Edexcel GCE

Specification

Edexcel Advanced Subsidiary GCE in Physics (8540)

For examination from summer 2003

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Issue 4 October 2003

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This specification is Issue 4 and is valid for AS examination from summer 2003 and for A2 examination from summer 2004. Key changes to requirements are highlighted. Centres will be informed in the event of any necessary future changes to this specification. The latest issue can be found on the Edexcel website, www.edexcel.org.uk

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Acknowledgements

This specification has been produced by Edexcel on the basis of consultation with teachers, examiners, consultants and other interested parties. Edexcel acknowledges its indebtedness to all those who contributed their time and expertise to the development of Advanced Subsidiary/Advanced GCE specifications.

Authorised by Peter Goff

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Contents

Introduction

Key features

The specification offers:

- both staged and linear routes
- experimental and investigative skills assessed by practical tests
- minimal change from the previous modular syllabus
- reduction in the course content in line with the QCA revised subject criteria
- topics in applied and research physics
- a written synoptic test
- a comprehensive INSET programme to support the delivery of the specification
- linked textbooks and on-line support.

Unit availability

Unit number	Unit title	Jan 2004	Jun 2004	Jan 2005	Jun 2005	Jan 2006	Jun 2006
6731	Unit 1: Mechanics and radioactivity Unit test PHY1 (AS and A)	✓	✓	✓	✓	✓	✓
6732	Unit 2: Electricity and thermal physics Unit test PHY2 (AS and A)	✓	✓	✓	✓	✓	✓
6733/01 6733/02	Unit 3: Topics Topics test PHY3 and Practical test PHY3 (AS and A)	✓	✓	✓	✓	✓	✓
6734	Unit 4: Waves and our universe Unit test PHY4 (A only)	✓	✓	✓	✓	✓	✓
6735/01 6735/02	Unit 5: Fields and forces Unit test PHY5 and Practical test PHY5 (A only)	✓	✓	×	✓	×	✓
6736	Unit 6: Synthesis Synoptic test PHY6 (Terminal Unit) (A only)	✓	✓	×	✓	×	✓

- Unit tests may be taken during or at the end of the course.

Rationale for the specification

In addition to subject-specific consultation meetings and questionnaires, a general consultation exercise was undertaken. The findings of this exercise, which included more than 50 personal interviews with teachers and heads of department/faculty, demonstrate that the specification meets the needs and expectations of centres in the ways identified below.

- The overall scheme is simple and transparent; pathways are clearly identified.
- Flexibility in options and breadth in choice of topics are maximised.
- As well as drawing on established knowledge, the subject matter of the specification is modern and contemporary.
- The specification contains practical applications as well as theory, knowledge and understanding.
- The course content and units of assessment are appropriate and accessible to all levels of ability.

- There is continuity with current provision, which will allow use of existing resources.
- Reading lists and prescribed texts contain both contemporary and more established texts.
- Coursework is not a requirement.
- A mixture of examination formats and question types is used, including short answer, data response, extended writing.

Broad objectives

Advanced Subsidiary (AS) and Advanced (A) GCE Physics are level 3 qualifications in the National Qualifications Framework. They serve the needs of a wide range of students as they follow their paths in their individual routes through lifelong learning.

Advanced Subsidiary and Advanced GCE Physics offer the following routes:

- progression from appropriate level 2 science qualifications
- progression to appropriate level 4 qualifications in the science, engineering, and medical sectors
- progression to employment, in particular in the science, engineering, and medical sectors.

Summary of the scheme of assessment

The scheme of assessment is in two parts. Three units make up the Advanced Subsidiary (AS) assessment, and a further three (A2) units make up the six units required for Advanced (A) GCE assessment. The three Advanced Subsidiary units together have a weighting of 50% of the Advanced GCE course and the three A2 units together also have a weighting of 50% of the Advanced GCE course. The Advanced Subsidiary units are designed to provide an appropriate assessment of the knowledge, understanding and skills of students who have completed the first half of a full Advanced GCE qualification.

Unit	Method of assessment		Time	AS	A
1	Unit test	AS	1 h 15 min	30%	15%
2	Unit test	AS	1 h 15 min	30%	15%
3	Practical test and topics test	AS	1 h 30 min 30 min	20% 20%	10% 10%
4	Unit test	A	1 h 20 min		15%
5	Practical test and unit test	A	1 h 30 min 1 h		7.5% 7.5%
6	Synoptic test	A	2 h		20%

In Unit 3, the practical test and the topics test take place on different days.

In Unit 5, the practical test and the unit test take place on different days.

Summary of the specification content

Unit 1: Mechanics and radioactivity **AS and A**

This unit leads on from GCSE and covers rectilinear motion, forces and moments, Newton's first and third laws, dynamics, momentum, Newton's second law, mechanical energy, radioactive decay and the nuclear atom.

Unit 2: Electricity and thermal physics **AS and A**

This unit includes electric current and potential difference, electrical circuits, heating matter, specific heat capacity, specific latent heat, temperature, kinetic model of matter, conservation of energy, the first law of thermodynamics and efficiency.

Unit 3: Topics **AS and A**

Students study *one* out of the following four topics.

3A — Astrophysics

Observing stars; the lives of stars.

3B — Solid materials

Investigating materials; engineering materials.

3C — Nuclear and particle physics

Stable and unstable nuclei; fundamental particles.

3D — Medical physics

Nuclear medicine; X-rays and ultrasonics.

Unit 4: Waves and our Universe **A only**

This unit includes circular motion and oscillations, simple harmonic motion, waves, superposition of waves, quantum phenomena and the expanding Universe.

Unit 5: Fields and forces **A only**

The first part of this unit covers gravitational fields, electric fields, capacitance, magnetic fields, and electromagnetic induction.

Unit 6: Synthesis **A only**

This is a synoptic unit. Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. The emphasis of synoptic assessment is on understanding and application of the principles included in the specification.

The first section of this unit compares springs and capacitors; electric and gravitational fields; capacitor discharge and radioactive decay, The second part, Accelerators, is intended to show how an area of modern physics unites different areas of physics, such as electric fields, circular motion and momentum. It should be regarded as illustrating applications of these areas. Both of these sections will be assessed synoptically as part of the synoptic test.

Specification overview

Subject criteria

This specification is based on the GCE Advanced Subsidiary (AS) and Advanced (A) Specification Subject Criteria for Physics specified by the Qualifications and Curriculum Authority (QCA) which is mandatory for all awarding bodies.

Aims of the specification

The aims of the Advanced Subsidiary and Advanced GCE Physics specifications are to encourage students to:

- develop essential knowledge and understanding in physics and, where appropriate, the applications of physics, and the skills needed for the use of this in new and changing situations
- develop an understanding of the link between theory and experiment
- appreciate how physics has developed and is used in present day society
- show the importance of physics as a human endeavour which interacts with social, philosophical, economic and industrial matters
- sustain and develop their enjoyment of, and interest in, physics
- recognise the quantitative nature of physics and understand how mathematical expressions relate to physical principles.

In addition, in Advanced GCE physics specifications are to encourage students to:

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

Assessment objectives

The assessment objectives 1, 2 and 3 are the same for Advanced Subsidiary and Advanced GCE. Assessment objective 4 applies only to the A2 part of the Advanced GCE course. Knowledge, understanding and skills are closely linked. Students are required to demonstrate the following assessment objectives in the context of the content and skills specified:

AO1 Knowledge with understanding

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

AO2 Application of knowledge and understanding, synthesis and evaluation

- describe, explain and interpret phenomena and effects in terms of physical principles and concepts, presenting arguments and ideas clearly and logically, using specialist vocabulary where appropriate;
- interpret and translate, from one form to another, data presented as continuous prose or in tables, diagrams and graphs;
- carry out relevant calculations;
- apply physical principles and concepts to unfamiliar situations including those which relate to the ethical, social, economic and technological implications and applications of physics;
- assess the validity of physical information, experiments, inferences and statements.

AO3 Experiment and investigation

- devise and plan experimental activities, selecting appropriate techniques;
- demonstrate safe and skilful practical techniques;
- make observations and measurements with appropriate precision and record these methodically;
- interpret, explain, and evaluate the results of experimental activities, using knowledge and understanding of physics and to communicate this information clearly and logically in appropriate forms, *for example: prose, tables and graphs*, using appropriate specialist vocabulary.

AO4 Synthesis of knowledge, understanding and skills

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

These assessment objectives are weighted in this specification as indicated in this table:

Assessment Objectives		**Weighting**		
		AS	**A2**	**A**
AO1	Knowledge with understanding	45 %	22.5 %	33.75 %
AO2	Application of knowledge and understanding, synthesis and evaluation	35 %	22.5 %	28.75 %
AO3	Experiment and investigation	20 %	15 %	17.5 %
AO4	Synthesis of knowledge, understanding and skills	0 %	40 %	20 %

Synoptic assessment

This specification includes 20% synoptic assessment contained in Unit 6. The definition of synoptic assessment in the context of physics is as follows:

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. The emphasis of synoptic assessment is on understanding and application of the principles included in the specification.

Forbidden combinations and related subjects

The classification code for this specification is 1210

Centres should be aware that students 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.

Students entering for this specification may not, in the same series of examinations, enter for any other specification with the title Advanced Subsidiary or Advanced GCE Physics.

Some of the content of this Advanced Subsidiary and Advanced GCE Physics specification may complement that found in other level 3 qualifications. In particular an Advanced Subsidiary or Advanced GCE Science qualification will complement a proportion of the content of this specification, as will Advanced VCE in Science. There will be a small overlap of content with Advanced Subsidiary or Advanced GCE Chemistry, for example, in the area of content related to gas laws. In that this Advanced Subsidiary and Advanced GCE Physics specification requires application of mathematical skills, any Advanced Subsidiary or Advanced GCE Mathematics specification will complement this specification and there will be some overlap with applied mathematics topics.

Key skills

All the key skills may be delivered and assessed through the study of physics. They are:

- communication
- information technology
- application of number
- working with others
- improving own learning and performance
- problem solving.

Opportunities for the delivery and assessment of key skills are indicated by the letter K in the right hand column of the specification content followed by initial(s) in subscript to indicate the particular key skill.

Key skills are explained in detail in the section key skills development, starting on page 48.

Quality of written communication

Questions involving the writing of continuous prose will expect students to:

- show clarity of expression
- construct and present coherent argument
- demonstrate effective use of spelling, punctuation and grammar.

The mark schemes for questions will take into account the quality of written communication used by students in their answers.

Progression

The course is a sound preparation for studies at level 4, for example BTEC Higher Nationals (HNCs and HNDs) in the science sector, as well as degree-level courses in physics and related sciences, engineering, and medicine as well as chemical engineering and related programmes.

The Advanced Subsidiary GCE Physics specification leads to a qualification in its own right. This specification contains optional topics within Unit 3 of the AS. The topics ‘Astrophysics’ and ‘Nuclear and particle physics’ each provide a sound foundation for further studies in pure physics and related courses. The topic ‘Solid materials’ provides a sound foundation for further studies in engineering subjects. The topic ‘Medical physics’ provides a sound foundation for further studies in medicine and related subjects.

Advanced GCE Physics is a recognised entry qualification for a wide range of higher education courses.

Advanced Subsidiary and Advanced GCE Physics are a sound preparation for a wide range of employment in the science sector through engineering to medicine. Possible areas include radiography and biotechnology.

Advanced Subsidiary and Advanced GCE Physics are also recognised as suitable qualifications for a wide range of employment.

Prior learning

Advanced Subsidiary and Advanced GCE Physics are level 3 qualifications in the National Qualifications Framework. Students undertaking either course are expected to have an appropriate qualification at level 2, for example at least grade C in GCSE Science: Double Award or GCSE Science: Physics. Students may enter with Intermediate GNVQ Science if they have achieved an appropriate level. Students should also have attained GCSE Mathematics grade C or an equivalent qualification.

Spiritual, cultural and moral aspects

These Advanced Subsidiary and Advanced GCE specifications in Physics offer opportunities to students to explore spiritual, moral and cultural dimensions as well as to gain scientific knowledge and understanding of physics topics. Students may experience a sense of amazement as they understand the extent to which physical principles may explain the natural world and the nature of the Universe. For example, the behaviour of fundamental particles is studied in Unit 6 and the Universe is studied in Unit 4. Their studies will lead them to consider ethical issues relating to the use of physics knowledge and its applications and their effects on human activities. Their understanding of physics should help raise debate on the decisions, which may be taken at a personal and wider national and international level, on these applications.

Environmental and health education and the European dimension

In certain sections of the specification there are topics relating to the environment. Through their studies, students can discover and learn to appreciate the powerful influence of humans through the application of physics within communities. Application of knowledge gained from studying these topics will enable students to acquire an appreciation of the influence of physics. For example, radioactivity is studied in Unit 1 and heat engines and efficiency are studied in Unit 2. Students will be able to achieve a fuller understanding of the potential of physics for affecting the environment at a local level and from a regional perspective through to a global scale. Through these there will be opportunities to consider the European dimension.

In the specification there are topics relating to health education. In particular, radioactivity and its effects are met in Unit 1. Application of knowledge gained from studying these topics will enable students to achieve a fuller understanding of related health issues. In the delivery of this specification centres will need to comply with current health and safety regulations, particularly with respect to practical physics; and students will need to be made fully aware of and the underlying reasons for these regulations.

Candidates with particular requirements

Regulations and guidance relating to students with particular requirements are published annually by the Joint Council for General Qualifications and are circulated to Examinations Officers. Further copies of guidance documentation may be obtained from the address below or by telephoning 0870 240 9800.

Edexcel is happy to assess whether special consideration or concession can be made for candidates with particular requirements. Requests should be addressed to:

Special Requirements
Edexcel
Stewart House
32 Russell Square
London WC1B 5DN

Scheme of assessment

The Advanced Subsidiary examination consists of two written unit tests and a practical test and a written test on an optional topic. The Advanced GCE examination includes the Advanced Subsidiary tests, two more written unit tests, a practical test and a written terminal synoptic test.

All unit tests may be taken during or at the end of the course (see page 2 for availability of unit tests).

The unit tests will examine mainly knowledge and understanding of each unit and how this may be applied to other situations, but will include some testing of relevant skills and processes. The synoptic test will contain questions that test skills acquired during the whole course as well as some questions that require some integration of knowledge derived from two or more units. The practical tests will comprise questions based on material contained in the AS units for the Advanced Subsidiary practical test and all the units for the Advanced GCE practical test.

Units and resit rules

There is no restriction on the number of times a unit may be attempted prior to claiming certification for the qualification. The best available result for each unit will count towards the final grade.

Results of units will be held in Edexcel's unit bank for as many years as this specification remains available. Once the AS or Advanced level qualification has been certificated, all unit results are deemed to be used up. These results cannot be used again towards a further award of the same qualification at the same level.

Awarding and reporting

The grading, awarding and certification of this specification will comply with the requirements of the most recent version of the GCE Code of Practice for courses starting in September 2002, which is published by the Qualifications and Curriculum Authority. Qualifications will be graded and certificated on a five-grade scale from A to E. Individual results will be reported.

Language of assessment

Assessment of this specification will be available in English only. Assessment materials will be published in English only and all written and spoken work submitted for examination and moderation must be produced in English.

The question papers

In the tests for Units 1, 2, 3 (Topics), 4, 5 (Fields and forces), and 6 (Synoptic), there will normally be one or two marks awarded for quality of written communication; these will be attached to specific parts of questions.

