version 1.1

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Physics 2007

Specification B

This specification should be read in conjunction with:

Specimen and Past Papers and Mark Schemes

Reports on the Examination

Teachers' Guide

AQA ADVANCED SUBSIDIARY GCE 5456
AQA ADVANCED GCE 6456

The specification will be published annually on the AQA Website (www.aqa.org.uk). If there are any changes to the specification centres will be notified in print as well as on the Website. The version on the Website is the definitive version of the specification.

Vertical black lines indicate a significant change or addition to the specification published for 2006.

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Background Information

1 Advanced Subsidiary and Advanced Level Specifications

1.1 Advanced Subsidiary (AS)

Advanced Subsidiary courses were introduced in September 2000 for the award of the first qualification in August 2001. They may be used in one of two ways:

- as a final qualification, allowing candidates to broaden their studies and to defer decisions about specialism;
- as the first half (50%) of an Advanced Level qualification, which must be completed before an Advanced Level award can be made.

Advanced Subsidiary is designed to provide an appropriate assessment of knowledge, understanding and skills expected of candidates who have completed the first half of a full Advanced Level qualification. The level of demand of the AS examination is that expected of candidates half-way through a full A Level course of study.

1.2 Advanced Level (AS+A2)

The Advanced Level examination is in two parts:

- Advanced Subsidiary (AS) – 50% of the total award;
- a second examination, called A2 – 50% of the total award.

Most Advanced Subsidiary and Advanced Level courses will be modular. The AS will comprise three teaching and learning modules and the A2 will comprise a further three teaching and learning modules. Each teaching and learning module will normally be assessed through an associated assessment unit. The specification gives details of the relationship between the modules and assessment units.

With the two-part design of Advanced Level courses, centres may devise an assessment schedule to meet their own and candidates' needs. For example:

- assessment units may be taken at stages throughout the course, at the end of each year or at the end of the total course;
- AS may be completed at the end of one year and A2 by the end of the second year;

AS and A2 may be completed at the end of the same year
Details of the availability of the assessment units for each specification are provided in Section 3.

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Specification at a Glance
Physics B

at Advanced Level

AS Examination 5456	
Unit 1	
1½ hours	35% of the total AS marks *17.5% of the total A Level marks*
examines Module 1 - Foundation Physics contains short answer and structured questions	
Unit 2	
1½ hours	35% of the total AS marks *17.5% of the total A Level marks*
examines Module 2 - Waves and Nuclear Physics contains short answer and structured questions	
Unit 3	
2 hours	30% of the total AS marks *15% of the total A Level marks*
assessment of practical skills by examination contains three externally set and externally marked exercises	

Advanced Subsidiary Award
5456

+

A2 Examination 6456	
Unit 4	
1½ hours	15% of the total A Level marks
examines Module 4 - Further Physics contains structured questions	
Unit 5	
2 hours	20% of the total A Level marks
examines Module 5 - Fields and their Applications and includes synoptic assessment contains structured questions and a comprehension question	
Unit 6	
3 hours	15% of the total A Level marks
external assessment of practical skills and synoptic assessment in a practical context contains two exercises which are externally set and marked	

Advanced Award
6456

3 Availability of Assessment Units and Entry Details

3.1 Availability of Assessment Units

Examinations based on this specification are available as follows:

	Availability of Units		Availability of Qualification	
	AS	**A2**	**AS**	**Advanced**
January	All	PHB4	✓	✓
June	All	All	✓	✓

3.2 Sequencing of Units

Subject to the availability given in Section 3.1, no restrictions are placed on the sequencing of Units 1, 2, 3 and 4.
Units 5 and 6 contain synoptic assessment.

3.3 Entry Codes

Normal entry requirements apply, but the following information should be noted.

The following unit entry codes should be used:

AS	A2
Unit 1 - *PHB1*	Unit 4 - *PHB4*
Unit 2 - *PHB2*	Unit 5 - *PHB5*
Unit 3 - *PHB3*	Unit 6 - *PHB6*

The **Subject Code** for entry to the AS only award is *5456*.

The **Subject Code** for entry to the Advanced Level award is *6456*.

3.4 Prohibited Combinations

Candidates entering for this examination are prohibited from entering any other GCE Physics specification in the same examination series. More specifically, candidates entered for Advanced Subsidiary or Advanced Level Physics *5456* and/or *6456* may not enter Physics *5451* and/or *6451* in the same examination series with AQA. This does not preclude candidates from taking AS and A2 units from the same AQA specification in the same examination series.

Every specification is assigned to a national classification code indicating the subject area to which it belongs.

Centres should be aware that candidates who enter for more than one GCE qualification with the same classification code will have only one grade (the highest) counted for the purpose of the School and College Performance Tables.

The classification code for this specification is 1210.

3.5 Private Candidates

This specification is available to private candidates. However, candidates should be aware that centres may require them to attend for practical assessments other than in January or June. Private candidates should write to AQA for a copy of *'Supplementary Guidance for Private Candidates'*.

3.6 Access Arrangements and Special Consideration

AQA pays due regard to the provisions of the Disability Discrimination Act 1995 in its administration of this specification.

Arrangements may be made to enable candidates with disabilities or other difficulties to access the assessment. An example of an access arrangement is the production of a Braille paper for a candidate with a visual impairment. Special consideration may be requested for candidates whose work has been affected by illness or other exceptional circumstances.

Further details can be found in the Joint Council for Qualifications (JCQ) document:
Access Arrangements and Special Consideration
Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examination
GCE, VCE, GCSE, GNVQ, Entry Level & Key Skills
This document can be viewed via the AQA web site (www.aqa.org.uk)

Applications for access arrangements and special consideration should be submitted to AQA by the Examinations Officer at the centre.

3.7 Language of Examinations

All assessment units in this subject are provided in English only.

Scheme of Assessment

4 Introduction

Introduction

AQA has developed two Physics specifications: Physics A and Physics B.

This is the Physics B specification.

The Physics B specification is derived from the existing AEB syllabus. The subject content is broadly based, has no optional topics and is up-to-date with examples of modern Physics and its applications. Assessment of practical skills is part of the scheme of assessment for both AS and A2. Practical assessment is by examination for AS, and by externally set and marked exercises for A2.

Physics A, like Physics B, reflects modern developments in Physics and its applications. Additionally, it offers continuity from the existing NEAB syllabus and provides a solid foundation for further study. Further, there is the provision of optional areas in A2 and coursework and practical examinations in both AS and A2.

The Physics B specification complies with:

- the Subject Criteria for Physics
- the GCSE and GCE A/AS Code of Practice
- the GCE Advanced Subsidiary and Advanced Level Qualification-Specific Criteria
- the Arrangements for the Statutory Regulation of External Qualifications in England, Wales and Northern Ireland; Common Criteria

Prior level of attainment and recommended prior learning

This specification is designed to build on the knowledge and understanding achieved by study of a GCSE Double Award Science course. It assumes the prior learning represented by a minimum level of attainment of Grade CC.

However, a qualification in GCSE Science is not a requirement and it is anticipated that candidates from different educational backgrounds and with a similar level of prior learning in Physics will find this specification accessible.

AS and A Level Physics are Level 3 qualifications within the National Framework and as such form a good basis for related Level 4 and higher qualifications. They are widely accepted entry qualifications for higher education. In addition, they provide a worthwhile course for candidates of various ages and from diverse backgrounds in terms of general education and lifelong learning.

5 Aims

This specification in Physics encourages candidates to:

At AS and A Level

5.1

a. develop essential knowledge and understanding in Physics and, where appropriate, the applications of Physics, and the skills needed for the use of this in new and changing situations;

b. develop an understanding of the link between theory and experiment;

c. appreciate how Physics has developed and is used in present day society;

d. show the importance of Physics as a human endeavour which interacts with social, philosophical, economic and industrial matters;

e. sustain and develop their enjoyment of, and interest in, Physics;

f. recognise the quantitative nature of Physics and understand how mathematical expressions relate to physical principles;

At A Level

5.2

a. bring together knowledge of ways in which different areas of Physics relate to each other;

b. study how scientific models develop.

6 Assessment Objectives

Candidates should be able to:

At AS and A Level

6.1 Knowledge with understanding (AO1)

a. recognise, recall and show understanding of specific physical facts, terminology, principles, relationships, concepts and practical techniques;

b. draw on existing knowledge to show understanding of the ethical, social, economic, environmental and technological implications and applications of Physics;

c. select, organise and present relevant information clearly and logically, using specialist vocabulary where appropriate;

6.2 Application of knowledge and understanding, synthesis and evaluation (AO2)

a. describe, explain and interpret phenomena and effects in terms of physical principles and concepts, presenting arguments and ideas clearly and logically, using specialist vocabulary where appropriate;

b. interpret and translate, from one form to another, data presented as continuous prose or in tables, diagrams and graphs;

c. carry out relevant calculations;

d. apply physical principles and concepts to unfamiliar situations including those which relate to the ethical, social, economic and technological implications and applications of Physics;

e. assess the validity of physical information, experiments, inferences and statements;

6.3 Experiment and investigation (AO3)

a. devise and plan experimental activities, selecting appropriate techniques;

b. demonstrate safe and skilful practical techniques;

c. make observations and measurements with appropriate precision and record these methodically;

d. interpret, explain, and evaluate the results of experimental activities, using knowledge and understanding of Physics and to communicate this information clearly and logically in appropriate forms (for example prose, tables and graphs), using appropriate specialist vocabulary;

At A Level

6.4 Synthesis of knowledge, understanding and skills (AO4)

a. bring together principles and concepts from different areas of Physics and apply them in a particular context, expressing ideas clearly and logically and using specialist vocabulary where appropriate;

b. use the skills of Physics in contexts which bring together different areas of the subject.

6.5 Quality of Written Communication

The quality of written communication is assessed in all AS and A2 assessment units where candidates are required to produce extended written material. Candidates will be assessed according to their ability to:

- select and use a form and style of writing appropriate to purpose and complex subject matter;
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate;
- ensure text is legible, and spelling, grammar and punctuation are accurate, so that meaning is clear.

The assessment of the quality of written communication is included in all four Assessment Objectives detailed above. Therefore, all six assessment units contain questions which include assessment of quality of written communication.

Marks are awarded according to the following criteria:

the use of Physics terms is inaccurate, the answer is disjointed, with significant errors in spelling, punctuation and grammar	0 marks
the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor	1 mark
the use of Physics terms is accurate, the answer is fluent / well argued with few errors in spelling, punctuation and grammar.	2 marks

7 Scheme of Assessment – *Advanced Subsidiary (AS)*

The Scheme of Assessment has a modular structure. The Advanced Subsidiary (AS) award comprises three compulsory assessment units.

