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A Level

Physics

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1984
Science Subjects

GENERAL CERTIFICATE OF EDUCATION

EXAMINATION SYLLABUSES FOR
1984

PHYSICS
AND
ENGINEERING SCIENCE
ELECTRICITY AND ELECTRONICS

UNIVERSITY OF CAMBRIDGE
LOCAL EXAMINATIONS SYNDICATE
INTERNATIONAL EXAMINATIONS
June 1982

PHYSICS
9240

GCE Advanced Level/HSC Principal Level

General Notes

(*a*) Problems in which the mathematics is the main interest will not be set.

(*b*) Although the syllabus is intended to be self-contained, a good grounding in physics of O-level standard is assumed.

(*c*) The absence of a direct reference in the syllabus to a well-known, commonly accepted term will not necessarily preclude the use of such a term in the question papers.

(*d*) Attention is also drawn to Circular to Schools 78/20 on practical work published in October 1978.

(*e*) The interboard committee set up to consider the development of a National Core A-level Physics syllabus has submitted its recommendations to the GCE Boards. Assimilation of the agreed core into the syllabus is under consideration.

AIMS AND OBJECTIVES OF COURSE

This syllabus is intended to indicate the scope of the course and not to dictate the teacher's approach to the subject. Its character results from an attempt to provide a course which is stimulating and worthwhile, both educationally and culturally, for the variety of students who study physics at A-level. The course should be attractive and valuable to those who might take it with no expectation of using it later, as well as suitable for those for whom physics will form a major part of their studies at a university or technical college or for whom A-level physics is a necessary prerequisite for further study in some other area. The style of the syllabus represents a compromise between simply indicating the spirit of the course on the one hand and giving a detailed coverage of every topic on the other. While it may well be thought best to teach the subject 'vertically', developing the hierarchy of ideas through each particular topic in turn, there is adequate opportunity for 'horizontal' development, i.e. emphasis of the concepts which link across the topics, as the student's maturity allows. The course is successful if it imparts an increased understanding of, and fascination in, the things of the physical world around us, and if it develops the ability for thinking clearly.

The particular qualities which it is hoped that the A-level physics course will promote may be summarised as follows:

(*a*) knowledge of physical facts and terminology,

(*b*) knowledge and understanding of physical principles,

(*c*) the ability to understand and interpret scientific information presented in verbal, mathematical or graphical form and to translate such information from one form to another,

(*d*) the ability to describe phenomena in terms of models, laws and principles,

(*e*) the ability to formulate and perform relevant calculations,

(*f*) the ability to test hypotheses and to use information to formulate hypotheses,

(*g*) the ability to solve problems which are unfamiliar or presented in a novel manner,

(*h*) the ability to design and perform good experiments,

(*i*) confidence in using scientific equipment,

(*j*) a critical attitude to information and ideas,

(*k*) the ability to organise ideas and facts and to present them clearly.

The examination is designed as a test of these qualities. Questions dealing with qualitative aspects of physics will be included.

At Advanced level, there will be three theory papers and a 3½-hour practical test. The practical test will carry 45 marks.

Paper 1 (2½ h, 100 marks) made up of
1 hour of short, structured questions in which there will be no choice
and
1½ hours of essay-type questions, concerning mainly general physics; thermal physics; properties of matter. Candidates are required to attempt any three out of six questions.

Paper 2 (1¼ h, 60 marks) made up of 40 multiple-choice items.

Paper 3 (1½ h, 54 marks) made up of essay-type questions, concerning mainly oscillations and waves; electromagnetism; microscopic physics. Candidates are required to attempt any three out of six questions.

A list of fundamental physical constants will be provided for each theory paper. These data are included in the revised *Data Booklet* for the A level physical sciences, dated October 1980. Other data, specific to individual questions, will be given with the individual questions.

In the practical test, three questions will be set, one of which will be a compulsory question. Candidates will be required to attempt two questions.

In order to obtain a pass-grade (i.e. grades A to E) at A level, candidates must achieve the required aggregate mark and a pass-mark in at least one of the theory papers.

The Special Paper (available only in June for UK candidates) will be a 3-hour paper containing ten questions, candidates being required to attempt any five.

See p. 37 regarding Individual Studies.

There are key concepts, such as energy, field, potential, waves, conserved quantities, which run 'horizontally' throughout physics. These concepts do not, however, provide convenient headings for the subdivision of a syllabus. This syllabus is set out more in terms of its 'vertical' structure, that is, the grouping of the items has more reference to the *sequence* of concepts on which the various areas depend. It is nevertheless hoped that the individual teacher will encourage his pupils to appreciate the way in which the key concepts permeate and unify the subject.

