PHYSICS

ADVANCED LEVEL

AIMS

A course of study based on this Syllabus should :

1. provide a balanced course for further study and give an appreciation of the nature and the importance of physics in daily life;
2. help candidates to develop interest, motivation and a sense of achievement in their study of physics;
3. develop an appreciation of the developments in physics and an awareness of the relationship of physics to everyday life, and of the role of the applications of physics in the fields of engineering and technology;
4. establish a conceptual framework for physics and provide an understanding of its methodology;
5. encourage a balance between an experimental and a theoretical approach to physics;
6. develop skills relevant to the application of physics, such as experimental design, experimental technique, problem solving, mathematical analysis, critical appraisal and communication; and
7. to help candidates to acquire a sense of moral and social values and readiness to becoming responsible citizens in a changing world.

ASSESSMENT OBJECTIVES

Candidates should acquire the ability to :

1. recall and show understanding of factual knowledge, terminology, definitions, conventions, experimental methods, laws and models;
2. demonstrate experimental techniques : planning and execution of experiments, analysis and presentation of results and simple treatment of errors;
3. demonstrate the application of physics knowledge in problem solving and experimental investigation, including qualitative and numerical, theoretical and practical techniques;
4. communicate by compilation of clear, concise accounts of experimental work and theoretical treatments, including interpretation and transposition of data, and use of models to explain phenomena;
5. demonstrate evaluation and judgement by the analysis and assessment of situations or data, and decision making on the basis of such judgements.

THE EXAMINATION

1. The examination consists of two written papers and a practical component assessed by Teacher Assessment Scheme (TAS) or the practical examination. The examination structure and the allocation of marks will be as follows:

PAPER 1	3 hours, Structured-type questions	42%
PAPER 2	3 hours, Multiple choice (25%) and essays (18%)	43%
PAPER 3	TAS (see point 3 below)	15%
PAPER 4	1 hour 30 minutes, Practical	15%

2. Paper 1 contains structured-type questions, all of which are to be attempted. Paper 2 consists of two sections, A and B. Section A contains multiple-choice questions and Section B contains essay-type questions, and candidates are required to answer 3 out of 4 questions in this section.
3. Candidates may opt to sit the practical examination (Paper 4) or to use their previous TAS results (obtained in 2011 or 2012 exam.) to substitute the practical examination. Paper 4 consists of one experiment to test candidates' practical skills and their ability to report on experiments.
4. Knowledge of the prescribed experimental work is required, and questions requiring knowledge and understanding of these experiments may be set.
5. A broad knowledge of the Hong Kong Certificate of Education Physics Syllabus is assumed and questions requiring such knowledge may be set.
6. Practical skills expected and mathematical knowledge recommended are listed in appendices to the syllabus.
7. In general questions will be set in SI units. Wherever letter symbols, signs and abbreviations are used, they will follow the recommendations made in the Association for Science Education Report SI units, Signs, Symbols and Abbreviations.
8. The purpose of the examination will be to evaluate understanding rather than factual recall. Where possible, questions requiring simple recall of 'bookwork' will be avoided.

THE SYLLABUS

Notes

1. Teachers should note that many of the suggested experiments are very short, and could be used most effectively as quick demonstrations to introduce a topic or start a lesson. Other experiments are long and these should be done by the candidates themselves, wherever possible.
2. The material of the syllabus including descriptions of experiments can be found in many recent A-level physics textbooks.
3. Subject materials need not be taught in the order given.

Section A : Mechanics

Syllabus	*Notes*	*Suggested Experimental Work*
1.1 Statics		
Friction	Qualitative treatment only. Distinction between static (including the limiting case) and kinetic friction.	E1. Study the effects of the normal force, materials involved and surface area on the force of friction using a block.
Moment of a force	Moment of a force as the product of the force and its perpendicular distance from the pivot. Knowledge and use of torques and couples. The principle of moments and its applications in simple balanced situations.	
Static equilibrium	Two-dimensional treatment only. Conditions for equilibrium of forces acting on a point mass and a rigid body.	
	Centre of gravity and its experimental determination. Stability (very briefly).	E2. Determination of C.G. of a body of any shape.

