Oxford Cambridge and RSA Examinations

OCR AS GCE in Physics A (3883)

OCR Advanced GCE in Physics A (7883)

Approved Specifications – Revised Edition

First AS assessment January 2001 — QAN (3883) 100/0624/2

First A2 assessment June 2002 — QAN (7883) 100/0456/7

Foreword to Revised Edition

This Revised Edition has been produced to consolidate earlier revisions to these specifications and any changes contained within have previously been detailed in notices to centres. **There is no change to the structure or teaching content of the specification and most differences are cosmetic**. Sidelining will be used to indicate any significant changes.

The main changes are:

Re-sits of Units – The restrictions on re-sitting units have been removed, enabling candidates to re-take units more than once (for details see page 18).

Foreword (continued)

This booklet contains OCR's Advanced Subsidiary GCE (AS) and Advanced GCE (A level) Physics A specifications for teaching from September 2004.

The AS GCE is assessed at a standard appropriate for candidates who have completed the first year of study of a two year Advanced GCE course, i.e. between GCSE and Advanced GCE. It forms the first half of the Advanced GCE course in terms of teaching time and content. When combined with the second half of the Advanced GCE course, known as 'A2', the AS forms 50% of the assessment of the total Advanced GCE. However, the AS can be taken as a 'stand-alone' qualification. A2 is weighted at 50% of the total assessment of the Advanced GCE.

In these specifications the term **module** is used to describe specific teaching and learning requirements. The term **unit** describes a unit of assessment.

Each teaching and learning module is assessed by its associated unit of assessment.

These specifications meet the requirements of the Common Criteria (Qualifications and Curriculum Authority, 1999), the GCE AS and Advanced Level Qualification-Specific Criteria (QCA, 1999) and the relevant Subject Criteria (QCA, 1999).

Biology	**3881 & 7881**
Chemistry	**3882 & 7882**
Physics A	**3883 & 7883**
Geology	**3884 & 7884**
Science	**3885 & 7885**

Contents

Specification Summary

Outline

The OCR AS GCE and Advanced GCE in **Physics A** specifications cover all the content identified in the Physics subject criteria (QCA, 1999) in compulsory modules, whilst including optional modules to give candidates the opportunity to explore an area of physics in depth. Some options deal with modern applications of physics, whilst others cover more traditional areas. The assessment of experimental skills is flexible with coursework and practical examination alternatives in both AS and A2.

Specification Content

Modules 2821,2822, 2823, 2824, and 2826 draw, as appropriate, on the content identified in the QCA Subject Criteria for Physics. The content is chosen to provide a balanced and coherent study of physics. In addition, the specifications require candidates to develop abilities used in making sense of scientific information. Module 2825 provides five optional components of which **one** is chosen for study. The optional components are as follows:

- Component 01 Cosmology
- Component 02 Health Physics
- Component 03 Materials
- Component 04 Nuclear and Particle Physics
- Component 05 Telecommunications

Scheme of Assessment

The AS GCE forms 50% of the assessment weighting of the full Advanced GCE. AS GCE is assessed at a standard between GCSE and Advanced GCE and can be taken as a stand-alone specification or as the first part of the full Advanced GCE course.

Assessment is by means of **three Units of Assessment** for AS and **six Units of Assessment** for Advanced GCE:

AS GCE	Candidates take units 2821, 2822 and 2823.
Advanced GCE	Candidates take units 2821, 2822, 2823, 2824, 2825 and 2826.

Note: In Unit 2823, candidates take **either** components 01 and 02 **or** components 01 and 03.

In Unit 2825, candidates take **one** of components 01 – 05.

In Unit 2826, candidates take **either** components 01 and 02 **or** components 01 and 03.

Units of Assessment

Level	Unit/ Component (where relevant)	Name	Duration	Mode of Assessment	Weighting	
					AS	Advanced GCE
AS	**2821**	Forces and Motion	1 hour	Written Examination	30%	15%
AS	**2822**	Electrons and Photons	1 hour	Written Examination	30%	15%
AS	**2823**	Wave Properties/ Experimental Skills 1				
	/01	Wave Properties	45 mins	Written Examination	20%	10%
	/02	Coursework 1	-	Coursework	20%	10%
	/03	Practical Examination 1	1 hour 30 mins	Practical Examination	20%	10%
A2	**2824**	Forces, Fields and Energy	1 hour 30 mins	Written Examination	-	15%
A2	**2825**	Options in Physics (**one** of)				
	/01	Cosmology	1 hour 30 mins	Written Examination	-	15%
	/02	Health Physics	1 hour 30 mins	Written Examination	-	15%
	/03	Materials	1 hour 30 mins	Written Examination	-	15%
	/04	Nuclear and Particle Physics	1 hour 30 mins	Written Examination	-	15%
	/05	Telecommunications	1 hour 30 mins	Written Examination	-	15%
A2	**2826**	Unifying Concepts in Physics/ Experimental Skills 2				
	/01	Unifying Concepts in Physics	1 hour 15 mins	Written Examination	-	10%
	/02	Coursework 2	-	Coursework	-	10%
	/03	Practical Examination 2	1 hr 30 mins	Practical Examination	-	10%

Question Paper Requirements

The question papers for units 2821, 2822, 2823 (Component 01), 2824 and 2826 have a common format. They contain both structured questions and questions which require more extended answers. All questions on these papers are compulsory. Quality of written communication is assessed in Units 2821, 2822 and 2824, within those parts of the questions which require more extended answers.

The question papers for Unit 2825 (Components 01 – 05), Unit 2826 (Component 01) and Unit 2826 (Component 03) contain questions covering synoptic assessment. Unit 2826 (Component 01) is a synoptic paper, which requires candidates to draw together their knowledge and understanding developed through study of modules 2821, 2822 and 2823 (Component 01) of the AS specification and module 2824 in A2. All questions in examination paper 2826 (Component 01) are compulsory; some questions require more extended writing.

All questions on the practical examination papers, Unit 2823 (Component 03) and Unit 2826 (Component 03), are compulsory. These practical examination papers are alternatives to coursework (Unit 2823 (Component 02) and Unit 2826 (Component 02) respectively).

Experimental and Investigative Skills

Experimental skills for AS and Advanced level are assessed

- **either** by coursework (Unit 2823, Component 02 and Unit 2826, Component 02)
- **or** by external examination (Unit 2823, Component 03 and Unit 2826, Component 03).

Candidates may combine the two methods of assessment by taking the coursework component in AS and the practical examination component in A2 or *vice versa*.

Coursework

For both AS GCE and Advanced GCE, candidates can be internally assessed on four experimental and investigative skills. One mark per skill must be awarded for each candidate, for AS (Unit 2823 Component 02) and for A2 (Unit 2826 Component 02). Work is marked by the teacher, internally standardised at the Centre, and externally moderated by OCR. There is an element of synoptic assessment in Unit 2826, Component 02.

External examination

For both AS GCE and Advanced GCE, candidates can take an externally set and marked practical examination (Unit 2823, Component 03 and Unit 2826, Component 03 respectively). There is an element of synoptic assessment in Unit 2826, Component 03.

1 Introduction

These OCR specifications lead to qualifications at AS GCE and Advanced GCE in **Physics**. Candidates take three Units of Assessment for AS and a further three for A2. AS and A2 combined constitute the full Advanced GCE specification. There are coursework alternatives in both AS and A2.

These specifications have been developed for candidates who wish to continue with a study of Physics after GCSE. Some candidates may wish to follow a Physics course for only one year as an AS GCE, in order to broaden their curriculum. Others will continue for a further year extending their course to Advanced GCE. Such a course will prepare candidates to progress into further or higher education, to follow courses in Physics, Engineering, one of the other sciences or related subjects, or to enter employment where a knowledge of Physics would be useful. The study of Physics at AS GCE and Advanced GCE should also be seen as making a contribution towards life-long learning and an understanding of technological advances and their impact on modern day society.

These AS GCE and Advanced GCE Physics specifications cover important physical knowledge, understanding and skills. The AS GCE specification builds from grade CC in Science: Double Award courses or equivalent science based-qualifications, such as Intermediate level GNVQ. Recommended prior knowledge within AS modules is described in terms of National Curriculum statements.

Experience of the role of experimental work is important in any course in Physics and is recognised in these specifications by the inclusion of coursework components, or practical examinations, at both AS and A2, based on assessment of experimental skills.

The assessment of experimental and investigative skills builds from GCSE. The skills cover the same areas as Sc1 of GCSE, and the mark descriptors are formulated in the same way as the GCSE mark descriptors.

It is expected that social, economic, environmental, ethical, medical and technological aspects of physics will be incorporated into the delivery of these specifications. References to these aspects of physics are integrated into modules throughout the course.

1.1 Certification Title

These qualifications are shown on a certificate as:

- OCR Advanced Subsidiary GCE in Physics.
- OCR Advanced GCE in Physics

1.2 Language

These specifications and associated assessment materials are available in English only.

1.3 Overlap with other qualifications

Links with Key Stage 4

The AS GCE specification builds on from grade CC in GCSE Science: Double Award courses, or equivalent. Recommended prior knowledge within AS modules is described in terms of National Curriculum statements. For candidates who have not studied the National Curriculum, the equivalent background knowledge is expected.

The assessment of experimental and investigative skills also builds on from GCSE. The four skills assessed are the same as in Sc1 of GCSE and the mark descriptors are formulated in the same way as the GCSE mark descriptors.

Links with other AS GCE and Advanced GCE specifications

Physics has overlap with other AS GCE and Advanced GCE specifications, particularly Biology and Chemistry.

Examples of overlap include:

Biology

Module 2805, Component 05: Mammalian Physiology and Behaviour. Support and Locomotion (5.9.3). This overlaps Section 5.6.1, Body Mechanics in Module 2825, Component 02 Health Physics.

Module 2805, Component 05: Mammalian Physiology and Behaviour. Sense Organs and the Reception of Stimuli (5.9.5). This overlaps Section 5.6.2, The Eye and Sight in Module 2825, Component 02, Health Physics.

Module 2805, Component 05: Mammalian Physiology and Behaviour. Sense Organs and the Reception of Stimuli (5.9.5). This overlaps Section 5.6.3, The Ear and Hearing in Module 2825, Component 02, Health Physics.

Chemistry

Module 2811: Foundation Chemistry. Atomic Structure (5.1.2). This overlaps with Section 5.4.11, The Nuclear Atom in Module 2824, Forces, Fields and Energy.

Module 2815, Component 04: Methods of Analysis and Detection. Atomic emission spectra (5.8.3). This overlaps with Section 5.2.4, Quantum Physics in Module 2822, Electrons and Photons.

Links with GNVQ

There is some overlap of content and material in modules 2821, 2822, 2823 (Component 01), 2824, 2825 (Component 01) and 2826 (Component 01) can be used to support the physics-based units in GNVQ Advanced Science courses.

1.4 Exclusions

Candidates who enter for this AS GCE specification may **not** also enter for any other AS GCE specification with the certification title Physics in the same examination session.

Candidates who enter for this Advanced GCE specification may **not** also enter for any other Advanced GCE specification with the certification title Physics or Science in the same examination session.

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 these specifications is 1210.

1.5 Code of Practice requirements

These specifications will comply in all respects with the 2004 revised Code of Practice.

2 Specification Aims

The aims of these AS GCE and Advanced GCE specifications are to:

(a) provide, through well designed studies of theoretical and practical physics, a worthwhile educational experience for all students, whether or not they go on to study physics at a higher level and, in particular, to enable them to acquire sufficient understanding and knowledge to:

- become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific import;
- recognise the usefulness, and limitation, of scientific method and to appreciate its applicability in other disciplines and in everyday life;
- be suitably prepared for employment and/or further studies beyond AS GCE or Advanced GCE.

(b) encourage candidates to:

- 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;
- develop an understanding of the link between theory and experiment;
- appreciate how physics has developed and is used in present day society;
- show the importance of physics as a human endeavour which interacts with social, philosophical, economic, industrial and environmental matters;
- sustain and develop their enjoyment of, and interest in, physics;
- recognise the quantitative nature of physics and understand how mathematical expressions relate to physical principles.

In addition, the A2 specification aims to encourage candidates to:

- bring together knowledge of ways in which different areas of physics relate to each other;
- study how scientific models develop.

2.1 Spiritual, Moral, Ethical, Social and Cultural Issues

These specifications provide an opportunity for candidates to appreciate the following:

- the endeavour of physics in describing the structure and functioning of the natural and material world;
- a sense of awe and wonder at the scale and impact of physical processes and phenomena;
- the ethical and moral implications of some of the applications of science and technology.

See, for example, sections 5.1.7, 5.3.1, 5.4.2, 5.4.11, 5.4.12, 5.5, 5.6.2 and 5.7.4.

2.2 Environmental Education

Aspects of environmental education occur in relation to problems associated with reprocessing and storage of radioactive materials, linking with moral and environmental issues.

Aspects of environmental education are covered in sections 5.1.6, 5.1.7, 5.4.4, 5.4.11, 5.4.12, 5.8.2 and 5.9.7.

2.3 European Dimension

There have been many contributions to the understanding of physics by European physicists. Coulomb, Einstein and Curie appear in the specification along with many others. There are also other aspects, not mentioned in the specification, which could be drawn into the course. For example:

- European co-operation in joint scientific projects (JET)
- Problems associated with reprocessing and storage of radioactive materials, linking with moral and environmental issues

The European dimension is covered in sections 5.7, 5.8.2 and 5.9.

2.4 Health and Safety Issues

The following Health and Safety Issues feature in these specifications:

- radioactivity;
- health physics;
- safe practice in laboratories;
- problems associated with reprocessing and storage of radioactive materials, linking with moral and environmental issues.

Health and safety issues are covered in sections 5.1.6, 5.1.7, 5.4.4, 5.4.12, 5.6 and 5.9.

2.5 Avoidance of Bias

OCR has taken great care in the preparation of these specifications and assessments materials to avoid bias of any kind.

3 Assessment Objectives

Knowledge, understanding and skills are closely linked. These specifications require that candidates demonstrate the following assessment objectives in the context of the content and skills prescribed. Assessment Objectives AO1-AO3 are the same for AS GCE and Advanced GCE; AO4 applies only to the A2 half of the Advanced GCE course.

AO1 Knowledge with Understanding

Candidates should be able to:

(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 appropriate vocabulary where appropriate.

AO2 Application of Knowledge and Understanding, Synthesis and Evaluation

Candidates should be able to:

(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 into another, data presented as continuous prose or in tables, diagrams, drawings and graphs;

(c) apply physical principles and concepts to unfamiliar situations including those which relate to the ethical, social, economic, and technological implications and applications of physics;

(d) assess the validity of physical information, experiments, inferences and statements.

AO3 Experiment and Investigation

Candidates should be able to:

(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 their experimental activities, using knowledge and understanding of physics and to communicate this information clearly and logically in appropriate forms e.g. prose, tables and graphs, using appropriate specialist vocabulary.

AO4 Synthesis of Knowledge, Understanding and Skills

Candidates should be able to:

(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 appropriate specialist vocabulary;

(b) use skills of physics in contexts which bring together different areas of the subject.

The assessment objectives are weighted as follows:

	AS GCE	A2	Advanced GCE
AO1	48%	25%	36.5%
AO2	32%	25%	28.5%
AO3	20%	10%	15%
AO4	0%	40%	20%

3.1 Specification Grid

The relationship between the assessment objectives and the components of the units of assessment is shown in the specification grid below.

Unit of Assessment		Level	Percentage of A Level				Total
			AO1	AO2	AO3	AO4	
2821		AS	9	6	0	0	15
2822		AS	9	6	0	0	15
2823	Component 01	AS	6	4	0	0	10
	Components 02/03	AS	0	0	10	0	10
2824		A2	7.5	7.5	0	0	15
2825	(Each of Components 01 – 05)	A2	5	5	0	5	15
2826	Component 01	A2	0	0	0	10	10
	Components 02/03	A2	0	0	5	5	10
Total			36.5	28.5	15	20	100

3.2 Quality of Written Communication

The requirement for all AS GCE and Advanced GCE specifications to assess candidates' quality of written communication is met through all four assessment objectives. Questions which provide an assessment of quality of written communication are included in question papers for Units 2821,2822 and 2824, and in the assessment of experimental skills in Unit 2823, Components 02/03 and in Unit 2826, Components 02/03.

4 Scheme of Assessment

Candidates take three units of assessment, including an experimental skills component, for AS GCE, followed by a further three units of assessment, including an experimental skills component at A2, if they are seeking an Advanced GCE award.

