OCR ADVANCED SUBSIDIARY GCE IN PHYSICS B (Advancing Physics) (3888)

OCR ADVANCED GCE IN PHYSICS B (Advancing Physics) (7888)

Foreword to Second Edition

This booklet contains OCR's Advanced Subsidiary (AS) and Advanced GCE (A Level) Physics B (*Advancing Physics)* specifications for teaching from September 2002. It has been revised to take account of the QCA Review of Curriculum 2000.

There is no change to the structure or teaching content of the specification and most differences are cosmetic or clarifications. Significant changes are sidelined. The main changes are as follow:

Synoptic Assessment	**–**	**it is no longer a requirement to take synoptic units at the end of the course.**
Specification Content	**–**	**sections of Module 2864/01 have been clarified.**
Appendix C	**–**	**this now lists relationships which will not be provided in Question Papers.**

The Advanced Subsidiary 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 Advanced Subsidiary forms 50% of the assessment of the full Advanced GCE. However, the Advanced Subsidiary can be taken as a 'stand-alone' qualification. A2 is weighted at 50% of the total assessment of the Advanced GCE.

The first year of certification of the OCR Advanced Subsidiary Physics B (*Advancing Physics*) was 2001.

The first year of certification of the OCR Advanced GCE Physics B (*Advancing Physics*) was 2002.

In these specifications the term **module** is used to describe specified 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* (QCA, 1999), the *GCE Advanced Subsidiary and Advanced Level Qualification-Specific Criteria* (QCA, 1999) and the relevant Subject Criteria (QCA, 1999).

Qualification Accreditation Numbers:

Advanced Subsidiary GCE: 100/0625/4

Advanced GCE: 100/0457/9

CONTENTS

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Specification Summary

Outline

Advancing Physics is a new Advanced Subsidiary GCE and Advanced GCE course, reflecting physics as it is practised and used today.

The Advanced Subsidiary course provides a satisfying experience for the candidate who chooses to take Advanced Subsidiary GCE Physics as part of a broad post-16 curriculum. At the end of the course candidates should know more of what physics is about and its place in the world. At the same time the Advanced Subsidiary course provides a sound foundation for the candidate who chooses to go on to the second year and to take the Advanced GCE award.

The A2 course leads to an Advanced GCE qualification which enables candidates to go on to degree level studies at University, particularly physics or engineering; at the same time it provides an interesting and stimulating experience for the candidate who does not pursue the subject further. The course appeals to, and provides for, all candidates, whether they anticipate achieving a grade E or a grade A.

For each year of the course there will be a Students' Book and CD-ROM and for the teacher an enhanced CD-ROM and Handbook, all published by Institute of Physics Publishing. The *Advancing Physics* website, http://post16.iop.org/advphys/, maintained by the Institute of Physics, provides up to date material to support candidates and teachers and a way of teachers sharing their ideas. More information about all these resources can be found on the website.

In *Advancing Physics* there are opportunities for candidates to:

- develop practical skills
- practise data-handling skills
- increase their understanding of the part that mathematics plays in physics
- use their imagination
- place physics in a social or historical context and argue about the issues that arise
- be rewarded for initiative and interest in learning
- use information and communication technology.

Specification Content

The *Advancing Physics* course includes all the material defined in the Subject Criteria for Physics (QCA, 1999). There is some material new to Advanced GCE and there are also some new approaches to familiar topics.

In the AS course Modules 2860 and 2861 are each set out in two parts. Internally assessed coursework (Module 2862: Physics in Practice) is integrated into the delivery of these two modules.

Physics in Action (Module 2860) provides a graduated path from GCSE into the Advanced Subsidiary course, showing a wide variety of ways in which physics is currently put to use.

- **Communication** is about electric circuits, waves as signals and about images, including some optics.
- **Designer materials** introduces properties of materials and how these are used to make new materials.

Understanding Processes (Module 2861) is organised around different ways of understanding processes of change, the focus being on ‘curiosity-driven’ physics.

- **Waves and quantum behaviour** is mainly about superposition phenomena of waves, especially electromagnetic waves, with a brief account of the quantum behaviour of photons.
- **Space, Time and Motion** develops classical mechanics, including vectors.

In A2, Component 01 of Module 2863 and Component 01 of Module 2864 deliver the new physics in the second half of the Advanced GCE course. The two internally assessed coursework components (Component 02 of Module 2863 and Component 02 of Module 2864) are less closely tied to the content of the course, allowing candidates to chose their own context for further study. The final module in A2 (Module 2865) uses case studies to show that to solve problems physicists may need to call on a variety of aspects of physics. This part of the course prepares candidates for the synoptic element of the assessment.

Rise and fall of the Clockwork Universe (Module 2863 Component 01) develops the grand conception of the world as a 'mathematical machine', which transformed Western culture. Some of its limits are also shown. The content of this component is set out in two parts:

- **Models and rules** covers the core physics of random decay and the decay of the charge on a capacitor, energy and momentum, the harmonic oscillator and circular orbits. The field model is developed through consideration of gravitational fields;
- **Matter in extremes** shows how theories of matter and atoms explain behaviour: covering the kinetic theory of gases, thermal behaviour of matter and the effect of temperature.

Field and Particle Pictures (Module 2864, Component 01) introduces the modern picture of fields and particle interactions as fundamental mechanisms of nature. The content of this component is set out in two parts:

- **Fields** covers ideas about electromagnetism, electric field and potential;
- **Fundamental particles** is about atomic, nuclear and sub-nuclear structure, with attention to ionising radiation and risk.

Advances in Physics (Module 2865) consolidates, puts together and uses physics ideas from the whole course. A number of case studies show how different aspects of the physics in the course are used to tackle problems.

Scheme of Assessment

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

Assessment is by means of **3 units of assessment** for Advanced Subsidiary GCE and **6 units of assessment** for Advanced GCE:

Advanced Subsidiary GCE Candidates take Units 2860, 2861 and 2862.

Advanced GCE Candidates take Units 2860, 2861, 2862, 2863, 2864, and 2865.

Unit 2863 and Unit 2864 each contain two compulsory components.

Units of Assessment

Unit/ Component (where relevant)	Level	Name	Duration	Mode of Assessment	Weighting	
					AS	Advanced GCE
2860	AS	**Physics in Action**	1 hour 30 mins	Written examination	33.4%	16.7%
2861	AS	**Understanding Processes**	1 hour 30 mins	Written examination	36.6%	18.3%
2862	AS	**Physics in Practice**	-	Coursework	30%	15%
2863		**Rise and fall of the Clockwork Universe/ Practical Investigation**				
/01	A2	Rise and fall of the Clockwork Universe	1 hour 10 mins	Written examination	-	9.2%
/02	A2	Practical Investigation	-	Coursework	-	7.5%
2864		**Field and Particle Pictures/ Research Report**				
/01	A2	Field and Particle Pictures	1 hour 10 mins	Written examination	-	10.8%
/02	A2	Research Report	-	Coursework	-	7.5%
2865	A2	**Advances in Physics**	1 hour 30 mins	Written examination	-	15%

Question Paper Requirements

The question papers for Units 2860, 2861, 2863 Component 01 and 2864 Component 01 have a similar format. The papers are straightforward and allow for a variety of experience. There are short focused questions and longer structured questions. In Units 2860 and 2861 there are also some more open-ended questions designed for candidates to have time and freedom to show what they have learned independently. Some questions may set the physics studied during the course into a new context.

Unit 2865 is a synoptic paper that gives candidates the opportunity to show that they can draw together ideas in physics and link different aspects of the subject. The paper includes a comprehension / data analysis exercise. Candidates receive a copy of the text some weeks before the examination so that they are able to study the passage and research any aspects which they do not understand. In the examination they receive a new copy of the text together with a series of (unseen) questions about the physics in the passage. There are also two other structured questions about physics in a context which may be new to the student.

Coursework requirements

All the coursework is assessed by the candidate's physics teacher using criteria set by OCR and externally moderated by OCR.

In the Advanced Subsidiary GCE course candidates carry out three short tasks: an **Instrumentation task**, **Research and presentation** and **Making sense of data.** Together these comprise Unit 2862: Physics in Practice.

In the A2 half of the Advanced GCE course the coursework consists of two more substantial pieces of work, recognising the more developed skills and maturity of candidates by this stage. The candidates tackle a **Practical Investigation** (Unit 2863, Component 02) and produce a **Research Report** (Unit 2864, Component 02).

Key Skills

Key Skills signposting appears in three sections of OCR specifications:

(1) *Key Skills Coverage* – the matrix aids curriculum managers in mapping the potential Key Skills coverage within each OCR Advanced Subsidiary/Advanced GCE specification.

(2) *Specification Content (section 5)* – the specific evidence references enable subject teachers to identify opportunities for meeting specific Key Skills evidence requirements within the modules they are delivering.

(3) *Appendix A* – provides guidance to teachers in trying to identify those parts of their normal teaching programme which might most appropriately be used to develop or provide evidence for the Key Skills signposted.

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.

In section 5 the symbol  is used 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 QCA Key Skills specifications for use in programmes starting from September 2000. References in section 5 and Appendix A, for example **C3.1,** show the Key Skill (Communication), the level (3) and subsection (1).

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

Key Skills Coverage

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

	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
2860	✓	✓	✓	✓	✓	✓
2861	✓	✓	✓		✓	
2862	✓	✓	✓	✓	✓	
2863	✓	✓	✓	✓	✓	✓
2864	✓	✓	✓		✓	
2865	✓	✓	✓		✓	

Overlap with other qualifications

There are overlaps between the content of this course and OCR VCE Science. For instance:

- the Practical Investigation in Module 2863 has very similar aims and objectives as the VCE mandatory Unit Carrying out Scientific Investigations (Unit 7440);
- *Communication* in Module 2860 has significant overlap with the content of the VCE Optional Unit *Imaging and Sensing* (Unit 7445);
- *Designer materials* in Module 2860 has significant overlap with the content of the VCE Optional Unit *Making polymers for a purpose* (Unit 7449).

1 Introduction

The *Advancing Physics* course provides a distinctive structure within which candidates learn both about fundamental physical concepts and about physics in technological settings. A primary aim of the course is to show how physics is practised and used today. Equally important, however, is to show the usefulness of the subject, and to illustrate the kind of impact which discoveries in physics have had on the way people live.

Key features of the course are:

- new material – a simple, direct and rigorous approach to modern ideas;
- new perspectives – different angles on familiar topics;
- encouragement for teachers and candidates to select topics of interest for further individual study;
- assessment methods which reflect and reward the teaching and learning styles encouraged by the course;
- extremely extensive support materials for both teachers and candidates; including appropriate software, providing a variety of learning activities.

In *Advancing Physics* there are opportunities for candidates to:

- develop practical skills (for example, in choosing and using materials and equipment);
- practise data-handling skills (for example, estimating, presenting and analysing data);
- use their imagination (for example, inventing an explanation);
- place physics in a social or historical context and argue about the issues that arise;
- be rewarded for initiative and interest in learning – for finding out for themselves;
- use information and communication technology as an integral part of learning physics.

Physics and mathematics go together naturally and inevitably. Three main kinds of mathematical activity crucial to physics are identified: 'getting out numbers'; analysis and presentation of data and making models. It seems essential to see certain aspects of mathematics as an integral part of doing physics, as an integral part of the *pleasures* of physics. This course is very positive about mathematics, stressing and demonstrating its value in physics: its power, its beauty and how it aids the imagination. To this end the course incorporates the teaching of some mathematics within the context of the physics for which it is required. In this way essential mathematical content is learnt and used in interesting contexts.

A range of assessment methods are used. Some aims of the course can best be assessed by written examinations and others through coursework. This variety is essential if the assessment is to reflect the wide variety of learning activities, which is a feature of the course.

In the AS course candidates develop their ability to learn independently, their experimental and investigational skills and their research and communication skills. For the coursework assessment candidates carry out three short tasks, each of which is expected to take no more than three hours of contact time, together with a similar period of time for research and writing up. The tasks are:

1 **Instrumentation project**. This may involve one of: building and testing a sensor; carefully testing a given sensor, or putting together an instrumentation system. This project comes directly

out of the work candidates are doing in *Communication* and rewards their practical, experimental, planning and investigational skills.

2 **Research and presentation**. Candidates choose and research a material or a use of materials of interest to them. They present the results concisely, in a publicly accessible form (such as a talk, poster or computer based display such as web pages). This work is the culmination of their study of materials in *Designer materials*.

3 **Making sense of data** Candidates prepare a concise report interpreting, explaining and evaluating data from an experiment, using their understanding of physics and skill in analysing and effectively communicating data, to communicate clearly and logically the meaning and reliability of results.

In the A2 half of the Advanced GCE course the coursework consists of two more substantial pieces of work, recognising the more developed skills and maturity of students by this stage. The candidates tackle a **Practical Investigation** of an aspect of physics of their own choice. They also have an opportunity to follow up some aspect of physics studied during the course. This **Research Report** allows candidates to select an area of physics of particular interest to them. The task provides an opportunity for candidates to draw together ideas from various aspects of the course and use the skills they have developed to carry out research and then process the information for their report. The report allows candidates to demonstrate their synoptic skills by showing how different aspects of the subject are used to solve problems and explain phenomena.

A consistent assessment model is used for each of the pieces of work, marking the work under each of four headings. The criteria are clear and straightforward, easily used by teachers and understandable to students. The coursework makes a manageable and important contribution to the positive achievement of the student.

Support and resources for *Advancing Physics*

The course is supported by a full range of resources, both in print and in electronic form, published by Institute of Physics Publishing. There will be full colour Student texts and Students' CD-ROMs for each year of course. The CD-ROM includes a Study Guide to support the candidate throughout the course.

The Teachers' Handbook guides teachers through the course; helps with organising the teaching and learning; and gives guidance on the management of coursework. This Handbook also forms part of the content of a teacher's CD-ROM, which provides more detailed support for teaching the course. Further details of published resources can be found in section 7.

OCR and the *Advancing Physics* project will provide support for teachers through INSET, a user group network, a newsletter and a dedicated website. Further details of this support can be found in sections 6 and 7.

Choice for candidates – scope for teachers

As described above the course will be fully supported, to help teachers manage its many new, even radical features. But at the same time, the Advanced Subsidiary GCE and Advanced GCE specifications provide choice for candidates and real scope for initiative by teachers. Thus, although pathways through the specifications are provided and supported with resources, teachers are not restricted to these routes.

Similarly, the specifications provide scope for candidates to choose their own examples of ideas to follow up in detail and have credited, both through coursework and through examination questions which allow them to select the context of their answers.

For these reasons, resources for teachers and candidates will not remain static, but will be updated with the most recent examples of new discussions, inventions and applications.

It is hoped that candidates and teachers will find the course enjoyable. Enjoyment promotes motivation and enthusiasm, which encourages the development of imaginative teaching styles and foster profitable modes of learning. These may in turn lead candidates to a lifelong interest in the subject and encourage more of them to choose to study physics, or a related subject, in higher education.

Recommended prior learning

These specifications have been developed for students who wish to continue with a study of physics after GCSE. The AS specification builds from grade CC in GCSE Science: Double Award and grade C in GCSE Physics and these qualifications should be seen as a requisite for entry to AS Physics. Students who have studied and passed an Intermediate GNVQ Science course should also have sufficient knowledge and understanding to study the AS Physics course. Mature students without these qualifications may have acquired sufficient ‘life skills’ to enable progression onto this course.

Recommended prior learning for the AS modules is described in terms of National Curriculum statements and these are shown in the introduction to each AS module. The A2 modules build upon the knowledge and understanding acquired at AS.

Recommended prior learning for the A2 course would be a successful performance at Advanced Subsidiary Physics.

1.1 Certification

These specifications 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

There are overlaps in the content of this course and the OCR VCE Science. For instance:

- the Practical Investigation in Module 2863 has very similar aims and objectives as the VCE mandatory Unit Carrying out Scientific Investigations (Unit 7440);
- *Communication* in Module 2860 has significant overlap with the content of the VCE Optional Unit *Imaging and Sensing* (Unit 7445);
- *Designer materials* in Module 2860 has significant overlap with the content of the VCE Optional Unit *Making polymers for a purpose* (Unit 7449).

1.4 Exclusions

Candidates entering this Advanced Subsidiary GCE specification may **not** enter any other Advanced Subsidiary GCE specification with the certification title Physics in the same examination series.

Candidates entering this Advanced GCE specification may **not** enter any other Advanced GCE specification with the certification title Physics in the same examination series.

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

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

The classification code for these specifications is 1210.

1.5 Code of Practice requirements

These specifications will comply in all respects with the revised Code of Practice requirements for courses starting from September 2000.

2 Specification Aims

The aims of the *Advancing Physics* course are summarised below.