	SYLLABUS	NOTES
A	**General Physics**	
1	Units, the International System (SI)	Reference should be made to the arbitrary nature of base units and to the derivation of all other relevant units as products of the base units.

2	Dimensions, including the following base quantities: mass, length, time, current, temperature, amount of substance. Application to check formulae for dimensional homogeneity.	Recognition that each base quantity provides a dimension. Note that it is acceptable to use the unit symbols to represent dimensions, e.g. kg m s^{-2} in place of the traditional M L T^{-2} for force, kg m^2 s^{-2} K^{-1} mol^{-1} to represent the dimensions of the molar gas constant R.
3	Vector and scalar quantities. Addition and resolution of vectors.	Quantity as the product of number and unit. Addition and resolution of vectors both by calculation and by drawing; equilibrium of forces, treated vectorially.
4	Errors and uncertainties, simple treatment.	Assessment of systematic and random error for a particular measured quantity. Actual uncertainty, effects of % (or fractional) uncertainties in addition, subtraction, products and quotients of measured quantities. Standard deviation and r.m.s. uncertainties are not required. See General Note (*a*).
5	Dynamics. Newton's laws; mass, velocity, acceleration, momentum, force. Work. Potential energy, kinetic energy, power. $F_x = -\mathrm{d}V/\mathrm{d}x$. Centre of mass.	Note that pairs of forces in Newton's third law are always of the same kind, e.g. both gravitational, both electrical etc. Projectile problems will be limited to cases of uniform acceleration in uniform gravitational and electrostatic fields.
6	Elastic collisions; conservation of momentum and energy. Inelastic collisions in one dimension only. Friction and viscous drag as forces opposing relative motion.	Note that the term *elastic* collision implies that kinetic energy is conserved; all other collisions are inelastic. Coefficient of restitution is not required. Coefficients of friction and explanation of the origin of friction are not required. Questions requiring a formal definition of viscosity will not be set.
7	Circular motion. Angular velocity. Centripetal forces and accelerations.	
8	Rotational motion. Moments and couples. Moment of inertia as $I = T/\ddot{\theta} = \Sigma mr^2$. Conservation of angular momentum.	Rotational motion limited to rotation about a fixed axis. Geometrical derivations of and experimental determination of moments of inertia are not required.
	Angular momentum $I\omega$ and rotational kinetic energy $\frac{1}{2}I\omega^2$.	Treated as analogues of linear motion: proofs of expressions are not required.
9	Gravitation, Newton's law and relation between G and g. Gravitational field and potential. Circular orbits. Speed of escape.	Determination of G not required.

	SYLLABUS	NOTES
10	Fluid pressure, $h\rho g$.	Familiarity with Archimedes' Principle will be assumed. Questions will not be set on hydraulic machines.
	B Oscillations and Waves	
11	Simple harmonic motion, linear cases only; use of equations: $\ddot{x} + \omega^2 x = 0$; $x = x_0 \sin \omega t$; $x = x_0 \cos \omega t$. Amplitude, frequency, angular frequency. Calculations of periods in simple cases. Determination of g. Kinetic and potential energy in s.h.m.	Formal integration of the differential form of the s.h.m. equation is not required.
12	Damped and forced oscillation treated qualitatively with reference to resonance and phase.	
13	Waves. Nature of motion in transverse and longitudinal, progressive and stationary waves; nodes and antinodes. Relation between speed, wavelength and frequency. Relation between intensity and amplitude. Polarisation.	Polarisation as a phenomenon associated with transverse waves.
	The Doppler effect and its application to various types of waves.	Proof of the relationship is only required for relative motion between source and observer on the same straight line in the case of sound. For electro-magnetic waves, analogous treatment for $v \ll c$ will suffice.
14	Superposition, interference and beats. Reflection, refraction and diffraction.	Illustration of stationary waves and beats by the graphical addition of two sine curves will suffice. A simple geometrical explanation of reflection, refraction and diffraction in terms of Huygens' principle is included. Simple treatment of two-slit interference and of the diffraction grating.
15	Sound as wave motion; determination of speed and frequency.	E.g. by examination of standing wave patterns by c.r.o.
16	Modes of vibration of strings and air columns.	Knowledge of factors affecting the speed of transverse waves in a string is not required. Awareness of end-correction in vibrating air columns is expected; use in finding speed of sound in air is included.
17	Electromagnetic waves. The spectrum.	Knowledge of the variety of electro-magnetic waves and their approximate wavelength ranges.

