Revision Checklist for AS/A Level Physics 9702

A Guide for Students

UNIVERSITY *of* CAMBRIDGE
International Examinations

Revision Checklist for AS/A Level Physics 9702

How to use this guide

The guide describes what you need to know about your GCE Advanced Subsidiary (AS) and Advanced level Physics examination.

It will help you to plan your revision programme for the written examinations and will explain what the examiners are looking for in the answers that you write. It will also help you to revise more effectively using the table given in Section 3, 'What do you need to know?'.

The guide contains the following sections:

Section 1: How you will be tested?

This section gives you information about the written papers and practical tests that will be available for physics. It briefly describes the rules for Advanced Subsidiary (AS) and Advanced Level certifications. It contains a table that summaries the examination papers you will take, the duration of each paper, the marks allocated to each paper and the percentage weighting of each paper. A list of all the available Options is also outlined. You will need to ask your teacher which of the Options you will be taking.

Section 2: What will be tested?

The Examiners take account of the following areas in your examination papers:

- Knowledge with understanding
- Handling, applying and evaluating information
- Experimental skills and investigations

This section describes the Assessment Objectives used by the Examiners to test you in the examination. It also contains a table showing the percentage of marks allocated to the three assessment objectives.

Section 3: What do you need to know?

The physics **core** has the following six sections:

- I: General Physics
- II: Newtonian Mechanics
- III: Matter
- IV: Oscillations and waves
- V: Electricity and magnetism
- VI: Modern Physics

The physics content is divided into **themes** and **topics**. The table in this section shows what you need to learn and has the following format:

Theme	Topic	You should be able to	Comments

Section 1: How will you be tested?

1.1 AS and A level Physics

Find out from your teacher what papers you are going to take.

If you have been entered for Advanced Subsidiary (AS) Physics, then you will be taking Papers 1, 2 and 3 at a **single** examination session.

After having received AS certification, if you wish to continue your studies to the full Advanced Level qualification, then your AS marks will be carried forward and you just take Papers 4, 5 and 6 in the examination session in which they require certification.

For the complete Advanced Level Physics qualification, you have to take all the papers in a single examination session.

1.2 Details about your examination papers

The table below gives you information about the Physics papers.

Paper	How long is the paper and how many marks?	What is in the papers?	What is the paper worth as a percentage of the AS examination?	What is the paper worth as a percentage of the A level examination?
Paper 1 Multiple-choice	1 hour (40 marks)	The paper will have 40 multiple-choice questions. You have to answer all the questions.	32%	16%
Paper 2 Structured questions	1 hour (60 marks)	You will have a number of short structured questions. All the questions are compulsory and you write on the question paper.	48%	24%
Paper 3 Practical Test	1¼ hours (25 marks)	This test will consist of a single experiment.	20%	10%
Paper 4 Structured questions (Core)	1 hour (60 marks)	This will consist of a variable number of structured questions of variable marks. The questions will test you on the A2 core. You will have to answer all the questions on the question paper.		23%
Paper 5 Practical Test	1 ½ hours (30 marks)	The test will consist of one experiment (20 marks) and one design question (10 marks).		11%
Paper 6 Options	45 min (40 marks)	You have to answer all the questions on two options (20 marks each) from the following Options:		16%

		Option A: Astrophysics and Cosmology **Option F**: The Physics of Fluids **Option M**: Medical Physics **Option P**: Environmental Physics **Option T**: Telecommunications		

Section 2: What will be tested?

2.1 The assessment objectives

The areas of knowledge and skills are called Assessment Objectives. The theory papers test mainly Objective A (Knowledge with understanding) and Assessment Objective B (Handling, applying and evaluating information). The practical papers are used to test you on the Assessment Objective C (Experimental skills and investigations). Your teacher will be able to provide you with more detailed information on the assessment objectives.

Assessment Objective A: Knowledge with understanding

Questions testing these objectives will often begin questions with one of the following words:

- Define
- State
- Describe
- Explain

Skill	You should demonstrate knowledge and understanding of:
A1	• Scientific phenomena • Facts • Laws • Definitions • Concepts • Theories
A2	• Scientific vocabulary • Terminology • Conventions (including symbols, quantities and units)
A3	• Scientific instruments and apparatus, including techniques of operation and aspects of safety
A4	• Scientific quantities and their determination
A5	• Scientific and technological applications with their social, economic and environmental implications

Assessment Objective B: Handling, applying and evaluating information.

Questions testing these objectives will often begin questions with one of the following words:

- Predict
- Suggest
- Deduce
- Calculate
- Determine.

Skill	You should be able, in words or by using written, symbolic, graphical and numerical forms of presentation, to:
B1	• Locate information from a variety of sources • Select information from a variety of sources • Organise information from a variety of sources • Present information from a variety of sources
B2	• Translate information from one form to another
B3	• Manipulate numerical and other data
B4	• Use information to identify o patterns o report trends o draw inferences

	o report conclusions
B5	• Present reasoned explanations for o phenomena o patterns o relationships
B6	• Make predictions and put forward hypotheses
B7	• Apply knowledge, including principles, to novel situations
B8	• Evaluate information and hypotheses
B9	• Demonstrate an awareness of the limitations of physical theories and models

Assessment Objective C: Experimental skills and investigations

Experiment skills are tested in the practical tests of papers 3 and 5.

Skill	**You should be able to:**
C1	• Follow a detailed set or sequence of instructions and use techniques, apparatus and materials safely and effectively
C2	• Make observations and measurements with due regard for precision and accuracy
C3	• Interpret and evaluate observations and experimental data
C4	• Identify a problem • Design and plan investigations • Evaluate methods and techniques and suggest possible improvement
C5	• Record observations, measurements, methods and techniques with due regard for precision, accuracy and units.

2.2 Marks allocated to the assessment objectives

The table below shows the percentage of marks allocated for the three assessment objectives.

