AM SYLLABUS (2011)

PHYSICS AM 26

SYLLABUS

Physics AM 26	(Available in September)
Syllabus	Paper 1 (3hrs) + Paper 2 (3hrs) + Practical paper 3 (2 hrs)

Aims of the Advanced Level Physics Curriculum

A course of study intended to prepare students for the Advanced Level Matriculation Examination in Physics should:

- promote an understanding of the nature and essence of physical principles;
- foster implementation of the scientific approach in the analysis of real life situations;
- encourage the development of problem solving techniques;
- encourage the development of practical skills;
- provide an appreciation that physical laws are universal;
- foster an appreciation and enjoyment of physics as a part of universal human culture;
- cultivate an appreciation of the influence of physics in everyday life;
- encourage an understanding of technological applications of physics and its importance as a subject of social, economic and industrial relevance.

Assessment Objectives

- Knowledge with understanding (35%)
- Applications of concepts and principles (30%)
- Communication and presentation (10%)
- Experimental design, investigation and analysis (25%)

Grade Descriptions

The grade descriptions indicate the criteria for awarding grades A, C and E. These criteria indicate the extent to which the assessment objectives are attained.

Objective/s	**A**	**C**	**E**
The candidate recalls and uses **knowledge** of Physics from…	the whole syllabus	most of the syllabus	some parts of the syllabus
The demonstration of the **understanding** of the principles and concepts is…	good	fair	poor
The candidate shows **application of concepts and physical principles** in contexts which…	are both familiar and unfamiliar	provide some guidance	are familiar or closely related
The candidate's level of **communication and presentation** is	clear, concise and direct	quite satisfactory	limited
In experimental work, the candidate **makes and records measurements** which are…	sufficient	almost sufficient	incomplete
In experimental work, the candidate shows **awareness for precision** which is	full	fair	lacking
In experimental work, the candidate's **analysis of experimental data** is…	rigorous	acceptable	mediocre

Examination

THREE papers as follows:

Paper I: 3 hours.
Paper intended to assess candidates on the following topics: Physical Quantities (Section 1), Mechanics (Section 2), Materials (Section 4), Electric Currents (Section 5), Quantum Theory (Section 7.5) and, Nuclear and Particle Physics (Section 8).
Section A - 8 short questions (90 minutes). Allotted 100 marks out of a total of 500 marks for the entire examination.
Section B - 7 longer structured questions to choose 4 (90 minutes). Allotted 100 marks out of a total of 500 marks for the entire examination.
Marks: 40%.

Paper II: 3 hours.
Paper intended to assess candidates on the following topics: Thermal Physics (Section 3), Fields (Section 6), Vibrations and Waves (Section 7 except for sub-Section 7.5).
Section A - 8 short questions (90 minutes). Allotted 100 marks out of a total of 500 marks for the entire examination.
Section B - 7 longer structured questions to choose 4 (90 minutes). Allotted 100 marks out of a total of 500 marks for the entire examination.
Marks: 40%.

Paper III: 2 hours.
Practical session: Experimental Physics (Section 9)
1 experiment designed to take up to ~ 1 hour allotted for taking measurements.
Questions will be set requiring candidates to present and analyse the experimental data and obtain from them specified quantities. Allotted 100 marks out of a total of 500 marks for the entire examination.
Marks: 20%.

Notes:
(i) Each paper does not exclude requirement of knowledge of topics examined in any other paper.
(ii) Scientific calculators may be used throughout the examination. Nevertheless, the use of graphical and/or programmable calculators is prohibited. Disciplinary action will be taken against students making use of such calculators.

Suggested Textbooks

(a) For Students and Teachers

Adams, S. Particle Physics. Heinemann. ISBN 0-435-57084-6.
Adams, S. and Allday, J. *Advanced Physics*. Oxford University Press. ISBN 0-199-14680-2.
Akrill, T.B., Bennet, G. and Millar, C. *Practice in Physics*. Hodder & Stoughton. ISBN 0-340-75813-9.
Carter, C. *Physics: Facts and Practice for A-Level*. Oxford University Press. ISBN 0-199-14768-X.
Chapple, M. *The Complete A-Z Physics Handbook*. Hodder & Stoughton. ISBN 0-340-68804-1.
Duncan, T. *Advanced Physics*. John Murray. ISBN 0-719-57669-5.
Muncaster, R. *A-Level Physics*. Hyperion Books. ISBN 0-748-71584-3.

(b) For Teachers

Bishop, C. *Particle Physics*. John Murray. ISBN 0-7195-8589-9
Muncaster, R. *Nuclear Physics and Fundamental Particles*. Stanley Thornes ISBN 0-748-71805-2.
Sang, D. *Nuclear and Particle Physics*. Thomas Nelson and Sons Ltd. ISBN 0-174-48238-8.

