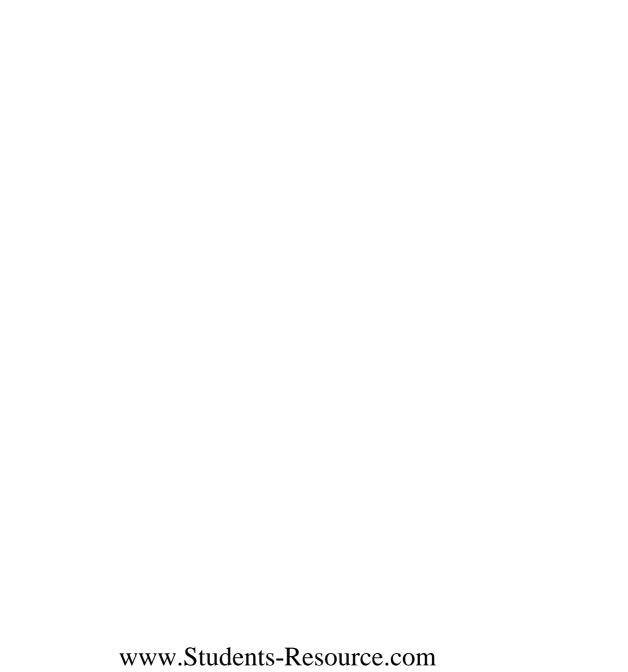General Certificate of Education (International)   **Syllabus**
Advanced Level and Advanced Subsidiary Level

PHYSICS 9702

For examination in June and November 2010

PHYSICS

GCE Advanced Subsidiary Level and

GCE Advanced Level 9702

CONTENTS

Notes

Attention is drawn to alterations in the syllabus by black vertical lines on either side of the text.

INTRODUCTION

This syllabus is designed to give flexibility both to teachers and to candidates and to place greater emphasis on the understanding and application of scientific concepts and principles than on the recall of factual material, whilst still giving a thorough introduction to the study of Physics.

Centres and candidates may choose:

- to take all Advanced Level components in the same examination session leading to the full A Level;
- to follow a **staged** assessment route to the Advanced Level by taking the Advanced Subsidiary (AS) qualification in an earlier examination session. Subject to satisfactory performance such candidates are then only required to take the final part of the assessment (referred to in this syllabus as A2) leading to the full A Level;
- to take the Advanced Subsidiary (AS) qualification only.

AIMS

These are not listed in order of priority.

The aims of a course based on this syllabus should be 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 and able to take or develop an informed interest in matters of scientific import;
    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 A Level in Physics, in Engineering or in Physics-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 the skills of enquiry;
    3.5 initiative;
    3.6 inventiveness.

4. stimulate interest in, and care for, the environment in relation to the environmental impact of Physics and its applications.

5. promote an awareness
    5.1 that the study and practice of Physics are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations;
    5.2 that the implications of Physics may be both beneficial and detrimental to the individual, the community and the environment;
    5.3 of the importance of the use of IT for communication, as an aid to experiments and as a tool for the interpretation of experimental and theoretical results.

6. stimulate students and create a sustained interest in Physics so that the study of the subject is enjoyable and satisfying.

ASSESSMENT OBJECTIVES

The assessment objectives listed below reflect those parts of the Aims which 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 written, 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, 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. evaluate information and hypotheses;
9. 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 which is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts which 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.)

C   Experimental skills and investigations

Candidates should be able to:

1. follow a detailed set or sequence of instructions and use techniques, apparatus and materials safely and effectively;
2. make observations and measurements with due regard for precision and accuracy;
3. interpret and evaluate observations and experimental data;
4. identify a problem, design and plan investigations, evaluate methods and techniques, and suggest possible improvement;
5. record observations, measurements, methods and techniques with due regard for precision, accuracy and units.

SCHEME OF ASSESSMENT

Paper	Type of Paper	Duration	Marks	Weighting	
				AS Level	A Level
1	Multiple-choice	1 h	40	31%	15%
2	AS structured questions	1 h	60	46%	23%
31/32	Advanced Practical Skills	2 h	40	23%	12%
4	A2 structured questions	1 h 45 min	100		38%
5	Planning, Analysis and Evaluation	1 h 15 min	30		12%

Paper 1

The paper will consist of 40 questions, all of the direct choice type with four options. All questions will be based on the AS syllabus. Candidates will answer all questions.

Paper 2

This paper will consist of a variable number of structured questions of variable mark value. All questions will be based on the AS syllabus. Candidates will answer all questions. Candidates will answer on the question paper.

Paper 31 / Paper 32

Paper 31 and Paper 32 will be equivalent and each candidate will be required to take only one of them. This is to allow large Centres to split candidates into two groups: one group will take Paper 31; the other group will take Paper 32. Each of these papers will be timetabled on a different day.

Each paper will consist of two experiments drawn from different areas of Physics. Candidates will be allowed to use the apparatus for each experiment for a maximum of 1 hour. The examiners will not be restricted by the subject content. Candidates will answer all questions. Candidates will answer on the question paper.

(Full details are given in the Practical Assessment section of the syllabus.)

Paper 4

This paper will consist of two sections.

Section A (70 marks) will consist of questions based on the A2 core, but may include material first encountered in the AS syllabus.

Section B (30 marks) will consist of questions based on Applications of Physics, but may include material first encountered in the core (AS and A2) syllabus.

Both sections will consist of a variable number of structured questions of variable mark value. Candidates will answer all questions. Candidates will answer on the question paper.

Paper 5

This paper will consist of two questions of equal mark value based on the practical skills of planning, analysis and evaluation. The examiners will not be restricted by the subject content. Candidates will answer all questions. Candidates will answer on the question paper.

Combinations of papers

- Candidates for Advanced Subsidiary (AS) certification will take Papers 1, 2 and either 31 or 32 at a single examination session.

- Candidates who, having received AS certification, wish to continue their studies to the full Advanced Level qualification may carry their AS marks forward and take just Papers 4 and 5 in the examination session in which they require certification.

- Candidates taking the complete Advanced Level qualification at the end of the course take all five papers in a single examination session.

Candidates may not enter for single papers either on the first occasion or for re-sit purposes. Candidates may only enter for the papers in the combinations indicated above.

WEIGHTING OF ASSESSMENT OBJECTIVES

	Assessment Objective	Weighting (%)	Assessment Components
A	Knowledge with understanding	37	Papers 1, 2 and 4
B	Handling information and solving problems	40	Papers 1, 2 and 4
C	Experimental skills and investigations	23	Papers 31/32 and 5

This gives a general idea of the allocation of marks to assessment objectives A, B and C. However, the balance on each paper may vary slightly.

Teachers should note that there is a greater weighting of 63% for skills (including handling information, solving problems, practical, experimental and investigative skills) compared to the 37% for knowledge and understanding. Teachers' schemes of work and the sequence of learning activities should reflect this balance, so that the aims of the syllabus may be met, and the candidates prepared for the assessment.

Mathematical Requirements

The mathematical requirements are given in a separate section of this syllabus. Those in **bold** type are not required for the AS qualification.

Data and Formulae

Data and Formulae, as printed in the Data and Formulae section of this syllabus, will appear as pages 2 and 3 in Papers 1, 2 and 4. Those in **bold** type are not required for the AS qualification.

Symbols, Signs and Abbreviations

Wherever symbols, signs and abbreviations are used in examination papers, the recommendation made in the ASE publication *Signs*, *Symbols* and *Systematics* (2000) will be followed. The units kW h, atmosphere, eV and unified atomic mass unit (*u*) may be used in examination papers without further explanation. Symbols for logic gates will conform to the American Standard ANSI Y 32.14 (1973) as shown in the ASE publication.

STRUCTURE OF THE SYLLABUS

The Subject Content of the syllabus is divided into an AS and A2 Core (made up of the first six sections) and Applications of Physics (Section VII). This structure is shown in the table below, in which the core sections are indicated by a lighter shade of grey. The table also shows which parts of the syllabus contain AS material and which parts contain A2 material.

Section	Part	AS	A2
I General Physics	**1. Physical Quantities and Units**	✓	✓
	2. Measurement Techniques	✓	✓
II Newtonian Mechanics	**3. Kinematics**	✓	
	4. Dynamics	✓	
	5. Forces	✓	
	6. Work, Energy, Power	✓	
	7. Motion in a Circle		✓
	8. Gravitational Field		✓
III Matter	**9. Phases of Matter**	✓	
	10. Deformation of Solids	✓	
	11. Ideal Gases		✓
	12. Temperature		✓
	13. Thermal Properties of Materials		✓
IV Oscillations and Waves	**14. Oscillations**		✓
	15. Waves	✓	
	16. Superposition	✓	
V Electricity and Magnetism	**17. Electric Fields**	✓	✓
	18. Capacitance		✓
	19. Current of Electricity	✓	
	20. D.C. Circuits	✓	
	21. Magnetic Fields		✓
	22. Electromagnetism		✓
	23. Electromagnetic Induction		✓
	24. Alternating Currents		✓
VI Modern Physics	**25. Charged Particles**		✓
	26. Quantum Physics		✓
	27. Nuclear Physics	✓	✓
VII Gathering and Communicating Information	**28. Direct Sensing**		✓
	29. Remote Sensing		✓
	30. Communicating Information		✓

Papers 1 and 2 will assess the AS parts of the Core. Section A of Paper 4 will assess the A2 parts of the Core. Section B of Paper 4 will assess Applications of Physics (Section VII).

The A2 parts of the syllabus, which will be examined only in the full Advanced Level qualification, are indicated in **bold** type in the subject content.

The Applications of Physics section occupies about 12% of the full Advanced Level course. A booklet covering this section can be purchased from CIE.

