

PHYSICS

ADVANCED SUPPLEMENTARY 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.

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; and
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 Teacher Assessment Scheme (TAS). The examination structure and the allocation of marks will be as follows:

PAPER 1	1 hour 10 minutes, Structured-type question	33%
PAPER 2	1 hour 50 minutes, Multiple choice (30%) and essays (22%)	52%
PAPER 3	TAS (<i>compulsory for school candidates</i>)	15%
PAPER 4	1 hour 30 minutes, Practical (<i>for private candidates only</i>)	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 2 out of 4 questions in this section.
3. Paper 3 is a Teacher Assessment Scheme, which is compulsory for all school candidates. Their practical abilities will be assessed internally by subject teachers. These abilities include the following:
 - (i) demonstrate manipulative skills in carrying out experiments
 - (ii) make accurate observations and measurements
 - (iii) record and present data properly
 - (iv) interpret results and draw conclusions

The regulations, guidelines and methods of assessment can be found in the Handbook on the A/AS Physics Teacher Assessment Scheme issued by the Hong Kong Examinations and Assessment Authority to participating schools.
4. For private candidates, they may opt to sit the practical examination (Paper 4) or to use their previous TAS results to substitute the practical examination. Paper 4 consists of one experiment to test candidates' practical skills and their ability to report on experiments.
5. Knowledge of the prescribed experimental work is required, and questions requiring knowledge and understanding of these experiments may be set.
6. A broad knowledge of the Hong Kong Certificate of Education Physics Syllabus is assumed and questions requiring such knowledge may be set.
7. Practical skills expected and mathematical knowledge recommended are listed in appendices to the syllabus.
8. 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.
9. 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

<i>Syllabus</i>	<i>Notes</i>	<i>Suggested Experimental Work</i>
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.

1.2 Kinematics

Uniformly accelerated motion in one dimension

Displacement, velocity and acceleration in one dimension. Graphical representation of motion. 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).

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 $P = Fv \cos \theta$. 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.	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 $F = \frac{mv^2}{r}$ by whirling a rubber bung.

1.6 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.

Section B : Wave Motion

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| 2.1 | Wave propagation. Nature of motions in longitudinal and transverse progressive waves. Relation between v , λ and f . | Questions will <i>not</i> 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. |
| 2.2 | Wave phenomena
Huygens' principle | Explanation of laws of reflection and refraction. |
| | Reflection | Examples to include brief discussion of radar and sonar. 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. |
| | Superposition | Mathematical treatment <i>not</i> required. |
- E7. Superposition of transverse waves on a slinky spring.

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.

Plane transmission grating as an interference system. Use of the formula $d \sin \theta = n\lambda$.

- E8. Estimation of the wavelength of light using
(a) double slit; and
(b) plane diffraction grating.
- E9. Observation of interference fringes in soap film.

2.3 Stationary waves

Graphical treatment only.

- E10. Demonstration of stationary waves on a rubber cord and in a spring.

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.

E11. Study of electrostatic phenomena using the "shuttling ball" experiment.

E12. Investigation of the electric field between parallel metal plates using a charged foil strip.

Electric potential V

$V = Ed$ for uniform field. Electric potential of a point charge $V = Q/4\pi\epsilon_0 r$ (derivation *not* required).

E13. Observation of electric field patterns produced by electrodes of different shapes.

E14. 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.

E15. 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). $C = \epsilon_0 A/d$ for a parallel-plate capacitor. Series and parallel combinations of capacitors.	E16. Study the transfer of charge between two conductors --- the 'spooning' of charge from an e.h.t. power supply to an electrometer. E17. Investigation of the relationship between the charge on a capacitor and the p.d. across it by charging it with a constant current.
Energy of a charged capacitor	$E = \frac{1}{2} CV^2$ (Derivation <i>not</i> required.)	E18. Study the energy stored in a charged capacitor by discharging it through a small motor.
3.3 Current electricity	Electric current due to charges in motion. Unit : ampere (A).	
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.	E19. Demonstration of the drop in terminal p.d. of power supplies delivering current. E20. 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 <i>special case</i> of resistance behaviour. Resistivity defined by $\rho = RA/\ell$. Qualitative effects of temperature on resistance of metals and semiconductor.	

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 $1 \text{ N A}^{-1} \text{ m}^{-1}$.
The generalized expression $F = BI\ell \sin \theta$.

- E21. 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

$$F = BQv \sin \theta.$$

Measurement of magnetic fields.

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, and (iii) a display device for studying waveforms.

- E22. The use of cathode ray oscilloscope.
E23. 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.

Torque on a rectangular current-carrying coil in a uniform magnetic field $\tau = BAN I \sin \phi$

Quantitative treatment of the force between currents in long straight parallel conductors.

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 . $\mathcal{E} = -d\Phi/dt$. Faraday's and Lenz's laws. Interpretation of B as magnetic flux density.

Simple a.c. and d.c. generators 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.

E24. Investigation of the factors affecting the induced e.m.f. in a coil.

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 ($pV = \text{constant}$). The equation of state $pV = nRT$ where $n = \text{number of moles}$.

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 $pV = Nmc^2/3$. Order of magnitude of $\sqrt{c^2}$. Distribution of molecular speeds (qualitatively). Avogadro's law and the Avogadro constant. Interpretation of temperature for an *ideal gas* using $mc^2/2 = 3RT/2N_A$.

E25. Investigation of the relationship between pressure, volume and temperature of a gas.

4.2 Radioactivity

Properties of α , β and γ radiations

Revision and consolidation of lower form work.

E26. Magnetic deflection of β rays.

E27. 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).

Random nature of decay	$dN/dt = -kN$ derived from analogy with dice decay. Interpretation of decay constant k as the constant chance of an atom decaying per unit time.	E28. Simulation of radioactive decay by throwing dice.
Natural nuclear transformations	Change of N and Z in radioactive decay (details of radioactive series <i>not</i> required).	E29. Demonstration of random variation of count rate using GM counter and source.
Exponential law of decay. Half-life. The Becquerel.	$N = N_0 e^{-kt}$. Relationship between k and $t_{1/2}$. Relevance of long half-lives to the disposal of radioactive waste and to radioactive fallout. 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).	
4.3 Nuclear energy	The unified atomic mass unit (carbon scale). Interpretation of equations representing nuclear reactions.	
Energy release in fission and fusion. The electron-volt (eV).	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.	

- 4.4 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.

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 $y = b x^a$.

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^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.

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| 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 $> 2\pi$. 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.

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.

6. Differentiation of kx^n , $\sin kx$ and $\cos kx$, e^{kx} and $\ln kx$ where n and k are constants.

7. Calculation of maximum and minimum in simple cases involving the above functions.

8. Integration as the inverse of differentiation. The definite integral as the limit of a sum.

$$\lim_{\delta x \rightarrow 0} \frac{\delta y}{\delta x} = \frac{dy}{dx}$$

Reference to some physical examples : e.g. potential gradient dV/dx , current as dQ/dt , etc.

Graphical illustration in all cases, including graphs of dy/dx and d^2y/dx^2 against x . (Sketches based on simple reasoning should be used, in preference to plots based on calculators/tables.)

Tests for maximum or minimum using d^2y/dx^2 are not required.

Its representation as an area under a curve.