7.1 Assessment Units

Unit 1	Written Unit	1½ hours
35% of the total AS marks	75 marks	

This unit assesses Module 1 of the AS Subject Content. The unit is in the form of a combined question/answer booklet. All questions are compulsory. The first section consists of short answer questions, with structured questions forming the remainder of the unit. Four marks are allocated for quality of written communication.

Unit 2	Written Unit	1½ hours
35% of the total AS marks	75 marks	

This unit assesses Module 2 of the AS Subject Content. The unit is in the form of a combined question/answer booklet. All questions are compulsory. The first section consists of short answer questions, with structured questions forming the remainder of the unit. Four marks are allocated for quality of written communication.

Unit 3	Practical Examination	2 hours
30% of the total AS marks	78 marks	

The Practical Examination comprises 3 compulsory exercises, details of which are given below. The exercises are designed to assess the practical skills detailed in Module 3 - Experimental Work, but they also require candidates to use their theoretical knowledge of Physics and apply it to a practical situation. The exercises are externally set and externally marked. Four marks are allocated for quality of written communication.

Details of the apparatus needed for the Practical Examination and instructions on setting up the exercises are given in the 'Instructions to Supervisors' (PHB3/TN) which are despatched to centres at least 10 weeks before the date of the examination.

The first exercise assesses planning. It takes 30 minutes. Candidates are given simple apparatus and instructions to make a small number of measurements. They are then required to suggest how they could develop the experimental method to investigate a given problem, and to justify their choices of equipment and measurements. They do not carry out their plan.

In the second exercise, which takes 30 minutes, candidates obtain a small data set using a given method. They process this data, making estimates of uncertainties, and suggest improvements to the method used. The exercise assesses candidates' ability to make measurements and to evaluate method and data.

In the final exercise, taking 1 hour, candidates make a series of measurements, using a given method, repeating and averaging as appropriate. They analyse their data using a graphical technique and make comments on whether their data support a proposed relationship. The exercise assesses candidates' ability to obtain and analyse a large data set.

7.2 Weighting of Assessment Objectives for AS

The approximate relationship between the relative percentage weighting of the Assessment Objectives (AOs) and the overall Scheme of Assessment is shown in the following table.

Assessment Objectives	**Unit Weightings** (%)			**Overall Weighting of AOs** (%)
	1	**2**	**3**	
Knowledge with understanding (AO1)	20	20	5	45
Application of knowledge and understanding, synthesis and evaluation (AO2)	15	15	5	35
Experiment and investigation (AO3)	0	0	20	20
Overall Weighting of Units (%)	35	35	30	100

Candidates' marks for each assessment unit are scaled to achieve the correct weightings.

8 Scheme of Assessment – *Advanced Level (AS+A2)*

The Scheme of Assessment has a modular structure. The A Level award comprises three compulsory assessment units from the AS Scheme of Assessment and three compulsory assessment units from the A2 Scheme of Assessment.

8.1 AS Assessment Units

Unit 1 — Written Unit — 1½ hours
17.5% of the total A Level marks — 75 marks

Unit 2 — Written Unit — 1½ hours
17.5% of the total A Level marks — 75 marks

Unit 3 — Practical Examination — 2 hours
15% of the total A Level marks — 78 marks

8.2 A2 Assessment Units

Unit 4	Written Unit	1½ hours
15% of the total A Level marks	75 marks	

This unit assesses Module 4 of the A2 Subject Content. The unit is in the form of a combined question/answer booklet. All the questions are structured and are compulsory. Four marks are allocated for quality of written communication.

Unit 5	Written Unit	2 hours
20% of the total A Level marks	100 marks	

This unit assesses Module 5 of the A2 Subject Content, and in addition contains synoptic questions. The unit is in the form a combined question/answer booklet and all the questions are compulsory.

The first questions, which are structured, focus on the content of Module 5. Later questions are more synoptic in nature and draw on the content of all the theory modules (Modules 1, 2, 4 and 5). One of the synoptic questions is a comprehension question. Four marks are allocated for quality of written communication.

Unit 6	Practical Exercises	3 hours
15% of the total A Level marks	78 marks	

This unit contains two exercises. Both exercises are externally set and marked, and each may have one or two questions. If there are two questions, they may be set in different practical contexts. The first exercise is carried out at a time suited to the requirements of the centre; the second is a timetabled examination. Each takes 1½ hours to complete. Four marks are allocated for quality of written communication.

The exercises are designed to assess the practical skills detailed in Module 6 – Experimental Work, but they also require candidates to draw on knowledge, understanding and skills gained throughout their study of A Level Physics, and apply them to a particular experimental context. Therefore, about one third of the marks in this unit are allocated to synoptic assessment.

In the first exercise, candidates are provided with apparatus and limited instructions for the experiment they are to perform, such as which independent variable to investigate and the hypothesis they are to test. They have to develop a method and obtain an extended data set. They analyse the data using a graphical method and draw conclusions about whether their data support the hypothesis, using their theoretical knowledge of Physics. The exercise assesses candidates' ability to develop and implement a plan, to obtain reliable measurements and to analyse, interpret and evaluate data. This exercise is carried out at a time suited to the requirements of the centre but must be undertaken by the scheduled date of the second exercise.

The second exercise is more open-ended. Candidates are provided with apparatus to perform initial rough tests. They develop a hypothesis and plan a detailed method to test it, using their theoretical knowledge of Physics to support their proposed method. They will also be provided with a description of a method and a set of data, and be required to evaluate the method by making reasoned estimates of uncertainties, to discuss how the method could be modified to give improved reliability and to analyse the data The date for this exercise is set by AQA - it is a timetabled examination.

The 'Instructions to Supervisors', which give details about setting up the assessments, are despatched to centres at least 16 weeks before the date of the timetabled examination. The despatch will include a briefing sheet for issue to candidates before they undertake the first exercise. Centres are required to administer the first exercise under examination conditions and at a time suited to the requirements of the centre. Candidates' scripts for the two exercises are collated and sent to the examiner after the date of examination for the second exercise.

8.3 Synoptic Assessment

The Advanced Subsidiary and Advanced Level Criteria state that A Level specifications must include synoptic assessment representing at least 20% of the total A Level marks. In this specification, Unit 5 contains 15% synoptic assessment and Unit 6 contains 5%. There is no synoptic assessment in the AS units. Synoptic assessment is defined by Assessment Objective AO4 - see Section 6.4.

8.4 Weighting of Assessment Objectives for A Level

The approximate relationship between the relative percentage weighting of the Assessment Objectives (AOs) and the overall Scheme of Assessment is shown in the following table.

A Level Assessment Units (AS + A2)

Assessment Objectives	**Unit Weightings** (%)						**Overall Weighting of AOs** (%)
	1	2	3	4	5	6	
Knowledge with understanding (AO1)	10	10	2.5	8	2.5	0	33
Application of knowledge and understanding, synthesis and evaluation (AO2)	7.5	7.5	2.5	7	2.5	0	27
Experiment and investigation (AO3)	0	0	10	0	0	10	20
Synthesis of knowledge, understanding and skills (AO4)	0	0	0	0	15	5	20
Overall Weighting of Units (%)	17.5	17.5	15	15	20	15	100

Candidates' marks for each assessment unit are scaled to achieve the correct weightings.

Subject Content

9 Summary of Subject Content

9.1 AS Modules

MODULE 1 – Foundation Physics

Scalars and vectors. Kinematics. Energy concepts. Current electricity. DC circuits. Information and communication.

MODULE 2 – Waves and Nuclear Physics

Waves. Diffraction and interference. Spectra. Radioactivity. Physics of particles. Information and communication.

MODULE 3 – Experimental Work

Planning. Implementing. Analysing evidence and drawing conclusions. Evaluating evidence and procedures. Linking experiment and theory.

9.2 A2 Modules

MODULE 4 – Further Physics

Circular motion. Oscillations. Work and energy. Molecular kinetic theory. Heating and working. Capacitance and exponential decay. Momentum concepts. Quantum phenomena.

MODULE 5 – Fields and their Applications

Electric and gravitational fields. Magnetic fields. Nuclear energy. Particle accelerators and detectors. Exponential decay.

MODULE 6 – Experimental Work

Planning. Implementing. Analysing evidence and drawing conclusions. Evaluating evidence and procedures. Linking experiment and theory.

10 AS Module 1 *Foundation Physics*

During the teaching and learning of Module 1, as in Module 2, candidates are expected to consider and discuss how the Physics they are learning is relevant in the context of information and communication in the modern world. In Module 1, this context provides candidates with opportunities to use sensors to collect information in their experimental work and to gain some understanding of the physical principles underlying the operation of these sensors. The context of information and communication is amplified in Section 10.6, but aspects of it appear throughout the earlier sections of the module. Apart from some basic principles associated with communications, it is not intended that Section 10.6 adds further Physics principles to the content of the module.

10.1 Scalars and Vectors

Addition of vectors	Use of scale diagram to add vectors. Mathematical calculation limited to two perpendicular vectors.
Resolution of vectors into two components at right angles to each other	Resolution of forces and velocities in particular should be discussed. Examples should include the components of forces along and perpendicular to an inclined plane.
Moment of a force Torque	Defined as force × perpendicular distance from a pivot.
Principle of moments	In problems, candidates are not required to resolve forces or calculate perpendicular distances using sines and cosines.

10.2 Kinematics

Graphical representation of uniformly accelerated motion	Candidates should know the shapes of $v-t$, $s-t$ and $a-t$ graphs for uniformly accelerated motion. Candidates should know one experiment to measure g by a free fall method.
Use of kinematic equations in one dimension for motion with constant velocity or acceleration	Use of $v = u + at$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$; $s = \frac{1}{2}(u + v)t$. Derivations are **not** required.

Recognition of independence of vertical and horizontal motion of a projectile moving freely under gravity	Problems will be soluble from first principles. The memorising of projectile equations is not required.
Interpretation of speed-time and displacement-time graphs for motion with non-uniform acceleration	The significance of areas and gradients is required. Candidates may be required to determine such quantities from graphs.
Drag and lift forces	Thrust = drag and lift = weight for constant velocity.
Effects of frictional forces and air resistance on motion of falling objects and motion of vehicles	Knowledge that air resistance increases with speed.
Concept of a terminal speed for a falling object and the reason for a maximum speed for a vehicle with fixed output power	The general shape of speed-time and acceleration-time graphs for such situations should be appreciated.
Practical treatment of factors affecting period and the effect of damping on mechanical oscillators	Candidates should know the terms period and amplitude and the appropriate experimental procedures necessary to investigate the factors affecting the period of an oscillator and the damping of a mechanical oscillator system. No understanding of simple harmonic motion analysis of any oscillator is expected. Candidates might however be required to make reasoned qualitative judgements relating to the factors that affect period and damping. The simple pendulum and mass spring system are treated analytically in Module 4 and an experimental treatment here would prepare candidates for this.
	In practical work relating to this Section candidates should have some experience of using data logging techniques and should appreciate the limitations of whatever system they use (links with Section 10.6).