Objective	**Marks allocated for AS Physics**	**Marks allocated for A level Physics**
A (Papers 1, 2, 4 and 6)	40%	37%
B (Papers 1,2, 4 and 6)	40%	42%
C (Papers 3 and 5)	20%	21%

Section 3: What do you need to know?

The table below lists the things that you may be tested on in the examination.

You can use the table throughout your Physics course to check the topic areas you have covered. You can also use the table as a **revision aid**. You can make notes to yourself as you go through the table in the comments column. These could be reminders like:

'*Need to go through some more questions on momentum'*
'*See the teacher about more questions on resistivity*'

or simply place a tick (✓) in the comments column to show that you have a decent understanding of that particular physics.

Details of all the Options are also given. You **must** check with your teacher which of the Options you need to be prepared for.

Theme	Topic	You should be able to	Comments
I: GENERAL PHYSICS			
Physical Quantities and SI Units	Physical Quantities and SI units	• Show an understanding that all physical quantities consist of a numerical magnitude and a unit. • Recall the following base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), **amount of substance** (**mol**). • Express derived units as products or quotients of the base units and use the named units listed in this syllabus as appropriate. • Use base units to check the homogeneity of physical equations. • Show an understanding and use the conventions for labelling graph axes and table columns as set out in the ASE publication *SI Units, Signs, Symbols and Abbreviations*, except where these have been superseded	

Theme	Topic	You should be able to	Comments
	Physical Quantities and SI units continued	• Use the following prefixes and their symbols to indicate decimal sub-multiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T). • Make reasonable estimates of physical quantities included within the syllabus.	
	The Avogadro constant	• Show an understanding of the significance of the Avogadro constant as the number of atoms in 0.012 kg of Carbon-12. • Use molar quantities where one mole of any substance is the amount containing a number of particles equal to the Avogadro constant.	
	Scalars and vectors	• Distinguish scalar and vector quantities and give examples of each. • Add and subtract coplanar vectors. • Represent a vector as two perpendicular components.	
Measurement Techniques	Measurements	• Use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the ranges of magnitude implied by the relevant parts of the syllabus. In particular, students should be able to: o measure lengths using a ruler, vernier scale and micrometer, o measure weight and hence mass using spring and lever balances, o measure an angle using a protractor, o measure time intervals using clocks, stopwatches	

Theme	Topic	You should be able to	Comments
	Measurements continued	and the calibrated time-base of a cathode-ray oscilloscope (c.r.o), o measure temperature using a thermometer as a sensor, o use ammeters and voltmeters with appropriate scales, o use a galvanometer in null methods, o use a cathode-ray oscilloscope (c.r.o), o use a calibrated Hall probe. • Use both analogue scales and digital displays. • Use calibration curves.	
	Errors and uncertainties	• Show an understanding of the distinction between systematic errors (including zero errors) and random errors. • Show an understanding of the distinction between precision and accuracy. • Assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties (a rigorous statistical treatment is not required).	
II: NEWTONIAN MECHANICS			
Kinematics	Linear motion	• Define displacement, speed, velocity and acceleration. • Use graphical methods to represent displacement, speed, velocity and acceleration. • Find displacement from the area under a velocity-time graph.	

Theme	Topic	You should be able to	Comments
	Linear motion continued	• Use the slope of a displacement-time graph to find the velocity. • Use the slope of a velocity-time graph to find the acceleration. • Derive, from the definitions of velocity and acceleration, equations which represent uniformly accelerated motion in a straight line. • Solve problems using equations which represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitational field **without** air resistance. • Recall that the weight of a body is equal to the product of its mass and the acceleration of free fall. • Describe an experiment to determine the acceleration of free fall using a falling body.	
	Non-linear motion	• Describe qualitatively the motion of bodies falling in a uniform gravitational field with air resistance. • Describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction.	
Dynamics	Newton's laws of motion	• State each of Newton's laws of motion. • Show an understanding that mass is the property of a body which resists change in motion. • Describe and use the concept of weight as the effect of a gravitational field on a mass.	

Theme	Topic	You should be able to	Comments
	Newton's laws of motion continued	• Define linear momentum as the product of mass and velocity. • Define force as rate of change of momentum. • Recall and solve problems using the relationship $F = ma$, appreciating that acceleration and force are always in the same direction.	
	Linear momentum and its conservation	• State the principle of conservation of momentum. • Apply the principle of conservation of momentum to solve simple problems including elastic and inelastic interactions between two bodies in one dimension. (Knowledge of the concept of coefficient of restitution is not required.) • Recognise that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation. • Show an understanding that, whilst momentum of a system is always conserved in interactions between bodies, some change in kinetic energy usually takes place.	
Forces	Types of force	• Describe the forces on mass and charge in uniform gravitational and electric fields, as appropriate. • Show an understanding of the origin of the upthrust acting on a body in a fluid. • Show a qualitative understanding of frictional forces and viscous forces including air resistance. (No treatment of the coefficients of friction and viscosity is required.)	

Theme	Topic	You should be able to	Comments
	Equilibrium of forces	• Use a vector triangle to represent forces in equilibrium.	
	Centre of gravity	• Show an understanding that the weight of a body may be taken as acting at a single point known as its centre of gravity.	
	Turning effects of forces	• Show an understanding that a couple is a pair of forces which tends to produce rotation only. • Define and apply the moment of a force and the torque of a couple. • Show an understanding that, when there is no resultant force and no resultant torque, a system is in equilibrium. • Apply the principle of moments.	
Work, Energy, Power	Energy conversion and conservation	• Give examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples.	
	Work	• Show an understanding of the concept of work in terms of the product of a force and displacement in the direction of the force. • Calculate the work done in a number of situations including the work done by a gas which is expanding against a constant external pressure: $W = p\,\Delta V$.	
	Potential energy, kinetic energy and internal energy	• Derive, from the equations of motion, the formula $E_k = \frac{1}{2}mv^2$. • Recall and apply the formula $E_k = \frac{1}{2}mv^2$. • Distinguish between gravitational potential energy, electric potential energy and elastic potential energy.	