Units of Assessment

Level	Unit/ Component (where relevant)	Name	Duration	Mode of Assessment	Weighting	
					AS	Advanced GCE
AS	**2821**	Forces and Motion	1 hour	Written Examination	30%	15%
AS	**2822**	Electrons and Photons	1 hour	Written Examination	30%	15%
AS	**2823**	Wave Properties/ Experimental Skills 1				
	/01	Wave Properties	45 mins	Written Examination	20%	10%
	/02	Coursework 1	-	Coursework	20%	10%
	/03	Practical Examination 1	1 hour 30 mins	Practical Examination	20%	10%
A2	**2824**	Forces, Fields and Energy	1 hour 30 mins	Written Examination	-	15%
A2	**2825**	Options in Physics (**one** of)				
	/01	Cosmology	1 hour 30 mins	Written Examination	-	15%
	/02	Health Physics	1 hour 30 mins	Written Examination	-	15%
	/03	Materials	1 hour 30 mins	Written Examination	-	15%
	/04	Nuclear and Particle Physics	1 hour 30 mins	Written Examination	-	15%
	/05	Telecommunications	1 hour 30 mins	Written Examination	-	15%
A2	**2826**	Unifying Concepts in Physics/ Experimental Skills 2				
	/01	Unifying Concepts in Physics	1 hour 15 mins	Written Examination	-	10%
	/02	Coursework 2	-	Coursework	-	10%
	/03	Practical Examination 2	1 hr 30 mins	Practical Examination	-	10%

Rules of Combination

Candidates must take the following combination of Units of Assessment:

AS GCE	Units 2821, 2822 and 2823
Advanced GCE	Units 2821, 2822, 2823, 2824, 2825 and 2826

Note:

- In Unit 2823 candidates take either components 01 and 02 or components 01 and 03.
- In Unit 2826 candidates take either components 01 and 02 or components 01 and 03.
- In Unit 2825, candidates take one of components 01 – 05.
- For Units 2823 and 2826, both chosen components must be taken in the same examination session.
- If a candidate re-takes either Unit 2823 and/or Unit 2826 within 12 months, they have the opportunity to carry forward the mark for the coursework component (component 02).
- All candidates for units 2823 and 2826 should be entered under the relevant unit code with one of the following option codes.

Option Code	Components to be taken	
A	01	Written Paper
	02	Coursework
B	01	Written Paper
	82	Coursework mark carried forward
C	01	Written Paper
	03	Practical Examination

- All candidates for Unit 2825 should be entered under the relevant unit code with one of the following option codes:

Option code	Component to be taken	
A	01	Cosmology
B	02	Health Physics
C	03	Materials
D	04	Nuclear and Particle Physics
E	05	Telecommunications

Unit Availability

There are two unit sessions each year, in January and June.

The availability of units is shown below.

Unit	Level	Unit Title	Jan 2005	June 2005
2821	AS	Forces and Motion	✓	✓
2822	AS	Electrons and Photons	✓	✓
2823	AS	Wave Properties / Experimental Skills 1	✓	✓
2824	A2	Forces, Fields and Energy	✓	✓
2825	A2	Options in Physics	✓	✓
2826	A2	Unifying Concepts in Physics / Experimental Skills 2	✓	✓

The availability shown for 2005 will be the same in subsequent years.

Sequence of Units

The normal sequence in which the units could be taken is Units 2821, 2822 and 2823 in the first year of a course of study, leading to an AS GCE award, then Units 2824, 2825 and 2826 in the second year, together leading to the Advanced GCE award. However, units may be taken in other sequences.

Alternatively, candidates may take all units at the end of their AS GCE or Advanced GCE course in a 'linear' manner, if desired.

Synoptic Assessment

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. Assessment Objective AO4 relates specifically to synoptic assessment. The emphasis of synoptic assessment is on understanding and application of the principles included in the specification. It accounts for 20% of the total Advanced GCE marks and is assessed only in A2 Units 2825 and 2826 (all components). Units 2825 and 2826 should normally, therefore, be taken at the end of the course, but this is no longer a requirement.

Synoptic assessment:

- requires candidates to make and use connections between different areas of physics, for example, by applying knowledge and understanding of more than one area to a particular situation or context;
- provides opportunities for candidates to use ideas and skills which permeate physics, for example, the analysis and evaluation of empirical data and other information, in contexts which may be new to them.

Questions are set in the examination papers for Units 2825 and 2826 (components 01 and 03) which will require candidates to demonstrate these abilities.

During experimental and investigative work, synoptic assessment

- allows candidates to apply knowledge and understanding of principles and concepts of physics in planning experimental work and in the analysis and evaluation of data.

All practical work assessed internally by centres for the A2 coursework component (Unit 2826 Component 02) should draw on the range of experience that the candidate has acquired during the AS course. It is particularly important that an exercise used to evaluate planning skills should involve an element of research which goes beyond the repetition of an experiment that simply reflects the use of ideas or techniques met within the module, currently being studied. Likewise an assessment involving the analysing and evaluation of evidence must require a candidate to use knowledge and understanding acquired outside the confines of a standard experiment recently practised. During the process of moderation, evidence will be sought that such breadth has been achieved.

Unit 2826, Component 02 also, therefore, includes an element of synoptic assessment.

Certification

Candidates may enter for:

- AS GCE certification;
- AS GCE certification, bank the result, and complete the A2 assessment at a later date.
- Advanced GCE certification.

Candidates must enter the appropriate AS and A2 units to qualify for the full Advanced GCE award.

Individual unit results, prior to certification of the qualification, have a shelf-life limited only by that of the qualification.

Re-sits of Units

The restrictions on re-sitting units have been removed, enabling candidates to re-take units more than once. Upon making an entry for certification, the best attempt will be counted towards the final award. This change applies to all candidates, including those who have already been entered for any units or full qualifications.

Re-sits of AS and Advanced Level

Candidates may still enter for the full qualification an unlimited number of times.

4.1 Question Papers

4.1.1 AS

Unit 2821 - Forces and Motion (1 hour) (60 marks)
Unit 2822 - Electrons and Photons (1 hour) (60 marks)

The question papers for Units 2821 and 2822 have a common format. They contain questions comprising both structured parts and parts which require more extended answers. The distribution of marks is approximately 50 marks for the structured parts and 10 marks for the extended answers. All questions on these examination papers are compulsory. Quality of written communication is assessed within those parts of the questions which require more extended answers.

Unit 2823, Component 01 – Wave Properties (45 minutes) (45 marks)

The question paper contains structured questions. Some may require more extended writing. All questions on this paper are compulsory.

Unit 2823, Component 03 - Practical Examination 1 (1 hour 30 minutes) (60 marks)

Details of the external assessment of Experimental and Investigative Skills (Practical Examination 1) can be found in Section 4.2.

The question paper consists of a Planning Exercise set by OCR and a Practical Test. Details of the Planning Exercise will be sent to Centres before the date of the Practical Test. The Practical Test consists of two questions.

4.1.2 A2

Unit 2824 - Forces, Fields and Energy (1 hour 30 minutes) (90 marks)
Unit 2825 – Options in Physics (1 hour 30 minutes) (90 marks)

The question papers for Units 2824 and 2825 (Components 01 – 05) have the same format as the question papers for Units 2821 and 2822. They contain questions comprising both structured parts and parts which require more extended answers. The distribution of marks is approximately 75 marks for the structured parts and 15 marks for the extended answers. All questions on these papers are compulsory. Quality of written communication is assessed in Unit 2824 within those parts of the questions which require more extended answers.

In each of the components 01 – 05 of Unit 2825, approximately 30 marks is allocated to questions which involve the analysis of data and/or comprehension. These synoptic questions/part questions require candidates to draw on their knowledge of modules 2821, 2822 and 2823 (Component 01) and 2824.

Unit 2826 Component 01 – Unifying Concepts in Physics (1 hour 15 minutes) (60 marks)

The question paper contains questions which require extended writing. All questions on this paper are compulsory. Candidates are expected to draw together knowledge, understanding and skills from modules 2821, 2822 and 2823 (Component 01) and module 2824 and to show connections between different aspects of physics.

Unit 2826 Component 03 – Practical Examination 2 (1 hour 30 minutes) (60 marks)

Details of external assessment of Experimental and Investigative Skills (Practical Examination 2) can be found in Section 4.2.

4.2 Experimental and Investigative Skills

Experimental and Investigative skills may be assessed either internally (by coursework) or externally (by a combination of an externally marked task and a practical examination).

Candidates' work contributing directly to coursework assessment should occupy between five and ten hours for each of AS and A2. Further time is, of course, necessary for the acquisition of experimental and investigative skills.

Entries are made for Unit 2823, Component 02 or Component 03 (in AS) and/or Unit 2826, Component 02 or Component 03 (in A2). In each of these units candidates must take two components - a written paper (Component 01) which assesses a part module of content and one of the above two assessments of experimental and investigative skills (Component 02 or Component 03). Both written paper and skills assessment components must be taken in the same examination session.

In Unit 2823 (Components 02 and 03), marks contribute towards Assessment Objective AO3, Experiment and Investigation.

In Unit 2826 (Components 02 and 03), marks contribute equally to Assessment Objectives AO3 and AO4, Synthesis of Knowledge, Understanding and Skills. There is assessment of AO4, because:

- candidates are required to use physical knowledge and understanding from other units of the specification in planning their experimental and investigative work, and in analysing evidence and drawing conclusions;
- in the assessment of all four experimental skills in Unit 2826 (Components 02 and 03), taken at the end of the course of study, candidates are expected to draw on their experience of such work throughout the course, and in particular on the outcome of the assessment of these skills in Unit 2823 (Components 02 and 03).

The Skills

The experimental and investigative skills to be assessed are:

Skill P Planning

Candidates should:

- identify and define the nature of a question or problem using available information and knowledge of science;
- choose effective and safe procedures, selecting appropriate apparatus and materials and deciding the measurements and observations likely to generate useful and reliable results.

Skill I Implementing

Candidates should:

- use apparatus and materials in an appropriate and safe way;
- carry out work in a methodical and organised way with due regard for safety;
- make and record detailed observations in a suitable way, and make measurements to an appropriate degree of precision, using IT where appropriate.
- respond to serious sources of systematic and random error by modifying procedures in order to generate results which are as accurate and reliable as allowed by the apparatus.

Skill A Analysing Evidence and Drawing Conclusions

Candidates should:

- communicate scientific information and ideas in appropriate ways, including tabulation, line graphs, histograms, continuous prose, annotated drawings and diagrams, using IT where appropriate;
- recognise and comment on trends and patterns in data;
- understand the concept of statistical significance;
- draw valid conclusions by applying scientific knowledge and understanding.

Skill E Evaluating Evidence and Procedures.

Candidates should:

- assess the reliability and precision of experimental data and the conclusions drawn from it;
- evaluate the techniques used in the experimental activity, recognising their limitations.

Internal Assessment (Coursework option)

Unit 2823, Component 02 – Coursework (60 Marks)
Unit 2826, Component 02 – Coursework (60 Marks)

Assessment of candidates' experimental and investigative work is made by the teacher (as coursework) and moderated externally by OCR.

Skills **P** and **A** are each marked out of 8 and Skills **I** and **E** are each marked out of 7. One mark per skill must be awarded for each candidate for AS (Unit 2823, Component 02) and for A2 (Unit 2826, Component 02). Hence, a raw mark out of 30 is initially calculated for each component. The marks are then doubled so that the final mark submitted for each component is out of 60.

In AS and in A2 the skills may be assessed in the context of separate practical exercises, although more than one skill may be assessed in any one exercise. The skills may also be assessed all together in the context of a single 'whole investigation' in which the task is set by the teacher, or using individual investigations in which each candidate pursues his or her own choice of assignment.

The skills may be assessed at any time during the course using suitable practical activities, based on laboratory or field work, related to or part of the content of the teaching course. The context(s) for the assessment of the coursework for Unit 2823, Component 02 should be drawn from the content of AS Units 2821, 2822 and 2823 (Component 01). The context(s) for the assessment of the coursework for Unit 2826 Component 02 should be drawn from the content of A2 Units 2824 and 2825, in which the level of demand of the related scientific knowledge and understanding is higher.

A similar set of mark descriptors is used for both AS and A2 (see Appendix C). These descriptors have been written to provide clear continuity from the assessment of Sc1 in GCSE Science. The difference in standard of AS and A2 is a product of the level of demand and complexity of the work undertaken and the level of demand of the related scientific knowledge and understanding.

It is expected that IT will be used for the capture, processing and presentation of data, where appropriate.

Notes for Guidance on Coursework assessment and submission are given in Appendix B. Mark descriptors for the experimental and investigative skills are fully detailed in Appendix C.

Further details including copies of relevant coursework forms are given in the Physics Coursework Handbook, copies of which can be ordered from the OCR Publications Department.

External Assessment (Practical Examination option)

Unit 2823, Component 03 - Practical Examination 1 (1 hour 30 minutes) (60 Marks)
Unit 2826, Component 03 - Practical Examination 2 (1 hour 30 minutes) (60 Marks)

External assessment of Experimental and Investigative Skills addresses the same skills as those covered by the Coursework option, as listed above.

Skill P Planning

Skill P is assessed using an OCR-set task which is externally marked. Candidates are asked to plan an investigation set by OCR in the context of the units they have studied. Thus, for the AS Unit 2823, Component 03, the task is set in the context of the content of Units 2821, 2822 and 2823, Component 01; for the A2 Unit 2826, Component 03, the task is set in the context of the content of Units 2824 and 2826, Component 01.

At a date, which will be published on the examination timetable, before the date of the practical examination, candidates will be given the Planning Task. Candidates' work must be handed in on or before the day of the practical examination, at the discretion of the Centre. The Centre is required to despatch this work to the examiner with the practical examination scripts, and the work must therefore be kept securely until the day of the examination. Candidates may be given access, if they request it and at the discretion of the Centre, to laboratory space and facilities in order to be able to carry out preliminary work which will help in constructing their plan. It should be noted that the responsibility for health and safety during this period rests with the Centre, and the attention of teachers is drawn to Health and Safety section in Appendix B. Access to suitable library and other resources will also be required. Whilst time at home or in private study may be necessary to complete the task to a high standard, sufficient work must be completed under direct supervision to allow the teacher to authenticate the work with confidence as that of the candidates concerned.

It should be recognised that the Planning Tasks contribute just 2.5% to the full Advanced GCE for each of the AS and A2 assessments. Candidates should thus be guided to spend an appropriate amount of time on the work and it is suggested that they should be given between 7-10 days to complete it. Candidates work should be no more than 500 words.

If a candidate is given guidance during the period in which the task has to be completed, this must be recorded and submitted with the candidate's work.

The mark scheme for the Planning Task is closely based on the coursework mark descriptors for Skill P, shown in Appendix C, and a copy of these descriptors should be provided to candidates to assist them in their work.

Skill I **Implementing**

Skill A **Analysing Evidence and Drawing Conclusions**

Skill E **Evaluating Evidence and Procedures.**

Skills I, A and E are assessed in the practical examination itself which consists of two questions. Candidates are asked to carry out a practical experiment (Question 1) which will be set in the same general context as that used for the planning exercise, but will not be the same task. Thus, while the research work carried out for the planning task may assist candidates in their interpretation of the results of the experiment, they will not be asked to carry out the investigation they have planned.

Question 2 in the Practical Test is also a practical experiment, shorter in length than the first question.

Skill **I** is assessed on the conduct of the experiments and the observations and/or measurements taken, and Skills **A** and **E** are assessed on candidates' analysis and evaluation of the results of the experiments, together with other data and information given in the paper itself.

The mark scheme for the paper is closely based on the coursework mark descriptors for these skills (see Appendix C) and teachers are recommended to draw these to the attention of candidates in their preparation for the paper.

Details of the apparatus and/or materials required for the practical examination are sent to Centres before the date of the examination. Centres should contact OCR if Instructions are not received. It is essential that confidentiality is maintained in advance of the examination date.

Further details concerning the administration and conduct of this option are given in Appendix J.

4.2.1 Experimental and Investigative Work at AS and A2

The assessment descriptors given in Appendix C are used for the assessment of coursework in both AS and A2. The mark schemes for the practical examinations are also based on these descriptors which are similar for both AS and A2 components.

Assessments at AS and A2 are differentiated by the complexity of the tasks set and the contexts of the underlying scientific knowledge and understanding. In A2, candidates will be required to apply knowledge, understanding and skills from the AS and A2 parts of the specification in planning experimental work and in the evaluation of data (synoptic assessment).

At AS, experimental and investigative work is likely to be qualitative or require processing in a context that is familiar to students.

- Planning exercises, although novel, focus on apparatus and techniques which have previously been encountered, based on knowledge and understanding from a limited part of the AS specification.
- Implementing involves the manipulation of simple apparatus and the application of easily recognised safety procedures.
- Analysing and concluding involves simple data handling, reaching conclusions based on a limited part of the AS specification.
- Evaluation expects the recognition of the main sources of error and direct methods for improving accuracy.

At A2, assessments will expect a greater level of sophistication and higher levels of skill.

- Planning exercises require research to provide a satisfactory solution to a problem which can be addressed in more than one way. The underlying knowledge, understanding and skills will be drawn from several different parts of the AS and A2 specifications.
- Implementing involves a detailed risk assessment and the careful use of sophisticated techniques or apparatus to obtain results that are precise and reliable.
- Analysing and concluding involves sophisticated data handling and the synthesis of several strands of evidence. In developing conclusions, candidates will have the opportunity to demonstrate their skills in drawing together principles and concepts from different parts of the AS and A2 specifications.
- Evaluation requires recognition of the key experimental limitations and other sources of error as well as an understanding of the methods that may be used to limit their effect. The evaluation is likely to draw together principles and concepts from different parts of the specification.