Use of $F = ma$ in situations where the mass is constant	Formal statements of Newton's laws will not be required. Candidates should be able to apply the laws in simple problems. Candidates should appreciate that for equilibrium, ie at rest or for no acceleration, no resultant force is acting on a body. They may be required to analyse simple force situations using the principles from Section 10.1 to determine whether a system is in equilibrium. Analysis for translational equilibrium only is required. Candidates may be required to interpret graphs. Use to explain why motion of a falling object is independent of mass when air resistance is neglected. Note that treatment of Newton's second law as force = rate of change of momentum is not required until Module 4. Note also that treatment of circular motion is not required until Module 4.

10.3 Energy Concepts

Principle of conservation of energy	Candidates should know and be able to apply this principle in the context of topics in Module 1 and in particular to the energy transformations in simple systems, e.g. mechanical or electro-mechanical systems.
Electrical energy sources	It is expected that candidates will have reviewed in general terms the availability of carbon-based resources, solar energy, wave energy, wind energy, nuclear energy and geothermal energy. Candidates should appreciate the role of the sun and moon in renewable sources such as wind and wave energy. They should know the form of the energy in each case and should be able to describe in general terms the processes involved in converting each into electrical energy. Candidates should know at least one advantage and one disadvantage for each. In particular they should consider the appropriateness of each for use in the UK. Candidates should have some simple appreciation of the relative capital, running costs and environment impact of providing similar power outputs using each source of energy. When quantitative work is required candidates will be given information. Questions will not demand knowledge of physics beyond that elsewhere in the module. Candidates should know about thermal energy losses in cables when transmitting over long distances and may be required to do calculations involving DC voltages to demonstrate these losses (links with section 10.5). Knowledge of the roles of alternating current and transformers in overcoming these difficulties is expected but the physics of generators and transformers is not required.
Quantitative application of conservation of energy in uniform gravitational fields	Candidates should be able to apply the equations: change in PE = $mg\Delta h$ and KE = $\frac{1}{2}mv^2$.

Energy stored for a stretched spring. Spring stiffness k	Energy stored = $\frac{1}{2}F\Delta l = \frac{1}{2}k(\Delta l)^2$. Only situations where k is constant are required. Note that the work in this Section is extended in Modules 4 and 5 to include other energy transformations.

10.4 Electricity

Electric current as rate of flow of charge, $I = \Delta Q/\Delta t$	Candidates should appreciate that the charge that has flowed is the area under a current-time graph.
The nature of charge carriers in metals, liquids and gases	
Use of $I = nAvq$	Candidates are not expected to recall the derivation of $I = nAvq$ but it is expected that they will have discussed the derivation.
Emf and potential difference	Definition of the volt as work done per coulomb of charge transferred between two points.
The definition and concept of internal resistance	Candidates should be able to determine the total emf and internal resistance of cells in series. Awareness of the use to limit current in HT and EHT supplies.
Concept of 'lost volts'	Terminal p.d. = $E - Ir$.
Resistance and resistivity	Resistance defined by $R = V/I$. Resistivity defined by $\rho = RA/l$.
Ohm's law as a special case where $I \propto V$	
Comparison of V–I graphs for a metal, a negative temperature coefficient (ntc) thermistor and a diode	Qualitative and experimental treatment of effects of temperature on the resistance of a metal and on a negative temperature coefficient thermistor. In problems diodes will be assumed to be ideal. Rectifying property and the use of diodes in receivers should be appreciated. Experiments: calibration of a thermistor; investigate characteristics of a filament lamp, diode and LED. Use of the effect of temperature on resistance in a temperature sensor (links with Section 10.6). Temperature coefficient of resistance is **not** required.

Qualitative and experimental treatment of effects of light intensity on resistance of an LDR	Investigation of resistance of an LDR with light intensity (links with Section 10.6).
Simple explanation of the change in resistance with temperature for a metal and with temperature and light intensity for a semiconductor	Explanation in terms of the number and motion of charge carriers. Questions referring to holes as charge carriers will **not** be set.
Superconductivity	Knowledge of the existence of a transition temperature when some materials become superconductors. Applications of superconducting materials: e.g. production of powerful electromagnets with no generation of internal energy; long term energy storage and low noise electronic devices.

10.5 DC Circuits

Currents, voltages and resistances in series and parallel circuits	
Conservation of charge and energy in simple DC circuits	Current into a junction = current out of the junction. Emf is sum of p.d.s across each component in a series circuit. Formal statements of Kirchhoff's laws are not expected but candidates should be aware of them and their use in simple circuits.
Power dissipation	$P = VI;\ P = I^2R;\ P = V^2/R$ Effect of resistance in wires when transmitting information should be discussed (links with Sections 10.3 and 10.6).
Potential difference in terms of energy transfer	$V = W/Q;\ V = P/I$ Variation of terminal p.d. and energy dissipated in a load with load resistance and load current.
Effective resistance of combinations of series and parallel resistors	$R = R_1 + R_2 + R_3 + \ldots\ldots$ in series circuit $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$ in parallel circuit

The potential divider

output voltage across R_1

$$= \left\{\frac{R_1}{R_1+R_2}\right\} \times \text{input voltage}$$

Emphasis should be on its use to produce lower potential differences and to produce varying potential differences.

Examples should include the use of thermistors and LDRs in potential divider circuits (links with Section 10.6).

Appreciation that the light output of an LED can be varied by changing the input voltage to it and the relevance to changing audio information to optical information (links with Section 10.6).

The use of the potentiometer as a measuring instrument is not required.

10.6 Information and Communication

The nature of information and its transmission

Appreciation that any scientific measurement is information and that our understanding of the universe is based on gathering information in a variety of forms. They should appreciate the advantages of capturing information using sensors for future analysis (links with Section 10.2).

Data collection

The difference between digital and analogue data. Electrical variations produced by potential divider systems and on/off switches (links with Sections 10.4 and 10.5).

The concept of converting analogue into digital data using two voltage levels. For examination purposes, knowledge of binary numbers 1 to 10 (0000 to 1010) is adequate. The ability to do binary arithmetic is **not** required. Knowledge of electronic circuitry is **not** required.

The idea of sampling data when monitoring. Appreciation that more frequent sampling produces higher quality information.

Candidates should appreciate the use of a variety of sensors to collect data by converting a physical parameter into a voltage, for example, sensors that are used to monitor light intensity and temperature (links with Sections 10.4 and 10.5). The reasons for use of remote sensing should be understood.

Data transmission

Candidates should study transmission by metal cables. They should understand why signal strength falls with distance. The problems caused by thermal energy due to electrical heating when considering further miniaturisation of systems should be appreciated (links with section 10.5).

11

AS Module 2
Waves and Nuclear Physics

During the teaching and learning of Module 2, as in Module 1, candidates are expected to consider and discuss how the Physics they are learning is relevant in the context of information and communication in the modern world. In Module 2, this context provides candidates with opportunities to explore how information about space is collected in astronomy, how information is obtained in studies of the microscopic aspects of matter, and how information is gathered in engineering and medicine. The context of information and communication is amplified in Section 11.6, but aspects of it appear throughout the earlier sections of the module. Section 11.6 contains some basic principles associated with communications, but it is not intended that Section 11.6 adds further Physics principles to the content of the module.

11.1 Waves

Origin of waves	Knowledge that mechanical waves originate from a vibration and that complex sounds are the addition of numerous sinusoidal waves.
Speed, wavelength, frequency, amplitude and phase	Recall and use of $v = f\lambda$.
Principles of measurement of speed of waves and pulses	Candidates should know a laboratory method of measurement of the speed of sound in free air.
Transverse and longitudinal waves	Characteristics and examples of each type of wave.
Qualitative treatment of polarisation	Appreciation that polarisation is a property of transverse waves. Consideration of aerial alignment for transmitter and receiver.
Reflection, refraction and absorption	Candidates should know the laws of reflection, have a qualitative understanding of refraction and its effects, appreciate that energy is partially transmitted and reflected at an interface, and that energy is absorbed by a transmitting medium. The relevance to ultrasound, X-ray and other waves in medical diagnosis should be appreciated (links with Section 11.6).

11.2 Diffraction and Interference

Diffraction	Appreciation that the angle at which intensity falls to a minimum increases for increasing wavelength and decreasing aperture size. Minimum occurs when $\sin\theta = \lambda / b$ (no proof required). Relevance to satellite dishes and loudspeakers.
Diffraction as factor which limits resolution of two objects. Effect of aperture and wavelength on resolution	Awareness that resolution is worse with increasing wavelength and decreasing aperture size. Relevance to use of radio telescopes when gathering information in astronomy (links with Section 11.6). Appreciation of the advantages of using short wavelength when using ultrasound for imaging.
Concept of path difference of waves from two sources	
Phase and coherence	Candidates should be able to express phase difference in degrees. Use of radian measure is not required.
Quantitative treatment of superposition of waves from two sources	Fringe spacing = $\lambda D / d$. Experimental work should include work with light, sound or ultrasound, and radio or microwaves. Lasers could be useful in experimental work here, but the principle of operation of lasers is studied in Module 4. Interference between waves partially reflected from two parallel reflectors.
Diffraction grating	Use of formula $d \sin\theta = n\lambda$ without proof. Use to produce spectra.
Inverse square law for intensity at a distance from a point source of energy	Appreciation that energy is spread over a surface area = $4\pi r^2$.
Intensity proportional to (amplitude of the resultant wave)^2	
Stationary waves	Conditions for a stationary wave to be produced.

Graphical treatment of standing waves	Diagrams of possible modes of vibration for a stretched string. Idea of electron standing waves in atoms may be introduced at this stage. It is studied in Module 4.
Nodes and antinodes	Appreciation of direction of vibration of particles at positions other than the nodes.
Stationary waves in strings	Relation between the length and possible wavelengths of modes of vibrations for strings.
Factors affecting the frequency of the fundamental	Candidates should investigate the factors affecting frequency of the fundamental for strings.

11.3 Spectra

Types of spectra and their origin: line, band and continuous spectra; emission and absorption spectra	Appreciation of information gained from studying spectra in atomic and nuclear Physics and astronomy. Candidates should appreciate that the temperatures and other information about stars can be estimated from a study of their electromagnetic spectra (links with Section 11.6).
Electromagnetic spectrum	Knowledge of the orders of magnitude of the wavelengths, frequencies and photon energies for radio waves, microwaves, visible radiation and gamma radiation.
Doppler effect	Proof of formulae is **not** required. Candidates should know that for $v \ll c$ the fractional change in frequency $\frac{\Delta f}{f} = \frac{v}{c}$. Candidates should be aware of examples of the phenomenon in light and sound (links with Section 11.6). Knowledge that red shift provides evidence for an expanding universe and that the red shift of radiation from galaxies provides information about their distance from the earth (links with Section 11.6).
The Hubble law	$v = Hd$ where H is the Hubble constant and d is the distance.

