UNIVERSITY ENTRANCE EXAMINATION
PHYSICS SYLLABUS

1. **PHYSICAL QUANTITIES AND UNITS**

    All physical quantities understood as consisting of a numerical magnitude and unit. International System of Units (SI).

    Base unit: mass, length, time, current, temperature, amount of substance.
    Other Unit expressible as products or quotients of base units.

    Student should understand and use the conventions for indicating units and for labelling graph axes and table columns as set out in the current *ASE Report SI Units*, *Signs, Symbols and Abbreviations.*

    Use of units or dimensions to check homogeneity of physical equations.
    Use of dimensions to derive possible forms of physical equations is not required.
    Scalars and vectors. Composition and perpendicular resolution of vectors. (Coplanar examples are sufficient.)

2. **RELATIVE MASSES OF ATOMS AND MOLECULES**

    (a)   Relative atomic, isotopic, molecular and formula masses, based on the ^{12}C scale. (A_r and M_r). The term relative formula mass or M_r will be used for ionic compounds.

    (b)   The mole, the Avogadro constant (see 4.1).

    (c)   The determination of relative masses

    (i)   by mass-spectrometry, treated as consisting of an ion generator, a velocity selector, a magnetic field and a detector.
    (ii)   for gases and volatile liquids by a syringe or other simple laboratory method base don $pV = nRT$ (see 9.3).
    (iii)   Details of the physics of mass spectrometry are not required but interpretation of results (in relation to isotopic abundances and the presence of molecular fragments) is included.

    (d)   The calculation of empirical and molecular formulae, using composition by mass and combustion data.
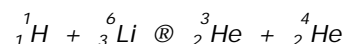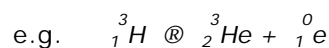

3.   **ATOMIC STRUCTURE**

3.1   **Electrons, Protons and Neutrons**

    Their relative charges and relative masses.

3.2   **The Nucleus of the Atom**

    (a)   Isotopes and mass number.

    (b)   Radioactivity (a treatment of proton: neutron ratio is not required).

    (i)   The nature of α- and β- particles and of γ- rays.
    Radioactive decay as a random phenomenon.
    Differences in penetrating ability should be mentioned, form the point of view of radiation protection, but a treatment of the detailed physical evidence establishing the nature of α- and β- particles and γ- rays is not intended.

    (ii)   Half-life, as a measure of the relative stability of the nucleus.
    Calculations on half-life and use of the exponential decay law.

(iii)   The effect of α- and β- particle emission on mass number and atomic number.

(iv)   The balancing of nuclear equations.

e.g. $^3_1H \rightarrow {}^3_2He + {}^0_1e$

$^1_1H + {}^6_3Li \rightarrow {}^3_2He + {}^4_2He$

(c)   The common isotopes of uranium, ^{235}U and ^{238}U.

The neutron-induced fission of ^{235}U resulting in

(i)   the release of large quantities of energy (given by $E = mc^2$),
(ii)   the production of further neutrons – leading to the possibility of chain reaction,
(iii) the formation of lighter radioactive fission fragments.

(d)   Fusion of light elements as a source of energy.

Reference should be made to the fact that the source of energy in the sun is a series of fusion reactions.

3.3   **The Electronic Structure of the Atom**

(a)   Outline of experimental results leading to photon energy $E = hf$.

(b)   The relevance of ionisation energies to electronic configuration.

(c)   The concept of electronic energy levels, illustrated by successive ionisation energies, e.g. for sodium, and the characteristic line spectrum for hydrogen given by $E_1 - E_2 = hf$ (see also section 9.7).

(d)   Extranuclear structure as the basis of periodicity. The filling of orbitals according to their energy and the pairing of electrons.

4.   **GASES, LIQUIDS AND SOLIDS**

4.1   **Gases**

Derivation of ideal gas equations leading to Boyle's law and Avogadro's hypothesis.

$p = {}^1/_3\, n_v m < c^2 >$; temperature defined by $pV_m = RT$; $p = n_v kT$. (see 9.3)
The Avogadro constant [see 2(b)].

A simplified treatment (e.g. particles in a rectangular box with statistics treated by dividing the molecules into three groups) will suffice.

The assumptions for ideal gas behaviour and their limitations for real gases at high pressure and low temperature. No treatment or use a Van de Waals' equation or of critical phenomena is required.
Graphical representation of the Boltzmann distribution of molecular speeds. The effect of temperature change on the distribution of kinetic energies. The Boltzmann constant.

4.2   **Liquids**

Liquids: the kinetic concept of the liquid state and a simple kinetic-molecular description of melting, vaporisation and vapour pressure. Saturated and unsaturated vapours.