Detailed advice on the choice of experimental and investigative work suitable for AS and A2, and guidance on the application of the assessment descriptors to exemplar tasks, is provided in the Physics Coursework Handbook, which can be ordered from the OCR Publications Department.

4.2.2 Assessment and Moderation

Coursework in Unit 2823, Component 02 and Unit 2826, Component 02 is marked by the teacher and internally standardised by the Centre. Marks are then submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures. The purpose of moderation is to ensure that the standards for the award of marks in coursework are the same for each Centre, and that each teacher has applied the standards appropriately across the range of candidates within the Centre.

Coursework submissions should be clearly annotated by the Centre to support the marks awarded to the candidates.

The sample of work which is submitted to the Moderator for moderation must show how the marks have been awarded in relation to the marking criteria.

4.2.3 Minimum Coursework Requirements

If a candidate submits no work for a coursework component, Unit 2823, Component 02 and/or Unit 2826, Component 02, then the candidate should be indicated as being absent from that component on the coursework mark sheets submitted to OCR. If a candidate completes any work at all for the coursework component then the work should be assessed according to the mark descriptors and marking instructions and the appropriate mark awarded, which may be 0 (zero).

4.2.4 Authentication of Coursework

As with all coursework, the teacher is required to verify that the work submitted for assessment is the candidate's own. Sufficient work must be carried out under direct supervision to allow the teacher to authenticate the coursework marks with confidence.

4.3 Special Arrangements

For candidates who are unable to complete the full assessment or whose performance may be adversely affected through no fault of their own, teachers should consult the *Inter-Board Regulations and Guidance Booklet for Special Arrangements and Special Consideration*. In such cases advice should be sought from OCR as early as possible during the course. Applications for special consideration in coursework components should be accompanied by Coursework Assessment Forms, giving the breakdown of marks for each skill.

4.4 Differentiation

In the question papers, differentiation is achieved by setting questions which are designed to assess candidates at their appropriate levels of ability and which are intended to allow all candidates to demonstrate what they know, understand and can do.

In coursework, differentiation is by task and by outcome. Candidates undertake assignments which enable them to display positive achievement.

4.5 Awarding of Grades

The AS has a weighting of 50% when used in an Advanced GCE award. The Advanced GCE award is based on the certification of the weighted AS (50%) and A2 (50%) marks.

Both AS GCE and Advanced GCE qualifications are awarded on the scale A to E, or U (unclassified).

4.6 Grade Descriptions

The following grade descriptions indicate the level of attainment characteristic of the given grade at Advanced GCE. They give a general indication of the required learning outcomes at each specified 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 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 some 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 that 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 implementation. They present results appropriately and provide some descriptive interpretation of the outcomes of the investigation

.

5 Specification Content

Throughout this section the symbol is used in the margin to highlight where Key Skills development opportunities are signposted. For more information on Keys Skills coverage please refer to Appendix A.

5.1 Module 2821: Forces and Motion

Aims

In addition to the general aims of the specifications, this module is intended to build on the knowledge, understanding and skills set out in the National Curriculum Key Stage 4 programme of study for Science: Double Award and to provide a foundation for the study of further modules.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this module to new situations and/or to solve related problems. Candidates are expected to use physical quantities, units and measurement techniques appropriate to the content of this module.

5.1.1 Scalars and Vectors

Recommended Prior Knowledge

Candidates should appreciate that some quantities have magnitude only; others have magnitude and direction.

Content

- Scalars and vectors
- Combination and resolution of vectors

Learning Outcomes

Candidates should be able to:

(a) distinguish between scalar and vector quantities and give examples.

(b) use a vector triangle to determine the resultant of two coplanar vectors.

(c) calculate the resultant of two perpendicular vectors.

(d) resolve a vector into two perpendicular components.

(e) understand the independent nature of perpendicular components of a vector.

5.1.2 Kinematics

N3.2; IT3.2, IT3.3.

Recommended Prior Knowledge

Candidates should know:

- the quantitative relationship between speed, distance and time. (*KS3*)
- how distance, time and speed can be determined and represented graphically. (*4.2a*)
- about acceleration as change in velocity per unit time. (*4.2d*)

Content

- Rectilinear motion
- Non-linear motion

Learning Outcomes

Candidates should be able to:

(a) define displacement, speed, velocity and acceleration.

(b) use graphical methods to represent distance travelled, displacement, speed, velocity and acceleration.

(c) find the distance travelled by calculating the area under a speed-time graph.

(d) use the slope of a displacement-time graph to find velocity, and of a distance-time graph to find speed.

(e) use the slope of a velocity-time graph to find acceleration.

(f) derive, from the definitions of velocity and of acceleration, equations which represent uniformly accelerated motion in a straight line.

(g) use equations which represent uniformly accelerated motion in a straight line, including falling in a uniform gravitational field without air resistance.

(h) interpret displacement-time and speed-time graphs for motion with non-uniform acceleration.

(i) explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction.

5.1.3 Dynamics

Recommended Prior Knowledge

Candidates should know:

- that balanced forces do not alter the velocity of a moving object. (*4.2e*)
- the quantitative relationship between force, mass and acceleration. (*4.2f*)
- the force acting on falling bodies. (*4.2h*)
- why falling bodies reach a terminal velocity. (*4.2i*)

Content

- Mass, density and weight
- Force, mass and acceleration

Learning Outcomes

Candidates should be able to:

(a) demonstrate an understanding that mass is the property of a body which resists change in motion.

(b) define and use the equation *density* = *mass*/*volume*.

(c) recall and use the equation $F = ma$, in situations where mass is constant, appreciating that force and acceleration are always in the same direction.

(d) define the newton.

(e) describe and use the concept of weight as the effect of a gravitational field on a mass.

(f) recall and use the relationship *weight* = *mass* x *gravitational field strength*.

(g) describe qualitatively the motion of bodies falling in a uniform gravitational field with fluid resistance.

5.1.4 Force, Work and Power

Recommended Prior Knowledge

Candidates should know:

- that forces can cause objects to turn about a pivot. (*KS3*)
- the principle of moments and its application to situations involving one pivot. (*KS3*)
- the quantitative relationship between the force acting normally per unit area on a surface and the pressure on that surface. (*KS3*)

- the quantitative relationship between force and work. (*4.5f*)
- how to calculate power in terms of working or transferring energy. (*4.5g*)

Content

- Centre of gravity
- Turning effects of forces
- Equilibrium of forces
- Pressure
- Work and Energy
- Power

Learning Outcomes

Candidates should be able to:

(a) understand that the weight of a body may be taken as acting at a single point known as its centre of gravity.

(b) understand a couple as a pair of equal parallel forces tending to produce rotation only.

(c) define and use the moment of a force and the torque of a couple.

(d) show an understanding that, when there is no resultant force and no resultant torque, a system is in equilibrium.

(e) apply the principle of moments to solve problems involving forces acting in two dimensions.

(f) define pressure.

(g) recall and use the equation $p = \frac{F}{A}$

(h) understand the concept of work in terms of the product of force and displacement in the direction of the force.

(i) define the joule.

(j) recall and use the equation $W = Fx$, where F is a constant force along the direction of motion.

(k) recall and use equations for kinetic energy $\Delta E_k = ½\, mv^2$ and change in gravitational potential energy $\Delta E_p = mg\Delta h$.

(l) relate power to work done and time taken.

(m) define the watt.

(n) recall and use the equation $W = Pt$.

5.1.5 Deformation of Solids

C3.3; N3.2, N3.3.	**WO3.1**

Recommended Prior Knowledge

Candidates should know how extension varies with applied force for a range of materials. (*4.2j*)

Content

- Tensile stress and strain
- Elastic and plastic behaviour

Learning Outcomes

Candidates should be able to:

(a) appreciate that deformation is caused by a pair of forces and that, in one dimension, the deformation can be tensile or compressive.

(b) describe the behaviour of springs and wires in terms of load, extension, Hooke's law and the spring constant.

(c) define and use the terms elastic limit, stress, strain and the Young modulus.

(d) describe an experiment to determine the Young modulus of a metal in the form of a wire.

(e) distinguish between elastic and plastic deformation of a material.

(f) deduce the strain energy in a deformed material from the area under the force-extension graph.

(g) demonstrate knowledge of the force-extension graphs for typical ductile, brittle and polymeric materials, including an understanding of ultimate tensile stress.

5.1.6 Forces on vehicles

Recommended Prior Knowledge

Candidates should know:

- that when two bodies interact, the forces they exert on each other are equal and opposite. (*4.2g*)
- sections 5.1.1 – 5.1.4 of this module.

Content

- Motive forces
- Motive power

Learning Outcomes

Candidates should be able to:

(a) understand the terms motive force and braking force.

(b) describe how driving wheels can generate a motive force.

(c) explain the importance of friction in acceleration and deceleration.

(d) recall and use the relationship *motive power* = *driving force* x *speed*.

Car Safety

C3.1a; IT3.1	WO3.1.

Recommended Prior Knowledge

Candidates should know:

- about factors affecting vehicle stopping distance. (*4.2b*)
- sections 5.1.1 – 5.1.5 of this module.

Content

- Car safety

Learning Outcomes

Candidates should be able to:

(a) analyse car accidents using equations of uniformly accelerated motion and $F = ma$.

(b) describe the physical principles of seat belts, air bags and crumple zones.

(c) understand and make calculations using the terms thinking distance, braking distance and stopping distance.

(d) relate qualitatively tyre tread and road conditions to braking distance.

5.2 Module 2822: Electrons and Photons

Aims

In addition to the general aims of the specifications, this module is intended to build on the knowledge, understanding and skills set out in the National Curriculum Key Stage 4 programme of study for Science: Double Award and to provide a foundation for the study of further modules.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this module to new situations and/or to solve related problems. Candidates are expected to use physical quantities, units and measurement techniques appropriate to the content of this module.

5.2.1 Electric Current

C3.3; IT3.1, IT3.3.	**PS3.1, PS3.3.**

Recommended Prior Knowledge

Candidates should know:

- the quantitative relationship between resistance, voltage and current. (*4.1f*)
- that resistors are heated when charge flows in them. (*4.1c*)
- how current varies in a range of devices, including resistors, filament bulbs, diodes, light-dependent resistors (LDRs) and thermistors, (*4.1g*)
- the quantitative relationship between steady current, charge and time. (*4.1p*)
- that electric current is the flow of free electrons in metals (or of ions during electrolysis). (*4.1q*)
- that voltage is the energy transferred per unit charge. (*4.1h*)
- the quantitative relationship between power, voltage and current. (*4.1i*)

Content

- Electric current
- Potential difference
- Ohm's law
- Resistance and resistivity
- Electrical energy and power

Learning Outcomes

Candidates should be able to:

(a) understand electric current as a net flow of charged particles.

(b) understand the concept of charge in terms of the product of current and time.

(c) recall and use $\Delta Q = I\Delta t$.

(d) define the coulomb.

(e) appreciate the difference between the directions of conventional current and of electron flow.

(f) define potential difference and the volt in terms of energy transfer.

(g) recall and use $V = \dfrac{W}{Q}$ and $V = \dfrac{P}{I}$.

(h) sketch and explain the I/V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp.

(i) define resistance and the ohm.

(j) recall and use $R = \dfrac{V}{I}$.

(k) state Ohm's law.

(l) define resistivity.

(m) recall and use $\rho = \dfrac{RA}{l}$.

(n) recall and use $P = I^2 R$ and $P = V^2 / R$.

(o) recall and use $W = IVt$.

(p) understand and use the kilowatt-hour (kW h) as a unit of energy.

(q) sketch the variation with temperature of the resistance of a pure metallic conductor and of a negative temperature coefficient (NTC) thermistor.

5.2.2 D.C. Circuits

Recommended Prior Knowledge

Candidates should know:

- how to measure current in series and parallel circuits. (*4.1a*)
- that energy is transferred from batteries and other sources to other components in electrical circuits. (*4.1b*)
- the qualitative effect of changing resistance on the current in a circuit. (*4.1d*)
- how to make measurements of voltage. (*4.1e*)

Content

- Practical circuits
- Electromotive force and internal resistance
- Kirchhoff's laws
- Series and parallel arrangements
- Potential divider

Learning Outcomes

Candidates should be able to:

(a) recall and use appropriate circuit symbols as set out in *SI Units, Signs, Symbols and Abbreviations* (ASE, 1981) and *Symbols and Systematics* (ASE, 1995).

(b) draw and interpret appropriate circuit diagrams.

(c) use the concept that e.m.f. is defined in terms of the energy transferred by a source in driving unit charge round a complete circuit.

(d) use energy considerations to distinguish between e.m.f. and p.d.

(e) appreciate that sources of e.m.f. have internal resistance and understand the simple consequences of internal resistance for external circuits.

(f) recall Kirchhoff's first law and appreciate this as a consequence of conservation of charge.

(g) understand Kirchhoff's second law as a consequence of conservation of energy.

(h) recall and use a formula for the combined resistance of two or more resistors in series.

(i) recall and use a formula for the combined resistance of two or more resistors in parallel.

(j) solve problems involving series and parallel circuits for one source of e.m.f.

(k) understand the use of a potential divider as a source of variable p.d.

(l) describe and explain the use of thermistors and light-dependent resistors in potential dividers to provide a potential difference which is dependent on temperature and on light intensity respectively.

5.2.3 Magnetic effects of current

Recommended Prior Knowledge

Candidates should know:

- that a current in a coil produces a magnetic field pattern. (*KS3*)
- that a force is exerted on a current-carrying wire in a magnetic field (and the application of this in simple electric motors). (*4.1s*)

Content

- Magnetic fields caused by electric currents
- Forces acting on current-carrying conductors

Learning Outcomes

Candidates should be able to:

(a) sketch magnetic field patterns caused by current in a long straight wire, a flat circular coil and a long solenoid.

(b) appreciate that a force may act on a current-carrying conductor placed in a magnetic field.

(c) recall and use $F = BIl$, with directions as interpreted by Fleming's left-hand rule.

(d) define magnetic flux density and the tesla.

(e) use Fleming's left-hand rule to predict the direction of forces acting on two long, straight parallel current-carrying conductors.

(f) understand that the forces between current-carrying conductors provide the basis of the definition of ampere - no definition required.

5.2.4 Quantum Physics

IT3.1.	

Recommended Prior Knowledge

Candidates should know:

- that waves transfer energy without transferring matter. (*4.3g*)
- the meaning of frequency, wavelength and amplitude of a wave. (*4.3e*)
- the quantitative relationship between speed, frequency and wavelength of a wave. (*4.3f*)
- that waves can be reflected, refracted and diffracted. (*4.3d*)
- how energy is transferred by radiation. (*4.5c*)

Content

- Energy of a photon
- Photoelectric emission
- Wave-particle duality

Learning Outcomes

Candidates should be able to:

(a) describe the photoelectric effect.

(b) appreciate that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provide evidence for a wave nature.

(c) show an appreciation of the particulate nature of electromagnetic radiation, i.e. a photon model.

(d) recall and use $E = hf$.

(e) explain why the maximum kinetic energy of photoelectrons is independent of intensity, and why the photoelectric current is proportional to intensity of the incident radiation.

(f) explain photoelectric phenomena in terms of photon energy and work function energy.

(g) recall, use and explain the significance of $hf = \phi + \frac{1}{2}mv_{max}^2$, where ϕ is the work function energy of the surface.

(h) explain the significance of threshold frequency.

(i) define, understand and use the electronvolt (eV) as a unit of energy.

(j) describe and interpret qualitatively the experimental evidence provided by electron diffraction for the wave nature of particles.

(k) recall and use the de Broglie equation $\lambda = \frac{h}{mv}$.

5.2.5 *Electromagnetic Waves*

IT3.3.	

Recommended Prior Knowledge

Candidates should know that the electromagnetic spectrum includes radio waves, microwaves, infra-red, visible light, ultra-violet waves, X-rays and gamma-rays. (*4.3h*)

Content

- Electromagnetic waves

Learning Outcomes

Candidates should be able to:

(a) describe the main features of the electromagnetic spectrum and recall that all electromagnetic waves travel with the same speed in free space.

(b) recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays.

5.3 Module 2823, Component 01: Wave Properties

Aims

In addition to the general aims of the Scheme, this component is intended to build on the knowledge, understanding and skills set out in the National Curriculum Key Stage 4 programme of study for Science: Double Award and to provide a foundation for the study of further modules.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems. Candidates are expected to use physical quantities, units and measurement techniques appropriate to the content of this component.

5.3.1 Reflection and Refraction

Recommended Prior Knowledge

Candidates should know:

- that light (and sound) can be reflected, refracted (and diffracted). (*4.3a*)
- the conditions for total internal reflection (and its use in optic fibres). (*4.3b*)

Content

- Refraction of light
- Total internal reflection

Learning Outcomes

Candidates should be able to:

(a) recall the laws of refraction of light.

(b) define refractive index n as c_i / c_r and recall the use of the expression $n = \sin i / \sin r$.

(c) describe what is meant by critical angle and total internal reflection.

(d) relate refractive index to critical angle by the equation $n = 1 / \sin C$.

