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Specification

GCE Physics

Edexcel Advanced Subsidiary GCE in Physics (8PH01)
First examination 2009

Edexcel Advanced GCE in Physics (9PH01)
First examination 2010

Issue 4

This specification is supported by an e-Spec

A PEARSON COMPANY

Edexcel GCE in Physics e-Spec

Everything you need

The e-Spec provides a range of useful resources including:

- A Senior Examiner explaining the changes to the new specification
- A customisable student guide to help recruit students
- A course planner to make it easy to plan delivery
- Links to sample assessment materials so you can see what is expected
- Student exemplars to show the standards required
- Information on the products and services provided by Edexcel to support the specification.

Edexcel GCE in Physics — Foreword

Edexcel is delighted that this specification has been developed in collaboration with the Salters Horners Advanced Physics project, a leader for many years in developing innovative approaches to teaching and learning in physics at A level.

Salters Horners Advanced Physics is developed and supported by the University of York Science Education Group, a major force for innovation in science education. Following a two-year pilot, the course has now been running successfully since the year 2000.

Many key elements of this approach, such as studying the contemporary uses and cutting edge application of physics, are now part of the *How Science Works* strand required in all A level Science specifications. Edexcel GCE in physics has benefited enormously from the expertise built up by the Salters Horners project in incorporating effectively this important new aspect of A level physics into the new specification.

The Salters Horners project continues to support students and teachers with INSET and resources in addition to the support offered by the Edexcel team.

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The University of York
UYSEG
Science Education Group

About this specification

The Edexcel GCE in Physics is designed for use in schools and colleges. It is a part of a suite of GCE qualifications offered by Edexcel.

Key features of the specification

An innovative specification

Edexcel's Physics specification provides the basis of an innovative course that has been designed to engage and inspire students who have different needs and abilities by providing two distinct, flexible, teaching and learning approaches:

- a concept-led approach. This approach begins with a study of the laws, theories and models of physics and finishes with an exploration of their practical applications
- a context-led topic approach. This approach begins with the consideration of an application that draws on many different areas of physics, and then moves on to the laws, theories and models of physics underlying this application. This approach is based on the Salters Horners Advanced Physics Project.

These teaching approaches can be mixed to allow variety in course delivery. Teachers may select the approach that best meets the needs of their students. These different approaches lead to the same common assessment paper for each unit.

Why choose this specification?

A motivating specification

This specification enables motivating, up-to-date, contemporary contexts, to be included in the teaching and learning programme. Opportunities for practical work are identified throughout the specification.

This specification has a realistic, manageable level of content and assessment and therefore provides an enjoyable teaching and learning experience.

A supported specification

Edexcel provides extensive support for this specification, including guidelines for the internal assessments and schemes of work.

The Salters Horners Advanced Physics project team at the University of York organises courses for teachers and technicians who operate this specification, and also provides an advice service to help with questions concerning the teaching of the course.

Teachers will find that many of their current resources for expiring specifications will be applicable to this specification; this will reduce the amount of preparation time that is required to teach this specification.

Supporting you

Edexcel aims to provide the most comprehensive support for our qualifications. We have therefore published our own dedicated suite of resources for teachers and students written by qualification experts. We also endorse a wide range of materials from other publishers to give you a choice of approach.

For more information on our wide range of support and services for this GCE in Physics qualification, visit our GCE website: www.edexcel.com/gce2008.

Specification updates

This specification is Issue 4 and is valid for Advanced Subsidiary (AS) examination from 2009 and A2 examination from 2010. If there are any significant changes to the specification Edexcel will write to centres to let them know. Changes will also be posted on our website.

For more information please visit www.edexcel.com/or www.edexcel.com/gce2008

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A Specification at a glance

AS Unit 1: Physics on the go — *Unit code 6PH01

- Externally assessed
- Availability: January and June
- First assessment: January 2009

40% of the total AS marks | **20% of the total GCE marks**

Content summary:

This unit involves the study of mechanics (rectilinear motion, forces, energy and power) and materials (flow of liquids, viscosity, Stokes' Law, properties of materials, Young's' modulus and elastic strain energy).

Part of this topic may be taught using applications that relate to, for example, sports. The other part of this topic may be taught using, for example, a case study of the production of sweets and biscuits. It may also be taught using the physics associated with spare part surgery for joint replacements and lens implants.

Assessment:

This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration, which will consist of objective questions, short questions and long questions.

AS Unit 2: Physics at Work — *Unit code 6PH02

- Externally assessed
- Availability: January and June
- First assessment: January 2009

40% of the total AS marks | **20% of the total GCE marks**

Content summary:

This unit involves the study of waves (including refraction, polarisation, diffraction and standing (stationary) waves), electricity (current and resistance, Ohm's law and non-ohmic materials, potential dividers, emf and internal resistance of cells, and negative temperature coefficient thermistors) and the wave/particle nature of light.

Several different contexts may be used to teach parts of this unit including music, medical physics, technology in space, solar cells and an historical study of the nature of light.

Assessment:

This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration, which will consist of objective questions, short questions and long questions.

AS Unit 3: Exploring Physics — *Unit code 6PH03

- Internally or externally assessed
- Availability: June
- First assessment: June 2009

20% of the total AS marks | **10% of the total GCE marks**

Content summary:

This unit involves an experiment that is based on a physics-based visit **or** a case study of an application of physics.

Assessment:

This unit is assessed by means of an experiment that is founded on either a physics-based visit **or** a case study of an application of physics. Students write a report that is either internally marked and externally moderated or externally marked by Edexcel.

A2 Unit 4: Physics on the Move — *Unit code 6PH04

- Externally assessed
- Availability: January and June
- First assessment: January 2010

40% of the total A2 marks | **20% of the total GCE marks**

Content summary:

This unit involves the study of further mechanics (momentum and circular motion), electric and magnetic fields, and particle physics.

Several different contexts may be used to teach parts of this unit including a modern rail transport system, communications and display techniques.

Particle physics is the subject of current research, involving the acceleration and detection of high-energy particles. This area of the specification may be taught by exploring a range of contemporary experiments.

Assessment:

This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration, which will consist of objective questions, short questions and long questions.

A2 Unit 5: Physics from Creation to Collapse — *Unit code 6PH05

- Externally assessed
- Availability: January and June
- First assessment: January 2010

40% of the total A2 marks

20% of the total GCE marks

Content summary:

This unit involves the study of thermal energy, nuclear decay, oscillations, astrophysics and cosmology.

Several different contexts may be used to teach parts of this unit including space technology, medical physics and the construction of buildings in earthquake zones. The astrophysics and cosmology section of this specification may be taught using the physical interpretation of astronomical observations, the formation and evolution of stars, and the history and future of the universe.

Assessment:

This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration, which will consist of objective questions, short questions and long questions.

A2 Unit 6: Experimental Physics — *Unit code 6PH06

- Internally or externally assessed
- Availability: June
- First assessment: June 2010

20% of the total A2 marks

10% of the total GCE marks

Content summary:

This unit involves planning an experiment, carrying out an experiment and analysing experimental results.

Assessment:

Students must plan an experiment and then carry out a plan of an experiment which may be their own plan, a plan provided by Edexcel or a plan devised by the centre.

Students write a report that is either marked by the teacher and externally moderated or externally marked by Edexcel.

See Appendix 5 for description of this code and all other codes relevant to this qualification.

B Specification overview

Summary of assessment requirements

Unit number and unit title	Level	Assessment information	Number of marks allocated in the unit
Unit 1: Physics on the go	AS	This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not seen before. It is recommended that students have access to a scientific calculator for this paper. Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.	80 marks
Unit 2: Physics at Work	AS	This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not seen before. It is recommended that students have access to a scientific calculator for this paper. Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.	80 marks
Unit 3: Exploring Physics	AS	This unit is assessed by means of an experiment that is founded on either a physics-based visit **or** a case study of an application of physics. The experiment must be conducted under supervised conditions. Students write a report that is either marked by the teacher and externally moderated or marked by Edexcel. The experiment can be done in a normal lesson.	40 marks
Unit 4: Physics on the Move	A2	This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not seen before. Students may use a scientific calculator for this paper. Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.	80 marks

Unit number and unit title	Level	Assessment information	Number of marks allocated in the unit
Unit 5: Physics from Creation to Collapse	A2	This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not seen before. Students may use a scientific calculator for this paper. Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.	80 marks
Unit 6: Experimental Physics	A2	Students must plan an experiment and then carry out a plan of an experiment which may be their own plan, a plan provided by Edexcel or a plan devised by the centre. The production of a plan may be done at a different time from the implementation of the plan. This assessment must be conducted under supervised conditions. Students write a report that is either marked by the teacher and externally moderated or externally marked by Edexcel. The assessment will take up to two hours.	40 marks

Information for international centres

A 100 per cent examination option is available **ONLY** to international centres wishing to take GCE Physics. This will take the form of alternative written papers for Units 3 and 6.

This option is **not** available for home centres.

International private centres, including all centres entering candidates via the British Council, are not permitted to enter candidates for internal assessment and therefore must take the alternative written papers.

For further details please refer to the Edexcel international website www.edexcel-international.org.

Assessment objectives and weightings

		% in AS	% in A2	% in GCE
A01	Knowledge and understanding of science and of '*How Science Works*'	40%	30%	35%
A02	Application of knowledge and understanding of science and of '*How Science Works*'	40%	50%	45%
A03	'*How Science Works*'	20%	20%	20%
	TOTAL	100%	100%	100%

Relationship of assessment objectives to units

Unit number	Assessment objective			
	AO1	AO2	AO3	Total for AO1, AO2 and AO3
Unit 1	9.5%	9.5%	1%	20%
Unit 2	9.5%	9.5%	1%	20%
Unit 3	1%	1%	8%	10%
Unit 4	7%	12%	1%	20%
Unit 5	7%	12%	1%	20%
Unit 6	1%	1%	8%	10%
Total for Advanced GCE	**35%**	**45%**	**20%**	**100%**

Qualification summary

Subject Criteria

The General Certificate of Education is part of the Level 3 provision. This specification is based on the Advanced Subsidiary GCE and Advanced GCE Subject Criteria for Science which are prescribed by the regulatory authorities and are mandatory for all awarding bodies.

The GCE in Physics has been designed to encourage students to:

a develop their interest in, and enthusiasm for, the subject, including developing an interest in further study and careers in the subject

b appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society

c develop and demonstrate a deeper appreciation of the skills, knowledge and understanding of *How Science Works*

d develop essential knowledge and understanding of different areas of the subject and how they relate to each other.

Aims

The aims of the Edexcel Advanced Subsidiary and Advanced GCE in Physics are to:

- provide seamless progression from the Key Stage 4 programme of study and enable students to sustain and develop an enjoyment of, and interest in, physics and its applications
- develop an understanding of the link between theory and experiment and foster the development of skills in the design and execution of experiments
- develop essential knowledge and understanding in physics and, where appropriate, the applications of physics with an appreciation of their significance and the skills needed for the use of these in new and changing situations
- demonstrate the importance of physics as a human endeavour that interacts with social, philosophical, economic and industrial matters
- be a suitable preparation for higher educational courses in physics and related courses.

AS/A2 knowledge and understanding

This Advanced Subsidiary and Advanced GCE specification requires students to:

- recognise, recall and show understanding of scientific knowledge
- select, organise and communicate relevant information in a variety of forms
- analyse and evaluate scientific knowledge and processes
- apply scientific knowledge and processes to unfamiliar situations
- assess the validity, reliability and credibility of scientific information.

AS/A2 skills

This Advanced Subsidiary and Advanced GCE specification requires students to:

- demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods
- make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy
- analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

C Physics unit content

Concept-led approach

Unit 1 Physics on the go 17

Unit 2 Physics at Work 23

Unit 3 Exploring Physics 33

Unit 4 Physics on the Move 41

Unit 5 Physics from Creation to Collapse 49

Unit 6 Experimental Physics 57

Context-led approach based on the Salters Horners Advanced Physics project

Unit 1 Physics on the go 65

Unit 2 Physics at Work 73

Unit 3 Exploring Physics 83

Unit 4 Physics on the Move 91

Unit 5 Physics from Creation to Collapse 101

Unit 6 Experimental Physics 109

Course structure

- Edexcel's GCE in Physics comprises six units and contains an Advanced Subsidiary subset of three AS units.
- The Advanced Subsidiary GCE is the first half of the GCE course and consists of Units 1, 2 and 3. It may be awarded as a discrete qualification or can contribute 50 per cent of the total Advanced GCE marks.
- The full Advanced GCE award consists of the three AS units (Units 1, 2 and 3), plus three A2 units (Units 4, 5 and 6) which make up the other 50 per cent of the Advanced GCE. Students wishing to take the full Advanced GCE must, therefore, complete all six units.
- The structure of this qualification allows teachers to construct a course of study which can be taught and assessed either as:
  - distinct modules of teaching and learning with related units of assessment taken at appropriate stages during the course; or
  - a linear course which is assessed in its entirety at the end.

Administration of internal assessment

Internal standardisation

Teachers choosing the option of marking the internal assessment must show clearly how the marks have been awarded in relation to the assessment criteria. If more than one teacher in a centre is marking students' work, there must be a process of internal standardisation to ensure that there is consistent application of the assessment criteria.

