A Level

Physics

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PHYSICS

Examination Syllabuses for 1994 and 1995
(UK Centres only)

PHYSICS
9240

GCE ADVANCED LEVEL

INTRODUCTION

This syllabus is intended to be accessible to students who have studied either GCSE Physics or a balanced Science course leading to a dual GCSE award. The syllabus encompasses the 'Common Core' syllabus for A-level Physics as agreed by the GCE Boards.

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 that
   - 5.1 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 the applications of Physics may be both beneficial and detrimental to the individual, the community and the environment.
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*, *explain* or *outline*. (See the glossary of terms on page 36.)

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.

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 that are within the syllabus and apply them in a logical, reasoned or deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: *predict*, *suggest*, *deduce*, *calculate* or *determine*. (See the glossary of terms on page 36.)

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. design and plan investigations, evaluate methods and techniques, and suggest possible improvement;
5. record observations, measurements, methods and techniques with due regard for precision, accuracy and units.

SCHEME OF ASSESSMENT

Candidates will be required to enter for Papers 1, 2, 3 and either Papers 4 or 5, or 9.
Paper 7 (Individual Study) and Paper 0 (Special Paper) are optional.

Paper	*Type of Paper*	*Duration*	*Marks*
1	Multiple Choice	1 h	60
2	Structured Questions	1 h 30 min	80
3	Longer, Structured Questions	2 h 15 min	110
9	Centre-based assessment of practical work	—	60
4	Practical Examination (Summer only)	2 h 30 min	60
5	Practical Examination (Winter only)	2 h 30 min	60

Papers 1 and 2 will be timetabled together.

Paper 1 (1 h, 60 marks) — 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 30 min, 80 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 the comprehension and analysis of data and will carry 18 marks.

Paper 3 (2 h 15 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 12 questions, 3 questions 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 35 minutes on Section B.

Paper 9 — A centre-based assessment of practical work carried out during the course. Further information is given on page 30.

Paper 4 (2 h 30 min, 60 marks) (Summer examination only) — Practical examination. The practical paper will consist of 2 compulsory questions, each of 1 h 15 min duration.

Paper 5 (2 h 30 min, 60 marks) (Winter examination only) — Practical examination. The practical paper will consist of 2 compulsory questions, each of 1 h 15 min duration.

Paper 9 is increasingly regarded as the means of assessing candidates' practical work. Papers 4 and 5 are provided for private candidates and for those Centres who prefer assessment by means of a practical examination.

Candidates re-entering in the November examination have the option of carrying forward their practical mark from the June examination as Paper 84.

Special Paper (Paper 0, 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. The paper consists of ten questions of which candidates are required to attempt any five. 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 identified as requiring the use of calculus.

Individual Studies (Paper 7, 60 marks)

The individual study is based on extended practical work, and further information is given on page 29.

A candidate offering Paper 7 will be credited with the mark for this paper if it is higher than the candidate's mark on Paper 9 or Paper 4.

MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Theory Papers (Papers 1, 2 and 3) (250 marks in total)

Knowledge with understanding—approximately 70 marks allocated to recall and 60 marks allocated to understanding.

Handling, applying and evaluating information—approximately 120 marks.

Practical Examinations (Papers 4 and 5) (60 marks)

Experimental skills and investigations—the practical papers are intended to test appropriate aspects of skills C 1–5 on page 4, although some aspects of these skills may be tested in theory papers. The practical papers may also involve some calculations based on experimental results.

MATHEMATICAL REQUIREMENTS

The mathematical requirements are given on page 35.

DATA BOOKLET

A Data Booklet will be provided for Papers 1, 2, 3 and the Special Paper. The booklet contains a list of fundamental physical constants and the appropriate extract is reproduced on page 39.

SYMBOLS, SIGNS AND ABBREVIATIONS

Wherever symbols, signs and abbreviations are used in examination papers, the recommendation made by the ASE in the report *SI units, Signs Symbols and Abbreviations (1981)* will be followed. The units kWh, atmosphere and eV may be used in examination papers without further explanation. Symbols for logic gates will conform to the American Standard ANSI Y 32.14 (1973).

STRUCTURE OF THE SYLLABUS

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

Four options are currently available:

(*a*) Option S Sound and Music
(*b*) Option C Communications
(*c*) Option M Medical Physics
(*d*) Option T Physics of Transport

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. 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.

SUBJECT CONTENT

(CORE: Section I–V inclusive)

SECTION I GENERAL PHYSICS

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 37 and 38 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 current ASE report *SI Units, Signs, Symbols and Abbreviations.*
(*f*) understand the significance of the Avogadro constant as the number of atoms in 0.012 kg of carbon-12.
(*g*) use molar quantities where one mole of any substance is the amount containing a number of particles equal to the Avogadro constant.
(*h*) distinguish between vector and scalar quantities and give examples.
(*i*) add and subtract coplanar vectors.
(*j*) 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,
(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 and use equations which represent uniformly accelerated motion in a straight line.
(*g*) describe qualitatively the motion of bodies falling in a uniform gravitational field with and without air resistance.
(*h*) 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 interactions between two bodies in two dimensions and inelastic interactions in one dimension. (Knowledge of the concept of coefficient of restitution is not required.)
(*i*) understand that, whilst momentum of a system is always conserved in interactions between bodies, some change in kinetic energy usually takes place.
(*j*) explain conservation of momentum in terms of Newton's third law.

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.
(*b*) understand the origin of the upthrust acting on a body in a fluid.
(*c*) understand qualitatively frictional 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*) appreciate that reserves of non-renewable sources such as oil and gas are finite, and show an awareness of the importance of alternative renewable sources such as hydro-electric, geothermal, tidal, solar, wind and wave.
(*c*) understand the concept of work in terms of the product of a force and displacement in the direction of the force.
(*d*) calculate the work done in a number of situations including the work done by a gas which is expanding against a constant external pressure.
(*e*) derive and use $E_k = \frac{1}{2}mv^2$.
(*f*) distinguish between gravitational potential energy, electrostatic potential energy and strain energy.
(*g*) understand and use the relationship between force and potential energy in a uniform field.
(*h*) derive and use $E_p = mgh$ for potential energy changes near the Earth's surface.
(*i*) understand the concept of internal energy.
(*j*) appreciate the importance of energy losses in practical devices and use the concept of efficiency.
(*k*) 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 $F = G\,(m_1m_2)/r^2$.
(*c*) derive and use the equation $g = Gm/r^2$ for the gravitational field of a point mass.
(*d*) appreciate that on the surface of the Earth g is approximately constant and is called the acceleration of free fall.
(*e*) describe an experiment to determine the acceleration of free fall using a falling body.
(*f*) define potential at a point as the work done in bringing unit mass from infinity to the point.
(*g*) use the equation $\Phi = -Gm/r$ for the potential in the field of a point mass.

