A Level

Physics

Session: 2000
Type: Syllabus
Code: 9244

OCR

RECOGNISING ACHIEVEMENT

Physics (Linear)

9244, 9433

2000

former Cambridge UCLES syllabus

Advanced Level

Syllabus

General Certificate of Education

9244 Physics

Advanced Level

Cambridge Linear Syllabus

9433 Physics Special Paper

Certification in 2000

CONTENTS

PHYSICS

GCE ADVANCED LEVEL

Subject 9244

Introduction

The Syllabus builds on knowledge and understanding appropriate to Physics at Grade C in a GCSE examination in Science: Double Award (or equivalent in Science: Physics). The Syllabus encompasses the *Subject Core* syllabus for A-level Physics as prescribed by SEAC, July 1993.

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 communications, 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 on pages 72 and 73.)

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;
10. organise and present information, ideas, descriptions and arguments clearly and logically, using appropriate spelling, punctuation and grammar.

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 on pages 72 and 73.)

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, plan experimental work, evaluate methods and techniques, and suggest possible improvements;
5. record observations, measurements, methods and techniques with due regard for precision, accuracy and units.

SCHEME OF ASSESSMENT

Candidates will be required to enter for Papers 1, 2, 3 and either Paper 4 or 5 or 7 or 9. Paper 9433 (Special Paper) is optional and freestanding.

Paper	Type of Paper	Duration	Marks
1	Multiple Choice	1 h	60
2	Structured Questions	1 h 45 min	90
3	Longer, Structured Questions	2 h 30 min	110
4 or 5	Practical Test	3 h	50
7	Extended Investigation	—	50
9	Separate Skills Assessment	—	50

Paper 1 (1 h, 30 marks weighted to 60)

30 multiple-choice questions based on the Core Syllabus. All questions will be of the direct choice type with four options.

Paper 2 (1 h 45 min, 90 marks)

A variable number of structured questions based on the Core Syllabus. All questions will be compulsory, and answers will be written in spaces provided on the Question Paper.

The last question will involve comprehension and the analysis of data and will carry 20 marks.

In this paper, a maximum of four marks will be allocated to the assessment of Quality of Language.

Paper 3 (2 h 30 min, 110 marks)

Section A will consist of 6 longer structured questions based on the Core Syllabus of which candidates will answer four. Each question will carry 20 marks.

Section B will consist of 7 structured questions, 1 question based on each of the Options. Candidates will be required to answer 2 questions with **no** restriction on choice of question. Each question will carry 15 marks. The rubric will advise candidates to spend about 40 minutes on *Section B*.

Paper 4 or 5 (3 h, 50 marks)

Paper 4 is not available in the UK in the November examination.

Practical Test. The paper will consist of two compulsory half-hour design exercises (16 marks) and two compulsory one-hour practical experiments (34 marks). See pages 50–55.

Paper 7

A Centre-based assessment of an Extended Investigation. Further details are given on pages 56 to 59 and 63 to 65.

Paper 9

A Centre-based assessment of three skills assessed during the course. Further details are given on pages 60 to 65.

Candidates re-entering in the November examination have the option of carrying forward their practical mark for *Paper 4, 5, 7 or 9* from the June examination by entering for *Paper 84 or 85 or 87 or 89* respectively.

***Special Paper** (9433)* (100 marks)

The Paper is optional and requires an extra fee. It is of 3 hours duration and contains more difficult questions based only on the Core Syllabus. *Section A* will be compulsory and will consist of a number of short questions. This section will carry 40 marks. The rubric will advise candidates to spend about 70 minutes on *Section A*. *Section B* will consist of 6 longer questions of which candidates will answer any three. Each of these questions will carry 20 marks. In *Section B* a maximum of two questions will be set in which a knowledge of differential and/or integral calculus will be advantageous. Such questions will be marked with an asterisk (*) and will be identified as requiring the use of calculus. **Candidates may be entered for the special paper even if they have not been entered for syllabus 9244.**

MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

***Theory Papers** (Papers 1, 2 and 3)* (260 marks in total)

Knowledge with understanding **(Assessment Objectives *A1–A5*)** – approximately 70 marks allocated to recall and 70 marks allocated to understanding.

Handling, applying and evaluating information **(Assessment Objectives *B1–B9*)**– approximately 120 marks.

Fifteen per cent of the total marks will be awarded for awareness of the social, economic, environmental and technological implications and applications of Physics. These will be awarded within the ***Knowledge with understanding*** and ***Handling, applying and evaluating information*** categories.

***Practical Test** (Paper 4 or 5)* (50 marks)

Experimental skills and investigations – the practical papers are intended to test appropriate aspects of skills ***C1–C5*** on page 6 although some aspects of these skills may be tested in theory papers. The practical papers may also involve some calculations based on experimental results. See also pages 50–55.

Mathematical Requirements

The mathematical requirements are given on pages 66 to 67.

Data and Formulae

A data sheet and a formulae sheet will be inserted as pages 2 and 3 in papers 0, 1, 2 and 3. See also pages 68 to 69.

Symbols, Signs and Abbreviations

Wherever symbols, signs and abbreviations are used in examination papers, the recommendation made in the ASE publication *SI Units, Signs, Symbols and Abbreviations* will be followed, except where these have been superseded by *Signs, Symbols and Systematics* (*The ASE Companion to 5–16 Science, 1995*). 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 1995 ASE publication.

STRUCTURE OF THE SYLLABUS

The Syllabus has been constructed on a 'core plus options' basis in which the 'core' represents approximately 90% of the whole course. Candidates will be expected to study two options, representing approximately 10% of the course.

Seven options are available:

(a) Option A Astrophysics and Cosmology

(b) Option C The Physics of Materials

(c) Option E Electronics

(d) Option F The Physics of Fluids

(e) Option M Medical Physics

(f) Option P Environmental Physics

(g) Option T Telecommunications

In order to specify the syllabus as precisely as possible and also to emphasise the importance of skills other than recall, assessment objectives have been used throughout. Each part of the syllabus is specified by a brief **Contents** section followed by detailed **Assessment Objectives**. Although this format, of necessity, makes the syllabus a much lengthier document, it is hoped that the format will be helpful to teachers. 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 assessment objectives 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.

The leaflet *IT Usage in A-level and AS-level Physics (Linear and Modular)* suggesting appropriate applications of IT, is printed on pages 75–87.

SUBJECT CONTENT

SECTION I GENERAL PHYSICS
(CORE: Sections I–V inclusive)

1. Physical Quantities and Units

Content

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

Assessment Objectives

Candidates should be able to:

(a) understand 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 on pages 70 and 71 as appropriate.

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

(e) understand and use the conventions for labelling graph axes and table columns as set out in the ASE publication *SI Units, Signs, Symbols and Abbreviations*, except where these have been superseded by *Signs, Symbols and Systematics* (*The ASE Companion to 5–16 Science*, 1995).

(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) understand 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 between scalar and vector quantities and give examples.

(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

Assessment Objectives

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, micrometer, and callipers;

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

(3) measure an angle using a protractor;

(4) measure lengths of time using clocks, stopwatches, and the calibrated time-base of a cathode-ray oscilloscope;

(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.

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

**(c)* use calibration curves.

(d) understand the distinction between systematic errors (including zero errors) and random errors.

(e) understand 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

3. Kinematics

Content

3.1 Rectilinear motion
3.2 Non-linear motion

Assessment Objectives

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 the distance travelled by calculating 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)* use equations which represent uniformly accelerated motion in a straight line, including falling in a uniform gravitational field without air resistance.

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

**(i)* 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

Assessment Objectives

Candidates should be able to:

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

(b) demonstrate 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 use the relationship $F = ma$, appreciating that acceleration and force are always in the same direction.

(g) state the principle of conservation of momentum.

**(h)* use the principle of conservation of momentum in simple applications 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)* understand 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

Assessment Objectives

Candidates should be able to:

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

(b) understand the origin of the upthrust acting on a body in a fluid.

(c) understand qualitatively 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) understand that the weight of a body may be taken as acting at a single point known as its centre of gravity.

(f) understand a couple as a pair of forces tending to produce rotation only.

(g) define and use 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

Assessment Objectives

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) understand 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 use the formula $E_k = \frac{1}{2}mv^2$.

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

**(g)* understand and use the relationship between force and potential energy in a uniform field.

(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) understand the concept of internal energy.

(k) appreciate the importance of energy losses in practical devices and use the concept of efficiency.

(l) understand and use the kilowatt hour (kW h) as a unit of energy.

(m) appreciate the importance of energy costs.

*(n) relate power to work done and time taken using appropriate examples, and identify power as the product of force and velocity.

7. Gravitational Field

Content

7.1 Gravitational field
7.2 Force between point masses
7.3 Field of a point mass
7.4 Field near to the surface of the Earth
7.5 Gravitational potential

Assessment Objectives

Candidates should be able to:

(a) understand a gravitational field as a 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 $g = Gm/r^2$ for the gravitational field strength of a point mass.

(d) recall and use the equation $g = Gm/r^2$ for the gravitational field strength of a point mass.

(e) appreciate that on the surface of the Earth g is approximately constant and is called the acceleration of free fall.

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

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

(h) use the equation $\phi = -Gm/r$ for the potential in the field of a point mass.

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

8. Motion in a Circle

Content

8.1 Kinematics of uniform circular motion
8.2 Centripetal acceleration
8.3 Centripetal force

Assessment Objectives

Candidates should be able to:

(a) express angular displacement in radians.

(b) understand and use the concept of angular velocity.

(c) recall and use $v = r\omega$.

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

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

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

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

(h) understand geostationary orbits and their application.

SECTION III OSCILLATIONS AND WAVES

9. Oscillations

Content

9.1 Simple harmonic motion
9.2 Energy in simple harmonic motion
9.3 Damped and forced oscillations: resonance

Assessment Objectives

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)* describe graphically the changes in displacement, velocity and acceleration during simple harmonic motion.

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

(f) 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.

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

(h) 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.

(i) appreciate that there are some circumstances in which resonance is useful and other circumstances in which resonance should be avoided.

10. Waves

Content

10.1 Reflection and refraction of light
10.2 Total internal reflection
10.3 Progressive waves
10.4 Transverse and longitudinal waves. Polarisation
10.5 Determination of speed, frequency and wavelength

Assessment Objectives

Candidates should be able to:

(a) recall the laws of reflection of light.

(b) show awareness of the properties of the image as seen in a plane mirror.