The course should encourage candidates to:

- develop their knowledge and understanding of physics and an appreciation of the link between theory and experiment;
- appreciate how physics has developed and is used in present day society, acknowledging the importance of physics as a human endeavour which has historical, social, philosophical, economic and technological connections;
- 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 the Advanced GCE course they should appreciate how scientific models are developed and the power they can have to help understanding;
- bring together knowledge to illustrate ways in which different areas of physics relate to each other.

The course should provide for candidates' futures by:

- developing their ability to learn independently;
- opening new horizons, giving them visions of a variety of possible lives;
- providing a variety of activities to help them understand their own strengths and the possibilities for their future;
- providing opportunities for students to acquire and demonstrate competence in the Key Skills.

The course should develop candidates' interests by:

- stimulating their curiosity;
- providing depth and challenge;
- providing manageable choice;
- being up to date and connected to the life of the candidate.

The course should be made enjoyable by:

- using a wide range of teaching and learning styles;
- providing opportunities for students to explore their interests;
- giving candidates ownership of their learning.

The course must meet the expectations of:

- the candidate who is looking for interest, enjoyment and a worthwhile qualification;
- the teacher who is looking for a varied stimulating course with room for initiative and professional involvement;
- employers and HE who expect qualified candidates to have certain skills and knowledge.

The course develops a culture of success through:

- being accessible to students from a range of backgrounds;
- providing opportunities for positive achievement;
- having an assessment model which is accessible and provides profitable experiences, whilst being discriminating, reliable and valid.

The course should tell of the values and virtues of physics, whilst never suggesting that it can cure all ills and answer all problems.

Not all of the above aims can, or should be, assessed although they do form an important part of both the Advanced Subsidiary and A2 courses. The knowledge, skills and understanding which candidates are required to demonstrate are set out in more detail in the assessment objectives below.

2.1 Spiritual, moral, ethical, social and cultural issues

The course develops candidates' understanding of how scientific ideas are accepted and rejected on the basis of empirical evidence, and how scientific controversies can arise from different ways of interpreting such evidence. The course provides many opportunities to discuss the way physics is applied and used, and to evaluate the benefits and drawbacks of scientific and technological developments for individuals, communities and environments. It reflects some of the contributions of physics to culture and some of the influence of culture on physics.

Such opportunities are specifically and systematically built into the course materials throughout, and are identified in the specifications.

2.2 Environmental education

There are opportunities within *Advancing Physics* to consider environmental issues in the context of the physics ideas. For example:

- tracking changes in the environment using remote sensing (Communication in Module 2860);
- consideration of the impact of the manufacturing, use and disposal of materials (Designer Materials in Module 2860);
- the effect on the environment of radioactivity, both natural and man made (Fundamental particles in Module 2864 Component 01).

2.3 European dimension

Physics is of its nature international in outlook. European (and other) contributions to physics are explicitly recognised in the course. The value of European co-operation is reflected both in discussion of its role in particle physics (in Module 2864, Component 01) and through historical examples of European cross-fertilisation of ideas, for example in wave theory (in Module 2861) and electromagnetism (in Module 2864, Component 01). The Research report could, circumstances permitting, exploit visits abroad (for example CERN, DESY, or Grenoble). In both the **Research and Presentation** (Module 2862) and the **Research Report** (in Module 2864, Component 02) students are asked to place the physics in a wider context, which may include the European context.

2.4 Health education

There are opportunities within *Advancing Physics* to consider issues related to Health Education including

- use of a variety of imaging techniques in medicine (Communication in Module 2860);
- developing materials for use in medicine, such as artificial limbs (Designer Materials in Module 2860);
- use of radioactivity in diagnosis and treatment and the risks it poses (Fundamental particles in Module 2864 Component 01);
- analysis of risk (Fundamental particles in Module 2864 Component 01).

2.5 Economic and industrial understanding

There are opportunities within *Advancing Physics* to develop ideas about how physics interacts with industrial development and how development of physics is affected by economic decisions including

- the development of communications technology (Communication in Module 2860);
- the development of new materials (Designer Materials in Module 2860);
- the use of imaging to collect and use information (Communication in Module 2860);
- the consequence of developments in transport and travel (Space and time in Module 2861);
- the development of large multinational physics experiments (Fields in Module 2864 Component 01);
- the generation and distribution of electricity (Fields in Module 2864 Component 01);
- the design of electromagnetic machines (Fields in Module 2864 Component 01);
- assessing risk (Fundamental particles in Module 2864 Component 01).

2.6 Avoidance of Bias

OCR has taken great care in the preparation of these specifications and assessment 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.

AO1, AO2 and AO3 are the same for Advanced Subsidiary GCE and Advanced GCE. AO4 applies only to the Advanced GCE specification.

AO1 Knowledge with understanding

Candidates should be able to:

- recognise, recall and show understanding of:
    - specific physical facts, terminology, principles, relationships and concepts;
    - standard experimental and investigational techniques;
    - appropriate computational, algebraic and graphical techniques
- draw on existing knowledge to show understanding of the ethical, social, economic, environmental and technological implications and applications of Physics;
- select, organise and present relevant information clearly and logically, using specialist vocabulary where appropriate;
- ensure writing is legible with accurate use of spelling, grammar and punctuation in order to make meaning clear.

AO2 Application of knowledge and understanding, synthesis and evaluation.

Candidates should be able to:

- describe, explain and interpret familiar phenomena and effects in terms of physical principles and concepts;
- carry out relevant estimations and calculations;
- present arguments and ideas clearly and logically, using specialist vocabulary where appropriate;
- apply physical principles and concepts to new situations including those which relate to the ethical, social, economic and technological implications and applications of Physics;
- interpret and translate, from one form to another, data presented as continuous prose or in tables, diagrams and graphs;
- analyse and assess the validity of physical information, experiments, inferences and statements;
- demonstrate an understanding of the relationships between different areas of the subject.

AO3 Experiment and Investigation

Candidates should be able to:

- show initiative and independence in carrying out experiments and investigations;
- use knowledge and understanding of physics to devise and plan experimental activities, selecting appropriate experimental techniques;
- demonstrate safe and skilful practical techniques;
- make observations and measurements with appropriate precision and record these methodically;
- interpret, explain, evaluate and communicate the results of experimental activities using knowledge and understanding of physics;
- communicate the results of experimental activities 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:

- bring together principles and concepts from different areas of physics and apply them in a particular context, expressing ideas clearly and logically and using specialist vocabulary where appropriate;
- use the skills of physics in contexts which bring together different areas of the subject.

The assessment objectives are weighted as follows:

	Advanced Subsidiary GCE (%)	**A2 (%)**	**Advanced GCE (%)**
AO1	46	22	34
AO2	34	23	28.5
AO3	20	15	17.5
AO4	0	40	20

3.1 Specification grid

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

Unit / Component (where relevant)	Title	Level	Percentage of Advanced GCE				
			AO1	AO2	AO3	AO4	Total
2860	**Physics in action**	AS	10.0	6.7			**16.7**
2861	**Understanding processes**	AS	11.0	7.3			**18.3**
2862	**Physics in Practice**						
	Instrumentation Task	AS			5.0		**5.0**
	Research and Presentation	AS	2.0	3.0			**5.0**
	Making Sense of Data	AS			5.0		**5.0**
2863/01	**Rise and fall of the Clockwork Universe**	A2	4.6	4.6			**9.2**
2863/02	**Practical Investigation**	A2			7.5		**7.5**
2864/01	**Field and Particle Pictures**	A2	5.4	5.4			**10.8**
2864/02	**Research Report**	A2	1.0	1.5		5.0	**7.5**
2865	**Advances in Physics**	A2				15.0	**15.0**
Total			**34.0**	**28.5**	**17.5**	**20.0**	**100**

3.2 Quality of written communication

Candidates are assessed on their ability to organise and present information, ideas, descriptions and arguments clearly and logically, taking into account their use of grammar, punctuation and spelling. This assessment occurs on all written papers and within each of the coursework tasks.

4 Scheme of Assessment

The assessment will:

- test the candidate's knowledge and understanding of physics
- be accessible and rewarding, whilst at the same time being discriminating, reliable and valid
- provide opportunities for students to be credited for their initiative and independent learning
- use a range of assessment styles through a wide variety of activities
- provide opportunities for positive achievement
- aim to develop a culture of success.

To meet these aims a range of assessment methods will be used. The range of aims demands this; some can best be served by short focused questions, some require more open-ended questions where candidates have time and freedom to show what they have learned and others are best assessed through coursework. A variety of methods may also help candidates, particularly where their aptitudes for particular types of task vary. Finally, such variety is needed if the assessment is to reflect the wide variety of learning activities which is a feature of the course.

Candidates take three units for Advanced Subsidiary GCE; followed by a further three units at A2 if they are seeking an Advanced GCE award.

Units of Assessment

Unit/ Component (where relevant)	Level	Name	Duration	Mode of Assessment	Weighting	
					AS	**Advanced GCE**
2860	AS	**Physics in Action**	1 hour 30 mins	Written examination	33.4%	16.7%
2861	AS	**Understanding Processes**	1 hour 30 mins	Written examination	36.6%	18.3%
2862	AS	**Physics in Practice**	-	Coursework	30%	15%
2863		**Rise and fall of the Clockwork Universe/ Practical Investigation**				
/01	A2	Rise and fall of the Clockwork Universe	1 hour 10 mins	Written examination	-	9.2%
/02	A2	Practical Investigation	-	Coursework	-	7.5%
2864		**Field and Particle Pictures/ Research Report**				
/01	A2	Field and Particle Pictures	1 hour 10 mins	Written examination	-	10.8%
/02	A2	Research Report	-	Coursework	-	7.5%
2865	A2	**Advances in Physics**	1 hour 30 mins	Written examination	-	15%

Units 2863 and 2864 each consist of two components. Both components must be taken in each of these units.

If a candidate retakes one of these units within 12 months, they have the opportunity to carry forward the mark for the coursework component.

All candidates for Units 2863 and 2864 should be entered under the relevant unit code with one of the following option codes.

Entry Option	Components to be taken	
A	01	Written examination
	02	Coursework
B	01	Written examination
	82	Coursework mark carried forward

Rules of combination

Candidates must take the following combination of units:

Advanced Subsidiary GCE Units 2860, 2861 and 2862.

Advanced GCE Units 2860, 2861, 2862, 2863, 2864 and 2865.

Unit availability

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

The availability of units is shown below.

Unit	Title	Jan 2003	June 2003
2860	Physics in Action	✓	✓
2861	Understanding Processes	✓	✓
2862	Physics in Practice	✓	✓
2863	Rise and fall of the Clockwork Universe / Practical Investigation	✓	✓
2864	Field and Particle Pictures / Research Report	✓	✓
2865	Advances in Physics	✓	✓

The availability shown for 2003 will be the same in subsequent years.

Sequence of Units

The normal sequence in which the units could be taken is Units 2860, 2861 and 2862 leading to an Advanced Subsidiary award then Units 2863, 2864 and 2865, the six units together leading to the Advanced GCE award. However, units may be taken in other sequences.

Alternatively candidates may take all the Assessment Units at the end of their Advanced Subsidiary GCE or Advanced GCE course in a 'linear' fashion, if desired.

Synoptic assessment

Synoptic assessment requires the candidates to draw together knowledge, understanding and skills learned in different parts of the Advanced GCE course. The emphasis is on understanding and application of the ideas and principles of physics in this specification. The synoptic assessment accounts for 20% of the total Advanced GCE marks. In *Advancing Physics* there is particular emphasis on synoptic skills in the internally assessed *Research Report* (Unit 2864 Component 02) and in Unit 2865.

For Advanced GCE, Units 2864 and 2865 should normally be taken at the end of a candidate's course of study, but this is not a requirement.

Aggregation

Candidates may enter for:

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

Candidates must enter the appropriate Advanced Subsidiary 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

Candidates are permitted to re-sit units once only, before seeking an Advanced Subsidiary GCE or Advanced GCE award, and the better result will count.

Re-sits of Advanced Subsidiary GCE and Advanced GCE

Candidates may retake the whole qualification more than once.

4.1 Question Papers

4.1.1 Advanced Subsidiary

Unit 2860 – Physics in Action (1 hour 30 minutes) (90 marks)
Unit 2861 – Understanding Processes (1 hour 30 minutes) (90 marks)

The question papers are straightforward and allow for a variety of experience. There are short questions, structured questions and other questions which provide a framework within which the candidate can answer from the knowledge and particular contexts they have chosen to study during the course. Some questions may set the physics studied during the course into a new context.

In these question papers there are two sections. In Section A there are approximately 20 marks for the very short questions; in Section B approximately 40 marks for the structured questions and in Section C there are 30 marks for extended answers. All questions on these papers are compulsory. Quality of communication is assessed within Section C.

4.1.2 A2

Unit 2863 Component 01 – Rise and fall of the Clockwork Universe (1 hour 10 minutes) (70 marks)

Unit 2864 Component 01 – Field and Particle Pictures (1 hour 10 minutes) (70 marks)

The question papers for Unit 2863 Component 01and Unit 2864 Component 01 have a similar format to those for Units 2860 and 2861. There are short questions and structured questions. Some questions may set the physics studied during the course into a new context. The distribution of marks is approximately 20 marks for the short questions in Section A and 50 marks for the structured parts in Section B. All questions on these papers are compulsory. Quality of communication is assessed within Section B.

Unit 2865 – Advances in Physics (1 hour 30 minutes) (90 marks)

In preparation for Section A of this synoptic paper candidates receive a printed text about physics (approximately 1500 – 2000 words) which includes data and diagrams. This is supplied to candidates some weeks before the examination. They have the opportunity to study the passage in advance of the examination. In the examination they receive a new copy of the passage together with the (unseen) questions about the content. This form of comprehension / data analysis paper allows candidates to have plenty of time to read the passage and look up unfamiliar ideas before sitting down to answer the questions. Whilst the context of the passage may be unfamiliar to the candidate, the physics that they are asked to use will be drawn from across the whole Advanced GCE course. The paper tests the synoptic ability of the candidate.

Section B of this paper contains two structured questions. These further test synoptic abilities through questions about physics and its applications, in the context of problems that bring together ideas of physics from different areas of the course.

Quality of communication is assessed across the whole paper.

4.2 Coursework

Throughout the *Advancing Physics* course candidates develop their ability to learn independently, their experimental and investigational skills and their research and communication skills. There are many opportunities for formative assessment as a candidate follows the course. Candidates can see their progress through the levels in the criteria set. The assessment recognises the wide range of skills candidates develop during the course.

4.2.1 AS

Unit 2862: Physics in Practice (120 marks)

There are three short coursework tasks in Unit 2862. Each of these three tasks is expected to take no more than three hours of contact time and an equivalent amount of independent study for research and writing up. The work is carried out during the Advanced Subsidiary course, and assessed at that time. The three pieces of work together form a coursework portfolio for which a single mark is submitted for Unit 2862.

The three tasks are:

- Instrumentation task
- Materials research and presentation
- Making sense of data

Further details of the tasks are given in Section 5.3 of this specification.

4.2.2 A2

There are two coursework tasks in the A2 half of the Advanced GCE course. Each provides an opportunity for candidates to work independently, choosing their own topic for study. The tasks require more time from the candidate and it is expected there will be a significant difference in the outcome in comparison with those tasks tackled in the Advanced Subsidiary course. Each task is expected to take two weeks of contact time and the associated independent study time.

Unit 2863 Component 02: Practical Investigation (40 marks)

The practical investigation should be carried out on any aspect of physics of interest to the candidate. Further details are given in section 5.4.3.

Unit 2864 Component 02: Research Report (40 marks)

This consists of a written report based on the individual work of a candidate on a topic of physics of his or her own choosing which requires the use and synthesis of ideas from different areas of the subject. Further details are given in section 5.5.3.

4.2.3 Assessment of coursework

The purpose of the assessment is to ascertain the value of the work carried out by the candidate using the criteria for assessment. The criteria provide the framework within which fair-minded and informed decisions can be made which result in ratings which fairly reflect the level of performance, are internally consistent and comparable with those produced in other Centres. The person responsible for teaching the students must carry out the assessment. Where several teachers in a Centre are involved, it is expected that arrangements will be made to ensure that they are all interpreting the criteria in the same way and that their marking is internally standardised.

These criteria provide a consistent framework of assessment for **all** the coursework in *Advancing Physics*, both in Advanced Subsidiary and in A2. Since they cover relatively different tasks these formal criteria inevitably concentrate on some important general areas of the candidate's performance.

It is important to realise that the coursework can be fairly and effectively assessed at this general level, without becoming immersed in detail. Through INSET, by using the more specific guidance in the *Advancing Physics Coursework Handbook* and the exemplar material and with experience of moderation, teachers will become increasingly confident and consistent in their application of the criteria.

The assessment is recorded by annotation of the assessment sheets provided in Appendix E and annotation of the work. The teacher is asked to mark on the assessment sheet the 'best fit' descriptor for each of the criteria shown. These judgements are then used to determine the mark out of five awarded for that criterion. If necessary teachers are invited to write a few words about the evidence they are taking into account, both from personal observation and from the written outcome. The record of personal observation should be brief and factual, and will certainly be recollection rather than verbatim reporting.