8. MOTION IN A CIRCLE

CONTENT

8.1 Kinematics of uniform circular motion.
8.2 Centripetal acceleration.

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 $a = r\omega^2$, $a = v^2/r$.
(*f*) analyse circular orbits in inverse square law fields by relating the gravitational force to the centripetal acceleration it causes.

SECTION III OSCILLATIONS AND WAVES

9. OSCILLATIONS

CONTENT

9.1 Simple harmonic motion.
9.2 The kinematics of simple harmonic motion.
9.3 Energy in simple harmonic motion.
9.4 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*) recall, recognise and use the equation $a = -\omega^2 x$ as the defining equation of simple harmonic motion.

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

(*f*) derive and use expressions for the periods of a simple pendulum and a mass-spring system.

(*g*) recognise and use

$v = x_0 \omega \cos \omega t$

$v = \pm\omega\sqrt{(x_0^2 - x^2)}$.

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

(*i*) describe graphically the interchange between kinetic and potential energy during simple harmonic motion.

(*j*) 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.

(*k*) describe practical examples of forced oscillations and resonance.

(*l*) 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.

(*m*) 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 Progressive waves.

10.2 Transverse and longitudinal waves. Polarisation.

10.3 Determination of speed, frequency and wavelength.

ASSESSMENT OBJECTIVES

Candidates should be able to:

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

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

(*c*) deduce and use $v = f\lambda$.

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

(*e*) recall and use the relationship, intensity α (amplitude)^2.

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

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

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

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

(*j*) 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 either sound or microwaves.

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

(*e*) recall and use the equation $\lambda = a\Delta x/D$ for double-slit interference using light.

(*f*) describe experiments which demonstrate stationary waves for either sound or microwaves, and on stretched strings.

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

(*h*) explain the meaning of the term diffraction.

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

(*j*) recall the formula $d \sin \theta = n\lambda$ and describe the use of a diffraction grating to determine the wavelength of light. The 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 vacuo*.

(*b*) recall the orders of magnitude of the frequencies and wavelengths of the principal radiations from radio waves to gamma 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 OF ELECTRICITY

CONTENT

14.1 Electric current.
14.2 Nature of charge carriers in conductors.
14.3 Transport of charge.
14.4 Potential difference.
14.5 Resistance and resistivity.
14.6 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 use the equation $I = Q/t$.
(*d*) understand the simple mechanisms of charge flow in metals and semiconductors.
(*e*) derive and use the equation $I = nAve$ for single carrier systems.
(*f*) recall orders of magnitude of typical carrier drift speeds and explain the relatively large drift velocity in semiconductors compared to that in metals.
(*g*) define potential difference and the volt.
(*h*) recall and use $P = VI$.
(*i*) define resistance and the ohm.
(*j*) recall and use $V = IR$.
(*k*) sketch the I–V characteristics of a metallic conductor at constant temperature, a semiconductor diode, a filament lamp and a thermistor.
(*l*) state Ohm's law.
(*m*) recall and use $R = \rho l/A$.
(*n*) 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.
(*o*) use energy considerations to distinguish between e.m.f. and p.d.
(*p*) 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 the current ASE Report—*SI Units, Signs, Symbols and Abbreviations.*
(*b*) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, any other type of component referred to in the syllabus.
(*c*) use the fact that the sum of the p.d's across the components in a series circuit is equal to the total p.d. across the supply and appreciate this as a consequence of conservation of energy.
(*d*) derive and use a formula for the combined resistance of two or more resistors in series.
(*e*) use the fact that the current from a source is the sum of the currents in the separate branches of a parallel circuit, and appreciate this as a consequence of conservation of charge.
(*f*) derive and use a formula for the combined resistance of two or more resistors in parallel.
(*g*) apply Kirchhoff's laws to simple circuits. (No formal statements of the laws are required.)

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

(*i*) 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.

(*j*) 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 charge.

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

(*c*) recall and use Coulomb's law in the form $F = Q_1Q_2/4\pi\epsilon_0r^2$ for the force between two point charges in free space or air.

(*d*) use $E = Q/4\pi\epsilon_0r^2$ 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 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 $V = Q/4\pi\epsilon_0r$ for the potential in the field of a point charge.

17. CAPACITANCE

CONTENT

17.1 Capacitors and capacitance.
17.2 Energy stored in a capacitor.
17.3 Charge and discharge.

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 and use formulae for capacitors in series and parallel.

(*e*) describe and explain an experiment to measure capacitance using a reed switch.

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

(*g*) describe experiments to demonstrate the exponential nature of capacitor charge and discharge.

(*h*) recognise and use equations of the form $x = x_0 \exp(-t/CR)$ for current, charge and p.d. when a capacitor discharges through a resistor.

(*i*) recognise and use the equations of the forms $x = x_0 \exp(-t/CR)$ and $x = x_0(1 - \exp(-t/CR))$ for the current, charge and p.d. when a capacitor charges through a resistor.

(*j*) demonstrate a quantitative understanding of time constant in CR circuits.

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 means of field lines.

(*c*) represent the strength of a magnetic field by magnetic flux density.

(*d*) recall and use $\Phi = BA$.

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*) recall and use Fleming's left-hand rule to predict the direction of the force on a current-carrying conductor.

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

(*c*) recall and use the equation $F = BIl \sin \theta$.

(*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*) use the equations $B = \mu_0 I/2\pi d$, $B = \mu_0 NI/2r$ and $B = \mu_0 nI$ for the flux densities of the fields due to a long straight wire, a flat circular coil and a long solenoid.

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

(*j*) describe the principle of the electromagnet.

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

(*l*) derive and use the equation $F/l = \mu_0 I_1 I_2/2\pi d$ given $B = \mu_0 I/2\pi d$.

(*m*) understand how the equation for the force between currents leads to a definition of a unit of current (A formal definition of the ampere is not required.)

(*n*) show an awareness of the principles of measurement of the flux density of (i) a field using a Hall probe and (ii) a changing field using a search coil.

20. ELECTROMAGNETIC INDUCTION

CONTENT

20.1 Laws of electromagnetic induction.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) 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..