Theme	Topic	You should be able to	Comments
	Potential energy, kinetic energy and internal energy continued	• Show an understanding and use the relationship between force and potential energy in a uniform field to solve problems. • Derive, from the defining equation $W = Fs$, the formula $E_p = mgh$ for potential energy changes near the Earth's surface. • Recall and use the formula $E_p = mgh$ for potential energy changes near the Earth's surface. • Show an understanding of the concept of internal energy.	
	Power	• Show an appreciation for the implications of energy losses in practical devices and use the concept of efficiency to solve problems. • Define power as work done per unit time and derive power as the product of force and velocity.	
Motion in a Circle	Kinematics of uniform circular motion	• Express angular displacement in radians. • Understand and use the concept of angular velocity to solve problems. • Recall and use $v = r\omega$ to solve problems.	
	Centripetal acceleration	• Describe qualitatively motion in a curved path due to a perpendicular force, and understand the centripetal acceleration in the case of uniform motion in a circle. • Recall and use centripetal acceleration $a = r\omega^2$ $a = v^2/r$.	
	Centripetal force	• Recall and use centripetal force $F = m r\omega^2$, $F = mv^2/r$.	

Theme	Topic	You should be able to	Comments
Gravitational Field	Gravitational field	• Show an understanding of the concept of a gravitational field as an example of field of force and define gravitational field strength as force per unit mass.	
	Force between point masses	• Recall and use Newton's law of gravitation in the form $F = G(m_1m_2)/r^2$.	
	Field of a point mass	• Derive, from Newton's law of gravitation and the definition of gravitational field strength, the equation $\boldsymbol{g = \frac{GM}{r^2}}$ for the gravitational field strength of a point mass. • Recall and solve problems using the equation $\boldsymbol{g = \frac{GM}{r^2}}$ for the gravitational field strength of a point mass. • Recognise the analogy between certain qualitative and quantitative aspects of gravitational field and electric field. • Analyse circular orbits in inverse square law fields by relating the gravitational force to the centripetal acceleration it causes. • Show an understanding of geostationary orbits and their application.	
	Field near to the surface of the Earth	• Show an appreciation that on the surface of the Earth *g* is approximately constant and is called the acceleration of free fall.	
	Gravitational potential	• Define potential at a point as the work done in bringing unit mass from infinity to the point. • Solve problems using the equation $\boldsymbol{\phi = -\frac{GM}{r}}$ for the potential in the field of a point mass.	

Theme	Topic	You should be able to	Comments
III: MATTER			
Phases of Matter	Density	• Define the term density	
	Solids, liquids, gases	• Relate the difference in the structures and densities of solids, liquids and gases to simple ideas of the spacing, ordering and motion of molecules. • Describe a simple kinetic model for solids, liquids and gases. • Describe an experiment which demonstrates Brownian motion and appreciate the evidence for the movement of molecules provided by such an experiment. • Distinguish between the structure of crystalline and non-crystalline solids with particular reference to metals, polymers and amorphous materials.	
	Pressure in fluids	• Define the term pressure and use the kinetic model to explain the pressure exerted by gases. • Derive, from the definitions of pressure and density, the equation $p = \rho gh$. • Use the equation $p = \rho gh$.	
	Change of phase	• Distinguish between the processes of melting, boiling and evaporation.	
Deformation of Solids	Stress, strain	• Appreciate that deformation is caused by a force and that, in one dimension, the deformation can be tensile or compressive. • Describe the behaviour of springs in terms of load, extension, elastic limit, Hooke's law and the spring constant (i.e. force per unit extension).	

Theme	Topic	You should be able to	Comments
	Stress, strain continued	• Define and use the terms stress, strain and the Young modulus. • Describe an experiment to determine the Young modulus of a metal in the form of a wire.	
	Elastic and plastic behaviour	• Distinguish between elastic and plastic deformation of a material. • Deduce the strain energy in a deformed material from the area under the force-extension graph. • Demonstrate knowledge of the force-extension graphs for typical ductile, brittle and polymeric materials, including an understanding of ultimate tensile stress.	
Ideal Gases	Equation of state	• Recall and solve problems using the equation of state for an ideal gas expressed as $pV = nRT$. (n = number of moles)	
	Kinetic theory of gases	• Infer from a Brownian motion experiment the evidence for the movement of molecules. • State the basic assumptions of the kinetic theory of gases.	
	Pressure of a gas	• Explain how molecular movement causes the pressure exerted by a gas and hence deduce the relationship, $\boldsymbol{p} = \frac{1}{3}\frac{\boldsymbol{Nm}}{\boldsymbol{V}} < \boldsymbol{c}^2 >$. ($N$ = number of molecules) [A rigorous derivation is not required.]	
	Kinetic energy of a molecule	• Compare $\boldsymbol{pV} = \frac{\boldsymbol{1}}{\boldsymbol{3}}\boldsymbol{Nm} < \boldsymbol{c}^2 >$ with $pV = NkT$ and hence deduce that the average translational kinetic energy of a molecule is proportional to T.	

Theme	Topic	You should be able to	Comments
Temperature	Thermal equilibrium	• Show an appreciation that thermal energy is transferred from a region of higher temperature to a region of lower temperature. • Show an understanding that regions of equal temperature are in thermal equilibrium.	
	Temperature scales	• Show an understanding that there is an absolute scale of temperature which does not depend on the property of any particular substance (i.e. the thermodynamic scale and the concept of absolute zero). • Convert temperatures measured in kelvin to degrees Celsius: T / K = T / °C + 273.15.	
	Practical thermometers	• show an understanding that a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties. • Compare the relative advantages and disadvantages of resistance and thermocouple thermometers as previously calibrated instruments.	
Thermal Properties of Materials	Specific heat capacity	• Explain using a simple kinetic model for matter why o melting and boiling take place without a change in temperature, o the specific latent heat of vaporisation is higher than specific latent heat of fusion for the same substance, o a cooling effect accompanies evaporation. • Define and use the concept of specific heat capacity, and identify the main principles of its determination by electrical methods.	