11.4 Radioactivity

Background radiation	Examples of the origins should be known.
Spontaneous nuclear changes: the nature of alpha, beta and gamma emissions	Momentum and energy conservation and beta spectrum as evidence for existence of the anti-neutrino. A qualitative understanding of the evidence only is expected.
Ionising nature of charged particles and gamma rays	Energy loss when passing through matter (see also penetrating power). Appreciation that this forms the basis of the hazard when using radiation and the principle of detection methods. Knowledge of operation of particle detectors is not required.
Relative penetrating powers of α, β and γ radiations	Results of simple absorption experiments to distinguish between the types of radiation. Experimental arrangements for investigating relative absorption should be known. Knowledge of approximately inverse square law for γ radiation including experimental verification.
The random nature of the decay. Exponential decay as a process with constant half-life	Determination of half-life from a decay curve is expected, including correction of count rate for background radiation. Candidates should be familiar with activity - time, number of radioactive particles - time and count rate - time graphs. Candidates should appreciate that exponential changes occur because of the constant decay probability of a given nucleus. Number decaying in given time = probability of decay × number present. Use of $A = \lambda N$. Note that candidates are **not** expected to use the exponential decay equations until Module 5.
Understanding of nuclear nomenclature, Z and A and terms nuclide and isotope	Changes to nucleon number and proton number as a result of alpha, beta and gamma emissions.

11.5 Physics of Particles

Probing matter	Candidates should appreciate that knowledge of particles is gathered by bombarding matter with suitable particles of suitable energy. Candidates should have a qualitative understanding of the principles involved in the interpretation of cloud chamber and bubble chamber photographs.
Evidence for nuclear atom – alpha particle scattering	Simple qualitative treatment of the experiment.
Evidence for the existence of neutrons and protons in the nucleus	Candidates should appreciate that these are not fundamental particles. Knowledge of scattering experiments that provide evidence for substructure.
Antiparticles	Candidates should know of the existence of antiparticles and that a particle and its antiparticle annihilate when they meet.
Classification of particles	This section should serve as an introduction to the topic. Candidates should have knowledge of which particles are fundamental and which are not. Candidates should be introduced to the use of numbers associated with particle properties that are conserved in interactions. Leptons: (fundamental particles). Candidates should be familiar with the table of lepton numbers to describe properties of electrons, muons, taus and their neutrinos and be able to use this, for example, to check whether a given event is allowed. Electron and positron decay should be discussed in particular (links with Section 11.4). Hadrons: (not fundamental particles). Candidates should know that hadrons are mesons and baryons, that protons and neutrons are baryons and that the proton is the only stable baryon into which other baryons eventually decay. In particular, the decay of the neutron should be known.
Quarks as the basic building blocks for hadrons	Quarks: (possibly fundamental particles). A meson consists of a quark and an antiquark, and a baryon consists of three quarks. Candidates should be able to define the substructure of a proton and neutron in terms of up and down quarks and appreciate what happens to the quark structure when a neutron undergoes β decay. For examination purposes the range of quark properties (strangeness, colour and charm) is not required.

11.6 Information and Communication

Audio information

The nature of audio information. Candidates should know the range of human hearing. They should know that a sound is characterised by the frequencies present and the relative amplitudes of these frequencies. In particular they should consider typical human voices and the range of frequencies present in sounds from musical instruments (links with section 11.2).

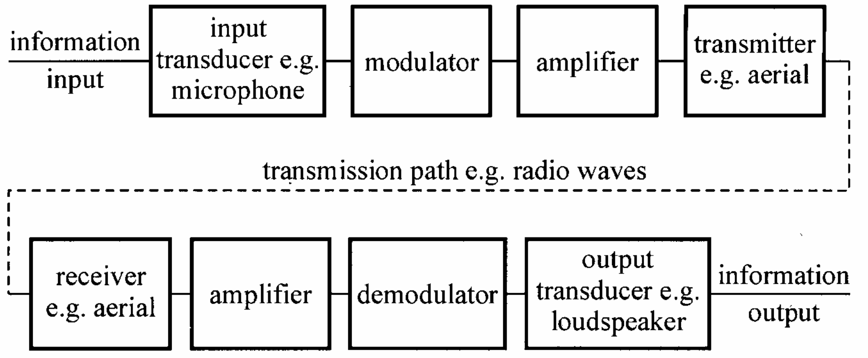
Base bandwidth as the range of frequencies that are transmitted for effective transmission of information. Candidates should be aware that the bandwidth requirement for video information is much greater than that for audio.

Concept of sampling audio signals for transmission in digital form. Minimum sampling rate required for effective transmission.

Knowledge of electronic circuitry is **not** required.

Transmission using waves

Block diagram of a "real time" communication system.



Candidates should know the purpose of each stage but no further detail of how the process is accomplished is required. Candidates should appreciate that the modulator uses the information to modify the amplitude or frequency of a carrier wave and appreciate that this process enables a large number of communication channels to use the same transmission path, the number depending on the bandwidth requirements of the information.

Candidates should understand the meaning of time division multiplexing in the transmission of digital information.

The idea of encoding a digital signal on to a high frequency carrier wave, e.g. using a flashing LED to transmit information along an optical fibre. Effect of noise in communication systems. Advantages of using digital communication systems compared with analogue systems.

Appreciation that at higher frequencies only line of sight transmission is possible. Typical range on Earth's surface. Appreciation that long distance communication can be achieved by diffraction around the Earth's surface using long wavelength, by using refraction and reflection of sky waves or by using satellites (links with Sections 11.1 and 11.2).

Candidates should be aware of the slower speed of transmission along cables than in free space. Candidates should know how information is transmitted in an optical fibre. Candidates should consider how fibre optics, copper cable and satellites are used to best advantage to transmit information in different circumstances (links with Section 11.1).

Information in waves from space	The relevant content appears in Sections 11.2 and 11.3.
Information using waves in medicine and industry	The use of light, ultrasound and X rays for medical diagnosis. Discussion should include how information is displayed and a comparison of the use of ultrasound and X rays for diagnosis. Appreciation of the use of fibre optics for internal investigations. The use of the Doppler effect for fluid flow measurements, for example of blood. Relevant content also appears in Sections 11.1 and 11.3.

12 AS Module 3 *Experimental Work*

12.1 Developing Practical Skills

Candidates should carry out experimental and investigative activities in order to develop their practical skills. Experimental and investigative activities for Module 3 should be set in contexts appropriate to, and reflect the demand of, the content of Modules 1 and 2. These activities should allow candidates to use their knowledge and understanding of Physics in planning, carrying out, analysing and evaluating their work.

Many experimental activities are relevant to the content in Modules 1 and 2. Some examples are given in Section 12.6. Except where an experiment is included in Modules 1 and 2, for example knowledge of a method of measuring g in Section 10.2, candidates will not be expected to recall details of experiments in written units. However, questions may be set in experimental contexts, in which case full details of the context will be given.

It is also expected that in their course of study, candidates will develop their ability to use IT skills in data capture, data processing and when writing reports. When using data capture packages, they should appreciate the limitations of the packages that are used. Candidates should be encouraged to use graphics calculators, spreadsheets or other IT packages for data analysis and again be aware of any limitations of the hardware and software.

Candidates' practical skills will be assessed in Unit 3 - the practical examination. Further details of this are given in Section 7.1. Candidates' IT skills will not be assessed practically in Unit 3. However, candidates may be asked to suggest approaches using IT in an experiment.

In the course of their experimental work, candidates should learn to:

12.2 Planning

a. identify and define a question or problem using available information and knowledge of Physics;

b. choose effective and safe procedures, selecting appropriate methods and apparatus;

12.3 Implementing

a. set up apparatus correctly and use it effectively with due regard to safety;

b. make and record sufficient relevant observations and measurements to the appropriate degree of precision, using IT where appropriate;

c. modify procedures and respond to serious sources of systematic and random error in order to generate results which are as accurate and reliable as allowed by the apparatus;

12.4 Analysing Evidence and Drawing Conclusions

a. present work appropriately in written, graphical or other forms;

b. analyse observations, where appropriate using IT, and show awareness of the limitations of experimental measurements when commenting on trends and patterns in the data;

c. draw valid conclusions by applying knowledge and understanding of Physics;

12.5 Evaluating Evidence and Procedures

a. assess the reliability of data and the conclusions drawn from them;

b. show awareness of the limitations inherent in scientific activity;

c. make use of IT in analysing data.

12.6 Topics for Linking Experiment and Theory

Module 1

In the context of Module 1, suitable experiments and other exercises for developing the practical skills in Sections 12.2 to 12.5 and for developing IT skills include:

Statics:
Investigating moments about a point and reactions.

Kinematics and energy transfer:
Experiments to study
- uniformly accelerated motion
- measurement of *g*
- small spherical objects falling in glycerine
- effect of force on acceleration
- conversion of elastic energy to KE energy stored in a spring
- conversion of gravitational PE to KE for falling objects.

Most of these can be studied using timing systems linked to a computer.
Use of spreadsheets and/or graphics calculators to analyse results and to model motion.
Research exercise using CD-ROMs and internet to study electrical energy sources.

Mechanical oscillating systems:
Use of data capture systems to plot displacement-time graphs for lightly damped and heavily damped pendulums and mass spring systems.
Use of a spreadsheet to study the effect of mass and stiffness of an oscillating system.

Electricity:
Experimental investigations using resistive components in dc circuits.
Factors affecting resistance of a wire - length, cross section, material.
Use of voltage, current, temperature and light sensors.
These may be used to study
- the effect of voltage on current
- the effect of temperature on resistance
- the effect of light intensity on resistance.

Module 2

In the context of Module 2, suitable experiments and other exercises for developing the practical skills in Sections 12.2 to 12.5 and for developing IT skills include:

Waves:
The properties of microwaves.
Measurement of the speed of e-m waves in coaxial cable.
Measurement of the speed of water waves and the speed of sound waves.
Experimental investigations of standing waves on stretched strings.
Factors affecting frequency.
Absorption of light through glass.

Diffraction and Interference:
Experimental investigations of interference and diffraction using slits and gratings.
Position of diffraction minimum.
Resolution of the eye.
Measurement of wavelength.
Inverse square law with light.
Candidates may study some of these effects using computer simulation software.