Mathematical Requirements

Sufficient mathematical background is necessary for one to be able to understand and apply the principles of physics at this level. Students should understand the use of calculus notation to express physical concepts such as those involving rate of change. The use of calculus to differentiate or integrate is not expected.

(a) Arithmetic and Computation

The use of decimal and standard form for numbers and recognize and use abbreviations for 10^{-12}, 10^{-9}, 10^{-6}, 10^{-3}, 10^{3}, 10^{6} and 10^{9}. The use of an electronic calculator for addition, subtraction, multiplication and division; for calculations involving angles in both degrees and radians; for calculations involving reciprocals, squares, sin θ, cosθ, tanθ, x^n, 10^x, e^x and their inverses (square roots, $\sin^{-1}\theta$, $\cos^{-1}\theta$, $\tan^{-1}\theta$, log x and ln x); for calculations involving arithmetic means. The numerical handling of data, especially being aware of the number of significant figures to quote in numerical answers, is expected. Making approximate estimations to find the order of magnitude of numerical expressions.

(b) Algebra

Manipulating algebraic expressions, such as changing the subject of a formula (including terms having positive or negative, integer or fractional powers). Solving algebraic equations including those involving inverse and inverse square relationships. Solving simultaneous quadratic equations is expected. Construct and use simple mathematical equations to model a physical situation and to identify situations where the use of the model is inadequate. The use of logarithms to manipulate expressions such as ab, a/b, x^n, e^{kx} is expected. Understand and use the symbols: $=$, $>$, $<$, $>>$, $<<$, $\approx$, $\propto$, $\sim$, Σx, Δx.

(c) Geometry and Trigonometry

Calculate the areas of triangles, the circumference and areas of circles, and the surface areas and volumes of rectangular blocks, cylinders and spheres. Use Pythagoras' theorem, similarity of triangles and the angle sum of a triangle and a quadrilateral. The use of sine, cosine and tangent in physical problems is expected. To be able to understand the relationship between angular measure in degrees and in radians, translate from one to the other ensuring that the appropriate system is used. Be aware that for small angles $\sin\theta \approx \tan\theta \approx \theta$ (in radians), and that $\cos\theta \approx 1$.

(d) Graphs

Translate information between numerical, algebraic, written and graphical form. Select and plot two variables from experimental or other data, choosing suitable scales for graph plotting. Drawing a suitable best straight line through a set of data points on a graph. Understanding and using the standard equation of a straight-line graph $y = mx + c$, and rearranging an equation to linear form where appropriate. Determine the gradient and intercept of a linear graph. Using logarithmic plots (both log and ln) not scales to test exponential and power law variations. Sketch and recognize plots of common expressions like $y = kx$, $y = kx^2$, $y = k/x$, $y = k/x^2$, $y = \sin kx$, $y = \cos kx$, $y = e^{kx}$ and $y = e^{-kx}$. Interpret rate of change as the gradient of the tangent to a curve and its determination from a suitable graph. Understand the notation dx/dt as the gradient of the graph of x against t, and hence the rate of change of x with t. Understand and use the area between a curve and the relevant axis when this area has physical significance, and to be able to calculate it or measure it by estimation or by counting squares as appropriate.

List of Experiments

List of Core Experiments

The following is a list of core experiments that form part of the syllabus. The candidate is required to have thorough knowledge (including experimental details) and understanding of each of them.

Experimental measurement of velocity and the subsequent calculation of acceleration.
Experimental investigation to prove that acceleration is proportional to the applied force for a body with a fixed mass.
Experimental investigation of the law of conservation of momentum.
Measurement of specific heat capacity and specific latent heat by electrical methods.
Experimental investigation with metals and polymers to determine their elastic properties, in particular the determination of Young's modulus for a wire.
Current-voltage characteristics for a metal wire at constant temperature, filament lamp and diode.
Determination of the temperature coefficient of resistance.
Experimental treatment of mechanical resonance, especially the variation of amplitude with forcing frequency.
Progressive wave method for finding the wavelength of sound waves.
Experiments to investigate reflection and refraction using visible light.
Use of the spectrometer to measure wavelength using a diffraction grating.
Experimental determination of the focal length of a thin converging lens by a graphical method.

List of Demonstrative Experiments

The following is a list of demonstrative experiments that form part of the syllabus. The candidate is required to have thorough understanding of each of them.

Experimental demonstration of the gas laws.
Use of a high-voltage voltmeter to measure charge.
Use of the Hall probe to investigate magnetic fields.
Experimental demonstration that rate of change/cutting of flux induces an e.m.f. in a circuit.
Experimental demonstration of Lenz's law.
Experiment to prove Faraday's second law $e \propto N\dfrac{d\Phi}{dt}$.
Experimental demonstrations of the effects of self-induction on growth and decay of current in d.c. circuits, and the chocking of an a.c. current.
Use of a search coil to investigate (oscillating) magnetic fields.
Experimental demonstration of stationary waves on a stretched wire.
Experiments to demonstrate reflection and refraction using microwaves.
Use of the Polaroid to demonstrate the transverse nature of electromagnetic waves.
Demonstration of diffraction of microwaves and visible light at a slit.
Demonstration of the two-slit experiment for the investigation of interference of light waves.