(e) describe the application of total internal reflection to the transmission of light along an optic fibre.

(f) demonstrate an awareness of multipath dispersion of a pulse of light in an optic fibre and how, in practice, this problem is overcome.

5.3.2 Waves

Recommended Prior Knowledge

Candidates should know:

- that waves transfer energy without transferring matter. (*4.3g*)
- about longitudinal waves and transverse waves in ropes, springs and water. (*4.3c*)
- the meaning of frequency, wavelength and amplitude of a wave. *(4.3e)*
- the quantitative relationship between speed, frequency and wavelength of a wave. (*4.3f*)
- that waves can be reflected, refracted and diffracted. (*4.3d*)

Content

- Progressive waves
- Transverse waves
- Longitudinal waves
- Polarisation

Learning Outcomes

Candidates should be able to:

(a) describe what is meant by wave motion as illustrated by vibrations in ropes, springs and ripple tanks.

(b) appreciate that waves can be reflected and refracted.

(c) understand and use the terms displacement, amplitude, period, phase difference, frequency, wavelength and speed.

(d) deduce, from the definitions of speed, frequency and wavelength, the equation $v = f\lambda$.

(e) recall and use the equation $v = f\lambda$.

(f) appreciate the energy transfer due to a progressive wave.

(g) describe the nature of the motions in transverse and longitudinal waves.

(h) interpret graphical representations of transverse and longitudinal waves.

(i) understand polarisation as a phenomenon associated with transverse waves.

(j) determine the frequency of sound using a calibrated c.r.o.

5.3.3 Superposition

Recommended Prior Knowledge

Candidates should know that waves can be reflected, refracted and diffracted. (*4.3d*)

Content

- Interference
- Standing waves
- Diffraction
- Two-source interference

Learning Outcomes

Candidates should be able to:

(a) explain and use the principle of superposition.

(b) understand the term interference.

(c) explain the meaning of the terms coherence and path difference.

(d) describe experiments which demonstrate standing (stationary) waves for stretched strings, air columns and microwaves.

(e) explain the formation of a standing wave using a graphical method, and identify nodes and antinodes.

(f) explain the meaning of the term diffraction.

(g) describe experiments which demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap.

(h) describe experiments which demonstrate two-source interference in a ripple tank, for light and for microwaves.

(i) recall and use the equation $\lambda = \dfrac{ax}{D}$ for double slit interference using light.

5.4 Module 2824: Forces, Fields and Energy

Aims

In addition to the general aims of the Scheme, this Module is intended to develop a further understanding of the links between various topics in physics through a study of the forces, fields and energies involved.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this module to new situations and/or to solve related problems. Candidates are also expected to use physical quantities, units and measurement techniques appropriate to the content of this module.

5.4.1 Dynamics

Recommended Prior Knowledge

Candidates should know that, when two bodies interact, the forces they exert on each other are equal and opposite. (*4.2g*)

Content

- Newton's law of motion.
- Linear momentum and its conservation.

Learning Outcomes

Candidates should be able to:

(a) state each of Newton's laws of motion.

(b) define, recall and use (linear) momentum as the product of mass and velocity.

(c) define force as rate of change of momentum, and use this definition in situations where mass is constant.

(d) state the principle of conservation of momentum.

(e) use the principle of conservation of momentum in simple applications including elastic and inelastic interactions between two bodies in one dimension, and the separation of an initially stationary object into two parts. (Knowledge of the concept of coefficient of restitution is not required.)

5.4.2 *Work and Energy*

Recommended Prior Knowledge

Candidates should know:

- the meaning of energy efficiency (and the need for economical use of energy resources). (*4.5e*)
- the quantitative relationship between force and work. (*4.5f*)
- the quantitative links between kinetic energy, potential energy, and work. (*4.5h*)
- Module 2821, section 5.1.4.

Content

- Energy conversion and conservation
- Work done
- Gravitational potential energy, kinetic energy

Learning Outcomes

Candidates should be able to:

(a) give examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples.

(b) calculate the work done by a constant force in situations including those where the force is not in the same direction as the displacement.

(c) recall and use the equation for kinetic energy, $E_k = ½mv^2$.

(d) recall and use, the equation $\Delta E_p = mg\Delta h$ for potential energy changes near the Earth's surface.

5.4.3 *Motion in a Circle*

Recommended Prior Knowledge

Candidates should know Module 2821, sections 5.1.1, 5.1.2 and 5.1.3.

Content

- Kinematics of uniform circular motion
- Centripetal acceleration

Learning outcomes

Candidates should be able to:

(a) describe qualitatively motion in a curved path due to a perpendicular force, and understand the centripetal acceleration in the case of uniform motion in a circle.

(b) express angular displacement in radians.

(c) recall and use centripetal acceleration $a = v^2 / r$.

(d) apply the equation $F = ma$ to uniform motion in a circle to derive $F = mv^2 / r$.

5.4.4 Oscillations

N3.2, N3.3.

WO3.2, WO3.3; PS3.1.

Recommended Prior Knowledge

Candidates should know Module 2821, sections 5.1.1, 5.1.2, 5.1.3 and 5.1.4.

Content

- Simple harmonic motion
- Energy in simple harmonic motion
- Damped and forced oscillations
- Resonance

Learning Outcomes

Candidates should be able to:

(a) understand and use the terms displacement, amplitude, period, frequency and phase difference.

(b) express period in terms of frequency.

(c) define simple harmonic motion.

(d) describe graphically the changes in displacement, velocity and acceleration during oscillations.

(e) understand velocity as the gradient of the displacement-time graph.

(f) recall and use $a = -(2\pi f)^2 x$, and the solutions $x = A\sin 2\pi f\, t$, $x = A\cos 2\pi f\, t$ for simple harmonic motion.

(g) describe practical examples of damped oscillations with particular reference to the effects of the degree of damping in such cases as a car suspension system.

(h) describe practical examples of forced oscillations and resonance.

(i) describe graphically how the amplitude of a forced oscillation changes with frequency near to the natural frequency of the system.

5.4.5 Gravitational Fields

Recommended Prior Knowledge

Candidates should know Module 2821, sections 5.1.1, 5.1.2, 5.1.3 and 5.1.4.

Content

- Concept of gravitational field
- Force between point masses
- Gravitational field of a point mass

Learning Outcomes

Candidates should be able to:

(a) understand a gravitational field as a field of force and define, recall and use gravitational field strength as force per unit mass.

(b) use field lines to represent a gravitational field.

(c) recall and use Newton's law of gravitation for point masses in the form $F = Gm_1m_2 / r^2$.

(d) recall and use $g = Gm / r^2$ for the gravitational field strength of a point mass.

(e) appreciate that, on the surface of the Earth, the magnitude of g is approximately constant and equal to the acceleration of free fall.

5.4.6 Electric fields

Recommended Prior Knowledge

Candidates should know:

- about common electrostatic phenomena in terms of the movement of electrons. (*4.1n*)
- Module 2822, section 5.2.1.

Content

- Concept of an electric field
- Force between point charges
- Electric field of a point charge
- Uniform electric fields

Learning Outcomes

Candidates should be able to:

(a) understand an electric field as an example of a field of force and define, recall and use electric field strength as force per unit positive charge.

(b) use field lines to represent an electric field.

(c) recall and use Coulomb's law for point charges in a vacuum in the form $F = kQ_1Q_2 / r^2$, where $k = 1 / 4\pi\varepsilon_0$.

(d) recall and use $E = kQ / r^2$ for the electric field strength of a point charge.

(e) recall and use $E = V/d$ for the magnitude of the uniform electric field strength between charged parallel plates.

(f) recognise the similarities of, and differences between, electric fields and gravitational fields.

5.4.7 *Capacitors*

N3.2, N3.3.	

Recommended Prior Knowledge

Candidates should know Module 2822, sections 5.2.1 and 5.2.2.

Content

- Capacitors and capacitance
- Capacitors in series and parallel
- Energy stored in a charged capacitor
- Discharge of a capacitor

Learning Outcomes

Candidates should be able to:

(a) define capacitance and the farad.

(b) recall and use $C = Q / V$.

(c) use formulae for the capacitance of capacitors in series and in parallel.

(d) recall and use $W = ½QV$, for the energy of a charged capacitor.

(e) describe the discharge of a capacitor through a resistor, sketch graphs showing the variation with time of the potential difference, charge stored and current during this discharge.

(f) appreciate the practical importance of time constant for discharge of a capacitor through a resistor.

(g) recall $\tau = CR$ for the time constant of a capacitor-resistor circuit.

(h) use equations of the form $x = x_0 \, e^{-t/CR}$ for the discharge of a capacitor.

5.4.8 *Electromagnetism*

	WO3.2, WO3.3.

Recommended Prior Knowledge

Candidates should know Module 2822, section 5.2.3.

Content

- Force on a current-carrying conductor
- Force on a moving charge
- Circular orbits

Learning Outcomes

Candidates should be able to:

(a) recall and use $F = BIl\sin\theta$, with directions as interpreted by Fleming's left-hand rule, for the force on a current-carrying conductor in a uniform magnetic field.

(b) recall and use $F = BQv$, for the force on a charge moving in a uniform magnetic field.

(c) analyse the circular orbits of charged particles moving in a plane perpendicular to a uniform magnetic field by relating the electromagnetic force to the centripetal acceleration it causes.

5.4.9 Electromagnetic Induction

WO3.2, WO3.3.

Recommended Prior Knowledge

Candidates should know:

- that the voltage is induced when a conductor cuts magnetic field lines and when the magnetic field through a coil changes. (*4.1t*)
- how simple a.c. generators and transformers work. (*4.1u*)
- Module 2822, section 5.2.3.

Content

- Magnetic flux
- Magnetic flux linkage
- Laws of electromagnetic induction

Learning Outcomes

Candidates should be able to:

(a) define magnetic flux and the weber.

(b) recall and use $\Phi = BA$.

(c) define magnetic flux linkage, $N\Phi$.

(d) recall and use Faraday's law of electromagnetic induction.

(e) recall and use Lenz's law to determine the direction of an induced e.m.f.

(f) recall and use the equation *magnitude of induced e.m.f. = rate of change of flux linkage*.

5.4.10 *Thermal Physics*

Recommended Prior Knowledge

- Candidates should know that differences in temperature can lead to transfer of energy. (4.5a)
- Module 2821, section 5.1.4.
- Module 2822, section 5.2.1.

Content

- Internal energy
- Temperature scales
- Specific heat capacity
- The ideal gas equation
- Kinetic energy of a molecule

Learning Outcomes

Candidates should be able to:

(a) show an awareness that internal energy is determined by the state of the system and can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of the system.

(b) relate a rise in temperature of a body to an increase in internal energy.

(c) demonstrate knowledge that there is an absolute scale of temperature which does not depend upon the physical property of any particular substance, i.e. the thermodynamic scale.

(d) appreciate that, on the thermodynamic (Kelvin) scale, absolute zero is the temperature at which all substances have a minimum internal energy.

(e) show familiarity with temperatures measured in kelvin and degrees Celsius.

(f) define and use specific heat capacity, and show an awareness of the principle of its determination by an electrical method.

(g) recall and use $\Delta Q = mc\Delta\theta$.

(h) describe melting and boiling in terms of energy input without a change in temperature.

(i) recall and use the ideal gas equation $pV = nRT$, where n is the amount of gas in moles.

(j) appreciate that one mole is 6.02×10^{23} particles and that 6.02×10^{23} mole^{-1} is the Avogadro constant N_A .

(k) recall that the mean kinetic energy of a molecule of an ideal gas is proportional to the thermodynamic temperature.

5.4.11 The Nuclear Atom

C3.1b.

Recommended Prior Knowledge

Candidate should know:

- the nature of alpha (and beta) particles (and of gamma radiation). (*4.6b*)
- Module 2822, section 5.2.4.

Content

- Probing matter
- The nucleus
- Isotopes
- Mass difference and nuclear binding energy
- Nuclear processes

Learning Outcomes

Candidates should be able to:

(a) demonstrate a qualitative understanding of the α-particle scattering experiment and the evidence this provides for the existence, charge and small size of the nucleus.

(b) demonstrate a qualitative understanding of X-ray diffraction and the evidence this provides for crystal structure.

(c) demonstrate a qualitative understanding of neutron diffraction and the evidence this provides for crystal structure.

(d) demonstrate a qualitative understanding of electron diffraction and the evidence this provides for the spacing of atoms.

(e) demonstrate a qualitative understanding of high-energy electron scattering and the evidence this provides for the radius of the nucleus.

(f) show an awareness of the relative sizes of nuclei, atoms and molecules.

(g) distinguish between nucleon (mass) number and proton (atomic) number.

(h) understand that an element can exist in various isotopic forms, each with a different number of neutrons.

(i) use the usual notation for the representation of nuclides and represent simple nuclear reactions by nuclear equations.

(j) appreciate the equivalence between mass and energy, and recall and use the equation $\Delta E = \Delta mc^2$.

(k) appreciate that nuclear processes involve the conservation of charge and of mass-energy.

(l) describe the processes of nuclear fission and nuclear fusion and appreciate that these reactions involve a release of energy.

5.4.12 Radioactivity

C3.2; N3.2.	WO3.2, WO3.3.

Recommended Prior Knowledge

Candidates should know:

- that radioactivity arises from the breakdown of an unstable nucleus. (*4.6a*)
- that there is background radiation. (*4.6b*).
- that there are three types of radioactive emission with different penetrating powers. (*4.6c*).
- the nature of alpha and beta particles and of gamma radiation. (*4.6d*)
- the meaning of the term 'half-life'. (*4.6e*)

Content

- Types of ionising radiation
- Hazards and safety precautions
- Radioactive decay

Learning Outcomes

Candidates should be able to:

(a) appreciate the spontaneous and random nature of radioactive decay of unstable nuclei.

(b) describe the nature, penetration and range of α-particles, β-particles and γ-rays as different types of ionising radiation.

(c) represent radioactive decay by nuclear equations.

(d) show an awareness of the hazards of ionising radiation and the safety precautions which should be taken in the handling, storage and disposal of radioactive materials.

(e) define the terms activity and decay constant.

(f) recall and use $A = \lambda N$.

(g) recognise, use and represent graphically solutions of the decay law bases on $x = x_0 e^{-\lambda t}$ for activity, number of undecayed nuclei and corrected count rate.

(h) define half-life as the mean time for the number of nuclei of a nuclide to halve.

(i) use the relation $\lambda t_{½} = 0.693$.

5.5 Module 2825, Component 01: Cosmology

WO3.1, WO3.2, WO3.3.

Aims

In addition to the general aims of the specifications, this component is intended to build on the knowledge, understanding and skills in modules 2821, 2822 and 2824 and to provide insight into the large-scale structure of the Universe.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems. Candidates are also expected to use physical quantities, units and measurement techniques appropriate to the content of this component.

5.5.1 Models of the Known Universe

Recommended Prior Knowledge

Candidates should know Module 2824, sections 5.4.3 and 5.4.5.

Content

- Early models
- Newton's law of Gravitation
- Scale of the Universe

Learning Outcomes

Candidates should be able to:

(a) describe the models of the Universe as proposed by Copernicus and Kepler.

(b) describe the progress in the understanding of the Universe as a result of the work of Copernicus, Kepler and Galileo.

(c) use Newton's law of Gravitation to derive an expression for the radius of the circular orbit of a planet around the Sun in terms of the period of the orbit.

(d) recall and use Kepler's laws as applied to circular orbits.

(e) recall how the existence of Neptune was predicted from the orbit of Uranus.

(f) appreciate the significance of Kepler's third law as evidence of Newton's law of Gravitation.

(g) describe the contents of the Solar System in terms of the Sun, planets, planetary satellites and comets. Details of individual planets are not required.

(h) show awareness of the principal contents of the Universe, including stars, galaxies and radiation.

(i) define distances measured in astronomical units (AU), parsecs (pc) and light-years.

(j) recall the approximate magnitudes, in metres, of the AU, pc and light-year.

(k) recall the distances involved between objects in the Universe, including distance to nearest stars, distance across a galaxy, size of observable Universe.

(l) appreciate the range of magnitudes of the sizes and masses of objects in the Universe.

5.5.2 Stars and Galaxies

Recommended Prior Knowledge

Candidates should know Module 2824 section 5.4.5 and 5.4.11.

Content

- Magnitude of stars and galaxies
- Temperature of stars
- Evolution of stars
- Structure of galaxies

Learning Outcomes

Candidates should be able to:

(a) describe the nuclear fusion processes taking place within the Sun.

(b) calculate the energy released as a result of the fusion processes taking place within the Sun.

(c) understand and use the magnitude scales for stars and galaxies.

(d) recall and use the equation $m = -2.5 \lg I + \text{constant}$, where m is the apparent magnitude and I is the intensity.

(e) understand the concept of absolute magnitude M.

(f) recall and use the inverse square law to derive the relation between apparent magnitude, absolute magnitude and distance: $m - M = 5 \lg (r/10)$.

(g) recall and use the relationship $m - M = 5 \lg (r/10)$.

(h) sketch and interpret a Hertzsprung-Russell diagram of absolute magnitude plotted against temperature in order to recognise and identify different classes of star.