(*b*) recall and use the laws of electromagnetic induction to determine the magnitude and direction of induced e.m.f's. (Candidates will not be required to give a formal statement of the laws.)

(*c*) 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 by an equation of the form $I = I_0 \sin \omega t$.

(*d*) understand the distinction between r.m.s. and peak values and recall and use the relationship $I_{r.m.s.} = I_0/\sqrt{2}$ 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 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 4 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.

22. ELECTRONICS

CONTENT

22.1 Systems approach.

22.2 Digital systems.

22.3 Analogue systems.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) appreciate the systems approach to electronics.

(*b*) distinguish between digital systems and analogue systems with reference to similarities and differences.

(*c*) understand the function of each of the following logic gates: NOT, AND, NAND, NOR, OR, EX-OR, EX-NOR and represent these functions by means of truth tables (limited to a maximum of 2 inputs).

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

(*e*) analyse circuits using combinations of logic gates to perform binary arithmetic, including the half-adder and the principle of linking half-adders to produce a full-adder.

(*f*) appreciate that a bistable circuit gives an output which depends not only on the input but also on its previous output state.

(*g*) show an awareness that certain circuits are triggered only on the rising edge of a pulse and represent this action by means of a timing diagram.

(*h*) describe the properties of an ideal operational amplifier.
(*i*) understand the use of an operational amplifier as a comparator.
(*j*) understand the principle of feedback in an amplifier.
(*k*) use the virtual earth approximation to derive an expression for the gain of inverting amplifiers.
(*l*) recall and explain the effect of negative feedback on the gain and bandwidth of an operational amplifier.
(*m*) describe the use of operational amplifiers in inverting, non-inverting and differential amplifier circuits.

SECTION V MATTER

23. PHASES OF MATTER

CONTENT

23.1 Density.
23.2 Solids, liquids, gases.
23.3 Pressure in fluids.
23.4 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 glasses.
(*f*) define the term pressure and use the kinetic model to explain the pressure exerted by gases.
(*g*) derive and use the equation $\Delta p = \rho g \Delta h$.
(*h*) distinguish between the processes of melting, boiling and evaporation.

24. DEFORMATION OF SOLIDS

CONTENT

24.1 Stress, strain.
24.2 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 load-extension graph.
(*g*) demonstrate knowledge of the force-extension graphs for typical ductile, brittle and polymeric materials.

25. TEMPERATURE

CONTENT

25.1 Temperature scales.

25.2 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. (The thermodynamic scale.)

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

26. THERMAL PROPERTIES OF MATERIALS

CONTENT

26.1 Heat capacity.

26.2 Latent heat.

26.3 Internal energy.

26.4 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*) define and use molar heat capacity.

(*d*) explain why the molar heat capacity of a gas at constant volume is different from that at constant pressure.

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

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

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

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

(*i*) 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, $\Delta U = q + w$.

27. IDEAL GASES

CONTENT

27.1 Equation of state.

27.2 Kinetic theory of gases.

27.3 Pressure of a gas.

27.4 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 $pV = nRT$, $pV_m = RT$ and $pV = NkT$.

(*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 $p = \frac{1}{3}\rho < c^2 >$.

(*d*) compare $p = \frac{1}{3}\rho < c^2 >$ with $pV = NkT$ and hence deduce that the average translational kinetic energy of a monatomic molecule is given by $(3/2)kT$.

28. TRANSFER OF THERMAL ENERGY

CONTENT

28.1 Thermal conduction.

28.2 Thermal conductivity.

28.3 Convection.

28.4 Radiation.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) describe mechanisms of thermal conduction limited to a qualitative understanding of the processes of electron diffusion and lattice vibration in metals and non-metallic crystals.

(*b*) recall and use $q/t = -\lambda A \Delta T/\Delta x$ for one-dimensional flow.

(*c*) appreciate the analogy between heat conduction and electrical conduction.

(*d*) understand the principles of determination of thermal conductivity of good and bad conductors (details of experiments are not required).

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

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

29. CHARGED PARTICLES

CONTENT

29.1 Electrons.

29.2 Beams of charged particles.

29.3 Cathode-ray oscilloscope.

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.

(*f*) describe the basic structure of a cathode-ray tube regarded as an electron gun, an electrostatic deflection system and a means of display.

(*g*) describe the use of a cathode-ray oscilloscope as a measuring instrument including an appreciation of the functions of amplifiers and the time-base.

30. QUANTUM PHYSICS

CONTENT

30.1 Energy of a quantum.

30.2 Photoelectric emission of electrons.

30.3 Wave-particle duality.

30.4 Line spectra.

30.5 Energy levels in atoms.

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*) distinguish between emission and absorption line spectra.
(*k*) understand the existence of discrete electron energy levels in isolated atoms and explain how this leads to spectral lines.

31. ATOMIC STRUCTURE

CONTENT

31.1 The nuclear atom.
31.2 The nucleus.
31.3 Isotopes.
31.4 Mass excess and nuclear binding energy.
31.5 Nuclear processes.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) demonstrate a qualitative understanding of the alpha 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*) describe the principle of a mass spectrometer and understand its use to demonstrate the existence of isotopes and to indicate their relative abundance.
(*g*) appreciate the association between mass and energy as represented by $\Delta m = E/c^2$.
(*h*) illustrate graphically the variation of binding energy per nucleon with nucleon number.
(*i*) describe the relevance of binding energy per nucleon to nuclear fusion and nuclear fission.
(*j*) appreciate that nucleon number, proton number, energy and mass are all conserved in nuclear processes.
(*k*) represent simple nuclear reactions by nuclear equations of the form
$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$.

32. RADIOACTIVITY

CONTENT

32.1 Types of ionising radiation.
32.2 Detection of ionising radiation.
32.3 Hazards and safety precautions.
32.4 Radioactive decay.
32.5 Radioisotopes.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) appreciate the spontaneous nature of nuclear decay.

(*b*) show an awareness of the existence, origins and 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 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 a solution to the decay law to derive, $\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$.

(*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 S

SOUND AND MUSIC

In this option the term 'note' will be used to indicate an instrumental sound which includes the fundamental and other overtones. The term 'pure tone' will be used for sound of a single frequency.

The term 'overtone' will be used to indicate those frequencies above the fundamental which can be detected in a note. The term 'harmonic' will be used for an overtone for which the frequency f is given by nf_0, where n is an integer $\geqslant 2$ and f_0 is the fundamental frequency.