Syllabus

1. PHYSICAL QUANTITIES

1.1 Base quantities and units of the S.I. system:

Mass (kilogram, kg), length (metre, m), time (second, s), current (Ampere, A), temperature interval (Kelvin, K), amount of substance (mole).	Definitions of derived quantities may be given in terms of a word equation, e.g. Momentum = mass times velocity. The ability to obtain derived units in terms of base units will be examined. Definitions of the base units will not be examined.
Homogeneity of physical equations.	Homogeneity (using base units of the S.I. system only and not dimensions) as a necessary but not sufficient condition for the correctness of physical equations. The use of base units or dimensions to derive physical relationships is not required.

1.2 Scalar and vector quantities:

The addition, subtraction, and resolution of vectors. Product of two vectors.	Recognition of physical quantities as vectors or scalars. The knowledge that the product of two vectors may or may not be a vector. Scalar and vector products are not expected. Problems involving relative velocity will not be set.

2. MECHANICS

2.1 Rectilinear motion:

Displacement, speed, velocity and acceleration. Equations for uniformly accelerated motion. Displacement-time and velocity-graphs. Direct measurement of the acceleration of free fall.	Experimental measurement of velocity and the subsequent calculation of acceleration. Velocity = rate of change of displacement with time = slope of displacement-time graph = ds/dt. Acceleration = rate of change of velocity with time = slope of velocity-time graph = dv/dt.
Projectiles.	Emphasis on independence of perpendicular vectors.

2.2 Newton's laws of motion:

Newton's first law.	Forces outside the nucleus may be either gravitational or electromagnetic.The use of free-body diagrams to represent forces acting on bodies. Velocity-time graph for a body falling in a viscous medium: terminal speed. Laws of friction are not included. Experimental investigation to prove that acceleration is proportional to the applied force for a body with a fixed mass.
Linear momentum.	
Newton's second law.	Force = $d(mv)/dt$. Problems where both mass and velocity change are excluded.

The Newton.	The reasoning from the second law to the definition of the Newton should be understood.
Impulse.	
Newton's third law.	Students should be able to identify appropriate pairs of Newton third law forces.
Conservation of linear momentum in elastic and inelastic collisions.	Law of conservation of momentum derived from Newton's laws. Experimental investigation is expected. Problems on oblique collisions are excluded.

2.3 Energy:

Work.	Work done by a varying force.
Power.	Power (energy transfer/s) = force times velocity.
Potential energy.	Gravitational and elastic potential energy.
Kinetic energy.	½ mv^2 at low speeds. The derivation of this expression is not required.
Law of conservation of energy.	Energy transformation in simple systems from different branches of physics. Concept of efficiency.

2.4 Circular motion:

Angular speed, period, frequency. Centripetal acceleration and centripetal force.	The derivation of $a = v^2/r$, for a body moving at constant speed in a circular path is required. Examples to include the bicycle rider, banking of circular tracks and motion in a vertical circle.

2.5 Equilibrium:

Turning effect of forces.	Principle of moments, couple and torque.
Centre of gravity.	
Conditions for equilibrium of a rigid body.	Consideration of stability is not expected.

2.6 Rigid bodies:

Energy of a rigid body rotating about a fixed axis.	The concept of moment of inertia. $E = ½ I\omega^2$ should be understood but its derivation will not be examined.
Angular momentum and its conservation.	Use of the equations for rotational motion with constant angular acceleration may be examined.

3. THERMAL PHYSICS

3.1 Temperature and heat:

Thermal equilibrium and temperature.	Temperature regarded as a property that tells whether systems are in thermal equilibrium or not.
The ideal gas temperature scale.	Use of $T = 273.16\ X/X_{tp}$ to establish a temperature scale. Use of the constant-volume gas thermometer and the equation, $T = 273.16\ P/P_{tp}$ Kelvin in the limit as P_{tp} approaches zero, to establish the ideal gas temperature scale. Students must be aware that more practical thermometers are available for reading Kelvin scale temperature (Qualitative description only. No structural details of thermometers are required.)
Definition of Celsius temperature scale.	The Celsius temperature scale is defined by $\theta = \{T\,(\text{K}) - 273.15\ \text{K}\}$°C.
Heat defined as energy transfer to due to a temperature difference.	