It is an important feature of the coursework that it is assumed that teacher and candidate will work closely together throughout. This must be done in such a way that it is possible for the teacher to work closely with a candidate *and* allow room for the candidate to perform at all levels.

The candidates' work is assessed using criteria which are grouped in four strands:

Strand A: Initiative and independence: Planning and use of resources

Strand B: Use of knowledge, skill and understanding of physics

Strand C: Quality of communication

Strand D: Meeting the demands of the particular task

The same strands are used in each of the assessment tasks. However on each occasion the emphasis is different and the different demands of each task allow candidates to demonstrate different strengths.

The criteria framework is outlined in Appendix E.

4.2.4 Moderation of coursework

The purpose of moderation is to ensure that the standards 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. For all coursework components there are two tiers in the moderation procedure: Internal Standardisation and External Moderation.

Internal standardisation

The purpose of internal standardisation is to check that the work of all candidates from the Centre has been assessed to a common standard, in keeping with the criteria. To produce a single reliable set of marks for each coursework component, the Centre will conduct internal standardisation of the coursework marks if more than one teacher is involved. It is the responsibility of the Centre to ensure that internal standardisation is carried out effectively, and to provide evidence of this process.

Two possible schemes of internal standardisation, which have been effectively used by teachers in Centres, are listed below:

- marked scripts are circulated between colleagues, re-read, and the ratings confirmed;
- scripts from different batches, which have been given the same ratings totals, are re-read and checked for comparability.

External Moderation

After all coursework has been marked by the teacher and internally standardised by the Centre, marks are submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures.

Annotation of Coursework

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

The writing of comments on candidates' work can provide a means of communication between teachers during internal standardisation of coursework. The main purpose of writing comments on candidates' coursework is, however, to provide a means of communication between teacher and coursework moderator.

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 achieved and must also indicate where errors in physics have been noticed.

4.2.5 Minimum Coursework Requirements

If a candidate submits no work for a coursework component, 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 criteria and marking instructions and the appropriate mark awarded, which may be 0 (zero).

4.2.6 Authentication of Coursework

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

4.2.7 Health and Safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for GCE AS and Advanced GCE this is likely to be the local education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to co-operate 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.

Preparing COSHH risk assessments for project work in schools, SSERC, 1991

Hazardous chemicals: A manual for science education, SSERC 1998

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

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 was inadequate or the skills of the candidates were 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.

4.3 Differentiation

In the question papers, differentiation is achieved by setting questions which are designed to assess candidates at their appropriate level 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 tasks which enable them to display positive achievement.

4.4 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.

4.5 Awarding of Grades

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

Both Advanced Subsidiary GCE and Advanced GCE results 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 which bring together different areas of the subject.

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

5 Specification Content

These specifications are set out in the form of teaching modules. Each teaching module is assessed by its associate unit of assessment.

The specification content reflects the course aims. The emphasis is on the candidate's own learning through a variety of modes of teaching. The specification outcomes are written in terms of what the candidate **can do**. For clarity, the outcomes are grouped under four headings, reflecting and defining different kinds of achievement, from which follow appropriate forms of assessment. These headings are explained here, and are used with these meanings throughout.

Candidates should demonstrate :

(a) Knowledge and understanding of phenomena, concepts and relationships by describing and explaining .....

There is within the course a core body of knowledge of phenomena, ideas and relationships. Candidates should be able to describe these phenomena, including where appropriate how these phenomena may be observed and measured, and explain them in terms of appropriate ideas and relationships. They should be able to show that certain relationships can be derived from others. They should be able to use the essential ideas in new contexts.

Within these specifications learning outcomes which use the expression *Describe and explain ....* indicate phenomena which candidates are expected to know and for which they should be able to give a simple theoretical account, including where appropriate showing how relationships can be derived from others. *Describe...* used alone indicates phenomena whose explanation is not required.

(b) Comprehension of the language and representations of physics by making appropriate use of the terms ..... and by sketching and interpreting graphs and diagrams

Candidates need to be able to understand and use the language of physics, including graphs and diagrams as well as terminology.

Where the learning outcomes use the expression *Make appropriate use of the terms ....* candidates should understand the terms listed when they read them and use them correctly in writing. They should be able to interpret graphs and diagrams and use sketch graphs and diagrams to help in their explanations of ideas.

(c) Quantitative and mathematical skills, knowledge and understanding by making calculations and estimates ..... and by showing graphically

Within these specifications learning outcomes which use the expression *Make calculations and estimates …..* outline the ideas for which calculations or manipulation of equations may be required. Candidates may be asked to make sensible estimates of quantities and then show some calculation. Sometimes it is more appropriate to describe a relationship graphically. Candidates should be able to use diagrams to support their thinking when that is helpful.

Equations other than those explicitly prohibited are available on the Formula and data sheet *Data, Formulae and Relationships* (See Appendix B).

(d) Initiative and independence in learning by giving and explaining examples of.....

Candidates following the course have many opportunities for independent study. They are required to research for themselves interesting applications and contexts for the physics taught in the course. Sometimes they may be able to share their findings with the rest of the class, as a written or spoken presentation. Spoken presentations provide opportunities to discuss ideas within the group. The examination provides opportunities for candidates to use this work to answer questions which invite them to give their own examples of the physics in the question.

Thus within the AS specification learning outcomes which use the expression *Give and explain examples of....* indicate where candidates are expected to be able to produce their own example of a given principle, idea or

method, and to explain it in detail, including showing why it is in fact an example of the principle (questions might ask for less than all of this).

One aim of such statements is to provide a way of requiring a common set of principles, ideas and methods to be studied, whilst giving candidates and teachers some freedom to follow and develop their own interests, in selecting examples. They are also intended to facilitate provision of occasions for developing key skills, notably communication, by making it reasonable for practice for the examination to include candidates making presentations about examples which they have researched. Instances offered as examples should not be taken as an exclusive list; candidates and teachers are encouraged to look out for new and different examples. Although such contexts may be used in other questions on the paper, they will be fully described and the nature of the question will not advantage those who have studied that context as their special example.

Statement (d) is not included in the A2 specification because opportunities for independent study are provided by the two pieces of extended coursework – the Practical Investigation (Unit 2863, Component 02) and the Research Report (Unit 2864, Component 02). However it is expected that this mode of learning will continue to be used to teach the content of the A2 course.

Italicised phrases in the following statements are intended to clarify the scope of the topic for the teacher and candidate. Their function is normally to limit the scope.

5.1 Module 2860: Physics in Action

C3.1a C3.1b; N3.1 N3.2 N3.3; IT3.1 IT3.2 IT3.3

WO3.1 WO3.2 WO3.3; LP3.1; PS3.1 PS3.2 PS3.3

This initial teaching module is intended:

- to connect with candidates' interests and develop them further
- to provide a graduated path from GCSE work into Advanced level work
- to offer a satisfying and broad variety of kinds of experience and knowledge
- to show a wide variety of ways in which physics is currently put to use
- to develop skills and habits of independent working, and individual practical confidence and competence
- to offer up-to-date but accessible ideas and methods in physics

The work is organised around a study of Communication (sections 5.1.1 and 5.1.2), and a study of Designer Materials (section 5.1.3), planned so that the essential core topics find a natural and stimulating place within them. Either part may be taught first.

The main focus in this module is on varieties of physics in action, preparing the way for more theoretical 'curiosity driven' material in Module 2861. This is not to say that fundamental ideas are neglected: important ideas about information are approached through imaging and signalling; basic concepts of measurement are approached through sensors; the crucial problems of relating macroscopic and microscopic views of the world are approached through the study of modern materials. Fundamental understandings of the world have a place too: for example the existence of atoms, information from astronomical images, basic structures of matter, the fact that matter is made of charged particles.

The choice of examples of physics in action is intended to reflect current but long-lasting and important developments in the subject: the increasing importance of visualisation; the impact of micro-technology and communication technology; the drive to better instrumentation; the expanding field of studies of materials and condensed matter in all their many forms. The choice also reflects the great variety of ways in which physics is used today, including medical physics, communication, industrial measurement, optics and opto-electronics, and the study of new materials.

Candidate activities are also carefully chosen, and encouraged by appropriate coursework tasks, to begin early on developing confidence, initiative, responsibility and good study habits, together with clearly focused experimental skills and knowledge.

5.1.1 Communication

Content

5.1.1.1 Imaging and signalling

5.1.1.2 Sensing

These sections are about electric circuits and waves and about images, including some optics. The physics is approached through a study of sensors and how they work and of how information can be processed, transmitted and presented.

Candidates have opportunities to develop IT skills through the use of image processing, data capture, signal processing and data analysis software.

Opportunities are given to put the physics in a broader perspective by considering, for example, images of the distant universe and their interpretation or human visual perception.

Recommended prior knowledge

This work is a continuation of work on electricity and waves at GCSE. Candidates are expected to:

- know about electric current, potential difference, resistance and power in circuits (Sc4.1 a-i);
- know the relationship between current, charge and time (Sc4.1 p);
- be able to connect up series and parallel circuits and measure current and potential difference. (Sc4.1 a, e);
- to be familiar with the phenomena of reflection and refraction and be able to give a simple description of them (Sc4.3 a – d);
- know the meaning of frequency, wavelength and amplitude of a wave and know and be able to use the relationship $v = f\lambda$. (Sc4.3 e –f);
- know about the electromagnetic spectrum and some uses of radio waves, microwaves, infra-red and visible light in communications (Sc4.3 h-k);

Opportunities are provided for consolidating and developing this material, placing it on a more secure basis, so providing an appropriate path into Advanced GCE work.

5.1.1.1 Imaging and signalling

In the context of the digital revolution in communication, this section introduces elementary ideas about image formation and digital imaging, and about the storage and transmission of digital information.

The material can be taught using up-to-date contexts such as fax, email, and medical scanning. There are opportunities to address human and social concerns, for example the consequences of the growth of world-wide digital communications.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing:

- the formation of a real image by a thin converging lens, understood as the lens changing the curvature of the incident wave-front;
- the storage of images in a computer as an array of numbers which may be manipulated to alter the image;
- digitising a signal; advantages and disadvantages of digital signals;

  a qualitative account is sufficient
- the presence of a range of frequencies in a signal (its spectrum);

  a qualitative account is sufficient
- evidence of the polarisation of electromagnetic waves.

(b) comprehension of the language and representations of physics:

by making appropriate use of the terms:

- pixel, bit, byte, focal length and power, magnification, resolution, sampling, spectrum, polarisation

and by sketching and interpreting:

- diagrams of the passage of light through a converging lens
- diagrams of waveforms, and their spectra

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- the amount of information in an image = no. of pixels $\times$ bits per pixel
- power of a converging lens, as change of curvature of wavefronts produced by the lens; use of

  $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$ (Cartesian convention); linear magnification;

  restricted to thin converging lenses and real images
- $v = f\lambda$;
- amounts and rates of transmission of information.

(d) initiative and independence in learning by giving and explaining their own example of:

- an application of image formation;
- an application of signal transmission.

5.1.1.2 Sensing

This section covers ideas involved in understanding electrical circuits, especially current, charge, potential difference, resistance, conductance and potential dividers in the context of modern sensors and instrumentation.

Candidates should develop experimental and investigational skills. It is expected that work will be taught in part through measurement and instrumentation tasks carried out in teams and reported to others.

An assessed outcome of this section is short instrumentation task, to make and test a sensor, or test and determine the qualities of a given sensor, or use a sensor and appropriate circuitry to detect a signal or make a measurement. This is assessed as part of Unit 2862.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining:

- current as the flow of charged particles;
- potential difference as energy per unit charge;
- resistance and conductance, including series and parallel combinations;
- effect of internal resistance and the meaning of emf;
- dissipation of power in electric circuits;
- the relation between potential difference and current in ohmic resistors ('Ohm's Law');
- action of a potential divider.

(b) comprehension of the language and representations of physics:

by making appropriate use of the terms:

- emf, potential difference, current, charge, resistance, conductance, series, parallel, internal resistance, load.

by sketching and interpreting:

- simple circuit diagrams;
- graphs of current against potential difference; graphs of resistance or conductance against temperature.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- $R = V/I$ $(G = I/V)$, $V = W/Q = P/I$, $P = IV = I^2R$, $W = VIt$, $V = E - Ir_{internal}$;
- $I = \Delta Q/\Delta t$, $R = R_1 + R_2 + ...$ *(series)*, $G = G_1 + G_2 + ...$ (parallel);
- simple cases of a potential divider in a circuit.

(d) initiative and independence in learning by giving and explaining their own example of:

- choice and use of a sensor for an application.

Relevant Key Skills in sections 5.1.1.1 and 5.1.1.2

Specific attention is given to the analysis and presentation of data and there are opportunities for moral development through the discussion of honest and dishonest presentations of data.

Communication

Candidates are asked to write a report of an instrumentation task (to be submitted as part of Unit 2862), providing an opportunity to demonstrate a wide range of communication skills. **C3.2, C3.3**

Application of Number

Candidates should construct well designed tables, graphs and displays to communicate relationships amongst data effectively, making appropriate use of IT tools.

The use of very large and very small numbers is developed and logarithmic scales (informally presented as 'times' scales) are introduced. **N3.1, N3.3**

IT

There are opportunities to use IT for image processing and for data capture, manipulation, and presentation. Software for analysing signals into their frequency spectra can be used. **IT3.2, IT3.3**

5.1.2 Designer materials

This section is about materials and how their properties are related to their uses and their structure. Microscopic images are used to give evidence of structure at different scales.

One of the main assessed outcomes of this section is an individual case study of a material and/or use of a material, together with knowledge of examples of the relationship between uses and properties of the material. This is assessed as part of Unit 2862.

The physics may be put into perspective through contexts such as the study of medical replacement materials, biological materials and engineering materials. Human and cultural issues arise, for example, in considering the impact of materials on technology and society and through the aesthetic appeal of materials.

*It is **not** intended that candidates acquire a detailed knowledge of a wide range of materials, and the terminology associated with each. It **is** intended that they demonstrate understanding of specific examples about which they have collected information, and have a reading comprehension of terms needed to understand accounts of the structure, uses and properties of materials.*

Properties to be studied are restricted to simple mechanical, optical and electrical properties.

Recommended prior knowledge

Some of this work is a continuation of the work on light and on forces at GCSE. Candidates are expected to:

- know about reflection and refraction (Sc4.3 a – b);
- know about the effect of forces on materials (Sc4.2 j);
- be able to calculate pressure (Key Stage 3);
- know about the relationships between current, potential difference and resistance in circuits (Sc4.1a, d-g).

Some of this work is provided with a foundation in *Communication*, in particular through ideas of resistance and conductance in circuits. If candidates are not confident with measuring resistance with an ohm-meter or with thinking of current as a flow of charged particles, that work may need to be brought forward here if *Designer Materials* is taught before *Communication*.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining:

- simple mechanical behaviour: types of deformation and fracture;
- simple optical behaviour: reflection and refraction;
- simple electrical behaviour: the broad distinction between metals, semiconductors and insulators;

  only in terms of the number of mobile charge carriers, not their mobility
- direct evidence of the size of particles and their spacing.

(b) Comprehension of the terms needed to understand texts about properties and uses of materials:

- for mechanical properties and behaviour stress, strain, Young modulus, fracture stress and yield stress, stiff, elastic, plastic, ductile, hard, brittle, tough;
- for optical properties: reflection, refraction, refractive index;
- for electrical properties: resistivity, conductivity.

(c) ability to sketch and interpret:

- stress-strain graphs up to fracture;
- tables and diagrams comparing materials by properties;
- images showing structures of materials.

2nd Edition Sept 2002

(d) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- $\frac{\sin i}{\sin r} = n$, total internal reflection;
- $R = \frac{\rho l}{A}$; $G = \frac{\sigma A}{l}$
- tensile/compressive stress, strain, Young modulus $E = \frac{stress}{strain}$

(e) initiative and independence in learning:

by giving and explaining their own example of:

- the relationship between uses, properties and structures of one material

Relevant Key Skills in this section

Communication

This section provides substantial opportunities to develop and offer evidence of communication skills, through the requirement for a public presentation which may be followed by a discussion. **C3.1a. C3.1b**

Application of Number

Opportunities arise for comparing quantities over a very wide range of values, giving practice in making and interpreting logarithmic plots. Presentations about materials give opportunities for making effective displays of quantitative comparisons. **N3.1, N3.2, N3.3**

IT

There are opportunities to use IT for searching for information about materials both on CD-ROM and on the Internet; for tabulating and graphing data on properties of materials; and for using simulation and other software for visualising behaviour at the atomic scale. **IT3.1, IT3.2, IT3.3**

5.2 Module 2861: Understanding Processes

C3.1a, C3.2; N3.1; IT 3.1, IT3.2 **LP3.1**

Module 2861 provides progression from Module 2860 which has a strong orientation towards application. Module 2861 is organised around different ways of understanding processes of change: motion in space and time, wave motion, quantum behaviour. Its focus, more than in Module 2860, is on 'curiosity-driven' physics. Whilst providing a sound foundation in the classical physics of mechanics and waves, the module takes the story further forward, touching on the quantum probabilistic view.