Syllabus	*Notes*	*Suggested Experimental Work*
1.2 Kinematics		
Uniformly accelerated motion in one dimension	Displacement, velocity and acceleration in one dimension. Graphical representation. Knowledge and use of equations of uniformly accelerated motion.	
1.3 Dynamics		
Newton’s laws of motion	Knowledge and use of Newton’s laws of motion.	
Principle of conservation of linear momentum in one and two dimensions	Use of the impulse-momentum equation $Ft = mv - mu$. Consistency of Newton’s third law with conservation of linear momentum. Distinction between elastic and inelastic collisions. Coefficient of restitution *not* required. Principle of measuring inertial mass e.g. using $m_x/m_y = \Delta v_y/\Delta v_x$ for explosive separation of two masses initially at rest. Examples of conservation of linear momentum to include recoil of rifles, collision of α particles with helium atoms (analysis of cloud chamber photographs).	

Syllabus	*Notes*	*Suggested Experimental Work*
Work, energy and power	Understanding of the relationship between work and different forms of energy. Work as transfer of energy defined by $W = Fs\cos\theta$. Knowledge and use of change of gravitational potential energy, $mg\Delta h$. Kinetic energy= $\frac{1}{2}mv^2$ derived from the energy transferred. Power as the rate at which energy is transferred. Knowledge and use of $P = F\,v\cos\theta$. Efficiency.	
Law of conservation of energy	Knowledge and use of the transformations between potential energy and kinetic energy.	
1.4 Projectile Motion	Resolution of velocities. Independence of horizontal and vertical motions for projectiles. Simple calculations. Terminal velocity (e.g. of a parachutist).	E3. Demonstration of the independence of horizontal and vertical motions using the "monkey and hunter" kit.
1.5 Circular motion	Angular velocity ω (rad s^{-1}). Linear velocity $v = \omega r$. Centripetal acceleration $a = v^2/r$ and centripetal force. Examples to include vehicles rounding bends (with and without banking), aircraft turning in flight, looping the loop, the centrifuge (qualitatively).	E4. Experimental test of $F = \dfrac{mv^2}{r}$ by whirling a rubber bung.

1.6 Gravitation

Gravitational force between masses	Newton's law of universal gravitation for point masses and its extension to spherically symmetrical bodies (proof *not* required). Method of measuring the gravitational constant G is *not* required.
Field strength g	g taken as gravitational force per unit mass. Knowledge and use of $g = \mathrm{G}\dfrac{M}{r^2}$ (assuming the Earth to be a sphere of uniform density). Calculation of the Earth's mass.
Gravitational potential energy U	Derivation of $U = -\mathrm{G}\dfrac{Mm}{r}$ considering the gravitational potential energy at infinity to be zero. Velocity of escape and launching of satellites. Circular orbits (including parking orbits). Weightlessness.
Planetary motion	Quantitative treatment of circular orbits only. Knowledge and use of Kepler's laws. Consistency of Kepler's law (r^3/T^2 = constant) with Newton's law of gravitation.

1.7	Oscillation		
	Simple harmonic motion	Isochronous oscillation. Acceleration $a = -\omega^2 x$, displacement $x = A \sin \omega t$ (or $A \cos \omega t$). Period $T = 1/f = 2\pi/\omega$. Simple harmonic motion developed through analysis of uniform motion in a circle (rotating vector model). Applications to include the simple pendulum and loaded spring. Hooke's law. Knowledge of $T = 2\pi\sqrt{l/g}$ and $T = 2\pi\sqrt{m/k}$. Quantitative treatment of kinetic and potential energy. Phase lead and phase lag through rotating vector model.	E5. Investigation of the extension and vibrations of a loaded spring. E6. Study of the motion of a simple harmonic oscillator.
	Forced vibrations. Resonance and damping	Qualitative treatment only. Free and forced vibration (qualitatively). Descriptive treatment of frequency response and resonance. Phase relationship *not* required. Mechanical, acoustic and electrical examples. Link with experiments in other parts of the syllabus.	E7. Investigation of forced oscillations.