Radioactivity:
Randomness of radioactive decay.
Investigations of absorption of alpha, beta and gamma radiation.
Inverse square law for gamma radiation.
Exponential decay of protactinium.
Software is available to enable data capture in these experiments which are also suitable for analysis of data using IT packages, for example, the use of a spreadsheet to model radioactive decay.

Physics of particles:
Candidates can use the internet to access pictures of events from recent experiments in particle physics and learn about latest developments.

Communication:
Candidates can investigate the loss of information due to band width restrictions on an internal telephone system.
IT could be used to investigate the effect of adding waves of different frequencies.

Further information on experimental work for the different sections of the specification is given in the Teachers' Guide, which also covers the use of IT in experimental and other work.

13 A2 Module 4 *Further Physics*

13.1 Circular Motion

Application of $F = ma$ to motion in a circle at constant speed	$F = mv^2/r$; $a = v^2/r$; $v = r\omega$ Proofs of formulae are not required. Candidates should be aware of their relevance in a variety of practical situations and, in particular, in the context of other Sections of this module. Links with the orbital periods and speeds of planets and satellites in Section 14.1 should be considered. Links with particle accelerators and particle detection / analysis in bubble chambers in Section 14.4 should also be made.

13.2 Oscillations

Simple harmonic motion	Characterised by period, independent of amplitude. The link between oscillations and wave motion should be established. The role of oscillations in the production and transmission of waves should be established (links with Section 11.1).
Conditions for shm	Acceleration $= -(2\pi f)^2 x$. $x = A \cos 2\pi ft$ Maximum acceleration $= (2\pi f)^2 A$. Velocity as gradient of the displacement time graph. Maximum speed $= 2\pi fA$.
Qualitative and experimental treatment including graphical treatment of displacement, velocity and acceleration; concept of phase difference	Study of mass-spring system. $T = 2\pi\sqrt{(m/k)}$ The analogy between this and an atom in a lattice should be appreciated. Study of a simple pendulum. $T = 2\pi\sqrt{(l/g)}$ An experiment to measure g is expected (links with Section 10.2). Candidates should be aware that measurements of g can provide geophysicists with information about the interior structure of the Earth.

Energy of an oscillator	Energy proportional to (amplitude)^2. Variation of KE, PE and total energy with position and time.
Qualitative and experimental treatment of free and forced vibrations, damping and resonance	Variations of amplitude with frequency and effect of damping on the sharpness of resonance are expected. Candidates should be aware that there is an electrical equivalence that is used in selecting a communication channel. No quantitative work is expected.

13.3 Work and Energy

Principle of conservation of energy	Applied to energy changes in an oscillator. Candidates should also be able to apply the principle to other contexts in this Module.
Calculation of work done for constant forces	Problems may be set where the line of action of the applied force is not in the direction of the displacement.
Definition of efficiency	$\text{Efficiency} = \dfrac{\text{useful power output}}{\text{power input}}$.
Factors affecting efficiency in mechanical and simple electro-mechanical systems	

13.4 Molecular Kinetic Theory

Evidence for molecular model	Evidence should include Brownian motion.
Concept of internal energy as the random distribution of potential and kinetic energy amongst molecules	
Ideal gas equation $pV = nRT$	p–V, p–T and V–T relationships for an ideal gas.
Explanation of relationships between p, V and T in terms of particle model	

Concept of absolute zero; approximation of a real gas to an ideal gas at low pressure	
Definition of thermodynamic scale of temperature	Temperature at triple point of water. $\theta_{tr} = 273.16$ K $T/\text{K} = (pV)_T/(pV)_{tr} \times 273.16$
Avogadro constant: molar mass	
Application of $pV = \frac{1}{3}Nm\langle c^2\rangle$	The assumptions and principles of the derivation should be known but candidates will not be required to derive the formula. Candidates should appreciate that molecules have a range of speeds, but calculation of rms speeds is not required (links to momentum in Section 13.7).
$T \propto$ average kinetic energy of molecules for an ideal gas	
Knowledge of average kinetic energy of a molecule of an ideal gas	Energy of molecule = $3kT/2$. k is the Boltzmann constant.
Zeroth law	Appreciation that two bodies in contact are in thermal equilibrium when they are at the same temperature.

13.5 Heating and Working

First law	$\Delta U = Q + W$ The sign convention assumes that W is work done **on** the system. Appreciation that the first law is an energy conservation law. Processes which change internal energy; heating and working. Application of first law to adiabatic, isothermal and constant volume changes.
Specific and molar heat capacity	$Q = mc\,\Delta\theta$ Candidates should be familiar with examples in which a fluid is continuously heated by flowing through a heated compartment.

Specific latent heat	$Q = ml$ Candidates are not expected to recall details of experiments to determine c or l.
Calculation of work done for constant forces when force is along the line of motion	Work done is area under a force-distance graph. $W = Fs$
Power	Power = rate of transformation of energy; $P = Fv$.
Compression and expansion of gases	Work done on or by the gas = $p\,\Delta V$ for constant pressure p. Significance of area under $p - V$ graph and area inside a cycle of changes.
Stretching solids	Work done in compressing or expanding a solid in form of a cylinder of wire = $\frac{1}{2}F\Delta l$ = elastic stored energy.
Concept of stiffness; Young modulus; yielding and breaking stresses and strains	Stress = F/A ; strain = $\Delta l/l$; E = stress/strain. Experiments: stretching wires and samples of rubber. Typical graphs for metals and rubber should be known.

13.6 Capacitance and Exponential Decay

Definition of capacitance	$C = Q/V$
Significance of markings on an electrolytic capacitor	
Calculation of effective capacitance of combinations of series and parallel capacitors	$1/C = 1/C_1 + 1/C_2$ $C = C_1 + C_2$ Proof of formulae is not required.
Energy stored by a capacitor	$W = \frac{1}{2}QV$; $\frac{1}{2}CV^2$; $\frac{1}{2}Q^2/C$ Use as energy storage for backup in computers.

Factors affecting capacitance	$C = \varepsilon_0 \varepsilon_r A/d$ Experimental treatment is expected, e.g. using a reed switch.
Quantitative and experimental treatment of charge and discharge curves including the curves for the resistor and capacitor in a circuit	$Q = Q_0 e^{-t/RC}$ and equivalent formulae for current and voltage. Candidates should be aware of the slope of a charge-time graph and that charge is the area under a current-time graph. Numerical questions using formulae will be set only on capacitor discharge.
Time constant and time for quantity to halve	Time constant = RC. Time to halve = 0.69 RC. Use of $Q = Q_0(1 - e^{-t/RC})$ is **not** expected. Candidates should appreciate the application of Kirchhoff's law to an RC circuit.

13.7 Momentum Concepts

Definition of momentum	Momentum = mv.
Principle of conservation of momentum	Application of conservation of momentum limited to problems in one dimension. Application to particle collisions is particularly appropriate in this module.
Force as rate of change of momentum	Impulse $Ft = \Delta(mv)$. Situations where mass is constant including examples where force is not constant. Discussions of situations where force is small because time of impact large or vice versa.
Significance of area under a force-time graph	

13.8 Quantum Phenomena

Waves and particles	The teaching should stress the way in which the wave-particle model has developed due to a wave or particle theory alone being inadequate in enabling the explanation of all phenomena associated with matter and electromagnetic radiation.

Evidence for electrons as particles with mass and charge	Candidates should be aware of experiments which demonstrate the particle nature of electrons.
Photon model of electromagnetic radiation	$E = hf$
Photoelectric effect, including work function W	Photon energy = work function energy + maximum electron kinetic energy. $hf = \Phi + KE_{max}$ Candidates should be familiar with a demonstration of the effect.
Line spectrum of atomic hydrogen as evidence for discrete energy levels	$hf = E_2 - E_1$ Candidates should be aware that transitions may give rise to visible, infrared or ultraviolet radiation.
Lasers	Principles of operation of a laser: concept of having more excited than unexcited atoms which are stimulated to relax simultaneously by incident photons so that emitted light from each atom is in phase; need for a long lived metastable state. Uses of high and low energy lasers should be known, e.g. use in CD players; medical uses in micro surgery; cutting tools.
Particle diffraction. Wave-particle duality	Candidates should appreciate which evidence suggests particle behaviour and which wave behaviour as applied to electromagnetic radiation and particles such as electrons. Candidates should be familiar with an experiment illustrating electron diffraction and be aware that in principle all particles may be diffracted.
De Broglie wavelength	$\lambda = h/mv$
Experimental evidence for wave behaviour of particles; electron diffraction and interference	Qualitative understanding of the evidence from an electron diffraction tube experiment (links with Section 11.2).
Significance of amplitude of the de Broglie wave	Probability of finding an electron at a point $\propto$ amplitude^2.
Simple approach to prediction of energy levels	The development of a simple model in which an electron stationary wave fits the radius of an atom (links with Sections 11.1 and 11.2).

14 A2 Module 5 *Fields and their Applications*

14.1 Electric and Gravitational Fields

Concept of a force field as a region in which a body experiences a force	$E = F/Q$; $g = F/m$ Use of field lines to represent magnitude and direction of the fields.
Use of graphs and equations for force and field strength for spherical charges and masses treated as points in a vacuum	
Force between point charges	Magnitude of force $F = kQ_1Q_2/r^2$. $k = \dfrac{1}{4\pi\varepsilon_0}$ Measurement of ε_0 is not required.
Force between point masses	Magnitude of force $F = Gm_1m_2/r^2$. Measurement of G is not required.
Field strength for point charge	Magnitude of electric field strength $E = kq/r^2$.
Field strength for point mass	Magnitude of gravitational field strength $g = GM/r^2$. Candidates should study the orbital periods and speeds of planets and satellites in circular orbits. Geosynchronous orbit (links with Section 11.6).
Uniform electric field	Field strength $E = V/d$.
Energy transformed in fields	Concept of equipotentials and their relation to field lines; concept of a conservative field.

Quantitative application of conservation of energy in uniform gravitational and electric fields	$mg\Delta h$; $\frac{1}{2}mv^2$; Vq Candidates should be able to use $mc\,\Delta\theta$ in problems on energy transformations (links with Section 13.3 and 13.5).
Use of force-distance graphs to determine changes in potential energy	
Calculation of potential energy changes in gravitational and electric fields	Magnitude of change in PE for point masses. $\Delta PE = Gm_1m_2\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$ Magnitude of change in PE for point charges. $\Delta PE = kQ_1Q_2\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$ The definition of absolute potential is required. Candidates should have a basic understanding of the role of gravitation in the arguments relating to whether the universe is open, critical or closed. Candidates should be able to determine whether the potential energy change is an increase or decrease for the charge or mass concerned.
Similarities and differences between electric and gravitational fields	Appreciation that masses always attract but charges may attract or repel.
The strong nuclear force	Appreciation that the strong nuclear force is short range and much greater than the electrostatic repulsion of protons or gravitational attraction. Candidates should know of the existence of the strong interaction between quarks and hadrons. Appreciation that the strong force is responsible for holding nucleus together. Simple description of nuclear fission: nuclear deformation produced by absorbed neutron reaches point where there is no strong force so nuclei repel.