	SYLLABUS	NOTES
18	Determination of *c*.	Knowledge of any one direct terrestrial method.
19	Conditions for interference; interference in thin films.	Limited to cases of approximately normal incidence. Wedge fringes treated quantitatively (noting possibility of phase change) and Newton's rings treated qualitatively will suffice.
20	Diffraction of a plane wave at a wide slit with derivation of first minimum.	No treatment of resolving power of diffraction grating is required but a simple derivation of the resolving power of a telescope (optical/radio) is included: the 1.22 factor for a circular aperture may be assumed.
21	Production, detection and components of plane-polarised e.m. waves.	For light, production by polaroid and by reflection (Brewster's law not required): for radio, production by dipole aerial. Quantitative effect of rotation of polaroid or dipole aerial on plane-polarised radiation is included.
22	Quantisation of radiation; photoelectric effect and the Einstein relation; photons.	An example of wave-particle duality.
23	Rectilinear propagation.	Limiting case of diffraction when apertures are much greater than wavelengths, justifying ray treatments.
24	Refraction and its explanation in terms of speeds; refractive index, Snell's law.	Critical angle and total internal reflection is assumed to have been treated at O-level.
25	Mirrors and lenses as image-forming devices. Focal length and use of the relation between u, v, f.	
26	Simple astronomical telescope in normal adjustment and simple two-lens microscope in normal adjustment.	Simple treatment of angular magnification is included.
27	Spectrometer as collimator, diffraction grating and telescope.	Details of mechanical adjustment of spectrometer are not required.

C Electromagnetism

	SYLLABUS	NOTES
28	Steady currents. Sources of current. Effects of current.	No details of cells are required.
29	Force between current-carrying conductors; the ampere, μ_0: the coulomb.	It should be appreciated that the definition of the ampere is equivalent to fixing the value μ_0 as $4\pi \times 10^{-7}$ H m^{-1}.

	SYLLABUS	NOTES
30	Potential difference as power dissipated/current; the volt. Calibration of voltmeter by an electrical heating method. E.M.F.	Calibration of voltmeter necessary in order to relate the volt to mechanical units (V = W A^{-1} or J C^{-1}), a specific heat capacity by mechanical means being assumed.
31	Resistance, $R = V/I$. I/V relationships for materials in linear and non-linear cases, including diodes; Ohm's law as a special case.	The Lorenz method for resistance is not required.
32	Resistivity, conductance and conductivity.	
33	Nature of charge carriers in metals, semi-conductors and electrolytes. Quantitive relationship between current I, current density J, cross-sectional area A and drift velocity v in single carrier systems. Interpretation of drift velocity in terms of mean time τ between collisions, $v = eE\tau/2m$ leading to $\sigma = J/E = ne^2\tau/2\,m$:	In these formulae, e is the charge on the carrier, E is the electric field, m is the mass of a carrier, n is the number of carriers per unit volume, τ is the mean time *between* collisions.
34	Temperature dependence of resistance in metals. Temperature dependence of resistance in semi-conductors including simple idea of temperature dependence of carrier concentration in intrinsic semiconductors.	Temperature coefficient of resistance is not required. Qualitative treatment only.
35	Simple d.c. circuits, Kirchhoff's laws, series and parallel combinations.	Simple network calculations. Derivation and formulae for resistors in series and parallel is included.
36	Potentiometer and the basic Wheatstone bridge circuit; use of standard resistors and standard cells.	For the measurement of currents and of small e.m.f.s., e.g. thermoelectric e.m.f.s., for the comparison of cell e.m.f.s. and of resistances. See note 78. Familiarity with slide wire bridges and potentiometers is expected.
37	Internal resistance of sources.	The existence of internal resistance in sources and its simple consequences for external circuits.
38	Use of shunts and series resistors in ammeters and voltmeters.	

	SYLLABUS	NOTES
39	Electromagnetics. Magnetic flux density defined by $B = F/I\ l \sin\theta$. Force on moving charge in a magnetic field.	
40	Simple cases of the motion of charged particles in electric and magnetic fields.	The electron volt, eV, as a unit of energy.
41	The Hall effect.	Its use in semiconductors to measure B. Questions requiring the formal definition of the Hall coefficient will not be set.
42	Measurement of e/m and v for electrons and ions.	Any one method for e/m and for e/m_e.
43	The cathode-ray tube.	Basic structure of oscilloscope to include the electron gun, deflecting and display systems, time base and external circuit connections: details of time base and amplifier circuitry are not required. Uses of the oscilloscope for measurement and display. It is expected that appropriate use will be made of the oscilloscope at various points of the course.
44	Couple on rectangular coil in uniform field; the moving-coil galvanometer.	
45	Ballistic use of galvanometers.	Theoretical proof that throw is proportional to charge passed is not required and only a qualitative reference to damping is intended.
46	Field near a long straight wire, at centre of circular coil, inside and at the end of a long straight solenoid.	Proofs are not required.
47	Force between long, straight, parallel current-carrying conductors.	See also Item 29.
48	Magnetic medium filling the whole space; permeability μ, relative permeability μ_r.	Theory of ferromagnetism and of B—H curves is not expected.
49	Qualitative description of fields of permanent and electromagnets.	
50	Magnetic flux $\Phi = BA$.	
51	Induced e.m.f.; Faraday's and Lenz's laws.	