In order to specify the syllabus as precisely as possible and also to emphasise the importance of skills other than recall, Learning Outcomes have been used throughout. Each part of the syllabus is specified by a brief **Contents** section followed by detailed **Learning Outcomes.** It is hoped that this format will be helpful to teachers and students. It must be emphasised that the syllabus is not intended to be used as a teaching syllabus, nor is it intended to represent a teaching order.

It is hoped that teachers will incorporate the social, environmental, economic and technological aspects of physics wherever possible throughout the syllabus (see **Aims** 4 and 5). Some examples are included in the syllabus and students should be encouraged to apply the principles of these examples to other situations introduced in the course. Inclusion of further examples in the syllabus has been resisted as this would merely increase the amount of factual recall required of students.

Aim 5.3 emphasises the importance of Information Technology in this Physics course. It is hoped that students will make full use of IT techniques in their practical work. Teachers may also use IT in demonstrations and simulations. Asterisks (*) placed alongside Learning Outcomes indicate areas of the syllabus where it is anticipated that teachers might use applications of IT, as appropriate. It should be appreciated that the list is not exhaustive.

Advice on the use of IT in A Level Physics is printed at the back of the syllabus.

SUBJECT CONTENT

AS and A2 CORE: Sections I-VI inclusive

SECTION I : GENERAL PHYSICS

Recommended Prior Knowledge

Candidates should be aware of the nature of a physical measurement, in terms of a magnitude and a unit. They should have experience of making and recording such measurements in the laboratory.

1. **Physical Quantities and Units**

    Content

    1.1   Physical quantities
    1.2   SI Units
    1.3   The Avogadro constant
    1.4   Scalars and vectors

Learning Outcomes

Candidates should be able to:

(a)   show an 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)   express derived units as products or quotients of the base units and use the named units listed in this syllabus as appropriate.

(d)   use 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)   **show an understanding of the significance of the Avogadro constant as the number of atoms in 0.012 kg of Carbon-12.**

(i)   **use molar quantities where one mole of any substance is the amount containing a number of particles equal to the Avogadro constant.**

(j)   distinguish scalar and vector quantities and give examples of each.

(k)   add and subtract coplanar vectors.

(l)   represent a vector as two perpendicular components.

2.   Measurement Techniques

Content

2.1   Measurements
2.2   Errors and uncertainties

Learning Outcomes

Candidates should be able to:

(a)   use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the ranges of magnitude implied by the relevant parts of the syllabus.

In particular, candidates should be able to:

(1)   measure lengths using a ruler, vernier scale and micrometer.

(2)   measure weight and hence mass using spring and lever balances.

(3)   measure an angle using a protractor.

(4)   measure time intervals using clocks, stopwatches and the calibrated time-base of a cathode-ray oscilloscope (c.r.o).

(5)   measure temperature using a thermometer as a sensor.

(6)   use ammeters and voltmeters with appropriate scales.

(7)   use a galvanometer in null methods.

(8)   use a cathode-ray oscilloscope (c.r.o).

(9)   **use a calibrated Hall probe**.

*   *(b)*   use both analogue scales and digital displays.

*   *(c)*   use calibration curves.

   (d)   show an understanding of the distinction between systematic errors (including zero errors) and random errors.

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

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

SECTION II : NEWTONIAN MECHANICS

Recommended Prior Knowledge

Candidates should be able to describe the action of a force on a body. They should be able to describe the motion of a body and recognise acceleration and constant speed. They should be able to use the relationship *average speed = distance / time*.

3. Kinematics

Content

3.1 Linear motion
3.2 Non-linear motion

Learning Outcomes

Candidates should be able to:

(a) define displacement, speed, velocity and acceleration.

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

* *(c)* find displacement from the area under a velocity-time graph.

* *(d)* use the slope of a displacement-time graph to find the velocity.

* *(e)* use the slope of a velocity-time graph to find the acceleration.

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

* *(g)* 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.

(h) recall that the weight of a body is equal to the product of its mass and the acceleration of free fall.

* *(i)* describe an experiment to determine the acceleration of free fall using a falling body.

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

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

4. Dynamics

Content

4.1 Newton's laws of motion
4.2 Linear momentum and its conservation

Learning Outcomes

Candidates should be able to:

(a) state each of Newton's laws of motion.

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

(c) describe and use the concept of weight as the effect of a gravitational field on a mass.

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

(e) define force as rate of change of momentum.

* *(f)*   recall and solve problems using the relationship *F = ma*, appreciating that acceleration and force are always in the same direction.

(g)   state the principle of conservation of momentum.

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

* *(i)*   recognise that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation.

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

5.   Forces

Content

5.1   Types of force
5.2   Equilibrium of forces
5.3   Centre of gravity
5.4   Turning effects of forces

Learning Outcomes

Candidates should be able to:

(a)   describe the forces on mass and charge in uniform gravitational and electric fields, as appropriate.

(b)   show an understanding of the origin of the upthrust acting on a body in a fluid.

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

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

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

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

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

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

(i)   apply the principle of moments.

6.   Work, Energy, Power

Content

6.1   Energy conversion and conservation
6.2   Work
6.3   Potential energy, kinetic energy and internal energy
6.4   Power

Learning Outcomes

Candidates should be able to:

(a) give examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples.

(b) show an understanding of the concept of work in terms of the product of a force and displacement in the direction of the force.

* *(c)* calculate the work done in a number of situations including the work done by a gas which is expanding against a constant external pressure: $W = p\,\Delta V$.

(d) derive, from the equations of motion, the formula $E_k = \frac{1}{2}mv^2$.

(e) recall and apply the formula $E_k = \frac{1}{2}mv^2$.

(f) distinguish between gravitational potential energy, electric potential energy and elastic potential energy.

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

(h) derive, from the defining equation $W = Fs$, the formula $E_p = mgh$ for potential energy changes near the Earth's surface.

(i) recall and use the formula $E_p = mgh$ for potential energy changes near the Earth's surface.

(j) show an understanding of the concept of internal energy.

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

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

(m) solve problems using the relationships power = work done per unit time and power = force × velocity.

7.   **Motion in a Circle**

   Content

   7.1   Kinematics of uniform circular motion
   7.2   Centripetal acceleration
   7.3   Centripetal force

Learning Outcomes

Candidates should be able to:

(a)   **express angular displacement in radians.**

(b)   **understand 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.**

www.Students-Resource.com

(e)   **recall and use centripetal acceleration $a = r\omega^2$, $a = v^2/r$.**

(f)   **recall and use centripetal force $F = m\, r\omega^2$, $F = mv^2/r$.**

8.   Gravitational Field

Content

8.1   **Gravitational field**
8.2   **Force between point masses**
8.3   **Field of a point mass**
8.4   **Field near to the surface of the Earth**
8.5   **Gravitational potential**

Learning Outcomes

Candidates should be able to:

(a)   **show an understanding of the concept of a gravitational field as an example of field of force and define gravitational field strength as force per unit mass.**

* *(b)*   **recall and use Newton's law of gravitation in the form $F = G(m_1 m_2)/r^2$.**

(c)   **derive, from Newton's law of gravitation and the definition of gravitational field strength, the equation $g = \dfrac{GM}{r^2}$ for the gravitational field strength of a point mass.**

* *(d)*   **recall and solve problems using the equation $g = \dfrac{GM}{r^2}$ for the gravitational field strength of a point mass.**

(e)   **show an appreciation that on the surface of the Earth g is approximately constant and is called the acceleration of free fall.**

(f)   **define potential at a point as the work done in bringing unit mass from infinity to the point.**

* *(g)*   **solve problems using the equation $\phi = -\dfrac{GM}{r}$ for the potential in the field of a point mass.**

(h)   **recognise the analogy between certain qualitative and quantitative aspects of gravitational field and electric field.**

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

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

SECTION III : MATTER

Recommended Prior Knowledge

Candidates should be able to describe matter in terms of particles, with a qualitative understanding of their behaviour.

9. **Phases of Matter**

Content

9.1 Density
9.2 Solids, liquids, gases
9.3 Pressure in fluids
9.4 Change of phase

Learning Outcomes

Candidates should be able to:

(a) define the term density.

(b) relate the difference in the structures and densities of solids, liquids and gases to simple ideas of the spacing, ordering and motion of molecules.

(c) describe a simple kinetic model for solids, liquids and gases.

(d) describe an experiment which demonstrates Brownian motion and appreciate the evidence for the movement of molecules provided by such an experiment.

(e) distinguish between the structure of crystalline and non-crystalline solids with particular reference to metals, polymers and amorphous materials.

(f) define the term pressure and use the kinetic model to explain the pressure exerted by gases.

(g) derive, from the definitions of pressure and density, the equation $p = \rho g h$.

(h) use the equation $p = \rho g h$.

(i) distinguish between the processes of melting, boiling and evaporation.

10. **Deformation of Solids**

Content

10.1 Stress, strain
10.2 Elastic and plastic behaviour

Learning Outcomes

Candidates should be able to:

(a) appreciate that deformation is caused by a force and that, in one dimension, the deformation can be tensile or compressive.

(b) describe the behaviour of springs in terms of load, extension, elastic limit, Hooke's law and the spring constant (i.e. force per unit extension).

(c) define and use the terms stress, strain and the Young modulus.

(d) describe an experiment to determine the Young modulus of a metal in the form of a wire.

(e) distinguish between elastic and plastic deformation of a material.

(f) deduce the strain energy in a deformed material from the area under the force-extension graph.

(g) demonstrate knowledge of the force-extension graphs for typical ductile, brittle and polymeric materials, including an understanding of ultimate tensile stress.