Section B : Wave Motion

2.1	Wave propagation. Nature of motions in longitudinal and transverse progressive waves. Relation between v, λ and f. Velocity of propagation of mechanical waves along stretched strings or springs and in solids.	Questions will *not* be set on the equation $y = a \sin(\omega t - kx)$, but an understanding of the variation of displacement with time (x constant) and with distance (t constant) in a progressive wave is expected. Factors affecting the speed of propagation. The expression $v = \sqrt{T/m}$ and $\sqrt{E/\rho}$ (proofs *not* required).	E8.	Investigation of the factors affecting the speed of transverse progressive waves along a slinky spring.
2.2	Wave phenomena			
	Huygens' principle	Explanation of laws of reflection and refraction.		
	Reflection	Examples to include brief discussion of radar, sonar and long distance propagation of radio waves by reflection from the ionosphere. Phase change on reflection, illustrated for example, using a slinky spring.		
	Refraction	Refraction as a result of change in wave speeds. Refractive index in terms of speeds.		
	Polarization	Polarization by selective absorption, reflection and scattering. Practical applications to include polaroid spectacles, VHF and UHF antennas (briefly).	E9.	Polarizing light by (a) reflection from a shiny surface; (b) absorption using a sheet of polaroid; and (c) scattering using cloudy water.

Superposition	Mathematical treatment *not* required.	E10.	Superposition of transverse waves on a slinky spring.
Beats	Qualitative treatment. Use in tuning.	E11.	Observation of beats on a CRO.
Diffraction	Diffraction of light at apertures (simple qualitative treatment only).	E12.	Looking at a lamp through a slit or a pin-hole to study how the diffraction patterns depend on (a) the shape of the aperture; (b) the size of the aperture; and (c) the wavelength of light.
Interference	Two-source interference with quantitative treatment for maxima and minima. Conditions for observable interference. Practical applications of interference to include the blooming of lenses and the testing of the flatness of a surface (very briefly). Quantitative treatment of interference effects at normal incidence in parallel-sided and wedge-shaped thin films. Everyday examples to include the colours of oil films and soap bubbles. Newton's rings (qualitatively).	E13. E14.	Estimation of the wavelength of light using (a) double slit; and (b) plane diffraction grating. Observation of Newton's rings and interference fringes in soap film.

		Plane transmission grating as an interference system. Use of the formula $d \sin \theta = n\lambda$. Proportionality between intensity and square of the amplitude (by analogy with harmonic oscillator and energy delivered by an alternating current). Energy distribution in interference patterns.	E15.	Investigation of the amplitude and energy distribution in an interference pattern of sound waves.
2.3	Stationary waves. Modes of vibrations of strings and air columns. Harmonics and the quality of sound.	Graphical treatment only.	E16.	Demonstration of stationary waves on a rubber cord and in a spring.
2.4	Acoustics	Pressure and displacement in sound waves.		
	Intensity and loudness	Frequency response of the ear.		
	The decibel	Relationship between intensity and loudness. Thresholds of hearing and pain. Noise pollution (very briefly). Typical noise levels in everyday life. Absorption of sound and sound proofing.		
	Velocity of sound	Order of magnitude of speed of sound in solids, liquids and gases. Knowledge of $(\gamma P/\rho)^{1/2}$ *not* required.	E17.	Measurement of the speed of sound in air (e.g. using a Kundt's tube).