	SYLLABUS	NOTES
52	Measurement and comparison of flux densities.	By force on a current-carrying conductor, search coil with indicator, Hall effect. (See topics 40 and 41).
53	Mutual and self-inductance, the henry. Energy stored in an inductor carrying a current, $\frac{1}{2}LI^2$.	Theoretical derivation of formulae for mutual and self-inductances will not be required. The quantitative effect of self-induction on the exponential growth and decay of currents will not be tested mathematically. Proof of $\frac{1}{2}LI^2$ is not required.
54	Simple a.c. and d.c. generators, and d.c. motors.	Quantitative reference to back e.m.f. in motors and to back motor effect in generators is expected.
55	Electrostatics. Simple electrostatic phenomena. Current as charge in motion.	Attraction, repulsion, induction, distinction between conductors and insulators. Conservation of charge. Current as charge in motion by passing electrostatic charge through a galvanometer, e.g. when earthing, in charging by induction or by Van de Graaff machine.
56	Coulomb's law, ϵ_0.	Experimental verification is not required.
57	Concept of electrical field, $E = F/Q$.	
58	Electric potential; the relationship $E_x = -dV/dx$.	Electric potential defined as work done per unit charge brought up and hence $E_x = -dV/dx$.
59	Dielectric medium filling the whole space; permittivity ϵ, relative permittivity ϵ_r.	
60	E and V near point charges and surfaces.	Electric fields (i) inside an insulated hollow charged conductor, (ii) near a sphere, (iii) near a long cylinder, (iv) near a plane surface. Simple treatment by Gauss' law and symmetry will suffice.
	Distribution of charge on conductors.	Effects near sharp points.
61	Principle of Van de Graaff machine.	
62	Capacitance, $C = Q/V$, the farad.	Note increase of capacitance resulting from presence of nearby conductor.
63	Measurement and comparison of capacitors.	Measurement by vibrating switch method or by comparison by means of a ballistic galvanometer will suffice.

	SYLLABUS	NOTES
64	Charge and discharge of capacitors through resistors including time dependence $\exp(-t/\tau)$ with time constant, $\tau = RC$.	
65	Energy of charged capacitor, $\frac{1}{2}CV^2$.	Proof is not required.
66	Series and parallel connection.	Derivation of formulae for capacitors in series and parallel is included.
67	Parallel plate capacitor. Determination of ϵ_0.	Derivation of capacitance. Determination of ϵ_0 by direct measurement of capacitance of capacitor of known dimensions, e.g. vibrating switch method.
68	Relation of ϵ_0, μ_0 to c.	Proof of relation is not required.
69	Alternating currents: frequency, phase and amplitude; peak and r.m.s. values; their relation in the sinusoidal case.	
70	Energy and power in resistive loads.	
71	Alternating e.m.f.'s applied to resistors, capacitors and inductors separately; phase lag and lead.	Calculation of reactance.
72	Phasor representation and addition of alternating quantities, exemplified by quantitative treatment of resistor and capacitor in series.	Impedance as summation of resistance and reactance.
73	Ideal transformer.	An experimental approach and reference to principle of conservation of energy are expected.
74	Resonant circuits; quantitative treatment of resonant frequency of parallel L-C circuit without resistance: qualitative discussion of effect of damping.	
75	Electronics. Diode as circuit element; rectification and capacitor smoothing; use in a.c. instruments.	

	SYLLABUS	NOTES
D	**Thermal Physics**	
76	Temperature. Idea of thermal equilibrium, Zeroth law, temperature.	
77	Empirical scales of temperature.	Centigrade scales defined in terms of $t/°C = 100\ (x_t - x_1)/(x_s - x_1)$ where x represents any thermometric property.
78	Simple thermometry: resistance, thermo-electric, liquid in glass etc.; their inconsistencies.	Simple potentiometric and bridge circuits (with brief qualitative reference to compensating leads) will suffice.
79	Thermodynamic temperature determined by gas thermometry $T/T_{tr} = (pV)_T/(pV)_{tr}$ as evaluated from a series of measurements by extrapolating to $p = 0$ with T_{tr} chosen as 273.16 K; the kelvin. The Celsius scale defined by $t/°C = T/K - 273.15$.	The term thermodynamic is introduced because of its occurrence in the SI definition of the kelvin but understanding of the significance of the term is not expected. Brief reference should be made to the triple point of water as an invariant.
80	Boyle's law. The ideal gas equation $pV_m = RT$.	$pV \propto T$ is a consequence of adopting the gas scale.
81	Internal energy, work and heat, and first law of thermodynamics.	
82	Determination of heat capacities; electrical methods including constant flow.	Method of determining C_V for a gas is not required.
83	Isothermal and adiabatic changes in a perfect gas; work done in expansion, principal molar heat capacities: $C_{p,m} - C_{V,m} = R$: $\gamma = C_p/C_V$.	See note (c) in the preamble.
84	pV^γ = constant for adiabatic changes.	Proof of pV^γ is not required.
85	Thermal conduction, quantitative treatment in linear geometry.	Qualitative understanding of mechanisms of conduction in metals and non-metals (electron diffusion, lattice vibration).
86	The principles of methods of determining thermal conductivity for good and bad conductors.	Experimental details will not be required.