Units 1 and 2 — 1h 15 min — AS and A

The test for Unit 1 will not include reference to material from any other unit. The test for Unit 2 will mainly examine the material contained in the unit but some questions might refer to relevant physical principles contained in Unit 1.

These will consist of about eight compulsory structured questions each allocated from four to 12 marks, presented in a question-answer booklet. The shorter questions will be designed to test mainly knowledge and understanding of the specification content of the particular unit. The longer questions will also test skills of interpretation and evaluation of data or information related to the content of the particular unit. Each test will include a similar range of question styles.

Unit 3: Practical test — 1 h 30 min — AS and A

This test will be based on the content of Units 1 and 2 and will be designed to examine practical laboratory skills: planning; implementing; analysing evidence and drawing conclusions; evaluating evidence and procedures. The test will consist of two questions, each 40 minutes in duration: apparatus may be used for the first 35 minutes of each question. There will be a further 10 minutes writing up time at the end of the test. The first question will consist of short practical exercises of 4–15 marks each. The main focus of these will be on setting up and using apparatus and recording observations. However, they will also involve some planning and analysis. One of these exercises may involve drawing a graph. The second question will focus on planning and evaluation of methods, although the students will be required to use apparatus to make simple measurements. Part of either question may require students to use their own experience of practical datalogging techniques, but will not require the use of datalogging apparatus.

Unit 3: Topics test — 30 min — AS and A

There will be four structured questions, one relating to each of the four topics included in the unit, and students will be expected to answer one of these in the question–answer book. These questions will be designed mainly to test knowledge and understanding of the material in the topic, and how this may be applied to other situations. The questions may contain data or information for interpretation and will usually require part of the answer to be given in free prose.

The practical test and the topics test will be taken on separate dates.

Unit 4 — 1h 20 min — A only

The test for Unit 4 will assume that Units 1 and 2 have been studied but will not examine the content again in detail.

These will consist of about eight compulsory structured questions each allocated from four to 12 marks presented in a question-answer booklet, similar in style and format to the structured questions in Units 1 and 2.

Unit 5: Practical test 1h 30 min A only

This test will be based on material from any part of the basic specification and will be designed to build on the practical laboratory skills tested at AS: planning; implementing; analysing evidence and drawing conclusions; evaluating evidence and procedures. The test will consist of three questions, each of duration 25 minutes: apparatus may be used for the first 20 minutes of each question. There will be a further 15 minutes writing up time at the end of the test. The first question will usually contain two exercises of approximately equal length. These will focus on setting up and using apparatus and recording observations. The second question will assess using apparatus and evaluating results, with some planning being required. In the third question the emphasis will be on planning, with aspects of analysis and evaluation. At least one of the questions will involve drawing a graph, which may involve use of logarithms. Part of any question may require students to use their own experience of practical datalogging techniques, but will not require the use of datalogging apparatus. In all questions, students will have the freedom to modify their plan as they proceed. Students will be expected to demonstrate more advanced skills of analysis and evaluation than in AS. Information regarding the organisation of the practical tests is given in the section on practical work, starting on page 37.

Unit 5: Unit test 1h 00 min A only

The test for Unit 5 will assume that Units 1, 2 and 4 have been studied. Much of the content of Unit 5 builds on these units and this will be reflected in the questions, although these will all be set in the context of Unit 5.

The practical test and the written test which make up Unit 5 will be taken on separate dates.

Unit 6: Synoptic test 2h 00 min A only

The timings and mark allocations suggested for the different types of question within the tests are for guidance only and are not prescriptive. This unit is intended to test accumulated understanding of the whole Advanced GCE specification, with an emphasis on skills and principles rather than detailed knowledge and content.

Passage analysis 45 min approximately, about 32 marks

The passage will be taken or adapted from a book or an article of a scientific or technological nature, and will not necessarily be derived directly from the content of the specification. The questions might ask students to explain the meaning of terms used in the passage, to perform calculations and deductions, and may include additional material which has to be related to the content of the passage itself.

Long structured questions 75 min approximately, about 48 marks

Three questions will be set.

The first will be based on Unit 6 (Synthesis) and will require candidates to show understanding and application of the principles from across the specification that are drawn together in Unit 6 (Synthesis).

Each of the other two questions will draw on other areas of the specification. They will be designed to examine knowledge and skills acquired during the Advanced GCE course and will require the understanding of principles from more than one unit.

Specification for the examination

The percentage weighting of each of the Assessment Objectives in the Advanced Subsidiary and Advanced GCE examinations will be approximately as shown in the table below.

Please note that all values are given as percentages.

Percentage weightings of assessment objectives and components										
	Assessment objective									
Component	**AO1** Knowledge with understanding		**AO2** Application of knowledge and understanding, synthesis and evaluation		**AO3** Experiment and investigation		**AO4** Synthesis of knowledge, understanding and skills		**Overall weighting**	
	AS	**A**	**AS**	**A**	**AS**	**A**	**-**		**AS**	**A**
Unit 1: Mechanics and radioactivity test	17	8.5	13	6.5	-	-	-		**30**	**15**
Unit 2: Electricity and thermal physics test	17	8.5	13	6.5	-	-	-		**30**	**15**
Unit 3: Practical test	-	-	-	-	20	10	-		**20**	**10**
Unit 3: Topics test	11	5.5	9	4.5	-	-	-		**20**	**10**
AS totals	45	22.5	35	17.5	20	10	-		100	50
	A2	**A**	**A2**	**A**	**A2**	**A**	**A2**	**A**	**A2**	**A**
Unit 4: Waves and our Universe test	15	7.5	15	7.5	-	-	-	-	**30**	**15**
Unit 5: Practical test	-	-	-	-	15	7.5	-	-	**15**	**7.5**
Unit 5: Fields and forces test	7.5	3.75	7.5	3.75	-	-	-	-	**15**	**7.5**
Unit 6: Synoptic test (Terminal)	-	-	-	-	-	-	40	20	**40**	**20**
A2 totals	22.5	11.25	22.5	11.25	15	7.5	40	20	100	50
Advanced GCE totals	33.75		28.75		17.5		20		100	

Notes on the examination

Terminology and units

SI units and terminology will be used in accordance with the recommendations of *Signs, Symbols and Systematics* (1995) published by the Association for Science Education. Certain non-SI units, such as the kilowatt-hour and electronvolt, will remain in use.

Definitions and equations

Where a question requires the definition of a physical quantity to be stated, a word equation will be expected, although any correct definition will always be given full credit. A defining equation written in symbols will be given full credit provided that the meanings of the symbols are given. The use of limiting values in some definitions (eg instantaneous speed) should be understood and students will be expected to relate limiting values to the gradients of the relevant graphs.

Experimental determinations

Where a knowledge of the experimental determination of a physical quantity is included in the specification, any one reliable method is acceptable. Where a question is set on a particular method, sufficient detail will be given to enable a student unfamiliar with the method to attempt the question.

Calculators

Students will be expected to have an electronic calculator conforming to Edexcel regulations when answering all tests. The calculators should have the following keys:

$+$, $-$, $\times$, $\div$, π, x^2, $\sqrt{x}$, $1/x$, x^y, $\ln x$, e^x, $\lg x$, 10^x

$\sin\theta$, $\cos\theta$, $\tan\theta$ and their inverses, in degrees and decimals of a degree, and in radians, and a memory.

Calculations

In carrying out calculations, and especially when using a calculator, students should show clearly all expressions to be evaluated and record all the steps in their working. The number of significant figures given in an answer to a numerical question should match the number of significant figures given in the question.

Graphs

Questions which require students to plot a series of points on graph paper will generally be set only in the practical tests and the synoptic test. In any test, students may be asked to sketch a graph to show a relationship, and in this case the axes and line of the graph should be drawn directly in the answer book.

Background mathematical requirements

A list of mathematical requirements is given in *Appendix 4*, page 86.

Data, formulae and relationships

Students will be expected to know the formulae and relationships required by the Advanced Subsidiary (AS) and Advanced (A) GCE Specifications Subject Criteria for Physics, and these are given in *Appendix 5*, page 88. A list of data and other formulae and relationships for the specification will be provided for students to use in each written test of the examination, and this list is given in *Appendix 6*, page 90.

Dictionaries and textbooks

Students may use a bilingual dictionary between their mother tongue and English in the examination in accordance with Edexcel regulations. The dictionary must be a basic translation dictionary that does not contain additional information that could give a student an unfair advantage. Dictionaries of scientific terms and textbooks may *not* be used under any circumstances.

Quality of written communication

Quality of written communication will be assessed in unit tests 1, 2, 3 (Topics test), 4, 5 (Fields and forces) and 6. Marks will be awarded to students for their ability to show understanding of specialist vocabulary and present coherent arguments.

Specification content

Introduction

The Advanced Subsidiary (AS) specification, contained in Units 1, 2 and 3 builds on the knowledge, understanding and skills set out in the National Curriculum Key Stage 4 programme of study for Double Award Science. The AS content is intended to form either a complete course in itself or the first half of a full Advanced GCE course. The level of achievement expected at AS is that of a student half way through her/his studies of the full Advanced GCE course. (This equates to a level between that of GCSE and that of the full Advanced GCE.) The Advanced GCE specification, Units 4, 5 and 6, is designed to build on the AS units.

Unit 1 provides a suitable progression route from the Science National Curriculum. Knowledge of the basic principles contained in Unit 1 will be assumed in the other unit tests. Units 4 and 5 depend to some extent on concepts developed in the AS units. Unit 6, the synoptic unit, will require students to draw together and make links between concepts as well as access skills developed throughout the course.

The content is presented in numbered sections but there is no requirement to deliver them in this order. Teachers may prefer to combine material from different sections or from different units when constructing their teaching programmes. In these cases, care must be taken to ensure that all of the material in each unit has been covered before students are entered for the relevant unit tests. The Advanced Subsidiary content is designed to be taught during the first half of an Advanced GCE course, but there is no reason why centres may not include suitable material from the Advanced GCE content as part of the teaching programme where appropriate. If the course is being taught as a two-year Advanced GCE course there is no obligation to sit the AS examination at the end of the first year.

The specification content for each unit is set out with the main headings in the left hand column and amplification in the centre column. The right hand column contains some suggested activities. This is not intended to be a comprehensive list and centres may choose alternative activities to support their delivery of the specification. The right hand column also indicates opportunities for developing or providing evidence for the assessment of key skills. Key skills opportunities are indicated (that is, 'signposted') by the letter 'K' followed by initial(s) in subscript to indicate the particular key skill. Again, these are not intended to be comprehensive and centres may choose alternative activities to support their delivery of key skills through this subject. Key skills are explained in detail in the section 'key skills development' starting on page 48.

Where the recall of a derivation of a formula is not explicitly required by the specification, students should nevertheless have followed through some form of proof or an experimental check and be satisfied that the formula is a reasonable conclusion.

Great importance is attached to practical work and it should be encouraged wherever possible. Throughout the course students will build upon the experience gained through GCSE experimental and investigative science. It is envisaged that the teaching will include both demonstrations and individual experiments and investigations. Further information about the apparatus required for teaching the specification and setting up the practical tests is given in the section on practical work starting on page 37.

General requirements

An understanding of the following is expected and may be assessed in all units of the specification:

1 Physical quantities and their units.

Understanding of the distinction between base and derived physical quantities and their units in SI. Luminous intensity and the candela are *not* included.

2 Order of magnitude.

Appreciation of the order of magnitude of common physical quantities.

3 Word equations.

The use, where appropriate, of word equations to define physical quantities and their units.

4 An understanding of the concept rate of change with time, eg

average $\upsilon = \Delta x/\Delta t$ average $a = \Delta \upsilon/\Delta t$

Instantaneous value as gradient of graph is expected.

5 Graphs.

Translate information between graphical, numerical and algebraic forms.

Plot two variables from experimental or other data.

Understand that $y = mx + c$ represents a linear relationship.

Determine the slope and intercept of a linear graph.

Draw and use the slope of a tangent to a curve as a measure of rate of change.

Understand the possible physical significance of the area between a curve and the x axis and be able to calculate it or measure it by counting squares as appropriate.

eg Work done = area under a force-displacement graph.

6 Homogeneity.

Understanding of homogeneity of equations and its use as a check for possible correctness.

7 Vectors and scalars.

The recognition of a physical quantity as a vector or a scalar.

Resolution of a vector into two components at right angles to each other.

Addition rule for two vectors, mathematical calculations limited to two perpendicular vectors.

An understanding of the following is expected and may be assessed in all A2 units of the specification.

8 Graphs.

Use logarithmic plots to test exponential and power law variations; sketch simple functions including $y = k/x$, $y = kx^2$, $y = k/x^2$, $y = \sin x$, $y = \cos x$, $y = e^{-kx}$.

Unit 1: Mechanics and radioactivity

An understanding of the principles in this unit and in the general requirements is expected in familiar and unfamiliar situations. In examination questions where the context is beyond the content of the specification it will be fully described.

			Suggested activities
	Rectilinear motion		
1.1	Distance, displacement, speed, velocity and acceleration. Equations for uniformly accelerated motion in one dimension.	Experimental study of uniformly accelerated motion, based on laboratory measurements of displacement and speed. $\upsilon = u + at$ $x = ut + \frac{1}{2}at^2$ $\upsilon^2 = u^2 + 2ax$	*Light gates to measure speed and acceleration of a trolley rolling down a slope.* $K_C\,K_N\,K_{IT}K_{PS}K_{LP}$
		Measurement of the acceleration of free fall. A method involving a body in free fall is expected.	*Light gates or electronic timer to measure g.* *Research — Galileo.* $K_C\,K_N\,K_{IT}$
1.2	Displacement-time and velocity — time graphs and their interpretation, for motion with uniform and non-uniform acceleration.	Identify and use the physical quantities derived from the gradient and area of velocity — time graphs and the gradient of displacement — time graphs.	*Motion sensor or ticker tape timer to produce v/t and x/t graphs.* $K_C\,K_{WO}/K_{PS}$
1.3	Projectiles.	The independence of vertical and horizontal motion should be understood. Numerical problems will involve *either* vertical *or* horizontal projection.	*Strobe photography or video camera to analyse projectile motion.* K_{WO}/K_{PS}
	Forces and moments		
1.4	Force interpreted as a push or a pull and identified as the push or pull of A on B.	Familiarity with gravitational, electric, magnetic and nuclear forces; normal and frictional contact forces; viscous and drag forces; tension.	*Estimate then measure the weight of familiar objects.*
	Weight.	The gravitational pull of the Earth (or Moon, etc.) on an object. Weight = mg	
1.5	Free-body force diagrams.	Use of free-body force diagrams to represent forces on a particle or on an extended but rigid body. Centre of gravity.	*Find the centre of gravity of an irregular rod.* K_{PS}
1.6	Newton's first law.	Bodies in equilibrium. Vector forces on body sum to zero.	*Investigation: 'three force' equilibrium using spring balances and weights.* *Research — Newton.* K_CK_{IT}