(c) recall the laws of refraction of light.

(d) define refractive index as $\sin i/\sin r$ and as c_1/c_2.

(e) describe what is meant by critical angle and total internal reflection.

(f) relate refractive index to critical angle by the equation $n = 1/\sin C$.

(g) describe applications of total internal reflection such as reflecting prisms and fibre optics.

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

(i) understand and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed.

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

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

(l) appreciate the energy transfer due to a progressive wave.

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

(n) describe the nature of the motions in transverse and longitudinal waves.

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

(p) understand polarisation as a phenomenon associated with transverse waves.

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

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

11. Superposition

Content

11.1 Interference
11.2 Two-source interference patterns
11.3 Stationary waves
11.4 Diffraction
11.5 Diffraction grating

Assessment Objectives

Candidates should be able to:

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

(b) understand the term interference.

(c) describe experiments which demonstrate two-source interference in a ripple tank, for light and for microwaves.

(d) explain the meaning of the term coherence.

(e) understand the conditions required if two-source interference fringes are to be observed.

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

**(g)* describe experiments which demonstrate stationary waves for microwaves, stretched strings and air columns.

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

(i) explain the meaning of the term diffraction.

(j) describe experiments which demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap.

(k) recall 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.)

12. Electromagnetic Waves

Content

12.1 The electromagnetic spectrum

Assessment Objectives

Candidates should be able to:

(a) describe the main features of the electromagnetic spectrum and recall that all electromagnetic waves travel with the same speed in free space.

(b) recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays.

SECTION IV ELECTRICITY AND MAGNETISM

13. Electrostatics

Content

13.1 Simple electrostatic phenomena

Assessment Objectives

Candidates should be able to:

(a) state that there are two types of charge.

(b) describe and explain charging by friction and by induction, appreciating that charge is always conserved.

(c) describe an experiment which demonstrates that like charges repel and unlike charges attract.

(d) distinguish between electrical conductors and insulators and give typical examples.

(e) use a simple electron model to distinguish between conductors and insulators.

(f) describe simple practical applications of electrostatic phenomena including paint spraying and dust extraction.

(g) appreciate the potential hazards associated with charging by friction.

14. Current Electricity

Content

14.1 Electric current
14.2 Transport of charge
14.3 Potential difference
14.4 Resistance and resistivity
14.5 Sources of electromotive force

Assessment Objectives

Candidates should be able to:

(a) understand electric current as the flow of charged particles.

(b) define charge and the coulomb.

(c) understand that current is rate of flow of charge, and recall and use the equation $Q = It$.

(d) define potential difference and the volt.

(e) recall and use $V = W/Q$.

(f) recall and use $P = VI$, $P = I^2R$.

(g) define resistance and the ohm.

(h) recall and use $V = IR$.

**(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.

(k) state Ohm's law.

(l) recall and use $R = \rho l/A$.

(m) use the concept that e.m.f. is defined in terms of the energy transferred by a source in driving unit charge round a complete circuit.

(n) use energy considerations to distinguish between e.m.f. and p.d.

(o) appreciate that sources of e.m.f. have internal resistance and understand the simple consequences of internal resistance for external circuits.

15. D.C. Circuits

Content

15.1 Practical circuits
15.2 Conservation of charge and energy
15.3 Balanced potentials

Assessment Objectives

Candidates should be able to:

(a) recall and use appropriate circuit symbols as set out in *SI Units, Signs, Symbols and Abbreviations* (ASE, 1981) and *Signs, Symbols and Systematics* (ASE, 1995).

(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 this as a consequence of conservation of charge.

(d) recall Kirchhoff's second law and appreciate this as a consequence of conservation of energy.

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

(f) use a 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) use a formula for the combined resistance of two or more resistors in parallel.

(i) apply Kirchhoff's laws to simple circuits.

(j) understand the use of a potential divider as a source of variable p.d.

**(k)* describe and 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 understand the principle of the potentiometer as a means of comparing potential differences.

16. Electric Field

Content

16.1 Concept of an electric field
16.2 Force between point charges
16.3 Electric field of a point charge
16.4 Uniform electric fields
16.5 Electric potential

Assessment Objectives

Candidates should be able to:

(a) understand 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 Coulomb's law in the form $F = Q_1 Q_2/4\pi\varepsilon_0 r^2$ for the force between two point charges in free space or air.

**(d)* recall and use $E = Q/4\pi\varepsilon_0 r^2$ for the field strength of a point charge in free space or air.

(e) calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation.

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

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

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

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

**(j)* use the equation $V = Q/4\pi\varepsilon_0 r$ for the potential in the field of a point charge.

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

17. Capacitance

Content

17.1 Capacitors and capacitance
17.2 Energy stored in a capacitor

Assessment Objectives

Candidates should be able to:

(a) understand the function of capacitors in simple circuits.

(b) define capacitance and the farad.

(c) recall and use $C = Q/V$.

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

(e) use formulae for capacitors in series and in parallel.

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

18. Magnetic Fields

Content

18.1 Concept of magnetic field

Assessment Objectives

Candidates should be able to:

(a) understand a magnetic field as 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.

19. Electromagnetism

Content

19.1 Force on a current-carrying conductor
19.2 Force on a moving charge
19.3 Magnetic fields due to currents
19.4 Force between current-carrying conductors

Assessment Objectives

Candidates should be able to:

(a) appreciate that a force might act on a current-carrying conductor placed in a magnetic field.

(b) recall and use 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) understand 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 use $F = BQv\sin\theta$.

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

(h) demonstrate a qualitative knowledge of the effect of a ferrous core on the field due to a solenoid.

(i) describe the principle of the electromagnet and appreciate its uses.

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

**(k)* show an awareness of the ability to measure flux density using a calibrated Hall probe.

20. Electromagnetic Induction

Content

20.1 Laws of electromagnetic induction

Assessment Objectives

Candidates should be able to:

(a) define magnetic flux and the weber.

(b) recall and use $\Phi = BA$.

(c) define magnetic flux linkage.

**(d)* describe and interpret experiments which demonstrate the relationship between the magnitude and direction of an induced e.m.f. and the change of flux linkage producing the e.m.f.

(e) recall and use Faraday's law of electromagnetic induction to determine the magnitude, and Lenz's law to determine the direction of induced e.m.f's.

(f) describe and explain simple applications of electromagnetic induction.

21. Alternating Currents

Content

21.1 Characteristics of alternating currents
21.2 The transformer
21.3 Transmission of electrical energy
21.4 Rectification

Assessment Objectives

Candidates should be able to:

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

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

**(c)* represent an alternating current or an alternating voltage by an equation of the form $x = x_0 \sin \omega t$.

(d) understand the distinction between r.m.s. and peak values and recall and use the relationship $I_{rms} = I_0/\sqrt{2}$ for the sinusoidal case.

(e) describe the structure and principle of operation of a simple iron-cored transformer.

(f) recall and use $N_s/N_p = V_s/V_p = I_p/I_s$ for an ideal transformer.

(g) appreciate the scientific and economic advantages of alternating current and of high voltages for the transmission of electrical energy.

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

(i) describe and explain the use of a single diode for the half-wave rectification of an alternating current.

(j) describe and explain the use of four diodes (bridge rectifier) for the full-wave rectification of an alternating current.

**(k)* describe and explain the use of a single capacitor for smoothing, including the effect of the value of capacitance in relation to the load resistance.

SECTION V MATTER

22. Phases of Matter

Content

22.1 Density
22.2 Solids, liquids, gases
22.3 Pressure in fluids
22.4 Change of phase

Assessment Objectives

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 $p = \rho gh$.

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

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

23. Deformation of Solids

Content

23.1 Stress, strain
23.2 Elastic and plastic behaviour

Assessment Objectives

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, 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.

24. Temperature

Content

24.1 Temperature scales
24.2 Practical thermometers

Assessment Objectives

Candidates should be able to:

(a) appreciate how a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties.

*(b) describe the principal features of liquid-in-glass, resistance and thermocouple thermometers as previously calibrated instruments, and be aware of their relative advantages and disadvantages.

(c) demonstrate knowledge 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).

(d) show familiarity with temperatures measured in kelvin, degrees Celsius and on empirical centigrade scales.

25. Thermal Properties of Materials

Content

25.1 Specific heat capacity
25.2 Specific latent heat
25.3 Internal energy
25.4 First law of thermodynamics

Assessment Objectives

Candidates should be able to:

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

(b) define and use specific heat capacity, and show an awareness of the principles of its determination by electrical methods.

(c) describe melting and boiling in terms of energy input without a change in temperature.

(d) define and use specific latent heat, and show an awareness of the principles of its determination by electrical methods.

(e) describe and explain the cooling which accompanies evaporation both in terms of specific latent heat and in terms of the escape of high energy molecules.

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

(g) recall 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.

26. Ideal Gases

Content

26.1 Equation of state
26.2 Kinetic theory of gases
26.3 Pressure of a gas
26.4 Kinetic energy of a molecule

Assessment Objectives

Candidates should be able to:

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

(b) recall the basic assumptions of the kinetic theory of gases.

(c) explain how molecular movement causes the pressure exerted by a gas and provide a simple derivation of $p = \frac{1}{3}\frac{Nm}{V}<c^2>$. ($N$ = number of molecules.)

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

27. Transfer of Thermal Energy

Content

27.1 Thermal equilibrium
27.2 Thermal conduction
27.3 Convection
27.4 Radiation

Assessment Objectives

Candidates should be able to:

(a) appreciate that thermal energy is transferred from a region of higher temperature to a region of lower temperature.

(b) appreciate that regions of equal temperature will be in thermal equilibrium.

(c) describe and explain the process of convection as a consequence of change of density.

(d) demonstrate a qualitative understanding that bodies emit electromagnetic radiation at a rate which increases with increasing temperature.

(e) describe and explain simple applications involving the transfer of energy by conduction, convection and radiation.

28. Charged Particles

Content

28.1 Electrons
28.2 Beams of charged particles

Assessment Objectives

Candidates should be able to:

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

**(b)* understand the principles of determination of e by Millikan's experiment.

**(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 principles of one method for the determination of v and e/m_e for electrons.

29. Quantum Physics

Content

29.1 Energy of a photon
29.2 Photoelectric emission of electrons
29.3 Wave-particle duality
29.4 Energy levels in atoms
29.5 Line spectra

Assessment Objectives

Candidates should be able to:

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

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

**(c)* describe the phenomena of the photoelectric effect.

(d) recall the significance of threshold frequency.