(i) describe how clouds of gas, consisting mainly of hydrogen and helium, form into young Main Sequence stars.

(j) describe the probable evolution of the Sun into a red giant and represent this evolution on a Hertzsprung-Russell diagram.

(k) recall that the Main Sequence stars may evolve into red giants, white dwarfs, supernovae, neutron stars or black holes.

(l) recall and understand that the nuclear processes occurring in a star, the time it spends on the Main Sequence and its ultimate fate depends on its mass.

(m) describe the structure of our own Galaxy and the Sun's position in it.

(n) explain qualitatively how other galaxies differ from our own.

(o) recall and use Newton's law of Gravitation to relate the mass of a galaxy to orbital speed within it.

5.5.3 *Structure of the Universe*

Content

- Olbers' paradox
- The Cosmological Principle
- Age of the Universe
- Hubble's law

Learning Outcomes

Candidates should be able to:

(a) recall Olbers' paradox.

(b) interpret Olbers' paradox to explain why it suggests that the model of an infinite, static Universe is incorrect.

(c) understand what is meant by the Cosmological principle.

(d) recall and interpret Hubble's law for the expansion of the Universe and the size of the observable Universe.

(e) convert Hubble's 'constant' H_0 from its conventional units (km s^{-1} Mpc^{-1}) to SI (s^{-1}).

(f) describe and interpret the significance of the 3 K microwave background radiation.

(g) understand that the standard (big bang) model of the Universe implies a finite age for the Universe.

(h) recall and use the expression $t \approx 1/H_0$ to estimate the order of magnitude of the age of the Universe.

5.5.4 *Information from Stellar Observation*

Recommended Prior Knowledge

Candidates should know module 2822, section 5.2.5.

Content

- Line spectra
- Effect of the Earth's atmosphere
- Observation platforms
- Doppler shift

Learning Outcomes

Candidates should be able to:

(a) understand that stars and galaxies are detected by the electromagnetic radiation which they emit, whilst planets are detected by reflected sunlight.

(b) sketch and interpret a graph to illustrate the variation with wavelength of the transparency of the Earth's atmosphere for the electromagnetic spectrum.

(c) explain how the composition of stellar atmospheres may be obtained from stellar spectra.

(d) understand what is meant by the Doppler effect.

(e) recall and use $\Delta\lambda/\lambda = v/c$.

(f) understand what is meant by red-shift and by blue-shift and appreciate simple differences between red-shift and terrestrial Doppler effects.

5.5.5 How the Universe may evolve

Content

- Evolution of the Universe
- Possible fate of the Universe

Learning Outcomes

Candidates should be able to:

(a) appreciate that there is no direct experimental evidence for the physics involved at the energies prevailing during the evolution of the Universe before about l ms.

(b) outline the difficulties involved in projecting the evolution of the Universe back before 0.01s.

(c) describe qualitatively the evolution of the Universe from 0.01s after the big bang to the present, including the production of an excess of matter over antimatter, the formation of light nuclei, the recombination of electrons and nuclei and the formation of stars, galaxies and galactic clusters.

(d) understand that the Universe may be ‘open’, ‘flat’, or ‘closed’, depending on the mean density of matter in the Universe.

(e) appreciate that, until the mean density of matter in the Universe is known accurately, its age cannot be determined from the Hubble constant.

(f) understand that the ultimate fate of the Universe depends on the mean density of matter in the Universe.

(g) recall that it is currently believed that the mean density of matter in the Universe is close to, and possible exactly equal to, the critical density needed for a ‘flat’ cosmology.

(h) use Newton's law of Gravitation to derive the expression $\rho_0 = 3H_0^2/8\pi G$, and recognise that relativity is needed for a strict derivation.

(i) use the expression $\rho_0 = 3H_0^2/8\pi G$.

5.5.6 *Relativity*

Recommended Prior Knowledge

Candidates should know:

- Module 2821, section 5.1.2
- Module 2824, section 5.4.2.

Content

- Theory of special relativity
- Theory of general relativity

Learning Outcomes

Candidates should be able to:

(a) recall and explain the postulates of special relativity to include the invariance of the speed of light.

(b) describe a thought experiment, involving a vehicle carrying a clock, to illustrate time dilation.

(c) outline an experiment, involving the extended half-life of muons, to illustrate time dilation.

(d) describe a thought experiment to demonstrate length contraction.

(e) use the factor $\sqrt{\{1 - (v^2/c^2)\}}$ in calculations for time dilation and length contraction.

(f) appreciate that, if mass increases with speed, there is a maximum speed to which a body can be accelerated.

(g) appreciate the significance of the principle of equivalence of inertial and gravitational forces.

(h) explain the effect of gravity on time in terms of a thought experiment based on the principle of equivalence.

(i) describe a thought experiment to illustrate that light passing through an accelerating glass spacecraft appears to follow a curved path to an observer within the craft.

(j) appreciate the significance of observations made during the 1919 solar eclipse, and the measured precession of Mercury's perihelion, in supporting the general theory of relativity.

5.6 Module 2825, Component 02: Health Physics

Aims

In addition to the general aims of the specifications, this component is intended to give an insight into some of the physics of the working of the human body and to introduce candidates to a range of applications of physics in medical diagnosis and treatment.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems. Candidates are also expected to use physical quantities, units and measurement techniques appropriate to the content of this component.

5.6.1 Body Mechanics

Recommended Prior Knowledge

Candidates should know:

- Module 2821, section 5.1.4.
- Module 2824, section 5.4.2.

Content

- The body in equilibrium
- Walking and running

Learning Outcomes

Candidates should be able to:

(a) show an awareness of the basic bone structure of the body in terms of bones, ligaments, tendons, muscles and joints.

(b) apply the principle of moments and the concept of mechanical advantage to bones acting as levers.

(c) make a simple analysis of the forces involved in standing, bending and lifting.

(d) show an awareness of the importance of correct body posture, particularly when lifting.

(e) describe magnitudes and directions of forces between the body and the ground when standing, walking and running.

5.6.2 The Eye and Sight

N3.2.

Recommended Prior Knowledge

Candidates should know Module 2823, Component 01, section 5.3.1.

Content

- The eye
- Defects of the eye and their correction
- Response of the eye

Learning Outcomes

Candidates should be able to:

(a) understand and use the terms principal focus, principal axis, optical centre and focal length as applied to converging (convex) and diverging (concave) lenses.

(b) recall and use the sign convention ‘real is positive, virtual is negative’.

(c) recall and use the lens formula $\frac{1}{u} + \frac{1}{v} + \frac{1}{f}$.

(d) recall the structure of the eye in terms of cornea, aqueous humour, iris, lens, ciliary muscles, vitreous humour, retina and optic nerve, and outline their respective functions.

(e) explain how the eye forms a focused image of an object and how the eye adjusts for different object distances.

(f) understand and use the terms near point, far point, depth of field and accommodation.

(g) distinguish between short sight, long sight, presbyopia and astigmatism.

(h) describe and explain how short sight, long sight, presbyopia and astigmatism may be corrected with suitable lenses.

(i) use the lens formula to calculate the focal length of the auxiliary lenses to correct short sight, long sight and presbyopia.

(j) recall and use the equation relating focal length of a lens to its power is dioptres.

(k) recall that the retina contains rods and three types of cone.

(l) appreciate the role of cones in the perception and differentiation of colour.

(m) sketch and interpret a graphical representation of the variation with wavelength of the relative responses of cones.

(n) explain scotopic vision and photopic vision in terms of the action of rods and cones.

(o) describe the respective responses of rods and cones to variations in light intensity.

(p) understand that the perception of intensity of light and of colour has social implication in, for example, advertising and architecture.

5.6.3 The Ear and Hearing

N3.2. N3.3.

Recommended Prior Knowledge

Candidates should know Module 2823, Component 01, section 5.3.2.

Content

- The ear
- Sensitivity and frequency response of the ear

Learning Outcomes

Candidates should be able to:

(a) describe how the ear acts as a transducer in response to an incoming sound wave.

(b) explain what is meant by frequency response.

(c) appreciate the very wide range of intensities which can be detected by the ear.

(d) recall the orders of magnitude of the threshold intensity I_0 of hearing and of the intensity at which discomfort is experienced.

(e) understand the significance of the logarithmic response of the ear to intensity.

(f) use the equation *intensity level I.L.* = 10 lg (I / I_0), giving intensity level in dB in terms of intensity I and threshold intensity I_0 .

(g) understand that loudness is a subjective response of an individual to frequency and to intensity level.

(h) sketch and interpret a graphical representation of the variation with frequency of detectable intensity.

(i) understand that frequency response and minimum detectable intensity are influenced by factors such as age and exposure to noise.

5.6.4 *Medical Imaging*

Recommended Prior Knowledge

Candidates should know Module 2823, Component 01, section 5.3.1.

Content

- Diagnostic techniques used in medicine
- Production and use of X-rays
- Production and use of ultrasound
- Magnetic resonance imaging
- Endoscopes

Learning Outcomes

Candidates should be able to:

(a) describe in simple terms the need for non-invasive techniques in diagnosis.

(b) understand the nature of X-rays and give a simple description of their production.

(c) recall and use the expression $I = I_0 e^{-\mu x}$ to show how the intensity I of a collimated X-ray beam varies with thickness x of a medium.

(d) describe the use of X-rays in imaging internal body structures including the use of image intensifiers and of contrast media.

(e) describe the use of a rotating beam in the CT (computerised axial tomography) scanner.

(f) outline the principles of the production and of the detection of ultrasonic waves using piezoelectric transducers.

(g) understand the principle of ultrasonic echosounding, including the importance of acoustic impedance, to obtain diagnostic information about internal structures.

(h) understand that acoustic impedance of a medium is dependent on its density and on the speed of the wave in the medium.

(i) understand why a coupling medium is required for effective ulstrasound techniques.

(j) outline the principles of magnetic resonance, with reference to precession of nuclei, Larmor frequency, resonance and relaxation time.

(k) outline the use of MRI (magnetic resonance imaging) to obtain diagnostic information about internal structures.

(l) discuss the preferred uses and relative advantages of X-rays, ultrasound and MRI in examining internal structures.

(m) explain the use of optic fibres in endoscopes, including the importance of coherent bundles of fibres, resolution and brightness of the image.

(n) describe examples of the use of endoscopes.

5.6.5 Medical Treatment

Recommended Prior Knowledge

Candidates should know Module 2824 section 5.4.11.

Content

- Biological effects of ionising radiation
- Radiotherapy
- Lasers

Learning Outcomes

Candidates should be able to:

(a) describe in simple terms the microscopic and macroscopic effects, both direct and indirect, of ionising radiation on living matter.

(b) explain qualitatively the importance of limiting exposure to ionising radiation.

(c) distinguish between exposure and absorbed dose.

(d) define and use absorbed dose as energy absorbed per unit mass.

(e) define and use the gray (Gy) as the unit of absorbed dose.

(f) appreciate that the effect of absorbed dose is dependent on the nature of the ionising radiation.

(g) define and use dose equivalent in sievart (Sv) as the product of absorbed dose (in gray) and quality factor.

(h) distinguish between stochastic and non-stochastic effects of radiation.

(i) describe the action of ionising radiation in the treatment of malignancies.

(j) describe examples of the therapeutic use of lasers, including as a scalpel and as a coagulator.

(k) appreciate the advantages of laser surgery compared with conventional surgery.

5.7 Module 2825, Component 03: Materials

Aims

This component aims to help candidates appreciate the extent to which the microscopic characteristics of physical materials determine their observed macroscopic behaviour. In addition to the general aims of the Scheme, this component is intended to develop the range of knowledge, understanding and skills acquired during the study of the appropriate parts of modules 2821, 2822 and 2824 and, in particular, to provide candidates with appropriate further insights into the optical, electrical, magnetic and mechanical properties of materials.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this component to other situations and/or to solve related problems. Candidates are also expected to use physical quantities, units and measurement techniques appropriate to the content of this component.

5.7.1 Mechanical properties and microstructure

Recommended Prior Knowledge

Candidates should know

- Module 2821, section 5.1.5.
- Module 2824, section 5.4.6.

Content

- Microstructure
- Defects in crystals
- Elastic and plastic deformation

Learning Outcomes

Candidates should be able to:

(a) distinguish between single-crystal, polycrystalline and amorphous materials.

(b) use a simple model to describe particle packing in solids and to explain what is meant by close-packing.

(c) explain what is meant by point defect, dislocation, grain boundary, and slip plane.

(d) describe how the occurrence of point defects, dislocations, grain boundaries and slip planes may be illustrated in terms of appropriate models including bubble raft and ball models.

(e) explain elastic deformation in terms of the separation of atoms in a solid material.

(f) show an awareness that the resultant force between two atoms in a crystal is the vector sum of an attractive force and a repulsive force.

(g) sketch and interpret graphical representations of the variation with separation of the resultant force between two atoms.

(h) explain what is meant by equilibrium separation.

(i) explain plastic deformation in terms of slip.

(j) explain why plastic deformation occurs more readily when dislocations are present in a solid material.

5.7.2 Electrical Properties of Materials

Recommended Prior Knowledge

Candidates should know:

- Module 2821, section 5.1.2.
- Module 2822, sections 5.2.1, 5.2.2 and 5.2.3.
- Module 2824, sections 5.4.6 and 5.4.8.

Content

- Resistivity and conductivity
- Conductors, semiconductors and insulators
- Superconductors
- The Hall effect

Learning Outcomes

Candidates should be able to

(a) define electrical conductivity as the reciprocal of electrical resistivity.

(b) distinguish between the r.m.s. speed and the drift velocity of an electron which forms part of an electric current in a solid.

(c) derive and use $I = nAve$ for a single-charge carrier in a solid.

(d) appreciate that in a solid material the outer electrons of neighbouring atoms interact.

(e) distinguish between the conduction band and the valence band.

(f) recall that there is an energy gap between the conduction band and the valence band and that an electron cannot have a value of energy corresponding to the range of values defined by this gap.

(g) use band theory to describe the conduction of electrons in metals.

(h) use band theory to explain qualitatively the electrical properties of metals, insulators and intrinsic semiconductors.

(i) describe an experiment which illustrates how the resistance of a light dependent resistor (LDR) varies with the intensity of light incident upon it.

(j) describe an experiment which illustrates how the resistance of an intrinsic semiconductor varies with temperature.

(k) explain why, in terms of band theory and the free-electron concentration in the conduction band, the conductivity of an intrinsic semiconductor increases with temperature.

(l) show an appreciation of what is meant by a superconducting material.

(m) recall that the electrical resistance of a superconducting material suddenly falls to zero at the transition temperature of that material.

(n) outline the use of superconducting materials, for example, in strong magnets.

(o) describe an experiment which illustrates the Hall effect.

(p) recall and use the equation $V_H = Bvd$ to determine the Hall voltage V_H across a current-carrying conductor or semiconductor at right angles to a magnetic field.

(q) describe how a calibrated Hall probe may be used to measure magnetic flux density.

5.7.3 Magnetic Properties of Materials

Recommended Prior Knowledge

Candidates should know:

- that the magnetic poles repel and unlike magnetic poles attract. (*4.1r*)
- Module 2822, section 5.2.3.
- Module 2824, section 5.4.8.

Content

- Domain theory
- Hard and soft ferromagnetic materials
- Transformer cores

Learning Outcomes

Candidates should be able to:

(a) use the domain theory of magnetism to describe the macroscopic magnetic properties of ferromagnetic materials.

(b) use the domain theory to distinguish between hard and soft ferromagnetic materials.

(c) recall that a material which is fully magnetised has reached saturation.

(d) sketch and interpret graphical representations of the variation of flux density within a material with the flux density causing the magnetisation of an initially unmagnetised material.

(e) explain what is meant by magnetic hysteresis.

(f) sketch and interpret graphical representations of magnetic hysteresis loops for both soft and hard ferromagnetic materials.

(g) recall that the magnetic alignment of dipoles is completely disrupted at the Curie temperature of a given material.

(h) use the ideas of hysteresis loops, saturation flux densities, the movement of domain walls and the presence of eddy currents, to explain how energy losses from the core of a transformer affect the efficiency of the transformer.

(i) appreciate that new materials with energy-efficient microstructures have been developed for the cores of some transformers, for example metallic glass which is easy to magnetise in all directions.

(j) describe an experiment which illustrates how the efficiency of a transformer varies with the frequency of the supply.

(k) explain, with reference to Faraday’s law of electromagnetic induction, why energy losses caused by eddy currents in the core of a transformer depend upon the frequency of the supply.

5.7.4 Optical Properties of Materials

Recommended Prior Knowledge

Candidate should know:

- Module 2822, section 5.2.5.
- Module 2823, Component 01, section 5.3.1.

Content

- Absorption and emission of light in solid materials
- Scattering of light
- Transmission of light in optical fibres
- The behaviour of light-emitting diodes

Learning Outcomes

Candidates should be able to:

(a) use band theory to describe why insulators absorb photons with a given range of energies but fail to absorb photons with energies below this range.

(b) explain, in terms of their failure to absorb photons with the appropriate energies, why insulators can be transparent to visible light.