Authentication

All candidates must sign an authentication statement. Statements relating to work not sampled should be held securely in your centre. Those which relate to sampled candidates must be attached to the work and sent to the moderator. In accordance with a revision to the current Code of Practice, any candidate unable to provide an authentication statement will receive zero credit for the component. Where credit has been awarded by a centre-assessor to sampled work without an accompanying authentication statement, the moderator will inform Edexcel and the mark will be adjusted to zero.

Further information

For more information on annotation, authentication, mark submission and moderation procedures, please refer to the *Edexcel AS and GCE in Physics: Instructions and administrative documentation for internally assessed units* document, which is available on the Edexcel website.

For up-to-date advice on teacher involvement, please refer to the Joint Council for Qualifications (JCQ) — Instructions for conducting coursework/portfolio document on the JCQ website: www.jcq.org.uk. For up-to-date advice on malpractice and plagiarism, please refer to the Joint Council for Qualifications — Suspected Malpractice in Examinations: Policies and Procedures and the Joint Council for Qualifications (JCQ) — Instructions for conducting coursework/ portfolio documents on the JCQ website: www.jcq.org.uk.

CONCEPT-LED APPROACH

The following section shows how the specification may be taught using the concept-led approach

1.1 Introduction

Concept approach

This unit covers mechanics and materials. The unit may be taught using either a concept approach or a context approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. This section of the specification is presented in a format for teachers who wish to use the concept approach.

Context approach

This unit is presented in a different format on page 65 for teachers who wish to use a context approach. The context approach begins with the consideration of an application that draws on many different areas of physics, and then the laws, theories and models of physics that apply to this application are studied. The context approach for this unit uses three contexts for teaching this unit: sports, the production of sweets and biscuits and spare part surgery.

How Science Works

The QCA's GCE Science Criteria includes *How Science Works* (see *Appendix 6*). This should be integrated with the teaching and learning of this unit.

It is expected that students will be given opportunities to use spreadsheets and computer models to analyse and present data, and make predictions.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed *in Appendix 6* (internal assessment may require these skills). Students should communicate the outcomes of their investigations using appropriate scientific, technical and mathematical language, conventions and symbols.

Applications of physics should be studied using a range of contemporary contexts that relate to this unit.

1.2 Assessment information

Examination paper	This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not encountered before. The total number of marks available for this examination paper is 80. It contributes 40% to AS Physics and 20% to the Advanced GCE in Physics.
Calculator	It is recommended that students have access to a scientific calculator for this paper.
Formulae sheet	Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.

1.3 Mechanics

This topic leads on from the Key Stage 4 programme of study and covers rectilinear motion, forces, energy and power. It may be studied using applications that relate to mechanics, for example, sports.

Students will be assessed on their ability to:	Suggested experiments
1 use the equations for uniformly accelerated motion in one dimension: $v = u + at$ $s = ut + ½at^2$ $v^2 = u^2 + 2as$	
2 demonstrate an understanding of how ICT can be used to collect data for, and display, displacement/time and velocity/time graphs for uniformly accelerated motion and compare this with traditional methods in terms of reliability and validity of data	Determine speed and acceleration, for example use light gates
3 identify and use the physical quantities derived from the slopes and areas of displacement/time and velocity/time graphs, including cases of non-uniform acceleration	
4 investigate, using primary data, recognise and make use of the independence of vertical and horizontal motion of a projectile moving freely under gravity	Strobe photography or video camera to analyse motion
5 distinguish between scalar and vector quantities and give examples of each	
6 resolve a vector into two components at right angles to each other by drawing and by calculation	
7 combine two coplanar vectors at any angle to each other by drawing, and at right angles to each other by calculation	

Students will be assessed on their ability to:	Suggested experiments
8 draw and interpret free-body force diagrams to represent forces on a particle or on an extended but rigid body, using the concept of *centre of gravity* of an extended body	Find the centre of gravity of an irregular rod
9 investigate, by collecting primary data, and use $\Sigma F = ma$ in situations where m is constant (Newton's first law of motion ($a = 0$) and second law of motion)	Use an air track to investigate factors affecting acceleration
10 use the expressions for gravitational field strength $g = F/m$ and weight $W = mg$	Measure g using, for example, light gates. Estimate, and then measure, the weight of familiar objects
11 identify pairs of forces constituting an interaction between two bodies (Newton's third law of motion)	
12 use the relationship $E_k = ½ mv^2$ for the kinetic energy of a body	
13 use the relationship $\Delta E_{grav} = mg\Delta h$ for the gravitational potential energy transferred near the Earth's surface	
14 investigate and apply the principle of conservation of energy including use of work done, gravitational potential energy and kinetic energy	Use, for example, light gates to investigate the speed of a falling object
15 use the expression for work $\Delta W = F\Delta s$ including calculations when the force is not along the line of motion	
16 understand some applications of mechanics, for example to safety or to sports	
17 investigate and calculate power from the rate at which work is done or energy transferred	Estimate power output of electric motor (see also outcome 53)

1.4 Materials

This topic covers flow of liquids, viscosity, Stokes' law, properties of materials, Hooke's law, Young's modulus and elastic strain energy.

This topic may be taught using, for example, a case study of the production of sweets and biscuits. It could also be taught using the physics associated with spare part surgery for joint replacements and lens implants.

Learning outcomes 18–27 should be studied using variety of applications, for example, making and testing food, engineering materials, spare part surgery. This unit includes many opportunities to develop experimental skills and techniques.

Students will be assessed on their ability to:	Suggested experiments
18 understand and use the terms *density*, *laminar flow*, *streamline flow*, *terminal velocity*, *turbulent flow*, *upthrust* and *viscous drag*, for example, in transport design or in manufacturing	
19 recall, and use primary or secondary data to show that the rate of flow of a fluid is related to its viscosity	
20 recognise and use the expression for Stokes's Law, $F = 6\pi\eta rv$ and upthrust = weight of fluid displaced	
21 investigate, using primary or secondary data, and recall that the viscosities of most fluids change with temperature. Explain the importance of this for industrial applications	
22 obtain and draw force–extension, force–compression, and tensile/compressive stress-strain graphs. Identify the *limit of proportionality*, *elastic limit* and *yield point*	Obtain graphs for, example, copper wire, nylon and rubber

Students will be assessed on their ability to:	Suggested experiments
23 investigate and use Hooke's law, $F = k\Delta x$, and know that it applies only to some materials	
24 explain the meaning and use of, and calculate *tensile/compressive stress*, *tensile/compressive strain*, *strength*, *breaking stress*, *stiffness* and *Young Modulus*. Obtain the Young modulus for a material	Investigations could include, for example, copper and rubber
25 investigate elastic and plastic deformation of a material and distinguish between them	
26 explore and explain what is meant by the terms *brittle*, *ductile*, *hard*, *malleable*, *stiff* and *tough*. Use these terms, give examples of materials exhibiting such properties and explain how these properties are used in a variety of applications, for example, safety clothing, foodstuffs	
27 calculate the elastic strain energy E_{el} in a deformed material sample, using the expression $E_{el} = ½ Fx$, and from the area under its force/extension graph	

2.1 Introduction

Concept approach

This unit covers waves, electricity and the nature of light. The unit may be taught using either a concept approach or a context approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. This section of the specification is presented in a format for teachers who wish to use the concept approach.

Context approach

This unit is presented in a different format on page 73 for teachers who wish to use a context approach. The context approach begins with the consideration of an application that draws on many different areas of physics, and then the laws, theories and models of physics that apply to this application are studied. The context approach for this unit uses three contexts for teaching: music, technology in space and archaeology.

How Science Works

The QCA's GCE Science Criteria include *How Science Works* (see *Appendix 6*). This should be integrated with the teaching and learning of this unit.

It is expected that students will be given opportunities to use spreadsheets and computer models to analyse and present data, and make predictions while studying this unit.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed *in Appendix 6* (internal assessment may require these skills). They should communicate the outcomes of their investigations using appropriate scientific, technical and mathematical language, conventions and symbols.

Applications of physics should be studied using a range of contemporary contexts that relate to this unit.

2.2 Assessment information

Examination paper	This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not encounterd before. The total number of marks available for this examination paper is 80. It contributes 40% to AS Physics and 20% to the Advanced GCE in Physics.
Calculator	It is recommended that students have access to a scientific calculator for this paper.
Formulae sheet	Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.

2.3 Waves

This topic covers the properties of different types of waves, including standing (stationary) waves. Refraction, polarisation and diffraction is included.

This topic should be studied by exploring applications of waves, for example, applications in medical physics or applications in music. This topic includes many opportunities to develop experimental skills and techniques.

Students will be assessed on their ability to:	Suggested experiments
28 understand and use the terms *amplitude*, *frequency*, *period*, *speed* and *wavelength*	Wave machine or computer simulation of wave properties
29 identify the different regions of the electromagnetic spectrum and describe some of their applications	
30 use the wave equation $v = f\lambda$	
31 recall that a sound wave is a longitudinal wave which can be described in terms of the displacement of molecules	Demonstration using a loudspeaker Demonstration using waves on a long spring
32 use graphs to represent transverse and longitudinal waves, including standing waves	
33 explain and use the concepts of wavefront, coherence, path difference, superposition and phase	Demonstration with ripple tank
34 recognise and use the relationship between phase difference and path difference	
35 explain what is meant by a *standing (stationary) wave*, investigate how such a wave is formed, and identify nodes and antinodes	Melde's experiment, sonometer

Students will be assessed on their ability to:	Suggested experiments
36 recognise and use the expression for refractive index ${}_1\mu_2 = \sin i/\sin r = v_1/v_2$, determine refractive index for a material in the laboratory, and predict whether total internal reflection will occur at an interface using critical angle	
37 investigate and explain how to measure refractive index	Measure the refractive index of solids and liquids
38 discuss situations that require the accurate determination of refractive index	
39 investigate and explain what is meant by *plane polarised light*	Models of structures to investigate stress concentrations
40 investigate and explain how to measure the rotation of the plane of polarisation	
41 investigate and recall that waves can be diffracted and that substantial diffraction occurs when the size of the gap or obstacle is similar to the wavelength of the wave	Demonstration using a ripple tank
42 explain how diffraction experiments provide evidence for the wave nature of electrons	
43 discuss how scientific ideas may change over time, for example, our ideas on the particle/wave nature of electrons	
44 recall that, in general, waves are transmitted and reflected at an interface between media	Demonstration using a laser
45 explain how different media affect the transmission/reflection of waves travelling from one medium to another	

Students will be assessed on their ability to:	Suggested experiments
46 explore and explain how a pulse-echo technique can provide details of the position and/or speed of an object and describe applications that use this technique	
47 explain qualitatively how the movement of a source of sound or light relative to an observer/detector gives rise to a shift in frequency (Doppler effect) and explore applications that use this effect	Demonstration using a ripple tank or computer simulation
48 explain how the amount of detail in a scan may be limited by the wavelength of the radiation or by the duration of pulses	
49 discuss the social and ethical issues that need to be considered, eg, when developing and trialling new medical techniques on patients or when funding a space mission	

2.4 DC Electricity

This topic covers the definitions of various electrical quantities, for example, current and resistance, Ohm's law and non-ohmic materials, potential dividers, emf and internal resistance of cells, and negative temperature coefficient thermistors.

This topic may be studied using applications that relate to, for example, technology in space.

Students will be assessed on their ability to:	**Suggested experiments**
50 describe electric current as the rate of flow of charged particles and use the expression $I = \Delta Q / \Delta t$	
51 use the expression $V = W/Q$	
52 recognise, investigate and use the relationships between current, voltage and resistance, for series and parallel circuits, and know that these relationships are a consequence of the conservation of charge and energy	Measure current and voltage in series and parallel circuits Use ohmmeter to measure total resistance of series/parallel circuits
53 investigate and use the expressions $P = VI$, $W = VIt$. Recognise and use related expressions eg $P = I^2R$ and $P = V^2/R$	Measure the efficiency of an electric motor (see also outcome 17)
54 use the fact that resistance is defined by $R = V/I$ and that Ohm's law is a special case when $I \propto V$	
55 demonstrate an understanding of how ICT may be used to obtain current-potential difference graphs, including non-ohmic materials and compare this with traditional techniques in terms of reliability and validity of data	
56 interpret current-potential difference graphs, including non-ohmic materials	Investigate *I-V* graphs for filament lamp, diode and thermistor

Students will be assessed on their ability to:	Suggested experiments
57 investigate and use the relationship $R = \rho l/A$	Measure resisitivity of a metal and polythene
58 investigate and explain how the potential along a uniform current-carrying wire varies with the distance along it and how this variation can be made use of in a potential divider	Use a digital voltmeter to investigate 'output' of a potential divider
59 define and use the concepts of emf and internal resistance and distinguish between emf and terminal potential difference	Measure the emf and internal resistance of a cell eg a solar cell
60 investigate and recall that the resistance of metallic conductors increases with increasing temperature and that the resistance of negative temperature coefficient thermistors decreases with increasing temperature	Use of ohmmeter and temperature sensor
61 use $I = nqvA$ to explain the large range of resistivities of different materials	Demonstration of slow speed of ion movement during current flow
62 explain, qualitatively, how changes of resistance with temperature may be modelled in terms of lattice vibrations and number of conduction electrons	

2.5 Nature of Light

This topic covers the wave/particle nature of light.