There is progression in the use of mathematical ideas. In both modules, physical variables are extended from scalars to quantities that add like vectors, introducing this new mathematical structure. The work on motion is designed to pave the way for the introduction of differential equations in discrete time-step form in the A2 half of the Advanced GCE course.

The module is organised in two sections:

- Waves and Quantum Behaviour (section 5.2.1);
- Space, Time and Motion (section 5.2.2).

Either section may be covered first. Some teachers may wish to introduce work on vector addition from 5.2.2 before work on combining phasors in 5.2.1.

5.2.1 Waves and Quantum Behaviour

This section is mainly about superposition phenomena of waves, especially electromagnetic waves, with a brief account of the quantum behaviour of photons. Huygens construction provides a link between the two ideas. Quantum behaviour is discussed through considering possible photon paths, avoiding the wave/particle dichotomy.

Essential use is made of IT, with programs which model quantum behaviour.

Broader issues are raised in quantum theory about knowledge and its limits. Quantum theory provides a startling case where physicists have a mathematical framework that allows calculations of outstanding precision even though they do not have a fundamental agreement about the underlying picture of reality.

Recommended prior knowledge

Some of this work is a continuation of the work on light at GCSE. The candidates are expected to:

- know about reflection, refraction and diffraction (Sc4.3 a – b);
- know the meaning of frequency, wavelength and amplitude of a wave and know the relationship (Sc4.3 e – f).

$$v = f\lambda$$

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining:

- production of standing waves by waves travelling in opposite directions;
- interference of waves from two slits;
- diffraction of waves passing through a narrow aperture;
- diffraction by a grating;
- evidence that photons exchange energy in quanta $E = hf$;

  for example light emitting diodes, photoelectric effect or line spectra

- quantum behaviour: quanta have a certain probability of arrival; the probability is obtained by combining amplitude and phase for all possible paths;
- evidence from electron diffraction that electrons show quantum behaviour;

  In this section where waveforms, amplitudes and phases need to be combined, graphical methods are sufficient.

(b) comprehension of the language and representations of physics by making appropriate use of the terms:

- phase, phasor, amplitude, probability, interference, diffraction, superposition, coherence, path difference, intensity.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- wavelength of standing waves;

  end corrections not required

- path differences for double slits and diffraction grating, for constructive interference $n\lambda = d \sin\theta$;

  both limited to case of distant screen

- the energy carried by photons across the spectrum, $E = hf$.

(d) initiative and independence in learning: by giving and explaining their own example of:

- a superposition effect;

  for example, standing waves, interference, diffraction, for any kind of wave

- a phenomenon in which quantum effects are significant;

  for example, photoelectric effect, spectra, electron diffraction.

Relevant Key Skills in section 5.2.1

Communication

Candidates are expected to follow up examples of their own, providing opportunities for reporting and discussion. **C3.2**

Application of Number

In working on the addition of vectors candidates develop their skills in scale drawing and trigonometry. **N3.2**

IT

Essential use is made of computer-based support, using modelling software, both in visualising wave motions and in understanding quantum phenomena. **IT3.2**

5.2.2 Space, Time and Motion

This section develops classical mechanics, including vectors. The kinematics of uniformly accelerated motion and the dynamics of motion in two dimensions under a constant force are covered.

The discussion of vectors in the context of journeys provides opportunities to reflect on how history, geography and technologies are related.

IT skills may be developed through the use of the computer as a modelling tool, although an extended account of modelling is reserved for A2.

Recommended prior knowledge

This work is a continuation of the work on forces and motion at GCSE. The candidates are expected to:

- know and understand ideas about the way forces affect motion (Sc4.2 e – i);
- be able to calculate speeds and accelerations (Sc4.2 a – d).

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining

- the use of vectors to represent displacement, velocity and acceleration;
- the trajectory of a body moving under constant acceleration, in one or two dimensions;

  use of graphical addition of vectors and/or of computational methods is encouraged
- the independent effect of perpendicular components of a force;
- calculation of work done, including cases where the force is not parallel to the velocity;
- power as rate of transfer of energy.

(b) comprehension of the language and representations of physics**:**

by making appropriate use of the terms:

- displacement, speed, velocity, acceleration, force, mass, vector, scalar, power.

by sketching and interpreting:

- graphs of accelerated motion, including slope and area below the graph;

  displacement-time and velocity-time graphs; acceleration not necessarily constant
- graphical representation of addition of vectors and changes in vector magnitude and direction.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- the resolution of a vector into two components at right angles to each other;
- the addition of two vectors, graphically and algebraically;

  algebraic calculation restricted to two perpendicular vectors
- the kinematic equations $v = u + at$, $s = ut + {}^1/_2\, at^2$, $v^2 = u^2 + 2as$;
- the equation $F = ma$ where the mass is constant;
- kinetic energy = ${}^1/_2 mv^2$; work done $\Delta E = F\Delta S$;
- force, energy and power: power = $\Delta E/t$, power = Fv;
- one and two dimensional motion under a constant force.

  methods based on discrete time intervals are acceptable where appropriate

(d) initiative and independence in learning: by giving and explaining their own example of:

- a method of measuring the distance of a remote object.

Opportunities for the development of Key Skills in section 5.2.2

Communication

This section offers some matters for fundamental debate, providing opportunities for candidates to formulate and criticise arguments. **C3.1a, C3.2**

Application of Number

Vector quantities feature strongly. Work on logarithmic plots, featured in 5.1.1 is further strengthened. **N3.1**

IT

Possibilities are provided for the use of the computer as a modelling tool, using both commonly available packages (e.g. spreadsheet) and dedicated modelling programs. **IT3.1, IT3.2**

5.3 Module 2862: Physics in Practice

C3.1a C3.1b C3.2 C3.3; N3.1 N3.2 N3.3; IT3.1 IT3.2 IT3.3	**WO3.1 WO3.2 WO3.3; LP3.1 LP3.2 LP3.3**

Candidates carry out three short tasks.

5.3.1 Instrumentation Task

For this task, the candidate selects **one** of the following tasks:

- build and test a sensor;
- explore the characteristics of a given sensor;
- design and assemble a system, using a sensor to make a measurement.

A written report of the work done is produced. This task comes directly out of the work candidates have done in *Communication* in Module 2860. The assessment rewards practical, experimental, planning and constructional skills.

Managing the Instrumentation Task

This task is expected to take no more than three hours of contact time, used in the laboratory for setting up and experimental testing, and an equivalent amount of independent study for writing their report.

An outline plan and apparatus list needs to be discussed and agreed in advance. This can be arranged after candidates have met some sensors, and been introduced to other devices which are available, or are easily ordered from catalogues. Full performance data is available on CD-ROM from several suppliers (RS Components and Maplins), and could be available as datasheets or calibration graphs, to help guide planning.

What are the aims?

The time allocation for this sensor project sets a modest bound on what candidates are expected to achieve. The experience should build on practical coursework skills developed at GCSE, and should be the practical climax to *Communication* in Module 2860, having been prepared for by similar tasks carried out in teams. The open choice of task should allow candidates to follow their own interests and to demonstrate planning, as well as practical and observational skills. The experience should be enjoyable as they learn to manage their own time productively under guidance.

Assessing the Instrumentation Task

This task provides an opportunity for students to demonstrate their practical, experimental, planning and investigational skills. This task, together with *Making sense of data*, gives the opportunity within the AS course to assess the practical aspects of the assessment objective AO3 *Experiment and investigation*:

Details of application of the assessment criteria are given in Appendix E.

5.3.2 Materials research and presentation

This task involves researching the nature and use of a material, and making a presentation about it. Each candidate may choose to give the presentation as an illustrated talk, a web page, a video or a poster. It is envisaged that each candidate will choose the manner of presentation that appeals to them, and is suited to the audience and topic.

New materials offer a wide variety of stimulating choice, but the choice of material is not restricted to novel materials. The presentation should show relationships between the properties and uses of the material. Some aspect of the wider context, for example a social, historical, economic or personal context must be considered.

Material from the presentation must be available in a folder which can be sent to moderators.

This task comes directly out of the work done in relation to *Designer materials* in Module 2860. The assessment rewards independent learning, and presentation of physics in a non-written format.

Managing the Research and presentation

This task is expected to take no more than three hours of contact time, this includes that required for students' oral presentations to the whole class. Candidates should perhaps use around three further hours for research and writing.

What are the aims?

By the time of the Presentation, candidates' understanding and vocabulary should have developed significantly from the GCSE background with which they started the course. They should feel confident to access and make use of information from a variety of sources, and be extending their study in a direction which interests them.

It is hoped they will enjoy careful research, and consider their fellow-candidates the audience as they prepare this research for presentation.

Assessing the Research and presentation

This task provides an opportunity to assess the candidates' independent learning and presentation of physics in a non-written format. The assessment addresses in particular aspects of AO1 Knowledge with understanding and AO2 Application of knowledge with understanding, synthesis and evaluation.

Details of application of the assessment criteria are given in Appendix E.

5.3.3 Making sense of data

The task is to analyse a set of data, and write a report showing what can be understood from the data in relation to the physical principles involved. Data may come from a variety of sources. The candidate may have: performed an experiment to obtain the data; seen a demonstration which provides the data; taken data from a video of an experiment or event; or acquired data from an outside source. In all cases the candidate must be in a position to understand and report on: how the data were obtained; the physical principles involved; the features of the experiment which are needed to understand the results; and any uncertainties in the data.

The written report should include a brief description of the experiment and the physics underlying it; data presented appropriately and a discussion of the conclusions drawn from the experiment.

Managing the Making sense of data task

This task is expected to take about three hours of teaching time. Candidates should perhaps use the same amount of time again in analysis of the data and writing their report.

What are the aims?

Making sense of data is intended to allow candidates to show their skills in drawing meaning out of a collection of data, by presenting the data clearly, identifying patterns and trends, suggesting explanations for those findings and discussing the validity of their conclusions in the light of the experimental technique used. This task will most likely be assessed towards the end of the AS course, after the candidate has had the opportunity to interpret data from a variety of experiments and has developed the skills of data analysis being used.

It is important to realise that it is the skills of data analysis that are being assessed, **not** practical skilfulness in collecting the data itself. Each candidate must begin the task with a good set of data, however that is achieved. The purpose of collecting the data, or seeing the data collected, is to ensure the candidate is familiar with the origin of the data.

How to introduce the data

The data can be presented to candidates in one of a number of ways. They may be able to collect it, individually or in groups. They may watch a demonstration (either live or on video) during which data is collected. What is essential is that they have every opportunity to discuss and question their understanding of the purpose of the experiment, the details of the experimental technique and any underlying physical principles. This background to the origin of the data is needed if they are to make proper sense of it and particularly to discuss the validity of their findings.

However the data is collected each candidate must begin the task with a good set of data. Therefore if candidates are gathering data for themselves the teacher must have a good set of data available to hand to the candidate if their data is unlikely to allow them to gain the highest marks. Note that a ‘good set of data’ for this purpose is likely to include some anomaly worth noting and discussing.

Assessing the Making sense of data task

This task provides an opportunity for candidates to demonstrate their practical, experimental and investigational skills. This task particularly assesses the final two objectives in AO3 *Experiment and investigation*:

Details of application of the assessment criteria are given in Appendix E.

Opportunities for the assessment of Key Skills in this Module

The three coursework tasks present ideal opportunities for candidates to provide evidence that they have reached the required standard in many aspects of the key skills.

Communication

All three tasks require candidates to use their communication skills, in a variety of ways.

The *Research and Presentation* task provides opportunities for group discussion of the issues raised by the presentations. The presentations would be expected to include images. **C3.1a, C3.1b**

To carry out the research for the *Research and Presentation* candidates need to read at least two extended documents and draw together the ideas there. **C3.2**

Both the *Instrumentation task* and *Making sense of data* have as an outcome a written document about a complex subject. They would be expected to include images. **C3.3**

Application of Number

The *Making sense of data* task provides an opportunity for candidates to collect and interpret a set of data from an experiment; carry out calculations on the data, using formulae, taking into account the accuracy of the data. The candidate is then required to interpret the results of the calculations, and present their findings in a written report. **N3.1, N3.2, N3.3**

IT

In preparing for the *Research and presentation* task candidates have an opportunity to carry out a substantial activity which provides evidence for some or all aspects of **IT3.**

They can carry out research in a variety of ways which may include using CD-ROMs, databases and the Internet. **IT3.1**

They may need to bring the information together and develop it for their presentation. **IT3.2**

Candidates make a presentation, which may include some images, text and numbers. The presentation may be an illustrated talk, web pages or a poster. **IT3.3**

5.4 Module 2863 Component 01: Rise and fall of the Clockwork Universe

C3.1a C3.3; N3.1 N3.2 N3.3; IT3.2 IT3.3	

The grand conception, coming from Descartes, Newton and Liebniz, of the world as a 'mathematical machine', which transformed Western culture is developed. Some of its limitations are shown too. In this framework, the formalism of differential equations, an essential tool of the physicist, is developed as well as the concept of a field. This is the context for core work on force and motion, and orbits and gravity. But it leads towards the structure and behaviour of atoms, where quantum and statistical ideas start to take over.

Overall, the module raises issues of simplification and idealisation in models, and the extent to which these are desirable or necessary. Models can be seen as artificial worlds over which the human maker has complete control. This is the source of their definiteness and determinism. Models allow analogies to be seen between otherwise very different physical processes. A difference can be seen between models whose well-determined behaviour is due to exact rules operating on variables (as in the harmonic oscillator) or to smooth averages over many particles (as in radioactive decay). Both strategies inform the structure behind the half of the Advanced GCE A2 course.

The content of this component is set out in two parts:

Models and rules (sections 5.4.1, 5.4.1.1, 5.4.1.2, and 5.4.1.3)

Matter in extremes (sections 5.4.2, 5.4.2.1 and 5.4.2.2).

5.4.1 Models and rules

This part covers the core physics of radioactive decay and decay of charge on a capacitor, energy and momentum, the harmonic oscillator and circular orbits. The field model is developed through consideration of gravitational fields. The idea of differential equations and their solution by numerical or graphical methods is built up gradually using finite difference methods.

Candidates have opportunities to develop IT skills through the use of computational algorithms used to solve differential equations. Exponential and trigonometric functions play an essential role.

Opportunities arise to discuss the place of mathematics in physics: is mathematics part of the nature of the world or an artefact of our way of doing things? There are opportunities too for candidates to pursue their own interests when considering applications of these ideas.

Recommended prior knowledge

The work is a continuation of the AS course as well as picking up on some ideas from GCSE. Candidates are expected to:

- show knowledge and understanding of current as a flow of charged particles and potential difference as energy per unit charge (AS 5.1.1.2 Sensing);
- know that radioactivity arises from the breakdown of an unstable nucleus and that there are three main types of radioactive emission with different penetrating powers (Sc4.6 a, c);
- know the relationship between force and work (Sc4.5 f, g and AS 5.2.2 Space, time and motion);
- know the quantitative links between kinetic energy, potential energy and work (Sc4.5 h and AS 5.2.2 Space, time and motion);
- know about the bodies in the solar system and that gravitational forces determine the movement of planets, moons, comets and satellites (Sc4.4 a, b).

Content

5.4.1.1 Creating models

This section first considers models where the rate of change of a quantity is proportional to that quantity. It then goes on to consider the model of simple harmonic motion.

Candidates and teachers are encouraged to use computer modelling for this work, allowing candidates to develop their IT skills. The central importance of the exponential function develops candidates' skills in the Application of Number.

Radioactive decay and capacitor discharge provide a context, but the point of view is broader, looking at these as examples of any kind of change where the change is proportional to the amount. Candidates have the opportunity to study examples of their own choice, for example the action of heart defibrillators or camera flash units.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases involving:

- capacitance as the ratio $C = Q/V$
- the energy on a capacitor $E = 1/2\ QV$
- the exponential form of the decay of charge on a capacitor as due to the rate of removal of charge being proportional to the charge remaining;

  the use of finite difference numerical or graphical methods is acceptable and is encouraged here and for other decay and growth processes
- the exponential form of radioactive decay as depending on a fixed probability of decay;
- simple harmonic motion of a mass with a restoring force proportional to displacement such that

  $$\frac{d^2x}{dt^2} = -(k/m)x;$$

  use of iterative finite differences or of graphical methods is encouraged
- kinetic and potential energy changes in simple harmonic motion;
- free and forced vibrations, damping and resonance;

  qualitative treatment only.