11. Ideal Gases

Content

11.1 Equation of state
11.2 Kinetic theory of gases
11.3 Pressure of a gas
11.4 Kinetic energy of a molecule

Learning Outcomes

Candidates should be able to:

(a) **recall and solve problems using the equation of state for an ideal gas expressed as $pV = nRT$. (n = number of moles)**

(b) **infer from a Brownian motion experiment the evidence for the movement of molecules.**

(c) **state the basic assumptions of the kinetic theory of gases.**

(d) **explain how molecular movement causes the pressure exerted by a gas and hence deduce the relationship, $p = \dfrac{1}{3}\dfrac{Nm}{V}<c^2>$. ($N$ = number of molecules)**
   [A rigorous derivation is not required.]

(e) **compare $pV = \dfrac{1}{3}Nm<c^2>$ with $pV = NkT$ and hence deduce that the average translational kinetic energy of a molecule is proportional to T.**

12. Temperature

Content

12.1 Thermal equilibrium
12.2 Temperature scales
12.3 Practical thermometers

Learning Outcomes

Candidates should be able to:

(a) **show an appreciation that thermal energy is transferred from a region of higher temperature to a region of lower temperature.**

(b) **show an understanding that regions of equal temperature are in thermal equilibrium.**

(c) **show an understanding that a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties.**

* *(d)* **compare the relative advantages and disadvantages of resistance and thermocouple thermometers as previously calibrated instruments.**

(e) **show an understanding that there is an absolute scale of temperature which does not depend on the property of any particular substance (i.e. the thermodynamic scale and the concept of absolute zero).**

(f) **convert temperatures measured in kelvin to degrees Celsius:**
T / K = T / °C + 273.15.

13. **Thermal Properties of Materials**

   Content

   13.1 Specific heat capacity
   13.2 Specific latent heat
   13.3 Internal energy
   13.4 First law of thermodynamics

Learning Outcomes

Candidates should be able to:

(a) **explain using a simple kinetic model for matter why**

   (i) melting and boiling take place without a change in temperature,
   (ii) the specific latent heat of vaporisation is higher than specific latent heat of fusion for the same substance,
   (iii) a cooling effect accompanies evaporation.

(b) **define and use the concept of specific heat capacity, and identify the main principles of its determination by electrical methods.**

(c) **define and use the concept of specific latent heat, and identify the main principles of its determination by electrical methods.**

(d) **relate a rise in temperature of a body to an increase in its internal energy.**

(e) **show an understanding that internal energy is determined by the state of the system and that it can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of a system.**

(f) **recall and use the first law of thermodynamics expressed in terms of the change in internal energy, the heating of the system and the work done on the system.**

SECTION IV : OSCILLATIONS AND WAVES

Recommended Prior Knowledge

Candidates should be able to describe basic wave behaviour, gained through a study of optics. They should be aware of the basic ideas of reflection and refraction in light.

14. **Oscillations**

   Content

   14.1 Simple harmonic motion
   14.2 Energy in simple harmonic motion
   14.3 Damped and forced oscillations: resonance

Learning Outcomes

Candidates should be able to:

(a)   describe simple examples of free oscillations.

* *(b)*   investigate the motion of an oscillator using experimental and graphical methods.

(c)   understand and use the terms amplitude, period, frequency, angular frequency and phase difference and express the period in terms of both frequency and angular frequency.

(d)   recognise and use the equation $a = -\omega^2 x$ as the defining equation of simple harmonic motion.

(e)   recall and use $x = x_0 \sin \omega t$ as a solution to the equation $a = -\omega^2 x$.

(f)   recognise and use
$$v = v_0 \cos \omega t$$
$$v = \pm \omega \sqrt{\left(x_0^2 - x^2\right)}.$$

* *(g)*   describe with graphical illustrations, the changes in displacement, velocity and acceleration during simple harmonic motion.

(h)   describe the interchange between kinetic and potential energy during simple harmonic motion.

* *(i)*   describe practical examples of damped oscillations with particular reference to the effects of the degree of damping and the importance of critical damping in cases such as a car suspension system.

(j)   describe practical examples of forced oscillations and resonance.

* *(k)*   describe graphically how the amplitude of a forced oscillation changes with frequency near to the natural frequency of the system, and understand qualitatively the factors which determine the frequency response and sharpness of the resonance.

(l)   show an appreciation that there are some circumstances in which resonance is useful and other circumstances in which resonance should be avoided.

15.   Waves

    Content

       15.1 Progressive waves
       15.2 Transverse and longitudinal waves
       15.3 Polarisation
       15.4 Determination of speed, frequency and wavelength
       15.5 Electromagnetic spectrum

Learning Outcomes

Candidates should be able to:

(a)   describe what is meant by wave motion as illustrated by vibration in ropes, springs and ripple tanks.

(b)   show an understanding and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed.

www.Students-Resource.com

(c) deduce, from the definitions of speed, frequency and wavelength, the equation $v = f\lambda$.

(d) recall and use the equation $v = f\lambda$.

(e) show an understanding that energy is transferred due to a progressive wave.

(f) recall and use the relationship, *intensity $\propto$ (amplitude)^2*.

(g) compare transverse and longitudinal waves.

* *(h)* analyse and interpret graphical representations of transverse and longitudinal waves.

(i) show an understanding that polarisation is a phenomenon associated with transverse waves.

* *(j)* determine the frequency of sound using a calibrated c.r.o.

* *(k)* determine the wavelength of sound using stationary waves.

* *(l)* state that all electromagnetic waves travel with the same speed in free space and recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays.

16. Superposition

Content

16.1 Stationary waves
16.2 Diffraction
16.3 Interference
16.4 Two-source interference patterns
16.5 Diffraction grating

Learning Outcomes

Candidates should be able to:

* *(a)* explain and use the principle of superposition in simple applications.

* *(b)* show an understanding of experiments which demonstrate stationary waves using microwaves, stretched strings and air columns.

* *(c)* explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes.

(d) explain the meaning of the term diffraction.

(e) show an understanding of experiments which demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap.

(f) show an understanding of the terms interference and coherence.

(g) show an understanding of experiments which demonstrate two-source interference using water, light and microwaves.

(h) show an understanding of the conditions required if two-source interference fringes are to be observed.

(i) recall and solve problems using the equation $\lambda = ax / D$ for double-slit interference using light.

(j) recall and solve problems using the formula $d \sin\theta = n\lambda$ and describe the use of a diffraction grating to determine the wavelength of light. (The structure and use of the spectrometer is not included.)

SECTION V: ELECTRICITY AND MAGNETISM

Recommended Prior Knowledge

Candidates should be aware of the two types of charge, charging by friction and by induction. They should be able to distinguish between conductors and insulators using a simple electron model.

17.   Electric Fields

Content

17.1   Concept of an electric field
17.2   Uniform electric fields
17.3   Force between point charges
17.4   Electric field of a point charge
17.5   Electric potential

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 as force per unit positive charge.

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

(c) recall and use $E = V/d$ to calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation.

(d) calculate the forces on charges in uniform electric fields.

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

* *(f)* **recall and use Coulomb's law in the form $F = Q_1Q_2/4\pi\varepsilon_o r^2$ for the force between two point charges in free space or air.**

* *(g)* **recall and use $E = Q/4\pi\varepsilon_o r^2$ for the field strength of a point charge in free space or air.**

(h) **define potential at a point in terms of the work done in bringing unit positive charge from infinity to the point.**

(i) **state that the field strength of the field at a point is numerically equal to the potential gradient at that point.**

* *(j)* **use the equation $V = Q/4\pi\varepsilon_o r$ for the potential in the field of a point charge.**

(k) **recognise the analogy between certain qualitative and quantitative aspects of electric field and gravitational fields.**

www.Students-Resource.com

18.   Capacitance

   Content

   18.1   Capacitors and capacitance
   18.2   Energy stored in a capacitor

Learning Outcomes

Candidates should be able to:

(a)   **show an understanding of the function of capacitors in simple circuits.**

(b)   **define capacitance and the farad.**

(c)   **recall and solve problems using $C = Q/V$.**

(d)   **derive, using the formula $C = Q/V$, conservation of charge and the addition of p.ds, formulae for capacitors in series and in parallel.**

(e)   **solve problems using formulae for capacitors in series and in parallel.**

* *(f)*   **deduce from the area under a potential-charge graph, the equation $W = \frac{1}{2}QV$ and hence $W = \frac{1}{2}CV^2$.**

19.   Current of Electricity

   Content

   19.1   Electric current
   19.2   Potential difference
   19.3   Resistance and resistivity
   19.4   Sources of electromotive force

Learning Outcomes

Candidates should be able to:

(a)   show an understanding that electric current is the rate of flow of charged particles.

(b)   define charge and the coulomb.

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

(d)   define potential difference and the volt.

(e)   recall and solve problems using $V = W/Q$.

(f)   recall and solve problems using $P = VI$, $P = I^2R$.

(g)   define resistance and the ohm.

(h)   recall and solve problems using $V = IR$.

* *(i)*   sketch and explain the *I-V* characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp.

(j)   sketch the temperature characteristic of a thermistor. (Thermistors will be assumed to be of the negative temperature coefficient type.)

(k)   state Ohm's law.

(l)   recall and solve problems using $R = \rho l/A$.

(m)   define e.m.f. in terms of the energy transferred by a source in driving unit charge round a complete circuit.

(n)   distinguish between e.m.f. and p.d in terms of energy considerations.

(o)   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.

20.   D.C. Circuits

Content

20.1   Practical circuits
20.2   Conservation of charge and energy
20.3   Balanced potentials

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*.

(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)   recall Kirchhoff's first law and appreciate the link to conservation of charge.

(d)   recall Kirchhoff's second law and appreciate the link to conservation of energy.