This topic may be studied either by using applications that relate to, for example, solar cells or by the historical study of the nature of light.

Students will be assessed on their ability to:	Suggested experiments
63 explain how the behaviour of light can be described in terms of waves and photons	
64 recall that the absorption of a photon can result in the emission of a photoelectron	Demonstration of discharge of a zinc plate by ultra violet light
65 understand and use the terms threshold frequency and work function and recognise and use the expression $hf = \phi + ½ mv^2_{max}$	
66 use the non-SI unit, the electronvolt (eV) to express small energies	
67 recognise and use the expression $E = hf$ to calculate the highest frequency of radiation that could be emitted in a transition across a known energy band gap or between known energy levels	
68 explain atomic line spectra in terms of transitions between discrete energy levels	Demonstration using gas-filled tubes
69 define and use radiation flux as power per unit area	
70 recognise and use the expression efficiency = [useful energy (or power) output]/[total energy (or power) input]	

Students will be assessed on their ability to:	Suggested experiments
71 explain how wave and photon models have contributed to the understanding of the nature of light	
72 explore how science is used by society to make decisions, for example, the viability of solar cells as a replacement for other energy sources, the uses of remote sensing	

3.1 Unit description

Introduction

This unit requires that students undertake **either** a case study involving an application of physics and a related practical, **or** a physics-based visit and a related practical. The teacher, not the student, identifies the visit or case study that students will be doing. All candidates may do the same case study or the same visit; however it is vital that candidates demonstrate that the assessed work that they produce is entirely their own work.

This unit may be completed at any time during the AS course but it would be more appropriate to administer this assessment near the end of the AS year.

Case study

Edexcel will provide case studies for five different topics. Centres may either use one of the case studies provided by Edexcel or devise their own case study to match local needs and the interests of their candidates. Centre-devised case studies will not require approval from Edexcel; however, it is the responsibility of the centre to ensure that centre-devised case studies match the assessment criteria for this unit and that students have the opportunity to gain all the marks in the mark scheme. Candidates may all do the same case study or they may do different case studies. If all candidates do the same case study then they must ensure that work submitted for assessment is their own. There should be a connection between the case study and the practical work that is undertaken for this unit. For example a case study might be based on an application of Quantum Tunnelling Composite. This would offer the opportunity for practical work relating compressive force to resistance in this type of material. Ideally the case study should deal with concepts covered within the AS specification but this is not a requirement for the assessment of this unit.

Visit

The visit is intended to bring candidates into direct contact with a real-life example of physics in use. There should be a connection between the visit and the practical work that is undertaken for this unit. For example candidates might visit a church or concert hall. A related practical could be to investigate the relationship between the length of an organ pipe (using a glass tube to represent the organ pipe) and the frequency of its sound at resonance. The teacher or the host may provide briefing materials for the visit.

Practical	The practical that relates to the case study or visit should give candidates the opportunity to be assessed in four skill areas: ■ summarising details of a visit or case study ■ planning a practical ■ implementation and recording of measurements ■ analysis of results and drawing conclusions. The planning, implementation and analysis aspects of the practical work must be carried out individually and under supervision. The practical should lead to a graph relating two measured variables. Ideally the candidate should then attempt to derive the equation relating the two variables or a relevant quantity to the topic, for example the value of resisitivity for a particular material.
Use of ICT	Candidates may use a word processor to produce their summary of the visit or the case study, although they will not gain any extra marks for doing so. In order to ensure that candidates demonstrate their understanding of the principles and techniques involved in analysing data, the use of ICT, eg spreadsheets, may not be used for analysing data for this unit.
Draft work	Candidates should do a variety of practical work during the course so that they develop the necessary skills to succeed in this unit. They should **not**, therefore, submit draft work for checking and re-marking. However, teachers should check candidates' plans for health and safety issues. Work submitted for this unit must **not** be returned to candidates for them to improve it.
How Science Works	This unit will cover the following aspects of *how science works* as listed in *Appendix 6: How science works* 2, 3, 4, 5, 6, 8, and 9.

3.2 Assessment information

Summary of visit or case study	Students should produce a brief summary of the case study or physics-based visit as homework. It is recommended that students word process this part of the assessment. The summary should be between 500–600 words.
Plan	Students may be given the title of the experiment that they are to plan and carry out in advance. The plan should be produced under supervised conditions in class in the students' own handwriting. Students should not take any documents into the classroom as they should have gained sufficient experience of planning practical work during normal practical lessons. Teachers should collect in the plan at the end of the session to check for health and safety issues. The plan will need to be returned to students so that they can carry out their plan. At this stage teachers could either: i) photocopy the plan, mark the original plan if it is to be internally assessed and provide students with the photocopy in the laboratory so that they can carry out their plan ii) collect in the plan, not mark it and return it to students in the laboratory under supervised conditions so that they can carry out their plan.
Practical	The practical work should be carried out under supervised conditions in a separate session from the planning session. Unmarked plans should be returned to students so that they can carry out the experiment that they have planned. Students should work individually. If necessary, teachers may allow students to analyse results under supervision in their next lesson. In this situation, teachers must collect in the written work produced by their students. Teachers should not mark the plan or practical work. In the next lesson, the documents should be returned to students under supervised conditions for analysis. Students should not have access to any other sources of information while they are completing the analysis of their results

Assessing work	The assessment criteria are shown in the next section. Each criterion scores a maximum of 1 mark. The criteria are not hierarchical. The assessment of the summary of the visit or the case study, together with the planning, the recording of measurements and the analysis is based on documents produced by the students.
For centres marking the written report	The marks for the report should be submitted to Edexcel on the mark sheet for centres provided in the Edexcel *Coursework Guide* that will be available on the Edexcel website www.edexcel.com. Each piece of work should be annotated by the teacher. This can be done by writing the skill code eg A10 near to the appropriate section of the report and ticking the box A10 on the grid below.
For centres not marking the written report	The written report should be submitted to Edexcel as discussed in the Edexcel *Coursework Guide* that will be available on the Edexcel website www.edexcel.com.
Guidance to students	Teachers may provide guidance to students without penalty. Guidance is feedback that a teacher might reasonably be expected to give to a student who asks questions about the work that they are carrying out. In effect, the teacher is being used as a resource. Students may require assistance whereby the teacher needs to tell the student what they have to do. Assistance in this respect carries a penalty. The teacher should record details of any assistance provided on the report.
Important	Students should submit their work for assessment **once** only. Internally assessed work should **not** be given back to students to be improved.

3.3 Assessment criteria

A: Summary of case study or physics-based visit

Ref	Criterion	Mark
S1	Carries out a visit **OR** uses library, consulting a **minimum of three** different sources of information (eg books/websites/journals/magazines/case study provided by Edexcel/ manufacturers' data sheets)	1
S2	States details of visit venue **OR** provides **full** details of sources of information	1
S3	Provides a brief description of the visit **OR** case study	1
S4	Makes correct statement on relevant physics principles	1
S5	Uses relevant specialist terminology correctly	1
S6	Provides one piece of relevant information (eg data, graph, diagram) that is not mentioned in the briefing papers for the visit or case study	1
S7	Briefly discusses context (eg social/environmental/historical)	1
S8	Comments on implication of physics (eg benefits/risks)	1
S9	Explains how the practical relates to the visit or case study	1
	Maximum marks for this section	**9**

B: Planning

Ref	Criterion	Mark
P1	Lists all material required	1
P2	States how to measure one relevant quantity using the most appropriate instrument	1
P3	Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken	1
P4	States how to measure a second relevant quantity using the most appropriate instrument	1
P5	Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken	1
P6	Demonstrates knowledge of correct measuring techniques	1
P7	States which is the independent and which is the dependent variable	1
P8	Identifies and states how to control all other relevant variables to make it a fair test	1
P9	Comments on whether repeat readings are appropriate in this case	1
P10	Comments on safety	1
P11	Discusses how the data collected will be used	1
P12	Identifies the main sources of uncertainty and/or systematic error	1
P13	Draws an appropriately labelled diagram of the apparatus to be used	1
P14	Plan is well organised and methodical, using an appropriately sequenced step-by-step procedure	1
	Maximum marks for this section	**14**

C: Implementation and Measurements

Ref	Criterion	Mark
M1	Records all measurements using the correct number of significant figures, tabulating measurements where appropriate	1
M2	Uses correct units **throughout**	1
M3	Obtains an appropriate number of measurements	1
M4	Obtains measurements over an appropriate range	1
	Maximum marks for this section	**4**

D: Analysis

Ref	Criterion	Mark
A1	Produces a graph with appropriately labelled axes and with correct units	1
A2	Produces a graph with sensible scales	1
A3	Plots points accurately	1
A4	Draws line of best fit (either a straight line or a smooth curve)	1
A5	Comments on the trend/pattern obtained	1
A6	Derives relation between two variables or determines constant	1
A7	Discusses/uses related physics principles	1
A8	Attempts to qualitatively consider sources of error	1
A9	Suggests realistic modifications to reduce error/improve experiment	1
A10	Calculates uncertainties	1
A11	Provides a final conclusion	1
	Maximum marks for this section	**11**

E: Report

Ref	Criterion	Mark
R1	Summary contains few grammatical or spelling errors	1
R2	Summary is structured using appropriate subheadings	1
	Maximum marks for this section	**2**

Total marks for this unit	**40**

4.1 Introduction

Concept approach

This unit covers further mechanics, electric and magnetic fields and particle physics. The unit may be taught using either a concept approach or a context approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. This section of the specification is presented in a format for teachers who wish to use the concept approach.

Context approach

This unit is presented in a different format on page 91 for teachers who wish to use a context approach. The context approach begins with the consideration of an application that draws on many different areas of physics, and then the laws, theories and models of physics that apply to this application are studied. The context approach for this unit uses two contexts for teaching: transport and communications. Particle physics may be studied via the acceleration and detection of high-energy particles and the interpretation of experiments.

How Science Works

The QCA's GCE Science Criteria include *How Science Works* (see *Appendix 6*). This should be integrated with the teaching and learning of this unit.

It is expected that students will be given opportunities to use spreadsheets and computer models to analyse and present data, and make predictions while studying this unit.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed *in Appendix 6* (internal assessment may require these skills). They should communicate the outcomes of their investigations using appropriate scientific, technical and mathematical language, conventions and symbols.

Applications of physics should be studied using a range of contemporary contexts that relate to this unit.

4.2 Assessment information

Examination paper	This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not encountered before. The total number of marks available for this examination paper is 80. It contributes 20% to the Advanced GCE in Physics.
Calculator	It is recommended that students have access to a scientific calculator for this paper.
Formulae sheet	Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.

4.3 Further Mechanics

This topic covers momentum and circular motion.

This topic may be studied using applications that relate to, for example, a modern rail transport system.

Students will be assessed on their ability to:	Suggested experiments
73 use the expression $p = mv$	
74 investigate and apply the principle of conservation of linear momentum to problems in one dimension	Use of, for example, light gates and air track to investigate momentum.
75 investigate and relate net force to rate of change of momentum in situations where mass is constant (Newton's second law of motion)	Use of, for example, light gates and air track to investigate change in momentum.
76 derive and use the expression $E_k = p^2/2m$ for the kinetic energy of a non-relativistic particle	
77 analyse and interpret data to calculate the momentum of (non-relativistic) particles and apply the principle of conservation of linear momentum to problems in one and two dimensions	
78 explain and apply the principle of conservation of energy, and determine whether a collision is elastic or inelastic	
79 express angular displacement in radians and in degrees, and convert between those units	
80 explain the concept of angular velocity, and recognise and use the relationships $v = \omega r$ and $T = 2\pi/\omega$	
81 explain that a resultant force (centripetal force) is required to produce and maintain circular motion	

Students will be assessed on their ability to:	Suggested experiments
82 use the expression for centripetal force $F = ma = mv^2/r$ and hence derive and use the expressions for centripetal acceleration $a = v^2/r$ and $a = r\omega^2$.	Investigate the effect of m, v and r of orbit on centripetal force

4.4 Electric and Magnetic Fields

This topic covers Coulomb's law, capacitors, magnetic flux density and the laws of electromagnetic induction. This topic may be studied using applications that relate to, for example, communications and display techniques.