Theme	Topic	You should be able to	Comments
	Specific latent heat	• Define and use the concept of specific latent heat, and identify the main principles of its determination by electrical methods.	
	Internal energy	• Relate a rise in temperature of a body to an increase in its internal energy. • Show an understanding that internal energy is determined by the state of the system and that it can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of a system.	
	First law of thermodynamics	• Recall and use the first law of thermodynamics expressed in terms of the change in internal energy, the heating of the system and the work done on the system.	
IV: OSCILLATIONS AND WAVES			
Oscillations	Simple harmonic motion	• Describe simple examples of free oscillations. • Investigate the motion of an oscillator using experimental and graphical methods. • Understand and use the terms amplitude, period, frequency, angular frequency and phase difference and express the period in terms of both frequency and angular frequency. • Recognise and use the equation $a = -\omega^2 x$ as the defining equation of simple harmonic motion. • Recall and use $x = x_o \sin \omega t$ as a solution to the equation $a = -\omega^2 x$.	

Theme	Topic	You should be able to	Comments
	Simple harmonic motion continued	• Recognise and use $v = v_o \cos \omega t$ and $v = \pm\omega\sqrt{(x_o^2 - x^2)}$. • Describe with graphical illustrations, the changes in displacement, velocity and acceleration during simple harmonic motion.	
	Energy in simple harmonic motion	• Describe the interchange between kinetic and potential energy during simple harmonic motion.	
	Damped and forced oscillations: resonance	• Describe practical examples of damped oscillations with particular reference to the effects of the degree of damping and the importance of critical damping in cases such as a car suspension system. • Describe practical examples of forced oscillations and resonance. • Describe graphically how the amplitude of a forced oscillation changes with frequency near to the natural frequency of the system, and understand qualitatively the factors which determine the frequency response and sharpness of the resonance. • Show an appreciation that there are some circumstances in which resonance is useful and other circumstances in which resonance should be avoided.	
Waves	Progressive waves	• Describe what is meant by wave motion as illustrated by vibration in ropes, springs and ripple tanks. • Show an understanding and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed.	

Theme	Topic	You should be able to	Comments
		• Deduce, from the definitions of speed, frequency and wavelength, the equation $v = f\lambda$. • Recall and use the equation $v = f\lambda$. • Show an understanding that energy is transferred due to a progressive wave. • Recall and use the relationship, *intensity* $\propto$ *(amplitude)*^{2}.	
	Transverse and longitudinal waves	• Compare transverse and longitudinal waves. • Analyse and interpret graphical representations of transverse and longitudinal waves.	
	Polarisation	• Show an understanding that polarisation is a phenomenon associated with transverse waves.	
	Determination of speed, frequency and wavelength	• Determine the frequency of sound using a calibrated c.r.o. • Determine the wavelength of sound using stationary waves.	
	Electromagnetic spectrum	• State that all electromagnetic waves travel with the same speed in free space and recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays.	
Superposition	Stationary waves	• Explain and use the principle of superposition in simple applications. • Show an understanding of experiments which demonstrate stationary waves using microwaves, stretched strings and air columns. • Explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes.	

Theme	Topic	You should be able to	Comments
	Diffraction	• Explain the meaning of the term diffraction. • Show an understanding of experiments which demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap.	
	Interference	• Show an understanding of the terms interference and coherence.	
	Two-source interference patterns	• Show an understanding of experiments which demonstrate two-source interference using water, light and microwaves. • Show an understanding of the conditions required if two-source interference fringes are to be observed. • Recall and solve problems using the equation $\lambda = ax / D$ for double-slit interference using light.	
	Diffraction grating	• Recall and solve problems using the formula $d \sin\theta = n\lambda$ and describe the use of a diffraction grating to determine the wavelength of light. (The structure and use of the spectrometer is not included.)	
V: ELECTRICITY AND MAGNETISM			
Electric Fields	Concept of an electric field	• Show an understanding of the concept of an electric field as an example of a field of force and define electric field strength as force per unit positive charge. • Represent an electric field by means of field lines.	

Theme	Topic	You should be able to	Comments
	Uniform electric fields	• Recall and use $E = V/d$ to calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation. • Calculate the forces on charges in uniform electric fields. • Describe the effect of a uniform electric field on the motion of charged particles.	
	Force between point charges	• Recall and use Coulomb's law in the form $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ for the force between two point charges in free space or air.	
	Electric field of a point charge	• Recall and use $E = Q/4\pi\varepsilon_0 r^2$ for the field strength of a point charge in free space or air. • Recognise the analogy between certain qualitative and quantitative aspects of electric field and gravitational fields.	
	Electric potential	• Define potential at a point in terms of the work done in bringing unit positive charge from infinity to the point. • State that the field strength of the field at a point is numerically equal to the potential gradient at that point. • Use the equation $V = Q/4\pi\varepsilon_0 r$ for the potential in the field of a point charge.	
Capacitance	Capacitors and capacitance	• Show an understanding of the function of capacitors in simple circuits. • Define capacitance and the farad. • Recall and solve problems using $C = Q/V$.	