(e)   derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series.

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

(g)   derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel.

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

(i)   apply Kirchhoff's laws to solve simple circuit problems.

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

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

(l)   recall and solve problems using the principle of the potentiometer as a means of comparing potential differences.

www.Students-Resource.com

21. Magnetic Fields

Content

21.1 Concept of magnetic field

Learning Outcomes

Candidates should be able to:

(a) **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.**

(b) **represent a magnetic field by field lines.**

22. Electromagnetism

Content

22.1 Force on a current-carrying conductor
22.2 Force on a moving charge
22.3 Magnetic fields due to currents
22.4 Force between current-carrying conductors

Learning Outcomes

Candidates should be able to:

(a) **show an appreciation that a force might act on a current-carrying conductor placed in a magnetic field.**

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

(c) **define magnetic flux density and the tesla.**

(d) **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.**

(e) **predict the direction of the force on a charge moving in a magnetic field.**

(f) **recall and solve problems using $F = BQv \sin\theta$.**

(g) **sketch flux patterns due to a long straight wire, a flat circular coil and a long solenoid.**

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

(i) **explain the forces between current-carrying conductors and predict the direction of the forces.**

(j) **describe and compare the forces on mass, charge and current in gravitational, electric and magnetic fields, as appropriate.**

23.   Electromagnetic Induction

   Content

   23.1 Laws of electromagnetic induction

Learning Outcomes

Candidates should be able to:

(a)   **define magnetic flux and the weber.**

(b)   **recall and solve problems using $\Phi = BA$.**

(c)   **define magnetic flux linkage.**

* *(d)*   **infer from appropriate experiments on electromagnetic induction:**
        (i)   that a changing magnetic flux 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.

(e)   **recall and solve problems using Faraday's law of electromagnetic induction and Lenz's law.**

(f)   **explain simple applications of electromagnetic induction.**

24.   Alternating Currents

   Content

   24.1 Characteristics of alternating currents
   24.2 The transformer
   24.3 Transmission of electrical energy
   24.4 Rectification

Learning Outcomes

Candidates should be able to:

(a)   **show an understanding of and use the terms period, frequency, peak value and root-mean-square value as applied to an alternating current or voltage.**

* *(b)*   **deduce that the mean power in a resistive load is half the maximum power for a sinusoidal alternating current.**

* *(c)*   **represent a sinusoidally alternating current or voltage by an equation of the form $x = x_o \sin \omega t$.**

(d)   **distinguish between r.m.s. and peak values and recall and solve problems using the relationship $I_{rms} = I_o / \sqrt{2}$ for the sinusoidal case.**

(e)   **show an understanding of the principle of operation of a simple iron-cored transformer and recall and solve problems using $N_s/N_p = V_s/V_p = I_p /I_s$ for an ideal transformer.**

(f)   **show an appreciation of the scientific and economic advantages of alternating current and of high voltages for the transmission of electrical energy.**

* *(g)*   **distinguish graphically between half-wave and full-wave rectification.**

(h) **explain the use of a single diode for the half-wave rectification of an alternating current.**

(i) **explain the use of four diodes (bridge rectifier) for the full-wave rectification of an alternating current.**

* *(j)* **analyse the effect of a single capacitor in smoothing, including the effect of the value of capacitance in relation to the load resistance.**

SECTION VI : MODERN PHYSICS

Recommended Prior Knowledge

Candidates should be able to describe matter in terms of atoms, with electrons orbiting a positively charged nucleus. Candidates should have studied some of the material in Section IV.

25. Charged Particles

Content

25.1 Electrons
25.2 Beams of charged particles

Learning Outcomes

Candidates should be able to:

* *(a)* **show an understanding of the main principles of determination of *e* by Millikan's experiment.**

(b) **summarise and interpret the experimental evidence for quantisation of charge.**

* *(c)* **describe and analyse qualitatively the deflection of beams of charged particles by uniform electric and uniform magnetic fields.**

(d) **explain how electric and magnetic fields can be used in velocity selection.**

* *(e)* **explain the main principles of one method for the determination of *v* and *e/m*$_e$ for electrons.**

26. Quantum Physics

Content

26.1 Energy of a photon
26.2 Photoelectric emission of electrons
26.3 Wave-particle duality
26.4 Energy levels in atoms
26.5 Line spectra

Learning Outcomes

Candidates should be able to:

(a) **show an appreciation of the particulate nature of electromagnetic radiation.**

(b) **recall and use *E = hf*.**

* (c) **show an understanding that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provide evidence for a wave nature.**

(d) **recall the significance of threshold frequency.**

(e) **explain photoelectric phenomena in terms of photon energy and work function energy.**

(f) **explain why the maximum photoelectric energy is independent of intensity whereas the photoelectric current is proportional to intensity.**

(g) **recall, use and explain the significance of $hf = \Phi + \frac{1}{2}mv^2_{max}$.**

* (h) **describe and interpret qualitatively the evidence provided by electron diffraction for the wave nature of particles.**

(i) **recall and use the relation for the de Broglie wavelength $\lambda = h/p$.**

* (j) **show an understanding of the existence of discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) and deduce how this leads to spectral lines.**

(k) **distinguish between emission and absorption line spectra.**

(l) **recall and solve problems using the relation $hf = E_1 - E_2$.**

27. **Nuclear Physics**

Content

27.1 The nucleus
27.2 Isotopes
27.3 Nuclear processes
27.4 Mass excess and nuclear binding energy
27.5 Radioactive decay

Learning Outcomes

Candidates should be able to:

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

* (b) describe a simple model for the nuclear atom to include protons, neutrons and orbital electrons.

(c) distinguish between nucleon number (mass number) and proton number (atomic number).

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

(e) use the usual notation for the representation of nuclides.

(f) appreciate that nucleon number, proton number, and mass-energy are all conserved in nuclear processes.

(g) represent simple nuclear reactions by nuclear equations of the form
$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$.

(h) show an appreciation of the spontaneous and random nature of nuclear decay.

(i) show an understanding of the nature and properties of α-, β- and γ- radiations (β^+ is not included: β- radiation will be taken to refer to β^-).

* *(j)* infer the random nature of radioactive decay from the fluctuations in count rate.

(k) **show an appreciation of the association between energy and mass as represented by $E = mc^2$ and recall and solve problems using this relationship.**

(l) **sketch the variation of binding energy per nucleon with nucleon number.**

(m) **explain the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission.**

(n) **define the terms activity and decay constant and recall and solve problems using $A = \lambda N$.**

* **(o)** **infer and sketch the exponential nature of radioactive decay and solve problems using the relationship $x = x_o \exp(-\lambda t)$ where x could represent activity, number of undecayed particles or received count rate.**

(p) **define half-life.**

(q) **solve problems using the relation $\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$.**

www.Students-Resource.com

APPLICATIONS OF PHYSICS: Section VII

SECTION VII : GATHERING AND COMMUNICATING INFORMATION

28.   Direct Sensing

Content

28.1 Sensing devices
28.2 The ideal operational amplifier
28.3 Operational amplifier circuits
28.4 Output devices

Learning Outcomes

Candidates should be able to:

(a)   **show an understanding that an electronic sensor consists of a sensing device and a circuit that provides an output voltage.**

(b)   **show an understanding of the change in resistance with light intensity of a light-dependent resistor (LDR).**

(c)   **sketch the temperature characteristic of a negative temperature coefficient thermistor.**

(d)   **show an understanding of the action of a piezo-electric transducer and its application in a simple microphone.**

(e)   **describe the structure of a metal-wire strain gauge.**

(f)   **relate extension of a strain gauge to change in resistance of the gauge.**

(g)   **show an understanding that the output from sensing devices can be registered as a voltage.**

(h)   **recall the main properties of the ideal operational amplifier (op-amp).**

(i)   **deduce, from the properties of an ideal operational amplifier, the use of an operational amplifier as a comparator.**

(j)   **show an understanding of the effects of negative feedback on the gain of an operational amplifier.**

(k)   **recall the circuit diagrams for both the inverting and the non-inverting amplifier for single signal input.**

(l)   **show an understanding of the virtual earth approximation and derive an expression for the gain of inverting amplifiers.**

(m)   **recall and use expressions for the voltage gain of inverting and of non-inverting amplifiers.**

(n)   **show an understanding of the use of relays in electronic circuits.**

(o)   **show an understanding of the use of light-emitting diodes (LEDs) as devices to indicate the state of the output of electronic circuits.**

(p)   **show an understanding of the need for calibration where digital or analogue meters are used as output devices.**

29. **Remote Sensing**

Content

29.1 **Production and use of X-rays**
29.2 **Production and use of ultrasound**
29.3 **Use of magnetic resonance as an imaging technique**

Learning Outcomes

Candidates should be able to:

(a) explain in simple terms the need for remote sensing (non-invasive techniques of diagnosis) in medicine.

(b) explain the principles of the production of X-rays by electron bombardment of a metal target.

(c) describe the main features of a modern X-ray tube, including control of the intensity and hardness of the X-ray beam.

(d) show an understanding of the use of X-rays in imaging internal body structures, including a simple analysis of the causes of sharpness and contrast in X-ray imaging.

(e) show an understanding of the purpose of computed tomography or CT scanning.

(f) show an understanding of the principles of CT scanning.

(g) show an understanding of how the image of an 8-voxel cube can be developed using CT scanning.

(h) explain the principles of the generation and detection of ultrasonic waves using piezo-electric transducers.

(i) explain the main principles behind the use of ultrasound to obtain diagnostic information about internal structures.

(j) show an understanding of the meaning of acoustic impedance and its importance to the intensity reflection coefficient at a boundary.