Students will be assessed on their ability to:	**Suggested experiments**
83 explain what is meant by an electric field and recognise and use the expression electric field strength $E = F/Q$	
84 draw and interpret diagrams using lines of force to describe radial and uniform electric fields qualitatively	Demonstration of electric lines of force between electrodes
85 use the expression $F = kQ_1Q_2/r^2$, where $k = 1/4\pi\varepsilon_0$ and derive and use the expression $E = kQ/r^2$ for the electric field due to a point charge	Use electronic balance to measure the force between two charges
86 investigate and recall that applying a potential difference to two parallel plates produces a uniform electric field in the central region between them, and recognise and use the expression $E = V/d$	
87 investigate and use the expression $C = Q/V$	Use a Coulometer to measure charge stored
88 recognise and use the expression $W = ½ QV$ for the energy stored by a capacitor, derive the expression from the area under a graph of potential difference against charge stored, and derive and use related expressions, for example, $W = ½ CV^2$	Investigate energy stored by discharging through series/parallel combination of light bulbs
89 investigate and recall that the growth and decay curves for resistor–capacitor circuits are exponential, and know the significance of the time constant RC	

Students will be assessed on their ability to:	Suggested experiments
90 recognise and use the expression $Q = Q_0\, e^{-t/RC}$ and derive and use related expressions, for exponential discharge in RC circuits, for example, $I = Io\, e^{-t/RC}$	Use of data logger to obtain I-t graph
91 explore and use the terms magnetic flux density B, flux Φ and flux linkage $N\Phi$	
92 investigate, recognise and use the expression $F = BIl \sin\theta$ and apply Fleming's left hand rule to currents	Electronic balance to measure effect of I and l on force
93 recognise and use the expression $F = Bqv \sin\theta$ and apply Fleming's left hand rule to charges	Deflect electron beams with a magnetic field
94 investigate and explain qualitatively the factors affecting the emf induced in a coil when there is relative motion between the coil and a permanent magnet and when there is a change of current in a primary coil linked with it	Use a data logger to plot V against t as a magnet falls through a coil of wire
95 investigate, recognise and use the expression $\varepsilon = -d(N\Phi)/dt$ and explain how it is a consequence of Faraday's and Lenz's laws	

4.5 Particle physics

This topic covers atomic structure, particle accelerators, and the standard quark-lepton model, enabling students to describe the behaviour of matter on a subatomic scale.

This topic is the subject of current research, involving the acceleration and detection of high-energy particles. It may be taught by exploring a range of experiments:

- alpha scattering and the nuclear model of the atom
- accelerating particles to high energies
- detecting and interpreting interactions between particles.

Students will be assessed on their ability to:	Suggested experiments
96 use the terms nucleon number (mass number) and proton number (atomic number)	
97 describe how large-angle alpha particle scattering gives evidence for a nuclear atom	
98 recall that electrons are released in the process of thermionic emission and explain how they can be accelerated by electric and magnetic fields	
99 explain the role of electric and magnetic fields in particle accelerators (linac and cyclotron) and detectors (general principles of ionisation and deflection only)	
100 recognise and use the expression $r = p/BQ$ for a charged particle in a magnetic field	
101 recall and use the fact that charge, energy and momentum are always conserved in interactions between particles and hence interpret records of particle tracks	

Students will be assessed on their ability to:	Suggested experiments
102 explain why high energies are required to break particles into their constituents and to see fine structure	
103 recognise and use the expression $\Delta E = c^2\Delta m$ in situations involving the creation and annihilation of matter and antimatter particles	
104 use the non-SI units MeV and GeV (energy) and MeV/c^2, GeV/c^2 (mass) and atomic mass unit u, and convert between these and SI units	
105 be aware of relativistic effects and that these need to be taken into account at speeds near that of light (use of relativistic equations not required)	
106 recall that in the standard quark-lepton model each particle has a corresponding antiparticle, that baryons (eg neutrons and protons) are made from three quarks, and mesons (eg pions) from a quark and an antiquark, and that the symmetry of the model predicted the top and bottom quark	
107 write and interpret equations using standard nuclear notation and standard particle symbols (eg π^+, e^-)	
108 use de Broglie's wave equation $\lambda = h/p$	

5.1 Introduction

Concept approach

This unit covers thermal energy, nuclear decay, oscillations, and astrophysics and cosmology. The unit may be taught using either a concept approach or a context approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. This section of the specification is presented in a format for teachers who wish to use the concept approach.

Context approach

This unit is presented in a different format on page 101 for teachers who wish to use a context approach. The context approach begins with the consideration of an application that draws on many different areas of physics, and then the laws, theories and models of physics that apply to this application are studied. The context approach for this unit uses two contexts for teaching this unit: Building design and cosmology.

How Science Works

The QCA's GCE Science Criteria includes *How Science Works* (see *Appendix 6*). This should be integrated with the teaching and learning of this unit.

It is expected that students will be given opportunities to use spreadsheets and computer models to analyse and present data, and make predictions while studying this unit.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed *in Appendix 6* (internal assessment may require these skills). They should communicate the outcomes of their investigations using appropriate scientific, technical and mathematical language, conventions and symbols.

Applications of physics should be studied using a range of contemporary contexts that relate to this unit.

5.2 Assessment information

Examination paper	This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not encountered before. The total number of marks available for this examination paper is 80. It contributes 20% to the Advanced GCE in Physics.
Calculator	It is recommended that students have access to a scientific calculator for this paper.
Formulae sheet	Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.

5.3 Thermal energy

This topic covers specific heat capacity, internal energy and the ideal gas equation.

This topic may be taught using applications that relate to, for example, space technology.

Students will be assessed on their ability to:	Suggested experiments
109 investigate, recognise and use the expression $\Delta E = mc\Delta\theta$	Measure specific heat capacity of a solid and a liquid using, for example, temperature sensor and data logger
110 explain the concept of internal energy as the random distribution of potential and kinetic energy amongst molecules	
111 explain the concept of absolute zero and how the average kinetic energy of molecules is related to the absolute temperature	
112 recognise and use the expression $\frac{1}{2} m\langle c^2\rangle = 3/2\, kT$	
113 use the expression $pV = NkT$ as the equation of state for an ideal gas	Use temperature and pressure sensors to investigate relationship between p and T Experimental investigation of relationship between p and V

Concept approach

5.4 Nuclear decay

This topic covers radioactive decay.

This topic may be taught using applications that relate to, for example, medical physics.

Students will be assessed on their ability to:	Suggested experiments
114 show an awareness of the existence and origin of background radiation, past and present	Measure background count rate
115 investigate and recognise nuclear radiations (alpha, beta and gamma) from their penetrating power and ionising ability	Investigate the absorption of radiation by paper, aluminium and lead (radiation penetration simulation software is a viable alternative)
116 describe the spontaneous and random nature of nuclear decay	
117 determine the half lives of radioactive isotopes graphically and recognise and use the expressions for radioactive decay: $dN/dt = -\lambda N$, $\lambda = \ln 2/t_{½}$ and $N = N_0 e^{-\lambda t}$	Measure the activity of a radioactive source Simulation of radioactive decay using, for example, dice
118 discuss the applications of radioactive materials, including ethical and environmental issues	

5.5 Oscillations

This topic covers simple harmonic motion and damping.

This topic may be taught using applications that relate to, for example, the construction of buildings in earthquake zones.

Students will be assessed on their ability to:	Suggested experiments
119 recall that the condition for simple harmonic motion is $F = -kx$, and hence identify situations in which simple harmonic motion will occur	
120 recognise and use the expressions $a = -\omega^2 x$, $a = -A\omega^2 \cos \omega t$, $v = A\omega \sin \omega t$, $x = A\cos \omega t$ and $T = 1/f = 2\pi/\omega$ as applied to a simple harmonic oscillator	
121 obtain a displacement – time graph for an oscillating object and recognise that the gradient at a point gives the velocity at that point	Use a motion sensor to generate graphs of SHM
122 recall that the total energy of an undamped simple harmonic system remains constant and recognise and use expressions for total energy of an oscillator	
123 distinguish between free, damped and forced oscillations	
124 investigate and recall how the amplitude of a forced oscillation changes at and around the natural frequency of a system and describe, qualitatively, how damping affects resonance	Use, for example, vibration generator to investigate forced oscillations
125 explain how damping and the plastic deformation of ductile materials reduce the amplitude of oscillation	Use, for example, vibration generator to investigate damped oscillations

5.6 Astrophysics and cosmology

This topic covers the physical interpretation of astronomical observations, the formation and evolution of stars, and the history and future of the universe.

Students will be assessed on their ability to:	Suggested experiments
126 use the expression $F = Gm_1m_2/r^2$	
127 derive and use the expression $g = -Gm/r^2$ for the gravitational field due to a point mass	
128 recall similarities and differences between electric and gravitational fields	
129 recognise and use the expression relating flux, luminosity and distance $F = L/4\pi d^2$ application to standard candles	
130 explain how distances can be determined using trigonometric parallax and by measurements on radiation flux received from objects of known luminosity (standard candles)	
131 recognise and use a simple Hertzsprung-Russell diagram to relate luminosity and temperature. Use this diagram to explain the life cycle of stars	
132 recognise and use the expression $L = \sigma T^4$ x surface area, (for a sphere $L = 4\pi r^2\sigma T^4$) (Stefan-Boltzmann law) for black body radiators	
133 recognise and use the expression: $\lambda_{max}T = 2.898 \times 10^{-3}$ m K (Wien's law) for black body radiators	

Concept approach

Students will be assessed on their ability to:	Suggested experiments
134 recognise and use the expressions $z = \Delta\lambda/\lambda \approx \Delta f/f \approx v/c$ for a source of electromagnetic radiation moving relative to an observer and $v = H_o d$ for objects at cosmological distances	
135 be aware of the controversy over the age and ultimate fate of the universe associated with the value of the Hubble Constant and the possible existence of dark matter	
136 explain the concept of nuclear binding energy, and recognise and use the expression $\Delta E = c^2\Delta m$ and use the non SI atomic mass unit (u) in calculations of nuclear mass (including mass deficit) and energy	
137 describe the processes of nuclear fusion and fission	
138 explain the mechanism of nuclear fusion and the need for high densities of matter and high temperatures to bring it about and maintain it	

6.1 Unit description

Introduction

This unit requires that students plan an experiment, carry out an experiment, record measurements, analyse their own results and draw conclusions.

This unit may be completed at any time during the second year of the course but it would be more appropriate to administer this assessment near the end of the A2 year. This assessment should take no more than 2 hours to complete.

All candidates within one class may produce a plan for the same experiment as each other and do the same practical work; however it is vital that candidates demonstrate that the assessed work that they produce is entirely their own work.

If more than one class of students take this assessment at different times, then the groups must submit different plans for assessment to prevent plagiarism.

Candidates' work may be based on briefing material provided by Edexcel or briefing material that is devised by the centre. The brief for this assessment is to be set by the teacher, not the student; however, briefs should reflect the interests of students where possible.

Planning component

The planning component of this assessment may be done at a different time to the other components. Plans produced by the students may be based on either a briefing provided by the centre or a briefing provided by Edexcel.

Experiment and analysis of results

The experiment and analysis of results may be based on the plan produced by each individual student in the first part of this assessment or it may be based on a plan that is provided by Edexcel or a plan that is devised by the centre. If the centre produces the plan on which the experiment is based, it is vital that the plan provides the opportunity for students to achieve the full range of marks that are available. Centre devised plans should contain some flaws so that students are able to modify the experiment while they are doing it and suggest improvements. Centre-devised plans should ensure that a non-linear relationship exists between the variables that are investigated.

Use of ICT	Candidates may use a word processor to produce their report, although they will not gain any extra marks for doing so. In order to ensure that candidates demonstrate their understanding of the principles and techniques involved in analysing data, the use of ICT, eg spreadsheets, may not be used for analysing data for this unit.
Draft work	Candidates should do a variety of practical work during the course so that they develop the necessary skills to succeed in this unit. They should not, therefore, submit draft work for checking. However, teachers should check candidates' plans for health and safety issues before they implement the plan. Neither the plan nor any practical work submitted for this unit should be returned to candidates for them to improve it.
How science works	This unit will cover the following aspects of how science works as listed in *Appendix 6: How science works* 2, 3, 4, 5, 6, 8, and 9.

6.2 Assessment information

Introduction	Candidates must produce a written plan for an experiment. They must also produce a laboratory report for an experiment that they have carried out. The experiment that they carry out may be based on the plan that they have produced; alternatively, the experiment that they carry out may be based on a plan that is either centre-devised or Edexcel-devised.

Plan

Students should not be given advanced details of the plan that they will carry out; they will be expected to draw on their experience of practical work that they have completed during the course for this assessment. Students should not take into the classroom any materials for this assessment.

If more than one group of students take this assessment at different times, then the groups must submit different plans for assessment to prevent plagiarism.

Centre-devised plans and experiments will not required Edexcel's approval; however, centre devised assessments must ensure that students have the opportunity to gain all the marks in the mark scheme.

If teachers are going to mark the plan they should not provide students with feedback on their plan until they have carried out their experiment and analysed their results. At this stage teachers could either:

i) photocopy the plan, mark the original plan and provide students with the photocopy in the laboratory so that they can carry out their plan

ii) collect in the plan, not mark it and return it to students in the laboratory under supervised conditions so that they can carry out their plan

iii) mark the plan and ask students to do an experiment based on a different plan.

If teachers are not going to mark the plan, they should collect the plan and check its feasibility. At this stage the teacher could either:

i) return it to students in the laboratory under supervised conditions so they can carry out their plan

ii) ask students to do an experiment based on a different plan.

Practical work	Students will not need to take any documents into the laboratory for the practical aspect of this assessment although they may bring a scientific calculator. Teachers should issue students with the (unmarked) plan of the practical that they are to carry out. If necessary, teachers may allow students to analyse results under supervision in the next lesson. In this situation, teachers must collect in the work produced by their students. Teachers should not mark the practical work. In the following lesson, the documents should be returned to students under supervised conditions. Students should not have access to any other sources of information while they are completing the analysis of their results. Teachers who opt for internal assessment should mark the practical work after students have completed the analysis of their results.
Assessing work	The assessment criteria are shown in the next section. Each criterion scores a maximum of 1 mark. The criteria are not hierarchical. The assessment of planning, recording and analysis is based on written evidence in the form of a report.
For centres marking the written report	The written evidence should be annotated. This can be done by writing the skill code eg A15 near to the appropriate section of the report and ticking the box A15 on the grid below. The marks given for the report should be submitted to Edexcel on the mark sheets as shown in the Edexcel *Coursework Guide* that will be available on the Edexcel website www.edexcel.com.
For centres not marking the written report	The written report should be submitted to Edexcel as discussed in the Edexcel *Coursework Guide* that will be available on the Edexcel website www.edexcel.com.
Supervision	Students must work on their own for each part of this assessment. All aspects of this assessment must be done under supervised conditions.