3.2 Energy transfer:

Energy transfer by mechanical and electrical processes, or by heating.	Use of $W = F\ \Delta s$; $W = P\ \Delta V$; $W = QV$; $Q = mc\Delta T$; $Q = mL$.
First law of thermodynamics.	Meaning of ΔU, ΔQ and ΔW in $\Delta U = \Delta Q + \Delta W$. The first law applied to a gas enclosed in a cylinder with a movable piston, to a filament lamp and the deformation of a metal wire. Changes at constant volume and constant pressure, including Cp, Cv and $Cp - Cv = R$.
Isothermal and adiabatic changes.	$\Delta T = 0$ implies $\Delta U = 0$ for an ideal gas only. $\Delta U = \Delta W$ for an adiabatic change. Work done = area under P-V graph. Use of PV^{γ} = Constant is expected.
Heat engines and heat pumps.	Principle of heat engine and heat pump. Use of the equation for the coefficient of performance of refrigerators and heat pumps. Efficiency of heat engines. Factors limiting practical efficiency.
Second law of thermodynamics.	Heat engine and heat pump statements of the second law of thermodynamics. The statement of the second law in terms of entropy is not expected.

3.3 Heating matter:

Measurement of specific heat capacity and specific latent heat by electrical methods.	Simple direct measurements emphasizing energy conversion. Identification of experimental errors. Calculation of heat losses is not included. Knowledge of constant flow techniques is not expected.

3.4 Kinetic theory of gases:

Brownian motion as evidence of the random motion of gas molecules.	
Gas laws.	Knowledge of their experimental demonstration. Graphs of PV/T against P for one mole of any real gas approach the constant R as P approaches zero.
The ideal gas equation.	Use of $PV = nRT = (m/M)RT$ for real gases at low pressures. Description of real gas behaviour is not expected.
The ideal gas model.	Derivation of $P = \frac{1}{3}\rho <c^2>$. Application to $PV = nRT$ and the internal energy of an ideal gas.
Relationship between absolute temperature and kinetic energy of molecules.	T proportional to the average kinetic energy of molecules. Derivation of $\frac{1}{2} m <c^2> = 3kT/2$. Concept of root-mean-square speed.
The distribution of molecular speeds.	A description of how molecular speeds are measured is not included. Qualitative approach only.

3.5 Transfer of heat:

Conduction, convection, radiation and evaporation.	Qualitative descriptions of these processes.
Thermal conductivity. Simple problems in one dimension.	Experiments to obtain k are not required. Use of $dQ/dt = -kA(d\theta/dx)$.
Radiation.	Qualitative idea of the variation of intensity with wavelength for the radiation from a black body at various temperatures. The inverse square law for decrease of intensity with distance from a point source.
Energy in buildings.	Space heating. Energy losses by conduction, convection and radiation. U-values, defined as follows: $U = (dQ/dt)/(A\ \Delta\theta)$

4. MATERIALS

4.1 Solids:

Force-extension graphs for metals, polymers (polythene and rubber) and glassy substances.	Hooke's law, elastic limit, yield point and plastic flow are included. Knowledge of experimental work with metals and polymers is required.
Stress, strain and Young's modulus.	Determination of Young's modulus for a wire.
Elastic energy stored in a stretched wire.	Elastic energy stored in a stretched wire is equal to the area under force against extension or force against compression graphs ($E = \frac{1}{2}kx^2$).

5. ELECTRIC CURRENTS

5.1 Charge and current:

Current as the rate of flow of charge.	Current = slope of charge-time graph = dQ/dt.
Current model.	Derivation of $I = nAve$ is expected. Distinction between conductors, semiconductors and insulators using the equation.
Intrinsic and extrinsic semiconductors	Crystal structure of silicon. Effect of impurities and temperature on conduction.
Simple band theory	To explain differences between conductors, intrinsic and extrinsic semiconductors, and insulators
Electrical potential difference.	Potential difference = work done/charge.
E.m.f. of a cell.	Definition of e.m.f.
Kirchoff's laws.	Simple circuit calculations. Emphasis on conservation of charge and energy.

5.2 Resistance:

Current-voltage characteristics for a metal wire at constant temperature, filament lamp and diode.	Experimental investigations are expected.
Resistivity and conductivity.	
Temperature dependence of resistance of metals and thermistors.	Experimental investigation included. Determination of the temperature coefficient of resistance.
Internal resistance of a cell and its measurement.	Practical importance of internal resistance in car battery and extra high-tension supplies.
Resistors in series and in parallel.	Simple circuit problems, including the use of Kirchoff's laws.
The potential divider.	The potential divider equation. Use of light-dependent resistor or thermistor to control voltage.
Balance of potentials and the principle of null methods.	Circuit principles are expected. Only simple numerical problems based on simple circuits can be set. Reference to terms such as 'potentiometer', 'Wheatstone Bridge', etc., are to be avoided.
Energy and power in d.c. circuits.	Including the kilowatt-hour.
Use of ammeters, voltmeters and multimeters.	Extension of range of electrical meters. Internal structure of meters is not included.