(e) explain why the maximum photoelectric energy is independent of intensity, and why the photoelectric current is proportional to intensity.

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

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

(h) appreciate 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.

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

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

**(k)* understand the existence of discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) and explain how this leads to spectral lines.

(l) distinguish between emission and absorption line spectra.

(m) recall and use the relation $hf = E_1 - E_2$.

30. Atomic Structure

Content

30.1 The nuclear atom
30.2 The nucleus
30.3 Isotopes
30.4 Mass excess and nuclear binding energy
30.5 Nuclear processes

Assessment Objectives

Candidates should be able to:

**(a)* demonstrate a qualitative understanding of the α-particle scattering experiment and the evidence it provides for 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) understand 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 the association between energy and mass as represented by $E = mc^2$.

(g) illustrate graphically the variation of binding energy per nucleon with nucleon number.

(h) describe the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission.

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

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

31. Radioactivity

Content

31.1 Types of ionising radiation
31.2 Hazards and safety precautions
31.3 Radioactive decay
31.4 Radioisotopes

Assessment Objectives

Candidates should be able to:

(a) appreciate the spontaneous and random nature of nuclear decay.

(b) show an awareness of the existence, origins and scientific and environmental importance of background radiation.

(c) describe the nature of α-particles, β-particles and γ-rays as different types of ionising radiation.

(d) distinguish between α-particles, β-particles and γ-rays with reference to charge, mass, speed, effect of electric and magnetic fields, and penetrating properties.

**(e)* illustrate the random nature of radioactive decay by observation of the fluctuations in count rate.

(f) show an awareness of the environmental hazards of ionising radiations and the safety precautions which should be taken in the handling and disposal of radioactive materials.

(g) define the terms activity and decay constant and recall and use $A = \lambda N$.

**(h)* recognise, use and represent graphically solutions of the decay law based on $x = x_0 \exp(-\lambda t)$ for activity, number of undecayed particles and received count rate.

(i) define half-life.

(j) use the relation $\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$.

(k) describe briefly the use of radioisotopes, providing one example of each of the following: the use of tracers; the use of the penetrating properties of radiation; the use of ionising radiation in radiotherapy.

OPTION A

Astrophysics and Cosmology

[A detailed treatment of this topic is given in the Option Booklet *Astrophysics and Cosmology*.]

A1. Contents and Scale of the Universe

Content

1.1 Contents of the Universe
1.2 Scale of the Universe

Assessment Objectives

Candidates should be able to:

(a) describe the principal contents of the Universe, including stars, galaxies and radiation.

(b) describe the Solar system in terms of the Sun, planets, planetary satellites and comets. Details of individual planets are not required.

(c) define distances measured in astronomical units (AU), parsecs (pc) and light-years.

(d) recall the approximate magnitudes, in metres, of the AU, pc and light-year.

(e) appreciate the sizes and masses of objects in the Universe.

(f) appreciate the distances involved between objects in the Universe.

A2. The Standard Model of the Universe

Content

2.1 Hubble's law
2.2 Olbers' paradox
2.3 The Cosmological Principle
2.4 Age of the Universe
2.5 Evolution of the Universe

Assessment Objectives

Candidates should be able to:

**(a)* describe and interpret Hubble's redshift observations.

(b) recall and interpret Hubble's law.

(c) convert the Hubble 'constant' (H_0) from its conventional units (km s^{-1} Mpc^{-1}) to SI (s^{-1}).

(d) recall Olbers' paradox.

(e) interpret Olbers' paradox to explain why it suggests that the model of an infinite, static Universe is incorrect.

(f) understand what is meant by the Cosmological Principle.

(g) describe, and interpret the significance of, the microwave background radiation.

(h) understand that the standard (hot big bang) model of the Universe implies a finite age for the Universe.

(i) recall and use the expression $t \approx 1/H_0$ to estimate the order of magnitude of the age of the Universe.

(j) describe qualitatively the evolution of the Universe from 0.01 s after the big bang to the present, including the production of an excess of matter over antimatter, the formation of light nuclei, the recombination of electrons and nuclei and the formation of stars, galaxies and galactic clusters.

(k) understand that the Universe may be 'open', 'flat' or 'closed', depending on its density.

(l) appreciate that the age of the Universe cannot be determined from the Hubble constant until its density is known accurately.

(m) understand that the ultimate fate of the Universe depends on its density.

(n) recall that it is currently believed that the density of the Universe is close to, and possibly exactly equal to, the critical density needed for a 'flat' cosmology.

(o) derive, from Newton's law of gravitation, the expression $\rho_0 = \dfrac{3H_0^{\,2}}{8\pi G}$ and recognise that General Relativity is needed for a strict derivation.

(p) use the expression $\rho_0 = \dfrac{3H_0^{\,2}}{8\pi G}$.

(q) appreciate that there is no experimental evidence for the physics involved at the energies prevailing during the evolution of the Universe before about 1 ms.

(r) outline the difficulties involved in projecting the evolution of the Universe back before 0.01 s.

A3. Techniques of Observation

Content

3.1 Electromagnetic radiation and the Earth's atmosphere
3.2 Observation platforms

Assessment Objectives

Candidates should be able to:

(a) appreciate that stars and galaxies are detected by the electromagnetic radiation which they emit.

**(b)* appreciate that planets are detected by reflected sunlight.

(c) describe the transparency of the Earth's atmosphere to different regions of the electromagnetic spectrum from radio waves to X-rays.

(d) explain why the transparency of the Earth's atmosphere has led to observations which are terrestrial, high-altitude, from satellites or from space probes.

**(e)* show an awareness of the conflict between the value of astronomical research and economic considerations.

OPTION C

The Physics of Materials

[A detailed treatment of this topic is given in the Option Booklet *The Physics of Materials*.]

C1. Structure of Crystals

Content

1.1 Cubic and hexagonal structures
1.2 Crystal defects

Assessment Objectives

Candidates should be able to:

(a) describe crystal structures including simple cubic, face-centred cubic (fcc) body-centred cubic (bcc) and hexagonal close-packed (hcp).

(b) describe cubic and hexagonal close-packed structures in terms of stacked, close-packed layers of identical spheres.

(c) appreciate that cubic close-packing gives a face-centred cubic structure.

(d) understand and use the concept of the Bravais lattice to describe cubic and hexagonal structures.

(e) recall that a stacking fault is a disruption in a regular sequence.

(f) understand what is meant by a dislocation in a lattice structure.

(g) describe how simple dislocations may be illustrated using bubble rafts.

(h) understand that in a close-packed metallic lattice, perfect dislocations dissociate into two partial dislocations separated by a stacking fault.

C2. Microstructure

Content

2.1 Grains and grain structure
2.2 Treatment of metals
2.3 Non-metallic materials

Assessment Objectives

Candidates should be able to:

(a) appreciate the concept of a metallic grain.

(b) recall the mechanical properties of strength and stiffness and appreciate that these properties may be affected by grain size.

(c) describe the grain structure of a typical single-phase metal, e.g. copper.

(d) relate the grain structure of a single-phase metal to its mechanical properties.

(e) describe simple experiments to illustrate quenching, annealing and tempering of steel.

(f) recall what is meant by work hardening.

(g) understand that work hardening increases the number of dislocations in the material and hence the impedance to dislocation movement, so increasing its strength and hardness.

(h) understand the distinction between tough, strong and stiff materials.

(i) recall the structures of simple polymers, glasses, ceramics and fibre-reinforced composites.

(j) relate the structures of simple polymers, glasses, ceramics and fibre-reinforced composites to their toughness.

C3. Materials Testing

Content

3.1 Materials testing
3.2 Properties and microstructure
3.3 Deterioration and failure

Assessment Objectives

Candidates should be able to:

(a) describe how a tensile test may be conducted on a sample of material.

(b) draw stress-strain and force-extension curves for a material and identify the following: limit of proportionality, elastic limit, yield point, ultimate tensile strength, breaking point.

(c) recall the region on the stress-strain or force-extension curve where elastic behaviour occurs and identify this with bond deformation.

(d) recall the region on the stress-strain or force-extension curve where plastic behaviour occurs and identify this with dislocation movement.

(e) understand the concept of hysteresis.

**(f)* relate the area of the hysteresis loop on a force-extension graph to work done and change in internal energy of the material.

(g) recognise fatigue as a consequence of cyclic stress insufficient to cause immediate failure.

(h) recall that steel shows a fatigue limit whereas many non-ferrous metals do not.

(i) recall the appearance of a fatigue failure.

(j) describe situations which lead to fatigue failure.

(k) recall that creep is failure due to sustained stress, below that required for immediate failure, combined with elevated temperature.

**(l)* apply knowledge of properties of materials to the solving of simple engineering problems.

OPTION E

Electronics

[A detailed treatment of this topic is given in the Option Booklet *Electronics*.]

E1. Analogue Systems

Content

1.1 Transducers
1.2 The ideal operational amplifier
1.3 Operational amplifier circuits

Assessment Objectives

Candidates should be able to:

**(a)* recall and understand the use of the light-dependent resistor (LDR), the thermistor (negative temperature coefficient only) and the strain gauge in potential divider circuits to provide voltages representative of physical quantities.

(b) recall and understand the use of the light-emitting diode (LED), the buzzer and the relay as output devices.

(c) describe the properties of the ideal operational amplifier.

(d) understand the use of an operational amplifier as a comparator.

(e) understand the principles of negative and of positive feedback in an amplifier.

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

(g) use the virtual earth approximation to derive an expression for the gain of inverting amplifiers.

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

(i) recall and explain the effect of negative feedback on the gain and on the bandwidth of an operational amplifier.

(j) describe the use of an operational amplifier as a summing amplifier in the inverting mode.

(k) describe the use of an operational amplifier as a voltage follower.

(l) describe the use of an operational amplifier as a non-inverting Schmitt trigger, with positive feedback provided by a potential divider.

E2. Digital Systems

Content

2.1 Logic gates
2.2 Logic gate combinations

Assessment Objectives

Candidates should be able to:

(a) understand the function of each of the following logic gates: NOT, AND, NAND, OR, NOR and represent these functions by means of truth tables (limited to a maximum of two inputs, where appropriate).

(b) recall how to combine AND, NOT and OR gates, or NAND gates only, to form EX-OR and EX-NOR gates.

(c) analyse circuits using combinations of logic gates to perform control functions.