87	Thermal radiation as a form of energy.	
88	Principle of simple resistance bolometer.	
89	Prévost's theory of exchanges.	
90	Qualitative effect of nature of surface on energy absorbed or emitted by it; black-body radiation.	
91	Stefan's law.	Proof is not required.
92	Wien's displacement law.	Proof is not required.
93	Distribution of energy in spectrum of black-body radiation; relation to the electromagnetic spectrum.	

E Microscopic Physics

94	de Broglie's relation. The phenomenon of electron diffraction.	Simple understanding that some properties of electrons require wave treatment. An example of wave-particle duality.
95	Measurement of *e*.	A simple treatment neglecting upthrust from air will suffice.
96	Atomic structure. Evidence from α-particle scattering experiments.	
97	Quantisation and simple ideas of energy levels in atoms. Excitation and ionisation energies. Emission and absorption spectra and explanation in terms of energy levels.	Deduction of the existence of energy levels from line spectra will suffice; knowledge of the Franck-Hertz experiment is not required.
98	X-ray spectra; principle of generation of X-rays. Maximum frequency for given tube potential.	Details of X-ray tubes as such are not required. Consideration should be given to both the continuous spectrum and the characteristic line spectrum. The effect of atomic number on the characteristic wavelengths is included but a formal treatment of Moseley's law is not required.
99	The atomic nucleus: neutrons and protons.	
100	$E = mc^2$, mass excess and nuclear binding energy.	It should be understood that energy and mass are not interconvertible. Energy has mass, the mass of energy E being given by E/c^2. Hence, energy is always conserved and mass is always conserved.
101	Charge and mass of nuclei; principles of mass spectrometry.	

	SYLLABUS	NOTES
102	Atomic number, relative atomic mass, isotopes.	Principles only of separation of isotopes by centrifuge and mass-spectrometer.
103	Radioactivity, random nature; decay law, use of exponential form, decay constant and half-life.	
104	Nature of α, β and γ rays.	
105	Detection of ionising radiations: cloud chamber, G-M tube, solid state detector.	Principles of operation in terms of generation of charge carriers.
106	Nuclear reactions: conservation of atomic number, mass number, energy and mass in simple reactions and in radioactive decay; nuclear energy.	Fission of ^{235}U by thermal neutrons. Technical details of reactor piles are not required. The balancing of nuclear equations by application of conservation laws is included.
107	Uses of radioactive isotopes.	It is expected that candidates will have a reasonable knowledge of two applications, one biological and one non-biological, rather than a superficial knowledge of several applications.
108	Kinetic theory. Evidence for belief in molecules.	
109	Microscopic model of ideal gas and derivation of $p = \frac{1}{3}nm\langle c^2\rangle = \frac{1}{3}\rho\langle c^2\rangle$ leading to $pV_m = \frac{1}{3}M\langle c^2\rangle = RT$.	Integration over angles is not required but the inadequacy of simpler treatments should be pointed out. Note the use of $\langle\dots\rangle$ to indicate 'mean' value.
110	The Boltzmann constant. Law of equi-partition of energy, degrees of freedom and the effect of their number on value of γ.	Qualitative reference to the possibility of the suppression of certain degrees of freedom is included.
111	Distribution of molecular speeds.	Principles of an experimental method of determining distribution is included. Knowledge of the general form of the distribution graph and the effect of temperature changes on its form will suffice.
112	Interatomic forces. The form of interatomic force and potential curves and their interrelation.	Considered for a pair of particles only. Force as the gradient of potential energy curve is included.
113	The condensed states.	Simple ideas of structure limited to the distinctions between gases, liquids, crystalline and amorphous solids.