4.3   **Solids**

(a)   Lattice structure and spacing.

Generally, only the qualitative idea that the particles are situated at fixed points in a regular pattern is expected, but for the examples quoted below, a

knowledge of the geometry (but not the dimensions) of the actual lattice is required. It should, however, be appreciated that the individual particles in a lattice may be atoms, molecules or ions.

 (i) NaCl as an ionic lattice.
 (ii) Cu as a cubic close-packed metal lattice.
 (iii) Graphite and diamond and their properties as examples of macromolecular structures.

 (b) Lattice energy.

  Only a qualitative appreciation that energy is required to break up the structure of a lattice is expected. Reference should be made to the qualitative differences in the forces between the particles in atomic, molecular and ionic lattices.

5. ELECTROCHEMISTRY

Electrolysis; the factors affecting the mass of substance liberated during electrolysis.
Calculations may be set.
The relationship between the Faraday and the Avogadro constants and the charge on the electron, $F = Le$, should be given.

6. MECHANICS

6.1 Couples

Couples, torques, moments of forces, equilibrium.

6.2 Dynamics

Kinematic equations of uniform linear acceleration.

Newton's laws of motion, leading to the concepts of force, mass and momentum.

Problems will be limited to cases of uniform linear acceleration *expect* for circular motion and simple harmonic motion (see sections 6.4 and 7.1).

Conservation of momentum.
Problems in one dimension are sufficient.

6.3 Energy, Work, Power

Kinetic energy. Potential energy in various forms. Conservation of energy.

Work as transfer of energy by processes of the nature of (force) x (displacement). Examples to include expansion of a gas against a constant pressure.

Power, the watt.

Force and potential energy, their relationship in uniform fields.
Force of attraction between two masses. Newton's law of gravitation, $F = Gm_1m_2/r^2$, will be quoted in the question if needed.

6.4 Motion in a circle

Angular velocity ω; linear velocity $v = \omega r$.
Centripetal accelerations and forces.
A simple treatment of uniform motion in a circle will suffice. A knowledge of $a = v^2/r = w^2r$ will be sufficient.

7. OSCILLATIONS AND WAVES

Items are selected for this section to provide a firm foundation for the understanding of periodic phenomena.

7.1   **Simple harmonic motion**

Experimental, analytical and graphical treatments of simple examples. Simple harmonic motion defined by the equation $a = -\omega^2 x$ and knowledge that its solution is of the form.
$x = x_0 \sin \omega t$.   Periodic time $T = 2\pi/\omega$.

The simple pendulum and vertical oscillations of a loaded spring should be treated experimentally and quantitatively.

Simple treatment of damping.

7.2   **Waves**

Amplitude, phase, frequency, wavelength, velocity $v = f\lambda$. Ripple tanks.

Displacement in a progressive wave and understanding of graphical representations of sinusoidal wave $x = x_0 \sin \omega t$ are included.

7.3   **Longitudinal and transverse waves**

Examples to include electromagnetic waves and sound waves.
Polarisation, as a phenomenon associated with transverse waves.
Stationary waves. Experimental demonstration. Graphical representation.
One dimensional examples are sufficient.

7.4   **Electromagnetic spectrum**

Order of magnitude of frequencies and wavelengths from radio waves to γ-rays.
Simple properties.

7.5   **Optics**

Basic laws on the reflection and refraction of light. Critical angle. Action of a thin converging lens on a beam of light. Ray diagrams. Dispersion of light by a glass prism.

7.6   **Superposition**

Interference of waves from two sources; coherence.
Single slit diffraction of parallel light with fringe pattern treated qualitatively only.
Diffraction grating treated experimentally. Calculations may be set on the grating formula $n \lambda = a\, sin\, q$.

8.   **ELECTRICITY AND MAGNETISM**

8.1.1   **Electric current**

Current and potential difference.
Definition of the ampere (see section 8.5).
Definition of the volt (see section 8.4).
Resistance, resistivity, conductivity.
Simple calculations may be set.
Metals, semiconductors, insulators and their relative conductivities.
General variation of current with p.d. in metallic and non-metallic solids (with Ohm's law as a special case), including reference to the charge carriers involved.
Transport of charge.
Conduction understood as the motion of charged particles.
Simple one-dimensional calculations are included.
Electro-motive force and internal resistance of a cell.

8.2   **Simple d.c. circuits**

Potential divider.

Balanced potentials and principle of null methods as applied to Wheatstone bridge and potentiometer circuits.

Theory of potentiometer: use of standard cell, application to measurement of p.d., current and resistance.

8.3   **Inverse square law fields**

Force between two point charges. $F = \dfrac{q_1 q_2}{4p e_\circ r^2}$

Concept of field and potential at a point.