6. FIELDS

6.1 Gravitational fields:

Newton's law of gravitation.	
Gravitational field strength g.	Variation of *g* over the earth's surface and with height, excluding variation with depth.
Gravitational potential in a radial field.	
Representation of uniform and radial fields by lines of force and equipotential surfaces.	
Motion of satellites in circular orbits. Escape velocity.	The idea of apparent weightlessness for freely falling bodies should be understood.
Satellites in communications	Geosynchronous and polar orbits. Advantages and disadvantages. Use of satellites (brief qualitative description only).

6.2 Electrostatic fields:

Simple electrostatic phenomena.	Charging conductors by induction. Point charges in vacuum.
Inverse square law in electrostatics.	Experimental demonstration is not required.
Use of lines of force and equipotentials to describe electric fields qualitatively.	
Electric field strength defined as $E = F/Q$.	E for uniform and radial fields.
Electric potential and potential difference.	V for uniform and radial fields.
Relation between E and V.	$E = -dV/ds$.
Acceleration of charged particles moving along the field lines of a uniform electric field.	Use of $QV = ½ mv^2$. Definition of the electron volt.
Physical principles of linear accelerators.	The linear accelerator to reach GeV. Understanding qualitatively that particles never reach the speed of light.
Deflection of charged particles in uniform electric fields.	

6.3 Capacitors:

Factors affecting the capacitance of a parallel plate capacitor.	
Relative permittivity.	$Q = CV$; $\varepsilon_r = C/C_o$; $C = \varepsilon_r \varepsilon_o A/d$. No experimental determination of the listed parameters is expected.

Different types of capacitors.	Structure of the electrolytic capacitor may be examined.
Charge stored on a capacitor.	$Q = VC$. Use of high resistance voltmeter to measure charge.
Exponential growth and decay of charge stored in a capacitor in series with a resistor. Time constant.	Exponential form of graph to be understood and related to the decay of radioactivity. Use of graph to determine RC. Use of equations for the growth and decay of charge, current and voltage in R-C circuits. Derivation of these equations is not required.
Energy stored in a capacitor.	½ CV^2 from area under a Q-V graph.
Capacitors in series and in parallel.	Simple circuits.

6.4 Magnetic fields:

Magnetic effect of a steady current.	B-field patterns near a straight conductor and solenoid.
Force on a straight current-carrying conductor in a uniform magnetic field.	
Magnetic flux density. The Tesla.	B defined from $F = BIl$. Vector nature of B.
Torque on a rectangular coil in a uniform and a radial magnetic field	Derivation and use of $\tau = BANI\cos\theta$.
Use of Hall probe to investigate B.	$B = \mu_o I/2\pi r$ and $B = \mu_o nI$ to be investigated experimentally but their derivation is not required. Derivation of equation for Hall voltage is required.
Force between two parallel current-carrying straight conductors.	Definition of the ampere. Awareness that the forces are Newton's Third Law pairs.
Force on a charged particle moving in a circular orbit through a magnetic field.	Derivation of $F = BQv$.
Crossed electric and magnetic fields.	At right angles only. The mass spectrometer as an application.
Physical principles of ring accelerators.	The cyclotron: derivation of the supply frequency for non-relativistic particles.

6.5 Electromagnetic induction:

Magnetic flux and flux linkage.	Experimental demonstration that the rate of change/cutting of flux induces an e.m.f. in a circuit.
Faraday's and Lenz's laws of electromagnetic induction.	$e = -Nd\phi/dt$. Derivation of $e = Blv$ is expected. Lenz's law and energy conservation. Use of search coil to investigate oscillating magnetic fields. Effect of speed on current. Experimental demonstration of Lenz's law. Experiment to prove

Back e.m.f. in electric motors.

Faraday's second law $e \propto N\frac{d\Phi}{dt}$.

Mutual inductance and self-inductance.

$e = -L\,dI/dt$ and $e = -M\,dI/dt$ obtained from $e = -N\,d\phi/dt$. $W = \frac{1}{2}LI^2$ (Derivation is not expected).

Growth and decay of current in inductive circuits.

Use of equations for I, V_R and V_L is expected but their derivation is not required. Experimental demonstrations of the effects of self-induction on growth and decay of current in d.c. circuits, and the chocking of an a.c. current.

The simple generator.

The e.m.f. produced when a rectangular coil rotates in a uniform magnetic field.

Electricity distribution.

Advantages of high voltage and low current transmission (the role of the transformer). Knowledge of typical voltages is expected.

6.6 Alternating currents:

Peak and root mean square values and their relationship for sinusoidal currents and potential difference.

Knowledge and use of $I_{rms} = I_o/\sqrt{2}$, and $V_{rms} = V_o/\sqrt{2}$. Derivation of these equations is not expected.

Use of the oscilloscope as a voltmeter and as a clock.