(d) understand how to construct and interpret truth tables for combinations of logic gates.

E3. Electronics in Society and Industry

Content

3.1 The impact of electronics in society and industry

Assessment Objectives

Candidates should be able to:

(a) describe the function of simple electronic devices and systems which are found in the home, in industry and in communications.

(b) appreciate the impact of electronic devices and systems on domestic and industrial activities.

(c) appreciate the impact of electronic devices and systems on modern communication.

OPTION F

The Physics of Fluids

[A detailed treatment of this topic is given in the Option Booklet *The Physics of Fluids*.]

F1. Buoyant Forces

Content

1.1 Archimedes' principle
1.2 Equilibrium of floating objects

Assessment Objectives

Candidates should be able to:

(a) recall that an upthrust is provided by the fluid displaced by a submerged or floating object.

(b) calculate the upthrust in terms of the weight of the displaced fluid (Archimedes' principle).

(c) understand that, for an object floating in equilibrium, the upthrust is equal to the weight of the object (the principle of flotation).

(d) appreciate that the upthrust on a floating object acts at the centre of mass of the displaced fluid (the centre of buoyancy).

(e) appreciate what is meant by the metacentre of a floating object, and understand how the relative positions of the metacentre and of the centre of mass of the object determine its stability.

(f) explain how Archimedes' principle is applied to marine craft and submarines.

F2. Non-Viscous Fluid Flow

Content

2.1 Ideal fluids in motion
2.2 Streamlines and the equation of continuity
2.3 The Bernoulli effect

Assessment Objectives

Candidates should be able to:

(a) understand the terms steady (laminar, streamline) flow, incompressible flow, non-viscous flow, as applied to the motion of an ideal fluid.

(b) understand how the velocity vector of a particle in an ideal fluid in motion is related to the streamline associated with that particle.

(c) understand how streamlines can be used to define a tube of flow.

(d) derive and use the equation Av = constant (the equation of continuity) for the flow of an ideal, incompressible fluid.

(e) appreciate that the equation of continuity is a form of the principle of conservation of mass.

(f) appreciate that pressure differences can arise from different rates of flow of a fluid (the Bernoulli effect).

(g) derive the Bernoulli equation in form $p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$ for the case of a horizontal tube of flow.

(h) appreciate that the Bernoulli equation is a form of the principle of conservation of energy.

**(i)* explain how the Bernoulli effect is applied in the filter pump, in the Venturi meter, in atomisers and in the flow of air over an aerofoil.

F3. Viscous Fluids

Content

3.1 Viscosity
3.2 Terminal velocity
3.3 Turbulence

Assessment Objectives

Candidates should be able to:

(a) recall that viscous forces in a fluid cause a retarding force to be exerted on an object moving through a fluid.

(b) understand that, in viscous flow, different layers of the liquid move with different velocities.

(c) appreciate what is meant by the velocity gradient in viscous flow.

(d) understand how the magnitude of the viscous force in fluid flow depends on the velocity gradient and on the viscosity of the fluid.

(e) use base units to confirm the form of the equation $F = Ar\eta v$, where A is a dimensionless constant (Stokes' law), for the drag force under laminar conditions in a viscous fluid.

**(f)* use Stokes' law to explain quantitatively how a body falling through a viscous fluid under laminar conditions attains a terminal velocity.

(g) describe an experiment, based on the measurement of terminal velocity, to determine the viscosity of a liquid.

(h) appreciate that, at a sufficiently high velocity, the flow of viscous fluid undergoes a transition from laminar to turbulent conditions.

(i) recall that the onset of turbulence is determined by the Reynolds' number $R_e = \rho vr/\eta$.

(j) use base units to show that the Reynolds' number is dimensionless.

(k) use base units to confirm the form of the equation $F = Br^2\rho v^2$, where B is a dimensionless constant, for the drag force under turbulent conditions in a viscous fluid.

(l) appreciate that the majority of practical examples of fluid flow and resistance to motion in fluids involve turbulent, rather than laminar, conditions.

(m) give qualitative explanations, in terms of turbulence and the Bernoulli effect, for the swing of a spinning cricket ball and the lift of a spinning golf ball.

**(n)* understand what is meant by the drag coefficient of a moving vehicle, and carry out simple calculations involving the coefficient.

OPTION M

Medical Physics

[A detailed treatment of this topic is given in the Option Booklet *Medical Physics*.]

M1. Medical Imaging

Content

1.1 Diagnostic techniques used in medicine
1.2 Production and use of X-rays
1.3 Production and use of ultrasound
1.4 Use of magnetic resonance, radioactive tracers and lasers

Assessment Objectives

Candidates should be able to:

(a) describe in simple terms the need for non-invasive techniques of diagnosis.

(b) understand qualitatively the importance of limiting exposure to radiation with particular reference to the type of radiation.

(c) give a simple description of the production of X-rays by electron bombardment of a metal target.

(d) understand the use of X-rays in imaging internal body structures, including an appreciation of sharpness and contrast in X-ray imaging.

**(e)* recall and use the equation $I = I_0 e^{-\mu x}$ for the attenuation of X-rays in matter.

(f) explain the principles of generation of ultrasonic waves using piezo-electric transducers.

(g) outline the use of ultrasound to obtain diagnostic information about internal structures.

**(h)* outline the use of magnetic resonance to obtain diagnostic information about internal structures.

(i) outline the use of lasers in diagnosis, e.g. in pulse oximetry and in endoscopes.

(j) describe examples of the use of radioactive tracers in diagnosis.

M2. Medical Treatment

Content

2.1 Biological effects
2.2 Radiotherapy
2.3 Laser treatment

Assessment Objectives

Candidates should be able to:

(a) describe in simple terms the effects of ionising radiation on living matter.

(b) understand qualitatively the importance of limiting exposure to ionising radiation.

(c) distinguish between dose rate and dose, paying particular attention to the type of incident radiation.

(d) describe the use of X-rays and of implanted sources in the treatment of malignancy.

(e) describe examples of the use of lasers in clinical therapy, e.g. as a scalpel or as a coagulator.

M3. The Physics of Sight

Content

3.1 The eye
3.2 Defects of the eye

Assessment Objectives

Candidates should be able to:

(a) explain how the eye forms focused images of objects at different distances.

(b) understand the terms depth of focus and accommodation.

(c) distinguish between short sight, long sight and astigmatism.

(d) distinguish between converging and diverging lenses and understand the significance of focal length.

(e) describe and explain how short sight, long sight and astigmatism can be corrected by using spectacle lenses or contact lenses.

(f) recall and use the lens formula to calculate the focal length of the auxiliary lenses required to correct short sight and to correct long sight.

(g) relate the focal length of a lens to its power in dioptres.

M4. The Physics of Hearing

Content

4.1 The ear
4.2 Sensitivity and frequency response of the ear

Assessment Objectives

Candidates should be able to:

(a) explain how the ear responds to an incoming sound wave.

(b) understand the significance of the terms sensitivity and frequency response.

(c) appreciate the very wide range of intensities which can be detected by the ear and recall the orders of magnitude of the threshold of hearing and the intensity at which discomfort is experienced.

(d) understand the significance of the logarithmic response of the ear to intensity.

*(e) recall and use the equation *intensity level* = $10\lg(I/I_0)$, giving intensity level in dB in terms of the intensity I and the threshold intensity I_0.

(f) understand that loudness is the subjective response of an individual to an intensity level.

OPTION P

Environmental Physics

[A detailed treatment of this topic is given in the Option Booklet *Environmental Physics*.]

P1. Power Sources

Content

1.1 The solar constant
1.2 Fossil fuels
1.3 Nuclear power
1.4 Water power
1.5 Wind power
1.6 Geothermal and other feasible power sources

Assessment Objectives

Candidates should be able to:

(a) understand and use the term solar constant.

(b) understand the geographical variation in solar constant.

(c) describe the structure of solar cells and solar panels.

(d) appreciate that solar cells produce electrical energy whereas solar panels produce thermal energy.

*(e) understand what is meant by resources and by reserves, and appreciate the difference between these terms.

(f) recall that there are different types of fossil fuel and appreciate that these fuels are abundant yet finite.

(g) recall the principles of the fission process.

*(h) recall the role of fuel rods, moderator, coolant, control rods and the reactor vessel in a nuclear reactor.

(i) calculate the potential energy stored in a lake, given its average depth, area and altitude.

(j) describe the principles of a pumped water storage scheme.

(k) estimate the power available from a water wave of given dimensions.

(l) use the potential energy of stored water to estimate the mean power output of a tidal barrage.

(m) estimate the maximum power available from a wind generator.

(n) comment on the difficulties and limitations associated with the following 'free' systems for producing power: geothermal including hot aquifers and geysers, biomass, methane generators from waste products.

P2. Power Consumption

Content

2.1 Variation in demand
2.2 Efficiency of different systems
2.3 Sankey diagrams
2.4 Long-term trends

Assessment Objectives

Candidates should be able to:

(a) describe and give reasons for daily and seasonal variations in the demand for electrical power.

(b) describe the complications which arise due to predictable and unpredictable variations in demand for electrical power.

(c) explain the benefits of a pumped water storage scheme.

(d) understand that, although the efficiency for conversion of electrical energy to internal energy for the consumer is 100%, the production of electrical energy is far less efficient.

(e) evaluate the overall efficiency, from production to consumer, of various domestic systems, e.g. cooking by gas or electricity.

(f) use Sankey diagrams.

(g) discuss the possible long-term effects on resources and on the environment of social changes such as increasing demand for housing, increasing affluence of third world countries and increasing use of air conditioning.

P3. Heat Engines

Content

3.1 Indicator diagrams
3.2 The petrol engine
3.3 The second law of thermodynamics

Assessment Objectives

Candidates should be able to:

(a) understand what is meant by an isothermal and by an adiabatic change.

(b) illustrate isothermal and adiabatic changes on indicator diagrams.

(c) understand and use indicator diagrams to determine the work done on or by a gas.

(d) recall the cycle of a four-stroke petrol engine.

**(e)* use an indicator diagram to illustrate the cycle of a four-stroke petrol engine.

(f) appreciate that the second law places an overall limit on the efficiency of a heat engine, and that this limit depends on the temperatures between which the engine is operating.

(g) recall and use the equation $E_{MAX} = (1 - T_L/T_H)$, where E_{MAX} is the maximum efficiency.

(h) understand that the second law leads to the conclusion that CHP (combined heat and power) schemes should be economical propositions.