Assistance for students	Students may require assistance whereby the teacher needs to tell the student what they have to do. Assistance in this respect carries a penalty. The teacher should record details of any assistance provided on the student's work.
Important reminder	Students should submit their work for assessment **once only**. **Neither** the plan **nor** the experiment should be given back to students to be improved.

6.3 Assessment criteria

A: Planning

Ref	Criterion	Mark
P1	Identifies the most appropriate apparatus required for the practical in advance	1
P2	Provides clear details of apparatus required including approximate dimensions and/or component values (for example, dimensions of items such as card or string, value of resistor)	1
P3	Draws an appropriately labelled diagram of the apparatus to be used	1
P4	States how to measure one quantity using the most appropriate instrument	1
P5	Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken	1
P6	States how to measure a second quantity using the most appropriate instrument	1
P7	Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken	1
P8	Demonstrates knowledge of correct measuring techniques	1
P9	Identifies and states how to control **all** other **relevant** quantities to make it a fair test	1
P10	Comments on whether repeat readings are appropriate for this experiment	1
P11	Comments on **all** relevant safety aspects of the experiment	1
P12	Discusses how the data collected will be used	1
P13	Identifies the main sources of uncertainty and/or systematic error	1
P14	Plan contains few grammatical or spelling errors	1
P15	Plan is structured using appropriate subheadings	1
P16	Plan is clear on first reading	1
	Maximum marks for this section	**16**

B: Implementation and measurements

Ref	Criterion	Mark
M1	Records all measurements with appropriate precision, using a table where appropriate	1
M2	Readings show appreciation of uncertainty	1
M3	Uses correct units throughout	1
M4	Refers to initial plan while working and modifies if appropriate	1
M5	Obtains an appropriate number of measurements	1
M6	Obtains measurements over an appropriate range	1
	Maximum marks for this section	**6**

C: Analysis

Ref	Criterion	Mark
A1	Produces a graph with appropriate axes (including units)	1
A2	Produces a graph using appropriate scales	1
A3	Plots points accurately	1
A4	Draws line of best fit (either a straight line or a smooth curve)	1
A5	Derives relation between two variables or determines constant	1
A6	Processes and displays data appropriately to obtain a straight line where possible, for example, using a log/log graph	1
A7	Determines gradient using large triangle	1
A8	Uses gradient with correct units	1
A9	Uses appropriate number of significant figures throughout	1
A10	Uses relevant physics principles correctly	1
A11	Uses the terms *precision* and either *accuracy* or *sensitivity* appropriately	1
A12	Discusses more than one source of error qualitatively	1
A13	Calculates errors quantitatively	1
A14	Compounds errors correctly	1
A15	Discusses realistic modifications to reduce error/improve experiment	1
A16	States a valid conclusion clearly	1
A17	Discusses final conclusion in relation to original aim of experiment	1
A18	Suggests relevant further work	1
	Maximum marks for this section	**18**
	Total marks for this unit	**40**

CONTEXT-LED APPROACH BASED ON THE SALTERS HORNERS ADVANCED PHYSICS PROJECT

The following section shows how the specification may be taught using the context-led approach.

7.1 Introduction

Context approach

This unit covers mechanics and materials. The unit may be taught using either a concept approach or a context approach. This section of the specification is presented in a format for teachers who wish to use the context approach. The context approach begins with the consideration of an application that draws on many different areas of physics, and then the laws, theories and models of physics that apply to this application are studied. The context approach for this unit uses three different contexts: sports, the production of sweets and biscuits and spare part surgery.

Concept approach

This unit is presented in a different format on page 17 for teachers who wish to use a concept approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. The concept approach is split into two topics: mechanics and materials.

How Science Works

The QCA's GCE Science Criteria includes *How Science Works* (see *Appendix 6*). This should be integrated with the teaching and learning of this unit.

It is expected that students will be given opportunities to use spreadsheets and computer models to analyse and present data, and make predictions while studying this unit.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed *in Appendix 6* (internal assessment may require these skills). Students should communicate the outcomes of their investigations using appropriate scientific, technical and mathematical language, conventions and symbols.

Applications of physics should be studied using a range of contemporary contexts that relate to this unit.

7.2 Assessment information

Examination paper	This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not encountered before. The total number of marks available for this examination paper is 80. It contributes 40% to AS Physics and 20% to the Advanced GCE in Physics.
Calculator	It is recommended that students have access to a scientific calculator for this paper.
Formulae sheet	Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.

7.3 Higher, faster, stronger (HFS)

In this topic, students use video clips, ICT and laboratory practical activities to study the physics behind a variety of sports:

- speed and acceleration in sprinting and jogging
- work and power in weightlifting
- forces and equilibrium in rock climbing
- forces and projectiles in tennis
- force and energy in bungee jumping.

There are opportunities for students to collect and analyse data using a variety of methods, and to communicate their knowledge and understanding using appropriate terminology.

Students will be assessed on their ability to:	Suggested experiments
1 use the equations for uniformly accelerated motion in one dimension: $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$	
2 demonstrate an understanding of how ICT can be used to collect data for, and display, displacement/time and velocity/time graphs for uniformly accelerated motion and compare this with traditional methods in terms of reliability and validity of data	Determine speed and acceleration, for example, use light gates
3 identify and use the physical quantities derived from the slopes and areas of displacement/time and velocity/time graphs, including cases of non-uniform acceleration	
4 investigate, using primary data, recognise and make use of the independence of vertical and horizontal motion of a projectile moving freely under gravity	Strobe photography or video camera to analyse motion
5 distinguish between scalar and vector quantities and give examples of each	

Students will be assessed on their ability to:	Suggested experiments
6 resolve a vector into two components at right angles to each other by drawing and by calculation	
7 combine two coplanar vectors at any angle to each other by drawing, and at right angles to each other by calculation	
8 draw and interpret free-body force diagrams to represent forces on a particle or on an extended but rigid body, using the concept of *centre of gravity* of an extended body	Find the centre of gravity of an irregular rod
9 investigate, by collecting primary data, and use $\Sigma F = ma$ in situations where m is constant (Newton's first law of motion ($a = 0$) and second law of motion)	Use an air track to investigate factors affecting acceleration
10 use the expressions for gravitational field strength $g = F/m$ and weight $W = mg$	Measure g using, for example, light gates Estimate, and then measure, the weight of familiar objects
11 identify pairs of forces constituting an interaction between two bodies (Newton's third law of motion)	
12 use the relationship $E_k = ½ mv^2$ for the kinetic energy of a body	
13 use the relationship $\Delta E_{grav} = mg\Delta h$ for the gravitational potential energy transferred near the Earth's surface	
14 investigate and apply the principle of conservation of energy including use of work done, gravitational potential energy and kinetic energy	Use, for example, light gates to investigate the speed of a falling object

Students will be assessed on their ability to:	Suggested experiments
15 use the expression for work $\Delta W = F\Delta s$ including calculations when the force is not along the line of motion	
17 investigate and calculate power from the rate at which work is done or energy transferred	Estimate power output of electric motor (see also outcome 53)
16 understand some applications of mechanics, for example, to safety or to sports	

7.4 Good enough to eat (EAT)

This topic uses a case study of the production of sweets and biscuits:

- measuring and controlling the flow of a viscous liquid
- mechanical testing of products.

There are opportunities for students to develop practical skills and techniques and thus to carry out experimental and investigative activities.

Students will be assessed on their ability to:	Suggested experiments
18 understand and use the terms *density*, *laminar flow*, *streamline flow*, *terminal velocity*, *turbulent flow*, *upthrust* and *viscous drag*, for example, in transport design or in manufacturing	
19 recall, and use primary or secondary data to show that the rate of flow of a fluid is related to its viscosity	
20 recognise and use the expression for Stokes's Law, $F = 6\pi\eta rv$ and upthrust = weight of fluid displaced	
21 investigate, using primary or secondary data, and recall that the viscosities of most fluids change with temperature. Explain the importance of this for industrial applications	
25 investigate elastic and plastic deformation of a material and distinguish between them	
26 explore and explain what is meant by the terms *brittle*, *ductile*, *hard*, *malleable*, *stiff* and *tough*. Use these terms, give examples of materials exhibiting such properties and explain how these properties are used in a variety of applications, for example, safety clothing, foodstuffs	

7.5 Spare part surgery (SUR)

A study of the physics associated with spare part surgery for joint replacements and lens implants:

- mechanical properties of bone and replacement materials
- 'designer' materials for medical uses.

There are opportunities for students to consider ethical issues relating to surgical intervention, and to learn how new scientific knowledge is validated and communicated through peer-reviewed publication.

Students will be assessed on their ability to:	Suggested experiments
22 obtain and draw force–extension, force–compression, and tensile/compressive stress-strain graphs. Identify the *limit of proportionality*, *elastic limit* and *yield point*	Obtain graphs for, for example, copper wire, nylon and rubber
23 investigate, and use Hooke's law, $F = k\Delta x$, and know that it applies only to some materials	
24 explain the meaning of, use and calculate *tensile/compressive stress*, *tensile/compressive strain*, *strength*, *breaking stress*, *stiffness* and *Young Modulus*. Obtain the Young modulus for a material	Investigations could include, for example, copper and rubber
27 calculate the elastic strain energy E_{el} in a deformed material sample, using the expression $E_{el} = ½ Fx$, and from the area under its force/extension graph	

8.1 Introduction

Context approach

This unit covers waves, electricity and the nature of light. The unit may be taught using either a concept approach or a context approach. This section of the specification is presented in a format for teachers who wish to use the context approach. The context approach begins with the consideration of an application that draws on many different areas of physics, and then the laws, theories and models of physics that apply to this application are studied. The context approach for this unit uses three different contexts: music, technology in space and archaeology.

Concept approach

This unit is presented in a different format on page 23 for teachers who wish to use a concept approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. The concept approach is split into three topics: waves, electricity and the nature of light.

How Science Works

The QCA's GCE Science Criteria includes *How Science Works* (see *Appendix 6*). This should be integrated with the teaching and learning of this unit.

It is expected that students will be given opportunities to use spreadsheets and computer models to analyse and present data, and make predictions while studying this unit.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed *in Appendix 6* (internal assessment may require these skills). They should communicate the outcomes of their investigations using appropriate scientific, technical and mathematical language, conventions and symbols.

Applications of physics should be studied using a range of contemporary contexts that relate to this unit.

8.2 Assessment information

Examination paper	This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not encountered before. The total number of marks available for this examination paper is 80. It contributes 40% to AS Physics and 20% to the Advanced GCE in Physics.
Calculator	It is recommended that students have access to a scientific calculator for this paper.
Formulae sheet	Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.

8.3 The Sound of Music (MUS)

A study of music and recorded sound, focusing on the production of sound by musical instruments and the operation of a CD player:

- synthesised and 'live' sounds
- standing waves in string and wind instruments
- reading a CD by laser.

Waves and photons are used to model the behaviour of light.

There are opportunities for students to develop ICT skills and other skills relating to practical investigation and to communication.

Students discuss environmental issues related to noise.

Students will be assessed on their ability to:	Suggested experiments
28 understand and use the terms *amplitude*, *frequency*, *period*, *speed* and *wavelength*	Wave machine or computer simulation of wave properties
29 identify the different regions of the electromagnetic spectrum and describe some of their applications	
30 use the wave equation $v = f\lambda$	
31 recall that a sound wave is a longitudinal wave which can be described in terms of the displacement of molecules	Demonstration using a loudspeaker Demonstration using waves on a long spring
32 use graphs to represent transverse and longitudinal waves, including standing waves	
33 explain and use the concepts of wavefront, coherence, path difference, superposition and phase	Demonstration with ripple tank
34 recognise and use the relationship between phase difference and path difference	

Students will be assessed on their ability to:	Suggested experiments
35 explain what is meant by a *standing (stationary) wave*, investigate how such a wave is formed, and identify nodes and antinodes	Melde's experiment, sonometer
36 recognise and use the expression for refractive index ${}_1\mu_2 = \sin i/\sin r = v_1/v_2$, determine refractive index for a material in the laboratory, and predict whether total internal reflection will occur at an interface using critical angle	
37 investigate and explain how to measure refractive index	Measure the refractive index of both solids and liquids
38 discuss situations that require the accurate determination of refractive index	
39 investigate and explain what is meant by *plane polarised light*	Models of structures to investigate stress concentrations
40 investigate and explain how to measure the rotation of the plane of polarisation	
44 recall that, in general, waves are transmitted and reflected at an interface between media	Demonstration using a laser
45 explain how different media affect the transmission/reflection of waves travelling from one medium to another	
63 explain how the behaviour of light can be described in terms of waves and photons	
68 explain atomic line spectra in terms of transitions between discrete energy levels	Demonstration using gas-filled tubes

8.4 Technology in Space (SPC)

This unit focuses on a satellite whose remote sensing and other instruments are run from a solar power supply:

- illuminating solar cells
- operation of solar cells
- combining sources of emf
- radar imaging.