(c) recall and use $E = hf$ to determine the energy condition for the transparency of an insulator.

(d) use band theory to explain why metals are opaque to infra-red and visible light.

(e) recall that the speed of electromagnetic radiation decreases as it passes from a medium of lower refractive index to a medium of higher refractive index.

(f) appreciate that the transmission of light through glass may be limited by the presence of metallic impurities and their absorption of light.

(g) recall that the microscopic density fluctuations in glass cause Rayleigh scattering.

(h) recall that the amount of Rayleigh scattering is inversely proportional to the fourth power of the wavelength of the light scattered.

(i) sketch and interpret graphical representations of the variation with wavelength of the percentage of visible and infra-red light transmitted per unit length of an optic fibre.

(j) recall that the transmission of visible and infra-red light along optic fibres is affected by the absorption and scattering of photons.

(k) recall that both lasers and light-emitting diodes (LEDs) may be used to produce signals for transmission along optic fibres.

(l) describe the advantages and disadvantages of lasers compared with LEDs for the transmission of signals along optic fibres.

(m) describe how the Planck constant may be determined by making measurements of the minimum voltages needed to produce visible photons from LEDs of different colours.

5.8 Module 2825, Component 04: Nuclear and Particle Physics

Aims

In addition to the general aims of the specifications, this component is intended to extend the knowledge, understanding and skills appropriate to Nuclear Physics developed in module D and to provide insights into the nature of fundamental particles.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems. Candidates are also expected to use physical quantities, units and measurement techniques appropriate to the content of this component.

5.8.1 The Nucleus

Recommended Prior Knowledge

Candidates should know: Module 2824, sections 5.4.5 , 5.4.6 and 5.4.11.

Content

- Nuclear radii
- Nuclear density
- The strong nuclear interaction

Learning Outcomes

Candidates should be able to:

(a) sketch and interpret a graphical representation of the variation with nucleon number of nuclear radius.

(b) use $r = r_0A^{1/3}$, where r_0 is the radius of the Hydrogen-1 nucleus, for the radius r of a nucleus.

(c) estimate the density of nuclear matter.

(d) use Coulomb's law to determine the force of repulsion, and Newton's law of gravitation to determine the force of attraction, between two protons at nuclear separations and hence appreciate the need for a short-range, attractive force between nucleons.

(e) recall the nature of the strong interaction (strong force) between nucleons.

(f) sketch and interpret a graphical representation of the variation with distance between nucleons of the strong interaction.

5.8.2 Neutrons and Nuclear Fission

Recommended Prior Knowledge

Candidates should know: Module 2824, sections 5.4.11 and 5.4.12.

Content

- Neutron-induced fission
- Uranium-235 as an energy source
- Uranium-238 and the absorption of neutrons

Learning Outcomes

Candidates should be able to:

(a) outline the mechanism of nuclear fission for unstable, massive, neutron-rich nuclei.

(b) explain the term thermal neutrons.

(c) understand what is meant by neutron-induced fission.

(d) sketch a graph of the variation with nucleon number of the relative yield of fission products for a fissile material.

(e) estimate, from the graphical representation of the variation with the nucleon number of binding energy per nucleon, the energy available from the fission of an Uranium-235 nucleus.

(f) recall that neutrons colliding with uranium nuclei can lead to the production of Plutonium-239 without any immediate fission.

(g) recall that Plutonium-239 is a by-product of nuclear fission reactors and decays through α-emission with a half-life of over 24,000 years.

5.8.3 Nuclear Fusion

Recommended Prior Knowledge

Candidates should know: Module 2824, sections 5.4.2, 5.4.6 , 5.4.8, 5.4.10 and 5.4.11.

Content

- Fusion and nucleons
- Fusion in the Sun
- Plasma confinement
- Fusion reactors

Learning Outcomes

Candidates should be able to:

(a) appreciate that, for protons to fuse, Coulomb forces of repulsion must be overcome.

(b) understand that, as two positively charged particles approach one another, their electric potential energy increases.

(c) use the concepts of kinetic energy and of electric potential energy, applied to charged particles, to explain why high temperatures are required for fusion.

(d) use $E_k = 2 \times 10^{-23}T$ and given values of electric potential energy to determine the temperature required for the fusion of nuclei.

(e) estimate, from the graphical representation of the variation with nucleon number of binding energy per nucleon, the energy available from the fusion of hydrogen to form helium.

(f) represent and interpret fusion reactions in terms of nuclear equations.

(g) outline what is meant by plasma.

(h) describe how gravitational fields, inertial confinement and magnetic fields may be used to confine a plasma.

(i) describe the conditions under which fusion takes place in the Sun.

(j) explain, from given details, the stages involved in the hydrogen cycle and in the carbon cycle.

(k) appreciate that practical fusion reactors are under development and show an awareness of the considerable difficulties involved.

(l) recall that the deuterium-tritium (D-T) reaction may be the most likely way of achieving fusion on a practical scale.

(m) outline the principles of operation of a prototype (JET) fusion reactor.

(n) describe how energy may be extracted from a nuclear fusion reactor.

(o) describe the possible advantages of nuclear fusion as an energy source.

5.8.4 Matter and Antimatter

Recommended Prior Knowledge

Candidates should know: Module 2824, sections 5.4.2, 5.4.3, 5.4.6 and 5.4.8.

Content

- Particle accelerators
- Antimatter

Learning Outcomes

Candidates should be able to:

(a) demonstrate an awareness of the use of both linear and circular particle accelerators to investigate the fundamental structure of matter.

(b) recall uses and relative advantages of fixed target and of colliding beam experiments.

(c) recall that antimatter exists and that antiparticles may be observed using high-energy particle accelerators.

(d) recall that particle-antiparticle pairs annihilate one another with the production high energy photons.

(e) recall that the positron is the antiparticle of the electron.

(f) describe the principles of operation of the cyclotron.

(g) derive and use an equation for the supply frequency of a cyclotron.

(h) appreciate that the Special Theory of relativity places constraints upon the speeds and energies achievable in particle accelerators.

(i) outline the principles of operation of a synchrotron.

(j) discuss the relative advantages of the use of cyclotrons and synchrotrons.

5.8.5 Fundamental Particles

Recommended Prior Knowledge

Candidates should know: Module 2824, sections 5.4.11 and 5.4.12.

Content

- Hadrons and baryons
- The quark model of hadrons
- The weak interaction and β decay.

Learning Outcomes

Candidates should be able to:

(a) recall that the strong interaction can be used to explain the forces between hadrons.

(b) recall that protons and neutrons are two of many types of hadron.

(c) demonstrate an awareness that all hadrons are thought to be unstable to some degree and are, consequently, subject to decay.

(d) recall that neutrons and protons within a nucleus are relatively stable.

(e) recall that free neutrons are unstable, with a half-life of approximately fifteen minutes, and decay to produce a proton and a β particle.

(f) appreciate that the half-life of free protons is thought to be of the order of 1032 years.

(g) recall that the electrical charge of a hadron is conserved during a transformation (reaction).

(h) recall that protons and neutrons are baryons with baryon number 1.

(i) recall that baryon number is conserved during an interaction.

(j) recall that protons and neutrons contain charged consistuents called quarks and are, therefore, not fundamental particles themselves.

(k) describe a simple quark model of hadrons in terms of up, down and strange quarks and their respective antiquarks, taking into account their charge, baryon number and strangeness.

(l) appreciate that the quark model may be extended to include the properties of charm, topness and bottomness.

(m) describe the properties of neutrons and protons in terms of a simple quark model.

(n) recall that the properties of all hadrons may be described in terms of a simple quark model.

(o) recall that there is a weak interaction between quarks and that this is responsible for β decay.

(p) recall that there are two types of β decay.

(q) predict, from the graphical representation of neutron-proton ratios within nuclei, whether a decay is likely to result in a β- or a β+ particle.

(r) describe the two types of β decay in terms of a simple quark model.

(s) demonstrate an awareness that (electron) neutrinos and (electron) antineutrinos are produced during β+ and β- decays respectively.

(t) recall that electrons and neutrinos are members of a group of particles known as leptons.

5.9 Module 2825, Component 05: Telecommunications

Aims

In addition to the general aims of the specifications, this component is intended to develop the range of knowledge, understanding and skills acquired during the study of appropriate parts of Modules 2822 and 2823 (Component 01). In particular, it is intended to provide an interesting and rewarding further study in Physics, allowing some insight into modern telecommunications.

Assessment Objectives

See section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems. Candidates are expected to use physical quantities, units and measurement techniques appropriate to the content of this component.

5.9.1 Electronic Signals

Recommended Prior Knowledge

Candidates should know: Module 2823, Component 01 sections 5.3.2 and 5.3.3.

Content

- Analogue signals
- Digital signals
- Monitoring signals
- Noise

Learning Outcomes

Candidates should be able to:

(a) describe an analogue signal in terms of continuous variation between two limits.

(b) describe a digital signal in terms of having two states only.

(c) represent an analogue and a digital signal graphically.

(d) determine the amplitude and frequency of a signal from a suitable graph or display on a calibrated c.r.o.

(e) understand that noise is any unwanted signal superimposed on the transmitted signal.

(f) appreciate the effect of noise on the quality of a signal.

5.9.2 Communication Principles

Recommended Prior Knowledge

Candidates should know: Module 2823, Component 01, sections 5.3.2 and 5.3.3.

Content

- Waveforms
- Principles of modulation
- Sidebands and bandwidth
- Transmission of information by digital means
- Transmission media

Learning Outcomes

Candidates should be able to:

(a) recall that any waveform can be resolved into or synthesised from sinusoidal components.

(b) understand the term modulation and distinguish between amplitude modulation (AM) and frequency modulation (FM).

(c) recall that a carrier wave, amplitude modulated by a single audio frequency, is equivalent to the carrier wave frequency together with two sideband frequencies.

(d) understand the term bandwidth.

(e) demonstrate an awareness of the relative advantages of FM and AM transmissions.

(f) recall the advantages of transmission signals in digital form.

(g) understand that the digital transmission of speech or music involves analogue-to-digital conversion on transmission and digital-to-analogue conversion on reception.

(h) demonstrate an awareness of how waveforms are encoded by digital sampling.

5.9.3 Digital Systems

Recommended Prior Knowledge

Candidates should know: Module 2823, Component 01, sections 5.3.2 and 5.3.3.

Content

- Digital encoding
- Time-division multiplexing

Learning Outcomes

Candidates should be able to:

(a) demonstrate an awareness of a method of digital encoding of information.

(b) describe how an analogue waveform may be sampled and encoded in binary form as a digital signal using an analogue-to-digital converter (ADC).

(c) describe how a digital signal may be decoded at the receiver.

(d) discuss the relative advantages and disadvantages of pulse-code-modulation.

(e) understand the significance of sampling rate on the output signal.

(f) understand the significance of word-length on the output signal. (Numerical/graphical problems will be limited to simple systems involving four-bit words.)

(g) describe the principles of time-division multiplexing.

5.9.4 Amplifier Circuits

Recommended Prior Knowledge

Candidates should know: Module 2822, sections 5.2.1 and 5.2.2.

Content

- The ideal operational amplifier (op-amp)
- The op-amp as an amplifier

Learning Outcomes

Candidates should be able to:

(a) recall the characteristic properties of an ideal op-amp in terms of voltage gain, input resistance, output resistance and saturation levels.

(b) understand the behaviour of an op-amp in terms of producing an output voltage which depends on the difference between two input voltages.

(c) understand the principle of negative feedback in an amplifier.

(d) recall and explain the effect of negative feedback on the gain and on the bandwidth of an amplifier circuit.

(e) recall the diagram for an inverting amplifier based on an op-amp.

(f) understand what is meant by a virtual earth.

(g) use the virtual earth approximation to derive an expression for the gain of an inverting amplifier with an ideal op-amp.

(h) recall and use the expression for the voltage gain of an inverting amplifier.

(i) design inverting amplifier circuits.

(j) describe and design experiments involving the use of an op-amp to provide a switched response to a gradual change in input voltage and understand how the input voltage at which switching takes place may be changed.

5.9.5 Radio Communication

Recommended Prior Knowledge

Candidates should know: Module 2823, Component 01, sections 5.3.2 and 5.3.3.

Content

- Amplitude-modulated radio reception
- Propagation of radio waves

Learning Outcomes

Candidates should be able to:

(a) use a systems approach to explain the function of each of the following elements in an amplitude-modulated radio receiver: aerial, tuning circuit, radio-frequency amplifier, detector (demodulator), audio-frequency amplifier, loudspeaker.

(b) draw a block diagram to show how the elements in (a) are combined in an amplitude-modulated radio receiver.

(c) understand the principle of the use of the half-wave dipole aerial as a transmitting antenna and the use of parabolic reflecting dishes and dipoles in receiving antennae.

(d) describe the effect of the Earth's surface on the propagation of radio waves over long distances.

(e) describe the use of the ionosphere as a reflector for the propagation of waves over long distances.

(f) describe the use of satellites in radio communication and appreciate the importance of geostationary satellites.

(g) recall the wavelengths used in different modes of radio communication.

5.9.6 Optic Fibre Communication

Recommended Prior Knowledge

Candidates should know:

- Module 2822, section 5.2.1.
- Module 2823, Component 01, section 5.3.1.

Content

- Optic fibres
- Optic fibre communication system

Learning Outcomes

Candidates should be able to:

(a) describe the propagation of light along step-index fibres.

(b) understand the nature of the distortion produced by the propagation of a light pulse down a step-index fibre and appreciate that this is reduced over long distances by using mono-mode fibres.

(c) recall a simple input system for an optic fibre based on an amplifier using an op-amp and an LED.

(d) recall a simple output system for an optic fibre based on an amplifier using an op-amp and a photodiode.

(e) describe an experimental investigation of an optic fibre system capable of communicating information, such as speech, over a short distance in a laboratory.

5.9.7 Telecommunications Systems and Networks

Recommended Prior Knowledge

Candidates should know:

- Module 2822 section 5.2.1.
- Module 2823, Component 01, sections 5.3.2 and 5.3.3

Content

- Modern telecommunications systems
- Communication networks
- Communications and society

Learning Outcomes

Candidates should be able to:

(a) recall that information may be carried by a number of different channels including wire-pairs, coaxial cables, radio and microwave links, and optic fibres.

(b) Discuss the relative advantages and disadvantages of channels of communication in terms of available bandwidth, noise, cross-linking, security, signal attenuation, regeneration, cost and convenience.

(c) recall and use the expression *number of decibels* (dB) = 10 lg (P_1 / P_2) for the ratio of two powers.

(d) understand and use gain of an amplifier expressed in dB.

(e) understand and use signal attenuation expressed in dB per kilometre.

(f) estimate and use typical power levels and attenuations associated with different channels of communication.

(g) demonstrate that a modern telecommunications system links together different channels of communication depending on location, distance and required bandwidth.

(h) appreciate the role of switching in a modern telecommunications system.

(i) explain the principles of operation of a cellular mobile telephone network.

(j) outline how information is transferred using the Internet, including World Wide Web, file transfer protocol and e-mail.

(k) demonstrate an awareness of social, economic, environmental and technological changes arising from modern communication methods, including the advent of tele-working from home.

Module 2826, Component 01: Unifying Concepts in Physics

Preamble

The aims of this component are to give the candidates the opportunity

- to demonstrate a knowledge and understanding of facts, principles and concepts studied in the AS specification and in Module 2824 in A2.
- to make connections between different areas of physics.

Assessment Objectives

See Section 3. Candidates are expected to bring together principles and concepts from different areas of physics and apply them in a particular context, expressing ideas clearly and logically and using appropriate specialist vocabulary. They are also expected to use skills of analysis and interpretation in contexts which may be unfamiliar.

Content
There is no content beyond that given in Modules 2821, 2822 and 2823 Component 01 of the AS specification and Module 2824 in A2. Questions in the paper require candidates to draw together knowledge, understanding and skills, and to show connections between different aspects of physics.

6 Further Information and Training for Teachers

To support teachers using these specifications, OCR will make the following materials and services available:

- a full programme of In-Service Training (INSET) meetings
- specimen question papers and mark schemes
- past question papers and mark schemes after each examination session
- coursework guidance materials, including a Physics Coursework Handbook which can be ordered from the OCR Publications Department
- written advice on coursework proposals
- individual feedback to each Centre on the moderation of coursework
- a report on the Examination, compiled by senior examining personnel, after each examination session.

If you would like further information about these specifications, please contact OCR.

7 Reading List

Cambridge University Press has produced new support material to accompany this course. They have been endorsed by OCR for use with this specification. Details are as follows:

AS Physics Core

Physics 1, by D. Sang, K. Gibbs and R. Hutchings, published by Cambridge University Press, ISBN 0-521-78718-1

A2 Physics Core

Physics 2, by D. Sang, published by Cambridge University Press, ISBN 0-521-79715-2

A2 Physics Options

Cosmology (Second Edition), by B. Milner, published by Cambridge University Press, ISBN 0-521-78722-X

Health Physics (Second Edition), by A. McCormick and A. Elliott, published by Cambridge University Press, ISBN 0-521-78726-2

Materials, by J. Taylor, published by Cambridge University Press, ISBN 0-521-79748-9

Nuclear and Particle Physics, by B. Milner, published by Cambridge University Press, ISBN 0-521-79837-X

Telecommunications, by S. Kennedy, published by Cambridge University Press, ISBN 0-521-79747-0

The books referred to below may prove useful in delivering AS GCE and Advanced GCE Physics.