(k) recall and solve problems by using the equation $I = I_0 e^{-\mu x}$ for the attenuation of X-rays and ultrasound in matter.

(l) explain the main principles behind the use of magnetic resonance to obtain diagnostic information about internal structures.

(m) show an understanding of the function of the non-uniform magnetic field, superimposed on the large constant magnetic field, in diagnosis using magnetic resonance.

30. **Communicating Information**

Content

30.1 **Principles of modulation**
30.2 **Sidebands and bandwidth**
30.3 **Transmission of information by digital means**
30.4 **Different channels of communication**
30.5 **The mobile-phone network**

www.Students-Resource.com

Learning Outcomes

Candidates should be able to:

(a) **understand the term modulation and be able to distinguish between amplitude modulation (AM) and frequency modulation (FM).**

(b) **recall that a carrier wave, amplitude modulated by a single audio frequency, is equivalent to the carrier wave frequency together with two sideband frequencies.**

(c) **understand the term bandwidth.**

(d) **demonstrate an awareness of the relative advantages of AM and FM transmissions.**

(e) **recall the advantages of the transmission of data in digital form.**

(f) **understand that the digital transmission of speech or music involves analogue-to-digital conversion (ADC) on transmission and digital-to-analogue conversion (DAC) on reception.**

(g) **show an understanding of the effect of the sampling rate and the number of bits in each sample on the reproduction of an input signal.**

(h) **appreciate that information may be carried by a number of different channels, including wire-pairs, coaxial cables, radio and microwave links, and optic fibres.**

(i) **discuss the relative advantages and disadvantages of channels of communication in terms of available bandwidth, noise, cross-linking, security, signal attenuation, repeaters and regeneration, cost and convenience.**

(j) **describe the use of satellites in communication.**

(k) **recall the relative merits of both geostationary and polar orbiting satellites for communicating information.**

(l) **recall the frequencies and wavelengths used in different channels of communication.**

(m) **understand and use signal attenuation expressed in dB and dB per unit length.**

(n) **recall and use the expression *number of dB* = 10 lg(P_1/P_2) for the ratio of two powers.**

(o) **understand that in a mobile-phone system, the public switched telephone network (PSTN) is linked to base stations via a cellular exchange.**

(p) **understand the need for an area to be divided into a number of cells, each cell served by a base station.**

(q) **understand the role of the base station and the cellular exchange during the making of a call from a mobile phone handset.**

(r) **recall a simplified block diagram of a mobile phone handset and understand the function of each block.**

www.Students-Resource.com

PRACTICAL ASSESSMENT

INTRODUCTION

Candidates should be directed towards the practice of experimental skills throughout the whole period of their course of study. As a guide, candidates should expect to spend at least 20% of their time doing practical work individually or in small groups. This 20% does not include the time spent observing teacher demonstrations of experiments. The practical work that candidates do during their course should aim to:

- provide learning opportunities so that candidates develop the skills they need to carry out experimental and investigative work;
- reinforce the learning of the theoretical subject content of the syllabus;
- instil an understanding of the interplay of experiment and theory in scientific method;
- prove enjoyable, contributing to the motivation of candidates.

Candidates' experimental skills will be assessed in Papers 31/32 and 5. In each of these papers, the examiners will not be strictly bound by the subject content of the syllabus in setting questions. Where appropriate, candidates will be told exactly what to do and how to do it: only knowledge of theory and experimental skills within the syllabus will be expected.

PAPER 31/32

Paper 31/32 will be a timetabled, laboratory-based practical paper focussing on the following experimental skills:

- manipulation, measurement and observation;
- presentation of data and observations;
- analysis, conclusions and evaluation.

Each paper will consist of two questions, each of 1 hour and each of 20 marks. The first question will be an experiment requiring candidates to collect data, to plot a graph and to draw simple conclusions. The second question will not require the plotting of a graph. In the second question, the experimental method to be followed will be inaccurate and candidates will be required to evaluate the method and suggest improvements. The two questions will be set in different areas of Physics. No prior knowledge of the theory will be required. The areas of Physics will not be confined to the AS subject content and may relate to A2 topics.

Paper 31 and Paper 32 will contain different questions, but will be equivalent in the skills assessed and in the level of demand. Each candidate should take one of these papers. Some schools may wish to divide their candidates so that some are entered for Paper 31 and the others are entered for Paper 32; other schools may wish to enter all of their candidates for the same paper.

Mark scheme for Paper 31/32

Paper 31/32 will be marked using the generic mark scheme below. The expectations for each mark category are listed in the sections that follow.

Question 1			
Skill		*Breakdown of marks*	
Manipulation, measurement and observation	9 marks	Successful collection of data	7 marks
		Range and distribution of values	1 mark
		Quality of data	1 mark
Presentation of data and observations	7 marks	Table of results: layout	1 mark
		Table of results: raw data	1 mark
		Table of results: calculated quantities	2 marks
		Graph: layout	1 mark
		Graph: plotting of points	1 mark
		Graph: trend line	1 mark
Analysis, conclusions and evaluation	4 marks	Interpretation of graph	2 marks
		Drawing conclusions	2 marks

Question 2			
Skill		*Breakdown of marks*	
Manipulation, measurement and observation	7 marks	Successful collection of data	6 marks
		Quality of data	1 mark
Presentation of data and observations	3 marks	Display of calculation and reasoning	3 marks
Analysis, conclusions and evaluation	10 marks	Drawing conclusions	1 mark
		Estimating uncertainties	1 mark
		Identifying limitations	4 marks
		Suggesting improvements	4 marks

Manipulation, measurement and observation

Successful collection of data

Candidates should be able to:

- set up apparatus correctly without assistance from the Supervisor;
- follow instructions given in the form of written instructions, diagrams or circuit diagrams;
- use their apparatus to collect an appropriate quantity of data;
- repeat readings where appropriate;
- make measurements using common laboratory apparatus, such as millimetre scales, protractors, stopwatches, top-pan balances, newton-meters, analogue or digital electrical meters, measuring cylinders, vernier callipers, micrometer screw gauges and thermometers;
- use both analogue scales and digital displays.

Some candidates will be unable to set up their apparatus without help. Such candidates may ask for assistance from the supervisor. Supervisors will be given clear instructions on what assistance may be given to candidates, but this assistance should never go beyond the minimum necessary to enable candidates to take some readings: under no circumstances should help be given with the presentation of data, analysis or evaluation sections. All assistance must be reported to the examiners, and candidates who require assistance will not be able to score full marks for the successful collection of data.

Range and distribution of values

Candidates should be able to:

- make measurements that span the largest possible range of values within the limits either of the equipment provided or of the instructions given;
- make measurements whose values are appropriately distributed within this range.

In most experiments, including those involving straight-line graphs, a regularly-spaced set of measurements will be appropriate. For other experiments, such as those requiring the peak value of a curved graph to be determined, it may be appropriate for the measurements to be concentrated in one part of the range investigated. Candidates will be expected to be able to identify the most appropriate distribution of values.

Quality of data

Candidates should be able to:

- make and record accurate measurements.

Marks will be awarded for measured data in which the values obtained are reasonable. In some cases, the award of the mark will be based on the scatter of points on a graph; in other cases, the candidate's data may be compared with information supplied by the supervisor or known to the examiners. The examiners will only consider the extent to which the candidate has affected the quality of the data: allowances will be made where the quality of data is limited by the experimental method required or by the apparatus used.

Presentation of data and observations

Table of results: layout

Candidates should be able to:

- present numerical data and values in a single table of results;
- draw up the table in advance of taking readings so that they do not have to copy up their results;
- include in the table of results columns for raw data and for values calculated from them;
- use column headings that include both the quantity and the unit and that conform to accepted scientific conventions.

As an example of accepted practice in column headings, if the quantity being measured is current in milliamperes, then 'I/mA' would be the usual way to write the column heading, but 'I in mA' or 'I (mA)' would be allowed. Headings such as 'I mA' or just 'mA' are not acceptable. The quantity or the unit or both may be written in words rather than symbols. Conventional symbols or abbreviations, such as p.d., may be used without explanation.

Table of results: raw data

Candidates should be able to:

- record raw readings of a quantity to the same degree of precision.

For example, if one measurement of length in a column of raw data is given to the nearest millimetre, then all the lengths in that column should be given to the nearest millimetre. The degree of precision used should be compatible with the measuring instrument used: it would be inappropriate to record a distance measured on a millimetre scale as '2 cm'.

Table of results: calculated quantities

Candidates should be able to:

- calculate other quantities from their raw data;
- use the correct number of significant figures for these calculated quantities.

Except where they are produced by addition or subtraction, calculated quantities should be given to the same number of significant figures (or one more than) the measured quantity of least accuracy. For example, if values of a potential difference and of a current are measured to 2 and 4 significant figures respectively, then the corresponding resistance should be given to 2 or 3 significant figures, but not 1 or 4. The number of significant figures may, if necessary, vary down a column of values for a calculated quantity.

www.Students-Resource.com

Graph: layout

Candidates should be able to:

- plot the independent variable on the *x*-axis and the dependent variable on the *y*-axis, except where the variables are conventionally plotted the other way around;
- clearly label graph axes with both the quantity and the unit, following accepted scientific conventions;
- choose scales for graph axes such that the data points occupy at least half of the graph grid in both *x*- and *y*-directions;
- use a false origin where appropriate;
- choose scales for the graph axes that allow the graph to be read easily, such as 1, 2 or 5 units to a 2 cm square;
- place regularly-spaced numerical labels along the whole of each axis.

The accepted scientific conventions for labelling the axes of a graph are the same as for the column headings in a table of results.

Graph: plotting of points

Candidates should be able to:

- plot all their data points on their graph grid to an accuracy of better than 1 mm.