114	X-ray diffraction by crystals; Bragg's law and Bragg angle.	Use of X-ray diffraction to determine layer separation is included.
115	Elasticity of solids, Hooke's law as linear approximation for small displacements, the Young modulus and its determination.	Experimental determination of the Young modulus for wires only. Significance of small value of maximum stress (approx. 0.1%) in relation to the interatomic force curve, see 113.
116	Qualitative understanding of origin of thermal expansion.	
117	Phenomena in extension of a wire beyond elastic limit.	A qualitative explanation taking account of dislocation movement is intended.
118	Work done in extension.	
119	Change of state, origin of latent heats: principles of methods of determining of latent heats.	

Mathematical Needs

Essential Requirements (N.B. A substantial part of the following is covered in most Mathematics courses up to O-level. Candidates not taking Mathematics at A-level will require special provision of Mathematics teaching during the A-level Physics course and cannot be expected to cope properly with the Physics syllabus without such provision.)

Make calculations involving addition, subtraction, multiplication and division of quantities expressed in decimal notation.

Make approximate evaluations of numerical expressions, using approximations such as $\pi \approx 3$.

Express small fractional changes as percentages, and vice versa.

Calculate an arithmetic mean.

Transform decimal notation to power of ten notation (standard form), and carry out calculations in standard form.

Use tables or calculators for evaluating squares, square roots, reciprocals, sines, cosines and tangents.

Multiply and divide using a calculator, logarithm tables or a slide rule.

Change the subject of an equation. Most such equations involve only the simpler operations, but do include positive and negative indices and square roots.

Substitute physical quantities into physical equations using consistent units so as to calculate one quantity. Check the dimensional consistency of such equations.

Solve simple algebraic equations. Most are linear, but they include equations involving inverse and inverse square relationships, and simultaneous equations.

Formulate simple algebraic equations as mathematical models of physical situations and identify failures of such models (applications include dynamics, electric circuits and kinetic theory).

Recognise the equivalent forms of the logarithms of each of ab, a/b, x^n and e^{kx} and be able to interconvert $\ln x$ and $\lg x$.

Recall and use in the context of error estimation and other simple applications the expansions to one term in x of numerical instances of the form $(1 \pm x)^n$, where n may be negative or fractional, but $0 < x \ll 1$. (Note $\ll$ very much less than).

Comprehend and use the symbols

$$<, >, \leqslant, \geqslant, \approx, /, \propto, \text{ and } \langle x \rangle \text{ (for mean value of } x)$$

Test tabulated pairs of values for direct proportionality, by a graphical method, or by constancy of ratio.

Geometry and Trigonometry

Calculate areas of right-angled and isosceles triangles, circumference and area of circles, areas and volumes of rectangular blocks, cylinders and spheres.

Identify simple shapes with areas that are approximate to those of more complex shapes (namely narrow triangles and areas of strips in integration).

Recognise applications of simple theorems: Pythagoras' theorem with application to the chord theorem for a diameter and a perpendicular chord, congruency and similarity of triangles, angle sum of triangle.

Use sines, cosines and tangents in problems; recall or quickly calculate values at 0°, 30°, 45°, 60°, 90°, 180°.

Translate from degree to radian measure, and vice versa.

Use radian measure particularly in connection with trigonometric functions.

Recognise and sketch graphs of $\sin\theta$, $\cos\theta$.

Use the identity $\sin^2\theta + \cos^2\theta = 1$.

Recall $\sin\theta \approx \theta$, $\cos\theta \approx 1$, $\tan\theta \approx \theta$ for small θ.

Sketch graphs of harmonically varying quantities, e.g. $A\sin(\omega t) + B\sin(2\omega t)$ or $A\sin(\omega t + \pi/2) + B\sin(2\omega t + \pi/2)$.

Vectors

Find the resultant of two vectors, recognising situations where vector addition is appropriate.

Obtain expressions for components of vectors in perpendicular directions recognising situations where vector resolution is appropriate.

Graphs

Translate information between graphical, numerical, algebraic and verbal forms.

Select appropriate variables and scales for graph plotting.

Determine the slope and intercept of a linear graph, in physical units.

Choose by inspection a straight line which will serve as the 'least bad' linear model for a set of data presented graphically.

Recall the form $y = mx + c$.

Use logarithmic plots to test exponential and power law variations.

Sketch and recognise the forms of curves such that $y \propto 1/x$, $y \propto x^2$, $y \propto 1/x^2$.

Understand and use the slope of a tangent to a curve as a measure of rate of change.

Understand and use the area 'below' a curve where the area has physical significance.

Calculus

Use natural logarithms in arithmetic calculations and algebraic manipulations of simple kinds.

Correctly combine absolute and fractional errors in simple error estimations.