			Suggested activities
1.7	Newton's third law.	Force pairs. A statement that the push or pull of A on B is always equal and opposite to the push or pull of B on A.	
1.8	Moment of a force.	Moment of F about O = $F \times$ (perpendicular distance from F to O).	
	Principle of moments.	For a rigid body in equilibrium, sum of clockwise moments about any point = sum of anticlockwise moments about that point. Problems will only be set involving sets of parallel forces.	*Principle of moments using a balanced metre rule.* K_C
1.9	Density.	Typical values for solids, liquids and gases. Measurement of the density of solids, liquids and gases is expected. Application of $\rho = m/V$	*Estimate densities of various objects. eg Earth, the Sun, an atomic nucleus.* K_{PS}
	Dynamics		
1.10	Linear momentum.	Defined as $p = m\upsilon$	
	Principle of the conservation of linear momentum.	Experimental study of conservation of linear momentum for collisions in one dimension only.	*Light gates and air track to investigate P.C.M.*
1.11	Newton's second law.	Force and rate of change of momentum. Resultant force as rate of change of momentum $F = \Delta p/\Delta t$ Calculations will only be set in situations where mass is constant. Impulse = change of momentum.	*Light gates to determine change of momentum during a collision. Force sensor to determine impulse during collision.*
1.12	Acceleration, mass and force.	Applications of $\Sigma F = ma$ Experimental investigation of uniformly accelerated motion where mass is constant.	*Light gates — investigation: factors affecting acceleration using an air track.* K_C K_N $K_{IT} K_{PS}/K_{W0}$
	Mechanical energy		
1.13	Work done and energy transfer.	Work done = average applied force multiplied by the distance moved in the direction of the force. $\Delta W = F\Delta x$ Calculation of work done when force is not along the line of motion. Energy transfer when work is done.	*Estimate then measure as appropriate, work required for various tasks: eg lifting a book, stretching a spring, climbing Mount Everest, writing a page of notes.*
1.14	Kinetic energy.	k.e. = $\frac{1}{2}m\upsilon^2$	*Estimate KE of various objects: eg speeding car, sprinter, oil tanker, air molecule.*
	Gravitational potential energy.	Changes in gravitational potential energy close to the Earth's surface. $\Delta E = mg\Delta h$	

			Suggested activities
1.15	Principle of the conservation of energy.	Qualitative study and quantitative application of conservation of energy, including use of work done, gravitational potential energy and kinetic energy.	*Light gates or motion sensor — investigation: speed of a falling object (GPE lost and KE gained).* K_C K_N $K_{IT}K_{PS}/K_{W0}$
1.16	Power.	Rate of energy transfer (or of work done). $P = \Delta W/\Delta t$ $P = F\upsilon$	*Measure power output of an electric motor.*
	Radioactive decay and the nuclear atom		
1.17	The existence and nature of radioactive emissions.	Sources of background radiation.	*Measure background count rate.* *Research — discovery of radiation.* K_CK_{IT}
1.18	Properties of alpha, beta (+ and -) and gamma radiation and corresponding disintegration processes.	Ionising properties of radiations linked to penetration and range. Experiments with sealed alpha and beta sources are expected.	*Investigation — absorption of alpha radiation by paper and beta by aluminium.* *Safety — protection.* *Environmental considerations.* K_CK_{IT}
1.19	Stable and unstable nuclei. Nucleon number and proton number.	The balancing of nuclear equations. Isotopes.	
1.20	Radioactivity as a random process. Exponential decay: decay constant and half-life.	Activity and the becquerel. Activity = λN The constant ratio property of exponential curves. The use of e^x and ln x are *not* required. $\lambda t_{½} = 0.69$ The experimental determination or modelling of half-life.	*Measure half-life of protactinium.* *Safety issues, implications of long half lives — environmental considerations.* *Model decay by throwing dice.* K_CK_{IT} K_N
1.21	The nuclear atom. Evidence for the existence and size of nuclei.	Size of atoms. Relative size of nuclei.	*Research — Rutherford and Bohr* K_CK_{IT}
	Elastic scattering.	Scattering as a means of probing matter.	
		Alpha particle scattering experiment in broad outline.	*'Scattering' of ball bearings on collision with a 1/r hill.* K_CK_{IT} *Model with IT.*
	Deep inelastic scattering.	The use of electrons of high energy to reveal the structure of protons and neutrons. A qualitative discussion of the processing and interpretation of data will be required.	

Unit 2: Electricity and thermal physics

An understanding of the principles in this unit and in the general requirements is expected in familiar and unfamiliar situations. In examination questions where the context is beyond the content of the specification it will be fully described.

			Suggested activities
	Electric current and potential difference		
2.1	Charge and current.	Electric current as rate of flow of charge. $I = \Delta Q/\Delta t$ Law of conservation of charge applied to currents at a junction. Use of ammeters.	*Measure current flow in series and parallel circuits.*
	Drift velocity.	An understanding of the equation $I = nAQ\upsilon$. The distinction between metals, semiconductors and insulators in terms of this equation. Typical carrier drift speeds in metals should be known.	*Demonstrate slow speed of ion movement during current flow.*
2.2	Electrical potential difference. E.m.f. of a cell.	P.d. as Work done/charge ie V or $\mathcal{E} = W/Q$ or as power/current ie V or $\mathcal{E} = P/I$	*Measure power input and efficiency of an electric motor.*
	Energy transferred electrically.	Electrical working. $\Delta W = IV\Delta t$ Use of voltmeters.	*Demonstrate electric heating (melting a wire).*
2.3	Current — potential difference relationships.	Measurements and typical graphs for wire filament lamp, ohmic resistor and semiconductor diode. Ohm's law.	
2.4	Resistance and resistivity.	$R = V/I$ $R = \rho l/A$ Experimental measurement of resistivity.	*Attempt to measure resistivity of polythene.* $K_C K_W/K_{PS}$
	Power dissipation.	$P = IV = I^2R = V^2/R$	
	Electrical circuits		
2.5	Conservation of energy in circuits.	Circuit e.m.f. = ΣIR.	*Measure voltages in series and parallel circuits.*
	Internal resistance.	$V = \mathcal{E} - Ir$ Measurement of internal resistance. Practical significance (eg car battery and e.h.t. power supply).	*Investigation — effect of load resistance on power output of a battery.* $K_C K_N K_{IT} K_{PS}/K_{W0}$

			Suggested activities
2.6	Series and parallel circuits.	Formulae for resistors in series and in parallel: $R = R_1 + R_2 + R_3$ and $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ Use of ohmmeters.	*Ohmmeter to demonstrate formulae for resistors in series and parallel.*
2.7	Change of resistance with temperature and illumination. The thermistor and light dependent resistor.	Qualitative effects and experimental treatment of the effect of temperature on the resistance of a metal and on a negative temperature coefficient (NTC) thermistor. Explanation of the change of resistance of metals with temperature. Understanding that LDR resistance decreases as illumination increases.	*Ohmmeter and temperature sensor — investigate R v T for a thermistor.* *Cold spray to demonstrate the decrease in resistance of thin copper wire when cooled.* *Investigation — effect of light intensity on R for an LDR.* K_C K_N $K_{IT}K_{PS}/K_{W0}$
2.8	Potential divider.	Practical applications. Potential dividers that are controlled by temperature or by illumination.	*Digital voltmeter — investigate 'output' voltage of a potential divider circuit.* *Design an electronic thermometer or lightmeter.* K_W/K_{PS}
	Heating matter		
2.9	Definition and meaning of specific heat capacity.	Measurement of specific heat capacities of solids and liquids: a direct method using an electric heater will be expected. Emphasis on calculation of energy transferred. Sources of serious experimental error should be identified and understood. Energy transfer = $mc\Delta T$	*Joulemeter to measure electrical energy transfer.* K_C/K_{PS} *Temperature sensor and data logger.*
2.10	Change of state. Specific latent heat.	Energy is needed to pull molecules apart. Energy transfer = $l\Delta m$ Direct experimental methods only. A method using an electric heater will be expected.	*Temperature sensor and data logger to display cooling curves — with and without changes of state.* K_{IT}
2.11	Pressure.	Solids transmit force, fluids transmit pressure. Application of $p = F/A$	*Model hydraulic lift.* *Pressure sensor to measure excess lung pressure.*
	The behaviour of gases.	Experiment demonstrating that for a fixed mass of gas at constant V p/T = constant	*Temperature and pressure sensors.* K_W/K_{PS}
	The absolute scale of temperature.	Concept of absolute zero of temperature. $T/\text{K} = \theta/^0\text{C} + 273$	

			Suggested activities
	Kinetic model of matter		
2.12	Ideal gas equation.	Experiment demonstrating that for a fixed mass of gas at constant T pV = constant For ideal gases $pV = nRT$ In calculations the amount of gas will be given in moles.	
2.13	Kinetic model of an ideal gas. Brownian motion.	The assumptions on which the model is founded. $p = {}^1/_3\, \rho \langle c^2 \rangle$ Average kinetic energy of molecules proportional to kelvin temperature. Use of the model to explain the change of pressure with temperature.	*Research — Brownian motion.* $K_C\, K_{IT}$ *'Kinetic model' apparatus.*
	Conservation of energy		
2.14	Internal energy.	For real gases the random distribution of potential and kinetic energy amongst molecules. Appreciation that hot and cold objects have different concentrations of internal energy.	
2.15	Heating.	Random interchange of energy between bodies in thermal contact, resulting in energy flowing from hot to cold.	
	Electrical and mechanical working.	Forces moving either charges or masses. Ordered processes, independent of temperature difference.	
	The first law of thermodynamics.	The increase in internal energy equal to the sum of the energy given by heating and working.	*Research — development of laws of thermodynamics* $K_C\, K_{IT}$
2.16	The heat engine.	Work done by engine when energy flows from a hot source to a cold sink.	*Demonstrate thermocouple engine.*
	Efficiency.	Efficiency of energy transfer as useful output divided by input. Maximum thermal efficiency $= (T_1 - T_2)/T_1$	*Environmental considerations.* *Use of energy and sustainable growth.* $K_W\, K_C\, K_{IT}$
	The heat pump.	Work needed to pump energy from cold to hot.	*Research — use for heating buildings.* $K_C\, K_{IT}$

Unit 3: Topics

Topic 3A — Astrophysics

		Key skills signposts
A1 Observing stars		
Recording star images.	Photographic emulsions and charge coupled devices (CCDs). Grain and pixel size; relative efficiencies; linearity of response.	
Benefits of observing from above the Earth's atmosphere.	The importance of different wavelengths of radiation as a means of discovering information about distant objects. Use of satellites such as Hubble telescope, IRAS and COBE.	$K_C\,K_{IT}\,K_{wo}$
The total power emitted; luminosity *L*.	The Planck distribution of energy. Stefan-Boltzmann law: $L = \sigma T^4$ x surface area, and for a sphere $L = 4\pi r^2 \sigma T^4$	
Surface temperature of stars.	Wien's law: $\lambda_{max}T = 2.898 \times 10^{-3}$ m K Appreciation that the surface temperatures of stars range from near absolute zero to 10^7 K, corresponding to peak wavelengths from radio to X-rays.	
Measuring distance by trigonometric parallax.	Use of annual parallax to measure the distance of nearby stars, including the use of the small angle approximation. The light year. (Parsecs and AU will *not* be required).	
Simple Hertzsprung-Russell diagram.	Simplified luminosity — temperature diagram showing main sequence, white dwarfs and red giants. The use of an *L/T* diagram to deduce *L* for a distant main-sequence star.	$K_C\,K_{IT}\,K_{wo}$
Estimating distance of more distant stars.	Use of intensity = $L/4\pi D^2$ to find distance of stars of known luminosity. Use of Cepheid variable stars to find distance to nearby galaxies.	
A2 The lives of stars		
Energy for stars.	Gravitational collapse and hydrogen 'burning'. $c^2\Delta m = \Delta E$. (Details of the p-p chain are *not* required.)	
Main sequence stars.	A star spends most of its life as a main sequence star.	$K_C\,K_{IT}\,K_{wo}$
White dwarfs.	Hot, low volume, low mass stars. Origins and typical masses, (less than about 1.4 solar masses). Core remnants.	
Red giants.	Cool, high volume, stars. Origins and typical masses, (between 0.4 and 8 solar masses). Core remnants.	
Supernovae (Type II only).	Rapid implosion of stars of more than eight solar masses. Shock wave: outer layers blown away.	
Neutron stars.	Core remnants greater than about 1.4 solar masses. Formation from electrons and protons. Very high density. Pulsars.	
Black holes.	Core remnants greater than about 2.5 solar masses. The dense core traps radiation.	

Topic 3B — Solid materials

		Key skills signposts
B1 Investigating materials		
Force-extension graphs.	Graphs to breaking point for natural rubber, copper, mild steel and high carbon steel.	
Elastic and plastic behaviour.	Reversible and permanent deformation. Hooke's law: $F = k\Delta x$	
Energetics of stretching. Elastic strain energy.	Work done as area under force — extension graph. For Hooke's law region $\Delta W = ½ F \Delta x$	
Stress and strain. Young modulus.	Stress = F/A; strain = $\Delta l/l$ E = stress/strain. Numerical exercises will involve stresses and strains in one direction only.	
Stress — strain graphs. Energy density.	For natural rubber, copper, mild steel and high carbon steel. Yield stress: the stress at which plastic deformation begins. Energy/volume = area under stress/strain graph. Hysteresis in rubbers.	
Describing the behaviour of materials.	Ultimate tensile (breaking) stress. Strong/weak. Stiff/flexible — related to the Young modulus. Tough/brittle — related to the energy required to break a material. An understanding of the terms elastic, plastic, ductile and malleable.	$K_C K_{IT} K_{wo}$
B2 Engineering materials		
Polycrystalline materials.	Stress — strain graphs to breaking point for metals, related to molecular structure. Plastic flow, necking and fracture.	$K_C K_{IT} K_{wo}$
Defects in crystals.	Edge dislocations and grain boundaries. Slip planes. Work hardening. Effects on strength of metals.	
Heat treatment.	Annealing copper and steels, quench hardening and tempering carbon steels.	
Failure mechanisms.	Fatigue. Creep. Cracks: stress concentrations and relieving them.	$K_C K_{IT} K_{wo}$
Thermoset and thermoplastic polymers.	Amorphous (Perspex) and semi-crystalline (Nylon and polythene) thermoplastics: macroscopic properties and uses. Rigid (Melamine) thermosets; macroscopic properties and uses. Microscopic properties: long chain molecules; cross linking.	
Elastomers.	Stress — strain graph for rubber, related to molecular structure.	
Composite materials.	Laminates, fibre and particle composites. Plywood, chipboard; fibre reinforced polymers.	
Bridging a space with beams.	Steel tension members; pre-stressed reinforced concrete. (Shear force *not* required.) Application of principle of moments to systems of non-parallel forces.	

Topic 3C — Nuclear and particle physics

Key skills signposts

C1 Stable and unstable nuclei

Nuclear matter.

Electrostatic repulsion between protons.
The strong nuclear force between nucleons.
Comparative ranges.
Variation of nuclear radius with nucleon number; $r = r_0 A^{1/3}$.
Density of nuclear matter.

N-Z curve for nuclides.

Region of stability; relevance to α, β^+ and β^- decay. Decay chains; principle of radioactive dating.

$K_C K_{IT} K_{wo}$

Nuclear decays.

Decay of n and p within the nucleus.
Energy spectra for α, β^+ and β^- particles and subsequent γ ray emissions. (Knowledge of $E = hf$ is *not* required.)
The neutrino and antineutrino.

Energy and the nucleus.

Nuclear masses in terms of u, the unified atomic mass unit.
Nuclear decay energies in MeV. the principle of conservation of mass-energy: 1u = 930 MeV. (Use of $c^2\Delta m = \Delta E$ *not* required.)
Binding energy per nucleon.

C2 Fundamental particles

Classification of particles.