Theme	Topic	You should be able to	Comments
	Capacitors and capacitance continued	• Derive, using the formula $C = Q/V$, conservation of charge and the addition of p.ds, formulae for capacitors in series and in parallel. • Solve problems using formulae for capacitors in series and in parallel.	
	Energy stored in a capacitor	• Deduce from the area under a potential-charge graph, the equation $W = \frac{1}{2}QV$ and hence $W = \frac{1}{2}CV^2$.	
Current of Electricity	Electric current	• Show an understanding that electric current is the rate of flow of charged particles. • Define charge and the coulomb. • Recall and solve problems using the equation $Q = It$.	
	Potential difference	• Define potential difference and the volt. • Recall and solve problems using $V = W/Q$. • Recall and solve problems using $P = VI$, $P = I^2R$.	
	Resistance and resistivity	• Define resistance and the ohm. • Recall and solve problems using $V = IR$. • Sketch and explain the I-V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp. • Sketch the temperature characteristic of a thermistor. • State Ohm's law. • Recall and solve problems using $R = \rho l/A$.	

Theme	Topic	You should be able to	Comments
	Sources of electromotive force	• Define e.m.f. in terms of the energy transferred by a source in driving unit charge round a complete circuit. • Distinguish between e.m.f. and p.d in terms of energy considerations. • Show an understanding of the effects of the internal resistance of a source of e.m.f. on the terminal potential difference and output power.	
D.C. Circuits	Practical circuits	• Recall and use appropriate circuit symbols as set out in *SI Units, Signs, Symbols and Abbreviations* (ASE, 1981) and *Signs, Symbols and Systematics* (ASE, 1995). • Draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus • Show an understanding of the use of a potential divider circuit as a source of variable p.d. • Explain the use of thermistors and light-dependent resistors in potential dividers to provide a potential difference which is dependent on temperature and illumination respectively.	
	Conservation of charge and energy	• Recall Kirchhoff's first law and appreciate the link to conservation of charge. • Recall Kirchhoff's second law and appreciate the link to conservation of energy. • Derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series. Solve problems using the formula for the combined resistance of two or more resistors in series.	

Theme	Topic	You should be able to	Comments
	Conservation of charge and energy continued	• Derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel. • Solve problems using the formula for the combined resistance of two or more resistors in parallel. • Apply Kirchhoff's laws to solve simple circuit problems.	
	Balanced potentials	• Recall and solve problems using the principle of the potentiometer as a means of comparing potential differences.	
Magnetic Fields	Concept of magnetic field	• Show an understanding that a magnetic field is an example of a field of force produced either by current-carrying conductors or by permanent magnets. • Represent a magnetic field by field lines.	
Electromagnetism	Force on a current-carrying conductor	• Show an appreciation that a force might act on a current-carrying conductor placed in a magnetic field. • Recall and solve problems using the equation $F = BIl\sin\theta$, with directions as interpreted by Fleming's left-hand rule. • Define magnetic flux density and the tesla. • Show an understanding of how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field using a current balance.	
	Force on a moving charge	• Predict the direction of the force on a charge moving in a magnetic field. • Recall and solve problems using $F = BQv\sin\theta$.	

Theme	Topic	You should be able to	Comments
	Magnetic fields due to currents	• Sketch flux patterns due to a long straight wire, a flat circular coil and a long solenoid. • Show an understanding that the field due to a solenoid may be influenced by the presence of a ferrous core.	
	Force between current-carrying conductors	• Explain the forces between current-carrying conductors and predict the direction of the forces. • Describe and compare the forces on mass, charge and current in gravitational, electric and magnetic fields, as appropriate.	
Electromagnetic Induction	Laws of electromagnetic induction	• Define magnetic flux and the weber. • Recall and solve problems using $\Phi = BA$. • Define magnetic flux linkage. • Infer from appropriate experiments on electromagnetic induction: o that a changing magnetic flux can induce an e.m.f. in a circuit, o that the direction of the induced e.m.f. opposes the change producing it, o the factors affecting the magnitude of the induced e.m.f. • Recall and solve problems using Faraday's law of electromagnetic induction and Lenz's law. • Explain simple applications of electromagnetic induction.	

Theme	Topic	You should be able to	Comments
Alternating Currents	Characteristics of alternating currents	• Show an understanding and use the terms period, frequency, peak value and root-mean-square value as applied to an alternating current or voltage. • Deduce that the mean power in a resistive load is half the maximum power for a sinusoidal alternating current. • Represent a sinusoidally alternating current or voltage by an equation of the form $x = x_o \sin \omega t$. • Distinguish between r.m.s. and peak values and recall and solve problems using the relationship $I_{rms} = I_o / \sqrt{2}$ for the sinusoidal case.	
	The transformer	• Show an understanding of the principle of operation of a simple iron-cored transformer and solve problems using $N_s/N_p = V_s/V_p = I_p/I_s$ for an ideal transformer.	
	Transmission of electrical energy	• Show an appreciation of the scientific and economic advantages of alternating current and of high voltages for the transmission of electrical energy.	
	Rectification	• Distinguish graphically between half-wave and full-wave rectification. • Explain the use of a single diode for the half-wave rectification of an alternating current. • Explain the use of four diodes (bridge rectifier) for the full-wave rectification of an alternating current. • Analyse the effect of a single capacitor in smoothing, including the effect of the value of capacitance in relation to the load resistance.	

Theme	Topic	You should be able to	Comments
VI: MODERN PHYSICS			
Charged Particles	Electrons	• Show an understanding of the main principles of determination of *e* by Millikan's experiment. • Summarise and interpret the experimental evidence for quantisation of charge.	
	Beams of charged particles	• Describe and analyse qualitatively the deflection of beams of charged particles by uniform electric and uniform magnetic fields. • Explain how electric and magnetic fields can be used in velocity selection. • Explain the main principles of one method for the determination of v and e/m_e for electrons.	
Quantum Physics	Energy of a photon	• Show an appreciation of the particulate nature of electromagnetic radiation. • Recall and use $E = hf$.	
	Photoelectric emission of electrons	• Show an understanding that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provide evidence for a wave nature. • Recall the significance of threshold frequency. • Explain photoelectric phenomena in terms of photon energy and work function energy. • Explain why the maximum photoelectric energy is independent of intensity whereas the photoelectric current is proportional to intensity.	