14.2 Magnetic Fields

Force on a straight wire.	$F = BIl$ Experiment using any form of current balance is expected. Definition of the tesla. Application to operation of a simple motor. Qualitative understanding of back emf in motors.
Force on a moving charge	$F = BQv$ The idea of balancing electric and magnetic forces on a moving charge in a velocity selector and other applications is expected. The link with electron tubes and identification of charged particles should be made.
Use of Fleming's left hand rule to predict direction of movement of current or charge	Examples will only be set in which a uniform field exists perpendicular to current or motion.
Concepts of flux ϕ and flux linkage Φ	$\Phi = N\phi$
Dependence of flux on flux density and area	$\phi = BA$
Electromagnetic induction: laws of Faraday and Lenz	Magnitude of induced emf = rate of change of flux linkage. Induced emf = $\Delta(N\phi)/t$. Candidates should know that the direction opposes the change that produces the emf. Simple induction calculations are expected.
Application of electromagnetic induction principles to the operation of a transformer, including turns ratio and efficiency	Candidates should appreciate the reasons for the use of transformers in transmission of electrical energy and be able to perform simple calculations on efficiency of the transmission. $N_s/N_p = V_s/V_p = I_p/I_s$ (for ideal transformer). Causes of inefficiency of a transformer.
Application of electromagnetic induction principles to the operation of a simple alternator consisting of a single coil	Qualitative understanding of the factors affecting the peak output voltage and the frequency.

Eddy currents	Cause of eddy currents. Use in damping and their significance in the design of motors and transformers.

14.3 Nuclear Energy

$E = mc^2$ applied to nuclear processes	Appreciation that $E = mc^2$ applies to all energy changes. Simple calculations relating mass difference to energy change. (Note that the alternative form $\Delta E = c^2\Delta m$ will not be used.) Candidates should appreciate that the equation works both ways and that in particle physics research, massive particles are created by collisions between particles with high KE (links with Section 11.5 and 14.4). Applications to spontaneous radioactive decay and to typical fission and fusion reactions. Appreciation that an isolated particle can only decay spontaneously into particles which have a lower total mass.
Calculation of the binding energy of a nucleus	Candidates should be familiar with the curve relating binding energy per nucleon to nucleon number.
Description of the processes of fission and fusion	Details of particular reactors are not required. The functions of the moderator, the control rods and the coolant should be understood.

14.4 Particle Accelerators and Detectors

Mass spectrometer: principles and understanding of its use to analyse the relative abundance and masses of nuclides	Experiment: electron tube to illustrate principles of q/m measurements.
Particle accelerators and their uses	General overview of principles and problems of achieving high energy particles and the reason for their development in the context of research into fundamental particles (links with Section 11.5).

	Principles of simple accelerators such as the electron gun (links with Sections 14.1 and 14.2). Principle of a cyclotron including knowledge of the cyclotron frequency (links with Section 13.1). Qualitative understanding of the operation of a synchrotron. Candidates should have a knowledge of the problem caused by relativistic increase in mass when accelerating particles. No quantitative work on relativity is expected.
Use of colliding beams and fixed targets in experimental physics to discover new particles	Appreciation that colliding beams provide greater energy than fixed targets whilst fixed targets provide data more readily (links with Sections 11.5 and 13.8). Candidates should be able to determine the energy of a particle that is needed to provide information about the substructure of a small particle by considering the appropriate de Broglie wavelength of the incident particle.
Particle detection	Use of cloud and bubble chambers to study particle interaction (links with Section 11.5). Candidates should know how charge and momentum of particles can be determined from the tracks. No knowledge of the principles of operation of the chambers is expected.
Quantitative treatment of radioactive decay	Decay constant λ and its relation to half-life. $t_{1/2} = 0.69/\lambda$ $N = N_0 e^{-\lambda t}$ $A = A_0 e^{-\lambda t}$ Activity $A = \lambda N$. This is an extension of the work done in Sections 11.4 and 13.6.

15 A2 Module 6 *Experimental Work*

15.1 Developing Practical Skills

Candidates should carry out experimental and investigative activities in order to develop their practical skills. Experimental and investigative activities for Module 6 should be set in contexts appropriate to, and reflect the demand of, the content of Modules 4 and 5. These activities should allow candidates to use their knowledge and understanding of Physics in planning, carrying out, analysing and evaluating their work.

Many experimental activities are relevant to the content in Modules 4 and 5. Some examples are given in Section 15.6. Except where an experiment is included in Modules 4 and 5, for example experimental studies of a mass-spring system and a simple pendulum in Section 13.2, candidates will not be expected to recall details of experiments in written units. However, questions may be set in experimental contexts, in which case full details of the context will be given.

It is also expected that in their course of study, candidates will develop their ability to use IT skills in data capture, data processing and when writing reports. When using data capture packages they should appreciate the limitations of the packages that are used. Candidates should be encouraged to use graphics calculators, spreadsheets or other IT packages for data analysis and again be aware of any limitations of the hardware and software.

Candidates' practical skills will be assessed in Unit 6 - the practical exercises. Further details of this are given in Section 8.2. Candidates' IT skills will not be assessed practically in Unit 6. However, candidates may be asked to suggest approaches using IT in an experiment.

In the course of their experimental work, candidates should learn to:

15.2 Planning

a. identify and define a question or problem using available information and knowledge of Physics;

b. choose effective and safe procedures, selecting appropriate methods and apparatus;

15.3 Implementing

a. set up apparatus correctly and use it effectively with due regard to safety;

b. make and record sufficient relevant observations and measurements to the appropriate degree of precision, using IT where appropriate;

c. modify procedures and respond to serious sources of systematic and random error in order to generate results which are as accurate and reliable as allowed by the apparatus;

15.4 Analysing Evidence and Drawing Conclusions

a. present work appropriately in written, graphical or other forms;

b. analyse observations, where appropriate using IT, and show awareness of the limitations of experimental measurements when commenting on trends and patterns in the data;

c. draw valid conclusions by applying knowledge and understanding of Physics;

15.5 Evaluating Evidence and Procedures

a. assess the reliability of data and the conclusions drawn from them;

b. show awareness of the limitations inherent in scientific activity;

c. make use of IT in analysing data.

15.6 Topics for Linking Experiment and Theory

Module 4

In the context of Module 4, suitable experiments and other exercises for developing the practical skills in Sections 15.2 to 15.5 and for developing IT skills include:

Simple Harmonic Motion:
Use of data capture systems to plot displacement-time graphs for lightly damped and heavily damped pendulums and mass spring systems.
Use of a spreadsheet to model simple harmonic motion. In this module candidates might create their own spreadsheet models.
Use of data capture to investigate resonance of oscillators.
Investigating resonance using computer modelling.

Work and energy:
Investigation of the efficiency of an electric motor or heater.

Gas laws:
Experiments to investigate relationships between p, V and T.
Use of temperature and pressure sensors may be used in such experiments. IT may be used for analysis.
Investigation of molecular size.

Heating and working:
Electrical heating methods to determine specific heat capacities.
Voltage, current and temperature sensors may be used in such experiments to monitor input power and temperature changes.
Simple determinations of Young's modulus for wires. Position sensors may be used to monitor extensions.

Capacitance and exponential decay:
Reed switch experiments to measure capacitance and the factors affecting capacitance.
Investigation of exponential decay of capacitors.
Use of voltage and current sensors to investigate decay.
Use of spreadsheets to model capacitor discharge and exponential decay.
Decay constant for a radioisotope.

Momentum:
Conservation experiments may use timing packages to measure speeds before and after collisions.
Experiments to show that force = rate of change of momentum.

Module 5

In the context of Module 5, suitable experiments and other exercises for developing the practical skills in Sections 15.2 to 15.5 and for developing IT skills include:

Electric, magnetic and gravitational fields:
Use of IT to model force-distance and potential-distance graphs for fields.
Plotting of equipotentials for two-dimensional electric fields using conducting paper.
Measurements of magnetic flux density using a current balance.
Use of magnetic field sensor to investigate fields near magnets and determine field strength.
Deflection of electrons by magnetic and electric fields.
Use of data capture techniques to monitor and investigate electromagnetic induction.
Investigations of voltages and currents in transformers and the efficiency of transformers.

Particle accelerators:
Measurement of e/m for electron.
Use of internet or CD-ROMs to explore the operation of particle accelerators and their use.

Further information on experimental work for the different sections of the specification is given in the Teachers' Guide, which also covers the use of IT in experimental and other work.

Key Skills and Other Issues

16 Key Skills – Teaching, Developing and Providing Opportunities for Generating Evidence

16.1 Introduction

The Key Skills qualification requires candidates to demonstrate levels of achievement in the Key Skills of *Application of Number*, *Communication* and *Information Technology*.

The units for the 'wider' Key Skills of *Improving own Learning and Performance*, *Working with Others* and *Problem-Solving* are also available. The acquisition and demonstration of ability in these 'wider' Key Skills is deemed highly desirable for all candidates, but they do not form part of the Key Skills qualification.

Copies of the Key Skills units may be downloaded from the QCA Website: (www.qca.org.uk/keyskills).

The units for each Key Skill comprise three sections:

A What you need to know.

B What you must do.

C Guidance.

Candidates following a course of study based on this specification for Physics can be offered opportunities to develop and generate evidence of attainment in aspects of the Key Skills of Application of Number, Communication, Information Technology. Improving own Learning, Working with Others and Problem-Solving. Areas of study and learning that can be used to encourage the acquisition and use of Key Skills, and to provide opportunities to generate evidence for Section B of the units, are signposted below. More specific guidance on integrating the delivery of Key Skills in courses based upon this specification is given in the AQA specification support material.

16.2 Key Skills Opportunities in Physics

The wide variety of approaches that can be used in the teaching and learning of Physics mean that candidates can be given opportunities to demonstrate the transferability of their Key Skills, to develop their knowledge and understanding of the Key Skills and to produce evidence of their application. The matrices below signpost the opportunities for the acquisition, development and production of evidence for Section B of each of the six Key Skills units at Level 3, in the teaching and learning modules of this specification. The degree of opportunity in any one module will depend upon a number of centre-specific factors, including teaching strategies and level of resources.