	Doppler effect	Quantitative treatment (change in the observed frequency and wavelength) for a stationary medium and movement along the source-observer line. Real-life examples (police cars, ambulances and radar speed traps, galaxy red shift indicating expanding universe, all treated qualitatively).		
2.5	Optical instruments	Formation of images by lenses. Use of the equation $1/u + 1/v = 1/f$ for a single, thin lens. Qualitative understanding of how optical instruments work (using simple ray diagrams only).	E18.	Measurement of focal length of lenses.
	Magnifying glass	Magnifying powers of magnifying glass, microscope and refracting telescope considered as ratio of visual angles subtended by the image and the object (as obtained from simple ray diagrams).		
	Microscope	Two-lens type only. Formation of image at least distance of vision.		
	Refracting telescope	Two-lens type only. Formation of image at infinity.		

Section C : Fields, Electricity and Electromagnetism

3.1 Electric Fields		
Electric field E	Force between point charges. Coulomb's law. Electric field due to a point charge. Uniform electric field. Electric field strength E considered as force per unit charge. Analogy of gravitational field and electric field.	E19. Study of electrostatic phenomena using the "shuttling ball" experiment. E20. Investigation of the electric field between parallel metal plates using a charged foil strip. E21. Observation of electric field patterns produced by electrodes of different shapes.
Electric potential V	Derivation of $V = Q/4\pi\varepsilon_o r$, $E = -\mathrm{d}V/\mathrm{d}r$. Distribution of potential and equi-potential surfaces for charged conductors.	E22. Plotting equipotential lines on a high resistance conducting surface. E23. Investigation of the electric potentials between parallel metal plates and around a charged sphere using a flame probe.
3.2 Storage of charge by capacitors	Introduction through a series of experiments with capacitors.	E24. Introducing capacitors by studying (a) the charging and discharging through a resistor; (b) equal and opposite charges on the plates of a capacitor; (c) charges stored in various capacitors; (d) charges on a capacitor and the p.d. across it; and (e) capacitors in series and in parallel.

	Capacitance	$Q = CV$. The farad F (and the sub-units μF and pF). $C = \varepsilon_o A/d$ for a parallel-plate capacitor. Series and parallel combinations of capacitors. Use of reed switch for measuring capacitance. Measurement of ε_o *not* required. Stray capacitance.	E25.	Study the transfer of charge between two conductors --- the 'spooning' of charge from an e.h.t. power supply to an electrometer.
			E26.	Investigation of the relationship between the charge on a capacitor and the p.d. across it by charging it with a constant current.
			E27.	Investigation of the factors affecting the capacitance of a parallel plate capacitor using an electrometer and/or a reed switch.
			E28.	Using a reed switch to measure the equivalent capacitance of capacitors in parallel and in series.
	Charging and discharging of capacitors	Exponential rise and decay of charge with time. Time constant *CR* and its experimental determination. Derivation of expressions $Q = Q_o e^{-t/RC}$ and $Q = Q_o(1 - e^{-t/RC})$.	E29.	Plotting the decay curve of charge in a capacitor using an electrometer or an ammeter.
	Energy of a charged capacitor	Proof of $E = ½\, CV^2$.	E30.	Study the energy stored in a charged capacitor by discharging it through a small motor.
3.3	Current electricity	The *general* flow equation $I = nAvQ$ and its application as a simple model for electron conduction in a metal. Estimation of electron drift velocity in a metal. Distinction between drift velocity and speed of electrical signals.		

	Electromotive force	E.m.f. of a source as the energy imparted by the source per unit charge passing through it. P.d. between two points as the energy converted from electrical potential energy to other forms per unit charge passing between the points outside the source. Internal resistance of power supplies.	E31.	Demonstration of the drop in terminal p.d. of power supplies delivering current.
			E32.	Using different voltmeters to measure the terminal p.d. of a power supply with high internal resistance.
	Resistance, Ohm's law. Resistivity. Variation of resistance with temperature.	The variation of current with applied p.d. in various conductors and circuit elements (metals, electrolytes, thermistors, diodes). Ohm's law as a *special case* of resistance behaviour. Resistivity defined by $\rho = RA/\ell$. Qualitative effects of temperature on resistance of metals and semiconductor. Kirchhoff's first law. (Kirchhoff's second law *not* required.)		
	Potential divider	Rotary *or* slide-wire types may be used for practical work. The use of the rotary-type to provide a variable p.d. is essential. Effect of external load resistance on the output voltage.		
3.4	Electromagnetism			
	Force on a current-carrying conductor in a magnetic field.	Relative directions of force, field and current.		