Theme	Topic	You should be able to	Comments
	Photoelectric emission of electrons continued	• Recall, use and explain the significance of $hf = \Phi + \frac{1}{2}mv^2_{max}$.	
	Wave-particle duality	• Describe and interpret qualitatively the evidence provided by electron diffraction for the wave nature of particles. • Recall and use the relation for the de Broglie wavelength $\lambda = h/p$.	
	Energy levels in atoms	• Show an understanding of the existence of discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) and deduce how this leads to spectral lines.	
	Line spectra	• Distinguish between emission and absorption line spectra. • Recall and solve problems using the relation $hf = E_1 - E_2$.	
Nuclear Physics	The nucleus	• Infer from the results of the α-particle scattering experiment the existence and small size of the nucleus. • Describe a simple model for the nuclear atom to include protons, neutrons and orbital electrons. • Distinguish between nucleon number (mass number) and proton number (atomic number).	
	Isotopes	• Show an understanding that an element can exist in various isotopic forms each with a different number of neutrons. • Use the usual notation for the representation of nuclides.	

Theme	Topic	You should be able to	Comments
	Nuclear processes	• Appreciate that nucleon number, proton number, and energy and mass are all conserved in nuclear processes. • Represent simple nuclear reactions by nuclear equations of the form $^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$. • Show an appreciation of the spontaneous and random nature of nuclear decay. • Show an understanding of the nature of α-, β- and γ-radiations. • Infer the random nature of radioactive decay from the fluctuations in count rate.	
	Mass excess and nuclear binding energy	• Show an appreciation of the association between energy and mass as represented by $E = mc^2$ and by recalling this relationship. • Sketch the variation of binding energy per nucleon with nucleon number. • Explain the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission.	
	Radioactive decay	• Define the terms activity and decay constant and recall and solve problems using $A = \lambda N$. • Infer and sketch the exponential nature of radioactive decay and solve problems using the relationship $x = x_o \exp(-\lambda t)$ where x could represent activity, number of undecayed particles or received count rate.	

Theme	**Topic**	**You should be able to**	**Comments**
	Radioactive decay continued	• Define half-life. • Solve problems using the relation $\lambda = \frac{\mathbf{0.693}}{t_{\frac{1}{2}}}$.	
OPTION A Astrophysics and Cosmology			
Contents and Scale of the Universe	Contents of the universe	• Describe the principal contents of the universe, including stars, galaxies and radiation. • Describe the Solar system in terms of the Sun, planets, planetary satellites and comets. Details of individual planets are not required.	
	Scale of the universe	• Define distances measured in astronomical units (AU), parsecs (pc) and light-years. • Recall the approximate magnitudes, in metres, of the AU, pc and light-year. • Appreciate the sizes and masses of objects in the universe. • Appreciate the distances involved between objects in the universe.	
The Standard Model of the Universe	Hubble's law	• Describe and interpret Hubble's redshift observations. • Recall and interpret Hubble's law • Convert the Hubble 'constant' (H_0) from its conventional units (km s^{-1} Mpc^{-1}) to SI (s^{-1}).	

Theme	**Topic**	**You should be able to**	**Comments**
	Olbers' paradox	• Recall Olbers' paradox. • Interpret Olbers' paradox to explain why it suggests that the model of an infinite, static universe is incorrect.	
	The Cosmological Principle	• Understand what is meant by the Cosmological Principle. • Describe, and interpret the significance of, the 3 K microwave background radiation.	
	Age of the universe	• Understand that the standard (hot big bang) model of the Universe implies a finite age for the universe. • Recall and use the expression $t \approx 1/H_0$ to estimate the order of magnitude of the age of the universe.	
	Evolution of the universe	• Describe qualitatively the evolution of the universe from 0.01 s after the big bang to the present, including the production of an excess of matter over antimatter, the formation of light nuclei, the recombination of electrons and nuclei and the formation of stars, galaxies and galactic clusters. • Understand that the universe may be 'open', 'flat' or 'closed', depending on its density. • Appreciate that the age of the universe cannot be determined from the Hubble constant until its density is known accurately. • Understand that the ultimate fate of the universe depends on its density. • Recall that it is currently believed that the density of the universe is close to, and possibly exactly equal to, the critical density needed for a 'flat' cosmology.	

Theme	**Topic**	**You should be able to**	**Comments**
	Evolution of the universe	• Derive, from Newton's law of gravitation, the expression $\rho_0 = \frac{3H_o^2}{8\pi G}$ and recognise that General Relativity is needed for a strict derivation. • Use the expression $\rho_0 = \frac{3H_o^2}{8\pi G}$. • Appreciate that there is no experimental evidence for the physics involved at the energies prevailing during the evolution of the universe before about 1 ms. • Outline the difficulties involved in projecting the evolution of the universe back before 0.01 s.	
Techniques of Observation	Electromagnetic radiation and the Earth's atmosphere	• Appreciate that stars and galaxies are detected by the electromagnetic radiation which they emit. • Appreciate that planets are detected by reflected sunlight. • Describe the transparency of the Earth's atmosphere to different regions of the electromagnetic spectrum from radio waves to X-rays.	
	Observation platforms	• Explain why the transparency of the Earth's atmosphere has led to observations which are terrestrial, high-altitude, from satellites or from space probes. • Show awareness of the conflict between the value of astronomical research and economic consideration.	