S1. CHARACTERISTICS OF SOUND

CONTENT

1.1 Human hearing.
1.2 Description of sound.
1.3 Musical scales.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) recall typical ranges of frequency and intensity for human hearing.

(*b*) understand pitch as the subjective description of the perceived frequency of a note so that notes from different instruments are said to be of the same pitch if they seem to a listener to be of the same predominant frequency.

(*c*) understand timbre as the subjective description of the waveform of a note, transients being the principal factor enabling the listener to distinguish sounds made by different instruments playing at the same pitch.

(*d*) understand loudness as the subjective qualitative perception of intensity, the perception varying with pitch and timbre and between individuals.

(*e*) appreciate that the diatonic scales are based on fractional changes in frequency.

S2. STRINGED INSTRUMENTS

CONTENT

2.1 Stationary waves on strings.
2.2 Overtones on strings.
2.3 Initiation of vibration.
2.4 Control of pitch.
2.5 Control of intensity.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) describe and explain the production of stationary waves on a stretched string.
(*b*) appreciate the relevance of stationary waves to the production of sound by stringed instruments.
(*c*) demonstrate an awareness of the presence of overtones which consist of odd and even harmonics.
(*d*) describe how a stationary wave can be initiated by striking, plucking or bowing.
(*e*) show an awareness that the relative intensities of the overtones is determined by the method of initiation, by the position of the initial disturbance, and by the characteristics of the instrument.
(*f*) recall and use $f_0 = \frac{1}{2l}\sqrt{\frac{T}{M}}$.
(*g*) understand how a string may be tuned by adjustment of tension and stopped to change the pitch.
(*h*) understand how the power transferred to the air by a string can be increased by the use of sounding boards.

S3. WIND INSTRUMENTS

CONTENT

3.1 Stationary waves in air columns.
3.2 Overtones in air columns.
3.3 Initiation of vibration.
3.4 Control of pitch.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) describe and explain the production of stationary waves in an air column.
(*b*) appreciate the relevance of stationary waves to the production of sound by air columns.
(*c*) show an awareness of the possibility of odd and even harmonics in open and closed pipes.
(*d*) relate the wavelength of a stationary wave to the length of the pipe and appreciate the relevance of end correction.
(*e*) describe how a stationary wave is initiated in a trumpet or trombone; in a flute, organ or recorder; and in a clarinet.
(*f*) understand how the pitch of the note can be changed
 (i) by changing the length of the air column, as in a trombone or organ,
 (ii) by the use of holes and valves, as in the trumpet or recorder,
 (iii) by the use of lips, as in the trumpet.

S4. PERCUSSION INSTRUMENTS

CONTENT

4.1 Stationary waves in membranes.
4.2 Modes of vibration in membranes.
4.3 Control of pitch.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) describe and explain the production of stationary waves in membranes.

(*b*) appreciate the relevance of stationary waves to the production of sound by percussion instruments.

(*c*) describe experiments in which Chladni figures are used to show circular and diametric modes, as in drums and tambourines.

(*d*) demonstrate an awareness that percussion instruments may have a high random noise component and hence may not have readily recognisable pitch.

(*e*) show a qualitative awareness that pitch may be determined by factors such as position of initial disturbance, hardness of drumstick, striking force, membrane tension, thickness and shape (including reference to steel band instruments), temperature.

S5. ACOUSTICS

CONTENT

5.1 Factors affecting acoustic properties.

5.2 Acoustic design.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) understand the importance of reflecting and absorbing materials in determining the acoustic properties of a room.

(*b*) explain the terms reverberation and reverberation time.

(*c*) recall and understand that reverberation time is conventionally defined as the time for the intensity level to fall by a factor of 10^6.

(*d*) describe qualitatively methods of sound insulation.

OPTION C

COMMUNICATIONS

C1. ALTERNATING CURRENT

CONTENT

1.1 Components in a.c. circuits.

1.2 Resonant circuits.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) recall that an inductor is a circuit component which opposes changes in current, the value of the inductance being measured in henries.

(*b*) describe experiments to investigate alternating current in circuits containing resistance, capacitance or inductance alone.

(*c*) understand the concepts of phase and reactance in a.c. circuits.

(*d*) recall the phase relationship between current and p.d. in a.c. circuits containing resistance, capacitance or inductance alone.

(*e*) describe the dependence of reactance on capacitance, inductance and frequency, representing the results graphically.

(*f*) recall and use $X_L = \omega L$ and $X_c = \frac{1}{\omega C}$.

(*g*) describe an experiment which demonstrates resonance in a parallel LC circuit, and investigate the effect of resistive damping in such a circuit.

(*h*) derive an expression for resonant frequency in terms of capacitance and inductance.

C2. RADIO COMMUNICATION

CONTENT

2.1 Waveforms.
2.2 Basic principles of modulation.
2.3 Side-bands and bandwidth in amplitude-modulated waves.
2.4 Amplitude modulated radio reception.
2.5 Audio-frequency amplification.
2.6 Propagation of radio waves.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) outline experiments, using an oscilloscope or a microcomputer, to demonstrate the synthesis of waveforms from sinusoidal components, and appreciate the significance of such synthesis for speech and music.

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

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

(*d*) appreciate the implications of bandwidth for radio reception.

(*e*) recall and understand the function of each of the following elements in an amplitude modulated radio receiver: aerial, tuning circuit, radio frequency amplifier, detector (de-modulator), audio frequency amplifier, loudspeaker.

(*f*) draw a block diagram showing how the elements in (*e*) are combined in an amplitude-modulated radio receiver.

(*g*) understand the principle of the use of the half-wave dipole aerial as a transmitting antennae and the use of parabolic reflecting dishes and dipoles in receiving antennae.

(*h*) describe an experiment which demonstrates how an operational amplifier with negative feedback can be used to provide audio-frequency amplification.

(*i*) use the expression for the voltage gain of an inverting amplifier circuit using an operational amplifier with negative feedback.

(*j*) appreciate the effect of the curvature 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.

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

(*l*) derive and use an expression for the radius of a geostationary satellite.

C3. DIGITAL METHODS OF COMMUNICATION

CONTENT

3.1 Comparison of analogue and digital signals.
3.2 Transmission of speech or music by digital methods.
3.3 Simultaneous transmission of messages along a single link.
3.4 Fibre optic links.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) distinguish between analogue and digital signal pulses.

(*b*) demonstrate an awareness of methods of digital encoding of information.

(*c*) describe the transmission of speech or music by digital methods, including transmission, reception and decoding.