Magnetic field B	$B = F/I\ell$ introduced using a simple current balance. The tesla (T) as $1\ \mathrm{N\,A^{-1}\,m^{-1}}$. The generalized expression $F = BI\ell\sin\theta$.	E33.	Using a current balance to measure the magnetic fields (a) between two magnadur magnets; (b) close to the end of a current-carrying coil; and (c) inside a flat solenoid carrying current.
Force on a moving charge in a magnetic field	$F = BQv\sin\theta$.		
Hall effect	Derivation of the Hall voltage $V_H = BI/nQt$.	E34	Use of the cathode ray oscilloscope
Measurement of magnetic fields	Hall probe, current balance, search coil and CRO. The cathode ray oscilloscope is used as (i) an a.c. and d.c. voltmeter (ii) for time and frequency measurement (iii) a display device for studying waveforms.	E35.	Using a Hall probe or a search coil to investigate the magnetic fields (a) around a long straight wire; (b) at the centre of a coil; (c) inside and around a slinky solenoid; and (d) inside a solenoid, carrying current.
Magnetic fields around a long straight wire, and inside a long solenoid, carrying current.	$B = \mu_0 I/2\pi r$ and $B = \mu_0 NI/\ell$ should be understood but derivations are *not* required. These relationships can be investigated experimentally.		
Definition of the ampere	Quantitative treatment of the force between currents in long straight parallel conductors.		
Torque on a rectangular current-carrying coil in a uniform magnetic field	$\tau = BANI\sin\phi$.		
Moving-coil galvanometer	Principle of design and operation. Sensitivity. Ballistic form *not* required.		

3.5 Electromagnetic induction			
Laws of electromagnetic induction	Induced e.m.f. resulting from (i) a moving conductor in a stationary magnetic field, and (ii) a stationary conductor in a changing field. Magnetic flux Φ. $\varepsilon = -\mathrm{d}\Phi/\mathrm{d}t$. Faraday's and Lenz's laws. Interpretation of B as magnetic flux density.	E36.	Investigation of the factors affecting the induced e.m.f. in a coil.
Simple a.c. and d.c. generators d.c. motor and back e.m.f.	Derivation of the alternating e.m.f. induced in a rectangular coil rotating in a uniform magnetic field.		
Eddy currents	Brief discussion of occurrence of eddy currents and their practical uses.		
Self-induction	$\varepsilon = -L\mathrm{d}I/\mathrm{d}t$. Derivation of energy stored in an inductor and analogy with charged capacitor. Implications for switch design.	E37.	Study of self-induction in a coil.
3.6 Alternating currents			
r.m.s. and peak values	Relationship for sinusoidal a.c. derived from mean heating effect in a pure resistance.		
Transformer	Derivation of $V_s/V_p \approx N_s/N_p$. Energy losses.	E38.	Study of transformer action: (a) the effect of the flux linkage; (b) the relationship between voltage ratio and turn ration; (c) the dependence of the current in the primary coil on the loading; (d) comparison between input and output power.