Communication

What you must do:		Signposting of Opportunities for Generating Evidence in Modules					
		1	2	3	4	5	6
C3.1a	Contribute to discussions	✓	✓	✓	✓	✓	✓
C3.1b	Make a presentation	✓	✓	✓	✓	✓	✓
C3.2	Read and synthesise information	✓	✓		✓	✓	
C3.3	Write different types of documents	✓	✓	✓	✓	✓	✓

Application of Number

What you must do:		Signposting of Opportunities for Generating Evidence in Modules					
		1	2	3	4	5	6
N3.1	Plan and interpret information from different sources			✓			✓
N3.2	Carry out multi-stage calculations	✓	✓	✓	✓	✓	✓
N3.3	Present findings, explain results and justify choice of methods	✓	✓	✓	✓	✓	✓

Information Technology

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
IT3.1 Plan and use different sources to search for and select information	✓	✓		✓	✓	
IT3.2 Explore, develop and exchange information, and derive new information			✓			✓
IT3.3 Present information including text, numbers and images	✓	✓	✓	✓	✓	✓

Working with others

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
WO3.1 Plan the activity			✓			✓
WO3.2 Work towards agreed objectives			✓			✓
WO3.3 Review the activity			✓			✓

Improving own learning and performance

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
LP3.1 Agree and plan targets	✓	✓	✓	✓	✓	✓
LP3.2 Seek feedback and support	✓	✓	✓	✓	✓	✓
LP3.3 Review progress	✓	✓	✓	✓	✓	✓

Problem Solving

What you must do:		**Signposting of Opportunities for Generating Evidence in Modules**					
		1	**2**	**3**	**4**	**5**	**6**
PS3.1	**Recognise, explain and describe the problem**			✓			✓
PS3.2	**Generate and compare different ways of solving problems**			✓			✓
PS3.3	**Plan and implement options**			✓			✓
PS3.4	**Agree and review approaches to tackling problems**			✓			✓

NB The signposting in the six tables above represents opportunities to acquire and produce evidence of the Key Skills which are possible through this specification. There may be other opportunities to achieve these and other aspects of Key Skills via this specification, but such opportunities are dependent on the detailed course of study delivered within centres.

16.3 Further Guidance

More specific guidance and examples of tasks that can provide evidence of one or more Key Skill are given in the AQA Teachers' Guide.

17 Spiritual, Moral, Ethical, Social, Cultural and Other Issues

17.1 Spiritual, Moral, Ethical, Social and Cultural Issues

The study of Physics can contribute to candidates' understanding of ethical, social and other issues.

For example, in Module 1, consideration of electricity generation could lead to a discussion of moral issues surrounding the use of finite resources and cultural issues relating to the use of appropriate technology; in Module 2, consideration of man's changing view of the Universe could involve a discussion of spiritual issues; in Module 4, the development of the wave-particle model could lead to a discussion of the development of scientific paradigms and the culture of science; and in Module 5, the ethical use of scientific knowledge could be considered in relation to the use of our knowledge of nuclear processes.

17.2 Environmental Education

AQA has taken account of the 1988 Resolution of the Council of the European Community and the Report '*Environmental Responsibility: An Agenda for Further and Higher Education*' 1993 in preparing this specification and associated specimen papers. The study of Physics as described in this specification can encourage a responsible attitude towards the environment. Relevant topics include:

- in Section 10.3 electricity generation;
- in Section 10.6 remote sensing;
- in Section 11.4 hazards of radioactivity;
- in Section 13.3 efficient use of energy;
- in Section 14.3 nuclear reactors.

17.3 Avoidance of Bias

AQA has taken great care in the preparation of this specification and associated specimen papers to avoid bias of any kind.

Awarding and Reporting

18 Grading, Shelf-Life and Re-Sits

18.1 Qualification Titles

The qualifications based on these specifications have the following titles:
AQA Advanced Subsidiary GCE in Physics B
AQA Advanced Level GCE in Physics B

18.2 Grading System

Both the AS and the full A Level qualifications will be graded on a five-grade scale: A, B, C, D and E. Candidates who fail to reach the minimum standard for grade E will be recorded as U (unclassified) and will not receive a qualification certificate.

Individual assessment unit results will be certificated.

18.3 Shelf-Life of Unit Results

The shelf-life of individual unit results, prior to the award of the qualification, is limited only by the shelf-life of the specification.

18.4 Assessment Unit Re-Sits

Each assessment unit may be re-taken an unlimited number of times within the shelf-life of the specification. The best result will count towards the final award. However, marks for individual units may be counted once only to an AS and/or A level award. Candidates who repeat an award and who do not decline their previous grade must re-take all units.

18.5 Minimum Requirements

Candidates will be graded on the basis of work submitted for the award of the qualification. Where a candidate is absent for an assessment unit, zero marks will be recorded.

18.6 Awarding and Reporting

This specification complies with the grading, awarding and certification requirements of the *GCSE, GCSE in vocational subjects, GCE, VCE, GNVQ and AEA Code of Practice 2004/5* and will be revised in the light of any subsequent changes for future years.

Appendices

A Grade Descriptions

The following grade descriptions indicate the level of attainment characteristic of the given grade at A Level. They give a general indication of the required learning outcomes at each specific grade. The descriptions should be interpreted in relation to the content outlined in the specification; they are not designed to define that content.

The grade awarded will depend in practice upon the extent to which the candidate has met the Assessment Objectives (as in Section 6) overall. Shortcomings in some aspects of the examination may be balanced by better performances in others.

Grade A Candidates recall and use knowledge of Physics from the whole specification with few significant omissions and show good understanding of the principles and concepts they use. They select appropriate information from which to construct arguments or techniques with which to solve problems. In the solution of some problems, candidates bring together fundamental principles from different content areas of the common specification and demonstrate a clear understanding of the relationships between these.

Candidates apply knowledge and physical principles contained within the specification in both familiar and unfamiliar contexts. In questions requiring numerical calculations, candidates demonstrate good understanding of the underlying relationships between physical quantities involved and carry out all elements of extended calculations correctly, in situations where little or no guidance is given.

In experimental activities, candidates identify a problem, independently formulate a clear and effective plan, using knowledge and understanding of Physics, and use a range of relevant techniques with care and skill. They make and record measurements which are sufficient and with a precision which is appropriate to the task. They interpret and explain their results with sound use of physical principles and evaluate critically the reliability of their methods.

Grade C Candidates recall and use knowledge of Physics from most parts of the specification and demonstrate understanding of a significant number of the main principles and concepts within it. They select and make good use of information that is presented in familiar ways to solve problems, and make some use of the concepts and terminology of Physics in communicating their answers. In their answers to some questions, candidates demonstrate some knowledge of the links between different areas of Physics.

Candidates apply knowledge and physical principles contained within the specification when the context provides some guidance on the required area of work. They show some understanding of the physical principles involved and the magnitudes of common physical quantities when carrying out numerical work. Candidates carry out calculations in most areas of Physics correctly when these calculations are of a familiar kind or when some guidance is provided, using correct units for most physical quantities.

In experimental activities, candidates formulate a clear plan. They make and record measurements with skill and care and show awareness of the need for appropriate precision. They interpret and explain their experimental results, making some use of fundamental principles of Physics and mathematical techniques.

Grade E Candidates recall knowledge of Physics from parts of the specification and demonstrate some understanding of fundamental principles and concepts. Their level of knowledge and understanding may vary significantly across major areas of the specification. They select discrete items of knowledge in structured questions and make some use of the terminology of Physics in communicating answers.

Candidates apply knowledge and principles of Physics contained within the specification to material presented in a familiar or closely related context. They carry out straightforward calculations where guidance is given, usually using the correct units for physical quantities. They use some fundamental skills of Physics in contexts which bring together different areas of the subject.

In experimental activities, candidates formulate some aspects of a practical approach to a problem. They make and record some appropriate measurements, showing care and appropriate procedure in interpretation of the outcomes of the investigation.

B

Overlaps with other Qualifications

Introduction

As stated in Section 3.4, candidates entering for examinations under this specification are not allowed concurrently to enter any other Advanced Subsidiary or Advanced Level GCE in Physics. At least 60% of the subject content of any other GCE in Physics is common with that in this specification.

The qualifications listed below are not prohibited combinations with GCE Physics qualifications, but their subject content overlaps to a greater or lesser extent with the subject content described in Sections 10 to 15 of this Advanced Subsidiary and Advanced Level GCE in Physics specification. The qualifications listed are AQA specifications - qualifications from other awarding bodies with the same or similar titles can be expected to have a similar degree of overlap.

Science for Public Understanding

some content in: Module 2 'Issues in the Physical Sciences'

also appears in this specification in: Module 1 Section 10.3
Module 2 Section 11.5

Electronics

some content in: Module 1 'Foundation Electronics'

also appears in this specification in: Module 1 Section 10.4
Module 4 Section 13.6

some content in: Module 4 'Communication Systems'

also appears in this specification in: Module 1 Section 10.6
Module 2 Section 11.7

Mathematics A

some content in: Module M1 'Mechanics 1'

also appears in this specification in: Modules 1 and 4

some content in: Module M2 'Mechanics 2'

also appears in this specification in: Modules 4 and 5

some content in: Module M3 'Mechanics 3'

also appears in this specification in: Module 4

some content in: Module M4 'Mechanics 4'

also appears in this specification in: Modules 4

Mathematics and Statistics B	some content in: Module M1 'Mechanics'	
	also appears in this specification in:	Module1
	some content in: Module M2 'Mechanics'	
	also appears in this specification in:	Modules 1 and 4
	some content in: Module MF1 'Mechanics'	
	also appears in this specification in:	Module 4
	some content in: Module MF2 'Mechanics'	
	also appears in this specification in:	Module 4
	there is no significant overlap with Module MF3 'Mechanics'	
Chemistry	some content in: Module 1 'Foundation Chemistry 1' and in Module 4 'Further Chemistry 1'	
	also appears in this specification in:	Module 5 Section 14.4
GNVQ Science – Advanced	some content in: Unit 4 - 'Controlling the transfer of energy'	
	also appears in this specification in:	Module 1 Section 10.2 Module 1 Section 10.3 Module 4 Section 13.5 Module 4 Section 13.7
	some content in: Unit 6 - 'Carrying out scientific investigations'	
	also appears in this specification in:	Modules 3 and 6
	some content in: Unit 13 - 'Choosing and using materials'	
	also appears in this specification in:	Module 4 Section 13.5
	some content in: Unit 14 - 'Energy resources and the environment'	
	also appears in this specification in:	Module 1 Section 10.3
	some content in: Unit 16 - 'Communications'	
	also appears in this specification in:	Module 1 Section 10.6 Module 2 Section 11.6
	some content in: Unit 17 - 'Medical physics'	
	also appears in this specification in:	Module 2 Section 11.1 Module 2 Section 11.4 Module 2 Section 11.6

C Formulae Sheets

The formulae for this specification are given in 3 lists.