The list is not intended to be exhaustive nor does inclusion on the list constitute a recommendation of the suitability of the resource for the specification. The list below contains books that are available in spring 2002. The possibility exists that more up to date texts which have been prepared for the revised GCE specifications may become available. Teachers will need to use their professional judgement in assessing the suitability of the material contained in this list.

Accessible Physics, by F.Azzopardi & B.Stewart, published by Macmillan, ISBN 0-333-2780-6

Advanced Physics (4^{th} Edition), by T.Duncan, published by John Murray, ISBN 0-7195-5199-4

Advanced Physics (2nd Edition), by K.Gibbs, published by Cambridge University Press, ISBN 0-521-39985-8

Advancing Physics, edited by J.Ling, published by Longman, ISBN 0-582-35596-6

Physics, by R.Hutchings, published by Nelson, ISBN 0-17-438510-2

Understanding Physics for Advanced Level (Third Edition), by J.Breihaupt, published by Stanley Thornes, ISBN 0-7487-1579-7

Cambridge Modular Science Series published by Cambridge University Press

Appendix A

Key Skills

These specifications provide opportunities for the development of the Key Skills of *Communication, Application of Number, Information Technology, Working With Others, Improving Own Learning and Performance* and *Problem Solving* as required by QCA's subject criteria for Physics.

Through classwork, coursework and preparation for external assessment, candidates may produce evidence for Key Skills at Level 3. However, the extent to which this evidence fulfils the requirements of the QCA Key Skills specifications at this level will be dependent on the style of teaching and learning adopted for each module. In some cases, the work produced may meet the evidence requirements of the Key Skills specifications at a higher or lower level.

Throughout section 5 the symbol  is used in the margin to highlight where Key Skills development opportunities are signposted. The following abbreviations are used to represent the above Key Skills:

C = Communication

N = Application of Number

IT = Information Technology

WO = Working with Others

LP = Improving Own Learning and Performance

PS = Problem Solving

These abbreviations are taken from the Key Skills specifications for use in programmes starting from September 2000. References in section 5 and Appendix A, for example **IT3.1**, show the Key Skill (IT), the level (3) and subsection (1).

Centres are encouraged to consider the OCR Key Skills scheme to provide certification of Key Skills for their students.

Detailed opportunities for generating Key Skills evidence through this specification are posted on the OCR website, www.ocr.org.uk

Key Skills Coverage

For each module, the following matrix indicates those Key Skills for which opportunities exist for at least some coverage of the relevant Key Skills specification.

	Communication	Application of Number	IT	Working with Others	Learning Performance	Problem Solving
Module	**Level 3**	**Level 3**	**Level 3**	**Level 3**	**Level 3**	**Level 3**
2821	✓	✓	✓	✓	✓	
2822	✓		✓		✓	✓
2823	✓	✓			✓	✓
2824	✓	✓	✓	✓	✓	✓
2825	✓	✓		✓	✓	
2826	✓	✓			✓	✓

Overlap with other qualifications

Overlap with other qualifications is detailed in Section 1.3.

Appendix B

Notes for Guidance on Coursework Assessment and Submission

This section is intended to provide guidance for teachers in assessing experimental and investigative skills, but should not exert an undue influence on the methods of teaching or provide a constraint on the practical work undertaken by candidates. It is not expected that all of the practical work undertaken by candidates would be appropriate for assessment.

For examples of suitable tasks for assessing practical skills, and for examples of possible individual studies, teachers should refer to the *Physics Coursework Handbook*. Copies can be ordered from the OCR Publications Department.

The experimental and investigative skills to be assessed are:

P Planning;

I Implementing;

A Analysing Evidence and Drawing Conclusions;

E Evaluating Evidence and Procedures.

It is expected that candidates will have had opportunities to acquire experience and develop the relevant skills before assessment takes place.

The skills may be assessed at any time during the course using suitable practical activities, based on laboratory or field work, related to or part of the content of the teaching course. The context(s) for the assessment of the coursework for Unit 2823, Component 02, should be drawn from the content of AS Units 2821, 2822 and 2823 (Component 01); the context(s) for the assessment of the coursework for Unit 2826, Component 02, should be drawn from the content of A2 Units 2824 and 2825, in which the level of demand of the related scientific knowledge and understanding is higher.

In AS and in A2 the skills may be assessed in the context of separate practical exercises, although more than one skill may be assessed in any one exercise. They may also be assessed all together in the context of a single ‘whole investigation’ in which the task is set by the teacher, or using individual investigations in which each candidate pursues his or her own choice of assignment.

Skills **P** and **A** are marked out of 8 and Skills **I** and **E** are marked out of 7. Thus, for each candidate entered for Unit 2823, Component 2, and for Unit 2826, Component 2, Centres will be required to submit **one** mark for each of Skills **P**, **I**, **A** and **E**. Hence the maximum raw mark available for each of these components is 30. These marks are then doubled so that the final marks submitted are out of 60.

When a skill has been assessed on more than one occasion, in AS or in A2, the better or best mark for that skill should be submitted. However, Centres are recommended not to **assess** the skills on more than two occasions in each of AS and A2 since this may take up time which might better be devoted to other aspects of the specifications.

All coursework is marked by the teacher and internally standardised by the Centre. Marks are then submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures. The purpose of moderation is to ensure that the standard for the award of marks in coursework is the same for each Centre, and that each teacher has applied the standards appropriately across the range of candidates within the Centre.

The Demand of an Activity

The demand of an activity is an important feature of the assessment. From the bottom to the top of the mark range in a skill area the activity should involve increasing demands of associated scientific knowledge and understanding, manipulation, precision and accuracy and complexity.

The difference in standard of AS and A2 is a product of the level of demand and complexity of the work undertaken and the level of demand of the related scientific knowledge and understanding. Also, the mark descriptors for Skills **P** and **A** at A2 include synoptic assessment.

In A2, candidates will be required to apply knowledge, understanding and skills from the AS and A2 parts of the specification in planning experimental work and in the evaluation of data (synoptic assessment). Details of the way in which tasks can be differentiated are given in Section 4.2 and further guidance on setting appropriate tasks is given in the *Physics Coursework Handbook* which can be ordered from the OCR Publications Department.

Teachers should appreciate that the choice of an activity which is comparatively undemanding (primarily in terms of the level of the scientific knowledge and understanding that can be linked to the activity and in the range/complexity of the equipment/techniques used) may prevent access to the highest marks.

Teachers should be aware of this feature of the assessment so that, when considering the award of higher marks, the activity should require a sophisticated approach and/or complex treatment. Higher marks must **not** be awarded for work which is simplistic or trivial.

One of the factors, which determine the demand of an activity, is the level of guidance given to candidates. The use of a highly structured worksheet, for example, will reduce the number of decisions and judgements required by the candidate and so will limit the range of marks available.

Marking Candidates' Work

A similar set of mark descriptors is used for AS and A2 (see Appendix C). The descriptors should be used to make a judgement as to which mark best fits a candidate's performance.

The descriptors have been written to provide clear continuity from the assessment of Sc1 for GCSE. This should ensure an effective continuation of the development of candidates' skills from GCSE to AS GCE and Advanced GCE.

The mark descriptors within a skill area have been written to be hierarchical. Thus, in marking a piece of work, the descriptors for the lowest defined mark level should be considered first and only if there is a good match should the descriptors for the next level up be considered. Therefore, if a teacher is considering awarding a high mark for a piece of work, the work must have demonstrated a good match to all the lower mark descriptors.

For each skill, the scheme allows the award of intermediate marks (between the defined mark levels. Intermediate marks may be awarded when the work of a candidate exceeds the requirements of a defined mark level but does not meet the requirements of the next higher defined mark level sufficiently to justify its award. Thus, an intermediate mark could be awarded if the work meets only one of the two descriptors at the higher defined mark level, provides a partial match to both or provides a complete match to one and a partial match to the other.

In Skills **P** and **A**, a mark above the highest defined mark level should be awarded for work which meets all the requirements of the descriptors for the highest defined mark level and is judged to be of exceptional merit in terms of originality, depth, flair or the use of novel or innovative methods.

A mark of zero should be awarded where there has been an attempt to address the skill but the work does not meet the requirements of the lowest defined mark level.

The marks awarded should be based on both the final written work and the teacher's knowledge of the work carried out by the candidate. In assigning a mark, attention should be paid to the extent of any guidance needed by, or given to, the candidate.

In defining the various mark descriptors it is recognised that practical tasks vary widely, both in the experimental procedures used, and in the nature of the observations and measurements which may be made by the candidate. The mark descriptors for each defined level are intended to provide guidance to teachers on how to recognise levels of achievement. It is acknowledged that the balance between the statements provided for a particular level of performance will vary with the nature of the activity. Whilst both statements for a particular defined level **must** be considered in awarding the marks, it is clear that teachers will need to judge for themselves the relative weightings they attach to each of the statements.

Synoptic Assessment

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. Assessment Objective AO4 relates specifically to synoptic assessment and marks from the A2 Unit 2826, Component 02, contribute to the assessment of AO4.

During experimental and investigative work, synoptic assessment

- allows candidates to apply knowledge and understanding of principles and concepts of physics in planning experimental work and in the analysis and evaluation of data.
- allows candidates to apply skills and techniques learned during the course.

All practical work assessed internally by centres for the **A2 Unit 2826, Component 02** should draw on the range of experience that the student has acquired during the AS and A2 courses. It is particularly important that an exercise used to assess planning skills should involve an element of research which goes beyond the repetition of an experiment that simply reflects the use of ideas or techniques met within the module currently being studied. Likewise an assessment involving analysing evidence and drawing conclusions must require a candidate to use knowledge and understanding acquired outside the confines of a standard experiment recently practised. During the process of moderation, evidence will be sought that such breadth has been achieved.

The assessment descriptors for the skills of Planning (**P**) and Analysing Evidence and Drawing Conclusions (**A**), include statements that relate specifically to synoptic assessment. These are shown in bold and should be applied only when assessing A2 work. Thus, in A2, a candidate will not be able to achieve more than 2 marks in each of Skills **P** and **A** without demonstrating aspects of synoptic assessment. Candidates will also bring to the assessment of Skill **I** (Implementing) their experience of practical and investigative work from throughout the course. In Skill **E** (Evaluating Evidence and Procedures) aspects of Skills **P** and **A** are evaluated. Overall, in A2, approximately 15 of the 30 available marks can thus be identified as contributing to an assessment of AO4 (synoptic assessment).

Quality of Written Communication

Coursework must include an assessment of candidates' quality of written communication. At Level 3 candidates are required to:

- select and use a form of writing that is appropriate to the 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 the meaning is clear.

The mark descriptors for Skills **P** and **A** have been written to include these aspects and these skills carry an additional mark each in recognition of this.

Annotation of Candidates' Work

Each piece of assessed coursework must be annotated to show how the marks have been awarded in relation to the relevant skills.

The writing of comments on candidates' work can provide a means of dialogue and feedback between teacher and candidate and a means of communication between teachers during internal standardisation of coursework. The main purpose of annotating candidates' coursework should be, however, to provide a means of communication between teacher and Moderator, showing where marks have been awarded and why. The sample of work which is submitted for moderation **must** show how the marks have been awarded in relation to the marking criteria.

Annotations should be made at appropriate points in the margins of the text. The annotations should indicate both where achievement for a particular skill has been recognised and the mark awarded. It is suggested that the minimum which is necessary is that the 'shorthand' mark descriptors (for example, P.5a, I.3b) should be written at the point on the script where it is judged that the work has met the descriptors concerned.

For Skill **I**, Implementing, more detail is necessary and the Moderator will require evidence concerning candidates' use of practical techniques and safe working practice. This evidence could take the form of checklists or written notes.

Health and Safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for GCE AS and A level this is likely to be the education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to cooperate with their employer on health and safety matters.

Various regulations, but especially the COSHH Regulations 1996 and the Management of Health and Safety at Work Regulations 1992, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of *Safety in Science Education* (see below). For members, the CLEAPSS guide, *Managing Risk Assessment in Science* offers detailed advice.

Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X;

Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2;

Hazcards, 1995, CLEAPSS School Science Service*;

Laboratory Handbook, 1988-97, CLEAPSS School Science Service*;

Topics in Safety, 2nd edition, 1988, ASE ISBN 0 86357 104 2;

Safety Reprints, 1996 edition, ASE ISBN 0 86357 246 4.

Hazardous Chemicals, A Manual for Science Education, SSERC Limited 1997, ISBN 0 9531776 0 2.

* Note that CLEAPSS publications are only available to members or associates.

(Other publications have sometimes been suggested, eg the DES *Microbiology, an HMI Guide for Schools and FE,* but this is now out of print).

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment. Such adaptations might include a reduced scale of working deciding that the fume cupboard provision is inadequate or the skills of the candidates are insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications, this may well lead to the use of novel procedures, chemicals or micro-organisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting the CLEAPSS School Science Service (or, in Scotland, SSERC).

When candidates are planning their own practical activities, whether in project work or more routine situations, the teacher or lecturer has a duty to check the plans before practical work starts and to monitor the activity as it proceeds.

Suggested Tasks

The following lists a number of topics, which may be used for the assessment of Practical Skills in AS and A2. It should be appreciated that the formulation of the task, based on each topic, determines which skills may be assessed.

AS

The effect of temperature on the bounce of a squash ball.

The effect of pressure of the air, in a football, on the bounce of the football.

Efficiency of thermal insulation.

Spring constant: springs in series and parallel.

Characteristics of a bead thermistor thermometer.

Measurement of the acceleration of free fall.

A2

Efficiency of an electric motor.

Forced oscillations and damping of a mechanical system.

Specific heat capacity determination.

Use of a Hall probe.

Variation of resistance of an LDR with light intensity.

The effect on the smoothing of the load due to the capacitance of smoothing capacitors.

Resistive damping in an LC circuit.

For further guidance on the assessment of practical skills teachers should refer to the *Physics Coursework Handbook.* Copies can be ordered from the OCR Publications Department.

Appendix C

Mark Descriptors for Experimental and Investigative Skills

In defining the various mark descriptors, it is recognised that practical tasks vary widely, both in the experimental procedures used and in the nature of the observations and measurements which may be made by the candidate. The mark descriptors within each defined level are intended to provide guidance to teachers on how to recognise levels of achievement. It is acknowledged that the balance between the statements provided for a particular level of performance will vary with the nature of the activity. Whilst both statements for a particular level **must** be considered in awarding the marks, it is clear that teachers will need to judge for themselves the relative weightings they attach to each of the statements.

For examples of suitable tasks for assessing practical skills, and for examples of possible individual studies, teachers should refer to the *Physics Coursework Handbook.* Copies can be ordered from the OCR Publications Department.