(b) comprehension of the language and representations of physics:

by making appropriate use of the terms:

- in the context of a capacitor: half-life, time constant;
- in the context of radioactive decay: random, probability, half-life;
- simple harmonic motion, resonance.

by expressing in words and vice-versa:

- relationships of the form $dx/dy = -kx$ where rate of change is proportional to amount present (y will often be time t).

by sketching, plotting from data and interpreting:

- decay curves, plotted directly or logarithmically;
- energy of capacitor as area below Q–V graph;
- v-t and a-t graphs of simple harmonic motion including their relative phases;

  qualitative effects of damping in each of these cases
- amplitude of a resonator against driving frequency.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- calculating half life of a radioactive source from data;
- calculating time constant τ of a capacitor circuit from data;
- $C = Q/V$, $I = \Delta Q/\Delta t$, $\tau = RC$, $E = 1/2QV$, $E = 1/2\ CV^2$
- $T = 2\pi\sqrt{\frac{m}{k}}$, with $f = \frac{1}{T}$;

  and analogous equations such as that for the simple pendulum
- $f = kx$;
- $x = A\sin 2\pi ft$ *or* $x = A\cos 2\pi ft$;
- $d^2x/dt^2 = a = -(k/m)x$;
- $E_{total} = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$.

5.4.1.2 Out into space

This section develops ideas about gravitational field and potential. Free fall as 'zero gravity', space flight and planetary orbits are considered. Momentum, kinetic and potential energies and conservation laws are covered.

There are extended opportunities to use modelling software.

Space flight and astronomical data provide a context and there are opportunities to discuss how ideas developed by Galileo, Kepler and Newton make it possible to do such things as weigh the Earth, explain tides and broadcast TV globally by satellites.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases involving:

- force as rate of change of momentum;
- work done, including cases where the force is not along the line of motion;
- conservation of momentum;
- changes of gravitational and kinetic energy;
- motion in a uniform gravitational field;
- the gravitational field and potential of a point mass;
- motion in a horizontal circle and in a circular gravitational orbit.

(b) comprehension of the language and representations of physics:

by making appropriate use of the terms:

- kinetic and potential energy, momentum, gravitational field, gravitational potential.

by sketching and interpreting:

- graphs showing gravitational potential as area under the gravitational field versus distance graph;
- graphs showing force as related to the tangent of a graph of gravitational potential energy versus distance;
- diagrams of gravitational fields and the corresponding equipotential surfaces.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- gravitational potential energy change mgh;
- energy exchange, work done, $\Delta E = F\Delta s$; no work done when the force is perpendicular to the velocity;
- momentum, $p = mv$, $F = \Delta mv/\Delta t$;
- $a = \frac{v^2}{r}$, $F = \frac{mv^2}{r}$;
- $F_{grav} = -\frac{GmM}{r^2}$, $g = \frac{F_{grav}}{m} = -\frac{GM}{r^2}$;
- gravitational potential energy = $-\frac{GmM}{r}$;
- $V_{grav} = \frac{E_{grav}}{m} = -\frac{GM}{r}$.

5.4.1.3 Our place in the Universe

This section covers a descriptive and mainly qualitative outline of the main features of the observable universe consistent with the hot big bang model of its origin. The idea of the universality of the speed of light is mentioned.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing:

- the use of radar-type measurements to determine distances within the Solar system; how distance is measured and defined in units of time;
- how distant objects are observed at earlier times;
- the measurement of relative velocities by radar observation;

  simple arguments using two successive pulses are sufficient
- evidence of a 'hot big bang' origin of the Universe from:
  - cosmological red-shifts (Hubble's law)
  - cosmological micro-wave background.

(b) comprehension of the language and representations of physics by sketching and interpreting:

- logarithmic scales of magnitudes of quantities: distance, size, mass, energy, power.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- distances and ages of astronomical objects;
- distances and relative velocities from radar-type measurements.

Opportunity to develop Key Skills in sections 5.4.1.1, 5.4.1.2 and 5.4.1.3.

Communication

Opportunities to lead and take part in discussions about how our ideas about our place in the Universe have developed. **C3.1a**

Application of Number

Candidates have opportunities to work with data, plot and interpret graphs and discover the limits of numerical analysis. **N3.1, N3.2, N3.3**

IT

The computational approach suggested makes *essential* use of IT, and provides opportunities to discuss the power and limitations of computational models as well as to develop IT skills related to modelling and data display. Computers may be used to carry out calculations and build models to show how a gravitational field can be predicted. There are opportunities to use computer research, particularly using the World Wide Web to seek data about space flights and astronomical discoveries. **IT3.1, IT3.2**

5.4.2 Matter in extremes

In *Matter in extremes*, how the kinetic theory explains the behaviour of matter in probabilistic and mechanical terms is considered. These ideas are extended to high and low temperatures. The beginnings of the basis of thermodynamic thinking appear in the form of the Boltzmann factor. These are all fundamental ideas of importance in understanding matter.

Recommended prior knowledge

The work is a continuation of work from earlier in the A2 course as well as picking up on some ideas from GCSE. Candidates are expected to:

- show knowledge and understanding of conservation of energy and momentum (A2 5.4.1.2);
- know how the volume of a fixed mass of gas at constant temperature changes as the pressure changes (Sc4.2 l);
- know about energy transfers as a result of temperature differences (Sc4.5 a-e).

Content

5.4.2.1 Matter: very simple

5.4.2.2 Matter: hot or cold

5.4.2.1 Matter: very simple

The behaviour of an ideal gas is explained in terms of kinetic theory. Its behaviour is understood as the result of averaging over a very large number of individual particle interactions.

There are opportunities to consider the work in its historical context and to compare competing ideas and the resistance to ideas about the existence of atoms and the nature of a vacuum.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases involving:

- energy transfer producing a change in temperature;
- the behaviour of ideal gases;
- the kinetic theory of ideal gases;
- temperature as proportional to average energy per particle; average energy $\cong kT$ as a useful approximation.

(b) comprehension of the language and representations of physics by making appropriate use of the terms:

- ideal gas, root mean square speed, absolute temperature, internal energy.

by sketching and interpreting:

- relationships between p, V and T for an ideal gas.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- temperature and energy change using $\Delta E = mc\,\theta$
- $pV = nRT$
- $pV = \frac{1}{3}Nm\overline{c^2}$

5.4.2.2 Matter: hot or cold

In this section, temperature is related to the probability that particles occupy states of different energies and the Boltzmann factor is introduced as the link between energy and temperature. The important idea that differences drive change is developed here.

Opportunities are provided for considering a range of contemporary topics such as the state and behaviour of matter in the early Universe, superconductivity at low temperatures, the behaviour of 'soft matter' (such as polymers) and rates of reaction.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases involving:

- ratios of numbers of particles in states of different energy, at different temperatures;

  Classical approximation only

- qualitative effects of temperature in processes with an activation energy;

  for example: changes of state, thermionic emission, ionisation, conduction in semiconductors

(b) comprehension of the language and representations of physics by sketching and interpreting:

- graphs showing the variation of the Boltzmann factor with energy and temperature.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- Ratios of characteristic energies to the energy kT ;
- Boltzmann factor, $e^{-\varepsilon/kT}$.

Opportunity to develop Key Skills in sections 5.4.2.1 and 5.4.2.2.

Communication

An opportunity to present and discuss how these ideas developed, in a historical context. **C3.1a, C3.1b**

Application of Number

An opportunity to develop understanding of the exponential function. **N3.2**

IT

Extensive use can be made of computational models of the thermal motion of particles and of the distribution of particles between states of different energy. Other such models help develop concepts related to probability. **IT3.2**

5.4.3 Module 2863 Component 02: Practical Investigation

C3.3; N3.1 N3.2 N3.3; IT3.2 IT3.3 **PS3.1 PS3.2 PS3.3 PS3.4**

Each candidate carries out an investigation of a practical problem related to physics or its applications. It is anticipated that candidates will use a wide variety of experiments and techniques in this extended investigation. The most suitable topic is a clearly defined problem, which offers scope for genuine investigation, rather than routine, mechanical and unimaginative work. The topic should afford the candidate the opportunity to use physics at an Advanced GCE standard.

What are the aims?

One of the central features of the course is the emphasis placed on learning physics through the interplay of theory and experiment - so that candidates understand where ideas come from, how they make sense and how they may be used. This is made possible through the range and variety of illustrative experiments, practical demonstrations and investigations which candidates meet during the course. But the importance of the experimental work extends beyond the fulfilment of this objective. Many students will study more science when they leave school or college, and there are some whose careers will involve science. An ability to investigate an unfamiliar situation in a sensible and scientific way is an asset not only to these students, but to all in tackling practical problems in everyday life. To this end, it is hoped that the development of experimental and investigative skills is a significant feature throughout the course.

The outcome of the task is a written report which describes the process of the investigation and discusses the conclusions which may be drawn from the practical work done.

Managing the Practical Investigation

The time allocated to this task is ten hours of teaching time and an equivalent amount of time in research and writing up the report.

To begin, the candidate chooses an interesting topic for investigation and carries out some preliminary research – analysing the topic, getting 'a feel' for the relevant factors, considering the selection of appropriate apparatus and measuring techniques, carrying out a literature search, if appropriate – with a view to deciding upon an experimental design which will allow the first set(s) of readings to be taken.

The next stages are to carry out the Investigation in the laboratory, to write-up the findings of the experimental work, in the form of a daily diary, and then to submit the finished report to the teacher for assessment. The assessment should be based on observation of the work done, and on discussion with the candidate, as well as information revealed in the written report.

This task provides an opportunity for candidates to demonstrate their Experimental and investigative skills. The assessment addresses all aspects of AO3 *Experiment and investigation*.

Details of application of the assessment criteria are given in Appendix E.

Opportunities for the assessment of Key Skills in this Component

This task presents an ideal opportunity for candidates to provide evidence that they have reached the required standard in many aspects of the key skills.

Communication

The Investigation has as the outcome a written document about a complex subject. Candidates are expected to include images where relevant. **C3.3**

2nd Edition Sept 2002

Application of Number

The Investigation provides an opportunity for candidates to:

collect and interpret a set of data from an experiment; **N3.1**

carry out calculations on the data, using formulae, taking into account the accuracy of the data. **N3.2**

The candidate is then required to interpret the results of the calculations and present their findings in a written report. **N3.3**

IT

Candidates have the opportunity to use IT to bring together the information collected during their investigation and develop it for their report. **IT3.2**

Candidates need to make a written report, which includes some images, text and numbers. **IT3.3**

5.5 Module 2864 Component 01: Field and particle pictures

C3.1a C3.1b C3.2 C3.3, N3.2, IT3.2

The idea of a field is now of fundamental importance in physics, particularly the electromagnetic field, of importance in engineering and as the origin of forces binding charges together in atoms. Fundamental particles have come to be seen not just as acted on by fields, but as carriers of the field. This makes it appropriate that ideas of field and particle are developed together.

The aim is to achieve a balance between developing basic ideas, such as electric field and potential, and the constituent particles of atoms, nuclei and nucleons, and of recognising important areas of application, such as electromagnetic machines and the uses and dangers of radioactive materials and ionising radiation. Fields and particles play crucial roles in both.

The content of this component is set out in two parts:

Fields (sections 5.5.1, 5.5.1.1 and 5.5.1.2)

and **Fundamental particles (sections 5.5.2, 5.5.2.1 and 5.5.2.2)**

5.5.1 Fields

Electromagnetic machines – transformer, dynamo, motor – introduce magnetic fields in a strongly applied context. An introduction of this kind can help to give the field, otherwise a difficult abstraction, a greater sense of practical reality through studying real devices.

The electric field, as the interaction between charges at rest, links back by analogy to the gravitational field (5.4.1.2), with the idea of electric potential also drawing together previous ideas about potential difference. The ideas find immediate use in consideration of scattering and of forces between sub atomic particles (5.5.2.1).

These two sections can be taken in either order.

Opportunities exist to discuss the social impact of the widespread distribution and use of electrical power, and its influence on industrial societies.

There are opportunities to use computers to build models, for example of electric fields or equipotential surfaces.

Recommended prior knowledge

The work is a continuation of the Advanced Subsidiary course as well as picking up on some ideas from GCSE. Candidates are expected to:

- know about magnetism and electromagnetic forces and of electromagnetic induction (Sc4.1 r-w);
- know about radial gravitational fields and gravitational potential (A2 5.4.1.2 Out into space).

5.5.1.1 Electromagnetic machines

This section covers the design and working of transformers, dynamos and motors, and through them develops fundamental equations and relationships of electromagnetism.

There is scope for discussing a wide variety of electromagnetic devices, with uses in for example: transport, medicine and power generation, seen from a largely technological point of view. There is an opportunity to consider the influences on technological development and the social changes such developments might bring.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases involving:

- the action of a transformer: magnetic flux from a coil; induced emf = rate of change of flux linked;
- the action of a generator: change of flux linked produced by relative motion of flux and conductor;
- the action of a motor: including simple induction motor.

(b) comprehension of the language and representations of physics:

by making appropriate use of the terms:

- B-field, flux, flux linkage, induced emf.

by sketching and interpreting:

- graphs of variations of currents, flux and induced emf;
- diagrams of lines of flux in magnetic circuits.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- $\Phi = BA$, $\varepsilon = -\dfrac{d(\Phi N)}{dt}$
- $F = BIL$;

  calculations restricted to current or velocity perpendicular to the magnetic field

- $\dfrac{V_1}{V_2} = \dfrac{N_1}{N_2}$ for an ideal transformer

5.5.1.2 Charge and field

This section covers interactions between charged particles, and ideas about electric field and potential. The main work here is the core study of static electric fields and the inverse square law, seen as analogous to the gravitational case. But candidates will be aware that 'at rest' is a relative notion, and reference can be made here and elsewhere to connections between electric and magnetic effects.

It would be possible to integrate this with work in section 5.5.2.1 on scattering by charged particles.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases involving:

- uniform electric field $E = V/d$;
- the electric field of a charge, and the force on a charge in an electric field; Inverse square law;
- electrical potential energy and electric potential due to a point charge; 1/r relationship;
- evidence for the discreteness of the charge on an electron;
- the force on a moving charged particle due to a magnetic field;
- use of electric and magnetic fields in particle accelerators. Details of the construction of accelerators **not** required.

(b) comprehension of the language and representations of physics by making appropriate use of the terms:

- electric field and potential; electronvolt, electron.

by sketching and interpreting:

- graphs of electric force versus distance; electric potential as area under curve;
- graphs of electric potential or potential energy against distance; relation of electric field to tangent to graph;
- diagrams of electric fields and the corresponding equipotential surfaces.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- $F_{electric} = \frac{kqQ}{r^2}$, $E_{electric} = \frac{F_{electric}}{q} = \frac{kQ}{r^2}$ $\left[k = \frac{1}{4\pi\varepsilon_0}\right]$
- $E_{electric} = -\frac{dV_{electric}}{dx}$, $E_{electric} = \frac{V}{d}$ (*for a uniform field*)
- $V_{electric} = \frac{kQ}{r}$
- $F = qvB$

Opportunity to develop Key Skills in sections 5.5.1.1 and 5.5.1.2

Communication

There are opportunities to make a presentation about, or to discuss, the way a developing technology influences the lives of people. **C3.1a, 3.1b**

Application of Number

There are many opportunities to develop number skills, including building models, using graphs and numerical analysis. **N3.2**

IT

There are opportunities to develop computer modelling skills in coming to an understanding of fields. **IT3.2**

5.5.2 Fundamental particles

The work here concerns the structure and binding of atoms and nuclei and the nature of fundamental particles, successively going into deeper and deeper levels of structure. Besides taking this fundamental viewpoint, the practical implications of radioactivity and ionising radiation are considered, with an introduction to the idea of risk.

There are opportunities to develop ICT skills through data analysis, and research using electronic information sources.

Opportunities exist to consider social issues, particularly financial and environmental costs and benefits. The section also raises questions about the ultimate nature of the physical world.

Recommended prior knowledge

The work is a continuation of the AS course as well as picking up on some ideas from GCSE. Candidates are expected to:

- know about the force acting on a charge moving in a magnetic field (A2 5.5.1.1 Electromagnetic machines);
- know about motion in a circle (A2 5.4.1.2 Out into space);
- know that radioactivity arises from the breakdown of an unstable nucleus and that there are three main types of radioactive emission with different penetrating powers (Sc4.6a, c);
- know about the exponential form of radioactive decay (A2 5.4.1.1 Creating models);
- know about elementary quantum behaviour, $E = hf$ $\lambda = \frac{h}{p}$ (AS 5.2.1)
- know about superposition of waves (AS 5.2.1).

5.5.2.1 Probing deep into matter

A central notion here is that of scattering, as a source of evidence about the structure of atoms and nucleons. The use of accelerators helps reinforce understanding of the motion of charged particles in electric and magnetic fields. Evidence is given of discrete energy levels in atoms, and quantum ideas (AS) are put to use in explaining their origin, using a crude model of a particle in a box. Simple relativistic thinking (section 5.4.1.3) explains the increased measured lifetimes of fast-moving decaying particles.