These are:

1. the list below of the formulae which candidates are expected to recall - these will not be given in assessment units;
2. a list of the formulae which are relevant to the AS content;
3. a list of the formulae which are relevant to the A2 content.

The second list will appear as a perforated sheet in Units 1 and 2. The second and third lists will appear as a perforated sheet in Units 4 and 5.

Candidates are expected to know and understand the following formulae, which will not be provided in assessment units.

$$v = \frac{s}{t}$$

$$F = ma$$

$$a = \frac{\Delta v}{\Delta t}$$

$$\rho = \frac{m}{V}$$

$$\text{momentum} = mv$$

$$W = Fs$$

$$\text{power} = \frac{W}{t} = \frac{\text{energy transferred}}{t}$$

$$\text{weight} = mg$$

$$\text{K.E.} = \tfrac{1}{2}mv^2$$

$$\text{change in P.E.} = mg\Delta h$$

$$\text{pressure} = \frac{F}{A}$$

$$pV = nRT$$

$$\Delta Q = I\Delta t$$

$$V = IR$$

$$\text{power} = VI$$

$$\text{p.d.} = \frac{W}{Q}$$

$$R = \frac{\rho l}{A}$$

$$\text{energy} = VIt$$

$$v = f\lambda$$

$$F = \frac{mv^2}{r}$$

$$F = \frac{kQ_1Q_2}{r^2}$$

$$F = \frac{Gm_1m_2}{r^2}$$

$$C = \frac{Q}{V}$$

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$ for a transformer

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Foundation Physics Mechanics Formulae

moment of force $= Fd$

$v = u + at$

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

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

$s = \frac{1}{2}(u + v)t$

for a spring, $F = k\Delta l$

energy stored in a spring $= \frac{1}{2}F\Delta l = \frac{1}{2}k(\Delta l)^2$

$T = \frac{1}{f}$

Foundation Physics Electricity Formulae

$I = nAvq$

terminal p.d. $= E - Ir$

in series circuit, $R = R_1 + R_2 + R_3 + \ldots\ldots$

in parallel circuit, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$

output voltage across $R_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times$ input voltage

Waves and Nuclear Physics Formulae

fringe spacing $= \frac{\lambda D}{d}$

single slit diffraction minimum $\sin\theta = \frac{\lambda}{b}$

diffraction grating $n\lambda = d\sin\theta$

Doppler shift $\frac{\Delta f}{f} = \frac{v}{c}$ for $v << c$

Hubble law $v = Hd$

$A = \lambda N$

Properties of Quarks

Type of quark	Charge	Baryon number
up u	$+\frac{2}{3}e$	$+\frac{1}{3}$
down d	$-\frac{1}{3}e$	$+\frac{1}{3}$
$\overline{u}$	$-\frac{2}{3}e$	$-\frac{1}{3}$
$\overline{d}$	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

Particle	Lepton number L		
	L_e	L_μ	L_τ
e^-	1		
e^+	–1		
ν_e	1		
$\overline{\nu}_e$	–1		
μ^-		1	
μ^+		–1	
ν_μ		1	
$\overline{\nu}_\mu$		–1	
τ^-			1
τ^+			–1
ν_τ			1
$\overline{\nu}_\tau$			–1

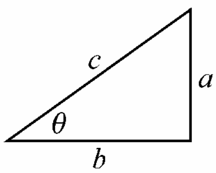
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

area of a circle $= \pi r^2$

surface area of sphere $= 4\pi r^2$

volume of sphere $= \frac{4}{3}\pi r^3$



$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$

$c^2 = a^2 + b^2$

Detach this perforated page at the start of the examination.

Circular Motion and Oscillations

$v = r\omega$

$a = -(2\pi f)^2 x$

$x = A \cos 2\pi ft$

maximum $a = (2\pi f)^2 A$

maximum $v = 2\pi f A$

for a mass-spring system $T = 2\pi\sqrt{\dfrac{m}{k}}$

for a simple pendulum $T = 2\pi\sqrt{\dfrac{l}{g}}$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{power input}}$$

Fields and their Applications

uniform electric field strength, $E = \dfrac{V}{d} = \dfrac{E}{Q}$

$E = kq/r^2$

$k = \dfrac{1}{4\pi\varepsilon_0}$

$g = \dfrac{F}{m}$

$g = \dfrac{GM}{r^2}$

for point masses, $\Delta PE = GM_1 M_2\left(\dfrac{1}{r_1} - \dfrac{1}{r_2}\right)$

for point charges, $\Delta PE = kQ_1 Q_2\left(\dfrac{1}{r_1} - \dfrac{1}{r_2}\right)$

$F = BIl$ for a straight wire

$F = BQv$ for a moving charge

$\phi = BA$

induced emf $= \dfrac{\Delta(N\phi)}{t}$

$E = mc^2$

Temperature and Molecular Kinetic Theory

$T/\text{K} = \dfrac{(pV)_T}{(pV)_{tr}} \times 273.16$

$pV = \frac{1}{3} Nm\langle c^2\rangle$

energy of a molecule $= \frac{3}{2} kT$

Heating and Working

$\Delta U = Q + W$

$Q = mc\Delta\theta$

$Q = ml$

$P = Fv$

work done on gas $= p\Delta V$

work done on a solid $= \frac{1}{2} F\Delta l$

stress $= \dfrac{F}{A}$

strain $= \dfrac{\Delta l}{l}$

Young modulus $= \dfrac{\text{stress}}{\text{strain}}$

Capacitance and Exponential Change

in series $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2}$

in parallel $C = C_1 + C_2$

energy stored by capacitor $= \frac{1}{2} QV$

parallel plate capacitance $C = \dfrac{\varepsilon_0 \varepsilon_r A}{d}$

$Q = Q_0 e^{-t/RC}$

time constant $= RC$

time to halve $= 0.69\ RC$

$N = N_0 e^{-\lambda t}$

$A = A_0 e^{-\lambda t}$

half-life, $t_{\frac{1}{2}} = 0.69/\lambda$

$A = \lambda N$

Momentum and Quantum Phenomena

$Ft = \Delta(mv)$

$E = hf$

$hf = \Phi + \text{KE}_{max}$

$hf = E_2 - E_1$

$\lambda = \dfrac{h}{mv}$

D Mathematical Requirements

In order to be able to develop the knowledge, understanding and skills in Modules 1 to 6, candidates need to have been taught and to have acquired competence in the areas of mathematics set out below. Material given in bold type is for Modules 4, 5 and 6 only.

Candidates should be able to:

Arithmetic and computation

- recognise and use expressions in decimal and standard form;
- use ratios, fractions and percentages;
- use calculators to find and use x^n, $1/x$, $\sqrt{x}$, $\log_{10}x$, $\boldsymbol{e^x}$, $\boldsymbol{\log_e x}$;
- use calculators to handle sin x, cos x, tan x when x is expressed in degrees or **radians**.

Handling data

- make order of magnitude calculations;
- use an appropriate number of significant figures;
- find arithmetic means.

Algebra

- change the subject of an equation by manipulation of the terms, including positive, negative, integer and fractional indices;
- solve simple algebraic equations;
- substitute numerical values into algebraic equations using appropriate units for physical quantities;
- understand and use the symbols: $=, <, \ll, \gg, >, \propto, \sim$.

Geometry and trigonometry

- calculate areas of triangles, circumferences and areas of circles, surface areas and volumes of rectangular blocks, cylinders and spheres;
- use Pythagoras' theorem, and the angle sum of a triangle;
- use sines, cosines and tangents in physical problems;
- **understand the relationship between degrees and radians and translate from one to the other.**

Graphs

- translate information between graphical, numerical and algebraic forms;
- plot two variables from experimental or other data;
- understand that $y = mx + c$ represents a linear relationship;
- determine the slope and intercept of a linear graph;
- draw and use the slope of a tangent to a curve as a measure of rate of change;
- understand the possible physical significance of the area between a curve and the x-axis and be able to calculate it or measure it by counting squares as appropriate;
- **use logarithmic plots to test exponential and power law variations;**
- **sketch simple functions including** $\boldsymbol{y = k/x}$, $\boldsymbol{y = kx^2}$, $\boldsymbol{y = k/x^2}$, $\boldsymbol{y = \sin x}$, $\boldsymbol{y = \cos x}$, $\boldsymbol{y = e^{-kx}}$.

E

Symbols, Signs and Safety

Units

The units of measurement used in assessment units are those set out in BS5555: 1993, '*Specification for SI units and recommendation for the use of their multiples and of certain other units*'. Candidates should also be familiar with non-SI units in common use in Physics, such as kW h and eV.

Electrical and Electronic Symbols

The symbols used in assessment units are those set out in BS3939: 1985, '*Graphical symbols for electrical power, telecommunications and electronics diagrams*'. These symbols are summarised in the British Standards Institution publication, '*Graphical symbols for use in schools and colleges*', PP7307: 1989. Candidates must be familiar with the symbols reproduced on the next page. Any generally accepted circuit symbols used by candidates in answering questions will be given full credit.

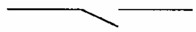
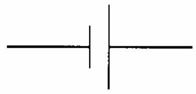
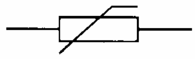
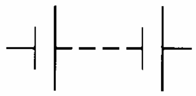
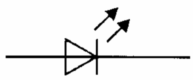
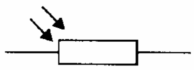
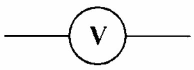
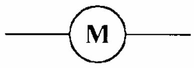
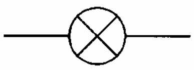
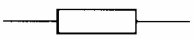
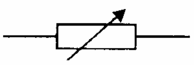
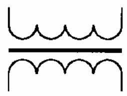
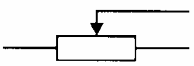
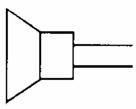
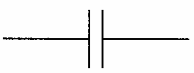
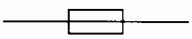
Safety

AQA recognises the need for safe practice in laboratories and tries to ensure that experimental work required for this specification and associated assessment units complies with up-to-date safety recommendations.

Nevertheless, centres are primarily responsible for the safety of candidates and teachers should carry out their own risk assessments.

The attention of centres is drawn to the following publications.

1. '*Safety in Science Education*', DfEE, 1996, ISBN 0-11-270915-X.
2. '*Safeguards in the School Laboratory*', Association for Science Education, 10th edition, 1996, ISBN 086357 2502.
3. Hazcards (CLEAPSS, 1995).

Symbol	Circuit Component	Symbol	Circuit Component
	normally open switch		diode
	primary or secondary cell		thermistor
	battery of cells		light emitting diode
	ammeter		light dependent resistor
	voltmeter		motor
	filament lamp		a.c. power supply
	fixed resistor		inductor
	variable resistor		transformer with magnetic core
	potential divider		loudspeaker
	capacitor		fuse