Points should be finely drawn with a sharp pencil, but must still be visible. A fine cross or an encircled dot is suitable; a thick pencil blob is not.

Graph: trend line

Candidates should be able to:

- identify when the trend of a graph is linear or curved;
- draw straight lines of best fit or curves to show the trend of a graph;
- draw tangents to curved trend lines.

The trend line should show an even distribution of points on either side of the line along its whole length. Lines should be finely drawn and should not contain kinks or breaks.

Display of calculation and reasoning

Candidates should be able to:

- show their working in calculations, and the key steps in their reasoning;
- justify the number of significant figures in a calculated quantity.

Analysis, conclusions and evaluation

Interpretation of graph

Candidates should be able to:

- relate straight-line graphs to equations of the form $y = mx + c$, and hence to derive expressions that equate to the gradient or the *y*-intercept of their graphs;
- read the co-ordinates of points on the trend line of a graph;
- determine the gradient of a straight-line graph or of a tangent to a curve;
- determine the *y*-intercept of a straight-line graph or of a tangent to a curve, including where these are on graphs with a false origin.

When a gradient is to be determined, the points on the line chosen for the calculation should be separated by at least half of the length of the line drawn.
In cases where the *y*-intercept cannot be read directly from the *y*-axis, it is expected that the co-ordinates of a point on the line and the gradient will be substituted into $y = mx + c$.

Drawing conclusions

Candidates should be able to:

- draw conclusions from an experiment, including determining the values of constants, considering whether experimental data supports a given hypothesis, and making predictions.

Estimating uncertainties

Candidates should be able to:

- estimate, quantitatively, the uncertainty in their measurements;
- express the uncertainty in a measurement as an actual, fractional or percentage uncertainty, and translate between these forms.

Identifying limitations

Candidates should be able to:

- identify and describe the limitations in an experimental procedure;
- identify the most significant sources of error in an experiment;
- show an understanding of the distinction between systematic errors (including zero errors) and random errors.

Suggesting improvements

Candidates should be able to:

- suggest modifications to an experimental arrangement that will improve the accuracy of the experiment or to extend the investigation to answer a new question;
- describe these modifications clearly in words or diagrams.

Candidates' suggestions should be realistic, so that in principle they are achievable in practice. The suggestions may relate either to the apparatus used or to the experimental procedure followed. Candidates may include improvements that they have actually made while carrying out the experiment. The suggested modifications may relate to sources of error identified by the candidate.

Administration of the Practical Test

Detailed regulations on the administration of CIE practical examinations are contained in the Handbook for Centres.

A document called the Confidential Instructions will be despatched to Centres, usually about six weeks before the date of the examination. The Confidential Instructions detail the apparatus that will be required and how it should be laid out for candidates, and contain sufficient details to allow testing of the apparatus. Centres should contact the Despatch Department at CIE if they believe the Instructions have not been received.

Access to the question paper itself is not permitted in advance of the examination. It is essential that absolute confidentiality be maintained in advance of the examination date: the contents of the Confidential Instructions must not be revealed either directly or indirectly to candidates.

The Confidential Instructions contains a Supervisor's Report Form. A copy of this form must be completed and enclosed in each envelope of scripts. A sample set of results may also be helpful to the examiners, especially if there was any local difficulty with apparatus. A missing report can impede the marking process.

Apparatus that is used regularly

The list below gives some of the items that are regularly used in the practical test. The list is not intended to be exhaustive; in particular, to instil some variation in the questions set, some novel items are usually required. If there is any doubt about the interpretation of the Confidential Instructions or the suitability of the apparatus available, enquiries should be sent to the Product Manager for Physics at CIE, using either e-mail (international@cie.org.uk) or fax (+44 1223 553558) or telephone (+44 1223 553554).

Ammeter: (digital or analogue) f.s.d. 100 mA and 1 A (digital multimeters are suitable)
Cells: 1.5 V
Lamp and holder: 6 V 60 mA; 2.5 V 0.3 A
Leads and crocodile clips
Power supply: variable up to 12 V d.c. (low resistance)
Rheostat
Switch
Voltmeter: (digital or analogue) f.s.d. 5 V, 10 V (digital multimeters are suitable)
Wire: constantan 26, 28, 30, 32, 34, 36, 38 s.w.g. or metric equivalents

Long stem thermometer: −10 °C to 110 °C x 1 °C
Means to heat water safely to boiling (e.g. an electric kettle)
Plastic or polystyrene cup 200 cm^3
Stirrer

Balance to 0.1 g (this item may often be shared between sets of apparatus)
Bar magnet
Bare copper wire: 18, 26 s.w.g.
Beaker: 100 cm^3, 200 cm^3 or 250 cm^3
Blu-Tack
Card
Expendable steel spring
G-clamp
Magnadur ceramic magnets
Mass hanger
Micrometer screw gauge (this item may often be shared between sets of apparatus)
Newton-meter (1 N, 10 N)
Pendulum bob
Plasticine
Protractor
Pulley
Rule with a millimetre scale (1 m, 0.5 m, 300 mm)
Scissors
Sellotape
Slotted masses (100 g, 50 g, 20 g, 10 g) or alternative
Spring
Stand, boss and clamp
Stopwatch (candidates may use their wristwatches), reading to 0.1 s or better
Stout pin or round nail
String/thread/twine
Vernier calipers (this item may often be shared between sets of apparatus)
Wire cutters
Wood or metal jaws

PAPER 5

Paper 5 will be a timetabled, written paper focussing on the following higher-order experimental skills:

- planning;
- analysis, conclusions and evaluation.

This examination paper will not require laboratory facilities.

It should be stressed that candidates cannot be adequately prepared for this paper without extensive laboratory work during their course of study.

In particular, candidates cannot be taught to plan experiments effectively unless, on a number of occasions, they are required:

- to plan an experiment;
- to perform the experiment according to their plan;
- to evaluate what they have done.

This requires many hours of laboratory-based work, and it also requires careful oversight from teachers to ensure that experiments are performed with due regard to safety.

The paper will consist of two questions each of 15 marks. The first question will be a planning question, in which candidates will be required to design an experimental investigation of a given problem. The question will not be highly structured: candidates will be expected to answer with a diagram and an extended piece of writing. The second question will be an analysis, conclusions and evaluation question, in which candidates will be given an equation and some experimental data, from which they will be required to find the value of a constant. This question also will not be highly structured: candidates will be expected to decide for themselves what they need to do in order to reach an answer. They will also be required to estimate the uncertainty in their answer.

Some questions on this paper may be set in areas of Physics that are difficult to investigate experimentally in school laboratories, either because of the cost of equipment or because of restrictions on the availability of, for example, radioactive materials. No question will require prior knowledge of theory or equipment that is beyond the syllabus: where necessary, candidates will be given the information that they need.

Mark scheme for Paper 5

Paper 5 will be marked using the generic mark scheme below. The expectations for each mark category are listed in the sections that follow.

Question 1			
Skill		*Breakdown of marks*	
Planning	15 marks	Defining the problem	3 marks
		Methods of data collection	5 marks
		Method of analysis	2 marks
		Safety considerations	1 mark
		Additional detail	4 marks

Question 2			
Skill		*Breakdown of marks*	
Analysis, conclusions and evaluation	15 marks	Approach to data analysis	1 mark
		Table of results	2 marks
		Graph	3 marks
		Conclusion	4 marks
		Treatment of errors	5 marks

Planning

Defining the problem

Candidates should be able to:

- identify the independent variable in the experiment;
- identify the dependent variable in the experiment;
- identify the variables that are to be kept constant.

Methods of data collection

Candidates should be able to:

- describe the method to be used to vary the independent variable;
- describe how the independent and dependent variables are to be measured;
- describe how other variables are to be kept constant;
- describe, with the aid of a clear labelled diagram, the arrangement of apparatus for the experiment and the procedures to be followed.

For full marks to be scored in this section, the overall arrangement must be workable, that is, it should be possible to collect the data required without undue difficulty if the apparatus were assembled as described. The measuring instruments chosen should be fit for purpose, in that they should measure the correct physical quantity to a suitable precision for the experiment.

Method of analysis

Candidates should be able to:

- describe how the data should be used in order to reach a conclusion, including details of derived quantities to be calculated and graphs to be drawn as appropriate.

Safety considerations

Candidates should be able to:

- assess the risks of their experiment;
- describe precautions that should be taken to keep risks to a minimum.

Additional detail

Up to four marks will be available for additional relevant detail. How these marks are awarded will depend on the experiment that is to be planned, but they might for example include marks for describing how additional variables are to be kept constant, or for a diagram of a circuit needed to make a particular measurement, or for additional safety considerations.

Analysis, conclusions and evaluation

Approach to data analysis

Candidates should be able to:

- rearrange expressions into the forms $y = mx + c$, $y = ax^n$ and $y = ae^{kx}$;
- plot a graph of y against x and use the graph to find the constants m and c in an equation of the form $y = mx + c$;
- plot a graph of log y against log x and use the graph to find the constants a and n in an equation of the form $y = ax^n$;
- plot a graph of ln y against x and use the graph to find the constants a and k in an equation of the form $y = ae^{kx}$;
- decide what derived quantities to calculate from raw data in order to enable an appropriate graph to be plotted.

Table of results

Candidates should be able to:

- complete a table of results following the conventions required for Paper 31/32;

Where logarithms are required, units should be shown with the quantity whose logarithm is being taken, e.g. ln (*d*/cm). The logarithm itself does not have a unit.

Graph

Candidates should be able to:

- plot a graph following the conventions required for Paper 31/32;
- show error bars, in both directions where appropriate, for each point on the graph;
- draw a straight line of best fit and a straight worst acceptable line through the points on the graph.