Opportunities are provided to discuss international co-operation in large-scale experiments. Social debate about the costs and benefits of pure fundamental research can be discussed.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining:

- evidence from scattering for a small massive nucleus within the atom;
- evidence of discrete energy levels in atoms;

  for example, from collisions with electrons or from line spectra

- a simple model of the atom as the quantum behaviour of electrons in a confined space; Pauli exclusion principle (fermions);
- simple picture of the internal structure of protons and neutrons; as composed of up and down quarks;
- interaction as exchange of particles (bosons); pair creation and annihilation: energy change $E = mc^2$.

(b) comprehension of the language and representations of physics:

by making appropriate use of the terms:

- energy level, quark, gluon, nucleon, lepton, antiparticle, neutrino.

by sketching and interpreting:

- paths of scattered particles;
- simple diagrams showing particle exchanges.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- motion of a charged particle in magnetic field F = QvB;
- kinetic and potential energy of a scattered charged particle.

5.5.2.2 Ionising radiation and risk

This section deals with radioactive decay as a random process, bringing back quantum ideas about the statistical nature of quantum predictions. Changes in nuclear binding energy per nucleon are seen as driving the different types of decay, arising both from the strong forces between nucleons and from the charge on protons.

Opportunities exist to consider the uses and dangers of ionising radiations in for example medicine, food hygiene and power production.

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases involving:

- the nature and effects of ionising radiations: differences in ionising and penetrating power, effects on living tissue;
- the stability and decay of nuclei in terms of binding energy; transformation of nucleus on emission of radiation;
- nuclear fission and fusion.

(b) comprehension of the language and representations of physics:

by making appropriate use of the terms:

- nuclear fission and fusion, nucleon number, proton number, isotope, binding energy, activity, risk.
- Absorbed dose in gray; equivalent dose in sievert.

by sketching and interpreting:

- plots of binding energy of nuclei against proton and neutron number.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates involving:

- half life, decay constant and activity, $\frac{dN}{dt} = -\lambda t, \quad N = N_0 e^{-\lambda t}$;
- energy changes from nuclear transformations: $E_{rest} = mc^2$;
- compare equivalent doses in sieverts.

Opportunity to develop Key Skills in sections 5.5.2.1 and 5.5.2.2.

Communication

There are opportunities to make presentations and contribute to discussions about the way we assess risk. **C3.1a, 3.1b**

Application of Number

There are many opportunities to develop number skills, including working with exponential relationships; very large and small numbers and large data sets. **N3.1, N3.2**

IT

There are opportunities to search the Internet and databases for information about risk and using IT to process data. **IT3.1, 3.2**

5.5.5 Module 2864 Component 02: Research Report

C3.2 C3.3, N3.1 N3.2 N3.3, IT3.2 IT3.3 **LP3.1 LP3.2 LP3.3**

A written report is produced based on the individual work of a candidate on a topic of physics of his or her own choosing. The work is expected to be exploratory, with the aim of collecting and analysing information about an issue in which a range of physics ideas are significant. The report must also consider some aspect of the wider context of the physics, considering social, historical, economic, or environmental issues.

What are the aims?

This component is designed to assess the ability of a candidate to find information from a variety of sources; to compare and analyse information obtained; to use this material to discuss an issue and draw conclusions; and to bring together ideas from different parts of the subject in a synoptic way. The Research Report gives each candidate an opportunity to display, and be rewarded for, the skills they have developed during the course. The assessment rewards such skills as:

- working independently;
- drawing together ideas from different aspects of physics;
- selecting and extracting information from a variety of sources;
- applying knowledge and understanding of basic ideas ;
- translating and interpreting information;
- placing the physics ideas in a wider human or social context;
- communicating scientific ideas in continuous prose using good English;
- using published material as part of research.

The information is expected to be obtained from the candidate's own research from a suitably representative range and variety of sources. These sources might include books, journals, pamphlets, surveys, interviews, libraries, data bases and web sites on the Internet.

The outcome is a written report based on the individual work of a candidate on a topic of physics of his or her own choosing. The topic must be approved in advance by the class teacher. The teacher should ensure that the candidate chooses a topic which will enable them to demonstrate their skills in drawing together a variety of physics ideas.

The report should be between 2000 and 4000 words long.

Managing the Research Report task

To begin, the candidate chooses a suitable topic for research and then spends some time collecting relevant information from a suitably varied range of sources. Clearly it is impossible for a candidate to consult all existing sources and so the immediate task ahead is to locate and consult a range of relevant source material in order to obtain as representative a sample of the information available as is possible. This initial phase of the research may be spread over several weeks, and carried out in the candidates' own time. During this period, the teacher may designate a single period of 'physics teaching' time each week to allow time for supervision of the candidates' progress and so that the internal assessor is familiar with each candidate's work at all stages. Internal assessors are encouraged to monitor the candidate during the project and to offer tactful advice at any stage during the work, so that the latter becomes fully aware of how to maximise his/her performance. If help is asked for it should be given, as far as possible, in a way which allows candidates to gain credit for using such advice in their own way.

The next stage is to select an interesting aspect /issue/ application/ problem which has arisen from the material surveyed and to research it more thoroughly. The candidate then summarises the findings of the research in the form of a written report or article addressed to scientifically knowledgeable readers. Candidates should be encouraged to use word-processing and other IT packages. The time allocated for making sense of the information collected *(analysis)* and for writing the scientific article *(communication)* is about 10 hours of 'physics teaching' and the equivalent amount of 'homework' time. All information sources consulted must be accredited, and published material used should be given full references.

Assessing the Research Report

This task provides an opportunity for candidates to demonstrate their research, analysis and communication skills. At this level, in A2, candidates are expected to be able to draw together ideas from different parts of physics, to synthesise their ideas and place the physics in a wider context. The assessment addresses some aspects of AO1 *Knowledge with understanding* and AO2 *Application of knowledge with understanding*, synthesis and evaluation. But in particular this task gives an opportunity within the A2 half of the Advanced GCE course to assess the objectives of AO4 *Synthesis of knowledge, understanding and skills*.

Details of application of the assessment criteria are given in Appendix E.

Opportunities for the assessment of Key Skills in this Component

The *Research Report* present an ideal opportunity for candidates to provide evidence that they have reached the required standard in many aspects of the key skills.

Communication

To carry out the research candidates need to read at least two extended documents and draw together the ideas there. **C3.2**

The outcome for this task is a written document about a complex subject. Candidates are expected to include images. **C3.3**

Application of Number

Depending on their choice of topic candidates may collect and interpret a set of data; carry out calculations on the data, using formulae, taking into account the accuracy of the data. **N3.2**

The candidate will interpret the results of the calculations and present their findings in a written report. **N3.3**

IT

In preparing for the Research report candidates have an opportunity to carry out a substantial activity which provides evidence for all or some of the aspects of **IT3**

They need to carry out research in a variety of ways which may include using CD-ROMs, databases and the Internet. **IT3.1**

They may need to bring the information together and develop it for their presentation. **IT3.2**

Candidates need to make a written report, which may include some images, text and numbers. **IT3.3**

5.6 Module 2865: Advances in Physics

C3.1a C3.1b C3.2, N3.2, IT3.1	**LP3.1, LP3.2, LP3.3**

This concluding module consolidates, by drawing together and using ideas from the whole course. It also requires skills to be used in new contexts. A range of examples, each bringing together ideas from more than one part of the course, is discussed. The examples illustrate how the subject has continually advanced, creating new understanding, new tools, and new useful engineered devices of practical value. All examples require knowledge of different aspects of physics, and skills learned elsewhere, to be put to use.

Opportunities exist for the use of ICT skills in searching for information about recent and past developments.

Opportunities are provided to illustrate the changing and developing nature of both physics and its applications, and to consider the motives which drive such change.

5.6.1 Advances in Physics

Learning outcomes

Candidates should demonstrate evidence of:

(a) knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases involving:

- ideas in physics from different parts of the course.

(b) comprehension of the language and representations of physics:

- by reading and writing about ideas in physics;

by sketching and interpreting:

- graphs and diagrams which describe physics in use.

(c) quantitative and mathematical skills, knowledge and understanding by making calculations and estimates from information provided about physics in use.

Opportunities to develop key skills in this Module

Communication

There are opportunities to research a case study; make a presentation to the group and discuss other case studies. **C3.1a, C3.1b, C3.2**

Application of Number

There are many opportunities to develop number skills, including working with exponential relationships and very large and small numbers; using formulae and equations and making multistage calculations. **N3.2**

IT

There are opportunities to search on CD-ROMs and the Internet for new and interesting case studies. **IT3.1**

6 Further Information and Training for Teachers

OCR supporting teachers

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

- up-to-date copies of these specifications;
- 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 the *Advancing Physics Coursework Handbook* containing advice on managing coursework, suggestions for coursework topics, further guidance on marking and moderation and exemplar material to support internal assessment;
- written advice on coursework proposals;
- individual feedback to each Centre on the moderation of coursework;
- a Report on the Examination, compiled by Principal Examiners and Moderators, after each examination session;
- a regional network of coursework consultants.

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

Advancing Physics Project supporting teachers

The *Advancing Physics* project will provide support for teachers through:

- INSET for teachers who plan to take up the course – covering new teaching material as well as new teaching approaches.
- A network of user groups so that teachers of the course can meet with colleagues using the materials in other schools and colleges.
- The *Advancing Physics* newsletter – helping teachers keep in touch with the publishers; the examination board, OCR; and the Project team at the Institute of Physics.
- The *Advancing Physics* website – providing an opportunity for teachers to keep up to date with new contexts for the physics in the course; to share ideas and to link to the wider physics community. http://post16.iop.org/advphys/

The *Advancing Physics* Project can be contacted at : Project Administrator, *Advancing Physics*, Institute of Physics, 76 Portland Place, London W1N 3DH, or by email: apsupport@iop.org

7 Support Materials for the Course

Advancing Physics – Published Resources

The course is supported by a full range of resources, both in print and in electronic form, published by Institute of Physics Publishing and endorsed by OCR.

Advancing Physics Student's book (one each for AS and AS2) 256 pages in full colour provides good physics reading for students as well as a grounding in the essential physics of the course.

Advancing Physics Student's CD-ROM (one each for AS and AS2) containing the Course Guide, Resource Finder and Physics A-Z. The CD-ROM include a study guide to support the student throughout the course. Whilst much of the Study Guide can be printed off as hard copy, the interactive nature of the medium enhances its use as a learning tool. The CD-ROM includes modelling software to enable students and teachers to try out physics models developed for the course as well as building their own models. The Study Guide provides many opportunities for self-study.

Advancing Physics Course Guide, (one for both AS and A2) which guides the teacher through the course and helps with organising the teaching and learning.

Advancing Physics Teacher's CD-ROM (one each for AS and A2) which holds all the Student CD-ROM and the text of the Teacher's Handbook, it also provides more detailed support for teaching the course, including background physics; materials for classroom activities – including photocopiable material for OHTs, worksheets, and tests; and listings of apparatus requirements. All the materials can be printed and customised to suit the particular circumstances of the school or college. Other resources for the teacher will include a bank of questions, with answers; data for use with software programs, tools and simulations.

For further information about published resources contact:

Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE UK

Tel: +44 (0)117 930 1148 (Direct) Fax: +44 (0)117 929 4318

E-mail: book.orders@ioppublishing.co.uk

Appendix A

Key Skills

This Appendix offers detailed guidance on the Key Skills evidence that a candidate might produce during their programme of study. It focuses on the evidence required to meet the criteria for the internally assessed Key Skills portfolio. For example, in producing work for assessment as evidence of C3.2 (Read and synthesise information from two extended documents about a complex subject. One of these documents should include at least one image.) a candidate is required to:

- select and read material that contains the information you need;
- identify accurately, and compare, the lines of reasoning and main points from text and images;
- synthesise the key information in a form that is relevant to your purpose.

The Key Skills and Evidence Requirements below are quoted from the Part B of the QCA Key Skills specifications and, as such, are addressed to the candidate. The text below the Evidence Requirements is guidance for teachers about how the specification might be used to provide teaching and learning opportunities and/or assessment opportunities for the Key Skill.

By its nature physics provides opportunities for candidates to develop their skills in the application of number during the analysis of the physics they are studying. The variety of teaching and learning styles in *Advancing Physics* provide many opportunities for candidates to develop their skills in communication – through discussion, writing reports, posters and mini-lectures. There are opportunities to use many aspects of IT such as data-logging, word processing, the use of modelling programs, spreadsheets and databases and researching information about new developments in physics through the Internet throughout the course.

The three personal skills can also be developed through the course. Many activities within the course require the candidate to take the initiative and work out how to tackle a task. This provides opportunities to develop and demonstrate problem solving skills. Candidates are encouraged to take on some tasks as a team, providing opportunities to show that they are able to work with others. Throughout the course candidates have opportunities to find out for themselves about examples of the relevant physics. Teachers can help candidates develop their own learning skills by graduating the amount of support the candidates receive in carrying out these tasks.

For further information about the requirements of these units, teachers should refer to QCA's Key Skills specifications (2000 version).

For further information about the assessment and certification of Key Skills, teachers should contact OCR.

C3 Communication Level 3

C3.1a

Contribute to a group discussion about a complex subject.

Evidence requirements

(i) Make clear and relevant contributions in a way that suits your purpose and situation.

(ii) Listen and respond sensitively to others, and develop points and ideas.

(iii) Create opportunities for others to contribute when appropriate.

Possible opportunities

There are opportunities throughout the course for candidates to take part in discussions about the contexts in which physics takes place – these may be historical, social, technological, cultural, economic or moral. Throughout the AS course candidates are asked to find their own examples of contexts for the physics they have studied. They may be asked to make a presentation to the rest of the group (See C3.1b). These presentations may be followed by discussion. In the A2 course there are opportunities to consider the historical development of ideas in physics as well as considering modern contexts for the subject.

Modules 2862 and 2863, Component 01

The assessed presentation in Module 2862 may be a talk or a poster presentation which would provide an opportunity for a class discussion.

In the Module 2863, Component 01, where mathematical modelling is developed, there is the opportunity to discuss the place of mathematics in physics.

C3.1b

Make a presentation about a complex subject, using at least one image to illustrate complex points.

Evidence requirements

(i) Speak clearly and adapt your style of presentation to suit your purpose, subject, audience and situation.

(ii) Structure what you say so that the sequence of information and ideas may be easily followed.

(iii) Use a range of techniques to engage the audience, including effective use of images.

Possible opportunities

Throughout the course candidates are asked to find their own examples of contexts for the physics they have studied. They may be asked to make a presentation to the rest of the group of their findings. In both the AS and the A2 course there are occasions when different candidates will be investigating different aspects of a topic and thus there are opportunities for them to report back to the group. Some of these occasions could be used as a chance for candidates to make a formal, assessed presentation.

Modules 2862 and 2865

The assessed presentation in Module 2862 may be a talk or a poster presentation to the rest of the group. A good assessment for the purposes of the AS assessment should also meet the criteria for C3.1b.

In Module 2865 candidates consider how different aspects of the physics they have studied are used together to tackle a problem. This is an opportunity for them to follow their own interests and then make a presentation to the group. Each member then learns about a whole range of cases.

C3.2

Read and synthesise information from two extended documents that deal with a complex subject. One of these documents should include at least one image.

Evidence requirements

(i) Select and read material that contains the information you need.

(ii) Identify accurately, and compare, the lines of reasoning and main points from texts and images.

(iii) Synthesise the key information in a form that is relevant to your purpose.

Possible opportunities

Throughout the course candidates are asked to find their own examples of contexts for the physics they have studied. To do this they will need to carry out research by reading a variety of sources and then summarising the ideas for themselves, or to make a presentation.

Modules 2862 and 2864

The assessed Presentation in Module 2862 and the Research Report in Module 2864 (Component 02) will both require candidates to carry out research using a variety of sources of information. They need to find their own sources, which will almost inevitably include images, and compare the information there, referring to discrepancies in their final report.

C3.3 Write two different types of documents about complex subjects. One piece of writing should be an extended document and include at least one image.

Evidence requirements

(i) Select and use a form and style of writing that is appropriate to your purpose and complex subject matter.

(ii) Organise relevant information clearly and coherently, using specialist vocabulary when appropriate.

(iii) Ensure your text is legible and your spelling, grammar and punctuation are accurate so your meaning is clear.

Possible opportunities

Throughout the course candidates are asked to find their own examples of contexts for the physics they have studied. Following from their research they will need to write about the topic. On some occasions the task may be to write briefing notes for the rest of the teaching group, on other occasions the outcome will be a more extended piece of writing for part of the assessed coursework.

