were seen as independent phenomena. Then in 1820, Hans Christian Oersted announced that he had observed a compass needle being deflected by an electrical current in a nearby wire. The exact relationship between an electric current and the magnetic field it produced was deduced mainly through the work of Andre Marie Ampere. However, the final major discoveries in electromagnetism were made by two of the greatest names in physics, Michael Faraday and James Clerk Maxwell.

In this section, we examine the interaction and effects of electric charges; the relationship between current flow, resistance, potential difference, charge, energy and power in electrical circuits; effects of magnetism and applications of electromagnetism and electromagnetic induction. The concepts of electric and magnetic fields are introduced as regions of space in which electric charges and magnets experience a force respectively.

16. Static Electricity

Content

- Laws of electrostatics
- Principles of electrostatics
- Electric field
- Applications of electrostatics

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 unlike charges attract and like charges repel

(c) describe an electric field as a region in which an electric charge experiences a force

(d) draw the electric field of an isolated point charge and recall that the direction of the field lines gives the direction of the force acting on a positive test charge

(e) draw the electric field pattern between 2 isolated point charges

(f) show understanding that electrostatic charging by rubbing involves a transfer of electrons

(g) describe experiments to show electrostatic charging by induction

(h) describe examples where electrostatic charging may be a potential hazard

(i) describe an example of the use of electrostatic charging e.g. photocopier and laser printer

17. Current of Electricity

Content

- Conventional current and electron flow
- Electromotive force
- Potential Difference
- Resistance

Learning Outcomes:

Candidates should be able to:

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

(b) distinguish between conventional current and electron flow

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

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

(e) calculate the total e.m.f. where several sources are arranged in series

(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

(m) state Ohm's Law

(n) describe the effect of temperature increase on the resistance of a metallic conductor

(o) sketch and interpret the I/V characteristic graphs for a metallic conductor at constant temperature, for a filament lamp and for a semiconductor diode

(p) show an understanding of the use of a diode as a rectifier

18. D.C. Circuits

Content

- Current and potential difference in circuits
- Series and parallel circuits
- Potential divider circuit
- Thermistor and light-dependent resistor
- Use of cathode-ray oscilloscope

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, bells, light-dependent resistors, thermistors and light-emitting diodes

(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

(g) describe the action of a variable potential divider (potentiometer)

(h) describe the action of thermistors and light-dependent resistors and explain their use as input transducers in potential dividers

(i) solve simple circuit problems involving thermistors and light-dependent resistors

(j) describe the use of a cathode-ray oscilloscope (c.r.o.) to display waveforms and to measure p.d.s and short intervals of time (detailed circuits, structure and operation of the c.r.o. are not required)

(k) interpret c.r.o. displays of waveforms, p.d.s and time intervals to solve related problems

19. 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

20. Magnetism

Content

- Laws of magnetism
- Magnetic properties of matter
- Magnetic field

Learning Outcomes:

Candidates should be able to:

(a) state the properties of magnets

(b) describe induced magnetism

(c) describe electrical methods of magnetisation and demagnetisation

(d) draw the magnetic field pattern around a bar magnet and between the poles of two bar magnets

(e) describe the plotting of magnetic field lines with a compass

(f) distinguish between the properties and uses of temporary magnets (e.g. iron) and permanent magnets (e.g. steel)

21. Electromagnetism

Content

- Magnetic effect of a current
- Applications of the magnetic effect of a current
- Force on a current-carrying conductor
- The d.c. motor

Learning Outcomes:

Candidates should be able to:

(a) draw the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and/or direction of the current

(b) describe the application of the magnetic effect of a current in a circuit breaker

(c) describe experiments to show the force on a current-carrying conductor, and on a beam of charged particles, in a magnetic field, including the effect of reversing
  (i) the current
  (ii) the direction of the field

(d) deduce the relative directions of force, field and current when any two of these quantities are at right angles to each other using Fleming's left-hand rule

(e) describe the field patterns between currents in parallel conductors and relate these to the forces which exist between the conductors (excluding the Earth's field)

(f) explain how a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by increasing
  (i) the number of turns on the coil
  (ii) the current

(g) discuss how this turning effect is used in the action of an electric motor

(h) describe the action of a split-ring commutator in a two-pole, single-coil motor and the effect of winding the coil on to a soft-iron cylinder

22. Electromagnetic Induction

Content

- Principles of electromagnetic induction
- The a.c. generator
- The transformer

Learning Outcomes:

Candidates should be able to:

(a) deduce from Faraday's experiments on electromagnetic induction or other appropriate experiments:
  (i) that a changing magnetic field can induce an e.m.f. in a circuit
  (ii) that the direction of the induced e.m.f. opposes the change producing it
  (iii) the factors affecting the magnitude of the induced e.m.f.

(b) describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings (where needed)

(c) sketch a graph of voltage output against time for a simple a.c. generator

(d) describe the structure and principle of operation of a simple iron-cored transformer as used for voltage transformations

(e) recall and apply the equations $V_P / V_s = N_P / N_s$ and $V_P I_P = V_s I_s$ to new situations or to solve related problems (for an ideal transformer)

(f) describe the energy loss in cables and deduce the advantages of high voltage transmission

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

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

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*
pressure*	p, P	Pa*, N/m^2
atmospheric pressure		use of millibar
temperature	θ, T, t	°C, K
heat capacity	C	J/°C, J/K
specific heat capacity*	c	J/(g °C), J/(kg K)
latent heat	L	J
specific latent heat*	l	J/kg, J/g
frequency*	f	Hz
wavelength*	λ	m, cm
focal length	f	m, cm
angle of incidence	i	degree (°)
angles of reflection, refraction	r	degree (°)
critical angle	c	degree (°)
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 the acceleration of free fall
- Investigation of the effects of balanced and unbalanced forces
- Verification and application of the principle of moments
- Investigation of the factors affecting thermal energy transfer
- Determination of heat capacities of materials and latent heat of substances
- Verification and application of the laws of reflection
- Determination of the characteristics of optical images formed by plane mirrors
- Verification and application of the refraction of light through glass blocks
- Verification and application of the principle of total internal reflection
- Investigation of the properties of images obtained through a thin converging lens
- Determination of the speed, wavelength and frequency of sound waves
- Measurements of current and voltage by using appropriate ammeters and voltmeters
- Determination of the resistance of a circuit element using appropriate instruments
- Investigation of the magnetic effect of current in a conductor
- Investigation of the effects of electromagnetic induction

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 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. *Explain/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. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.
4. *List* requires a number of points with no elaboration. Where a given number of points is specified, this should not be exceeded.
5. *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.
6. *Discuss* requires candidates to give a critical account of the points involved in the topic.
7. *Predict or deduce* 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.
8. *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'.
9. *Calculate* is used when a numerical answer is required. In general, working should be shown.
10. *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.
11. *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.
12. *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.
13. *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.

14. *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.

    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.