(*d*) demonstrate an awareness of the importance of transmitting more than one message simultaneously along a single link.

(*e*) describe the simultaneous transmission of messages by the use of several carrier waves and the division of time intervals showing an awareness of the importance of bandwidth in the transmission of information.

(*f*) explain the exponential decay of optical power expressed by the equation $P = P_0 e^{-ax}$ and thus appreciate the importance of using low-loss material and repeater units.

(*g*) understand the principles of fibre optic transmission.

(*h*) compare fibre optic transmission with electric cable transmission.

OPTION M

MEDICAL PHYSICS

M1. IONISING RADIATION

CONTENT

1.1 Biological effects.

1.2 Production of X-rays.

1.3 Use of X-rays in diagnosis.

1.4 Radiotherapy.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) describe in simple terms the effects of ionisation on living matter.

(*b*) understand qualitatively the importance of limiting exposure to ionising radiation with particular reference to type of radiation, dose rate and dose.

(*c*) give a simple description of the way in which X-rays are produced by electron bombardment of a metal target.

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

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

(*f*) describe the use of the gamma camera as a radiation scanner.

(*g*) describe examples of the use of X-rays and gamma rays and of implanted sources in the treatment of malignancy.

M2. ULTRASONICS

CONTENT

2.1 Production of ultrasound.

2.2 Use of ultrasound in medical diagnosis.

ASSESSMENT OBJECTIVES

Candidates should be able to:

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

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

M3. THE PHYSICS OF SIGHT

CONTENT

3.1 The eye.

3.2 Defects of the eye and their correction.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) describe the optical structure of the eye.
(*b*) explain how the eye forms focused images of objects at different distances.
(*c*) understand the terms depth of focus and accommodation.
(*d*) distinguish between short sight, long sight and astigmatism.
(*e*) describe and explain how short sight, long sight and astigmatism can be corrected using spectacle lenses or contact lenses.
(*f*) distinguish between converging and diverging lenses, and understand the significance of focal length.
(*g*) recall and use the lens formula to calculate the focal length of the auxiliary lens required to correct short sight and long sight.
(*h*) 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*) describe the basic structure of the ear and 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.

M5. HUMAN MECHANICS

CONTENT

5.1 Elementary anatomy.
5.2 Forces and moments.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) understand that movement at joints is controlled by opposing sets of muscles attached by ligaments to the bones forming the joint.
(*b*) appreciate that the muscular-skeletal system of the body is a complex system of levers.
(*c*) provide a simple analysis of the forces involved in bending and lifting.
(*d*) provide a simple analysis of the interactions of the human body with the ground when walking and running.

M6. ENERGY CONSIDERATIONS

CONTENT

6.1 Energy-related processes.
6.2 Energy sources.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) explain the relationship between blood pressure and the rate of working of the heart.
(*b*) calculate the rate of working of the heart in terms of blood flow and pressure difference.
(*c*) appreciate that power is required to maintain body temperature.
(*d*) estimate the power typically provided by muscles.
(*e*) understand the process of perspiration as a means of increasing power dissipation.
(*f*) describe means of preventing excessive power dissipation by the use of insulating and reflecting covers such as duvets and reflective blankets.
(*g*) recall typical energy values of fats (triglycerides), carbohydrates and proteins.
(*h*) recall typical daily energy needs and explain the dependence on surface area and body volume.

OPTION T

PHYSICS OF TRANSPORT

T1. GENERATION OF FORWARD FORCE

CONTENT

1.1 Motive forces.

1.2 Conservation of momentum.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) describe how walking, or driving wheels, can generate a forward force at the ground.
(*b*) appreciate that pressure differences can result from different rates of flow of a fluid (the Bernouilli effect).
(*c*) understand how the Bernouilli effect of wind over sails leads to a force.
(*d*) use resolution of forces to explain how the force due to the air moving over the sail enables the craft to sail into the wind.
(*e*) use the principle of conservation of momentum to explain the thrust developed by rockets and jet engines.
(*f*) explain how a motive force is provided by a propeller.

T2. OTHER FORCES

CONTENT

2.1 Lift forces generated by aerofoils.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) explain the lift force which results from the Bernouilli effect of air moving over aerofoils.
(*b*) explain qualitatively, for a fixed wing aircraft, how the magnitude of the lift depends on the speed of the aircraft and the angle of attack of the wings.
(*c*) describe qualitatively, for a helicopter, how the lift is provided by the rotors.

T3. BALANCE OF FORCES

CONTENT

3.1 Straight level motion at constant speed.
3.2 Acceleration and deceleration.
3.3 Turning forces.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) understand that straight level motion at a constant speed is the result of a balance of horizontal and vertical components of forces.
(*b*) appreciate the continuous power required to compensate for the power dissipated by drag forces.
(*c*) calculate an approximate value for drag force using the magnitude of the power dissipated.
(*d*) appreciate the need to vary power in order to change speed.
(*e*) describe braking using friction pads with some appreciation of the need to dissipate the heat produced.
(*f*) state and explain the advantages of hydraulic braking systems in road vehicles.
(*g*) describe and explain the use of reverse thrust for the deceleration of aircraft and ships.
(*h*) understand that an additional lateral force is necessary for motion along a curved path and describe how such a force is provided in the case of road vehicles, aircraft and marine craft.

T4. STABILITY

CONTENT

4.1 Stability in turning.
4.2 Stability of boats and submarines.
4.3 Balance of couples on aircraft.
4.4 Upthrust provided by displaced water.
4.5 Drag due to turbulence.

ASSESSMENT OBJECTIVES

Candidates should be able to:

(*a*) explain how the banking of roads and railways can provide the lateral force required for motion along a curved path.
(*b*) calculate the angle of banking required to maintain motion in a specified circle at a given speed in the absence of lateral friction.
(*c*) explain the increased stability obtained by lowering the centre of gravity of a vehicle.
(*d*) explain how the stability of a boat or submarine is affected by the position of the centre of gravity.
(*e*) appreciate the need to counteract the lateral force of the wind on sails, and describe how this can be achieved by the use of a keel or centre board.
(*f*) specify the couples acting on an aircraft due to weight and lift and due to thrust and drag, and appreciate that, for equilibrium, the couples must be balanced.
(*g*) describe and explain the use of the rear rotor to counter the torque exerted by the main rotor of a helicopter.
(*h*) recall that an upthrust is provided by the water displaced by marine craft.
(*i*) calculate the upthrust in terms of the weight of the displaced water.
(*j*) appreciate that the vertical position of a submarine in the water can be controlled by flooding or emptying buoyancy tanks.
(*k*) derive and use a simple equation which suggests that the drag force due to turbulence in a fluid will be approximately proportional to the square of the speed.
(*l*) demonstrate an appreciation of the benefit of streamlining.