Use the notations: $\equiv$ (identity), Σ, $\int$, $\mathrm{d}/\mathrm{d}t$, $\mathrm{d}^2/\mathrm{d}t^2$, $\bar{x}$ and $\langle x \rangle$ (mean value), $f(x)$, e^x, Δx (finite increment), δx (small increment), $\ln x$, $\to 0$, $\to \infty$.

Use first and second derivatives in solving physical problems, usually involving only simple polynomials, trigonometric functions and the exponential function.

Construct equations of the form $\mathrm{d}y/\mathrm{d}t = ky$ and $\mathrm{d}^2y/\mathrm{d}t^2 = -k^2y$ as mathematical models of physical situations, and solve them in particular cases.

Use the relationship between the derivative and the slope of a curve, including the features of maxima and minima.

Appreciate the relationship between the definite integral as the area 'below' a curve, and integration as the reverse of differentiation.

Use the forms of the integrals x^n (including the special case of $n = -1$), $\sin \theta$, $\cos \theta$.

Numerical Calculation

Be able to estimate errors in numerical work.

Be able to handle numerical work so that significant figures are neither lost unnecessarily nor carried beyond what is justified.

Be able to estimate orders of magnitude, both in numerical work and from a knowledge of science.

Summary of key quantities

Candidates will be expected to be familiar with the following quantities, their symbols, their units and their interrelationships. They should also be able to carry out calculations and deal with questions involving them along the lines indicated in the detailed syllabus. The list should not be considered exhaustive.

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		
temperature	t, θ	°C
area	A, S	m^2
volume	V, v	m^3
density	ρ	kg m^{-3}
velocity	$u, v, w, \dot{x}, \ldots$	m s^{-1}
acceleration	$a, \ddot{x}, \ldots$	m s^{-2}
acceleration of free fall	g	m s^{-2}
force	F, **F**	N
work, energy	W, E, U	J
potential energy	V, Φ, E_p	J
kinetic energy	T, K, E_k	J
power	P	W
torque	T	N m
pressure	p	Pa
momentum	p, **p**	kg m s^{-1}
moment of inertia	I	kg m^2
angular velocity	$\omega, \Omega, \dot{\theta}$	rad s^{-1}
angular acceleration	$\dot{\omega}, \ddot{\theta}$	rad s^{-2}

Quantity	usual symbols	usual unit
angular momentum	p_θ, b, **L**	kg m^2 rad s^{-1}
gravitational constant	G	N kg^{-2} m^2
gravitational field	g	N kg^{-1} = m s^{-2}
gravitational potential	Φ	J kg^{-1}
period	T	s
frequency	f, ν	Hz
angular frequency ($2\pi f$)	ω	rad s^{-1}
wavelength	λ	m
refractive index	n	
speed of electromagnetic waves	c	m s^{-1}
Young modulus	E	Pa
tension	T	N
normal stress	σ	Pa
Planck constant	h, $\hbar$ ($= h/2\pi$)	J s
work function	Φ	V
critical angle	θ_c	o(degrees)
focal length	f	m
object distance	u	m
image distance	v	m
magnifying power	M	
electric charge	Q	C
electric potential	V, φ	V
electric potential difference	V	V
electromotive force	E	V
resistance	R	Ω
resistivity	ρ	Ω m
conductance	G	S = Ω^{-1}
conductivity	σ	S m^{-1} = Ω^{-1} m^{-1}
current density	J, j	A m^{-2}
magnetic flux density	B	T
Hall coefficient	R_H	m^3 C^{-1}
specific charge	q	C kg^{-1}
permeability	μ	H m^{-1}
permeability of free space	μ_0	H m^{-1}
relative permeability	μ_r	
magnetic flux	Φ	Wb
mutual inductance	M, L_{12}	H
self-inductance	L	H
permittivity	ε	F m^{-1}
permittivity of free space	ε_0	F m^{-1}
relative permittivity	ε_r	
electric field strength	E	V m^{-1}
capacitance	C	F
time constant	τ	s
reactance	X	Ω
impedance	Z	Ω
molar gas constant	R	J K^{-1} mol^{-1}
heat capacity	C	J K^{-1}
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}
ratio of principal heat capacities	γ	
thermal conductivity	k, λ	W m^{-1} K^{-1}
Stefan constant	σ	W m^{-2} K^{-4}
activity of radioactive source	A	s^{-1}
decay constant	λ	s^{-1}

half-life (ln 2/λ)	$T_{1/2}$, $t_{1/2}$	s
atomic mass	m_a	kg
relative atomic mass	A_r	
electron mass	m_e	kg
neutron mass	m_n	kg
proton mass	m_p	kg
unified atomic mass constant	m_u	kg
relative molecular mass	M_r	
molar mass	M	kg mol^{-1}
Boltzmann constant	k	J K^{-1}
angle of contact	θ	$o^{(degrees)}$
number per unit volume	n	M^{-3}
latent heat	L	J
specific latent heat	l	J kg^{-1}
Avogadro constant	L, N_A	mol^{-1}

The Practical Examination. The examiners will not be strictly bound by the syllabus in setting experiments; where necessary, candidates will be told exactly what to do, only knowledge of theory within the syllabus being demanded.