Rectification in power supplies	The diode as a uni-directional circuit element (internal mechanism *not* required). Half-wave and full-wave rectification using diodes. Bridge rectifier and its application in a.c. measuring instruments. Full-wave rectifier with storage capacitor and inductor-capacitor smoothing. Qualitative treatment only.	E39.	Rectification of an AC signal.
Sinusoidal a.c. in pure *R*, *C* and *L* taken separately. Phase lead and phase lag	Rotating vector (phasor) model. Physical origin of phase difference.	E40.	Study of the phase relationship between p.d. and current when a low frequency a.c. is passed through (a) a resistor; (b) a capacitor; and (c) an inductor
Reactance	Derivation of $X_c = 1/\omega C$ and $X_L = \omega L$.		
Series combination of *L*, *C* and *R*. Impedance.	Rotating vector method only	E41.	Study of the phase difference between p.d. and current in *CR* and *LR* circuits using split beam CRO.
Power factor	Power absorbed in resistive component only and hence $P = IV \cos \theta$ from vector diagram. Instantaneous power and related derivations or calculations *not* required.		
Resonance	Quantitative treatment only for series resonance. Parallel *LC* circuit for practical demonstration of resonance (*no* theory required). Application in radio tuning circuit.	E42.	Study of resonance in a parallel *LC* circuit using a CRO.

Section D : Matter

4.1 Gases

Ideal gases	Pressure $p = F/A$. Pressure-temperature and volume-temperature relationships of a gas. Absolute zero obtained by extrapolation of these relationships. *Macroscopic* definition of an ideal gas as one which obeys Boyle's law (pV = constant). The equation of state $pV = n\mathrm{R}T$ where n = number of moles.	E43.	Investigation of the relationship between pressure, volume and temperature of a gas.
A model for a gas : the kinetic theory. Use of the model to provide a microscopic interpretation of macroscopic phenomena.	*Microscopic* definition of an ideal gas. Assumptions of the kinetic model and derivation of $pV = Nm\overline{c^2}/3$. Order of magnitude of $\sqrt{\overline{c^2}}$. Distribution of molecular speeds (qualitatively). Avogadro's law and the Avogadro constant. Interpretation of temperature for an *ideal gas* using $m\overline{c^2}/2 = 3\mathrm{R}T/2\mathrm{N}_\mathrm{A}$.		
Real gases	Brief discussion of the departure of real gases from ideal behaviour at high pressures and low temperatures. Brief qualitative treatment of critical points. Experimental details *not* required.		

	Heat and energy	Distinction between heat and internal energy. Consideration of all forms of energy on microscopic scale as kinetic or potential. Heat and work as measures of energy transferred from one form to another. Use of the first law of thermodynamics $\Delta U = Q + W$ (increase in internal energy of a system equals the sum of heat transfer to and work done on the system) as an extension of the principle of conservation of energy to include heat.		
4.2	Solids			
	Physical properties	Macroscopic phenomena. Stress-strain behaviour for metals and non-metals: brief qualitative descriptions of strength, stiffness, brittleness and ductility. Explanation of plastic deformation *not* required. Young modulus defined as stress over strain and its experimental determination. Typical orders of magnitude. Energy stored in stretching (½ force × extension) and energy per unit volume (½ stress × strain).	E44.	Measurement of Young modulus for various materials.
	A model for a solid	Derivation of model from observed resistance of solids to deformation (compression and extension). Representation as curves of force and potential energy against interatomic separation. $F = - \mathrm{d}U/\mathrm{d}r$. Equilibrium spacing. Thermal expansion.		

4.3 Fluids			
Fluids in motion Bernoulli's Principle	Density $\rho = m/V$. Derivation of $p + ½\rho v^2 + \rho gh$ = constant. Applications to include jets and nozzles (bunsen burner, filter pump, sprays, carburrettors), spinning tennis or golf balls, aerofoils (aircraft, yachts sailing into the wind). The Pitot-static tube for measurement of fluid speed (quantitatively).	E45.	Study of Bernoulli effects using (a) sheets of paper; (b) an air blower and a polystyrene ball; and (c) Bernoulli tubes.
4.4 Electrons			
Electron beams : production and properties. The electron-volt.	Thermionic emission. Deflection of electrons in electric and magnetic fields.	E46.	Investigation of the properties of cathode rays using Teltron Maltese Cross and Deflection tubes.
Determination of e/m	Thomson's method using $v = E/B$ for zero deflection, or any other method.	E47.	Measurement of e/m using Deflection tube.
4.5 Extra-nuclear structure of the atom			
Evidence for light quanta Photons	The photoelectric effect. Explanation of the phenomenon of photoelectric emission leading to the quantum theory. Knowledge and uses of $E = hf$ and Einstein's photoelectric equation $½mv_{max}^2 = hf - hf_o$. Stopping potential and use of electron-volt (eV) as a unit of energy. Uses of photoelectric cells.		