ASSESSMENT OF PRACTICAL SKILLS

(PAPERS 9240/4+5, 9240/7, 9240/9)

Introduction

Assessment of Practical Skills may be undertaken through Papers 4 or 5, or through Paper 9. If Paper 7 is taken, it must be in conjunction with Paper 4 or Paper 9. (A candidate's score will be used in the subject aggregation if his Paper 7 score is better than his Paper 4 (or Paper 9) score.) All the practical papers address **ASSESSMENT OBJECTIVE C Experimental skills and investigations**. (See page 4.)

Papers 4 and 5

These papers form the externally set and marked practical components. Paper 4 is available in June only; Paper 5 is available in November only. Each paper will consist of two compulsory questions, each of 1 hour 15 minutes duration. The Examiners will not be strictly bound by the syllabus in setting experiments. Where necessary, 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.

A copy of the rubric from a typical practical examination paper is as follows:

Instructions to candidates:

Answer **both** *questions.*

Both questions carry the same number of marks.

You are expected to record all of your observations as soon as these observations are made, and to plan the presentation of the records so that it is not necessary to make a fair copy of them.

The working of the answers is to be shown.

Details of routine procedures and theory need not be written down. You may be asked to write about specific techniques you have used.

Provision has been made in the Question Paper for you to record your observations, readings, etc., and for you to plot the graphs required. Additional answer paper and graph sheets should be submitted only if it becomes necessary to do so.

Paper 7

This paper takes the form of an individual study. This scheme is available to internal candidates within the UK at the June examination only. All candidates must still be entered for either Paper 4 (the practical examination) or for Paper 9 (internal assessment).

It is recognised that only a minority of centres may wish, or be able, to take advantage of the scheme. It is intended that candidates should take part in the scheme on a voluntary basis, with the agreement of the centre staff, and that candidates should be free to suggest studies in accordance with their own particular interest, bearing in mind the facilities available and the Assessment Objectives (C) for practical skills and investigations given on page 4.

It is expected that work on any study submitted for assessment should not extend over more than three terms. It is recommended that, prior to work on individual studies, the candidate should take part in a straightforward group investigation in order to gain practice in the planning and writing up of an individual study.

Wherever possible, candidates should work individually on their studies but, if circumstances make it necessary for pairs of candidates to share apparatus and to do some of their experimental work together, separate accounts of the work done must be prepared independently by each candidate and should include statements of their individual contributions.

It is appreciated that the candidate's original aim may prove too ambitious or otherwise unrealistic and that the work finally submitted may therefore not exactly match the outline description. For instance, preliminary work on the study may raise points of interest which it seems more profitable to pursue and which may deflect the candidate into channels not directly contributing to the original aim. This will not necessarily count against the candidate since an intelligent study of the cause of some apparently anomalous finding may prove more worthwhile than the sustained pursuit of the original aim at the expense of leaving a number of experimental results unexplained.

Each centre with candidates wishing to offer Paper 7 must send to the Syndicate, for approval, on an OUTLINE SUBMISSION FORM (which will be provided on request), as precise a statement as possible of what each candidate proposes to do; broad titles conveying only a vague idea of what is intended must be avoided. The forms should be returned to the Syndicate by 1st November in the year preceding that in which the candidate will sit the Advanced Level examination.

The centre will be required to send to the Examiner the candidates' individual accounts of their work by 31st March in the year of the examination. For easy reference, candidates must include a table of contents and the pages must be numbered. Candidates should write on only one side of the paper, leaving a margin on each page. Each account should include a bibliography and appropriate acknowledgements of all external help.

The Examiner will visit each centre concerned on a date mutually arranged, and will interview each candidate separately (for approximately 15 minutes). The apparatus that has been used by the candidates must be available in working order during the Examiner's visit. The Examiners will make their assessment on the basis of the Assessment Objectives C (see page 4).

An additional fee per candidate will be charged, which should be included with the fee for the Advanced Level examination.

Paper 9

This paper forms the internally (teacher)-assessed and externally (Syndicate)-moderated practical component.

Some of the abilities and skills which should be developed as part of the A level Physics course (for example, manipulation of apparatus, observation, interpretation of results, and planning) can be taught adequately only through the medium of practical work.

A continuous assessment of practical work (by the teacher) throughout the A level course allows direct observation of all the practical Assessment Objectives (see page 4, C1 to C5). The scheme detailed below is intended to provide guidance for teachers in making the practical assessment, but should not exert 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 a candidate will be assessed.

The experimental skills to be assessed, given in terms of candidates' abilities, are as folllows:

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. design and plan investigations, evaluate methods and techniques, and suggest possible improvement;
5. record observations, measurements, methods, and techniques with due regard to precision, accuracy and units.

The five skills carry equal weighting.

Candidates should be made aware that continuous assessment is being applied, but this should be part of the normal teaching programme. Teachers must give their candidates opportunities to acquire a given skill before they make an assessment. Each candidate must be assessed at least twice for each of skills C1, C2, C3, C4 and C5. The assessment scores finally recorded should represent the candidates' best performances.

Criteria for Assessment of Experimental Skills

Each skill is assessed on a 6 point scale, level 6 being the highest level of achievement. A score of 0 is available if there is no evidence of positive achievement for the skill.

Each of the skills is defined in terms of three levels of achievement at scores of 2, 4 and 6.

For candidates who do not meet the criteria for a score of 2, a score of 1 is available if there is some evidence of positive achievement.

A score of 3 is available for candidates who go beyond the level defined for 2, but who do not meet fully the criteria for 4.

Similarly, a score of 5 is available for those who go beyond the level defined for 4, but do not meet fully the criteria for 6.

SKILL C1

FOLLOWING INSTRUCTIONS AND USING AND ORGANISING TECHNIQUES, APPARATUS AND MATERIALS

1

2 — With guidance, can perform a single practical operation using familiar apparatus and materials adequately.

3

4 — Adequate ability, generally able to apply an appropriate degree of precision to particular manipulations.

5

6 — Full range of skills well displayed. Experiment carried out skilfully and to a suitable degree of accuracy without assistance.