Hadrons (baryons and mesons) and leptons. Leptons as fundamental particles.

e	μ	τ
ν_e	ν_μ	ν_τ

The existence of antimatter.

Particles and antiparticles; e^- e+, p $\bar{p}$, ν $\bar{\nu}$; pair production and matter-antimatter annihilation. Calculations will use particle energies in MeV or GeV and rest masses in u: 1u = 930 MeV.

Quarks and antiquarks.

Quarks and antiquarks as the fundamental constituents of baryons and mesons.
Flavour.
Three quark structure of baryons, quark anti-quark structure of mesons.

u	c	t
d	s	b

$K_C K_{IT} K_{wo}$

Conservation laws in particle interactions.

Conservation of charge and baryon number. Students will *not* be expected to remember the quark constituents of individual hadrons except for n and p, nor the properties of individual quarks.

The four fundamental interactions.

Gravitational, electromagnetic, strong and weak interactions.
Gravitational — all particles with mass.
Electromagnetic — all charged particles.
Strong — quarks.
Weak — all particles; weak responsible for change in quark flavour (or type).

$K_C K_{IT} K_{wo}$

Forces described in terms of exchange particles.

Photons, W^+, W^- and Z^0 particles, gluons.
Use of simple Feynman diagrams involving exchange particles.

Topic 3D — Medical physics

		Key skills signposts
D1 Nuclear medicine		
Radioisotopes for nuclear medicine; metastable radio-nuclides.	Production by neutron irradiation and elution methods: in particular ^{123}I, ^{131}I and ^{99m}Tc.	
Radionuclides as tracers.	Dilution studies; measurement of body fluids. Uptake studies; use of model or 'phantom'. Imaging body parts.	
Physiological effects of radiation.	Range and effects of alpha, beta and gamma radiation. Destruction and mutation of cells.	$K_C K_{IT} K_{wo}$
Radioactive and biological half lives; effective half lives.	Basic principles of radiological protection. $\frac{1}{t_e} = \frac{1}{t_r} + \frac{1}{t_b}$	
Gamma camera.	Principles of collimator, scintillation counter and photomultiplier.	
Use of gamma radiation for therapy.	^{60}Co sources for destruction of tissue.	
Energy of radioactive emissions.	keV and MeV as measures of the energy of emitted radiations.	
D2 X-rays and ultrasonics		
X-ray production. The rotating anode X-ray tube.	Energy of accelerated electrons in eV. Efficiency. (Photons and a knowledge of $E = hf$ are *not* required.)	
MeV X rays for therapy.	Absorption not strongly dependent on proton number. Multiple beams and rotational treatment. Alignment devices. Criticality of dose.	
keV X-rays for diagnosis.	Absorption strongly dependent on proton number. Detection with photographic plates. Radiographs of bones, tissues and air spaces.	$K_C K_{IT} K_{wo}$
X-ray geometry.	Point source, shadows, use of a lead anti-scatter grid. Inverse square law.	
Ultrasonics in medicine.	The sonar principle. Knowledge of $c = f\lambda$ expected: small wavelengths give rise to better resolution.	
Scanning methods for ultrasonic diagnosis.	Basic principles only. A-scans and B-scans.	
Reflection and absorption. Acoustic impedance Z.	Dependence of Z on speed of wave and density of medium; $Z = c\rho$ Reflection coefficient = $(Z_1 - Z_2)^2/(Z_1 + Z_2)^2$ The need for a coupling medium.	
Comparison of ultrasonic and X-ray techniques in diagnosis.	Health and safety aspects of the use of ultrasound and X-rays.	$K_C K_{IT} K_{wo}$

Unit 4: Waves and our Universe

An understanding of the principles in this unit and in the general requirements is expected in familiar and unfamiliar situations. In examination questions where the context is beyond the content of the specification it will be fully described.

			Suggested activities
	Circular motion and oscillations		
4.1	Angular speed, period, frequency.	The radian. $\omega = \Delta\theta/\Delta t \quad \upsilon = \omega r$ $T = 2\pi/\omega \quad f = \omega/2\pi$	
4.2	Acceleration and resultant force.	For a body moving at a constant speed in a circular path, acceleration $a = \upsilon^2/r$. Resultant force F towards the centre of the circle equals $m\upsilon^2/r$. Idea of apparent weightlessness when objects are in free fall.	*Investigation — effect of m, υ and r of orbit on centripetal force.* $K_W/K_{PS}\ K_N\ K_C\ K_{IT}$
4.3	Simple harmonic motion.	Variation of displacement, velocity and acceleration with time, treated graphically. An understanding that s.h.m. results when acceleration is proportional to displacement and in the opposite direction.	*Motion sensor to generate v/t and x/t graphs of SHM. Computer modelling.* $K_N\ K_{IT}\ K_{LP}$
4.4	Frequency and period for simple harmonic motion.	The equation $a = -(2\pi f)^2 x$; $T = 1/f$.	
4.5	Undamped simple harmonic oscillations.	$x = x_0 \cos 2\pi ft$ Angles expressed in both degrees and radians. Maximum speed = $2\pi f x_0$ Velocity as gradient of displacement-time graph. Acceleration as gradient of velocity-time graph.	*Computer modelling or graphic calculator to explore the effects of changing x_0 and f.* $K_N\ K_{IT}$
4.6	Mechanical oscillators.	Experimental study of a simple pendulum. $T = 2\pi\sqrt{(l/g)}$ for small amplitude oscillations.	*Investigation — effect of m, l and amplitude on T.* K_{LP}
		Experimental study of mass-spring system. $T = 2\pi\sqrt{(m/k)}$ where k is the spring stiffness.	*Investigation — effect of m and k on T.* $K_{PS}\ K_N\ K_C\ K_{IT}$

			Suggested activities
4.7	Free and forced vibrations. Mechanical resonance.	An experimental and qualitative knowledge of mechanical resonance. Damping.	*Vibration generator – forced oscillations of a mass spring system (damped and undamped). Research — problems and applications.* K_C K_{IT}
	Waves		
4.8	Mechanical waves on water, along springs and in air (sound).	The emphasis should be on the generation of waves and the transmission of energy in the medium.	*Demonstrate loudspeaker and waves on long spring/ ripple tank.*
4.9	Electromagnetic waves.	It is expected that electromagnetic wave phenomena will be demonstrated using visible light and microwaves.	*Research — Sources/ Detectors and uses of various regions of the e.m. spectrum.* K_C K_{IT}
	The electromagnetic spectrum.	An outline of the whole spectrum: the order of magnitude of the wavelengths of the main regions should be known.	
4.10	Progressive waves: longitudinal and transverse waves.	Amplitude, speed, wavelength, frequency and phase interpreted graphically. $c = f\lambda$	*Wave machine or computer simulation of wave properties.*
	Plane polarisation.	Plane polarisation as a property of transverse waves demonstrated using light and microwaves.	*Polaroid to illustrate polarisation of light. Photoelastic stress analysis. Research –models of structures (stress concentration), microscopy.* K_C K_{IT}
4.11	Conservation of energy for waves in free space from a point source. Inverse square law.	Energy flux or intensity measured in W m^{-2} Intensity $I = P/4\pi r^2$	*Investigation — inverse square law using a light meter.* K_W/K_{PS} K_N K_C K_{IT}

			Suggested activities
	Superposition of waves		
4.12	The principle of superposition.	Graphical treatment.	*Ripple tank to illustrate two source interference. Demonstrate using spreadsheets and graphs.* K_C K_W/K_{PS} K_{IT}
4.13	Wavefronts.	By definition, all points on a wavefront are in phase.	*Wavefronts are most effectively illustrated using a ripple tank.*
	Phase difference and path difference.	$\Delta(\text{phase}) = \dfrac{2\,\pi\Delta(\text{path})}{\lambda}$	
4.14	Stationary waves and resonance.	Demonstration using waves on strings and microwaves. Half-wavelength separation of nodes or antinodes should be known but need *not* be derived.	*Microwaves or sound waves to show 'free' standing waves. Vibration generator with rubber cord or wire loop to demonstrate standing waves.*
4.15	Diffraction at a slit.	Demonstrated using water waves, microwaves and light. Appreciation of dependence of the width of central maximum on relative sizes of slit and wavelength.	*Laser and adjustable slit.*
4.16	Two slit interference patterns. Coherence.	Interpretation of the observed patterns using the principle of superposition, illustrated by the overlapping of two sets of circular waves on water. Measurements of wavelength with both visible light and microwaves. Knowledge of experimental details and typical dimensions is expected. $\lambda = xs/D$ for light; the limitations should be understood but the proof is *not* required.	*Measure wavelength of light using a laser.*
	Quantum phenomena		
4.17	The photon model of electromagnetic radiation.	The Planck constant. $E = hf$	*Measure the Planck constant using photo-cell.*
	The photoelectric effect. Work function and the photoelectric equation.	Simple demonstration (eg discharge of negatively charged zinc plate). The concept of stopping potential and its measurement. Maximum energy of photoelectrons $= hf - \varphi$	*Discharge of coulombmeter using UV lamp. Research — Einstein.* K_C K_{IT}

			Suggested activities
4.18	Energy levels. The electronvolt.	Possible energy states of an atom as fixed and discrete. $hf = E_1 - E_2$ The emission and absorption line spectrum of atomic hydrogen related to electron energy levels.	*Direct vision spectroscope or diffraction grating to observe spectra of gases and vapours.*
4.19	Wave properties of free electrons.	Electron diffraction.	*Observation of electron diffraction using suitable vacuum tube.*
	Wave-particle duality.	The de Broglie wavelength. $\lambda = h/p$	*Research — model development* K_C K_{IT}
	Stationary waves in the hydrogen atom.	Wave properties of electrons in atoms.	*Analogy with trapped standing waves on a wire loop.*
	The expanding Universe		
4.20	Optical line spectra.	Demonstration of spectra using a diffraction grating. Star spectra emission and absorption lines and their relation to chemical composition.	*Research — the discovery of helium.* K_C K_{IT}
4.21	Electromagnetic Doppler effect.	Doppler shift of spectral lines. $\Delta f/f = \Delta\lambda/\lambda = \upsilon/c$, where υ is the speed of a star or galaxy towards or away from the Earth. The light year.	*Demonstrate the Doppler effect by whirling a small loudspeaker on the end of a chain or wire.* *Research — discovery of pulsars.* K_C K_{IT}
	Expansion of the Universe. Hubble's law. The Big Bang.	The red shift of galaxies $\upsilon = Hd$, with H in s^{-1}. The age of the Universe: uncertainty in d and H.	*Model expansion by inflating a balloon.*
4.22	Open and closed Universes.	The average mass-energy density of the Universe: indefinite expansion or final contraction.	K_C K_{IT}

Unit 5: Fields and forces

An understanding of the principles in this unit and in the general requirements is expected in familiar and unfamiliar situations. In examination questions where the context is beyond the content of the specification it will be fully described.

			Suggested activities
	Gravitational fields		
5.1	The concept of a field.	Use of lines of force to describe fields qualitatively.	*Computer model to plot lines of force.*
	Gravitational field strength.	$g = F/m$ Field strength understood as a vector quantity.	*Estimate the attractive force between various masses.* *eg two people, two oil tankers.* K_C
5.2	Force between point masses.	$F = \frac{Gm_1 m_2}{r^2}$ Measurement of G is *not* required.	*Research — development of models.* K_C K_{IT}
	Gravitational field strength in radial fields.	Inverse square law for spherically symmetric masses $g = Gm/r^2$ Equipotential surfaces. (The relationship $V = -Gm/r$ is *not* required.) Application to satellite orbits.	*Estimate the mass of the Earth.* *Estimate g just outside the atmosphere.*
	Electric fields		
5.3	Electrostatic phenomena and electric charge.	Charging by contact (friction): two kinds of charge. Conductors and insulators.	*Charge polythene and acetate strips by rubbing; demonstrate attraction and repulsion.* K_C K_{PS}/K_{WO}
	The electronic charge.	The discrete nature of charge to be understood.	
	Measurement of charge.	Use of coulombmeter. Details of the meter are *not* required.	
5.4	Electric field strength.	$E = F/Q$	*Demonstrate electric lines of force between electrodes.* *Computer model to plot lines of force.*
5.5	Force between point charges.	$F = \frac{kQ_1Q_2}{r^2}$ where, for free space (or air), $k = \frac{1}{4\pi\varepsilon 0} = 9.0 \times 10^9$ N m^2 C^{-2} An experimental demonstration is *not* required.	*Measure force between two charges using electronic balance.*

			Suggested activities
5.6	Electric field strength in radial fields.	Inverse square law. $E = kQ/r^2$ (The relationship $V = kQ/r$ is *not* required.)	*Qualitative investigation of field around a charged sphere.* K_C K_{PS}
5.7	Electric field strength in uniform fields.	$E = V/d$ Equipotential surfaces.	
	Electric potential difference.	$V = W/Q$	*Qualitative investigation of field between two parallel plates.* K_C K_{PS}
	Electron beams.	Kinetic energy from $\Delta(\frac{1}{2}m_e\upsilon^2) = e\Delta V$	*Plot equipotentials using conducting paper.* *Demonstrate variation of brightness with accelerating voltage using Maltese Cross tube.*
	Capacitance		
5.8	Capacitance.	$C = Q/V$ Experimental investigation of charge stored. Appreciation of the significance of the area under an I-t graph.	*Coulombmeter to measure charge stored.*
5.9	Capacitors in series and parallel.	Equivalent capacitance formulae: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ $C = C_1 + C_2 + C_3$ Comparison with resistance formulae.	*Capacitance meter to demonstrate formulae for capacitors in series and parallel.*
5.10	Energy stored in a charged capacitor.	Energy stored $E = \frac{1}{2}CV^2 = \frac{1}{2}QV$ Energy stored represented by the area under a V-Q graph.	*Investigation: energy stored by discharging through series/parallel combinations of light bulbs.* K_{WO}/K_{PS} K_N *Research — applications eg flash photography* K_C K_{IT}
	Magnetic fields		
5.11	Permanent magnets.	Use of field lines to describe magnetic fields. Concept of a neutral point.	*Computer model to plot lines of force.*
5.12	Magnetic flux density (B-field).	Magnitude of B defined by $F = BIl$. Direction of B given by left-hand rule. Vector nature of B. Experimental study of the force on a current-carrying conductor in a magnetic field.	*Electronic balance to measure force.* *Investigation: effect of I and l on force.* K_{WO}/K_{PS} K_N K_C K_{IT}

			Suggested activities
5.13	Magnetic effect of a steady current.	Magnetic field in a solenoid and near a straight wire to be investigated experimentally using a pre-calibrated Hall probe. $B = \mu_0 nI$ and $B = \mu_0 I/2\pi r$	*Use Hall probe or flux density meter.* K_{WO}/K_{PS} K_N K_C K_{IT}
	Electromagnetic induction		
5.14	Magnetic flux, flux linkage.	Magnetic flux. $\Phi = BA$	
5.15	Electromagnetic induction.	Experimental demonstration that change of flux induces an emf in a circuit.	*Data logging: V against t as a magnet falls through coil.*
	Faraday's and Lenz's laws of electromagnetic induction.	Emf as equal to rate of change of magnetic flux linkage. Lenz's law as illustrating energy conservation. $\mathcal{E} = -N\Delta\Phi/\Delta t$	*Investigations: Faraday's law - variation of ε with N and rate of change of B.* K_{WO}/K_{PS} K_N K_C K_{IT}
5.15	The transformer.	Explained in terms of magnetic flux linkage. For an ideal transformer: $V_p/V_s = N_p/N_s$	*Investigation: number of turns and output voltage.* K_{PS} K_N

Unit 6: Synthesis

An understanding of the principles in this unit and in the general requirements is expected in familiar and unfamiliar situations. In examination questions where the context is beyond the content of the specification it will be fully described. The content of this unit draws together different areas of physics. The assessment will be synoptic, requiring students to show understanding and application of the principles involved rather than recall.