P4. Pollution

Content

4.1 Carbon dioxide emissions
4.2 Other forms of pollution

Assessment Objectives

Candidates should be able to:

(a) appreciate that zero pollution is not possible.

(b) understand that the burning of fossil fuels leads to a release of carbon dioxide into the atmosphere, whereas there is no such release from nuclear and hydro-electric power schemes.

(c) understand why carbon dioxide levels in the atmosphere are not rising rapidly.

(d) recall and describe other forms of pollution such as thermal pollution of the atmosphere, noise pollution, pollution of rivers.

OPTION T

Telecommunications

[A detailed treatment of this topic is given in the Option Booklet *Telecommunications*.]

T1. Communication Principles

Content

1.1 Waveforms
1.2 Principles of modulation
1.3 Sidebands and bandwidth
1.4 Transmission of information by digital means
1.5 Transmission media
1.6 Communications and society

Assessment Objectives

Candidates should be able to:

*(a) recall that any waveform can be resolved into or synthesised from sinusoidal components.

*(b) understand the term modulation and distinguish between amplitude modulation (AM) and frequency modulation (FM).

*(c) recall that a carrier wave, amplitude modulated by a single audio frequency, is equivalent to the carrier wave frequency together with two sideband frequencies, leading to an understanding of the term bandwidth.

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

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

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

*(g) demonstrate an awareness of how waveforms are encoded by digital sampling.

(h) appreciate the scientific and economic advantages of fibre optic transmission, compared with metal cable and radio transmission.

(i) demonstrate an awareness of social, economic and technological changes arising from modern communication methods.

T2. Communication Channels

Content

2.1 Channels of communication
2.2 Power levels

Assessment Objectives

Candidates should be able to:

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

(b) 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.

(c) understand and use signal attentuation expressed in dB per unit length.

(d) understand and use repeater gain measured in dB.

(e) estimate and use typical power levels and attenuations associated with different channels of communication.

T3. Radio Communication

Content

3.1 Propagation of radio waves

Assessment Objectives

Candidates should be able to:

(a) appreciate the effect of the Earth's surface on the propagation of radio waves over long distances, and the use of the ionosphere as a reflector if the waves are to be propagated over long distances.

(b) describe the use of satellites in radio communication and appreciate the importance of geostationary satellites.

(c) recall the wavelengths used in different modes of radio communication.

ASSESSMENT OF EXPERIMENTAL SKILLS

Introduction

Assessment of Practical Skills may be undertaken through Papers 4 or 5 (Practical Test), or through Paper 7 or 9 (Centre-Based Assessment).

Practical Test, Paper 4 or 5

These papers form the externally set and marked practical components. Each paper will consist of two compulsory half-hour design exercises and two compulsory one-hour practical experiments. The Examiners will not be strictly bound by 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.

Candidates will be assessed on the following skills:

- A Planning
- B Implementing
- C Interpreting and Concluding

There are six assessment criteria for each skill. Skill descriptions and assessment criteria are detailed on pages 54–55.

It should be appreciated that all 18 assessment criteria will not be tested in any one examination.

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 16% of their time on practical work and its assessment.

Further guidance

The aim of this section is to provide Centres with further guidance on the standard expected in the assessment of the practical test.

Experimental Questions

Experimental Method
A number of marks are awarded for the successful execution of the experiment. The candidate should be able to assemble the apparatus without help and take the prescribed number, or suitable number, of readings over a specified, or suitable large, range. It is expected that all readings will be recorded and repeated where appropriate, for example in the timing of oscillations. Calculations derived from raw readings should be correct and given to an appropriate number of significant figures, governed by the number of significant figures in the raw data. Generally, the number of significant figures in the calculated values should be equal in number to, or possibly one more than, the number of significant figures in the raw data. Results should be obtained of a high quality: this is often judged by looking at the scatter of points about the candidate's graph line.

Presentation of Results

Marks are also awarded for the presentation of results. Numerical data and values should be presented in a single table. It is expected that candidates will draw the table in advance of taking any readings: it should not be necessary for candidates to copy up their results. The table should include raw data and values calculated from them, for example logarithms of values. Column headings should conform to normal practice. If the quantity being measured is current, then the following would be allowed: I / mA; I in mA; I (mA); $\frac{I}{\text{mA}}$. The quantity or unit may be written in words. Conventional symbols or abbreviations may be used without further explanation, for example p.d. In cases of doubt, the quantity's name should be written in full. Headings such as 'I mA' or plain 'mA' are not acceptable. It is expected that all recorded raw readings of a quantity will be given to the same degree of accuracy. If one measurement of length in a set is given to the nearest millimetre, then all the measured lengths should be given to the nearest millimetre. Candidates will be penalised if the degree of precision used is incompatible with the measuring instrument used: an example would be a length measured on a millimetre scale, but recorded as '2 cm'. Calculated quantities must be given to the same number of significant figures as (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 3 significant figures respectively, then the corresponding quotient (resistance) should be given to 2 or 3 significant figures, but not 1 or 4. If both were measured to 3 significant figures, then the resistance could be given to 3 or 4 significant figures. It is, however, as a special case, acceptable for a periodic time to be given to 3 (or 4) significant figures, when measured on a centisecond stopwatch, to allow for errors in starting and stopping this device.

Graphical work

Graphical work contributes much to the assessment of the practical exercises. Candidates should be able to rearrange expressions to allow straight-line graphs to be plotted. Candidates should be familiar with the appropriate mathematical processes for taking logarithms and dealing with exponential functions. Graph axes should be clearly labelled with quantity and unit; drawn in conventional directions; occupy at least half the grid in both x- and y-directions; use convenient scales (e.g. 1, 2 or 5 units to a 2 cm square) and have clear numerical labels, not more than 6 cm (on the grid) apart. There should be no holes on the scale on a graph axis (i.e. labels which run, at 2 cm intervals, 0,1,3,4). All data points should be plotted on the grid: no credit is given for points drawn on the white margin to the grid. Points should be plotted to an accuracy of better than half a small (2 mm) square and must be finely drawn with a sharp pencil, yet still be visible. A fine cross or encircled dot is suitable. Thick pencil dots will be penalised. The line of best fit should show an even distribution of points either side of the line along its whole length. Thick or kinked lines do not gain credit. It is expected that the line will be drawn through the number of points specified in the question. Straight lines drawn where curves are expected will not gain any marks. When a gradient is to be measured, it is important that the points on the line chosen for the calculation are sufficiently separated: it is expected that the hypotenuse of the triangle (whether the triangle is actually drawn or not) should be at least half the length of the candidate's line. Read-offs from the graph should be accurate. If data points from the table are used, they must lie within half a small square of the line drawn, and fulfil the criteria for separation. Any intercept must be read to better than half a small square. Candidates should be taught how to determine the intercept from a graph drawn with a false origin.

Analysis
Experimental questions often conclude with some analysis, using the results from the graph. At this stage, it is important that candidates realise the importance of using the correct number of significant figures and the correct units, where appropriate.

Design Questions

The two questions provide candidates with the opportunity to demonstrate their mastery of Skill A in the scheme of assessment. The best preparation for these questions can be achieved by candidates designing some of their own experiments, under close, safe supervision, during their A Level course and by practising on questions from past papers. The contexts of the questions will often be unfamiliar to candidates, although it is expected that they will have used or learnt about suitable apparatus for completing the task. Details of unfamiliar apparatus may be given in the question paper. Candidates will typically be asked to select apparatus, describe the experimental arrangement and state the variables to be measured and those to be kept constant. Further detail of the procedure to be followed may be required, together with an outline of how the readings are to be treated, for example by means of a specified graph. Good marks can often be gained on relatively short answers, supported by clear labelled diagrams.

Administration of the Practical Test

The list below gives some of the items regularly used in the practical test. To instil some variation in the questions set, some novel items are usually required. Details of the apparatus required are usually sent to Centres about six weeks before the date of the examination. Centres should contact the Despatch Department at UCLES, if they believe Instructions have not been received. It is essential that absolute confidentiality be maintained in advance of the examination date. Further advice is included with the instructions and in the Handbook for Centres.

The number of sets of apparatus assembled for each experiment should be sufficient for half the candidates to undertake that particular experiment at the same time: some spare sets should be provided. Candidates should be told that they will have access to the apparatus for each experiment for one hour only. Candidates may be told which experiment to attempt first. They might then move on to the second experiment, before spending the third hour of the Paper on the design questions.

A copy of the Report, supplied as part of the Instructions, should be completed and enclosed in each envelope of scripts. A sample set of results may also be helpful for the Examiner, especially if there was any local difficulty with the apparatus. A missing Report can impede the marking process.

Apparatus that is used regularly

Electrical
Ammeter: (digital or analogue) f.s.d. 100 mA and 1 A
Voltmeter: (digital or analogue) f.s.d. 5 V, 10 V
Power supply: variable up to 12 V d.c. (low resistance)
Cells: 1.5 V

Lamp and holder: 6 V 60 mA; 2.5 V 0.3 A
Rheostat
Switch
Leads and crocodile clips
Wire: constantan 26, 28, 30, 32, 36, 38 s.w.g. or metric equivalents

Heat
Long stem thermometer: −10 °C to 110 °C × 1 °C
Metal calorimeter
Plastic or polystyrene cup 200 cm^3
Means to heat water safely to boiling
Stirrer

Mechanics and General items
Card
Pendulum bob
Wood or metal jaws
Stand, boss and clamp
G-clamp
Rule (1 m, 0.5 m, 300 mm)
Stopclock or stopwatch (candidates may use their own reading to 0.1 s or better)
Balance to 0.1 g*
Beaker: 100 cm^3, 200 or 250 cm^3
Plasticine
Blu-Tack
Wire cutters
Bare copper wire: 18, 26 s.w.g.
Stout pin or round nail
Scissors
Sellotape
Micrometer screw gauge*
String/thread/twine
Slotted 100 g masses or alternative
Spring

* item may often be shared between sets of apparatus

Skill A	*Planning*
Assessment Criterion	**Requirement**
A1 APPLICATION	Appropriate methods considered in approaching a stated problem.
A2 DEFINITION	Development of a hypothesis which can be tested experimentally.
A3 VARIABLES	Appropriate variables selected which are consistent with the stated problem.
A4 ORGANISATION	Plan involving a series of well-ordered steps.
A5 APPARATUS	Appropriate apparatus/materials selected.
A6 PROCEDURES	Plan would be effective in testing the stated hypothesis.