	Line spectra and transitions between energy levels	Line spectra of monatomic gases and explanation in terms of light quanta and energy levels. Ionization and excitation energies. Elastic and inelastic collisions of electrons with atoms. The hydrogen spectrum and interpretation in term of energy level equation $E = -13.6/n^2$ eV. Bohr theory of the atom *not* required. Simple explanations of fluorescence, X-rays and laser action.	E48. E49.	Observation of various line spectra (e.g. hydrogen, sodium, mercury, neon) using a diffraction grating. Observation of absorption spectrum.
	Continuous spectra	Sun's spectrum and Fraunhofer lines. Band spectra *not* required.		
4.6	Radioactivity			
	Properties of α, β and γ radiations	Revision and consolidation of lower form work.	E50. E51.	Magnetic deflection of β rays. Investigation of the absorption of α, β and γ radiations by different materials of various thickness.
	Detectors	Use of detectors (ionization chamber, cloud chamber and Geiger-Müller counter). Suitability of these detectors for α, β and γ emissions.		
	Random nature of decay	$dN/dt = -kN$ derived from analogy with dice decay.	E52.	Simulation of radioactive decay by throwing dice.
		Interpretation of decay constant k as the constant chance of an atom decaying per unit time.	E53.	Demonstration of random variation of count rate using GM counter and source.
	Natural nuclear transformations	Change of N and Z in radioactive decay (details of radioactive series *not* required).		

	Exponential law of decay. Half-life. The Becquerel.	$N = N_0 e^{-kt}$. Relationship between k and $t_{½}$. Relevance of long half-lives to the disposal of radioactive waste and to radioactive fall-out. Carbon-14 dating.
	Radiation hazards	Sources of background radiation and typical radiation doses. Hazards due to open and sealed sources. Handling precautions.
	Isotopes	The uses of radioisotopes (briefly).
4.7	Conservation of energy and mass	
	The mass-energy relationship	The unified atomic mass unit (carbon scale). Use of $E = mc^2$. Interpretation of equations representing nuclear reactions.
	Energy release in fission and fusion	Binding energy. Principle of the fission reactor. Qualitative treatment of fission and the chain reaction. The roles of fuel, moderator, coolant and control rod in the reaction process are expected. Nuclear power: advantages and disadvantages.

Conservation of energy	Energy transformation from one form to another. Illustrative examples from other parts of the syllabus. Coal and oil resources. Alternative energy resources (e.g. nuclear, solar, tidal and wind-based). Principles of methods and relative conversion efficiencies (briefly). Degradation of other forms to thermal energy. Energy as the unifying concept in the study of physics.

PRACTICAL EXAMINATION

1. In setting questions in the practical examination knowledge of all parts of the theory syllabus will be assumed.
2. Questions involving experimental methods mentioned in the Syllabus may be set, provided the necessary apparatus is generally available in schools.
3. The questions set will not necessarily be confined to topics and methods included in the Syllabus; but where they are not, candidates will be given detailed instructions as to exactly what to do, and also given any formulae or results required which are outside the Syllabus.
4. Techniques
    - i. Reading to the maximum accuracy of linear and angular scales; use of vernier scales; timing by stop-watch or stop-clock.
    - ii. accurate focusing and location of images (using pins, ray boxes, etc.).
    - iii. Connecting up and checking electrical circuit diagram; drawing a circuit diagram for a given simple circuit, already connected up.