In addition to points that may be specified in the question paper, the examiners will look for competence in the following respects: correct reading of scales, including estimation of fractions of a graduation in both linear and angular measure; recognition of circumstances where a very approximate determination of some quantity is adequate for the purposes of the experiment and the seeking of further accuracy would be a waste of time; appreciation of the possible value of a quick rough preliminary survey of the experiment to locate the most fruitful range for more detailed and careful measurements: the recording of check and repeat readings when made and the listing of any other precautions taken, showing an understanding of their importance.

Examiners will not expect candidates to calculate errors by statistical methods, but will expect them to show a common-sense appreciation of orders of accuracy, e.g. by refraining from expressing their readings and results to more figures than can be significant. Candidates will be expected to record their data clearly, in tabular form where appropriate, and may be asked to display their measurements in the form of a graph which provides a clear and suitable record of these and from which information can readily be extracted.

Questions requiring the use of a beam balance will not be set.

The rubrics of the Practical Examination papers include the following.

'*Answer Question 1 and* **one** *other question.*

Candidates will not be allowed to use the apparatus or write for the first fifteen minutes.

Mathematical tables, including reciprocals, are available.'

Candidates are expected to record on their script all their 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 handed in.

Details on the question paper should not be repeated in the answer, nor is the theory of the experiment required unless specifically asked for. Candidates should, however, record any special precautions they take and any particular features of their method of going about the experiment.

Marks are given mainly for a clear record of the observations actually made, for their suitability and accuracy, and for the use made of them.

Provision has been made in the question paper for you to record your observations and readings and for you to plot the graphs required. Additional answer paper and graphs should **only** *be submitted if it becomes* **necessary** *to do so.*

Particular attention is directed to the fourth paragraph of the rubric.

The attention of teachers is also drawn to Circular to Schools No. 78/20 dated October 1978.

PHYSICS (ADVANCED LEVEL) REGULATIONS FOR THE EXAMINATION OF INDIVIDUAL STUDIES (PAPER 7)

The scheme is available for school candidates in the U.K. who are taking Physics at Advanced Level. All candidates must still take the normal Practical Physics examination.

It is recognised that only a minority of schools 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 school staff, and that they should be free to suggest studies in accordance with their own particular interests in these subjects and with the facilities available.

Each school with candidates wishing to offer individual studies must send to the Syndicate for approval, on forms E39 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 should be avoided. The forms should be returned to the Syndicate by 1 November in the year preceding that in which the candidates will sit the Advanced Level examination. Provisional entries must be submitted on form E40 by 20 January in the year of examination and final entries confirmed on the school entry form submitted by 1 March.

It is expected that work on any study submitted for assessment will extend over about three or four terms. It is also recommended that, preceding work on individual studies, the candidates will preferably have taken 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 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.

The school will be required to send to the Examiner the candidates' individual accounts of their work, by 31 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 one side of the paper only, leaving a margin on each page. Each account should contain a bibliography and appropriate acknowledgments of all external help.

The Examiner will visit each school concerned, on dates mutually arranged, and will interview each candidate separately (for approximately 15 min). The apparatus that has been used by the candidates must be available in working order during the Examiner's visit.

The Examiner will make his assessments on the basis of the written accounts and the interviews and will take into consideration any original contribution which the candidate may have made to the design or construction of the apparatus. In particular, the Examiner will look for a precise statement of what the candidate set out to investigate, the understanding of essential physical principles, the ability to give a clear and concise account of work carried out, and evidence of judgement in deciding what, if anything, has been established at various stages of the investigation.

If a school wishes the candidates' written material to be returned to the school earlier than September in the year of the examination, written application should be made by 15 July.

It is appreciated that the candidate's original aim may prove too ambitious or otherwise unrealistic and that the work finally submitted may not exactly match the original 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 his original aim. This will not necessarily count against the candidate since an intelligent study of the cause of some apparently anomalous findings may prove more worthwhile than the sustained pursuit of the original aim at the expense of leaving a number of experimental results unexplained.

Bonus marks will be awarded and the following conditions will apply:

(*a*) bonus marks will not be taken into account in fixing the pass mark for the subject;

(*b*) the maximum benefit gained by any one candidate will be to raise his subject result by one grade.

An additional fee per candidate will be charged, which should be included with fees for other Advanced Level subjects.