Modules 2862, 2863 and 2864

Advanced GCE are required to produce 4 pieces of written coursework: in Module 2862 there is the report on an *Instrumentation Task* and the results of the *Making Sense of Data* task; in Module 2863, Component 02 there is the *Investigation report* and finally in Module 2864, Component 02 there is the *Research and report*. The AS tasks would result in a short document, but the A2 reports should both be extended documents and would be expected to include images.

A good assessment for the purposes of the AS and Advanced GCE assessments should also meet the criteria for C3.3.

N3 Application of Number Level 3

You must:

Plan and carry through at least one substantial and complex activity that includes tasks for N3.1, N3.2 and N3.3.

N3.1 Plan, and interpret information from two different types of sources, including a large data set.

Evidence requirements

(i) Plan how to obtain and use the information required to meet the purpose of your activity.

(ii) Obtain the relevant information.

(iii) Choose appropriate methods for obtaining the results you need and justify your choice.

Possible opportunities

Throughout the course candidates carry out experiments and investigations in which they collect data which has to be analysed.

Module 2863

In Module 2863, Component 02 candidates carry out a Practical Investigation which may involve collecting data for analysis. An Investigation which meets the requirements of the coursework assessment criteria well should also cover the requirements of N3.1.

N3.2 Carry out multi-stage calculations to do with:

(a) amounts and sizes;

(b) scales and proportion;

(c) handling statistics;

(d) rearranging and using formulae.

You should work with a large data set on at least **one** occasion.

Evidence requirements

(i) Carry out calculations to appropriate levels of accuracy, clearly showing your methods.

(ii) Check methods and results to help ensure errors are found and corrected.

Possible opportunities

Throughout the course candidates develop their skills in carrying out calculations, many of which will be multistage.

Modules 2862 and 2863

In Module 2862 candidates carry out a *Data handling* task, which is part of the internally assessed coursework. This involves analysing the data from an experiment. The data set may be large, depending on the experiment carried out. In Module 2863, Component 02 candidates carry out a Practical Investigation which may involve collecting data for analysis.

If the task or Investigation meets the requirements of the coursework assessment criteria well it should also cover the requirements of N3.2.

N3.3 Interpret results of your calculations, present your findings and justify your methods. You must use at least one graph, one chart and one diagram.

Evidence requirements

(i) Select appropriate methods of presentation and justify your choice.

(ii) Present your findings effectively.

(iii) Explain how the results of your calculations relate to the purpose of your activity.

Possible opportunities

Throughout the course candidates carry out experiments and investigations in which they collect data which has to be analysed. On some occasions they may be asked to present their findings to the rest of the group.

Modules 2862 and 2863

In Module 2862 candidates carry out a *Data handling* task, which is part of the internally assessed coursework. This involves analysing the data from an experiment. The data set may be large, depending on the experiment carried out. In Module 2863, Component 02, candidates carry out a Practical Investigation which may involve collecting data for analysis. The results of these findings must be presented in a written report.

If the task or Investigation meets the requirements of the coursework assessment criteria well it should also cover the requirements of N3.3.

IT3 IT Level 3

You must:

Plan and carry through at least one substantial activity that includes tasks for IT3.1, IT3.2 and IT3.3.

IT 3.1

Plan, and use different sources to search for, and select, information required for two different purposes.

Evidence requirements

(i) Plan how to obtain and use the information required to meet the purpose of your activity.

(ii) Choose appropriate sources and techniques for finding information and carry out effective searches.

(iii) Make selections based on judgements of relevance and quality.

Possible opportunities

The *Advancing Physics* course incorporates the use of IT into all aspects of the teaching and learning. There is a CD-ROM for students which uses a database to manage the information about the course. Throughout the course candidates are asked to find their own examples of contexts for the physics they have studied. Candidates are expected to use IT in their research, using CD-ROMs, any local networks and the Internet.

Modules 2862 and 2864

The assessed Presentation in Module 2862 and the Research Report in Module 2864 both require candidates to carry out research using a variety of sources of information. They need to find their own sources, which will generally include images, and compare the information there, referring to discrepancies in their final report.

IT 3.2 Explore, develop, and exchange information and derive new information to meet two different purposes.

Evidence requirements

(i) Enter and bring together information in a consistent form, using automated routines where appropriate.

(ii) Create and use appropriate structures and procedures to explore and develop information and derive new information.

(iii) Use effective methods of exchanging information to support your purpose.

Possible opportunities

The *Advancing Physics* course incorporates the use of IT into all aspects of the teaching and learning. There are many opportunities to use models to develop and explain ideas in physics. These models may be developed using a spreadsheet or using dedicated modelling software which is supplied on the student's CD-ROM. There are opportunities to share models with other students, both within the school or college and through the *Advancing Physics* website. Spreadsheets may also be used to process the data from candidate's own experiments.

Modules 2861, 2862 and 2863

In Module 2861 candidates meet examples of using models to help their understanding of vectors, first they use models devised by others, but they rapidly develop an understanding of how the software works and are then be able to develop new models to share with others. In Module 2863 candidates use mathematical models more and can learn how using IT enables them to develop these models much further and more efficiently than simply using pencil and paper. Again these models might be shared with other candidates.

In Module 2862 the *Making sense of data* task provides an ideal opportunity to use IT to analyse the data provided. In Module 2863 candidates carry out a practical Investigation which may give them another opportunity to use IT to draw together and analyse the information they have collected.

IT3.3 Present information from different sources for two different purposes and audiences. Your work must include at least one example of text, one example of images and one example of numbers.

Evidence requirements

(i) Develop the structure and content of your presentation using the views of others, where appropriate, to guide refinements.

(ii) Present information effectively, using a format and style that suits your purpose and audience.

(iii) Ensure your work is accurate and makes sense.

Possible opportunities

Throughout the course candidates have opportunities to develop their IT skills by making short presentations to their peers, perhaps giving a talk, making briefing notes or creating a display.

Modules 2862, 2863 (Component 02) and 2864 (Component 02)

The assessed coursework within Advancing Physics provides five opportunities for candidates to use IT to present information. Four of the tasks require a written report which might be word processed, and there may be diagrams graphs and charts which could be produced effectively using IT. The Presentation task does not require a written report, however there is the opportunity to make the presentation as a series of web pages, or electronic presentation or the candidate might use IT to create the images for a talk.

WO3 Working with Others Level 3

You must:

Provide at least one substantial example of meeting the standard for WO3.1, WO3.2 and WO 3.3 (you must show you can work in both one-to-one group and situations).

WO3.1

Plan complex work with others, agreeing objectives, responsibilities and working arrangements.

Evidence requirements

(i) Agree realistic objectives for working together and what needs to be done to achieve them.

(ii) Exchange information, based on appropriate evidence, to help agree responsibilities.

(iii) Agree suitable working arrangements with those involved.

Possible opportunities

Throughout the course there are opportunities for candidates to work with others, for instance sharing the responsibility for an experiment and reporting back to the rest of the group.

Module 2860

In Module 2860 candidates carry out team tasks to investigate a variety of sensors. These team tasks are preparation for an individual piece of coursework, and planning the task in a team would be helpful groundwork for the individual coursework assignments.

WO3.2

Seek to establish and maintain co-operative working relationships over an extended period of time, agreeing changes to achieve agreed objectives.

Evidence requirements

(i) Organise and carry out tasks so that you can be effective and efficient in meeting your responsibilities and produce the quality of work required

(ii) Seek to establish and maintain co-operative working relationships, agreeing ways to overcome any difficulties.

(iii) Exchange accurate information on progress of work, agreeing changes where necessary to achieve objectives.

Possible opportunities

Throughout the course there are opportunities for candidates to work with others, for instance sharing the responsibility for an experiment and reporting back to the rest of the group.

Module 2860

In Module 2860 candidates carry out team tasks to investigate a variety of sensors. These team tasks are preparation for an individual piece of coursework, so working in a team could be helpful in making candidates aware of some of the pitfalls of the individual task to come.

WO3.3

Review work with others and agree ways of improving collaborative work in the future.

Evidence requirements

(i) Agree the extent to which work with others has been successful and the objectives have been met.

(ii) Identify factors that have influenced the outcome.

(iii) Agree ways of improving work with others in the future.

Possible opportunities

Throughout the course there are opportunities for candidates to work with others, for instance sharing the responsibility for an experiment and reporting back to the rest of the group.

Module 2860

In Module 2860 candidates carry out team tasks to investigate a variety of sensors. These team tasks are preparation for an individual piece of coursework, so reflecting on the outcomes of the team task could help the candidates' preparation for future team tasks as well as informing their preparation for the individual assignment.

LP3 Improving own Learning and Performance Level 3

You must:

Provide at least one substantial example of meeting the standard for LP3.1, LP3.2 and LP3.3:

LP3.1

Agree targets and plan how these will be met over an extended period of time, using support from appropriate people.

Evidence requirements

(i) Seek information on ways to achieve what you want to do, and identify factors that might affect your plans.

(ii) Use this information to agree realistic targets with appropriate people.

(iii) Plan how you will effectively manage your time and use of support to meet targets, including alternative action for overcoming possible difficulties.

Possible opportunities

The resources for the *Advancing Physics* course include many which can be used by candidates outside the class room to advance their own learning. Two of the assessed coursework items require candidates to carry out research and make a report – one as a presentation and the other written.

Modules 2860 and 2861

In modules 2860 and 2861 candidates must find their own examples of applications and contexts for some of the physics taught in the course. It is expected that candidates will develop their research and writing skills during the course, beginning with small tasks so that when the assessed research tasks arise they have developed their study skills well.

LP3.2

Take responsibility for your own learning by using your plan, and seeking feedback and support from relevant sources to help meet your targets.

Improve your performance by:

- studying a complex subject;
- learning through a complex practical activity;
- further study or practical activity that involves independent learning.

Evidence requirements

(i) Manage your time effectively to complete tasks, revising your plan as necessary.

(ii) Seek and actively use feedback and support from relevant sources to help you meet targets.

(iii) Select and use different approaches to learning to improve your performance, adapting approaches to meet new demands.

Possible opportunities

The resources for the *Advancing Physics* course include many which can be used by candidates outside the class room to advance their own learning. Two of the assessed coursework items require candidates to carry out research and make a report – one as a presentation and the other written.

Modules 2862 and 2864

In Modules 2862 and 2864 Component 02 candidates must carry out research tasks. It is expected that between the task in Module 2862 and that in Module 2864 Component 02 candidates will show progression in their ability to manage their time effectively, particularly with regard to planning ahead for the task in A2 which is a bigger assignment and may need research to begin well ahead of the time for delivery of the finished report.

LP3.3 Review progress on **two** occasions and establish evidence of achievements, including how you have used learning from other tasks to meet new demands

Evidence requirements

(i) Provide information on the quality of your learning and performance, including factors that have affected the outcome.

(ii) Identify targets you have met, seeking information from relevant sources to establish evidence of your achievements.

(iii) Exchange views with appropriate people to agree ways to further improve your performance.

Possible opportunities

The resources for the *Advancing Physics* course include many which can be used by candidates outside the class room to advance their own learning. Two of the assessed coursework items require candidates to carry out research and make a report – one as a presentation and the other written.

Modules 2862 and 2864

In Modules 2862 and 2864 Component 02, candidates must carry out research tasks. It is expected that between the task in Module 2862 and that in Module 2864 Component 02 candidates will show progression in their ability to plan effectively. It is expected that the outcome of the first assignment in Module 2862 will inform the way they tackle the second assignment.

PS3 Problem Solving Level 3

You must:

Provide at least one substantial example of meeting the standard for PS3.1, PS3.2 and PS3.3.

PS3.1

Explore a complex problem, come up with **three** options for solving it and justify the option selected for taking it forward.

Evidence requirements

(i) Explore the problem, accurately analysing its features, and agree with others on how to show success in solving it.

(ii) Select and use a variety of methods to come up with different ways of tackling the problem.

(iii) Compare main features of each possible option, including risk factors, and justify the option you select to take forward.

Possible opportunities

There are many opportunities to develop problem-solving skills within the *Advancing Physics* course, for instance there is practical work which requires candidates to solve problems and there are opportunities to develop computer models of physical systems.

Module 2863

In Module 2863 candidates carry out a Practical investigation of a physics problem. They need to begin by planning their investigation which involves defining the problem they are tackling.

PS3.2

Plan and implement at least one option for solving the problem, review progress and revise your approach if necessary.

Evidence requirements

(i) Plan how to carry out your chosen option and obtain agreement to go ahead from an appropriate person.

(ii) Implement your plan, effectively using support and feedback from others.

(iii) Review progress towards solving the problem and revise your approach as necessary.

Possible opportunities

There are many opportunities to develop problem-solving skills within the *Advancing Physics* course, for instance there is practical work which requires candidates to solve problems and there are opportunities to develop computer models of physical systems.

Module 2863

In Module 2863 Component 02 candidates carry out a Practical Investigation of a physics problem. In the planning of their investigation they may need to consider a variety of strategies and experimental techniques and determine what will be possible in the time they have for the project. They can implement their plan, and review progress towards a solution, revising their approach if necessary.

PS3.3

Apply agreed methods to check if the problem has been solved, describe the results and review your approach to problem solving.

Evidence requirements

(i) Agree, with an appropriate person, methods to check if the problem has been solved.

(ii) Apply these methods accurately, draw conclusions and fully describe the results.

(iii) Review your approach to the problem solving, including whether alternative methods and options might have proved more effective.

Possible opportunities

There are many opportunities to develop problem-solving skills within the *Advancing Physics* course, for instance there is practical work which requires candidates to solve problems and there are opportunities to develop computer models of physical systems.

Module 2863

In Module 2863 Component 02 candidates carry out a Practical Investigation of a physics problem. In the carrying out their investigation they will need to monitor progress and discuss with their teacher any issues that arise.

Appendix B

Data, Formulae and Relationships

The information below is provided as a separate booklet for all *Advancing Physics* examinations.

Data

Values are given to three significant figures, except where more – or less – are useful.

Physical constants

speed of light	c	3.00×10^{8} ms^{-1}
permittivity of free space	ε_0	8.85×10^{-12} C^2 N^{-1} m^{-2} (or F m^{-1})
electric force constant	$k = \frac{1}{4\pi\varepsilon_0}$	8.98×10^{9} N m^2 C^{-2} ($\approx 9 \times 10^{9}$ N m^2 C^{-2})
permeability of free space	μ_0	$4\,\pi \times 10^{-7}$ N A^{-2} (or H m^{-1})
charge on electron	e	-1.60×10^{-19} C
mass of electron	m_e	9.11×10^{-31} kg = 0.000 55 u
mass of proton	m_p	1.673×10^{-27} kg = 1.007 3 u
mass of neutron	m_n	1.675×10^{-27} kg = 1.008 7 u
mass of alpha particle	m_α	6.646×10^{-27} kg = 4.001 5 u
Avogadro constant	L, N_A	6.02×10^{23} mol^{-1}
Planck constant	h	6.63×10^{-34} J s
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
gravitational force constant	G	6.67×10^{-11} N m^2 kg^{-2}

Other data

standard temperature and pressure (stp)		273 K (0 °C), 1.01×10^5 Pa (1 atmosphere)
molar volume of a gas at stp	V_m	2.24×10^{-2} m^3
gravitational field strength at the Earth's surface in the UK	g	9.81 N kg^{-1}

Conversion factors

unified atomic mass unit	1u	$= 1.661 \times 10^{-27}$ kg
	1 day	$= 8.64 \times 10^4$ s
	1 year	$\approx 3.16 \times 10^7$ s
	1 light year	$\approx 10^{16}$ m

Mathematical constants and equations

e = 2.72 $\pi = 3.14$ 1 radian = 57.3°

arc = $r\theta$

$\sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$ for small θ

$\ln(x^n) = n \ln x$

$\ln(e^{kx}) = kx$

circumference of circle = $2\pi r$

area of circle = πr^2

surface area of cylinder = $2\pi rh$

volume of cylinder = $\pi r^2 h$

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

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

Prefixes

10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^3	10^6	10^9
p	n	µ	m	k	M	G

Formulae and relationships

Optics

focal length	$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$	Cartesian convention (object distance *u*, image distance *v*, focal length *f*)
refractive index	$n = \frac{\sin i}{\sin r} = \frac{\text{speed of light in vacuo}}{\text{speed of light in medium}}$	(angle of incidence *i*, angle of refraction *r*)

Electricity

power	$P = IV = I^2R$	(power *P*, potential difference *V*, current *I*)
	$V_{\text{load}} = E - IR_{\text{internal}}$	(emf *E*, internal resistance R_{internal})
conductance	$G = \frac{I}{V}$	(conductance *G*)
	$G = G_1 + G_2 + \ldots\ldots$	(conductors in parallel)
resistance	$R = R_1 + R_2 + \ldots\ldots$	(resistors in series)
conductivity	$G = \frac{\sigma A}{l}$	(conductivity σ, cross section *A*, length *l*)
capacitance	$\text{energy stored} = \frac{1}{2}QV = \frac{1}{2}CV^2$	(charge Q, capacitance *C*)
discharge of capacitor	$Q = Q_0 e^{-t/RC}$	(initial charge Q_0, time constant *RC*)
	$\tau = RC$	(time constant τ)