5. Graphical Methods, etc.
    i. Display of results in tabular and/or graphical form.
    ii. Accurate plotting with suitable choice of scales.
    iii. Transformation of formulae into linear graphs; e.g. plotting of log y against log x for the function $y = \mathrm{b}x^{\mathrm{a}}$.
6. Procedures
    i. Making rough preliminary measurements and calculations where appropriate, e.g., to assess the best range for accurate measurements.
    ii. Careful recording of all actual measurements made (including checks and correction) without the need to make a fair copy later. (Deletions to be crossed out neatly, not erased, and reasons given briefly where appropriate.)
7. Order of accuracy
    i. Significant figures and decimal places.
    ii. Meaning of absolute and relative (or percentage) error.
    iii. Estimates of maximum error in simple cases.
    iv. Common-sense appreciation of orders of accuracy of common measurements (not merely of scale readings); and ability to quote results to a number of significant figures reasonably in keeping with their estimated accuracy.
8. Error Estimates (Statistical methods *not* required)
    Rules for combination of maximum errors in the simple cases :
    $x \pm y,\ xy,\ x/y,\ x^{\mathrm{n}}$

MATHEMATICAL KNOWLEDGE REQUIRED BY CANDIDATES

Competence in mathematics is important for the correct handling of physical concepts and models. A core of mathematical ability is therefore an essential part of Advanced Level Physics. However, teachers must keep the emphasis on understanding physics rather than elaborate manipulations or purely mathematical ingenuity.

In addition to general mathematics at secondary level, the following are required.

1.	Indices : integral, negative and fractional. Logarithms to bases 10 and e.	Relationship of $\log_{10}x$ and $\ln x$ Transformation of $y = bx^a$ to give a linear graph.
2.	Use of the approximation $(1 + x)^a \approx 1 + ax$ for small x.	
3.	The exponential function.	Mainly graphical treatment : form of the graphs of e^x, e^{-x}, $1 - e^{-x}$, etc.
4.	The sin, cos, tan, cot functions for positive and negative angles and for angles > 2π. The results $\sin\theta \rightarrow \theta$, $\tan\theta \rightarrow \theta$, and $\cos\theta \rightarrow 1$ as $\theta \rightarrow 0$. Ability to use the common trigonometric formulae in straightforward calculation. Meaning of $\sin^{-1} x$, etc.	Knowledge of the values for $\theta = 0, \pi/6, \pi/4, \pi/3, \pi/2$; and ability to deduce those for corresponding angles up to 2π. Ability to sketch the stated trigonometric functions without the aid of calculators/tables. The formulae for $\sin(\alpha \pm \beta)$, $\sin 2\alpha$, and $\cos 2\alpha$, should be known. Any others will be given if required. Graphs of inverse functions not required.

5.	The derivative as a limit.	$\lim_{\delta x \to 0} \frac{\delta y}{\delta x} = \frac{dy}{dx}$
	Interpretation as a gradient of the tangent to a curve; velocity at an instant in non-uniform motion; and as a rate of change in general, either in time or space. The second derivative.	Reference to some physical examples : e.g. potential gradient $\mathrm{d}V/\mathrm{d}x$, current as $\mathrm{d}Q/\mathrm{d}t$, etc.
6.	Differentiation of $\mathrm{k}\mathrm{x}^{\mathrm{n}}$, sin kx and cos kx, e^{kx} and ln kx where n and k are constants.	Graphical illustration in all cases, including graphs of $\mathrm{d}y/\mathrm{d}x$ and $\mathrm{d}^2y/\mathrm{d}x^2$ against x. (Sketches based on simple reasoning should be used, in preference to plots based on calculators/tables.)
7.	Calculation of maximum and minimum in simple cases involving the above functions.	Tests for maximum or minimum using $\mathrm{d}^2y/\mathrm{d}x^2$ are not required.
8.	Integration as the inverse of differentiation. The definite integral as the limit of a sum.	Its representation as an area under a curve.