Knowledge of the internal structure of the oscilloscope is not required.

The p-n junction diode. Forward and reverse bias characteristics.

Rectifying action of p-n junction diode in terms of majority and minority carriers. Depletion layer.

Half-wave and full-wave rectification circuits.

Single diode and bridge circuits including the use of the smoothing capacitor.

7. VIBRATIONS AND WAVES

7.1 Simple harmonic motion:

The simple harmonic motion of a particle treated algebraically and graphically.

Use of the equations for x, v, and a, but their derivation will not be examined. Connection of SHM with circular motion. Idea of phase is required.

Velocity-time and acceleration-time graphs.

Graphical and algebraic treatment.

Energy in simple harmonic motion.

Examples of simple harmonic systems.

Only the derivation of the equation for the period of the mass-spring system is required.

Free and forced oscillations.

Damped vibrations.

Decay of amplitude in damped vibrations.
An understanding of the difference between the different types of damping: light, critical and over-damped oscillations are required.

	Mechanical resonance.	Experimental treatment of variation of amplitude with forcing frequency. Examples to include vibrating strings.
7.2	**Waves:**	
	The progressive wave.	Amplitude, speed, wavelength, frequency and phase interpreted graphically. Displacement-position and displacement-time graphs. Knowledge of the progressive wave equation is required.
	Wave propagation.	Concept of wavefront. Huygens' construction for wave propagation to introduce the concept of wavefront only. Problems involving Huygen's construction will not be set.
	Longitudinal and transverse progressive waves.	Waves in water, waves along springs and sound waves as examples. Particle displacement graphs for transverse and longitudinal waves, and pressure variation for longitudinal waves.
	Measurement of the speed of sound in free air.	Progressive wave method for finding the wavelength of sound waves.
	Electromagnetic waves.	Reflection and refraction demonstrated using visible light and microwaves. Furthermore, for visible light, experimental investigation is required. Electromagnetic wave velocity in free space, $c = 1/\sqrt{(\varepsilon_o \mu_o)}$.
	Plane polarisation.	Use of the Polaroid to demonstrate the transverse nature of electromagnetic waves.
7.3	**Superposition of waves:**	
	The principle of superposition and the formation of stationary waves.	Displacement-position graphs used to explain formation of nodes and antinodes. Contrast between progressive and stationary waves.
	Stationary waves on strings as demonstration of resonance states.	Use of the formula $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ and the associated harmonics. Experimental demonstration of stationary waves on a stretched wire.
	Demonstration of diffraction of microwaves and visible light at a slit.	Effect of relative size of slit and wavelength on diffraction pattern. Derivation of $\theta = \lambda/a$, for a slit of width d is not required.
	Importance of resolving power for instruments.	Effect of aperture and wavelength on resolving power. Limit of resolution. Use of Sin $\theta = 1.22\ \lambda/a$, for resolution by circular apertures is expected. Derivation of formula is not expected.
	Interference of light waves in the two-slit experiment.	Explanation of the formation of the interference pattern in terms of phase difference between the two wave trains. Effect of changes in wavelength and slit separation on the interference pattern. Conditions for visible interference patterns.

		Proof of $\lambda = sd/D$, is not required. Knowledge of experimental details is expected and a demonstration of the experiment is essential.
	Optical transmission grating.	Use of the spectrometer to measure wavelength using a diffraction grating. Adjustments of spectrometer will not be examined. Comparison of the spectra produced by a diffraction grating and a prism.
7.4	**Optics:**	
	Laws of reflection and refraction.	Reflection and refraction at a plane interface only.
	Refractive index. Snell's law in terms of the ratio of velocities in different media.	Use of $n_1\sin\theta_1 = n_2\sin\theta_2$ and ${}_1n_2 = v_1/v_2$. Knowledge that the speed of light in material media depends on the frequency.
	Total internal reflection and critical angle.	
	Transmission of information through fibre optics	The main components needed for transmission of a signal using optical fibres (limited to step-index fibres). A block diagram approach is sufficient.
	Refraction of light by thin converging and diverging lenses.	Use of $1/f = 1/u + 1/v$, real is positive (or in Cartesian form) and magnification = v/u. Single lens problems only. Experimental determination of the focal length of a thin converging lens by a graphical method.
7.5	**Quantum theory:**	
	The photoelectric effect.	The inability of the wave theory to explain the experimental results. Einstein's photoelectric equation. Concept of stopping voltage and its measurement.
	Energy levels within the atom.	Explanation of emission and absorption line spectra. Use of $E_2 - E_1 = hf$.
	Wave properties of electrons.	Qualitative description of electron diffraction. The de Broglie equation $\lambda = h/(mv)$. Candidates should be aware that the square of the amplitude of the wave representing the electron, is indicative of the probability of finding the electron in a particular space. Eg. In a standing wave, there is a higher probability of finding the electron at its antinodes than at its nodes.
7.6	**The expanding universe:**	
	Electromagnetic Doppler effect.	Qualitative treatment of the Doppler shift of spectral lines
	Expansion of the Universe. Hubble's law.	The red shift of galaxies. $v = Hd$, with H in s^{-1} . Notion of the Big Bang. The age of the Universe: uncertainty in d and H. The various stages (e.g.

	quark-lepton era, hadron era) not to be examined.