As an example, a candidate who demonstrated all of the following attributes would score 6 marks; one who demonstrated 3 or 4 of the attributes would score 4 marks; and one who demonstrated 1 or 2 of the attributes would score 2 marks. The score of 1 would be reserved for a candidate who failed to demonstrate any of the attributes but who nevertheless showed some evidence of positive achievement.

The candidate

(*a*) set up the apparatus, with or without minor assistance;

(*b*) set up the apparatus, with no assistance;

(*c*) used the apparatus competently and confidently;

(*d*) used the apparatus to obtain the required outcomes sensibly and skilfully;

(*e*) took explicit steps to ensure the safety of the apparatus and other laboratory users.

SKILL C2

OBSERVING AND MEASURING

1

2 — Given guidance, makes some relevant observations or readings.

3

4 — Makes relevant observations or measurements.

5

6 — Makes a full range of relevant observations or measurements to an appropriate precision.

As an example, a candidate who demonstrated all of the following attributes would score 6 marks; one who demonstrated 3 or 4 of the attributes would score 4 marks; and one who demonstrated 1 or 2 of the attributes would score 2 marks. The score of 1 would be reserved for a candidate who failed to demonstrate any of the attributes but who nevertheless showed some evidence of positive achievement.

The candidate

(*a*) obtained some relevant observations, with or without minor assistance;

(*b*) obtained reasonable sets of observations, with no assistance;

(*c*) obtained sound observations, with or without minor exceptions;

(*d*) made accurate and reasonable interpolations or deductions;

(*e*) validated observations using sensible procedures such as repeating important observations or sets of observations.

SKILL C3

INTERPRETING AND EVALUATING EXPERIMENTAL OBSERVATIONS AND DATA

1
2 — Draws a simple conclusion from the results of an experiment.
3
4 — Draws a conclusion which is consistent with a series of results.
5
6 — Expresses conclusions as generalisations or patterns where appropriate. Able to appreciate the limitations of an experiment and the reliability of the conclusion.

As an example, a candidate who demonstrated all of the following attributes would score 6 marks; one who demonstrated 3 or 4 of the attributes would score 4 marks; and one who demonstrated 1 or 2 of the attributes would score 2 marks. The score of 1 would be reserved for a candidate who failed to demonstrate any of the attributes but who nevertheless showed some evidence of positive achievement.

The candidate

(*a*) used a sensible method of analysis of observations;
(*b*) made no major errors in the processing of observations;
(*c*) drew a conclusion which is consistent with the processed observations;
(*d*) made a reasonable estimate of the reliability of the conclusion;
(*e*) made a reasonable analysis of the limitations of the experiment and suggested sensible ways of overcoming the weaknesses.

SKILL C4

DESIGNING, PLANNING AND EVALUATING INVESTIGATIONS

1
2 — Is able to suggest a simple plan to carry out an investigation and, with guidance, is able to select sensible apparatus and variables.
3
4 — Suggests a sound plan requiring little modification, comments critically on their original plan, and implements appropriate changes in the light of the experience.
5
6 — Plans efficiently and times the various parts realistically; is capable of modifying the plan in the light of experience; considers alternative approaches.

As an example, a candidate who demonstrated all of the following attributes would score 6 marks; one who demonstrated 3 or 4 of the attributes would score 4 marks; and one who demonstrated 1 or 2 of the attributes would score 2 marks. The score of 1 would be reserved for a candidate who failed to demonstrate any of the attributes but who nevertheless showed some evidence of positive achievement.

The candidate

(*a*) selected a sensible set of variables, with or without minor assistance;
(*b*) selected sensible apparatus and procedures, with or without minor assistance;
(*c*) selected sensible apparatus and procedures, with no assistance;
(*d*) was capable of modifying the apparatus and procedures in the light of experience;
(*e*) considered at least one alternative approach in respect of either the selection of parameters or apparatus, or the methods of increasing reliability.

SKILL C5

RECORDING AND REPORTING

1

2 — Given guidance, reports on all major aspects of the work and records some observations.

3

4 — Some reference to all major aspects of the work in a report which is well organised and well presented. Graphs plotted, if appropriate.

5

6 — Reports on all aspects of the work in a report which is well organised, well presented with correct units and appropriate precision. Is able to plot graphs accurately.

As an example, a candidate who demonstrated all of the following attributes would score 6 marks; one who demonstrated 3 or 4 of the attributes would score 4 marks; and one who demonstrated 1 or 2 of the attributes would score 2 marks. The score of 1 would be reserved for a candidate who failed to demonstrate any of the attributes but who nevertheless showed some evidence of positive achievement.

The candidate's report

(*a*) included all major aspects of the work;

(*b*) was logically organised and easy to follow;

(*c*) was well presented with appropriate sub-headings;

(*d*) properly indicated units, symbols and equations and showed the appropriate number of significant figures throughout;

(*e*) included appropriate diagrams, correctly labelled, and graphs, accurately drawn.

ADMINISTRATION AND REGULATIONS

Centres should inform the Syndicate of their intention of entering candidates for Paper 9 using the Provisional Entries Estimate Form (PE1).

Paper 9 will not be available in the November examination, but candidates who entered for this paper in the June examination can have their assessment carried forward as Paper 89.

It is not expected that assessment will be carried out during the first term of the course. At whatever stage the assessments are done, the standards applied must be those exemplified by the stated criteria.

The scores for individual assessments should be recorded on the students' work as part of the normal feedback from the teacher. The final total mark, as submitted to the Syndicate, should not be given to the students.

The recording of assessments

The Syndicate will provide two forms for use in this scheme.

(i) Student Record Card. A record card to be used for each student.

(ii) Centre Record Card. A sheet, on one side of which are to be entered descriptions of the experiments used in the assessment scheme. Each experiment is to be numbered so that the number and the date on which that experiment was carried out by the student can be entered on the Student Record Card. The other side of the sheet is to be used as a summary of the marks for the whole centre. A duplicate card is to be retained at the centre.

In using the Student Record Card, the teacher should insert the date and experiment number, together with the appropriate two marks for each of the skills being assessed. The overall total should then be recorded on the Centre Record Card. A separate sheet must be completed for each set unless they are taught by the same teacher.

A pre-printed mark sheet, showing the index numbers and names of candidates, to be used for sending the total mark to the Syndicate, will then be forwarded to centres for return to the Syndicate by 30th April.

The Student Record Card, the Centre Record Card and the completed pre-printed mark sheet must be submitted to the Syndicate when requested.