Theme	**Topic**	**You should be able to**	**Comments**
OPTION F **The Physics of Fluids**			
Buoyant Forces	Pressure in a liquid	• Derive and use the equation $p = \rho gh$.	
	Archimedes' principle and Equilibrium of floating objects	• State that an upthrust is provided by the fluid displaced by a submerged or floating object. • Calculate the upthrust in terms of the weight of the displaced fluid. • Show an understanding that, for an object floating in equilibrium, the upthrust is equal to the weight of the object. • Show an appreciation that the upthrust on a floating object acts at the centre of mass of the displaced fluid (the centre of buoyancy). • Show an appreciation of what is meant by the metacentre of a floating object, and deduce the stability of an object from the relative positions of the metacentre and the centre of mass of the object. • Apply Archimedes' principle to marine craft and submarines.	
Non-Viscous Fluid Flow	Ideal fluids in motion	• Show an understanding of the terms steady (laminar, streamline) flow, incompressible flow and non-viscous flow, as applied to the motion of an ideal fluid.	
	Streamlines and the equation of continuity	• Show an understanding of how the velocity vector of a particle in an ideal fluid in motion is related to the streamline associated with that particle. • Show an understanding of how streamlines can be used	

		to define a tube of flow.	
Theme	**Topic**	**You should be able to**	**Comments**
		• Derive and solve problems using the equation Av = constant (the equation of continuity) for the flow of an ideal, incompressible fluid. • Show an appreciation that the equation of continuity is a form of the principle of conservation of mass.	
	The Bernoulli effect	• Show an appreciation that pressure differences can arise from different rates of flow of a fluid (the Bernoulli effect). • Derive the Bernoulli equation in form $p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$ for the case of a horizontal tube of flow. • Show an appreciation that the Bernoulli equation is a form of the principle of conservation of energy. • Explain how the Bernoulli effect is applied in the filter pump, in the Venturi meter, in atomisers and in the flow of air over an aerofoil.	
Viscous Fluids	Viscosity	• State that viscous forces in a fluid cause a retarding force to be exerted on an object moving through a fluid. • Show an understanding that, in viscous flow, different layers of the liquid move with different velocities. • Show an appreciation of what is meant by the velocity gradient in viscous flow. • Show an understanding of how the magnitude of the viscous force in fluid flow depends on the velocity gradient and on the viscosity of the fluid.	

Theme	**Topic**	**You should be able to**	**Comments**
	Viscosity	• Apply base units to confirm the form of the equation $F = Ar\eta v$, where A is a dimensionless constant (Stokes' law), for the drag force under laminar conditions in a viscous fluid.	
	Terminal velocity	• Apply Stokes' law to explain quantitatively how a body falling through a viscous fluid under laminar conditions attains a terminal velocity. • Describe an experiment, based on the measurement of terminal velocity, to determine the viscosity of a liquid.	
	Turbulence	• Show an appreciation that, at a sufficiently high velocity, the flow of viscous fluid undergoes a transition from laminar to turbulent conditions. • Apply base units to confirm the form of the equation $F = Br^2\rho v^2$, where B is a dimensionless constant, for the drag force under turbulent conditions in a viscous fluid. • Show an appreciation that the majority of practical examples of fluid flow and resistance to motion in fluids involve turbulent, rather than laminar, conditions. • Explain qualitatively, in terms of turbulence and the Bernoulli effect, for the swing of a spinning cricket ball and the lift of a spinning golf ball. • Show an understanding of what is meant by the drag coefficient of a moving vehicle, and carry out simple calculations involving the coefficient.	

Theme	**Topic**	**You should be able to**	**Comments**
OPTION M **Medical Physics**			
Medical Imaging	Diagnostic techniques used in medicine	• Describe in simple terms the need for non-invasive techniques of diagnosis. • Show a qualitative understanding of the importance of limiting exposure to radiation with particular reference to the type of radiation.	
	Production and use of X-rays	• Explain the principles of production of X-rays by electron bombardment of a metal target. • Show an understanding of the use of X-rays in imaging internal body structures, including a simple analysis of the causes of the sharpness and contrast in X-ray imaging. • Recall and solve problems using the equation $I = I_0 e^{-\mu x}$ for the attenuation of X-rays in matter.	
	Production and use of ultrasound	• Explain the principles of generation of ultrasonic waves using piezo-electric transducers. • Identify and explain the main ideas behind the use of ultrasound to obtain diagnostic information about internal structures.	
	Use of magnetic resonance, radioactive tracers and lasers	• Identify and explain the main ideas behind the use of magnetic resonance to obtain diagnostic information about internal structures. • Identify and explain the main ideas behind the use of lasers in diagnosis, e.g. in pulse oximetry and in endoscopes. • Describe examples of the use of radioactive tracers in	

		diagnosis.	
Theme	**Topic**	**You should be able to**	**Comments**
Medical Treatment	Biological effects	• Explain in simple terms the effects of ionising radiation on living matter.	
	Radiotherapy	• Show a qualitative understanding of the importance of limiting exposure to ionising radiation. • Distinguish between dose rate and dose, paying particular attention to the type of incident radiation. • Explain the use of X-rays and of implanted sources in the treatment of malignancy.	
	Laser treatment	• Describe examples of the use of lasers in clinical therapy, e.g. as a scalpel or as a coagulator.	
The Physics of Sight	The eye	• Explain how the eye forms focused images of objects at different distances. • Show an understanding of the terms depth of focus, near point, far point and accommodation.	
	Defects of the eye	• Distinguish between short sight, long sight and astigmatism. • Distinguish between converging and diverging lenses and show an understanding of the significance of focal length. • Explain how short sight, long sight and astigmatism can be corrected by using spectacle lenses or contact lenses. • Recall and apply the lens formula to calculate the focal length of the auxiliary lenses required to correct short sight and to correct long sight. • Relate the focal length of a lens to its power in dioptres.	