The worst acceptable line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points. It should be distinguished from the line of best fit either by being drawn as a broken line or by being clearly labelled.

Conclusion

Candidates should be able to:

- determine the gradient and *y*-intercept of a straight-line graph;
- derive expressions that equate to the gradient or the *y*-intercept of their straight lines of best fit;
- draw the required conclusions from these expressions.

The conclusion required will normally be the value of a constant.

Treatment of errors

Candidates should be able to:

- convert absolute error estimates into fractional or percentage error estimates and vice versa;
- show error estimates, in absolute terms, beside every value in a table of results;
- calculate error estimates in derived quantities;
- show error estimates as error bars on a graph;
- estimate the absolute error in the gradient of a graph by recalling that
  absolute error = gradient of line of best fit – gradient of worst acceptable line;
- estimate the absolute error in the *y*-intercept of a graph by recalling that
  absolute error = *y*-intercept of line of best fit – *y*-intercept of worst acceptable line;
- express a quantity as a value, an error estimate and a unit.

www.Students-Resource.com

SAFETY IN THE LABORATORY

Responsibility for safety matters rests with Centres. Attention is drawn to the following UK publications:

(a)   The requirements, as published in October 1989, of COSHH (the Committee on Safety of Substances Hazardous to Health).

(b)   Safe Practices in Chemical Laboratories, the Royal Society of Chemistry, 1989.

(c)   Safety in Science Laboratories, DES Safety Series, 2, HMSO, 1976.

(d)   Hazards in the Chemical Laboratory, ed. L. Bretherick, The Royal Society of Chemistry, 4th ed., 1986.

(e)   Safeguards in the School Laboratory, ASE, 9th ed., 1988.

(f)   Hazcards, as published by CLEAPSS Development Group, Brunel University, Uxbridge UB8 3PH.

MATHEMATICAL REQUIREMENTS

Arithmetic

Candidates should be able to:

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

(b)   recognise and use binary notation.

(c)   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)**.

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

(e)   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)   express small changes or errors as percentages and vice versa.

(g)   comprehend and use the symbols $<$, $>$, $\leqslant$, $\geqslant$, $\ll$, $\gg$, $\approx$, $/$, $\propto$, $<x>$ ($= \bar{x}$), Σ , Δx, δx, $\sqrt{}$.

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:**

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

www.Students-Resource.com

(d) **use sin $\theta \approx$ tan $\theta \approx \theta$ and cos $\theta \approx$ 1 for small θ ; sin^2 θ + cos^2 θ = 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) draw a curved trend line through a set of data points presented graphically, when the arrangement of these data points is clearly indicative of a non-linear relationship.

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

(g) 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}.

(h) **use logarithmic plots to test exponential and power law variations**.

(i) **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.**

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

www.Students-Resource.com

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, e.g. the Young modulus, relative molecular mass.

13. *Show* is used where a candidate is expected to derive a given result. It is important that the terms being used by candidates are stated explicitly and that all stages in the derivation are stated clearly.

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.

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The following list illustrates the symbols and units which will be used in question papers. This list is not differentiated between the AS and full A Level qualifications.

Corresponding lists of symbols and units have not been provided for the Options. Where possible, conventional, well-established symbols and units will be used in Options questions, i.e. as given in the current ASE publication.

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
heating	q, Q	J
change of internal energy	ΔU	J
power	P	W
pressure	p	Pa
torque	T	N m
gravitational constant	G	$N\ kg^{-2}\ m^2$
gravitational field strength	g	$N\ kg^{-1}$
gravitational potential	ϕ	$J\ kg^{-1}$
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	$rad\ s^{-1}$
wavelength	λ	m
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

www.Students-Resource.com

Quantity	Usual symbols	Usual unit
resistance	R	Ω
resistivity	ρ	Ω m
electric field strength	E	$N\,C^{-1}$, $V\,m^{-1}$
permittivity of free space	ε_o	$F\,m^{-1}$
capacitance	C	F
time constant	τ	s
magnetic flux	Φ	Wb
magnetic flux density	B	T
permeability of free space	μ_o	$H\,m^{-1}$
stress	σ	Pa
strain	ε	
spring constant	k	$N\,m^{-1}$
Young modulus	E	Pa
Celsius temperature	θ	°C
specific heat capacity	c	$J\,kg^{-1}\,K^{-1}$
molar heat capacity	C_m	$J\,mol^{-1}\,K^{-1}$
specific latent heat	L	$J\,kg^{-1}$
molar gas constant	R	$J\,mol^{-1}\,K^{-1}$
Boltzmann constant	k	$J\,K^{-1}$
Avogadro constant	N_A	mol^{-1}
number	N, n, m	
number density (number per unit volume)	n	m^{-3}
Planck constant	h	J s
work function energy	Φ	J
activity of radioactive source	A	Bq
decay constant	λ	s^{-1}
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 =	3.00×10^8 m s^{-1}
permeability of free space,	μ_o =	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o =	8.85×10^{-12} F m^{-1}
elementary charge,	e =	1.60×10^{-19} C
the Planck constant,	h =	6.63×10^{-34} J s
unified atomic mass constant,	u =	1.66×10^{-27} kg
rest mass of electron,	m_e =	9.11×10^{-31} kg
rest mass of proton,	m_p =	1.67×10^{-27} kg
molar gas constant,	R =	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A =	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k =	1.38×10^{-23} J K^{-1}
gravitational constant,	G =	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g =	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s =	$ut + \tfrac{1}{2}at^2$
	v^2 =	$u^2 + 2as$
work done on/by a gas	W =	$p\,\Delta V$
gravitational potential	ϕ =	$-\dfrac{Gm}{r}$
hydrostatic pressure	p =	$\rho g h$
pressure of an ideal gas	p =	$\dfrac{1}{3}\dfrac{Nm}{V}<c^2>$
simple harmonic motion	a =	$-\omega^2 x$
velocity of particle in s.h.m.	v =	$v_o \cos \omega t$
	v =	$\pm\omega\sqrt{\left(x_o^2 - x^2\right)}$
electric potential	V =	$\dfrac{Q}{4\pi\varepsilon_o r}$
capacitors in series	$1/C$ =	$1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	C =	$C_1 + C_2 + \ldots$
energy of charged capacitor	W =	$\tfrac{1}{2}QV$
resistors in series	R =	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$ =	$1/R_1 + 1/R_2 + \ldots$
alternating current/voltage	x =	$x_o \sin \omega t$
radioactive decay	x =	$x_o \exp(-\lambda t)$
decay constant	λ =	$\dfrac{0.693}{t_{\frac{1}{2}}}$

RESOURCE LIST

Teachers may find reference to the following books helpful. The list is by no means comprehensive but is intended to indicate some appropriate texts.

Texts should be chosen that will be of interest to students and that support the teacher's own style of presentation.

Endorsed textbooks: AS and A2 Core

The following book has been endorsed by CIE for use with this syllabus. It has been through an independent quality assurance process and matches the syllabus content closely.

International A/AS Level Physics, by C. Mee, M. Crundell, B. Arnold and W. Brown, ISBN 978-0340945643

Recommended textbooks: AS and A2 Core

The books listed below offer very comprehensive coverage of the Physics course. They do contain some material that is not required for this syllabus or that is treated at too great a depth.

Advanced Physics, by T. Duncan, published by Hodder & Stoughton, ISBN 978-0719576690

Advanced Physics, by S. Adams and J. Allday, published by Oxford University Press, ISBN 978-0199146802

Bath Advanced Science: Physics 2nd Edition, by R. Hutchings, published by Nelson Thornes, ISBN 978-0174387312

New Understanding Physics for Advanced Level (Fourth Edition), by J. Breithaupt, published by Nelson Thornes, ISBN 978-0748743148

The following books are smaller in extent than those listed above. They have been written to comply with particular A Level/AS syllabuses available in the UK. They contain less unnecessary material than the books listed above, but there are some differences between the UK and the CIE syllabuses, particularly as regards the way in which the subject matter is divided into AS and A2 sections.

Physics 1, by D. Sang, K. Gibbs and R. Hutchings, published by Cambridge University Press, ISBN 978-0521787185

Physics 2, by D. Sang, published by Cambridge University Press, ISBN 978-0521797153

Recommended textbooks: Applications of Physics

Each of the following books covers parts of the subject material of this section, but each book also contains much material that is not required.

Health Physics, by A. McCormick and A. Elliott, published by Cambridge University Press, ISBN 978-0521787262

Medical Physics (Second Edition), by M. Hollins, published by Nelson Thornes, ISBN 978-0174482536

Telecommunications, by J. Allen, published by Nelson Thornes, ISBN 978-0174482161

Telecommunications, by S. Kennedy, published by Cambridge University Press, ISBN 978-0521797474

Teachers' Resources: AS and A2 Core

The following books may be useful to teachers or students.

AS/A-Level Physics Essential Word Dictionary, by M. Crundell, published by Philip Allen Updates, ISBN 978-0860033776

The Complete A-Z Physics Handbook, by M. Chapple, published by Hodder & Stoughton, ISBN 978-0340688045

Advanced Level Practical Work for Physics, by M. Crundell and C. Mee, published by Hodder & Stoughton, ISBN 978-0340782453

www.Students-Resource.com

Practice in Physics (Third Edition), by T. Akrill and C. Millar, published by Hodder Murray, ISBN 978-0340758137

AS/A-Level Physics Question and Answer Guide, by M. Crundell, published by Philip Allen Updates, ISBN 978-0860037750

Teachers' Resources: Applications of Physics

The following book has been written to cover the subject material of the Applications of Physics section in this particular syllabus, and is strongly recommended. It is available from the CIE Publications Office using the appropriate order form.