Skill P – Planning		Total 8
Mark	**Descriptor**	**The candidate:**
1	**P.1a**	defines a question or problem in simple terms and plans a fair test or an appropriate practical procedure, making a prediction where relevant.
	P.1b	chooses appropriate equipment.
2		
3	**P.3a**	defines a question or problem using scientific knowledge and understanding **drawn from more than one module of the specification**; identifies the key factors to vary, control or take account of.
	P.3b	decides on a suitable number and range of observations and/or measurements to be made.
4		
5	**P.5a**	uses detailed scientific knowledge and understanding **drawn from more than one module of the specification** and information from preliminary work or a secondary source to plan an appropriate strategy, taking into account the need for safe working and justifying any prediction made; produces a clear account and uses specialist vocabulary appropriately.
	P.5b	describes a strategy, including choice of equipment, which takes into account the need to produce precise and reliable evidence.
6		
7	**P.7a**	retrieves and evaluates information from a variety of sources, and uses it to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding **drawn from different parts of the AS and A2 specification**; uses spelling, punctuation and grammar accurately.
	P.7b	justifies the strategy developed, including the choice of equipment, in terms of the need for precision and reliability.
8		

The statements in bold represent additional requirements for Unit 2826, Component 02; they are not to be used for Unit 2823, Component 02.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. All descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

Skill I – Implementing		Total 7
Mark	**Descriptor**	**The candidate:**
1	**I.1a**	demonstrates competence in simple techniques and some awareness of the need for safe working.
	I.1b	makes and records observations and/or measurements which are adequate for the activity.
2		
3	**I.3a**	demonstrates competence in practised techniques and is able to manipulate materials and equipment with precision.
	I.3b	makes systematic and accurate observations and/or measurements which are recorded clearly and accurately.
4		
5	**I.5a**	demonstrates competence and confidence in the use of practical techniques; adopts safe working practices throughout.
	I.5b	makes observations and/or measurements with precision and skill; records observations and/or measurements in an appropriate format; recognises sources of systematic and random error which could affect accuracy and reliability of results.
6		
7	**I.7a**	demonstrates skilful and proficient use of all techniques and equipment.
	I.7b	makes and records all observations and/or measurements in appropriate detail and to the degree of precision permitted by the techniques or apparatus; responds to serious sources of systematic and random error by modifying procedures where appropriate.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. All descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

Skill A – Analysing Evidence and Drawing Conclusions		Total 8
Mark	**Descriptor**	**The candidate:**
1	**A.1a**	carries out some simple processing of the experimental evidence.
	A.1b	identifies trends or patterns in the evidence and draws simple conclusions
2		
3	**A.3a**	processes and presents experimental evidence including, where appropriate, the use of appropriate graphical and/or numerical techniques.
	A.3b	links conclusions drawn from processed evidence with the associated scientific knowledge and understanding **drawn from more than one area of the specification.**
4		
5	**A.5a**	carries out detailed processing of evidence and analysis including, where appropriate, the use of advanced numerical techniques such as statistics, the plotting of intercepts or the calculation of gradients.
	A.5b	draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding **drawn from more than one module of the specification**; produces a clear account which uses specialist vocabulary appropriately.
6		
7	**A.7a**	where appropriate, uses detailed scientific knowledge and understanding **drawn from different parts of the AS and A2 specifications** to make deductions from the processed evidence, with due regard to nomenclature, terminology and the use of significant figures (where relevant).
	A.7b	draws conclusions which are well structured, appropriate, comprehensive, concise and accurate and which are coherently linked to underlying scientific knowledge and understanding **drawn from different parts of the AS and A2 specifications**; uses spelling, punctuation and grammar accurately.
8		

The statements in bold represent additional requirements for Unit 2826, Component 02; they are not to be used for Unit 2823, Component 02.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. All descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

Skill E – Evaluating Evidence and Procedures		Total 7
Mark	**Descriptor**	**The candidate:**
1	**E.1a**	makes relevant comments on the suitability of the experimental procedures.
	E.1b	recognises any anomalous results.
2		
3	**E.3a**	recognises how limitations in the experimental procedures and/or strategy may result in sources of error.
	E.3b	comments on the accuracy of the observations and/or measurements, suggesting reasons for any anomalous results.
4		
5	**E.5a**	indicates the significant limitations of the experimental procedures and/or strategy and suggests how they could be improved.
	E.5b	comments on the reliability of the evidence and evaluates the main sources of error.
6		
7	**E.7a**	justifies proposed improvements to the experimental procedures and/or strategy in terms of increasing the reliability of the evidence and minimising significant sources of error.
	E.7b	assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. All descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

Appendix D

Measurement and Measurement Techniques

Candidates should be able to use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the module which they are studying. In particular, candidates should be able to:

- measure lengths using a ruler, vernier scale, micrometer, and calipers.
- measure weight and hence mass using spring and lever balances.
- measure an angle using a protractor.
- measure lengths of time using clocks, stopwatches, and the calibrated time-base of a cathode-ray oscilloscope (c.r.o.).
- measure temperature using a thermometer as a sensor.
- use ammeters and voltmeters with appropriate scales.
- use a cathode-ray oscilloscope (c.r.o.).

In addition, candidates should be able to:

- use both analogue and digital displays.
- use calibration curves.
- understand the distinction between systematic errors (including zero errors) and random errors.
- understand the difference between precision and accuracy.

Appendix E

Mathematical Requirements

Material which is relevant to the A2 half of the Advanced GCE course is given in **bold** type.

Arithmetic and Computation

Candidates should be able to:

- recognise and use expressions in decimal and standard (scientific) form.
- use ratios, fractions and percentages.
- use electronic calculators for addition, subtraction, multiplication and division.
- use calculators to find and use arithmetic means, powers (including reciprocals and square roots), sines, cosines, tangents (and the inverse functions) when the angle is expressed in degrees, and logarithms (lg).
- use calculators to find and use sines, cosines and tangents (and the inverse functions) when the angle is expressed in **radians**.
- use calculators to find and use **exponentials** and **logarithms** (**ln**).
- make order of magnitude calculations.
- take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified.

Algebra

Candidates should be able to:

- change the subject of an equation by manipulation of the terms, including positive, negative, integer and fractional indices.
- solve simple algebraic equations. Most relevant equations are linear but some may involve inverse and inverse square relationships. **Linear simultaneous equations and the use of the formula to obtain the solutions of quadratic equations are included.**
- substitute numerical values into algebraic equations using appropriate units for physical quantities.
- formulate simple algebraic equations as mathematical models of physical situations, and identify inadequacies of such models.
- **recognise and use the logarithmic forms of expressions like ab, a/b, x^n, e^{kx}: understand the use of logarithms in relation to quantities with values that range over several orders of magnitude.**
- understand and use the symbols $=$, $\approx$, $<$, $<<$, $>$, $>>$, $\geq$, $\leq$, $<x>$, $<x^2>$, α, Δ, $\surd$.

Geometry and Trigonometry

Candidates should be able to:

- calculate the areas of triangles, circumference and area of circles, surface areas and volumes of rectangular blocks, cylinders and spheres.
- use Pythagoras' theorem, similarity of triangles, and the angle sum of a triangle.
- use sines, cosines and tangents in physical problems.
- use the trigonometrical relationship for triangles: $a/\sin A = b/\sin B = c/\sin C$, $\boldsymbol{a^2 = b^2 + c^2 - 2bc\cos A}$.
- **understand the relationship between degrees and radians and translate from one to the other.**
- **recall and use $\sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$ for small values of θ in radians.**

Graphs

Candidates should be able to:

- translate information between graphical, numerical, algebraic and verbal forms.
- select appropriate variables and scales for graph plotting.
- plot two variables from experimental or other data.
- for linear graphs, determine the slope, intercept and intersection.
- choose, by inspection, a straight line which will serve as the best straight line through a set of data points presented graphically.
- recall standard linear form $y = mx + c$, and rearrange relationships into linear form where appropriate.
- draw and use the slope of a tangent to a curve as a measure of rate of change.
- sketch and recognise the forms of plots of common simple expressions like $y = k/x$, $y = x^2$, $y = \sin x$, $y = \cos x$, $\boldsymbol{y = e^{-kx}}$.
- understand the possible physical significance of the area between a curve and the x-axis and be able to calculate or to measure the area by counting squares as appropriate.
- **use logarithmic plots to test exponential and power law variations.**

Appendix F

Data and Formulae Supplied in Question Papers

Data	
speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae	
uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
refractive index	$n = \dfrac{1}{\sin C}$
capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
capacitor discharge	$x = x_0\, e^{-t/CR}$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} <c^2>$
radioactive decay	$x = x_0\, e^{-\lambda t}$, $t_{½} = \dfrac{0.693}{\lambda}$
critical density of matter in the Universe	$\rho_0 = \dfrac{3H_O{}^2}{8\pi G}$
relativity factor	$= \sqrt{1 - \dfrac{v^2}{c^2}}$
current	$I = nAve$
nuclear radius	$r = r_0 A^{1/3}$
sound intensity level	$= 10\lg(I/I_0)$

Appendix G

Data and Formulae not Supplied in Question Papers

The following is a list of data and formulae which will not be supplied to candidates in examinations.	
speed	$v = s / t$
acceleration	$a = (v - u) / t$
force	$F = ma$
weight	$W = mg$
density	$\rho = m/v$
moment of a force	$T = Fx$
torque of a couple	$T = Fx$
pressure	$p = F / A$
work done	$W = Fd$
power	$P = W / t$ $P = Fv$
stress	$\sigma = F / A$
strain	$\varepsilon = \Delta l / l$
the Young modulus	$E = \sigma / \varepsilon$
electric current	$I = \Delta Q / \Delta t$
potential difference	$V = W / Q$, $V = P / I$
electrical resistance	$R = V / I$
resistivity	$\rho = RA / l$
power	$P = I^2R$ $P = V^2 / R$
electrical energy	$W = VIt$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$

The following is a list of data and formulae which will not be supplied to candidates in examinations. (continued)	
force on a current-carrying conductor	$F = BIl\sin\theta$
photon energy	$E = hf$
photo-electric effect	$hf = \Phi + ½mv_{max}^2$
de Broglie equation	$\lambda = h / mv$
refractive index	$n = c_i / c_r$ $n = \sin i / \sin r$
wave speed	$v = f\lambda$
double-slit interference	$\lambda = ax / D$
momentum	$p = mv$
force	$F = \Delta p / \Delta t$
kinetic energy	$E_k = ½mv^2$
gravitational potential energy	$\Delta E_p = mg\Delta h$
centripetal acceleration	$a = v^2 / r$
simple harmonic motion	$a = -(2\pi f)^2 x$ $x = A\sin 2\pi ft$ $x = A\cos 2\pi ft$
Newton's law of gravitation	$F = Gm_1m_2 / r^2$
gravitational field strength	$g = F / m$ $g = GM / r^2$
Coulomb's law	$F = Q_1Q_2 / 4\pi\varepsilon_0 r^2$
electric field strength	$E = F / Q$ $E = Q / 4\pi\varepsilon_0 r^2$ $E = V / d$
capacitance	$C = Q / V$
energy of charged capacitor	$W = ½QV$
time constant of CR circuit	$\tau = CR$
force on moving charged particle	$F = Bqv$
magnetic flux	$\Phi = BA$

The following is a list of data and formulae which will not be supplied to candidates in examinations. (continued)	
induced e.m.f	$e = N\Delta\Phi / \Delta t$
ideal transformer	$V_s / V_p = N_s / N_p = I_p / I_s$
ideal gas equation	$pV = nRT$
thermal energy change	$\Delta Q = mc\Delta\theta$
mass-energy	$\Delta E = \Delta mc^2$
radioactivity	$A = \lambda N$
apparent magnitude	$m = -2.5\,\lg I + \text{constant}$
apparent / absolute magnitude	$m - M = 5\,\lg(r / 10)$
Hubble's law	$v = H_0 d$
age of Universe	$t \approx 1 / H_0$
Doppler formula	$\Delta\lambda / \lambda = v / c$
lens formula	$power = 1/f = 1/u + 1/v$
X-ray attenuation	$I = I_0 e^{-\mu x}$
Hall voltage	$V_H = Bvd$
inverting amplifier gain	$G = -R_F / R_{IN}$
power ratio	$no.\ of\ decibels(\text{dB}) = 10\,\lg(P_1 / P_2)$

Appendix H

Summary of Key Quantities, Symbols and Units

The following list illustrates the symbols and units which will be used in question papers.

Corresponding lists of symbols and units have not been provided for the Options (Unit 2825). Where possible, conventional, well-established symbols and units will be used in Options questions, i.e. as given in **Symbols and Systematics**, ASE, 1995.

Quantity	Usual symbols	Usual Unit
mass	m	kg
length	l	m
time	t	s
electric current	I	A
thermodynamic temperature	T	K
amount of substance	n	mol
distance	d	m
displacement	s, x	m
area	A	m^2
volume	V	m^3
density	ρ	$kg\ m^{-3}$
speed	u, v, c	$m\ s^{-1}$
velocity	u, v, c	$m\ s^{-1}$
acceleration	a	$m\ s^{-2}$
acceleration of free fall	g	$m\ s^{-2}$
force	F	N
weight	W	N
momentum	p	N s
work	W	J

The following list illustrates the symbols and units which will be used in question papers.

Quantity	Usual symbols	Usual Unit
energy	E, U, W	J
potential energy	E_p	J
kinetic energy	E_k	J
heating	Q	J
change of internal energy	ΔU	J
power	P	W
pressure	p	Pa
torque	T	N m
gravitational constant	G	N kg^{-2} m^2
gravitational field strength	g	N kg^{-1}
angle	θ	°, rad
angular displacement	θ	°, rad
period	T	s
frequency	f	Hz
wavelength	λ	m
speed of electromagnetic waves	c	m s^{-1}
electric charge	Q	C
elementary charge	e	C
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
resistance	R	Ω
resistivity	ρ	Ω m
electric field strength	E	N C^{-1}, V m^{-1}

The following list illustrates the symbols and units which will be used in question papers.

Quantity	Usual symbols	Usual Unit
permittivity of free space	ε_0	F m^{-1}
capacitance	C	F
time constant	τ	s
magnetic flux	Φ	Wb
magnetic flux density	B	T
permeability of free space	μ_0	H m^{-1}
stress	σ	Pa
strain	ε	
spring constant	k	N m^{-1}
Young modulus	E	Pa
Celsius temperature	θ	°C
specific heat capacity	c	J kg^{-1} K^{-1}
specific latent heat	L	J kg^{-1}
molar gas constant	R	J K^{-1} mol^{-1}
Avogadro constant	N_A	mol^{-1}
number	N, n	
number density (number per unit volume)	n	m^{-3}
Planck constant	h	J s
work function energy	ϕ	J
activity of radioactive source	A	Bq
decay constant	λ	s^{-1}
half-life	$t_{½}$	s
atomic mass	m_a	kg, u

The following list illustrates the symbols and units which will be used in question papers.

Quantity	Usual symbols	Usual Unit
electron mass	m_e	kg, u
neutron mass	m_n	kg, u
proton mass	m_p	kg, u
molar mass	M	kg
proton number	Z	
nucleon number	A	
neutron number	N	

Appendix I

Glossary of Terms used in Question Papers

It is hoped that the glossary will prove helpful to candidates as a guide, although it is not exhaustive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context. They should also note that the number of marks allocated for any part of a question is a guide to the depth of treatment required for the answer.

(a) *Define* (*the term*[s])... is intended literally. Only a formal statement or equivalent paraphrase, such as the defining equation with symbols identified, being required.

(b) *Explain / What is meant by...* normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

(c) *State ...* implies a concise answer with little or no supporting argument, for example, a numerical answer that can be obtained by 'inspection'.

(d) *List* ... requires a number of points with no elaboration. Where a given number of points is specified, this should not be exceeded.

(e) *Describe* ... requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. The amount of description intended should be interpreted in the light of the indicated mark value.

(f) *Discuss* ... requires candidates to give a critical account of the points involved in the topic.

(g) *Deduce / Predict* ... implies that candidates are not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question. Predict also implies a concise answer with no supporting statement required.

(h) *Suggest* ... is used in two main contexts. It may either imply that there is no unique answer or that candidates are expected to apply their general knowledge to a 'novel' situation, one that formally may not be 'in the syllabus'.

(i) *Calculate* ... is used when a numerical answer is required. In general, working should be shown.

(j) *Measure* ... implies that the quantity concerned can be directly obtained from a suitable measuring instrument, for example, length using a rule, or angle using a protractor.

(k) *Determine* ... often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, for example, the Young modulus.

(l) *Show* ... is used when an algebraic deduction has to be made to prove a given equation. It is important that the terms being used by candidates are stated explicitly.

(m) *Estimate* ... implies a reasoned order of magnitude statement or calculation of the quantity concerned. Candidates should make such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.

(n) *Sketch* ... when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct. However, candidates should be aware that, depending on the context, some quantitative aspects may be looked for, for example, passing through the origin, having an intercept, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates clearly indicate what is being plotted on each axis.

(o) *Sketch ...* when applied to diagrams, implies that a simple, freehand drawing is acceptable. Nevertheless, care should be taken over proportions and the clear exposition of important details.

Appendix J

Notes for Guidance on Practical Examinations

Experimental Skills: AS and A2

The Practical Test papers normally consist of two questions. One of the questions in both the Practical Examination for AS (Unit 2823, Component 03) and for A2 (Unit 2826, Component 03) will be set in the same general context as that used for the preliminary planning exercise (see Section 4.2).

Administration of the Practical Examination

The list below gives some of the apparatus and materials commonly used in the Practical Examination. To instil some variation in the questions set, some novel items may be required. Details of the apparatus required are sent to Centres before the date of the examination. It is essential that absolute confidentiality be maintained in advance of the examination date.

A copy of the report, supplied as part of the Instructions, should be completed and enclosed in each envelope of scripts. A sample set of results may also be helpful for the Examiner, especially if there was any local difficulty with the apparatus.

Electrical Apparatus

Ammeter: (digital or analogue) f.s.d. 100mA and 1A

Voltmeter: (digital or analogue) f.s.d. 5V, 10V

Power supply: variable up to 12 V d.c. (low resistance)

Cells: 1.5 V

Lamp and holder: 6 V 60 mA; 2.5 V, 0.3 A

Rheostat

Switch

Leads and crocodile clips

Wire: corstantan 26, 28, 30, 32, 36, 38 s.w.g. or metric equivalents

Heat Apparatus

Long stem thermometer: -10°C to 110°C x 1°C

Metal calorimeter

Plastic or polystyrene cup 200cm3

Means to heat water safely to boiling

Stirrer

Optics Apparatus

None

Mechanics Apparatus and General Items

Card

Pendulum bob

Wood or metal jaws

Stand, boss and clamp

G-clamp

Rule (1m, 0.5 m, 300 mm)

Stopclock or stopwatch (candidates may use their own reading to 0.1 s or better)

Balance to 0.1g

Beaker: 100 cm3, 200 or 250 cm3

Plasticine

Blu-Tack

Wire cutters

Bare copper wire: 18, 26 s.w.g.

Stout pin or round nail

Scissors

Sellotape

Micrometer screw gauge

String/thread/twine

Slotted 100g masses or alternative