The first section of this unit compares springs and capacitors; electric and gravitational fields; capacitor discharge and radioactive decay. The second part, Accelerators, is intended to show how an area of modern physics unites different areas of physics, such as electric fields, circular motion and momentum. It should be regarded as illustrating applications of these areas. Both of these sections will be assessed synoptically, requiring candidates to show understanding and application of the principles involved rather than recall.

			Suggested activities
	Analogies in physics		
6.1	Comparison of springs and capacitors.	$F = kx$ and $V = Q/C$ *as* mathematical models for springs and capacitors. Energy stored.	
6.2	Comparison of electric and gravitational fields.	Inverse square law for radial fields. $E = kQ/r^2$ and $g = Gm/r^2$ (Concept of inverse potential *not* required.) Similarities and differences between the fields.	K_C
6.3	Comparison of capacitor discharge and radioactive decay.	Exponential decay: form of discharge graph. $Q = Q_o\, e^{-t/RC}$ and $N = N_o\, e^{-\lambda t}$ Current, $I = Q/RC$ and activity $A = \lambda N$ Time constant: $\frac{t_{½}}{RC} = \ln 2$ and $\lambda t_{½} = \ln 2$	*Data logging — I v t for capacitor charge/discharge. Demonstrate area under graph = charge stored.*
	Accelerators		
6.4	Conservation of mass-energy.	$\Delta E = c^2 \Delta m$ applies in all situations. Simple calculations relating mass difference to energy change. Unified atomic mass unit, u. Fission and fusion.	*Research — nuclear energy. Environmental considerations and Sustainable growth.* K_C K_{IT}
6.5	Principles of Linear accelerators. (Drawing together ideas from unit 1, Dynamics, Mechanical energy, Radioactive decay and the nuclear atom; unit 4, The expanding Universe; unit 5, Electric fields.)	Production of MeV particles using a Van de Graaff generator. Principle of a linac to reach GeV. Understanding that particles never reach the speed of light. (Knowledge of $m = \gamma m_o$ is *not* required.) Fixed target experiments.	*Research — significance to modern physics.* K_C K_{IT}

			Suggested activities
6.6	Principles of Ring accelerators. (Drawing together ideas from unit 1, Dynamics, Mechanical energy, Radioactive decay and the nuclear atom; unit 4, The expanding Universe; unit 5, Electric fields.)	Force on charged particle moving perpendicular to a uniform magnetic field, $F = BQ\upsilon$ Principle of the cyclotron: derivation of supply frequency for non-relativistic particles. Colliding beam experiments.	
6.7	Principles of Detecting particles. (Drawing together ideas from unit 1, Dynamics, Mechanical energy, Radioactive decay and the nuclear atom; unit 2, Kinetic model of matter; unit 4, Circular motion and oscillations; unit 5, Electric fields, Magnetic fields.)	Principles of cloud/bubble chambers and spark/drift chambers. Interpretation of photographs showing particle tracks: charge and momentum.	*Observation of alpha particle tracks in a cloud chamber.* K_C K_{IT}

Practical work

Students will be able to build upon the skills developed though their experience of experimental and investigative work at KS4. They will be expected to develop these skills further throughout the course. Performance of these skills will be assessed through practical tests.

Experiment and investigation

Advanced Subsidiary and Advanced GCE Physics require students to carry out experimental and investigative activities. These activities should allow students to use their knowledge of physics in planning, carrying out and evaluating their work and should involve the use of IT in data processing and capture.

Experimental and investigative activities for Advanced Subsidiary and Advanced GCE physics should be set in contexts appropriate to, and reflect the demand of, the content of these specifications. Experimental and investigative activities for the A2 part of the course should build upon and extend those met in AS. Activities for the A2 part of the course should also include opportunities to draw together knowledge, understanding and skills as described in the definition of synoptic assessment.

Assessment in A2 will reflect an expectation of more advanced skills in planning and implementation, with more emphasis on the student selecting the most appropriate experimental method and means of presenting data. Analysis in A2 will expect more rigorous testing of hypotheses, for example the use of logarithmic plots to investigate exponential or power functions, and a greater awareness of the limitations of data, with quantitative and critical analysis.

Planning

Students should:

- identify and define a question or problem using available information and knowledge of physics
- choose effective and safe procedures, selecting appropriate methods and apparatus.

Implementing

Students should:

- set up apparatus correctly and use it effectively with due regard to safety
- make and record sufficient relevant observations and measurements to the appropriate degree of precision, using IT where appropriate
- modify procedures and respond to serious sources of systematic and random error in order to generate results which are as accurate and reliable as allowed by the apparatus.

Analysing evidence and drawing conclusions

Students should:

- present work appropriately in written, graphical or other forms
- analyse observations and show awareness of the limitations of experimental measurements when commenting on trends and patterns in the data
- draw valid conclusions by applying knowledge and understanding of physics.

Evaluating evidence and procedures

Students should:

- assess the reliability of data and the conclusions drawn from them
- show awareness of the limitations inherent in their activity.

Students will be expected to have seen or carried out a wide range of practical exercises and be familiar with basic instruments and measuring techniques.

The limitations of various techniques and the relevant safety requirements should be appreciated. Some of the longer exercises should be designed to test a stated hypothesis that has been formulated by the student, and include analysis of the evidence obtained and evaluation of the validity of the investigation in accepting or rejecting the hypothesis.

The specification specifies some experiments that students should undertake, but as far as possible each area of study should be supported by a wider range of experiments and investigations. There are suggested activities in the right hand column of the specification content, but this is not intended to be a comprehensive list and centres may choose alternative activities to support their delivery of the specification. Suggestions for practical work are often contained in general textbooks and can also be found in, for example, the Nelson Advanced Modular Science Physics Experiment Sheets or the experimental sections of the Nuffield Advanced Science guides. Datalogging devices should be used in appropriate cases to record and process experimental results and observations.

Students should become aware of the principles involved in measuring such fundamental quantities as pressure, frequency, wavelength, velocity, acceleration, force, momentum, charge, capacitance, strain, magnetic flux density, potential difference, work, energy and power in a variety of contexts.

Treatment of uncertainties

A full treatment of statistical uncertainty is not required. Uncertainty may be estimated by considering either the precision of the scale used or the spread of the readings taken for a particular value.

Candidates should take repeat readings whenever it is reasonable to do so, in which case the percentage uncertainty should be based on the spread of the readings. The estimated uncertainty is then half the spread.

If it only possible to take one reading, then the percentage uncertainty should be based on the precision with which the scale can be read. The estimated uncertainty in this case is half of one scale division.

In both cases candidates should be aware that human error can increase the uncertainty of a measurement (eg reaction time when taking readings).

Readings may be combined *either* by addition or subtraction, in which case the uncertainties should be added, *or* by multiplication and division, in which case the *percentage* uncertainties should be added. Where a reading is raised to a power, the percentage uncertainty should be multiplied by the power.

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty}}{\text{Average value}} \times 100\%$$

Use of instruments

Students should be able to:

(a) explain the need to calibrate measuring instruments and the use of standards

(b) use analogue and digital instruments

(c) use suitable techniques for measuring mass, length and time, and current, potential difference and temperature

(d) use micrometer and vernier scales

(e) assemble electric circuits and use electrical measuring instruments

(f) use an oscilloscope to measure voltage, time and frequency, and with a known resistor to measure alternating currents. No theoretical understanding of the oscilloscope is required

(g) explain how to set up and use a datalogging device.

Organisation of the practical test

Up to two alternative practical tests (groups) will be offered in each June examination, to be taken on two different days. Centres with a large number of candidates may need to use both tests. Other centres should choose the day that suits their timetable better. There will normally be only one group in January. Centres will be provided about eight weeks in advance with confidential instructions for the preparation of the practical test.

Supervisors are encouraged to contact the Assessment Leader for Advanced Subsidiary and Advanced GCE Physics at Edexcel to clarify any problems at an early stage as it is usually possible to agree to the use of modified or alternative equipment.

Apparatus requirements

As far as possible the practical tests will be designed to require only basic laboratory apparatus of the type generally available in school and college laboratories, and simple adaptations of everyday materials. Only half of the students taking the Unit 3 practical test and a third of the candidates taking the Unit 5 practical test will need access to a particular set of apparatus at any one time.

It is anticipated that centres will have a range of digital meters having direct and alternating current and voltage ranges and resistance ranges, including:

(i) current in the range 200 μA to 20 A

(ii) voltage in the range 200 mV to 20 V

(iii) resistance in the range 200 Ω to 20 MΩ.

However, centres may use analogue meters if they are suitable.

Where micrometers or vernier callipers are specified, centres may use either analogue or digital instruments. Candidates may require access to an electronic balance capable of measuring to 0.01 g.

The more expensive items that centres may need to provide for practical work during the course are listed below. Edexcel is aware of the financial constraints on many centres and will ensure that the following items are not required in the practical tests.

Charge measuring devices

In order to measure charge it is envisaged that centres will use a high impedance digital voltmeter of greater than or equal to 10 MΩ resistance which can be connected across a known charged capacitor (coulombmeter).

Datalogging

A wide range of datalogging equipment is available. Students will be expected to explain how to set up and use a datalogging device where appropriate.

Variable frequency signal generator

This should be a sine wave generator supplying up to about 5 V r.m.s. within the range 10 Hz to 10 kHz. The output into a high impedance load should be fairly constant over the whole frequency range, but high accuracy of the frequency calibration is not essential. The generator must also have a low impedance output, for example about 5 Ω, for supplying about 1 W into a device such as a loudspeaker or vibration generator.

Oscilloscope

This should have a step-calibrated sensitivity which can be varied from about 0.1 V cm^{-1} to about 20 V cm^{-1}, and a step-calibrated time base which can be switched on and off and varied from about 0.1 ms cm^{-1} to about 200 ms cm^{-1}.

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 student 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.

Textbooks and other resources

The Nelson Advanced Modular Science texts have been updated for this new specification.

Author	Title	ISBN	Publisher
Recommended Texts			
Nelson Advanced Science	**(To address the Curriculum 2000 specification)**		
Ellse M and Honeywill C	Unit 1: Mechanics and radioactivity	0-17-448-2973	Nelson Thornes
Ellse M and Honeywill C	Unit 2: Electricity and thermal physics (with option topics)	0-17-448-2981	Nelson Thornes
Ellse M and Honeywill C	Unit 4: Waves and our Universe	0-17-448-299X	Nelson Thornes
Ellse M and Honeywill C	Unit 5: Fields, forces and synthesis	0-17-448-3007	Nelson Thornes
Ellse M and Honeywill C	NAS Teachers' Guide for AS and A level Physics (Online)	0-17-448-2876	Nelson Thornes
Watt A	NAS Physics Experiment Sheets 2nd ed.	0-17-448-304X	Nelson Thornes
Honeywill C	NAS Make the Grade in AS and A level Physics	0-17-448-2809	Nelson Thornes
Nelson Advanced Modular Science	**(To address the previous syllabus)**		
Ellse M and Honeywill C	Mechanics and Electricity	0-17-448260-4	Nelson
Ellse M and Honeywill C	Matter and Waves	0-17-448261-2	Nelson
Ellse M and Honeywill C	Thermal Physics	0-17-448262-0	Nelson
Ellse M and Honeywill C	Fields	0-17-448263-9	Nelson
Watt A	Physics Experiment Sheets	0-17-448265-5	Nelson
General			
Adams S and Allday J	Advanced Physics	0-19-914680-2	Oxford
Akrill T, Bennet G and Millar C	Practice in Physics, 3rd edition	0-340-75813-9	Hodder & Stoughton
Azzopardi F, Stewart B	Accessible Physics for A Level: A Guided Coursebook	0-333-62780-6	Macmillan
Breithaupt J	Physics	0-333-73302-9	Macmillan

Author	Title	ISBN	Publisher
Breithaupt J	Understanding Physics for Advanced Level	0-7487-1579-7	Stanley Thornes
Duncan T	Advanced Physics	0-71955199-4	John Murray
Fullick A, Fullick P	Heinemann Advanced Science: Physics	0-435-57078-1	Heinemann
Gibbs K	Advanced Physics	0-521-39985-8	Cambridge University Press
Hutchings R	Bath Advanced Science: Physics (2nd edition)	0-17-438-7318	Nelson
	Physics Education		Institute of Physics

Topics

Astrophysics

Aller L H	Atoms, Stars and Nebulae	0-521-31040-7	Cambridge University Press
Ingham N	Bath Science 16–19: Astrophysics	0-17-448-2396	Nelson
Jones B W	Images of the Cosmos	0-340-60065-9	Hodder & Stoughton
Jones B W	The Stars and the Interstellar Medium	0-74925125-5	Open University Educational Enterprises Ltd
Kaler J B	Stars	0-71675033-3	WH Freeman
Kaufmann III W J	Universe	0-71672379-4	W H Freeman
Longair M	Our Evolving Universe	0-521-55091-2	Cambridge University Press
McGillivray D	Physics and Astronomy	0-333-42861-7	Macmillan Educational
Milner B	Cosmology	0-521-42162-4	Cambridge University Press
Morrison P	Powers of Ten	0-71676008-8	WH Freeman
Muncaster R	Astrophysics and Cosmology	0-7487-2865-1	Stanley Thornes
Phillips A C	Physics of Stars	0-47194155-7	Wiley
Shu F H	Physical Universe	0-93570205-9	University Scientific Books, US
Tayler R J	The Stars	0-521-45885-4	Cambridge University Press
Zeilik M	Astronomy: the Evolving Universe	0471135666	John Wiley and Sons

TRUMP Astrophysics Resource Package	Part 1: Introduction to Astrophysics	1-85342-810-8	Science Education Group University of York
	Part 2: Observational Properties	1-85342-811-6	
	Part 3: Star Formation and Evolution	1-85342-812-4	
Solid materials			
Bolton W	Materials and their Uses	0-750-62726-3	Butterworth-Heinemann
Cooke B	Bath Science 16–19: Physics of Materials	0-17-448240-X	Nelson
Easterling K	Tomorrow's Materials	0901462837	Institute of Metals (IOM Communications)
Gordon J E	New Science of Strong Materials	0-14013597-9	Penguin
Gordon J E	Structures	0-14013628-2	Penguin
Medical physics			
Ball J L	Essential Physics for Radiographers	0-63203902-7	Blackwell Scientific
Hollins M	Bath Science 16-19: Medical Physics	0-17-448-1888	Nelson
McCormick A; Elliot A	Health Physics	0-521-42155-1	Cambridge University Press
Muncaster R	Medical Physics	0-7487-2324-2	Stanley Thornes
Pope J	Medical Physics	0-435-68682-8	Heinemann Educational
Pope J	Medical Physics: Imaging	0-435-57094-3	Heinemann Educational
Sumner D	Radiation Risks	1-87078106-6	Tarragon Press
Wilks R	Principles of Radiological Physics	0-44304816-9	Churchill Livingstone
Nuclear and particle physics			
Adams S	Particle Physics	0-435-57084-6	Heinemann Educational
Allday J	Quarks, Leptons and the Big Bang	0-7503-0462-6	Institute of Physics
Barlow R	Particle Physics: A Program for the BBC Archimedes		

Close F E	The Cosmic Onion	0-435-69171-6	Heinemann Educational
Fritzsch H	Quarks	0-14015863-4	Penguin
Gribbin J	In Search of the Big Bang	0-14026989-4	Penguin
Muncaster R	Nuclear Physics and Fundamental Particles	0-7487-1805-2	Stanley Thornes
Ne'eman Y and Kirsh Y	The Particle Hunter	0-521-47686-0	Cambridge University Press
Open University	Science — A Foundation Course	0-33516341-6	Open University Press
Pagels H R	Cosmic Code	0-14013688-6	Penguin
	Physics Education Vol 27 #2 March 1992		
Sang D	Bath Science 16-19: Nuclear and Particle Physics	0-17-448-2388	Nelson

Support and training

Publications

Edexcel publications are available from:

Edexcel Publications
Adamsway
Mansfield
Notts
NG18 4FN

Telephone: 01623 467 467
Fax: 01623 450 481
Email: publications@linneydirect.com

A full range of specimen papers, past papers and mark schemes is available from Edexcel Publications. The test papers from the previous syllabus for physics (8541 and 9541) are still generally helpful for this specifications, although it must be remembered that the old Advanced Supplementary examination (of modules PH1, PH2, PH5 and PH7) were intended to be of the same standard as the old Advanced level GCE whereas the current AS examination (Units 1, 2 and 3) is aimed at the standard expected of a student after studying the first half (normally the first year) of an Advanced GCE course.