Electric field of a point charge, $E = \dfrac{q_1}{4p e_\circ r^2}$

and potential $V = \dfrac{q_1}{4p e_\circ r^2}$

Their relationship in uniform fields is sufficient. $Ed = (V_2 - V_1)$
The first three expressions will be quoted on the examination paper where necessary. Derivations are not required.

8.4   **Capacitors**

Capacitance $C = Q/V$. A qualitative treatment of the factors affecting capacitance.
The farad and the volt.
Energy stored, i.e. $E = \tfrac{1}{2}CV^2 = \tfrac{1}{2}QV$ (proofs are not required).
Charge and discharge of a capacitor.
The effect of capacitance and resistance on charge and discharge curves treated qualitatively.

8.5   **Magnetic effects of currents**

Magnetic field.
Direction of magnetic fields associated with currents.
Magnetic flux. Definition of flux density B. The tesla T.
Qualitative description of fields due to long straight wire, plane coil and long solenoid.
Qualitative knowledge of effects of ferrous core with solenoids.
Force between long parallel current-carrying conductors $F = Bil$. Mutual directions.
SI definition of the ampere and the coulomb.

8.6   **Electromagnetic induction**

Faraday's and Lenz's laws treated qualitatively and illustrated by experime nts based on the rate of change of flux.
Inductance.
Self and mutual inductance treated qualitatively.

8.7   **Alternating current**

Frequency, amplitude, phase. (See 7.2).
An understanding of r.m.s. and peak values and of the relation between them is expected for the sinusoidal case.
Energy and power. Power = $I^2_{rms}R$ for pure resistive load only.
The effect of capacitance and inductance (treated separately and qualitatively) on voltage and current in an a.c. circuit. Lead and lag.

9.   **MATTER**

This section is constructed to show the variety of properties of materials, to develop some explanatory microscopic models, to develop ideas of energy in relation to matter and to provide an introduction to understanding of microscopic structure.

9.1   **Deformation of solids**

Elastic and plastic behaviour.
A qualitative knowledge of typical behaviour of copper, glass, elestomers.

Stress and strain.
Quantitative treatment of deformation in one dimension including work done; experimental determination of the Young modulus for a metal in the form of a wire. Calculations may be set.
A treatment of other elastic moduli is not required.

9.2 Temperature scales

Zeroth law of thermodynamics, application to thermometry.
Empirical temperature scales and temperature measurement.

$$T = N \ \frac{X_T - X_L}{X_U - X_L}$$

Where X is a thermometric property such as expansion of a gas or liquid, change of resistance, e.m.f. of thermocouple.
Existence of an absolute scale and absolute zero; temperatures expressed in kelvin. A discussion of the thermodynamic basis for thermodynamic temperature is not required. Conversion of temperature scales between celcius and kelvin.

9.3 Thermal expansion of matter

Expansion of solids and liquids. Simple calculations based on the coefficient of expansion a in $X_1 = X_o (1 + aDT)$.
Expansion of gases. The gas laws for an ideal gas. Use of $pV = nRT$.

9.4 Heat absorbed by matter

Specific heat of solids and liquids, and its determination by the method of mixtures. Temperature variation with time in change of state. Latent heat of fusion and latent heat of vaporization as exemplified by water.

9.5 Heat conduction

Thermal conductivity, k defined by the equition $\frac{\Delta Q}{\Delta t} = -kA \frac{\Delta T}{\Delta x}$

A simple experimental procedure for measurement of thermal conductivity.
Numerical problems involving one-dimensional conduction will suffice.

9.6 Charged particles

Descriptive outline of Millikan's oil drop experiment, his results interpreted as evidence for quantisation of charge.
Deflection of beams of charged particles by uniform electric and magnetic fields.
Force on charged particles moving in magnetic or electric fields.
Current as flow of charged particles.
An outline of the structure and operation of the cathode ray oscilloscope. Simple applications.

9.7 Photons and energy levels (see 3.3)

Photoelectric effect, Einstein's equation, work function.
Main features of experimental results leading to confirmation of Planck's postulate $E = hf$, energy level diagrams. [See 3.3(c)]
Wave-particle duality.

Reading List

Advanced Level Physical Science edited by J. Ling, published by Longman.

Advanced Physics by T Duncan, published by John Murray.

Advanced Physics by K. Gibbs, published by Cambridge University Press.

Understanding Physics for Advanced Level by T Breithaupt, published by Stanley Thornes.

Advanced Level Physics by Nelkon and Parker.

Reference should be made to the fact that eletromagnetic waves show some properties that are characteristic of waves and others that are characteristic of particles, and the electron may sometimes behave as particle and sometimes as a wave.