Mathematical models are developed to describe ohmic behaviour and the variation of resistance with temperature. Simple conceptual models are used for the flow of charge in a circuit, for the operation of a photocell, and for the variation of resistance with temperature.

Waves and photons are used to model the behaviour of light. Through a historical exploration of the photoelectic effect, students learn something of the provisional nature of scientific knowledge.

There are opportunities to develop ICT skills using the internet, spreadsheets and software for data analysis and display.

Through discussing the funding and execution of space missions, students have an opportunity to consider ethical and environmental issues and some of the decisions made by society regarding the use of technology.

Students will be assessed on their ability to:	Suggested experiments
29 identify the different regions of the electromagnetic spectrum and describe some of their applications	
69 define and use radiation flux as power per unit area	
67 recognise and use the expression $E = hf$ to calculate the highest frequency of radiation that could be emitted in a transition across a known energy band gap or between known energy levels	

Students will be assessed on their ability to:	Suggested experiments
66 use the non-SI unit, the electronvolt (eV) to express small energies	
64 recall that the absorption of a photon can result in the emission of a photoelectron	Demonstration of discharge of a zinc plate by ultra violet light
65 understand and use the terms threshold frequency and work function and recognise and use the expression $hf = \phi + \frac{1}{2} mv^2_{max}$	
63 explain how the behaviour of light can be described in terms of waves and photons	
71 explain how wave and photon models have contributed to the understanding of the nature of light	
50 describe electric current as the rate of flow of charged particles and use the expression $I = \Delta Q / \Delta t$	
51 use the expression $V = W/Q$	
52 recognise, investigate and use the relationships between current, voltage and resistance, for series and parallel circuits, and know that these relationships are a consequence of the conservation of charge and energy	Measure current and voltage in series and parallel circuits Use ohmmeter to measure total resistance of series/parallel circuits
53 investigate and use the expressions $P = VI$, $W = VIt$. Recognise and use related expressions, for example, $P = I^2R$ and $P = V^2/R$	Measure the efficiency of an electric motor (see also outcome 17)
54 use the fact that resistance is defined by $R = V/I$ and that Ohm's Law is a special case when $I \propto V$	

Students will be assessed on their ability to:	Suggested experiments
55 demonstrate an understanding of how ICT may be used to obtain current-potential difference graphs, including non-ohmic materials and compare this with traditional techniques in terms of reliability and validity of data	
56 interpret current-potential difference graphs, including non-ohmic materials	Investigate *I*-*V* graphs for filament lamp, diode & thermistor
70 recognise and use the expression efficiency = [useful energy (or power) output]/[total energy (or power) input]	
59 define and use the concepts of emf and internal resistance and distinguish between emf and terminal potential difference	Measure the emf and internal resistance of a cell, for example, a solar cell
60 investigate and recall that the resistance of metallic conductors increases with increasing temperature and that the resistance of negative temperature coefficient thermistors decreases with increasing temperature	Use of ohmmeter and temperature sensor
61 use $I = nqvA$ to explain the large range of resistivities of different materials	Demonstration of slow speed of ion movement during current flow
62 explain, qualitatively, how changes of resistance with temperature may be modelled in terms of lattice vibrations and number of conduction electrons	
46 explore and explain how a pulse-echo technique can provide details of the position and/or speed of an object and describe applications that use this technique	

Students will be assessed on their ability to:	Suggested experiments
47 explain qualitatively how the movement of a source of sound or light relative to an observer/detector gives rise to a shift in frequency (Doppler effect) and explore applications that use this effect	Demonstration using a ripple tank or computer simulation
48 explain how the amount of detail in a scan may be limited by the wavelength of the radiation or by the duration of pulses	
49 discuss the social and ethical issues that need to be considered, for example, when developing and trialling new medical techniques on patients or when funding a space mission	
72 explore how science is used by society to make decisions, for example, the viability of solar cells as a replacement for other energy sources, the uses of remote sensing	

8.5 Digging up the Past (DIG)

The excavation of an archaeological site, from geophysical surveying to artefact analysis and dating:

- resistivity surveying
- artefact analysis by X-ray diffraction
- artefact analysis by electron microscopy.

Photons are used to model the behaviour of light, and waves to model electron behaviour.

There are opportunities to develop ICT skills using the internet and software simulations.

Through case studies, students learn how data can help resolve conflict and uncertainty, and how new knowledge is disseminated and validated.

There are opportunities for students to consider ethical issues concerning the digging of archaeological sites and removal of artefacts for scientific study.

Students will be assessed on their ability to:	Suggested experiments
57 investigate and use the relationship $R = \rho l/A$	Measure resisitivity of a metal and polythene
58 investigate and explain how the potential along a uniform current-carrying wire varies with the distance along it and how this variation can be made use of in a potential divider	Use a digital voltmeter to investigate 'output' of a potential divider
29 identify the different regions of the electromagnetic spectrum and describe some of their applications	
41 investigate and recall that waves can be diffracted and that substantial diffraction occurs when the size of the gap or obstacle is similar to the wavelength of the wave	Demonstration using a ripple tank

Students will be assessed on their ability to:	Suggested experiments
42 explain how diffraction experiments provide evidence for the wave nature of electrons	
48 explain how the amount of detail in a scan may be limited by the wavelength of the radiation or by the duration of pulses	
43 discuss how scientific ideas may change over time, for example, our ideas on the particle/wave nature of electrons	

9.1 Unit description

Introduction

This unit requires that students undertake **either** a case study involving an application of physics and a related practical, **or** a physics-based visit and a related practical. The teacher, not the student, identifies the visit or case study that students will be doing. All candidates may do the same case study or the same visit; however it is vital that candidates demonstrate that the assessed work that they produce is entirely their own work.

This unit may be completed at any time during the AS course but it would be more appropriate to administer this assessment near the end of the AS year.

Case study

Edexcel will provide case studies for five different topics. Centres may either use one of the case studies provided by Edexcel or devise their own case study to match local needs and the interests of their candidates. Centre-devised case studies will not require approval from Edexcel; however, it is the responsibility of the centre to ensure that centre-devised case studies match the assessment criteria for this unit and that students have the opportunity to gain all the marks in the mark scheme. Candidates may all do the same case study or they may do different case studies. If all candidates do the same case study then they must ensure that work submitted for assessment is their own. There should be a connection between the case study and the practical work that is undertaken for this unit. For example a case study might be based on an application of Quantum Tunnelling Composite. This would offer the opportunity for practical work relating compressive force to resistance in this type of material. Ideally the case study should deal with concepts covered within the AS specification but this is not a requirement for the assessment of this unit.

Visit

The visit is intended to bring candidates into direct contact with a real-life example of physics in use. There should be a connection between the visit and the practical work that is undertaken for this unit. For example candidates might visit a church or concert hall. A related practical could be to investigate the relationship between the length of an organ pipe (using a glass tube to represent the organ pipe) and the frequency of its sound at resonance. The teacher or the host may provide briefing materials for the visit.

Practical	The practical that relates to the case study or visit should give candidates the opportunity to be assessed in four skill areas: ■ summarising details of a visit or case study ■ planning a practical ■ implementation and recording of measurements ■ analysis of results and drawing conclusions. The planning, implementation and analysis aspects of the practical work must be carried out individually and under supervision. The practical should lead to a graph relating two measured variables. Ideally the candidate should then attempt to derive the equation relating the two variables or a relevant quantity to the topic, for example the value of resisitivity for a particular material.
Use of ICT	Candidates may use a word processor to produce their summary of the visit or the case study, although they will not gain any extra marks for doing so. In order to ensure that candidates demonstrate their understanding of the principles and techniques involved in analysing data, the use of ICT, eg spreadsheets, may not be used for analysing data for this unit.
Draft work	Students should carry out a variety of practical work during the course so that they develop the necessary skills to succeed in this unit. They should **not**, therefore, submit draft assessment work for checking. However, teachers should check students' plans for health and safety issues. Work submitted for this unit must **not** be returned to students for them to improve it.
How Science Works	This unit will cover the following aspects of *how science works* as listed in *Appendix 6: How science works* 2, 3, 4, 5, 6, 8, and 9.

9.2 Assessment information

Summary of visit or case study	Students should produce a brief summary of the case study or physics-based visit as homework. It is recommended that students word process this part of the assessment. The summary should be between 500–600 words.
Plan	Students may be given the title of the experiment that they are to plan and carry out in advance. The plan should be produced under supervised conditions in class in the students' own handwriting. Students should not take any documents into the classroom as they should have gained sufficient experience of planning practical work during normal practical lessons. Teachers should collect in the plan at the end of the session to check for health and safety issues. The plan will need to be returned to students so that they can carry out their plan. At this stage teachers could either: i) photocopy the plan, mark the plan if it is to be internally assessed, and provide students with the photocopy in the laboratory so that they can carry out their plan ii) collect in the plan, not mark it and return it to students in the laboratory under supervised conditions so that they can carry out their plan.
Practical	The practical work should be carried out under supervised conditions in a separate session from the planning session. Unmarked plans should be returned to students so that they can carry out the experiment that they have planned. Students should work individually. If necessary, teachers may allow students to analyse results under supervision in their next lesson. In this situation, teachers must collect in the written work produced by their students. Teachers should not mark the plan or practical work. In the next lesson, the documents should be returned to students under supervised conditions for analysis. Students should not have access to any other sources of information while they are completing the analysis of their results

Assessing work	The assessment criteria are shown in the next section. Each criterion scores a maximum of 1 mark. The criteria are not hierarchical. The assessment of the summary of the visit or the case study, together with the planning, the recording of measurements and the analysis is based on documents produced by the students.
For centres marking the written report	The marks for the report should be submitted to Edexcel on the mark sheet for centres provided in the *Edexcel Coursework Guide* that will be available on the Edexcel website www.edexcel.com. Each piece of work should be annotated by the teacher. This can be done by writing the skill code eg A10 near to the appropriate section of the report and ticking the box A10 on the grid below.
For centres not marking the written report	The written report should be submitted to Edexcel as discussed in the Edexcel *Coursework Guide* that will be available on the Edexcel website www.edexcel.com.
Guidance to students	Teachers may provide guidance to students without penalty. Guidance is feedback that a teacher might reasonably be expected to give to a student who asks questions about the work that they are carrying out. In effect, the teacher is being used as a resource. Students may require assistance whereby the teacher needs to tell the student what they have to do. Assistance in this respect carries a penalty. The teacher should record details of any assistance provided on the report.
Important	Students should submit their work for assessment **once** only. Internally assessed work should **not** be given back to students to be improved.

9.3 Assessment criteria

A: Summary of case study or physics-based visit

Ref	Criterion	Mark
S1	Carries out a visit **OR** uses library, consulting a **minimum of three** different sources of information (eg books/websites/journals/magazines/case study provided by Edexcel/manufacturers' data sheets)	1
S2	States details of visit venue **OR** provides **full** details of sources of information	1
S3	Provides a brief description of the visit **OR** case study	1
S4	Makes correct statement on relevant physics principles	1
S5	Uses relevant specialist terminology correctly	1
S6	Provides one piece of relevant information (eg data, graph, diagram) that is not mentioned in the briefing papers for the visit or case study	1
S7	Briefly discusses context (eg social/environmental/historical)	1
S8	Comments on implication of physics (eg benefits/risks)	1
S9	Explains how the practical relates to the visit or case study	1
	Maximum marks for this section	**9**

B: Planning

Ref	Criterion	Mark
P1	Lists all material required	1
P2	States how to measure one relevant quantity using the most appropriate instrument	1
P3	Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken	1
P4	States how to measure a second relevant quantity using the most appropriate instrument	1
P5	Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken	1
P6	Demonstrates knowledge of correct measuring techniques	1
P7	States which is the independent and which is the dependent variable	1
P8	Identifies and states how to control all other relevant variables to make it a fair test	1
P9	Comments on whether repeat readings are appropriate in this case	1
P10	Comments on safety	1
P11	Discusses how the data collected will be used	1
P12	Identifies the main sources of uncertainty and/or systematic error	1
P13	Draws an appropriately labelled diagram of the apparatus to be used	1
P14	Plan is well organised and methodical, using an appropriately sequenced step-by-step procedure	1
	Maximum marks for this section	**14**

C: Implementation and Measurements

Ref	Criterion	Mark
M1	Records all measurements using the correct number of significant figures, tabulating measurements where appropriate	1
M2	Uses correct units **throughout**	1
M3	Obtains an appropriate number of measurements	1
M4	Obtains measurements over an appropriate range	1
	Maximum marks for this section	**4**

D: Analysis

Ref	Criterion	Mark
A1	Produces a graph with appropriately labelled axes and with correct units	1
A2	Produces a graph with sensible scales	1
A3	Plots points accurately	1
A4	Draws line of best fit (either a straight line or a smooth curve)	1
A5	Comments on the trend/pattern obtained	1
A6	Derives relation between two variables or determines constant	1
A7	Discusses/uses related physics principles	1
A8	Attempts to qualitatively consider sources of error	1
A9	Suggests realistic modifications to reduce error/improve experiment	1
A10	Calculates uncertainties	1
A11	Provides a final conclusion	1
	Maximum marks for this section	**11**

E: Report

Ref	Criterion	Mark
R1	Summary contains few grammatical or spelling errors	1
R2	Summary is structured using appropriate subheadings	1
	Maximum marks for this section	**2**

Total marks for this unit	**40**

10.1 Introduction

Context approach

This unit covers further mechanics, electric and magnetic fields, and particle physics. The unit may be taught using either a concept approach or a context approach. This section of the specification is presented in a format for teachers who wish to use the context approach. The context approach begins with the consideration of an application that draws on many different areas of physics, and then the laws, theories and models of physics that apply to this application are studied. The context approach for this unit uses two different contexts: transport and communications. Particle physics is studied via the acceleration and detection of high-energy particles and the interpretation of experiments.