A full set of unit mark schemes and examiners' reports is published after each June and January examination.

General support

Customer Services deals with straightforward general enquiries. Enquiries relating to specification content and support should be addressed to the Qualification Leader for Advanced Subsidiary and Advanced GCE Physics. Enquiries relating to assessment, eg the practical test instructions should be addressed to the Assessment Leader for Advanced Subsidiary and Advanced GCE Physics.

Detailed enquiries about the subject content or matters that might also involve the operation of other subjects usually have to be referred to other people and will usually take longer to answer. It is helpful if these more detailed enquiries are sent by letter.

The Customer Services telephone number is 0870 240 9800

Practical tests

The instructions for setting up the practical tests are sent to centres about eight weeks before the tests take place. The instructions aim to be specific requirements about the apparatus without being too prescriptive. It is accepted that some centres may have problems either in interpreting exactly what is required or in providing apparatus that meets the specification. Supervisors are encouraged to contact the Assessment Leader for Advanced Subsidiary and Advanced GCE Physics at Edexcel to clarify any problems at an early stage, as it is usually possible to agree to the use of modified or alternative equipment.

Training meetings

Each year Edexcel provides a programme of training courses covering aspects of the specifications and assessment. These courses take place throughout the country. For further information on what is planned, please consult the annual Training and Professional Development Guide, which is sent to all centres, or contact:

INSET
Edexcel
Stewart House
32 Russell Square
London WC1B 5DN

Telephone: 020 7758 5620
Fax: 020 7758 5950
Email: insetenquiry@edexcel.org.uk

A typical programme may include the following meetings:

Feedback meetings

The Principal Examiners review the main features of each unit test in the June examination and provide feedback on the marking. The meetings will include workshop activities on guidance on how to improve candidates' performance.

Sixth-form student days

These days are aimed at candidates in their final year of study for Advanced Subsidiary or Advanced GCE Physics. Principal Examiners offer help and advice on how to approach the written tests, and candidates spend a morning or afternoon in the laboratory working under supervision through two typical practical exercises and then discuss their results.

INSET days for the topics

These days are related directly to the content in each of the topics in Unit 3. Each day includes a review of the content by a Principal Examiner, and usually includes a talk by a guest speaker and a demonstration of, or visit to, some equipment relevant to the topic.

Datalogging and practical physics

The specification expects candidates to be familiar with datalogging techniques and this course gives teachers a practical demonstration of the various sensors and experiments that can be used in teaching, and also provides a general review of the practical tests.

Appendices

Appendix 1: Key skills development

The AS/Advanced GCE in Physics offers a range of opportunities for students to both:

- develop their key skills
- generate assessed evidence for their portfolios.

In particular the following key skills can be developed and assessed through this specification at level 3:

- application of number (N)
- communication (C)
- information technology (IT)
- improving own learning and performance (LP)
- working with others (WO)
- problem solving (PS)

Students requiring Application of number may be able to develop this skill through other parts of their Advanced GCE course or through stand-alone sessions.

Copies of the key skills specifications can be ordered through our publications catalogue. The individual key skills units are divided into three parts:

- Part A: what you need to know — this identifies the underpinning knowledge and skills required
- Part B: what you must do — this identifies the evidence that students must produce for their portfolios
- Part C: guidance — this gives examples of possible activities and types of evidence that may be generated.

This Advanced GCE specification signposts development and internal assessment opportunities which are based on Part B of the level 3 key skills units.

Opportunities for the delivery, practice and assessment of key skills are indicated by the letter K in the right hand column of the specification content followed by initial(s) in subscript to indicate the particular key skill.

Additional guidance is available for those students working towards levels 2 or 4 for any of the individual key skills units.

The evidence generated through this Advanced GCE will be internally assessed and contribute to the student's key skills portfolio. In addition, in order to achieve the key skills Qualification, students will need to take the additional external tests associated with Communication, Information technology and Application of number.

Each unit within the Advanced GCE in Physics will provide opportunities for the development of all six of the key skills identified. This section identifies the key skills evidence requirements and also provides a mapping of those opportunities. Students will need to have opportunities to develop their skills over time before they are ready for assessment. For each skill you will find illustrative activities that will aid this key skill development and facilitate the generation of appropriate portfolio evidence. To assist in the recording of key skills evidence Edexcel has produced recording documentation, which can be ordered from our publications catalogue.

Appendix 2: Mapping of key skills — summary table

Key skills (Level 3)	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Communication						
C3.1a	✓	✓	✓	✓	✓	✓
C3.1b	✓	✓	✓	✓	✓	✓
C3.2	✓	✓	✓	✓	✓	✓
C3.3	✓	✓	✓	✓	✓	✓
Information technology						
IT3.1	✓	✓	✓	✓	✓	✓
IT3.2	✓	✓	✓	✓	✓	✓
IT3.3	✓	✓	✓	✓	✓	✓
Application of number						
N3.1	✓	✓		✓	✓	✓
N3.2	✓	✓		✓	✓	✓
N3.3	✓	✓		✓	✓	✓

Key skills (Level 3)	**Unit 1**	**Unit 2**	**Unit 3**	**Unit 4**	**Unit 5**	**Unit 6**
Working with others						
3.1	✓	✓	✓	✓	✓	✓
3.2	✓	✓	✓	✓	✓	✓
Improving own learning and performance						
3.1	✓	✓		✓	✓	✓
3.2	✓	✓		✓	✓	✓
Problem solving						
PS3.1	✓	✓		✓	✓	✓
PS3.2	✓	✓		✓	✓	✓
PS3.3	✓	✓		✓	✓	✓
PS3.4	✓	✓		✓	✓	✓

Appendix 3: Key skills development suggestions

Application of number level 3

The AS/Advanced GCE in Physics provides opportunities for students to both develop the key skill of application of number and also to generate evidence for their portfolio. As well as undertaking tasks related to the three areas of evidence required students are also required to undertake a substantial and complex activity. An investigation or an extended experiment would be an example of a substantial and complex activity. This will involve students obtaining and interpreting information, using this information when carrying out calculations and explaining how the results of the calculations meet the purpose of the activity. Some examples are indicated below. Centres are not restricted to the use of these examples, but they must ensure that the relevant criteria are fulfilled through any other activity chosen.

Key skill evidence requirement		**AS/A unit**	**Opportunities for development or internal assessment**
N3.1	Plan and interpret information from *two* different types of sources, including a large data set		Students are required to plan how to obtain and use the information required. They should obtain relevant information (which may be from a large data set of over 50 items) using appropriate methods. Students should plan an experiment or an investigation that involves practical work and referring to another source. Most experiments and investigations will readily produce a large set of results, ie a large data set. The second source may be a text book containing data for comparison, or physical laws and principles to apply. Or, the internet may be used to gain information — this may also provide evidence for IT3.1 Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15. Students can plan to obtain information from the results of these investigations. Each of these can readily be used to produce a large data set of over 50 items.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained)
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B.
N3.2	Carry out multi-stage calculations to do with: • amounts and sizes • scales and proportions • handling statistics • rearranging and using formulae. You should work with a large data set on at least *one* occasion		Students must carry out their calculations, which could relate to volumes, powers, averages, formulae, etc, and show their methods of working. They must show how they have checked results and corrected their work as necessary. The results of a practical activity such as an experiment or investigation should be analysed involving multi-stage calculations. These will often involve the manipulation of formulae. In many circumstances the results will be a large data set. Opportunities for the use of statistics will need to be carefully chosen. Suitable suggested opportunities are found in 1.1, 1.17, 1.18, 1.20, 1.21. It may also be possible to perform a statistical analysis on the reliability results obtained in an investigation. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15. Each of these can readily be used to produce a large data set of over 50 items. The obtaining of results in these investigations will entail measuring amounts and sizes. Conversion of the units of measurement into appropriate forms will require competence at scales and proportions. Suggested activities involving estimation and measurement as appropriate will require competence at scales and proportions, eg in 1.4, 1.9, 1.13, 1.14.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). All these provide opportunities for dealing with amounts and sizes and re-arranging and using formulae. Opportunities to demonstrate competence at scales and proportions are found in the following activities: finding the centre of gravity of an irregular rod; the principle of moments; 'three force' equilibrium; estimate then measure the weight of familiar objects; estimate densities of various objects; estimate then measure as appropriate, work required for various tasks; estimate KE of various objects. Using light gates or electronic timer to measure g can give opportunity for a statistical analysis of the reliability of the evidence owing to the spread of results obtained, as will modelling, eg alpha particle scattering with ball bearings on collision with a 1/r hill; modelling decay by throwing dice. Measurements of radioactivity lend themselves to a statistical treatment, eg: measure background count rate. Investigation: absorption of alpha and beta radiation; measure half-life of protactinium. Safety issues, implications of long half lives — environmental considerations may entail research which would involve consideration of statistical evidence.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. All these provide opportunities for dealing with amounts and sizes and re-arranging and using formulae.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. All these provide opportunities for dealing with amounts and sizes and re-arranging and using formulae.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. All these provide opportunities for dealing with amounts and sizes and re-arranging and using formulae.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
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		Based on their findings, students must select appropriate methods of presentation, using as appropriate charts, diagrams, and tables. They should draw relevant conclusions from their findings. Students should indicate why they have chosen a particular approach and identify possible sources of error in their work and how this work relates to the purpose of the activity undertaken.
			Investigations and experiments provide opportunities for processed results (ie results of calculations) to be presented graphically and interpreted by drawing conclusions. The methods may be justified through the evaluation of the investigations or experiments. The use of appropriate graphs should be justified.
			There will often be occasions when a student will use charts and diagrams to illustrate her/his findings.
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). All these provide opportunities.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B.

Evidence

Student evidence for application of number key skill could include:

- copies of students plans
- records of information obtained
- justification of methods used
- records of calculations showing methods used
- reports of findings.

Communication level 3

For the communication key skill students are required to hold discussions and give presentations, read and synthesise information and write documents. Students will be able to develop all of these skills through an appropriate teaching and learning programme based on this Advanced GCE. Some suggested opportunities for students to both develop the key skill of communication and also to generate evidence for their portfolio are given below. Within each of the optional topics in Unit 3 there are opportunities for students to research areas and give class presentations. These may also provide evidence for the key skill working with others if carried out as a group activity.

Key skill evidence requirement		**AS/A unit**	**Opportunities for development or internal assessment**
C3.1a	Contribute to a group discussion about a complex subject		Topics in the physics specification will often lend themselves to form the basis of a group discussion. Complex subjects may involved discussion of theories, experimental or investigative procedures for use in the lab or wider issues relating to physics. These wider issues could be in relation to the development of scientific models and concepts, a historical perspective of the scientists involved or the ethical spiritual and moral implications of physics. They could address environmental issues and address sustainable growth. Specialist vocabulary may be used in the discussion. During the discussion students should make clear and relevant contributions, develop points and ideas whilst listening and responding sensitively to others. They should also create opportunities for others to contribute as appropriate. An investigation may be introduced by a group discussion. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15. Other suitable areas for a group discussion would be discussing issues in physics, eg in 1.18, 1.20, 2.16, 4.21, 4.22, 6.4; or discoveries and concept development, eg in 1.21, 2.15, 4.19, 4.20, 4.21, 5.2, 6.5, 6.7; or the work of scientists, eg in 1.1, 1.6, 1.17, 1.21, 2.13, 4.17, 4.20, 4.21, 5.15.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). Suitable issues include: radioactivity safety issues including implications of long half-lives, protection and environmental considerations. The purpose and validity of modelling can be discussed through modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. The role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr can be discussed.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. The role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion can be discussed.
		3	Each optional topic includes areas that provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. The role of scientists in the discovery of helium, the discovery of pulsars and the development of the model of wave-particle duality can be discussed.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B.
			The role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz can be discussed.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth.
			The role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field can be discussed.
C3.1b	Make a presentation about a complex subject, using at least *one* image to illustrate complex points		Following a period of research or after performing experimental work and investigations students could be given the opportunity to present their findings to the rest of the group. For example students could present their analysis of results, conclusions and evaluation resulting from an investigation or from research into an issue that they have undertaken.
			During the presentation students should speak clearly and use a style that is appropriate to their audience and the subject. The presentation should have a logical structure which allows the audience to follow the sequence of information and ideas. The presentation should include an appropriate range of techniques such as:
			the use of examples to illustrate complex points; tone of voice varied, etc.
			Where appropriate, images should be used to both illustrate points and help engage the audience. Images could include, graphs or charts and diagrams. At least one image should be used to illustrate and help convey a complex point and this will readily be achievable using a graph for experiments and investigations. IT is used to produce materials for a presentation it can also provide evidence for IT3.3.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). Suitable issues include: Radioactivity safety issues including implications of long half-lives, protection and environmental considerations. A presentation could be made about the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a $1/r$ hill and modelling decay by throwing dice. A presentation could be made about the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be made about the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas which provide opportunities for providing evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. A presentation could be made about the role of scientists in the discovery of helium, the discovery of pulsars and the development of the model of wave-particle duality.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. A presentation could be made about the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be made about the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.
C3.2	Read and synthesise information from *two* extended documents about a complex subject. One of these documents should include at least *one* image.		Students will have a number of opportunities to read and synthesise information from two extended documents. For example as part of their preparation for the discussion and presentation of a complex subject, students will need to carry out preliminary research. Also, as students undertake research for investigations or considering wider issues they should synthesise information from more than one source. Extended documents may include text books and reports and articles of more than three pages such as found in scientific journals. At least one of these documents should contain an image from which students can draw appropriate and relevant information. Students will need to select and read material that contains relevant information. From this information they will need to identify accurately and compare the lines of reasoning and main points from the text and images. Students will then need to synthesise this information into a relevant form — eg for a presentation, discussion or an essay. Appropriate topics which could form the basis of this research are given below.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). A presentation could be developed about the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. A presentation could be developed about the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be developed about the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas that provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. A presentation could be developed about the role of scientists in the discovery of helium, the discovery of pulsars and the development of the model of wave-particle duality.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. A presentation could be developed about the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be developed about the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.
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.		Students are required to produce two different types of document. At least one of these should be an extended document, for example a report of more than three pages. A report of an investigation or experimental work would be suitable. Students could also write a document as an outcome of their research into a complex subject. The document should have a form and style of writing that is fit both for its purpose and the complex subject matter covered. At least one of the documents should include an appropriate image that contains and effectively conveys relevant information. A graph will readily fulfil this requirement. Specialist vocabulary should be used where appropriate and the information in the document should be clearly and coherently organised, eg through the use of headings, paragraphs, etc. Students should ensure that the text is legible and that spelling, punctuation and grammar are accurate.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). Suitable issues include: Radioactivity safety issues including implications of long half-lives, protection and environmental considerations. A document could be written about the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. A document could be written about the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A document could be written about the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas that provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. A document could be written about the role of scientists in the discovery of helium, the discovery of pulsars and the development of the model of wave-particle duality.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. A document could be written about the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A document could be written about the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.