Skill B	*Implementing*
Assessment Criterion	**Requirement**
B1 CARRYING OUT	Experiment carried out in a careful and organised way, with apparatus set up and all relevant instructions followed.
B2 SAFETY	Sensible conduct, with concern shown for safety of self and others and/or for equipment.
B3 MANIPULATIVE SKILLS	Apparatus used skillfully.
B4 MAKING OBSERVATIONS	Sufficient number of readings obtained fully covering the range which is appropriate to the procedure and the apparatus.
B5 RECORDING OBSERVATIONS	Relevant readings presented in a suitable format.
B6 PRECISION/ ACCURACY	All measurements made are accurate and to the appropriate degree of precision, and, where relevant, there is appropriate validation.

Skill C *Interpreting and Concluding*

Assessment Criterion	Requirement
C1 PROCESSING	Processing of results.
C2 RELIABILITY	Reliability and accuracy of own experimental data and/or techniques assessed, including appropriate treatment of errors.
C3 MODIFICATION	Modifications suggested to procedures or justification offered for no modification.
C4 INTERPRETATION	Processed data interpreted appropriately.
C5 CONCLUSION	Conclusion drawn consistent with processed data.
C6 COMMUNICATION	Written account well presented with a clear logical structure.

INTERNAL ASSESSMENT OF EXPERIMENTAL SKILLS

Paper 7 or 9

It is expected that practical activities will underpin the teaching of the whole syllabus.

Students can be assessed on **either** an Extended Investigation **or** Separate Skills Assessment.

Paper 7: The Extended Investigation

General Information

The Extended Investigation must show evidence of a candidate's ability to identify an issue or problem, conduct appropriate practical work, collect and analyse data and present reasoned arguments in drawing conclusions and evaluating the data.

The Investigation can either be **Laboratory/Fieldwork based** or **Work-related** and must relate to subject content covered by the student.

The Extended Investigation should take up no more than 15 hours of work in total. The resulting account should be no more than 2500 words, excluding headings, graphs, tables and appendices.

All Investigations must have approval from OCR before the students begin the work (see notes under **Approval**, below).

The Extended Investigation (Work-related)

It is intended that this version of the Extended Investigation should be 'applied' in nature and should arise from the stimulus provided by a short work placement or visit.

The work placement should be with industrial/commercial companies whose work is related to Physics in its broadest sense.

During the work placement/visits the student should take the opportunity to look in detail at one application of Physics in the particular area of work, as well as gaining a more general knowledge of the work being carried out.

The practical aspect of the work **which must be an integral part of the work-related investigation**, could be work-place based if that can be arranged. If this is not possible, practical work arising from, or leading on from, the work placement may be carried out back in a school laboratory etc., if appropriate.

Approval

Titles and brief outlines of Extended Investigations must be submitted to OCR on an Outline Proposal Form (OPF) at least six weeks before the candidates are due to start work on the investigation.

Teacher Assessment of Extended Investigations

The assessment of the Extended Investigation is based on three skills:

- A Planning
- B Implementing
- C Interpreting and Concluding

There are **six** assessment criteria for each skill. Each assessment criterion is marked on a scale of 0–2. The marks awarded should be as follows:

- 2: criterion completely met
- 1: criterion partly met
- 0: criterion not met at all.

Skill descriptors and assessment criteria are fully detailed on pages 63 to 65. The skills assessed cover **Assessment Objectives *C1*** to ***C5***.

The marks awarded should be based on both the final written work and the teacher's knowledge of the work carried out by the candidate. In assigning a mark, attention should be paid to the extent of guidance needed by/given to the candidate.

For each candidate entered for Paper 7, Centres are required to submit one score out of 12 for each of skills A, B and C assessed in the context of an Extended Investigation.

The maximum number of raw marks available for the Extended Investigation is therefore 36.

Each Investigation account should be annotated to show how marks have been awarded in relation to the relevant assessment criteria. These annotations should be made at appropriate points in the margins of the text. Appropriate abbreviations or symbols may be used by the teacher to indicate the different marking criteria being assessed.

Moderation

(a) Internal Moderation

Where more than one teacher in a Centre is involved in marking the Extended Investigations, arrangements must be made within the Centre to ensure consistent application of the assessment criteria. A report of these arrangements must be included with the work sent to OCR for external moderation.

Internal moderation is essential to produce a single valid order of merit for the module entry from the Centre.

(b) External Moderation

(i) If there are 20 or fewer candidates from the Centre, then the written accounts of the Extended Investigation of **all the** candidates should be submitted to OCR for moderation.

(ii) If there are more than 20 candidates from a Centre, then the written accounts of the Extended Investigation of 20 **candidates** must be sent to OCR. The 20 candidates should represent the full mark range, as evenly spaced as possible, and should include candidates from each teaching group, if appropriate.

OCR may request the work of additional candidates in order to arrive at a decision regarding the standard of the work.

Authentication

Teachers must be able to supply evidence of their continuing supervision of the work. Where the nature of the subject requires candidates to undertake assessed coursework activities outside the Centre, a proportion of the work must take place under direct supervision. The proportion must be sufficient to enable the teacher to authenticate each candidate's work with confidence.

Safety in the Laboratory

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

(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.

(g) *Animals and Plants in Schools: Legal Aspects*, DES Administrative Memorandum No. 3/90.

Teachers are reminded that they must comply with school/college/local authority policies and procedures on work placements. OCR will take no responsibility for any injury, etc. which occurs to a student during a work placement.

Notes for Guidance of Candidates—Paper 7

The Extended Investigation should be an individual study, and should be either Laboratory/Fieldwork based, or Work-related. Each completed Investigation should be no more than 2500 words in length, excluding headings, tables, graphs and appendices.

Accounts of the Extended Investigation should consist of the following clearly identified sections.

1. A clearly stated title, an abstract and a contents list.

2. An introduction which should briefly put the investigation in context and should include a concise statement of the investigation.

3. An account of the method(s) used in obtaining information. This should include the sequence of experimental or observational work undertaken.

4. The results should be presented clearly and concisely. Tables, line graphs, bar charts, histograms, pie charts etc. are all commonly used and can be helpful, but they must be correctly derived from the observations. Raw data should be given in an appendix.

5. Conclusions or inferences based solely on the results obtained should be clearly stated. The discussion should include implications and relevance of the conclusions if pertinent.

6. Limitations, reliability and sources of error should be evaluated and discussed and their possible effects on the reliability of the data should be noted.

7. Suggestions for any modifications to the original design should be made, based on the evaluation of the results.

8. A bibliography or footnotes referencing any researched information.

9. A list of acknowledgements indicating the source and extent of any help that has been received.

Pages in the written accounts must be numbered, and the investigation should be submitted for external moderation in a light paper folder (**not** a heavy ring binder).

Paper 9: Separate Skills Assessment

Introduction

The scheme detailed below is intended to provide guidance for teachers in making the assessment of the Experimental Skills, but should not exert an undue influence on the methods of teaching or provide a constraint on the practical work undertaken by candidates. It is not expected that all of the practical work undertaken by the candidates would be appropriate for assessment.

The assessments may be carried out at any time during the course using suitable practical activities which are related to, or are part of, the teaching of the course. It is expected that students will have had opportunities to acquire experience and develop the relevant skills before assessment takes place.

Teacher Assessment of the Experimental Skills assessed separately

The Experimental Skills to be assessed separately are given below:

A Planning
B Implementing
C Interpreting and Concluding

There are **six** assessment criteria for each skill and each assessment criterion is marked on a scale of 0–2.

2: criterion completely met
1: criterion partly met
0: criterion not met at all.

The three skills carry equal weighting.

Skill descriptors and assessment criteria are fully detailed on pages 63–65.

The skills assessed cover **Assessment Objectives *C1* to *C5***.

It is expected that skills **A**, **B** and **C** will be assessed using different practical exercises. Within each skill area there are a number of assessment criteria. Teachers are advised, therefore, that they may need **to use more than one practical exercise** in order to assess all these assessment criteria.

At whatever stage assessments are carried out, the standards applied must be those of A level, i.e. those expected at the end of the course, as exemplified in the assessment criteria. Candidates should be informed when an assessment is to take place.

The marks awarded should be based on both the final written work and the teacher's knowledge of the work carried out by the candidate. In assigning a mark, attention should be paid to the extent of guidance needed by/given to the candidate.

For each candidate entered for Paper 9, Centres are required to submit one score out of 12 for each of Skills A, B and C assessed separately. Hence the maximum raw mark available for Paper 9 is 36.

Candidates should be assessed on each skill on a **minimum** of two occasions and the **better or best mark** for each Skill submitted.

Annotation of Coursework

Each piece of assessed practical coursework must be annotated to show how the marks have been awarded in relation to the relevant assessment criteria.

The writing of comments on candidates' work can provide a means of dialogue and feedback between teacher and candidate and a means of communication between teachers during internal moderation of coursework. The main purpose of writing comments on candidates' coursework is, however, to provide a means of communication between teacher and coursework moderator, showing where marks have been awarded and why.

For written coursework, annotations should be made at appropriate points in the margins of the text. The annotations should indicate where achievement against a specified assessment criterion for a particular skill has been noted. Appropriate abbreviations or symbols may be used to indicate the marking criterion concerned.

The annotations should also indicate the mark to be awarded for each skill.

The marks for individual assessments should be recorded on the candidate's work as part of the normal feedback from the teacher. The final total score, as submitted to OCR, should not be given to the candidates.

Suitability of Coursework

It is essential that all teachers assessing candidates' practical work relating to the separate Experimental Skills should be familiar with the requirements of the syllabus.

If teachers in a Centre are not certain that their proposed practical work will satisfy the syllabus requirements, then they should write to the relevant OCR Subject Officer to seek clarification **well before the proposed work is due to be carried out.**

A Handbook for Teachers containing exemplar material is available from OCR.

Moderation

(i) Internal Moderation

Where more than one teacher in a Centre is involved in internal assessment, arrangements must be made within the Centre to ensure consistent application of the assessment criteria. A report of these arrangements must be included with the work sent to OCR for external moderation.

Internal moderation is essential to produce a single valid order of merit for the module entry from the Centre.

(ii) External Moderation

Teachers should retain all work used as a basis for assessment.

Each Centre will be required to send the following information about the assessment to OCR:

1. A summary which identifies all of the activities used for assessment. This must show how the task was presented to candidates, including any worksheets or other documentation issued to candidates, and what marking criteria were applied. Form SSA/CW/I (Individual skills assessment) should be attached to each piece of any candidate's work.