Theme	**Topic**	**You should be able to**	**Comments**
The Physics of Hearing	The ear	• Explain how the ear responds to an incoming sound wave.	
	Sensitivity and frequency response of the ear	• Show an understanding of the significance of the terms sensitivity and frequency response. • Show an appreciation of the very wide range of intensities which can be detected by the ear and recall the orders of magnitude of the threshold of hearing and the intensity at which discomfort is experienced. • Show an understanding of the significance of the logarithmic response of the ear to intensity. • Recall and solve problems using the equation *intensity level* = 10 lg(I/I_o), giving intensity level in dB in terms of the intensity I and the threshold intensity I_o. • Show an understanding that loudness is the subjective response of an individual to an intensity level.	
OPTION P **Environmental Physics**			
Power Sources	The solar constant	• Show an understanding of the term solar constant and use it to solve problems. • Show an understanding of the geographical variation of solar intensity at the Earth's surface. • Identify and explain the main component of the structure of solar cells and solar panels. • Show an appreciation that solar cells produce electrical	

		energy whereas solar panels produce thermal energy.	
Theme	**Topic**	**You should be able to**	**Comments**
	Fossil fuels	• Distinguish between the terms resources and reserves. • State the different types of fossil fuel and show an understanding that these fuels are abundant yet finite.	
	Nuclear power	• State the principles of the fission process. • Explain the role of fuel rods, moderator, coolant, control rods and the reactor vessel in a nuclear reactor.	
	Water power	• Calculate the potential energy stored in a lake, given its average depth, area and altitude. • Show an understanding of the main principles of a pumped-water storage scheme. • Estimate the power available from a water wave of given dimensions. • Show an understanding of how the potential energy of stored water is used to estimate the mean power output of a tidal barrage.	
	Wind power	• Estimate the maximum power available from a wind generator.	
	Geothermal and other feasible power sources	• Comment on the difficulties and limitations associated with the following 'free' systems for producing power: geothermal including hot aquifers and geysers, biomass, methane generators from waste products.	
Power Consumption	Variation in demand	• Explain the daily and seasonal variations in the demand for electrical power. • Describe the complications which arise due to predictable and unpredictable variations in demand for electrical power.	

		• Explain the benefits of a pumped water storage scheme.	
Theme	**Topic**	**You should be able to**	**Comments**
	Efficiency of different systems	• Show an understanding that, although the efficiency for conversion of electrical energy to internal energy for the consumer is 100%, the production of electrical energy is far less efficient. • Evaluate the overall efficiency, from production to consumer, of various domestic systems, e.g. cooking by gas or electricity.	
	Sankey diagrams	• Apply Sankey diagrams.	
	Long-term trends	• Predict the possible long-term effects on resources and on the environment of social changes such as increasing demand for housing, increasing affluence of third world countries and increasing use of air conditioning.	
Heat Engines	Indicator diagrams	• Distinguish between an isothermal change and an adiabatic change. • Illustrate isothermal and adiabatic changes on indicator diagrams. • Use the indicator diagram to determine the work done on or by a gas.	
	The petrol engine	• Recall the cycle of a four-stroke petrol engine. • Illustrate and explain the cycle of a four-stroke petrol engine with the aid of an indicator diagram.	
	The second law of thermodynamics	• Show an appreciation that the second law of thermodynamics places an overall limit on the efficiency of a heat engine, and that this limit depends on the temperatures between which the engine is operating. • Recall and solve problems using the equation $E_{MAX} = (1 - T_L / T_H)$ where E_{MAX} is the maximum efficiency.	

Theme	**Topic**	**You should be able to**	**Comments**
	The second law of thermodynamics continued	• Deduce from the second law the conclusion that CHP (combined heat and power) schemes should be economical propositions.	
Pollution	Carbon dioxide emissions	• Show an appreciation that zero pollution is not possible. • Distinguish the burning of fossil fuels from nuclear and hydroelectric power schemes in terms of the release of carbon dioxide into the atmosphere. • Show an understanding why carbon dioxide levels in the atmosphere are not rising rapidly.	
	Other forms of pollution	• Show an understanding of other forms of pollution such as thermal pollution of the atmosphere, noise pollution, pollution of rivers.	
OPTION T **Telecommunications**			
Communication Principles	Waveforms	• Recall that any waveform can be resolved into or synthesised from sinusoidal components.	
	Principles of modulation	• Understand the term modulation and distinguish between amplitude modulation (AM) and frequency modulation (FM).	
	Sidebands and bandwidth	• Recall that a carrier wave, amplitude modulated by a single audio frequency, is equivalent to the carrier wave frequency together with two sideband frequencies, leading to an understanding of the term bandwidth. • Demonstrate awareness of the relative advantages of FM and AM transmissions.	

Theme	**Topic**	**You should be able to**	**Comments**
	Transmission of information by digital means	• Recall the advantages of transmission of data in digital form. • Understand that the digital transmission of speech or music involves analogue-to-digital conversion on transmission and digital-to-analogue conversion on reception. • Demonstrate an awareness of how waveforms are encoded by digital sampling.	
	Transmission media	• Appreciate the scientific and economic advantages of fibre optic transmission, compared with metal cable and radio transmission.	
	Communication and society	• Demonstrate an awareness of social, economic and technological changes arising from modern communication methods.	
Communication Channels	Channels of communication	• Appreciate that information may be carried by a number of different channels, including wire-pairs, coaxial cables, radio and microwave links, and optic fibres. • Discuss the relative advantages and disadvantages of channels of communication in terms of available bandwidth, noise, cross-linking, security, signal attenuation, repeaters and regeneration, cost and convenience.	
	Power levels	• Understand and use signal attenuation expressed in dB per unit length, including recall and use of the expression number of decibels (dB) = 10 lg (P_1 /P_2) for the ratio of two powers. • Understand and use repeater gain measured in dB. • Estimate and use typical power levels and attenuations associated with different channels of communication.	

Theme	**Topic**	**You should be able to**	**Comments**
Radio Communication	Propagation of radio waves	• Appreciate the effect of the Earth's surface on the propagation of radio waves over long distances, and the use of the ionosphere as a reflector if the waves are to be propagated over long distances. • Describe the use of satellites in radio communication and appreciate the importance of geostationary satellites. • Recall the wavelengths used in different modes of radio communication.	