Materials

for a material in tension

Hooke's law	$F = kx$	(tension *F*, spring constant *k*, extension *x*)

$$\text{stress} = \frac{\text{tension}}{\text{cross-sectional area}}$$

$$\text{strain} = \frac{\text{extension}}{\text{original length}}$$

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

$$\text{elastic strain energy} = \tfrac{1}{2}kx^2$$

Gases

kinetic theory of gases $pV = \frac{1}{3} Nm\overline{c^2}$ (pressure p, volume V, number of molecules N, mass of molecule m, mean square speed $\overline{c^2}$)

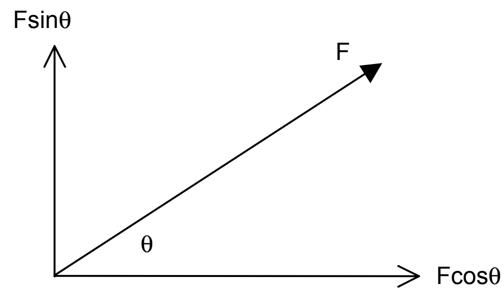
Motion and forces

force = rate of change of momentum

impulse = $F\Delta t$ (force F)

power = Fv (velocity v)

components of a vector in two perpendicular directions



equations for uniformly accelerated motion

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

$v = u + at$

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

(initial speed u, final speed v, time taken t, acceleration a, distance travelled s)

for circular motion $a = \frac{v^2}{r}$ (radius of circle r)

Energy and thermal effects

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

energy $\Delta E = mc\Delta\theta$ (change in energy ΔE, mass m, specific thermal capacity c, temperature change $\Delta\theta$)

Boltzmann factor $e^{(-\varepsilon/kT)}$ (ratio of numbers of particles in states differing by ε at temperature T)

Waves

	$n\lambda = d\sin\theta$	(on a distant screen from a diffraction grating or double slit; order *n*, wavelength λ, angles of maxima θ)

Oscillations

	$\frac{d^2x}{dt^2} = a = -\left(\frac{k}{m}\right)x = -(2\pi f)^2 x$	(acceleration *a*, force per unit displacement *k*, mass *m*, displacement *x* frequency *f*)
	$x = A \cos 2\pi ft$	(amplitude *A*, time *t*)
	$x = A \sin 2\pi ft$	
	$T = 2\pi\sqrt{\frac{m}{k}}$	(periodic time *T*)
	$f = \frac{1}{T}$	
total energy	$E = \frac{1}{2}kA^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$	

Atomic and nuclear physics

radioactive decay	$\frac{\Delta N}{\Delta t} = -\lambda N$	(number *N*, decay constant λ)
	$N = N_0 e^{-\lambda t}$	(initial number N_0)
	$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$	(half-life $T_{\frac{1}{2}}$)

absorbed dose = energy deposited per unit mass
risk = probability × consequence
expected random variation in N random counts is of the order $\sqrt{N}$

mass-energy relationship	$E_{rest} = mc^2$	(energy *E*, mass *m*, speed of light *c*)
energy-frequency relationship for photons	$E = hf$	(photon energy *E*, Planck constant *h*, frequency *f*)
	$\lambda = \frac{h}{p}$	(wavelength λ, Planck constant *h*, momentum *p* (= *mv* for slow moving particles))

Field and potential

for all fields	$\text{field strength} = -\frac{dV}{dr} \approx -\frac{\Delta V}{\Delta r}$	(potential gradient dV/dr)
gravitational fields	$g = \frac{F}{m}$	(gravitational field strength g, gravitational force F, mass m)
	$V_{grav} = -\frac{GM}{r}$	(gravitational potential V_{grav}, gravitational constant G, mass M, distance r)
Electric fields	$V_{elec} = \frac{kQ}{r}$	(electric potential V_{elec}, electric force constant k, charge Q, distance r)

Electromagnetism

force on a current carrying conductor	$F = IlB$	(flux density B, current I, length l)
force on a moving charge	$F = QvB$	(charge Q, velocity perpendicular to field v)
	$\varepsilon = -\frac{d(N\Phi)}{dt}$	(induced emf ε, flux Φ, number of turns linked N)

Appendix C

Relationships which will not be provided in Question Papers

In accordance with the subject criteria for Physics, candidates are required to recall the following relationships which will **not** be provided with Advanced Subsidiary and Advanced Level question papers.

(i) The relationship between speed, distance and time:

$$\textbf{Speed} = \frac{\textbf{distance}}{\textbf{time taken}}$$

(ii) The quantitive relationship between force, mass and acceleration:

Force = mass x **acceleration** **F = ma**

$$\textbf{Acceleration} = \frac{\textbf{change in velocity}}{\textbf{time taken}}$$

(iii) The concept of momentum and its conservation:

Momentum = mass x **velocity** **p=mv**

(iv) The quantitive relationships between force, distance, work, power and time:

Work done = force x **distance moved in direction of force**

(v) The relationships between mass, weight, potential energy, kinetic energy and work:

Weight = mass x **gravitational field strength**

Kinetic energy = $\frac{1}{2}$ x **mass** x **speed**^{2}

Change in potential energy = mass x **gravitational field strength** x **change in height**

(vi) The relationship between an applied force, the area over which it acts and the resulting pressure:

$$\textbf{Pressure} = \frac{\textbf{force}}{\textbf{area}}$$

2nd Edition Sept 2002

(vii) The Gas Law:

Pressure x **volume =**
number of moles x **molar gas constant** x **absolute temperature**

pV = nRT

(viii) The relationships between charge, current, potential difference, resistance and electrical power:

Charge = current x **time** $\Delta Q = I\Delta t$

Potential difference = current x **resistance** $V = IR$

Electrical power = potential difference x **current** $P = VI$

Power = $\dfrac{\textbf{energy transferred}}{\textbf{time taken}}$ **=** $\dfrac{\textbf{work done}}{\textbf{time taken}}$

(ix) The relationship between potential difference, energy and charge:

Potential difference = $\dfrac{\textbf{Energy transferred}}{\textbf{charge}}$ $V = \dfrac{W}{Q}$

(x) The relationship between resistance and resistivity:

Resistance = $\dfrac{\textbf{resistivity} \times \textbf{length}}{\textbf{cross sectional area}}$

(xi) The relationship between charge flow and energy transfer in a circuit:

Energy = potential difference x **current** x **time** ***E= VIt***

(xii) The quantitive relationship between speed, frequency and wavelength:

Wave speed = frequency x **wavelength** $v = f\lambda$

(xiii) The relationship between centripetal force, mass, speed and radius:

Centripetal force = $\dfrac{\textbf{Mass} \times \textbf{speed}^2}{\textbf{radius}}$ $F = \dfrac{mv^2}{r}$

(xiv) The inverse square laws for force in radial electric and gravitational fields:

$$F = \frac{kq_1q_2}{r^2} \qquad F = \frac{Gm_1m_2}{r^2}$$

(xv) The relationship between capacitance, charge and potential difference:

Capacitance = $\dfrac{\textbf{charge stored}}{\textbf{potential difference}}$ $\qquad C = Q/V$

(xvi) The quantitive relationship between the potential difference across the coils in a transformer and the number of turns in them:

$$\frac{\textbf{potential difference across coil 1}}{\textbf{potential difference across coil 2}} = \frac{\textbf{number of turns in coil 1}}{\textbf{number of turns in coil 2}} \qquad \frac{V_1}{V_2} = \frac{N_1}{N_2}$$

Appendix D

Symbols and Units used in Question Papers

The following list illustrates the symbols and units which are used in the AS and A2 question papers.

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	x or s	m
area	A	m^2
volume	V	m^3
density	ρ	$kg\ m^{-3}$
speed	u, v, c	ms^{-1}
velocity	u, v, c	ms^{-1}
acceleration	a	ms^{-2}
acceleration of free fall	g	ms^{-2}
force	F	N
momentum	p	Ns
work	W	J
energy	$E, W, \mathcal{E}$	J
potential energy	E_P	J
kinetic energy	E_K	J

Quantity	**Usual symbols**	**Usual Unit**
energy transferred thermally (heating)	Q	J
power	P	W
pressure	p	Pa
gravitational constant	G	N kg^{-2} m^2
gravitational field strength	g	N kg^{-1}
angle	θ	°, rad
angular displacement	θ	°, rad
angular speed	ω	rad s^{-1}
period	T	s
frequency	f	Hz
angular frequency	ω	rad s^{-1}
wavelength	λ	m
speed of electromagnetic waves	c	m s^{-1}
electric charge	Q, q	C
elementary charge	e	C
electric potential	V	V
electric potential difference	V	V
electromotive force (emf)	E	V
resistance	R	Ω
conductance	G	S
resistivity	ρ	Ω m
conductivity	σ	S m^{-1}
electric field strength	E	NC^{-1}, V m^{-1}
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}

Quantity	Usual symbols	Usual Unit
stress		Pa
strain		fraction or per cent
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}
Boltzmann constant	k	J K^{-1}
Avogadro constant	L, N_A	mol^{-1}
number	N, n, m	
number density (number per unit volume)	n	m^{-3}
Planck constant	h	J s
work function energy	W	J, eV
activity of radioactive source	A	Bq
decay constant	λ	s^{-1}
half-life	$T_{1/2}$	s
atomic mass	m_a	kg, u
electron mass	m_e	kg, u
neutron mass	m_n	kg, u
proton mass	m_p	kg, u
proton number	Z	
nucleon number	A	
neutron number	N	

Appendix E

Coursework Assessment

It is intended that the assessment of coursework should be transparent to candidates and straightforward for teachers. For this reason the assessment structure for each of the items of coursework and the method of applying them is the same in each case.

The criteria framework

The criteria consist of a general statement of the intent of the criterion, followed by statements describing levels of performance on a scale 1 to 5, with statements for ratings 1, 3 and 5. Levels 2 and 4 are to be obtained by interpolating. By basing each set of the specific criteria on the same structure it is intended that teachers will become familiar with the structure and so able to maintain a consistent standard across the coursework tasks and from student to student and from year to year. The framework of assessment which has been used to produce the specific criteria for each task:

Strand A : Initiative and independence : Planning and use of resources

During the coursework the teacher will work closely with the candidate. Discussions should be framed to allow the candidate to show initiative, personal involvement and interest in planning and pursuing the work. The overall impression given is that the candidate:

1 requires detailed instructions and outside motivation

3 responds to suggestions and has some definite and constructive ideas of their own

5 regularly takes the initiative and makes creative use of suggestions

The coursework requires the use of resources, whether apparatus, ICT or information based. Where the task involves practical work, there is due consideration for safety. Overall, the candidate uses:

1 one basic resource, perhaps with difficulty

3 more than one resource competently

5 a well selected range of resources with skill

Strand B: Use of knowledge, skill and understanding of physics

In completing the coursework the candidate needs to use the physics they have studied and their understanding of that physics, as well as the skills they have acquired during the course to develop a strategy for tackling the task. During the work the overall impression is that the candidate:

1 works in a straightforward way, concerned with the mechanics of the task

3 makes an attempt to understand, interpret and explain the work

5 shows clarity of thought to understand, interpret and explain the work

Throughout the coursework the candidate should have a critical and cautious attitude to information and data, identifying discrepancies. Overall the impression given is that the candidate:

1 accepts things at face value, makes unreflective assumptions

3 identifies and reports discrepancies, notes assumptions

5 accounts for discrepancy and takes or suggests action to minimise problems, questions assumptions

Strand C: Quality of Communication

The coursework ends with a written report or presentation and collection of evidence. In doing this the candidate is encouraged to add value to the work by showing critical and connected thought, moving beyond descriptive reporting. In the report the overall impression given is that the candidate:

1 reports in a descriptive and factual, and not necessarily appropriately ordered manner

3 makes an effort to order the account to inform

5 seeks to interest and inform, making connections within the work

The quality of expression and presentation of the final report or other product produced by the candidate must be considered separately from its content, as far as that is possible. The quality of expression can add to work of any technical quality, and the presentation of work on the page can assist interpretation and understanding for the reader. In a presentation the style adopted can be crucial in communicating information. Overall the impression given is that the candidate:

1 has given little thought to presentation and the impact of the report

3 communicates information intelligibly in an appropriate way

5 uses available resources to present concisely, with impact and clarity

Strand D: Meeting the demands of the particular task

Each piece of coursework sets a task. These tasks all make their own specific demands. To illustrate, a few of these task-specific demands are:

Advanced Subsidiary course

Instrumentation task: design of experiments; observation and measurement

Materials research and presentation: placing the material in a wider context; proving evidence of the presentation

Making sense of data: use of mathematics; interpreting graphs and tables

A2

Practical Investigation: evaluation of investigation and drawing conclusions

Research report: evaluation of sources; synoptic skills – showing how different aspects of physics are used in this case and placing the research in a wider context

Overall, taking into account both the demands of the general type of task, and any particular demands of that specific task, the impression given is that the candidate:

1 meets only the simplest demands of the task

3 meets a reasonable proportion of the significant demands of the task competently

5 shows wide ranging skill and competence in meeting most demands of the task

Applying the criteria to the coursework

For each coursework task a matrix of mark descriptors is provided in the Coursework Administration Pack. This is used by the assessor to determine the mark to be awarded for each aspect of the assessment.

Further details are given in the *Advancing Physics Teacher Support: Coursework Guidance*, available from OCR.

Appendix F

Mathematical Requirements

In order to be able to develop the knowledge, understanding and skills in these specifications candidates need to have been taught and to have acquired competence in the areas of mathematics set out below.

In *Advancing Physics* some parts of mathematics which are especially valuable in the education of the scientist are taught alongside the physics for which they are used. These include the numerical solution of differential equations and the use of exponential, sine and cosine functions. The course teaches the use of numerical and graphical methods, which lead naturally into the use of the computer to solve problems involving change and rates of change.

The following is a list of basic mathematical abilities which are assumed in setting the examination. This includes the mathematical requirements of the subject core for Physics.

Material relevant to the A2 half of the Advanced GCE is given in **bold** type.

Arithmetic and Computation

Candidates should be able to:

(a) recognise and use expressions in decimal and standard form (scientific notation);

(b) use ratios, fractions and percentages;

(c) use calculators to find and use x^n, $1/x$, x^2, $\sqrt{x}$, $\log_{10} x$, e^x, $\log_e x$;

(d) use calculators to handle $\sin\theta$, $\cos\theta$, $\tan\theta$, $\sin^{-1}\theta$, $\cos^{-1}\theta$, $\tan^{-1}\theta$ when θ is expressed in degrees or **radians**.

Handling data

Candidates should be able to:

(a) make order of magnitude calculations;

(b) use an appropriate number of significant figures;

(c) find arithmetic means and medians;

(d) express changes as percentages and vice versa;

(e) understand and use logarithmic scales in relation to quantities which range over several orders of magnitude.

Algebra

Candidates should be able to:

- change the subject of an equation by manipulation of the terms, including positive and negative, integer and fractional indices;
- check the dimensional consistency of physical equations and substitute numerical values into such equations using appropriate units for physical quantities;
- solve simple algebraic equations including $y=k/x$, $y=k/x^2$
- formulate and use simple algebraic equations as mathematical models of physical situations, and identify the inadequacy of such models
- understand and use the symbols: $=$, $<$, $<<$, $>>$, $>$, $\sim$, $\propto$, Σ, Δx, δx, dx/dt

Geometry and Trigonometry

Candidates should be able to:

(a) calculate areas of triangles, circumferences and areas of circles, surface areas and volumes of rectangular blocks, cylinders and spheres;

(b) use Pythagoras' theorem, similarity of triangles and the angle sum of a triangle;

(c) use sines, cosines and tangents in physical problems;

(d) use $\sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$ for small θ;

(e) understand the relationship between degrees and radians and translate from one to the other.

Graphs

Candidates should be able to:

(a) translate information between graphical, numerical and algebraic forms;

(b) plot two variables from experimental or other data;

(c) select appropriate variables for graph plotting;

(d) understand that $y = mx + c$ represents a linear relationship;

(e) determine the slope and intercept of a linear graph in the appropriate physical units;

(f) choose by inspection a straight line which will serve as the best straight line through a set of data points presented graphically;

(g) understand the possible physical significance of the area between a curve and the x axis and be able to calculate it or measure it by counting squares as appropriate;

(h) understand and use the slope of a tangent to a curve as a means to obtain the gradient. Understand and use the notation d/dt for a rate of change;

(i) understand and use multiplicative scales (1, 10, 100 ….);

(j) use logarithmic plots to test exponential and power law variations;

(k) sketch simple functions including $y = k/x$, $y = kx^2$ $y = k/x^2$, $y = \sin\theta$, $y = \cos\theta$, $y = e^{-kx}$.