2. One copy of the completed Mark Sheet (MS1), with assessment totals for all candidates.

3. If there are 20 or fewer candidates from the Centre, then the written work **contributing to their assessment totals**, of **all** the candidates, should be submitted for moderation.

4. If there are more than 20 candidates from a Centre, then the written work **contributing to their assessment totals**, of **20 candidates** must be sent to OCR. The 20 candidates selected should represent the full mark range, as evenly spaced as possible, and should include candidates from each teaching group.

OCR may request the work of additional candidates in order to arrive at a decision regarding the standard of the work.

Authentication

Teachers must be able to supply evidence of their continuing supervision of the work. Where the nature of the subject requires candidates to undertake assessed coursework activities outside the Centre, a proportion of the work must take place under direct supervision. The proportion must be sufficient to enable the teacher to authenticate each candidate's work with confidence.

Safety in the Laboratory

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

(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.

(g) *Animals and Plants in Schools: Legal Aspects*, DES Administrative Memorandum No. 3/90.

Experimental Skills (Physics)

Skill A — ***Planning***

	Assessment Criterion	Requirement	Maximum Mark Available
A1	APPLICATION	Appropriate methods considered in approaching a stated problem.	2
A2	DEFINITION	Development of a hypothesis which can be tested experimentally.	2
A3	VARIABLES	Appropriate variables selected which are consistent with the stated problem.	2
A4	ORGANISATION	Plan, involving a series of well-ordered steps.	2
A5	APPARATUS	Appropriate apparatus/materials selected.	2
A6	PROCEDURES	Plan would be effective in testing the stated hypothesis	2

Each assessment criterion is marked on a scale of 0–2.

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Skill B *Implementing*

	Assessment Criterion	Requirement	Maximum Mark Available
B1	CARRYING OUT	(a) Paper 7—Experiment carried out in a careful and organised way; (b) Paper 9—All relevant instructions followed.	2
B2	SAFETY	Sensible conduct, with concern shown for safety of self and others and/or for equipment.	2
B3	MANIPULATIVE SKILLS	Apparatus used skilfully.	2
B4	MAKING OBSERVATIONS	Sufficient number of readings obtained fully covering the range which is appropriate to the procedure and the apparatus.	2
B5	RECORDING OBSERVATIONS	Relevant readings presented in a suitable format.	2
B6	PRECISION/ ACCURACY	All measurements made are accurate and to the appropriate degree of precision, and, where relevant, there is appropriate validation.	2

Each assessment criterion is marked on a scale of 0–2.

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Skill C — *Interpreting and Concluding*

	Assessment Criterion	Requirement	Maximum Mark Available
C1	PROCESSING	Processing of results.	2
C2	RELIABILITY	Reliability and accuracy of own experimental data and/or techniques assessed, including appropriate treatment of errors.	2
C3	MODIFICATION	Modifications suggested to procedures or justification offered for no modification.	2
C4	INTERPRETATION	Processed data interpreted appropriately.	2
C5	CONCLUSION	Conclusion drawn consistent with processed data.	2
C6	COMMUNICATION	Written account well presented in a clear logical structure.	2

Each assessment criterion is marked on a scale of 0–2.

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

MATHEMATICAL REQUIREMENTS (9244)

(Please see note on page 8 concerning the Special Paper.)

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. $\pi^2 = 10$) 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 $<$, $>$, $\leqslant$, $\geqslant$, $\approx$, $/$, $\propto$, $\langle x \rangle$ $(= \bar{x})$, Σ, Δx, δx, $\surd$.

Geometry and trigonometry

Candidates should be able to:

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

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

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

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

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

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

Vectors

Candidates should be able to:

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

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

Graphs

Candidates should be able to:

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

(b) select appropriate variables and scales for graph plotting.

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

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

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

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

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

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

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

DATA AND FORMULAE (9244)

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant,	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\dfrac{Gm}{r}$
refractive index	$n = \dfrac{1}{\sin C}$
resistors in series	$R = R_1 + R_2 + \ldots.$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots.$
electric potential	$V = \dfrac{Q}{4\pi\epsilon_0 r}$
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	$W = \frac{1}{2}QV$
alternating current/voltage	$x = x_0 \sin\omega t$
hydrostatic pressure	$p = \rho g h$
pressure of an ideal gas	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
radioactive decay	$x = x_0 \exp(-\lambda t)$

decay constant	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$
mean density of mass in the Universe	$\rho_0 = \dfrac{3H_0^{\,2}}{8\pi G}$
equation of continuity	$Av = \text{constant}$
Bernoulli equation (simplified)	$p_1 + \frac{1}{2}\rho v_1^{\,2} = p_2 + \frac{1}{2}\rho v_2^{\,2}$
Stokes' law	$F = Ar\eta v$
Reynolds' number	$R_e = \dfrac{\rho v r}{\eta}$
drag force in turbulent flow	$F = Br^2 \rho v^2$

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The following list illustrates the symbols and units which will be used in question papers for 9244.

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 Report.

Reference should also be made to the section on *Signs, Symbols and Abbreviations* on page 9.

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	$\mathrm{kg\,m^{-3}}$
speed	u, v, w, c	$\mathrm{m\,s^{-1}}$
velocity	u, v, w, c	$\mathrm{m\,s^{-1}}$
acceleration	a	$\mathrm{m\,s^{-2}}$
acceleration of free fall	g	$\mathrm{m\,s^{-2}}$
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	J
change of internal energy	ΔU	J
power	P	W
pressure	p	Pa
torque	T	N m
gravitational constant	G	$\mathrm{N\,kg^{-2}\,m^2}$
gravitational field strength	g	$\mathrm{N\,kg^{-1}}$
gravitational potential	ϕ	$\mathrm{J\,kg^{-1}}$
angle	θ	°, rad
angular displacement	θ	°, rad
angular speed	ω	$\mathrm{rad\,s^{-1}}$
angular velocity	ω	$\mathrm{rad\,s^{-1}}$

Quantity	*Usual symbols*	*Usual unit*
period	T	s
frequency	f	Hz
angular frequency	ω	$\mathrm{rad\,s^{-1}}$
wavelength	λ	m
speed of electromagnetic waves	c	$\mathrm{m\,s^{-1}}$
electric charge	Q	C
elementary charge	e	C
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
resistance	R	Ω
resistivity	ρ	$\Omega\,\mathrm{m}$
electric field strength	E	$\mathrm{N\,C^{-1}}$, $\mathrm{V\,m^{-1}}$
permittivity of free space	ϵ_0	$\mathrm{F\,m^{-1}}$
capacitance	C	F
time constant	τ	s
magnetic flux	ϕ	Wb
magnetic flux density	B	T
permeability of free space	μ_0	$\mathrm{H\,m^{-1}}$
stress	σ	Pa
strain	ϵ	
force constant	k	$\mathrm{N\,m^{-1}}$
Young modulus	E	Pa
Celsius temperature	θ	°C
specific heat capacity	c	$\mathrm{J\,K^{-1}\,kg^{-1}}$
molar heat capacity	C_m	$\mathrm{J\,K^{-1}\,mol^{-1}}$
molar gas constant	R	$\mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann constant	k	$\mathrm{J\,K^{-1}}$
Avogadro constant	N_A	$\mathrm{mol^{-1}}$
number	N, n, m	
number density (number per unit volume)	n	$\mathrm{m^{-3}}$
Planck constant	h	J s
work function energy	Φ	J
activity of radioactive source	A	Bq
decay constant	λ	$\mathrm{s^{-1}}$
half-life	$t_{\frac{1}{2}}$	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	

GLOSSARY OF TERMS USED IN A LEVEL PHYSICS PAPERS

It is hoped that the glossary will prove helpful to candidates as a guide, although it is not exhaustive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context. They should also note that the number of marks allocated for any part of a question is a guide to the depth of treatment required for the answer.

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

2. *Explain/What is meant by* ... normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

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

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

5. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. The amount of description intended should be interpreted in the light of the indicated mark value.

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

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

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

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

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

11. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, e.g. the Young modulus, relative molecular mass.

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

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

14. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct. However, candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates clearly indicate what is being plotted on each axis.

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

MODULAR PHYSICS

Physics is also offered at Advanced and Advanced Supplementary levels through a modular scheme.

The following Physics modules are available:

Foundation
Basic 1
Basic 2
Further Physics
Nuclear Physics
Health Physics
Physics of Transport
Cosmology
Telecommunications
Instrumentation Electronics

The first five of these modules include a large proportion of the theory work for the A-level linear Physics (9244), i.e. all the theory but excluding the options.

If Centres wish to follow the 9244 Physics Syllabus, but in modular form, they should take the first five modules.

Candidates taking AS-level Physics in modular form do the first two of these modules (which contain the SEAC AS-level core) together with a module especially designed for AS-level. This module is only available to AS-level candidates and comprises one-half theory and one-half practical assessment.

The practical element remains at one-sixth of the total assessment in A-level and AS-level, whether linear or modular.

Information concerning the Modular Physics Syllabuses can be found in the Modular Sciences: Physics Syllabus Booklet.

9244, 9536, 8536 Physics

University of Cambridge
Local Examinations Syndicate

IT Usage in AS/A Level Physics
(Linear and Modular)

The use of I.T. in LINEAR and MODULAR AS and A level PHYSICS

Information Technology (I.T.) 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 I.T. 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 four 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 emf 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

Names and addresses of suppliers of Data Capture equipment are given on page 82.

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 best fit line).

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.

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.
EUREKA is one example of several spreadsheet programs available for the Archimedes.
MASTERFILE 2 is one example of a spreadsheet program for the BBC.

Names and addresses of suppliers of Data Analysis software are given on page 83.

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.

Names and addresses of suppliers of Physics software are given at the end of this information sheet.

4. Communications

Both the linear and the modular courses now require candidates who do not intend to sit the practical examination to communicate evidence of their practical and analytical skills in laboratory work. If students are given tuition on and access to WORD PROCESSORS it is more than likely that the quality and presentation of their written work will improve.

Word processing allows students to write out their ideas on the screen and then modify them. Completed work can easily be re-thought and then refined. Graphs and other images can easily be imported from other packages so that a very satisfying report, for students and teachers alike, can be produced.

Teachers requiring further guidance should write to the Physics Subject Officer.