Concept approach

This unit is presented in a different format on page 41 for teachers who wish to use a concept approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. The concept approach is split into three topics: further mechanics, electric and magnetic fields and particle physics.

How Science Works

The QCA's GCE Science Criteria include *How Science Works* (see *Appendix 6*). This should be integrated with the teaching and learning of this unit.

It is expected that students will be given opportunities to use spreadsheets and computer models to analyse and present data, and make predictions while studying this unit.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed *in Appendix 6* (internal assessment may require these skills). They should communicate the outcomes of their investigations using appropriate scientific, technical and mathematical language, conventions and symbols.

Applications of physics should be studied using a range of contemporary contexts that relate to this unit.

10.2 Assessment information

Examination paper	This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not seen before. The total number of marks available for this examination paper is 80. It contributes 20% to the Advanced GCE in Physics.
Calculator	It is recommended that students have access to a scientific calculator for this paper.
Formulae sheet	Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.

10.3 Transport on Track (TRA)

A study of a modern rail transport system with an emphasis on safety and control:

- track circuits and signalling
- sensing speed
- mechanical braking
- regenerative and eddy current braking
- crash-proofing.

Students use mathematical models to describe the behaviour of moving vehicles and to model electromagnetic induction and capacitor discharge.

There are opportunities to develop information and communication technology skills.

There are opportunities for students to discuss ethical, environmental and other issues relating to decisions about transport taken by government, by transport companies and by individuals.

Students will be assessed on their ability to:	Suggested experiments
73 use the expression $p = mv$	
74 investigate and apply the principle of conservation of linear momentum to problems in one dimension	Use of, for example, light gates and air track to investigate momentum
75 investigate and relate net force to rate of change of momentum in situations where mass is constant (Newton's second law of motion)	Use of, for example, light gates and air track to investigate change in momentum
78 explain and apply the principle of conservation of energy, and determine whether a collision is elastic or inelastic	
87 investigate and use the expression $C = Q/V$	

Students will be assessed on their ability to:	Suggested experiments
89 investigate and recall that the growth and decay curves for resistor–capacitor circuits are exponential, and know the significance of the time constant *RC*	
90 recognise and use the expression $Q = Q_0\ e^{-t/RC}$ and derive and use related expressions, for exponential discharge in RC circuits, for example, $I = I_o\ e^{-t/RC}$	Use of data logger to obtain I-t graph
91 explore and use the terms magnetic flux density *B*, flux Φ and flux linkage $N\Phi$	
92 investigate, recognise and use the expression $F = BIl \sin \theta$ and apply Fleming's left hand rule to currents	Electronic balance to measure effect of *I* and *l* on force
94 investigate and explain qualitatively the factors affecting the emf induced in a coil when there is relative motion between the coil and a permanent magnet and when there is a change of current in a primary coil linked with it	Use a data logger to plot V against t as a magnet falls through a coil of wire
95 investigate, recognise and use the expression $\varepsilon = d(N\Phi)/dt$ and explain how it is a consequence of Faraday's and Lenz's laws	

10.4 The Medium is the Message (MDM)

Students learn about the physics involved in some modern communication and display techniques:

- fibre optics and exponential attenuation
- CCD imaging
- cathode ray tube
- liquid crystal and LED displays.

Exponential functions are used to model attenuation losses.

There are opportunities to develop information and communication technology skills using computer simulations.

In studying various types of display technology, students consider their relative power demands and discuss the choices made by organisations and by individuals.

Students will be assessed on their ability to:	Suggested experiments
83 draw and interpret diagrams using lines of force to describe radial and uniform electric fields qualitatively	
84 explain what is meant by an electric field and recognise and use the expression electric field strength $E = F/Q$	Demonstration of electric lines of force between electrodes
86 investigate and recall that applying a potential difference to two parallel plates produces a uniform electric field in the central region between them, and recognise and use the expression $E = V/d$	
87 investigate and use the expression $C = Q/V$	Use a Coulometer to measure charge stored

Students will be assessed on their ability to:	Suggested experiments
88 recognise and use the expression $W = ½ QV$ for the energy stored by a capacitor, derive the expression from the area under a graph of potential difference against charge stored, and derive and use related expressions, for example, $W = ½ CV^2$	Investigate energy stored by discharging through series/parallel combination of light bulbs
91 explore and use the terms magnetic flux density B, flux Φ and flux linkage $N\Phi$	
93 recognise and use the expression $F = Bqv \sin \theta$ and apply Fleming's left hand rule to charges	Deflect electron beams with a magnetic field
98 recall that electrons are released in the process of thermionic emission and explain how they can be accelerated by electric and magnetic fields.	

10.5 Probing the Heart of Matter (PRO)

Probing the Heart of Matter (PRO)

An area of fundamental physics that is the subject of current research, involving the acceleration and detection of high-energy particles and the interpretation of experiments:

- alpha scattering and the nuclear model of the atom
- accelerating particles to high energies
- detecting and interpreting interactions between particles
- the quark-lepton model.

Students study the development of the nuclear model and the quark-lepton model to describe the behaviour of matter on a subatomic scale.

There are opportunities to develop ICT skills using the internet and computer simulations.

Students learn how modern particle physics research is organised and funded, and hence have opportunities to consider ethical and other issues relating to its operation.

Students will be assessed on their ability to:	Suggested experiments
76 derive and use the expression $E_k = p^2/2m$ for the kinetic energy of a non-relativistic particle	
77 analyse and interpret data to calculate the momentum of (non-relativistic) particles and apply the principle of conservation of linear momentum to problems in one and two dimensions	
79 express angular displacement in radians and in degrees, and convert between those units	
80 explain the concept of angular velocity, and recognise and use the relationships $v = \omega r$ and $T = 2\pi/\omega$	

Students will be assessed on their ability to:	Suggested experiments
81 explain that a resultant force (centripetal force) is required to produce and maintain circular motion	
82 use the expression for centripetal force $F = ma = mv^2/r$ and hence derive and use the expressions for centripetal acceleration $a = v^2/r$ and $a = r\omega^2$	Investigate the effect of m, v and r of orbit on centripetal force
85 use the expression $F = kQ_1Q_2/r^2$, where $k = 1/4\pi\varepsilon_0$ and derive and use the expression $E = kQ/r^2$ for the electric field due to a point charge	Use electronic balance to measure the force between two charges
99 explain the role of electric and magnetic fields in particle accelerators (linac and cyclotron) and detectors (general principles of ionisation and deflection only)	
100 recognise and use the expression $r = p/BQ$ for a charged particle in a magnetic field	
101 recall and use the fact that charge, energy and momentum are always conserved in interactions between particles and hence interpret records of particle tracks	
102 explain why high energies are required to break particles into their constituents and to see fine structure	
103 recognise and use the expression $\Delta E = c^2\Delta m$ in situations involving the creation and annihilation of matter and antimatter particles	
104 use the non-SI units MeV and GeV (energy) and MeV/c^2, GeV/c^2 (mass) and atomic mass unit u, and convert between these and SI units	

Students will be assessed on their ability to:	Suggested experiments
105 be aware of relativistic effects and that these need to be taken into account at speeds near that of light (use of relativistic equations not required)	
96 use the terms nucleon number (mass number) and proton number (atomic number)	
97 describe how large-angle alpha particle scattering gives evidence for a nuclear atom	
107 write and interpret equations using standard nuclear notation and standard particle symbols (eg π^+, e^-)	
106 recall that in the standard quark-lepton model each particle has a corresponding antiparticle, that baryons (eg neutrons and protons) are made from three quarks, and mesons (eg pions) from a quark and an antiquark, and that the symmetry of the model predicted the top and bottom quark	
108 use de Broglie's wave equation $\lambda = h/p$	

11.1 Introduction

Context approach

This unit covers thermal energy, nuclear decay, oscillations, and astrophysics and cosmology. The unit may be taught using either a concept approach or a context approach. This section of the specification is presented in a format for teachers who wish to use the context approach. The context approach begins with the consideration of an application that draws on many different areas of physics, and then the laws, theories and models of physics that apply to this application are studied. The context approach for this unit uses two different contexts: building design and cosmology.

Concept approach

This unit is presented in a different format on page 49 for teachers who wish to use a concept approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. The concept approach is split into four topics: thermal energy, nuclear decay, oscillations, and astrophysics and cosmology.

How Science Works

The QCA's GCE Science Criteria includes *How Science Works* (see *Appendix 6*). This should be integrated with the teaching and learning of this unit.

It is expected that students will be given opportunities to use spreadsheets and computer models to analyse and present data, and make predictions while studying this unit.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed *in Appendix 6* (internal assessment may require these skills). They should communicate the outcomes of their investigations using appropriate scientific, technical and mathematical language, conventions and symbols.

Applications of physics should be studied using a range of contemporary contexts that relate to this unit.

11.2 Assessment information

Examination paper	This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective questions, short questions and long questions. Students may be required to apply their knowledge and understanding of physics to situations that they have not encountered before. The total number of marks available for this examination paper is 80. It contributes 20% to the Advanced GCE in Physics.
Calculator	It is recommended that students have access to a scientific calculator for this paper.
Formulae sheet	Students will be provided with the formulae sheet shown in *Appendix 8*: *Formulae*. Any other physics formulae that are required will be stated in the question paper.

11.3 Reach for the Stars (STA)

The focus is on the physical interpretation of astronomical observations, the formation and evolution of stars, and the history and future of the universe:

- distances of stars
- masses of stars
- energy sources in stars
- star formation
- star death and the creation of chemical elements
- the history and future of the universe.

This topic uses the molecular kinetic theory model of matter and includes a study of the 'Big Bang' model of the universe. It also involves mathematical modelling of gravitational force and radioactive decay.

There are opportunities to develop ICT skills using the internet, data-logging and simulations.

There are several case studies that show how scientific knowledge and understanding have changed over time, providing students with opportunities to consider the provisional nature of scientific ideas.

Students will be assessed on their ability to:	**Suggested experiments**
109 investigate, recognise and use the expression $\Delta E = mc\Delta\theta$	Measure specific heat capacity of a solid and a liquid using, for example, temperature sensor and data logger
110 explain the concept of internal energy as the random distribution of potential and kinetic energy amongst molecules	
111 explain the concept of absolute zero and how the average kinetic energy of molecules is related to the absolute temperature	

Students will be assessed on their ability to:	Suggested experiments
112 recognise and use the expression ½ $m\langle c^2\rangle = 3/2\ kT$	
113 use the expression pV = NkT as the equation of state for an ideal gas	Use temperature and pressure sensors to investigate relationship between *p* and *T* Experimental investigation of relationship between p and V
114 show an awareness of the existence and origin of background radiation, past and present	Measure background count rate
115 investigate and recognise nuclear radiations (alpha, beta and gamma) from their penetrating power and ionising ability	Investigate the absorption of radiation by paper, aluminium and lead (radiation penetration simulation software is a viable alternative)
116 describe the spontaneous and random nature of nuclear decay	
117 determine the half lives of radioactive isotopes graphically and recognise and use the expressions for radioactive decay: $dN/dt = -\lambda N$, $\lambda = \ln 2/t_{½}$ and $N = N_0 e^{-\lambda t}$	Measure the activity of a radioactive source Simulation of radioactive decay using, for example, dice
136 explain the concept of nuclear binding energy, and recognise and use the expression $\Delta E = c^2\Delta m$ and use the non SI atomic mass unit (u) in calculations of nuclear mass (including mass deficit) and energy	
137 describe the processes of nuclear fusion and fission	

Students will be assessed on their ability to:	Suggested experiments
138 explain the mechanism of nuclear fusion and the need for high densities of matter and high temperatures to bring it about and maintain it	
118 discuss the applications of radioactive materials, including ethical and environmental issues	
126 use the expression $F = Gm_1m_2/r^2$	
127 derive and use the expression $g = -Gm/r^2$ for the gravitational field due to a point mass	
128 recall similarities and differences between electric and gravitational fields	
129 recognise and use the expression relating flux, luminosity and distance $F = L/4\pi d^2$ application to standard candles	
130 explain how distances can be determined using trigonometric parallax and by measurements on radiation flux received from objects of known luminosity (standard candles)	
131 recognise and use a simple Hertzsprung-Russell diagram to relate luminosity and temperature use this diagram to explain the life cycle of stars	
132 recognise and use the expression $L = \sigma T^4$ x surface area, (for a sphere $L = 4\pi r^2\sigma T^4$) (Stefan-Boltzmann law) for black body radiators	
133 recognise and use the expression: $\lambda_{max}T = 2.898 \times 10^{-3}$ m K (Wien's law) for black body radiators	

Students will be assessed on their ability to:	Suggested experiments
134 recognise and use the expressions $z = \Delta\lambda/\lambda \approx \Delta f/f \approx v/c$ for a source of electromagnetic radiation moving relative to an observer and $v = H_o d$ for objects at cosmological distances	
135 be aware of the controversy over the age and ultimate fate of the Universe associated with the value of the Hubble Constant and the possible existence of dark matter	

11.4 Build or Bust? (BLD)

A study of some aspects of building design, including withstanding earthquake damage, vibration isolation and sound-proofing:

- earthquake detection
- vibration and resonance in structures
- damping vibration using ductile materials.