Evidence

Student evidence for communication key skill could include:

- tutor observation records
- preparatory notes
- audio recordings/videotapes
- notes based on documents read
- essays.

Information technology level 3

When producing work for their Advanced GCE in Physics, students will have numerous opportunities to use information technology. The internet, CD-Rom, etc could be used to collect information. Documents can be produced using relevant software and images may be incorporated in those documents. Early drafts of documents could be emailed to tutors for initial comments and feedback.

For this key skill students are required to carry out at least one ‘substantial activity’. This is defined as ‘an activity that includes a number of related tasks, where the results of one task will affect the carrying out of the others.’ The activity should generate evidence for all three areas of evidence required in Part B of the IT unit. If students undertaking coursework as part of their AS/A in Physics use information technology they will have opportunities to generate evidence for all three sections identified as part of a ‘substantial activity’.

In addition, students will be able to use information technology to generate evidence for the communication key skill. For example the extended document with images, required for C3.3, could be generated using appropriate software.

As part of their physics programme students may not be able to generate sufficient evidence required for this unit. Examples include working with numbers through the use of a spreadsheet application or some aspects of database use. In this situation, students may use stand alone IT sessions for development and evidence generation and/or other parts of their Advanced GCE course.

Key skill evidence requirement		**AS/A unit**	**Opportunities for development or internal assessment**
IT3.1	Plan, and use different sources to search for, and select, information required for *two* different purposes.		Students will need to plan, and document, how they are to use IT as part of the activity, including how they will search for and incorporate relevant information from different electronic sources. These may include the internet and CD-Rom. Information selected must be relevant and of the appropriate quality. Suitable data may be found from sources to be used in the planning of investigations or experiments. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15. Students could also research using IT for a presentations on a physics topic. Suitable areas for research would be issues in physics, eg in 1.18, 1.20, 2.16, 4.9, 4.22, 6.4; or discoveries and concept development, eg in 1.21, 2.15, 4.19, 4.20, 4.21, 5.2, 6.5, 6.7; or the work of scientists, eg in 1.1, 1.6, 1.17, 1.21, 2.13, 4.17, 4.20, 4.21, 5.15.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). A presentation could be planned about the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. A presentation could be planned about the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be planned about the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas that provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. A presentation could be planned about the role of scientists in the discovery of helium, the discovery of pulsars and the development of the model of wave-particle duality.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. A presentation could be planned about the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be planned about the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.
IT3.2	Explore, develop and exchange information and derive new information to meet *two* different purposes.		Students are required to bring together in a consistent format their selected information and use automated routines as appropriate. For example using icons and macros to generate standard forms of lists, tables, images, etc. Students should sort and group the information generated, produce graphs and charts if appropriate, to allow them to draw conclusions. For example students could be working towards giving a presentation based on the results of an investigation. Information could be presented in handouts and/or as part of an automated slide show. Early drafts could be Emailed to their tutor for feedback, or could be stored on a shared drive for access by others. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15. Students could also develop a presentation on a physics topic using IT. Suitable areas for research would be issues in physics, eg in 1.18, 1.20, 2.16, 4.9, 4.22, 6.4; or discoveries and concept development, eg in 1.21, 2.15, 4.19, 4.20, 4.21, 5.2, 6.5, 6.7; or the work of scientists, eg in 1.1, 1.6, 1.17, 1.21, 2.13, 4.17, 4.20, 4.21, 5.15. Students may also use IT for modelling in physics. Suitable opportunities are found in 1.21, 4.3, 4.5, 4.12

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). A presentation could be developed about the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. A presentation could be developed about the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr. IT could be used in modelling alpha particle scattering with ball bearings on collision with a 1/r hill.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be developed about the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas which provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. A presentation could be developed about the role of scientists in the discovery of helium the discovery of pulsars and the development of the model of wave-particle duality. IT can be used to model simple harmonic motion and to explore the effects of changing x_0 and f, as well as the principle of superposition and two source interference.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. A presentation could be developed about the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be developed about the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.
IT3.3	Present information from different sources for *two* different purposes and audiences. This work must include at least *one* example of text, *one* example of images and *one* example of numbers.		In presenting information students will need to develop a structure that may involve the modification of templates, the application of page numbers, dates, etc. Tutors may provide early feedback on layout on content and style that will result in formatting changes (early drafts should be kept as portfolio evidence). The final format should be suitable for its purpose and audience eg AS coursework, OHTs/handouts for a presentation, etc. The document should have accurate spelling (use of spell-checker) and have been proof-read. A presentation may be the outcome of an investigation or experimental activity or the outcome of research into a physics issue. The results of an investigation or experimental activity will produce work containing text, images, eg graphs, and numbers, eg tables of results. A presentation will produce work containing text and should include an image(s) and may contain numbers. If the results of using IT to model behaviour are presented, a presented spreadsheet will be an example of numbers.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). A presentation could be made about the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. A presentation could be made about the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr. IT could be used in modelling alpha particle scattering with ball bearings on collision with a 1/r hill.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be made about the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas that provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. A presentation could be made about the role of scientists in the discovery of helium the discovery of pulsars and the development of the model of wave-particle duality. IT can be used to model simple harmonic motion and to explore the effects of changing x_0 and f, as well as the principle of superposition and two source interference.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. A presentation could be made about the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be made about the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.

Evidence

Student evidence for information technology key skill could include:

- tutor observation records
- preparatory plans
- print-outs with annotations
- draft documents.

Working with others level 3

To achieve this key skill students are required to carry out at least two complex activities. Students will negotiate the overall objective of the activity with others and plan a course of action. Initially the component tasks of the activity, and their relationships, may not be immediately clear. Within the activity, the topics covered may include ideas that may be some or all of the following: detailed, abstract, unfamiliar, sensitive.

During the activity the student must work in both group-based and one-to-one situations.

Suitable opportunities are presented by investigations. An investigation may be carried out as a group activity which will involve a student developing and providing evidence of working with others in a group. Students may also carry out research and make presentations about a complex subject such as an issue. These could provide opportunities for a complex activity that may be carried out as a group activity. Within each of the optional topics in Unit 3 there are opportunities for students to research areas and give class presentations.

Key skill evidence requirement		**AS/A unit**	**Opportunities for development or internal assessment**
WO3.1	Plan the activity with others, agreeing objectives, responsibilities and working arrangements		Students could work in groups of 6–8 and be required to investigate a given topic. Initial work will require identification of and agreeing of objectives and planning how to meet these, including any necessary action and resources required. The group needs to agree responsibilities and working arrangements. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15. Suitable areas for research would be issues in physics, eg in 1.18, 1.20, 2.16, 4.9, 4.22, 6.4; or discoveries and concept development, eg in 1.21, 2.15, 4.19, 4.20, 4.21, 5.2, 6.5, 6.7; or the work of scientists, eg in 1.1, 1.6, 1.17, 1.21, 2.13, 4.17, 4.20, 4.21, 5.15.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). A presentation could be planned about the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. A presentation could be planned about the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be planned about the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas that provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. A presentation could be planned about the role of scientists in the discovery of helium, the discovery of pulsars and the development of the model of wave-particle duality.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. A presentation could be planned about the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be planned about the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.
WO3.2	Work towards achieving the agreed objectives, seeking to establish and maintain co-operative working relationships in meeting your responsibilities.		When working towards their agreed objectives students could work in pairs with each pair taking a specific perspective(s), or role. Eg the use of text books or other written sources; the use of IT; the production of a report: proof-reading; the presentation of a report. Students must ensure that if such tasks are allocated each student will also have the opportunity to demonstrate competence in all the aspects of the other key skills when they are also addressed in one of these activities. Students will need to effectively plan and organise their work so that they meet agreed deadlines and maintain appropriate working relationships. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15. Suitable areas for research would be issues in physics, eg in 1.18, 1.20, 2.16, 4.9, 4.22, 6.4; or discoveries and concept development, eg in 1.21, 2.15, 4.19, 4.20, 4.21, 5.2, 6.5, 6.7; or the work of scientists, eg in 1.1, 1.6, 1.17, 1.21, 2.13, 4.17, 4.20, 4.21, 5.15.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). A presentation could be developed about the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. A presentation could be developed about the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr. IT could be used in modelling alpha particle scattering with ball bearings on collision with a 1/r hill.
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be developed about the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas that provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. A presentation could be developed about the role of scientists in the discovery of helium the discovery of pulsars and the development of the model of wave-particle duality. IT can be used to model simple harmonic motion and to explore the effects of changing x_0 and f, as well as the principle of superposition and two source interference.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. A presentation could be developed about the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be developed about the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.
WO3.3	Review the activity with others against the agreed objectives and agree ways of enhancing collaborative work.		Once completed the full group needs to review outcomes against the agreed objectives. In doing this they should identify factors that have influenced the outcome and agree on the ways in which the activity could have been carried out more effectively. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15. Suitable areas for research would be issues in physics, eg in 1.18, 1.20, 2.16, 4.9, 4.22, 6.4; or discoveries and concept development, eg in 1.21, 2.15, 4.19, 4.20, 4.21, 5.2, 6.5, 6.7; or the work of scientists, eg in 1.1, 1.6, 1.17, 1.21, 2.13, 4.17, 4.20, 4.21, 5.15.
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained). Presentations could include the purpose and validity of modelling in the context of modelling alpha particle scattering with ball bearings on collision with a 1/r hill and modelling decay by throwing dice. Presentations could include the role of scientists in the discovery of radiation and the work of the scientists Galileo, Newton, Rutherford and Bohr. IT could be used in modelling alpha particle scattering with ball bearings on collision with a 1/r hill.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR. Suitable issues include: use of energy and sustainable growth, including environmental considerations. Presentations could include the role of scientists in the development of laws of thermodynamics, kinetic theory and Brownian motion.
		3	Each optional topic includes areas that provide opportunities for generating evidence for this aspect of this key skill.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction. Presentations could include the role of scientists in the discovery of helium the discovery of pulsars and the development of the model of wave-particle duality. IT can be used to model simple harmonic motion and to explore the effects of changing x_0 and f, as well as the principle of superposition and two source interference.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B. Presentations could include the role of scientists in the discovery of development of models of gravitation and the role and work of the scientists Faraday and Lenz.
		6	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. Presentations could include the role and significance of particle tracks in a cloud chamber and the significance to modern physics of accelerators and the work of the scientists in this field.

Evidence

Student evidence for working with others key skill could include:

- tutor observation records
- preparatory plans
- records of process and progress made
- evaluative reports.

Improving own learning and performance level 3

Within Advanced GCE in physics programmes, students will have opportunities to develop and generate evidence that meets part of the evidence requirement of this key skill.

To achieve this key skill students will need to carry out two study-based learning activities and two activity-based learning activities. The Advanced GCE Physics will provide opportunities for students to undertake study-based learning. Evidence for activity-based learning may come from other Advanced GCEs in the students' programme or from enrichment activities.

One of the study-based learning activities must contain at least one complex task and periods of self-directed learning. Activities that generate evidence for this skill should take place over an extended period of time, eg 3 months. Over the period of the activity students should seek and receive feedback, from tutors and others, on their target setting and performance.

Any substantial project work is a suitable study-based learning activity and may be used to generate evidence for this key skill. It may be appropriate for tutors to negotiate appropriate learning activities from within the course through which students may set targets, meet them and review progress establishing evidence of achievements, and agree action for improving performance. The student's approach to experimental work and investigations may be used to develop and generate evidence which meets part of the evidence requirement of this key skill. Other activities may be chosen, but the centre must ensure that the criteria for the key skill Improving own learning and performance at this level are fully met.

Key skill evidence requirement		**AS/A unit**	**Opportunities for development or internal assessment**
LP3.1	Agree targets and plan how these will be met, using support from appropriate others.		Students plan how they are to perform experimental work and investigations. This will include setting realistic dates and targets and identification of potential problems and alternative courses of action. This will be determined with advice from others, eg their tutor. Examples of suggested investigations that may be used as a context for developing this aspect of this key skill are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
LP3.2	Use your plan, seeking feedback and support from relevant sources to help meet your targets, and use different ways of learning to meet new demands.		Students use the plan effectively when they perform experimental work and investigations. This will involve prioritising action, managing their time effectively and revising their development plan as necessary. Students should seek and use feedback and support and draw on different approaches to learning in order to meet their targets. Examples of suggested investigations that may be used as a context for developing this aspect of this key skill are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15.
LP3.3	Review progress establishing evidence of achievements, and agree action for improving performance.		Students should review their own progress and the quality of their learning and performance. They should identify targets met, providing evidence of achievements from relevant sources. They should identify with others, eg their tutor, action for improving their performance at experimental work and investigations Examples of suggested investigations that may be used as a context for developing this aspect of this key skill are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15.

Evidence

Student evidence for Improving own learning and performance could include:

- tutor records
- annotated action plans
- records of discussions
- learning log
- work produced.

Problem solving level 3

For this key skill students are required to apply their problem-solving skills to complex activities. They need to show that they can recognise, explore and describe problems, generate ways of solving problems, implement options and check whether the problem has been solved. For this Advanced GCE students may only be able to complete the first two stages of this process as there may be difficulties in implementing practical solutions in a school or college context. However, experimental activities such as performing substantial investigations should provide sufficient opportunity for generating evidence for competence at this key skill. Evidence ether for the key skill problem solving or that of working with others should be generated using a particular activity and not both at the same time.

Key skill evidence requirement		**AS/A unit**	**Opportunities for development or internal assessment**
PS3.1	Recognise, explore and describe the problem, and agree the standards for its solution.		Students will need to identify the problem and explore its main features and agree standards that have to be meet to show successful resolution of the problem. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15.
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained).
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire; Faraday's law — variation of ε with N and rate of change of B.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
PS3.2	Generate and compare at least *two* options which could be used to solve the problem, and justify the option for taking forward.		Students are required to select and use appropriate methods for generating different options for tackling the problem and compare the features of each option, selecting the most suitable one. Where there is a standard technique involved, eg the use of a Hall probe to investigate magnetic fields, students will need to be aware of other techniques. They will either have been taught them, or they will need to appreciate the need for thorough research into the relative merits of alternative techniques. Where more than one technique will have been taught, then it may be more appropriate to set a problem after students have had access to all the techniques for them better to judge the relative merits of these techniques as options for solving the problem set.
			Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15.
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained).
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire; Faraday's law — variation of ε with N and rate of change of B.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
PS3.3	Plan and implement at least *one* option for solving the problem, and review progress towards its solution.		The implementation of the chosen option will need to be planned and permission gained to implement it. Implementation of the plan should involve full use of support and feedback from others with progress reviews and alterations to the plan as necessary. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15.
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained).
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B.
PS3.4	Agree and apply methods to check whether the problem has been solved, describe the results and review the approach taken.		On completion the outcomes need to be checked against the standards agreed at the start. The results of this should be recorded and the approach taken reviewed. Examples of suggested investigations are to be found in the following sections of the specification content: 1.1, 1.12, 1.15, 2.5, 2.7, 4.2, 4.6, 4.11, 5.12, 5.13, 5.15.
		1	Investigations into motion include: Light gates to measure speed and acceleration of a trolley rolling down a slope; Light gates — factors affecting acceleration using an air track; Light gates or motion sensor — speed of a falling object (GPE lost and KE gained).
		2	Investigations include: effect of load resistance on power output of a battery; Ohmmeter and temperature sensor — R v T for a thermistor; effect of light intensity on R for an LDR.