8. NUCLEAR AND PARTICLE PHYSICS

8.1 Evidence for a nuclear atom:

Alpha scattering experiment.	Emphasis on the results of the experiment and their interpretation. The nuclear size. Distance of closest approach.
The need for the strong nuclear force between nucleons	Electrostatic repulsion between protons. Comparative ranges of the electrostatic and strong forces.
Nuclear size.	Variation of nuclear size with nucleon number. $R = R_o A^{1/3}$.
Deep inelastic scattering as experimental evidence of the existence of quarks.	The use of electrons of high energy to reveal the structure of the nucleons as made up of sub-atomic particles. No knowledge of the latter is expected. The quark composition of the nucleus is NOT required. Ability to determine the energy of bombarding particles by considering their appropriate de Broglie wavelength. Candidates should be aware that very high energy electrons constitute a beam of area of cross-section of the same order of magnitude as that of the proton.
Stable and unstable nuclei.	N-Z curve for stable nuclei.
The neutrino. The positron as an example of antimatter.	Decay of the n and p within the nucleus. Energy spectra for beta. The prediction of the neutrino and antineutrino. Their experimental confirmation is not expected.
Binding energy.	The binding energy per nucleon curve. Use of the unified mass constant u and $E = mc^2$.
Fission and fusion.	Treated as nuclear reactions in which a large amount of energy is given out as can be inferred from the binding energy per nucleon curve. Fission of the Uranium nucleus. Chain reaction. Nuclear fusion as a future source of energy.
Properties of alpha, beta (+ and −) and gamma radiation.	Inverse square law and absorption law for gamma radiation. Half-value thickness.
Health hazards and protection.	
Radioactivity as a random process.	Background radiation and its sources.
The law of radioactive decay.	Use of $dN/dt = -\lambda N$ and $N = N_o\,e^{-\lambda t}$. Derivation of $N = N_o\,e^{-\lambda t}$ is not required but the relation between decay constant and half-life should be understood.
Determination of the half-life of radon.	

9. EXPERIMENTAL PHYSICS

9.1 Laboratory practice and data analysis:

Systematic and random errors.	The appropriate handling of experimental data is expected but the composition of errors is not required. Qualitative description of sources of errors and precautions is expected.
Estimate of the uncertainty in a measured quantity.	The relevance of significant figures should be emphasized.
Suitable techniques for measuring mass, length, time, current and temperature.	
The use of micrometer and vernier scales. Use of the oscilloscope as a voltmeter and as a clock.	
The assembly of simple electric circuits and the use of electrical measuring instruments.	
The ability to design and carry out simple investigations will be examined.	

GENERAL NOTE

Analogies of physical phenomena across the syllabus should be highlighted.

Data Sheet

The following equations may be useful in answering some of the questions in the examination.

Uniformly accelerated motion:

Useful formulae:

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \left(\frac{u+v}{2}\right)t$

Mechanics:

Newton's second law: $F = \frac{d(mv)}{dt}$

Power: $P = Fv$

Momentum: $p = mv$

Circular motion:

Angular speed: $\omega = \frac{d\theta}{dt} = \frac{v}{r}$

Angular acceleration: $\alpha = \frac{d\omega}{dt} = \frac{a}{r}$

Centripetal acceleration: $a = \frac{v^2}{r}$

Torque: $\tau = I\alpha$

Work done in rotation: $T\theta = \frac{1}{2}I\omega^2$

Simple harmonic motion:

Displacement: $x = x_0 \sin(\omega t + \phi)$

Velocity: $v = \omega x_0 \cos(\omega t + \phi)$

Acceleration: $a = -\omega^2 x$

Period: $T = \frac{1}{f} = \frac{2\pi}{\omega}$

Mass on a light spring: $T = 2\pi\sqrt{\frac{m}{k}}$

Ray optics:

Refractive index: ${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$

${}_1n_2 = {}_1n_3 \cdot {}_3n_2$

Thin lenses: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (real is positive)

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ (Cartesian)

Magnification: $m = \frac{v}{u} = \frac{h_i}{h_o}$ (real is positive)

$m = -\frac{v}{u} = -\frac{h_i}{h_o}$ (Cartesian)

Current electricity:

Current: $I = nAve$

Resistors in series: $R_{TOTAL} = R_1 + R_2 + \ldots$

Resistors in parallel: $\frac{1}{R_{TOTAL}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