Applications of Physics: Gathering and Communicating Information, CIE publication

Multimedia: CD-ROM

The CD-ROM listed below contains simulations of A Level Physics experiments and is likely to appeal to many students. It is recommended as a means of consolidating theory taught in class, but should not be used to replace first-hand laboratory work.

Virtual Physics Laboratory, available from www.vplab.co.uk

IT USAGE IN A LEVEL PHYSICS

Information Technology (IT) is a term used to cover a number of processes which have nowadays become an indispensable part of modern life. These processes are almost all based on the ability of the microprocessor chip to handle and manipulate large volumes of binary data in a short time. The use of IT is now an important factor in Physics education and it is hoped that all A Level candidates will have the opportunity to experience something of each of the following five processes:

1. **Data Capture (Hardware)**

    Sensors and Data Loggers can be used in any experiment to measure and store a number of physical quantities which vary with time. The sensor usually converts the quantity (e.g. temperature, light/sound intensity, position, count rate, magnetic flux density) into a voltage and the data logger samples this voltage at regular intervals from a few microseconds to a few hours depending on the duration of the 'experiment'. Each sample is converted into a binary/digital number and then stored in memory. The number of samples which are taken and stored depends on the particular data logger in use but it is usually several hundred. This large number has the effect that when the stored data is subsequently plotted graphically, the data points are so close together that the physical quantity appears to vary continuously over the timescale of the experiment.

    Sensors and Data Loggers are invaluable where the timescale of the 'experiment' is either very long (e.g. the variation of temperature over several days) or very short (e.g. the microphone signal of a handclap).

    Although most suppliers of Sensors and Data Loggers will indicate the type of experiment in which they may be used, the following are some examples of their use in standard A Level Physics experiments:

    the variation of voltage in capacitor charge/discharge circuits

    the variation of temperature in a latent heat demonstration

    the variation of induced e.m.f. in a coil as a magnet falls through it

    the variation of count rate in radioactive half-life measurement

    the variation of the position of an oscillator in simple harmonic motion

2. **Data Analysis (Software)**

    The most important type of program which allows the analysis of data is the SPREADSHEET into which data may be added manually (via the keyboard) or automatically (via the data logger). These programs have a number of different functions.
    One of the most important uses of the spreadsheet is that it allows its data to be analysed graphically. Two or more sets of corresponding data can be plotted as histograms or as pie charts or as simple line graphs or as X~Y scattergraphs (with or without a line of best fit).

    Once a spreadsheet has some starting point, it can calculate further data by applying a formula to the existing information. For example, if the spreadsheet started with a column of voltages and another column of corresponding currents it could then calculate a third column of the product of the voltage and current (i.e. the power) and a fourth column of the quotient of voltage and current (i.e. the resistance).

    A spreadsheet allows alphanumeric and mathematical analysis of its data. For example, one column of a spreadsheet could contain the names of students in a class while neighbouring columns could contain their raw scores for the various skills in a number of assessed practicals. The program could sort the names into alphabetical order or it could calculate mean or total values or apply some scaling factor to the different scores.

www.Students-Resource.com

A spreadsheet may also be used to build mathematical models of physical situations by calculating and plotting the necessary data. For example, the dynamic model of the two dimensional flight of a ball subject to air resistance may be examined without resorting to the calculus of sophisticated differential equations. Here, the positions of the ball after successive increments of time would be calculated algebraically and added to successive cells in the spreadsheet. These positions can then be plotted to reveal the ball's trajectory.

There are a number of general spreadsheet programs available and there are also some dedicated to the process of graph plotting and graphical analysis. For example:

EXCEL is a general spreadsheet for use with MACs and PCs and commonly used in education.
LOTUS 123 is a general spreadsheet for use with PCs and commonly used in business.

3. Teaching Aids and Resources (Software)

There are now many software packages available which have been designed to assist the teaching of almost every topic in A Level Physics. Some of these can be used as self-learning programs for an individual student to work through at their own pace while others can be used as computer generated images for classroom demonstrations and simulations. For example, 'Moving Molecules' illustrates basic kinetic theory by allowing students to visualise what is happening to the molecules in gases, liquids and solids as temperature and pressure are changed.

Although there are at present very few CD-ROMs of direct relevance to A Level Physics, this is a potential growth area and it is likely that in the near future much more use will be made of this resource.

The videocassette and the laser disc are two further sources of sometimes excellent demonstrations of various topics in Physics.

4. World Wide Web (WWW)

The WWW is a huge resource for teachers and students as it provides a huge database of information/resources. Websites that have been carefully reviewed for its content and suitability may be incorporated in the teaching of physics or given as reference materials for students. The WWW offers pictures, video clips and data bases on science, slides of lecture material, lesson plans, concept maps and test questions that could be used as additional teaching aids. Perhaps one of the greatest advantages of the WWW is its abundance of JAVA applets which could be used to illustrate effectively a specific scientific concept.

One desirable feature of the Internet is its capability to facilitate communication and dissemination of information electronically. Students may post questions on a topic of interest to a forum page. They may consult experts and communicate with others on the topic of study through e-mail.

5. Open Tools

Students should be encouraged to communicate scientific concepts using effective and appropriate Open Tools when making presentation. Word-processor, graphic organiser and spreadsheet may be utilised to organise and present text, tables, charts or graphical information.

Learning Outcomes

Finally, students must develop an awareness of the many possible applications and limitations of IT. They should be able to judge when to use IT to collect, handle and analyse scientific investigation. Students must be aware of the need to be critical of information produced using IT and that the results may be affected by the use of inaccurate data or careless entry. Most importantly, students will, in the process, learn to adopt a critical and

www.Students-Resource.com

creative approach to problem solving that would enable them to meet the challenges of the new knowledge-based economy.

Certain Learning Outcomes of the Syllabus have been marked with an asterisk (*) to indicate the possibility of the application of IT. A brief commentary on some of these objectives follows. In some cases, software is available commercially; in others, teachers may be able to develop their own. References in the notes below are to Learning Outcomes.

2.   MEASUREMENT TECHNIQUES

2(*a*) and *(b)* introduce candidates to the presentation of data in analogue and digital forms. In *(c),* calibration data may be stored on disc, as well as being read from hard copy. Data-capture techniques may be used in the measurement of magnetic flux density *{(a)}*. The treatment of uncertainties in *(f)* may be illustrated using IT simulation methods.

3.   KINEMATICS

3(b), (c), (d), (e), (*g*) and (*i*) offer an opportunity to use computer programs to simulate particle motion, and to demonstrate how quantities such as displacement, velocity and acceleration are related. Data-capture techniques may also be used in practical work on kinematics.

4.   DYNAMICS

In *(f)*, some examples of the application of Newton's second law may be presented through computer simulations. Likewise, collision problems {*(h), (i)* and (*j*)} may be presented very effectively using IT simulations. Experimental investigations of collisions lend themselves to data-capture techniques.

6.   WORK, ENERGY, POWER

6(c), (*g*) and *(l)* may be approached using simulation methods.

7.   MOTION IN A CIRCLE

Computer simulation techniques may be used effectively in the analysis of circular orbits *{(d)}*.

8.   GRAVITATIONAL FIELD

Theoretical predictions from Newton's law of gravitation and the concept of gravitational potential may be presented through computer simulations {*(b), (d), (g)* and *(i)*}. Information on the orbits of planets in the Solar System could be stored on a spreadsheet.

12. TEMPERATURE

Data-capture methods may be used with certain types of thermometer {*(d)*}.

14. OSCILLATIONS

The relations between acceleration, velocity and displacement in simple harmonic motion {*(b)* and *(g)},* and in damped and forced oscillation {*(i)* and *(k)}* may be demonstrated using computer simulations.

15. WAVES

The graphical representation of transverse and longitudinal waves {*(h)*} may be illustrated using computer simulations. Data capture may be applied in the measurement of the frequency and wavelength of sound {*(j)* and *(k)*}.

16. SUPERPOSITION

Computer simulations may be used to help students to model the concept of superposition {*(a)*}, and to investigate stationary waves {*(b)* and *(c)*}.

17. ELECTRIC FIELDS

Theoretical predictions from Coulomb's law and the concept of electric potential may be presented through computer simulations {*(f), (g)* and *(j)*}.

18. CAPACITANCE

Computer simulations may be used to illustrate *(f)*.

19. CURRENT OF ELECTRICITY

19(*i*), on the current-voltage characteristics of a number of devices, may be presented through computer simulations and data-capture.

20. D.C. CIRCUITS

The characteristics of thermistors and light-dependent resistors {*(k)*} may be presented using computer simulation techniques and data-capture.

23. ELECTROMAGNETIC INDUCTION

Computer simulations may be used to illustrate the phenomena of electromagnetic induction {*(d)*}.

24. ALTERNATING CURRENTS

Computer simulations, or demonstrations using a cathode-ray oscilloscope, are powerful methods of demonstrating alternating currents {*(b), (c), (g)* and *(j)*}.

25. CHARGED PARTICLES

The classic experiments on the determination of e {*(a)*} and e/m_e {*(e)*} may be presented through computer simulations. Theoretical predictions of the motion of charged particles in electric and magnetic fields may also be presented in this way {*(c)*}.

26. QUANTUM PHYSICS

Important concepts of the quantum theory may be presented using simulation techniques, and theoretical predictions may be demonstrated {*(c)* and *(h)*}. The relation of spectral lines to systems of discrete electron energy levels {*(j)*} may also be presented in this way.

27. NUCLEAR PHYSICS

Computer simulations of an α-particle scattering experiment {*(a)*} may be very effective. Simple models of the nuclear atom {*(b)*} may be presented using computer simulations. Data-capture methods may be used in experiments on radioactive decay {*(j)* and *(o)*}.