Key skill evidence requirement		AS/A unit	Opportunities for development or internal assessment
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; mechanical oscillators — the effect of m, l and amplitude on T, the effect of m and k on T; inverse square law using a light meter.
		5	Investigations include: effect of current and length on the force on a current-carrying conductor in a magnetic field; magnetic field in a solenoid and near a straight wire using a pre-calibrated Hall probe; Faraday's law — variation of ε with N and rate of change of B.

Evidence

Student evidence for problem solving key skill could include:

- description of the problem
- tutor records and agreement of standards and approaches
- annotated action plans
- records of discussions
- descriptions of options
- records of reviews.

Appendix 4: Background mathematical requirements

The following mathematics is required by students for an understanding of the material contained in the specification. Students should understand the use of calculus notation to express such ideas as the rate of change, but the use of calculus techniques to differentiate or integrate mathematical functions is *not* expected.

Arithmetic and computation

Recognise and use expressions in decimal and standard form (scientific) notation.

Use ratios, fractions and percentages.

Recognise abbreviations for 10^{-12}, 10^{-9}, 10^{-6}, 10^{-3}, 10^{3}, 10^{6} and 10^{9}.

Use a calculator for:

- addition, subtraction, multiplication and division
- manipulating degrees (and radians for Advanced GCE)
- finding and using arithmetic means and reciprocals, and squares, sin θ, cos θ, tan θ, x^n and e^x, and their inverses (square roots, $\sin^{-1}\theta$, $\cos^{-1}\theta$, $\tan^{-1}\theta$, lg x and ln x).

Be aware of the precision of data, take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified.

Make approximate evaluations of numerical expressions (eg $\pi^2 \approx 10$) and use such approximations to check the order of magnitude of machine calculations.

Algebra

Change the subject of an equation by manipulation of the terms, including positive and negative and integer and fractional indices and square roots.

Solve algebraic equations including those involving inverse and inverse square relationships.

Substitute numerical values into algebraic equations using appropriate units for physical quantities, and check the dimensional consistency of such equations.

Formulate and use simple equations as mathematical models of physical situations, and identify inadequacies of such models.

Understand and use logarithms in relation to quantities which range over several orders of magnitude.

Recognise and use the logarithmic forms of expressions like ab, a/b, x^n and e^{kx}.

Express small changes or uncertainties as percentages and vice versa.

Understand and use the symbols $=$, $<$, $>$, $\ll$, $\gg$, $\approx$, $\propto$, $\sim$, Σx and Δx.

Geometry and trigonometry

Calculate the areas of triangles, the circumferences and areas of circles, and the surface areas and volumes of rectangular blocks, cylinders and spheres.

Use Pythagoras' theorem, similarity of triangles and the angle sum of a triangle.

Use sines, cosines and tangents in physical problems.

Be aware for small angles that $\sin\theta \approx \tan\theta$ (and $\approx \theta$ in radians for Advanced GCE), and that $\cos\theta \approx 1$.

For Advanced GCE only, understand the relationship between degrees and radians (defined as arc/radius), translate from one to the other and ensure that the appropriate system is used.

Vectors

Find the resultant of two coplanar vectors, recognising situations where vector addition is appropriate.

Obtain expressions for components of a vector in perpendicular directions, recognising situations where vector resolution is appropriate.

Graphs

Translate information between numerical, algebraic, written and graphical forms including histograms.

Select and plot two variables from experimental or other data, using appropriate scales for graph plotting.

Choose by inspection a straight line which will serve as the best straight line through a set of data points presented graphically.

Understand and use the standard linear form $y = mx + c$, and rearrange relationships into linear form where appropriate.

Determine the gradient and intercept of a linear graph and allocate appropriate physical units to them.

Sketch and recognise the forms of plots of common simple expressions like:

$y = kx$ $\quad y = kx^2$ $\quad y = k/x$ $\quad y = k/x^2$

$y = \sin x$ $\quad y = \cos x$ $\quad y = e^{-x}$ $\quad y = e^{-kx}$

Understand, draw and use the gradient of a tangent to a curve as a measure of rate of change.

Understand the notation dx/dt for the rate of change of x with t.

Understand and use the area between a curve and the relevant axis where the area has physical significance, and be able to calculate it or measure it by counting squares as appropriate.

For Advanced GCE only, use logarithmic plots (lg or ln) to test exponential and power law variations.

Appendix 5: Formulae and relationships

The Advanced Subsidiary (AS) and Advanced (A) GCE Specifications Subject Criteria for physics issued by QCA specify that certain relationships and formulae should not be provided to students in examinations. This is mandatory for all awarding bodies.

The relationships listed below will *not* be provided for Advanced Subsidiary and Advanced GCE students.

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

$$speed = \frac{distance}{time\ taken}$$

(ii) the relationship between force, mass and acceleration:

$force = mass \times acceleration \qquad F = ma$

$$acceleration = \frac{change\ in\ velocity}{time\ taken}$$

(iii) the relationship between density, mass and volume:

$$density = \frac{mass}{volume}$$

(iv) the concept of momentum and its conservation:

$momentum = mass \times velocity \qquad p = mv$

(v) the relationships between force, distance, work, power and time:

$work\ done = force \times distance\ moved\ in\ direction\ of\ force$

$$power = \frac{energy\ transferred}{time\ taken} = \frac{work\ done}{time\ taken}$$

(vi) the relationships between mass, weight, potential energy and kinetic energy:

$weight = mass \times gravitational\ field\ strength$

$kinetic\ energy = \frac{1}{2} \times mass \times speed^2$

$change\ in\ potential\ energy = mass \times gravitational\ field\ strength \times change\ in\ height$

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

$$pressure = \frac{force}{area}$$

(viii) the Gas Law:

$pressure \times volume = number\ of\ moles \times molar\ gas\ constant \times absolute\ temperature$

$pV = nRT$

(ix) the relationships between charge, current, potential difference, resistance and electrical power:

charge = current × time $\Delta q = I\Delta t$

potential difference = current × resistance $V = IR$

electrical power = potential difference × current $P = VI$

(x) the relationship between potential difference, energy and charge:

$$\text{potential difference} = \frac{\text{energy transferred}}{\text{charge}} \qquad V = W/q$$

(xi) the relationship between resistance and resistivity:

$$\text{resistance} = \frac{\text{resitivity} \times \text{length}}{\text{cross-sectional area}} \qquad R = \rho l/A$$

(xii) the relationship between charge flow and energy transfer in a circuit:

energy = potential difference × current × time $E = VIt$

(xiii) the relationship between speed, frequency and wavelength:

wave speed = frequency × wavelength $v = f\lambda$

(xiv) the relationship between centripetal force, mass, speed and radius:

$$\text{centripetal force} = \frac{\text{mass} \times \text{speed}^2}{\text{radius}} \qquad F = mv^2/r$$

(xv) the inverse square laws for force in radial electric and gravitational fields:

$F = kq_1q_2/r^2$ $\qquad F = Gm_1m_2/r^2$

(xvi) the relationship between capacitance, charge and potential difference:

$$\text{capacitance} = \frac{\text{charge stored}}{\text{potential difference}}$$

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

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

Appendix 6: Data, formulae and relationships

Appropriate subsets of this list will be issued with each AS examination paper. The list issued with the A2 papers will exclude those items that are relevant only to 6733/01, but include all the rest.

Data

Speed of light in vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$	
Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to the Earth)
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to the Earth)
Elementary (proton) charge	$e = 1.60 \times 10^{-19}\ \text{C}$	
Electronic mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Unified atomic mass unit	$\text{u} = 1.66 \times 10^{-27}\ \text{kg}$	
Molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$	
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Coulomb law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9}\ \text{N m}^{2}\ \text{C}^{-2}$	
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \text{N A}^{-2}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	

Rectilinear motion

For uniformly accelerated motion:

$$\upsilon = u + at$$

$$x = ut + {}^{1}/_{2}at^{2}$$

$$\upsilon^{2} = u^{2} + 2ax$$

Forces and moments

Moment of F about O = $F \times$ (Perpendicular distance from F to O)

Sum of clockwise moments about any point in a plane = Sum of anticlockwise moments about that point

Dynamics

Force $F = m\frac{\Delta \upsilon}{\Delta t} = \frac{\Delta p}{\Delta t}$

Impulse $F\Delta t = \Delta p$

Mechanical energy

Power $P = F\upsilon$

Radioactive decay and the nuclear atom

Activity $A = \lambda N$ (Decay constant λ)

Half-life $\lambda t_{½} = 0.69$

Electrical current and potential difference

Electric current $I = nAQ\upsilon$

Electric power $P = I^2R$

Electrical circuits

Terminal potential difference $V = \mathcal{E} - Ir$ (E.m.f. $\mathcal{E}$; Internal resistance r)

Circuit emf $\Sigma\mathcal{E} = \Sigma IR$

Resistors in series $R = R_1 + R_2 + R_3$

Resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Heating matter

Change of state: energy transfer = $l\Delta m$ (Specific latent heat or specific enthalpy change l)

Heating and cooling: energy transfer = $mc\Delta T$ (Specific heat capacity c; Temperature change ΔT)

Celsius temperature $\theta/°C = T/K - 273$

Kinetic theory of matter

Temperature and energy $T \propto$ Average kinetic energy of molecules

Kinetic theory $p = {}^1/_3\rho\langle c^2\rangle$

Conservation of energy

Change of internal energy $\Delta U = \Delta Q + \Delta W$ (Energy transferred thermally ΔQ; Work done on body ΔW)

Efficiency of energy transfer $= \dfrac{\text{Useful output}}{\text{Input}}$

Maximum efficiency of a heat engine $= \dfrac{T_1 - T_2}{T_1}$

Astrophysics

Stefan-Boltzmann law $L = \sigma T^4 \times \text{surface area}$ (Luminosity L; Stefan's constant σ)

Wien's law $\lambda_{max}T = 2.898 \times 10^{-3}$ m K

Estimating distance intensity $= L/4\pi D^2$

Mass-energy $\Delta E = c^2\Delta m$ (speed of light in vacuum c)

Solid materials

Hooke's law $F = k\Delta x$

Stress $\sigma = \dfrac{F}{A}$

Strain $\varepsilon = \dfrac{\Delta l}{l}$

Young modulus $E = \dfrac{\text{Stress}}{\text{Strain}}$

Work done in stretching $\Delta W = {}^{1}/_{2}F\Delta x$ (provided Hooke's law holds)

Energy density $=$ Energy/Volume

Nuclear and particle physics

Nuclear radius $r = r_0 A^{1/3}$

Mass-energy $1\ \text{u} = 930\ \text{MeV}$

Quark charge/e up $= +{}^{2}/_{3}$; down $= -\ {}^{1}/_{3}$

Medical physics

Effective half-life $\frac{1}{t_e} = \frac{1}{t_r} + \frac{1}{t_b}$ (Radioactive half-life t_r; Biological half-life t_b)

Acoustic impedance $Z = c\rho$ (Speed of sound in medium c; Density of medium ρ)

Reflection coefficient $= (Z_1 - Z_2)^2/(Z_1 + Z_2)^2$

Circular motion and oscillations

Angular speed $\omega = \frac{\Delta\theta}{\Delta t} = \frac{\upsilon}{r}$ (Radius of circular path r)

Centripetal acceleration $a = \frac{\upsilon^2}{r}$

Period $T = \frac{1}{f} = \frac{2\pi}{\omega}$ (Frequency f)

Simple harmonic motion:

displacement $x = x_0 \cos 2\pi ft$

maximum speed $= 2\pi f x_0$

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

For a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$ (Pendulum length l)

For a mass on a spring $T = 2\pi\sqrt{\frac{m}{k}}$ (Spring constant k)

Waves

Intensity	$I = \dfrac{P}{4\pi r^2}$	(Distance from point source r; Power of source P)

Superposition of waves

Two slit interference	$\lambda = \dfrac{xs}{D}$	(Wavelength λ; Slit separation s; Fringe width x; Slits to screen distance D)

Quantum phenomena

Photon model	$E = hf$	(Planck constant h)
Maximum energy of photoelectrons	$= hf - \varphi$	(Work function φ)
Energy levels	$hf = E_1 - E_2$	
de Broglie wavelength	$\lambda = \dfrac{h}{p}$	

Observing the Universe

Doppler shift	$\dfrac{\Delta f}{f} = \dfrac{\Delta\lambda}{\lambda} = \dfrac{\upsilon}{c}$	
Hubble law	$\upsilon = Hd$	(Hubble constant H)

Gravitational fields

Gravitational field strength	$g = F/m$	
for radial field	$g = Gm/r^2$, numerically	(Gravitational constant G)

Electric fields

Electric field strength	$E = F/Q$	
for radial field	$E = kQ/r^2$	(Coulomb law constant k)
for uniform field	$E = V/d$	
For an electron in a vacuum tube	$e\Delta V = \Delta(^1/_2 m_e \upsilon^2)$	

Capacitance

Energy stored $W = \frac{1}{2}CV^2$

Capacitors in parallel $C = C_1 + C_2 + C_3$

Capacitors in series $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Time constant for capacitor discharge $= RC$

Magnetic fields

Force on a wire $F = BIl$

Magnetic flux density (Magnetic field strength) $B = \mu_o nI$ (permeability of free space μ_o)

$B = \mu_o I/2\pi r$

Magnetic flux $\Phi = BA$

E.m.f. induced in a coil $\mathcal{E} = -\frac{N\Delta\Phi}{\Delta t}$ (Number of turns N)

Accelerators

Mass-energy $\Delta E = c^2\Delta m$

Force on a moving charge $F = BQ\upsilon$

Analogies in physics

Capacitor discharge $Q = Q_o\, e^{-t/RC}$

$\frac{t_{½}}{RC} = \ln 2$

Radioactive decay $N = N_o\, e^{-\lambda t}$

$\lambda t_{½} = \ln 2$

Experimental physics

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty} \times 100\%}{\text{Average value}}$$

Mathematics

	$\sin(90° - \theta)$	=	$\cos\theta$	
	$\ln(x^n)$	=	$n \ln x$	
	$\ln(e^{kx})$	=	kx	
Equation of a straight line	y	=	$mx + c$	
Surface area	cylinder	=	$2\pi rh + 2\pi r^2$	
	sphere	=	$4\pi r^2$	
Volume	cylinder	=	$\pi r^2 h$	
	sphere	=	${}^4/_3\pi r^3$	
For small angles:	$\sin\theta$	≈	$\tan\theta \approx \theta$	(in radians)
	$\cos\theta$	≈	1	

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