Power: $P = IV$

Resistivity: $\rho = \frac{R\,A}{l}$

Temperature coefficient: $\alpha = \frac{R_\theta - R_0}{R_0\theta}$

Alternating current:

For sinusoidal alternating current:

$I = I_0 \sin 2\pi ft$

Root mean square for sinusoidal alternating current and voltage: $I_{rms} = \frac{I_0}{\sqrt{2}}$; $V_{rms} = \frac{V_0}{\sqrt{2}}$

Ideal transformer: $\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$I_P V_P = I_S V_S$

Stationary waves:

Fundamental frequency (strings): $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

Wave motion:

Two slit interference: $s = \frac{\lambda D}{d}$

Diffraction grating: $d \sin\theta = n\lambda$

Single slit diffraction: $\theta = \frac{\lambda}{a}$

Diffraction of circular aperture: $\sin\theta = 1.22\frac{\lambda}{d}$

Fields:

Electric field strength: $E = \frac{F}{+q} = -\frac{dV}{ds}$

Uniform field: $E = \frac{F}{+q} = \frac{V}{d}$

Force between point charges: $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$

Electric field strength of a point charge:

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

Force between point masses: $F = G\frac{M_1 M_2}{r^2}$

Electric potential: $V = \frac{Q}{4\pi\varepsilon_0 r}$

Gravitational potential: $V_G = -\frac{GM}{r}$

Electromagnetism:

Force on wire: $F = BIl\sin\theta$

Force on moving charge: $F = BQv\sin\theta$

Magnetic flux: $\Phi = BA$

Field inside a solenoid: $B = \mu_0 nI$

Capacitance:

Capacitance of parallel plates: $C = \frac{\varepsilon_0\varepsilon_r A}{d}$

Capacitors in parallel: $C = C_1 + C_2 + \ldots$

Capacitors in series: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

Energy stored: $W = \frac{1}{2}CV^2$

Charging: $Q = Q_0\left(1 - e^{-\frac{t}{RC}}\right)$

Discharging: $Q = Q_0 e^{-\frac{t}{RC}}$

Inductance:

Mutual inductance: $M = -\frac{e}{dI/dt}$

Self inductance: $L = -\frac{e}{dI/dt}$

Energy stored: $W = \frac{1}{2}LI^2$

Growth of current: $I = I_0(1 - e^{\frac{-Rt}{L}})$

Decay of current: $I = I_0 e^{\frac{-Rt}{L}}$

Materials:

Hooke's law: $F = k\Delta x$

Stress: $\sigma = \frac{F}{A}$

Strain: $\varepsilon = \frac{\Delta l}{l}$

Young's modulus: $Y = \frac{\sigma}{\varepsilon}$

Energy stored in a stretched wire: $E = \frac{1}{2}kx^2$

Field near a long straight wire: $B = \mu_0 \dfrac{I}{2\pi r}$

Induced e.m.f.: $e = -N\dfrac{d\Phi}{dt}$

E.m.f. induced in a moving conductor:

$e = Blv$

Simple alternator e.m.f.: $e = E_0 \sin(\omega t + \phi)$

Hall voltage: $V_H = \dfrac{BI}{nQt}$

First and second laws of thermodynamics:

First law of thermodynamics: $\Delta U = \Delta Q + \Delta W$

Ideal heat engine: $\eta = 1 - \dfrac{T_c}{T_h}$

Gases:

Ideal gas equation: $PV = nRT = \dfrac{m}{M}RT$

Kinetic theory of an ideal gas:

$PV = \dfrac{1}{3}Nm < c^2 >$

Boltzmann's constant: $k = \dfrac{R}{N_A}$

Principal molar heat capacities of an ideal gas:

$\gamma = \dfrac{C_P}{C_V}$; $C_P - C_V = R$

Adiabatic process: PV^{γ} = Constant

Temperature:

Temperature (K): $T = 273.16\dfrac{X}{X_0}$ K

Ideal gas scale: $T = 273.16 \lim \dfrac{P}{P_{tr}}$ (as $P_{tr} \rightarrow 0$)

Celsius scale: θ (°C) = T (K) – 273.15 K

Thermal conduction:

Useful formula: $\dfrac{dQ}{dt} = -kA\dfrac{d\theta}{dx}$

U-value: $U = \dfrac{dQ/dt}{A\,\Delta\theta}$

Quantum phenomena:

Quantum energy: $E = hf$

Mass-energy $E = mc^2$

Photoelectric effect: $hf = \Phi + \left(\dfrac{1}{2}mv^2\right)_{\max}$

Energy levels: $hf = E_2 - E_1$

De Broglie wavelength: $\lambda = \dfrac{h}{mv}$

Radioactivity:

Decay rate: $\dfrac{dN}{dt} = -\lambda N$; $N = N_o e^{-\lambda t}$

Half life $T_{1/2} = \dfrac{\ln 2}{\lambda}$