Certain assessment objectives of the Syllabus have been marked with an asterisk (*) to indicate the possibility of the application of I.T. 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 assessment objectives.

ADVANCED LEVEL PHYSICS (LINEAR)

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. The treatment of uncertainties in (*f*) may be illustrated using I.T. 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 I.T. simulations. Experimental investigations of collisions lend themselves to data-capture techniques.

6. WORK, ENERGY, POWER
6(*c*), (*g*) and (*n*) may be approached using simulation methods.

7. GRAVITATIONAL FIELD
Theoretical predictions from Newton's law of gravitation and the concept of gravitational potential may be presented through computer simulations {(*b*), (*d*) and (*h*)}. Data-capture techniques may be employed in the determination of the acceleration of free fall {(*f*)}.

8. MOTION IN A CIRCLE
Computer simulation techniques may be used effectively in the analysis of circular orbits {(*g*)}. Information on the orbits of planets in the Solar System could be stored on a spreadsheet.

9. OSCILLATIONS
The relations between acceleration, velocity and displacement in simple harmonic motion {(*b*) and (*d*)}, and in damped and forced oscillation {(*f*) and (*h*)} may be demonstrated using computer simulations.

10. WAVES
The graphical representation of transverse and longitudinal waves {(*o*)} may be illustrated using computer simulations. Data-capture may be applied in the measurement of the frequency and wavelength of sound {(*q*) and {(*r*)}.

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

14. CURRENT OF ELECTRICITY
14(*i*), on the current-voltage characteristics of a number of devices, and (*j*), on the temperature characteristic of a thermistor, may be presented through computer simulations and data-capture.

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

16. ELECTRIC FIELD
Theoretical predictions from Coulomb's law and the concept of electric potential may be presented through computer simulations {(*c*), (*d*) and (*j*)}.

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

19. ELECTROMAGNETISM
Data-capture techniques may be used in the measurement of magnetic flux density {(*k*)}.

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

21. ALTERNATING CURRENTS
Computer simulations, or demonstrations using a cathode-ray oscilloscope, are powerful methods of demonstrating alternating currents {(*b*), (*c*), (*h*) and (*k*)}.

22. PHASES OF MATTER
Several aspects of the kinetic model of matter {(*c*) and (*i*)} may be effectively demonstrated using computer simulations.

23. DEFORMATION OF SOLIDS
Computer simulations may be used to illustrate (*f*) and (*g*).

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

28. CHARGED PARTICLES
The classic experiments on the determination of e {(*b*)} 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*)}.

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

30. ATOMIC STRUCTURE
Computer simulations of α-particle scattering experiment {(*a*)} may be very effective. Simple models of the nuclear atom {(*b*)} may be presented using computer simulations.

31. RADIOACTIVITY
Data-capture methods may be used in experiments on radioactive decay {(*e*) and (*h*)}.

A LEVEL OPTIONS

A2. THE STANDARD MODEL OF THE UNIVERSE
Observations on red-shift {(*a*)} may be presented through computer simulations.

A3. TECHNIQUES OF OBSERVATION
3(*b*) may lead to an appreciation of the need for I.T. techniques in observational astronomy.

C3. MATERIAL TESTING
Stress-strain, force-extension and hysteresis curves may be presented through computer simulations {(*b*) and (*f*)}.

E1. ANALOGUE SYSTEMS
1(*a*) and (*b*) refer to a number of sensors and output devices which have applications in Information Technology.

E2. DIGITAL SYSTEMS
2(*c*), on the use of logic gates to perform control functions, is an example of practical I.T. which may have many social and technological applications.

F2. NON-VISCOUS FLUID FLOW
Computer simulations may be useful to illustrate applications of the Bernoulli effect {(*i*)}.

F3. VISCOUS FLUIDS
3(*f*), on Stokes' law, lends itself to a presentation through computer simulation. Data-capture may be used in experimental work on terminal velocity. 3(*n*) suggests the use of computer simulations and predictions of drag coefficients.

M1. MEDICAL IMAGING
1(*e*), on the exponential attenuation of X-rays in matter, may be presented using computer simulations and predictions. 1(*h*) allows the discussion of the use of I.T. techniques in displays and in data storage.

M4. THE PHYSICS OF HEARING
The concept of the decibel scale {(*e*)} may be introduced using computer simulations.

P1. POWER SOURCES
The discussion of (*e*) might involve computer simulations of changes in resources and reserves. The operation of a nuclear reactor {(*h*)} may be modelling using computer simulations.

P3. HEAT ENGINES
The four-stroke petrol-engine cycle {(*e*)} can be presented using computer simulations.

T1. COMMUNICATION PRINCIPLES
1(*a*), (*b*), (*c*) and (*g*) may be presented effectively using computer simulations.

Suppliers names and addresses and products

Teachers may find the following addresses useful as a source of catalogues from which they may make their own decisions on suitability and cost.

1. Data Capture

Philip Harris Education, Lynn Lane, Shenstone, Lichfield, Staffordshire WS14 0EE.	DL Plus datalogging system linked to large range of Blue Box sensors. Designed for use with most common computers.
Griffin & George, Bishop Meadow Road, Loughborough, Leicestershire LE11 0RG.	LogIT datalogging system linked to large range of sensors. Designed for use with most common computers.
Unilab Ltd., The Science Park, Hutton Street, Blackburn BB1 3BT.	Microcomputer Interface linked to large range of sensors. Designed for use with Archimedes, BBC and PC.
Data Harvest Group Ltd., Educational Electronics, Waterloss Road, Linslade. Leighton Buzzard LU7 7NR.	Sense & Control dataloggers linked to large range of sensors. Designed for use with most common computers.
Forum Store, Southern Science & Technology, University of Southampton, Southampton SO9 5NH.	Watercress monitor and control with relatively inexpensive sensors. Designed for use with Archimedes, BBC and PCs.
Pasco Scientific, Admail 394, Cambridge CB1 1YY.	Computer Interface datalogger with selected sensors. For use with PCs and MAC only.
Economatics Education Ltd., Darnall Road, Attercliffe, Sheffield SA9 5AA.	Smart Box digital sensing only for use in control situations.
Visual Products, 34 Greenlands Lane, Prestwood, Buckinghamshire HP16 9QU.	PC Scope. Used in conjunction with a Sound Blaster card will turn a PC into a storage oscilloscope and signal analyser.

2. Data Analysis

All the suppliers of Data Capture equipment also sell corresponding software to support their own hardware. The following suppliers will provide further software packages to support and enhance the facilities of some of the more common dataloggers.

Homerton College, University of Cambridge, Cambridge CB2 2PH.	SoftLab 3 package.
Longman Logotron, 124 Cambridge Science Park, Milton Road, Cambridge CB4 4ZS.	Insight package.
School of Education, Leicester University, 21 University Road, Leicester LE1 7RF.	MacInsight package.
Research Machines plc, New Mill House, 183 Milton Park, Abingdon, Oxfordshire OX14 4SE.	Investigate package.

The following suppliers provide general purpose software such as spreadsheet packages for most common computers:

Amo Publishing,
Mill Lane,
Carshalton,
Surrey SM5 2WZ.

The Warwick Spreadsheet system for PC and MAC.

Microsoft Ltd.,
Winnersh,
Wokingham,
Berkshire RG11 5TP.

Claris Information Service,
PO Box 2935,
Dublin 1,
Ireland.

Computer Concepts,
Gaddesden Place,
Hemel Hempstead,
Herts HP2 6EZ.

Colton Software,
2 Signet Court,
Swann's Road,
Cambridge CB5 8LA.

Flexible Software,
PO Box 100,
Abingdon OX13 6PQ.

Kudlian Soft,
8 Barrow Road,
Kenilworth,
Warwickshire CV8 1EH.

SPA,
PO Box 59,
Tewksbury,
Gloucestershire GL20 6AB.

RISC Developments Ltd.,
Hatfield Road,
St Albans.

Clares Micro Supplies,
Middlewich Road,
Northwich,
Cheshire.

3. Teaching Aids and Resources

Some of the suppliers listed above also offer programs dedicated to Physics while those listed below offer a range of software packages illustrating various topics in the A level syllabus. If teachers are interested they should write for an up-to-date catalogue.

AVP,
School Hill Centre,
Chepstow,
Gwent NP6 5PH.

The supplier for a huge range of software resources for all areas of Science.

First & Best in Education Ltd.,
34 Nene Valley Business Park,
Oundle,
Peterborough PE8 4HL.

G.A. Herdman Educational,
43 Saint John's Drive,
Clarborough,
Retford,
Nottinghamshire DN22 9NN.

Cambridge Educational Press,
Shaftesbury Road,
Cambridge.

Soft Teach Educational,
Longbridge Deverill,
Warminster.

GSN Educational Software,
Manchester University Press,
Manchester.

It is worth noting that some of the main educational publishers (e.g. Longman, Heinemann) are now offering I.T. packages either in the form of software or CD-ROMs.

The following suppliers offer **CD-ROMS** for use in Physics Education:

Bradford Technology Ltd., 41 Oxford Avenue, Raynes Park, Wimbledon, London SW20 8LS.	Electricity and Magnetism for PC.
Andromeda Interactive Ltd., 11–15 The Vineyard, Abingdon, Oxfordshire OX14 3PX.	The Interactive Space Encyclopaedia for PC.
Anglia Television (SCA), PO Box 18, Benfleet, Essex SS7 1AZ.	Energy for PC and Archimedes.
Schools Direct, The Green, Ravensthorpe, Northampton NN6 8EP.	Forces & Effects for PC.
BTL Publishing, Business and Innovation Centre, Angel Way, Listerhills, Bradford BD7 1BX.	All of the above titles and more.
AVP, School Hill Centre, Chepstow, Gwent NP6 5PH.	Huge range of CD-ROMs for most areas of education. Of particular interest is the Physics Lab Simulator.
Cambridge Science Media, 354 Mill Road, Cambridge CB1 3NN.	The Physics of Motion for PCs.
Timestep, PO Box 2001, Newmarket CB8 8XB.	Landsat satellite images.

The following suppliers offer **videos** for use in Physics Education:

Classroom Video, Darby House, Bletchingley Road, Merstham, Redhill, Surrey RH1 3DN.	Selection of excellent videos in Physics topics.
Physics Curriculum & Instruction, 1700 Rhode Island Avenue, North Golden Valley, Minnesota, USA.	Selection of excellent videos of Physics demonstrations.

Many publishers are also producing suitable resources on video.