A duplicate Centre Record Card must be retained at the centre for reference purposes.

Moderation

Centres entering more than one teaching set for this scheme must ensure that all staff assess their students to a common standard. It is not necessary, however, for all students to follow the same series of experiments.

Schools will be required to submit all the assessed practical work, which forms the basis of the total mark submitted, from a sample of their students. These should be despatched to Cambridge on the day of the last theory paper for A level Physics. Such work should, therefore, be in a suitable form for despatch to the Syndicate. It is essential that the work includes the instructions given to the students, the marking scheme or criteria, and that the work is clearly marked and labelled.

Moderation will involve comparing samples of work and will not involve statistical moderation.

On the basis of the moderation procedure, the marks of individual schools may be adjusted, but the teacher's rank order will not normally be changed.

MATHEMATICAL REQUIREMENTS

(Please see note on page 5 concerning the Special Paper.)

Arithmetic

Candidates should be able to:

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

(*b*) use appropriate calculating aids (electronic calculator, tables or slide-rule) for addition, subtraction, multiplication and division. Find arithmetic means, reciprocals, square roots, sines, cosines, tangents, exponentials and logarithms.

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

(*d*) make approximate evaluations of numerical expressions (e.g. $\pi^2 = 10$) 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.

(*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, $<$, $>$, $\ll$, $\gg$, $\approx$, $/$, $\propto$, $<x>$ $(= \bar{x})$, Σ, Δx, δx.

Geometry and trigonometry

Candidates should be able to:

(*a*) calculate areas of right-angled and isosceles triangles, circumferences 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 and use the slope of a tangent to a curve as a means to obtain the gradient. understand 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.

GLOSSARY OF TERMS USED IN PHYSICS PAPERS

It is hoped that the glossary will prove helpful to candidates as a guide, although it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Define* (the term(s) . . .) is intended literally, only a formal statement or equivalent paraphrase being required.
2. *What do you understand by/What is meant by* (the term(s) . . .) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in 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 readily be obtained 'by inspection'.
4. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified this should not be exceeded.
5. *Explain* may imply reasoning or some reference to theory, depending on the context.
6. *Describe* requires the candidate to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena.

   In other contexts, *describe* and *give an account of* should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. *Describe and explain* may be coupled in a similar way to *state and explain*.
7. *Discuss* requires the candidate to give a critical account of the points involved in the topic.
8. *Outline* implies brevity, i.e. restricting the answer to giving essentials.
9. *Predict* or *deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an early part of the question.

   Predict also implies a concise answer with no supporting statement required.
10. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer, or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.
11. *Find* is a general term that may variously be interpreted as *calculate*, *measure*, *determine*, etc.
12. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.
13. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or mass, using a balance.
14. *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.
15. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.
16. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, *but* candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value.

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

SUMMARY OF KEY QUANTITIES SYMBOLS AND UNITS

The following list illustrates the symbols and units that will be used in question papers (relevant ones being used in the Data Booklet).

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.

Quantity	*Usual symbols*	*Usual unit*
Base Quantities		
mass	m	kg
length	l	m
time	t	s
electric current	I	A
thermodynamic temperature	T	K
amount of substance	n	mol
Other Quantities		
distance	d	m
displacement	s, x	m
area	A	m^2
volume	V, v	m^3
density	ρ	$kg\,m^{-3}$
speed	u, v, w, c	$m\,s^{-1}$
velocity	u, v, w, c	$m\,s^{-1}$
acceleration	a	$m\,s^{-2}$
acceleration of free fall	g	$m\,s^{-2}$
force	F	N
weight	W	N
momentum	p	N s
work	w, W	J
energy	E, U, W	J
potential energy	E_p	J
kinetic energy	E_k	J
heating	q	J
change of internal energy	ΔU	J
power	P	W
pressure	p	Pa
torque	T	N m
gravitational constant	G	$N\,kg^{-2}\,m^2$
gravitational field strength	g	$N\,kg^{-1}$
gravitational potential	Φ	$J\,kg^{-1}$
angle	θ	°, rad
angular displacement	θ	°, rad
angular speed	ω	$rad\,s^{-1}$
angular velocity	ω	$rad\,s^{-1}$
period	T	s
frequency	f	Hz
angular frequency	ω	$rad\,s^{-1}$
wavelength	λ	m
speed of electromagnetic waves	c	$m\,s^{-1}$
electric charge	Q	C
elementary charge	e	C
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
resistance	R	Ω
resistivity	ρ	Ω m
electric field strength	E	$N\,C^{-1}$
permittivity of free space	ϵ_0	$F\,m^{-1}$
capacitance	C	F

time constant	τ	s
magnetic flux	Φ	Wb
magnetic flux density	B	T
permeability of free space	μ_0	$H\,m^{-1}$
stress	σ	Pa
strain	ϵ	
force constant	k	$N\,m^{-1}$
Young modulus	E	Pa
Celsius temperature	t	°C
specific heat capacity	c	$J\,K^{-1}\,kg^{-1}$
molar heat capacity	C_m	$J\,K^{-1}\,mol^{-1}$
principal molar heat capacities	$C_{v,m}$; $C_{p,m}$	$J\,K^{-1}\,mol^{-1}$
molar gas constant	R	$J\,K^{-1}\,mol^{-1}$
Boltzmann constant	k	$J\,K^{-1}$
Avogadro constant	L	mol^{-1}
number	N, n, m	
number density (number per unit volume)	n	m^{-3}
thermal conductivity	λ	$W\,m^{-1}\,K^{-1}$
Planck constant	h	J s
work function energy	ϕ	J
activity of radioactive source	A	Bq
decay constant	λ	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	$kg\,mol^{-1}$
proton number	Z	
nucleon number	A	
neutron number	N	

UNIVERSITY OF CAMBRIDGE
LOCAL EXAMINATIONS SYNDICATE
INTERNATIONAL EXAMINATIONS

Data Booklet
Advanced Level
and
Higher School Certificate (Principal Level)
for
Physics, Chemistry and Physical Science

Physics p. 2

For use in all papers after January 1990 except practical examinations.

PHYSICS
(9240)

Values of constants

speed of light in a vacuum,	c	$= 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of a vacuum,	μ_0	$= 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of a vacuum,	ϵ_0	$= 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ $\approx (1/(36\pi)) \times 10^{-9}\ \mathrm{F\,m^{-1}}$
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,	L	$= 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
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	$= 9.81\ \mathrm{m\,s^{-2}}$