The behaviour of oscillators is modelled using the mathematics of simple harmonic motion, and physical models are used to explore the behaviour of structures.

There are opportunities to develop ICT skills using data logging and spreadsheets.

Students will be assessed on their ability to:	Suggested experiments
119 recall that the condition for simple harmonic motion is $F = -kx$, and hence identify situations in which simple harmonic motion will occur	
120 recognise and use the expressions $a = -\omega^2 x$, $a = -A\omega^2 \cos \omega t$, $v = A\omega \sin \omega t$, $x = A\cos \omega t$ and $T = 1/f = 2\pi/\omega$ as applied to a simple harmonic oscillator	
121 obtain a displacement – time graph for an oscillating object and recognise that the gradient at a point gives the velocity at that point	Use a motion sensor to generate graphs of SHM
122 recall that the total energy of an undamped simple harmonic system remains constant and recognise and use expressions for total energy of an oscillator	
123 distinguish between free, damped and forced oscillations	

Students will be assessed on their ability to:	Suggested experiments
124 investigate and recall how the amplitude of a forced oscillation changes at and around the natural frequency of a system and describe, qualitatively, how damping affects resonance	Use, for example, a vibration generator to investigate forced oscillations
125 explain how damping and the plastic deformation of ductile materials reduce the amplitude of oscillation	Use, for example, a vibration generator to investigate damped oscillations

12.1 Unit description

Introduction

This unit requires that students plan an experiment, carry out an experiment, record measurements, analyse their own results and draw conclusions.

This unit may be completed at any time during the second year of the course but it would be more appropriate to administer this assessment near the end of the A2 year. This assessment should take no more than 2 hours to complete.

All candidates within one class may produce a plan for the same experiment as each other and do the same practical work; however it is vital that candidates demonstrate that the assessed work that they produce is entirely their own work.

If more than one class of students take this assessment at different times, then the groups must submit different plans for assessment to prevent plagiarism.

Candidates' work may be based on briefing material provided by Edexcel or briefing material that is devised by the centre. The brief for this assessment is to be set by the teacher, not the student; however, briefs should reflect the interests of students where possible.

Planning component

The planning component of this assessment may be done at a different time to the other components. Plans produced by the students may be based on either a briefing provided by the centre or a briefing provided by Edexcel.

Experiment and analysis of results

The experiment and analysis of results may be based on the plan produced by each individual student in the first part of this assessment or it may be based on a plan that is provided by Edexcel or a plan that is devised by the centre. If the centre produces the plan on which the experiment is based, it is vital that the plan provides the opportunity for students to achieve the full range of marks that are available. Centre devised plans should contain some flaws so that students are able to modify the experiment while they are doing it and suggest improvements. Centre-devised plans should ensure that a non-linear relationship exists between the variables that are investigated.

Use of ICT

Candidates may use a word processor to produce their report, although they will not gain any extra marks for doing so.

In order to ensure that candidates demonstrate their understanding of the principles and techniques involved in analysing data, the use of ICT, eg spreadsheets, may not be used for analysing data for this unit.

Draft work

Candidates should do a variety of practical work during the course so that they develop the necessary skills to succeed in this unit. They should not, therefore, submit draft work for checking. However, teachers should check candidates' plans for health and safety issues before they implement the plan.

Neither the plan nor any practical work submitted for this unit should be returned to candidates for them to improve it.

How Science Works

This unit will cover the following aspects of how science works as listed in *Appendix 6: How science works* 2, 3, 4, 5, 6, 8, and 9.

12.2 Assessment information

Introduction

Candidates must produce a written plan for an experiment. They must also produce a laboratory report for an experiment that they have carried out. The experiment that they carry out may be based on the plan that they have produced; alternatively, the experiment that they carry out may be based on a plan that is either centre-devised or Edexcel-devised.

Plan

Students should not be given advanced details of the plan that they will carry out; they will be expected to draw on their experience of practical work that they have completed during the course for this assessment. Students should not take into the classroom any materials for this assessment.

If more than one group of students take this assessment at different times, then the groups must submit different plans for assessment to prevent plagiarism.

Centre-devised plans and experiments will not required Edexcel's approval; however, centre devised assessments must ensure that students have the opportunity to gain all the marks in the mark scheme.

If teachers are going to mark the plan they should not provide students with feedback on their plan until they have carried out their experiment. At this stage teachers could either:

i) photocopy the plan, mark the original plan and provide students with the photocopy in the laboratory so that they can carry out their plan

ii) collect in the plan, not mark it and return it to students in the laboratory under supervised conditions so that they can carry out their plan

iii) mark the plan and ask students to do an experiment based on a different plan.

If teachers are not going to mark the plan they should collect the plan and check its feasibility. At this stage the teacher could either:

i) retun it to students in the laboratory under supervised conditions so that they can carry out their plan

ii) ask students to do an experiment based on a different plan.

Practical work	Students will not need to take any documents into the laboratory for the practical aspect of this assessment although they may bring a scientific calculator. Teachers should issue students with the (unmarked) plan of the practical that they are to carry out. If necessary, teachers may allow students to analyse results under supervision in the next lesson. In this situation, teachers must collect in the work produced by their students. Teachers should not mark the practical work. In the following lesson, the documents should be returned to students under supervised conditions. Students should not have access to any other sources of information while they are completing the analysis of their results. Teachers who opt for internal assessment should mark the practical work after students have completed the analysis of their results.
Assessing work	The assessment criteria are shown in the next section. Each criterion scores a maximum of 1 mark. The criteria are not hierarchical. The assessment of planning, recording and analysis is based on written evidence in the form of a report.
For centres marking the written report	The written evidence should be annotated. This can be done by writing the skill code eg A15 near to the appropriate section of the report and ticking the box A15 on the grid below. The marks given for the report should be submitted to Edexcel on the mark sheets as shown in the Edexcel *Coursework Guide* that will be available on the Edexcel website www.edexcel.com.
For centres not marking the written report	The written report should be submitted to Edexcel as discussed in the Edexcel *Coursework Guide* that will be available on the Edexcel website www.edexcel.com.
Supervision	Students must work on their own for each part of this assessment. All aspects of this assessment must be done under supervised conditions.

Assistance for students	Students may require assistance whereby the teacher needs to tell the student what they have to do. Assistance in this respect carries a penalty. The teacher should record details of any assistance provided on the student's work.
Important reminder	Students should submit their work for assessment **once only**. **Neither** the plan **nor** the experiment should be given back to students to be improved

12.3 Assessment criteria

A: Planning

Ref	Criterion	Mark
P1	Identifies the most appropriate apparatus required for the practical in advance	1
P2	Provides clear details of apparatus required including approximate dimensions and/or component values (for example, dimensions of items such as card or string, value of resistor)	1
P3	Draws an appropriately labelled diagram of the apparatus to be used	1
P4	States how to measure one quantity using the most appropriate instrument	1
P5	Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken	1
P6	States how to measure a second quantity using the most appropriate instrument	1
P7	Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken	1
P8	Demonstrates knowledge of correct measuring techniques	1
P9	Identifies and states how to control **all** other **relevant** quantities to make it a fair test	1
P10	Comments on whether repeat readings are appropriate for this experiment	1
P11	Comments on **all** relevant safety aspects of the experiment	1
P12	Discusses how the data collected will be used	1
P13	Identifies the main sources of uncertainty and/or systematic error	1
P14	Plan contains few grammatical or spelling errors	1
P15	Plan is structured using appropriate subheadings	1
P16	Plan is clear on first reading	1
	Maximum marks for this section	**16**

B: Implementation and measurements

Ref	Criterion	Mark
M1	Records all measurements with appropriate precision, using a table where appropriate	1
M2	Readings show appreciation of uncertainty	1
M3	Uses correct units throughout	1
M4	Refers to initial plan while working and modifies if appropriate	1
M5	Obtains an appropriate number of measurements	1
M6	Obtains measurements over an appropriate range	1
	Maximum marks for this section	**6**

C: Analysis

Ref	Criterion	Mark
A1	Produces a graph with appropriate axes (including units)	1
A2	Produces a graph using appropriate scales	1
A3	Plots points accurately	1
A4	Draws line of best fit (either a straight line or a smooth curve)	1
A5	Derives relation between two variables or determines constant	1
A6	Processes and displays data appropriately to obtain a straight line where possible, for example, using a log/log graph	1
A7	Determines gradient using large triangle	1
A8	Uses gradient with correct units	1
A9	Uses appropriate number of significant figures throughout	1
A10	Uses relevant physics principles correctly	1
A11	Uses the terms *precision* and either *accuracy* or *sensitivity* appropriately	1
A12	Discusses more than one source of error qualitatively	1
A13	Calculates errors quantitatively	1
A14	Compounds errors correctly	1
A15	Discusses realistic modifications to reduce error/improve experiment	1
A16	States a valid conclusion clearly	1
A17	Discusses final conclusion in relation to original aim of experiment	1
A18	Suggests relevant further work	1
	Maximum marks for this section	**18**
	Total marks for this unit	**40**

D Assessment and additional information

Assessment information

Assessment requirements	For a summary of assessment requirements and assessment objectives, see *Section B*, *Specification overview*.
Entering candidates for the examinations for this qualification	Details of how to enter students for the examinations for this qualification can be found in Edexcel's Information Manual, a copy of which is sent to all examinations officers. The information can also be found on Edexcel's website: www.edexcel.com.
Resitting of units	There is no limit to the number of times that a student may retake a unit prior to claiming certification for the qualification. The best available result for each contributing unit will count towards the final grade. After certification all unit results may be reused to count towards a new award. Students may re-enter for certification only if they have retaken at least one unit. Results of units held in the Edexcel unit bank have a shelf life limited only by the shelf life of this specification.
Awarding and reporting	The grading, awarding and certification of this qualification will comply with the requirements of the current GCSE/GCE Code of Practice for courses starting in September 2008, which is published by the Qualifications and Curriculum Authority. The AS qualification will be graded and certificated on a five-grade scale from A to E. The full GCE Advanced level will be graded on a six-point scale A* to E. Individual unit results will be reported. A pass in an Advanced Subsidiary subject is indicated by one of the five grades A, B, C, D, E of which Grade A* is the highest and Grade E the lowest. A pass in an Advanced GCE subject is indicated by one of the six grades A*, A, B, C, D, E of which Grade A* is the highest and Grade E the lowest. To be awarded an A* students will need to achieve an A on the full GCE Advanced level qualification and an A* aggregate of the A2 units. Students whose level of achievement is below the minimum judged by Edexcel to be of sufficient standard to be recorded on a certificate will receive an unclassified U result.
Performance descriptions	Performance descriptions give the minimum acceptable level for a grade. See *Appendix 1* for the performance descriptions for this subject.

Unit results

The minimum uniform marks required for each grade for each unit:

Unit 1

Unit grade	A	B	C	D	E
Maximum uniform mark = 120	**96**	**84**	**72**	**60**	**48**

Candidates who do not achieve the standard required for a grade E will receive a uniform mark in the range 0–47.

Unit 2

Unit grade	A	B	C	D	E
Maximum uniform mark = 120	**96**	**84**	**72**	**60**	**48**

Candidates who do not achieve the standard required for a grade E will receive a uniform mark in the range 0–47.

Unit 3

Unit grade	A	B	C	D	E
Maximum uniform mark = 60	**48**	**42**	**36**	**30**	**24**

Candidates who do not achieve the standard required for a grade E will receive a uniform mark in the range 0–23.

Unit 4

Unit grade	A	B	C	D	E
Maximum uniform mark = 120	**96**	**84**	**72**	**60**	**48**

Candidates who do not achieve the standard required for a grade E will receive a uniform mark in the range 0–47.

Unit 5

Unit grade	A	B	C	D	E
Maximum uniform mark = 120	**96**	**84**	**72**	**60**	**48**

Candidates who do not achieve the standard required for a grade E will receive a uniform mark in the range 0–47.

Unit 6

Unit grade	A	B	C	D	E
Maximum uniform mark = 60	48	42	36	30	24

Candidates who do not achieve the standard required for a grade E will receive a uniform mark in the range 0–23.

Qualification results

The minimum uniform marks required for each grade:

Advanced Subsidiary Cash-in code 8PH01

Qualification grade	A	B	C	D	E
Maximum uniform mark = 300	240	210	180	150	120

Candidates who do not achieve the standard required for a grade E will receive a uniform mark in the range 0–119.

Advanced GCE Cash-in code 9PH01

Qualification grade	A	B	C	D	E
Maximum uniform mark = 600	480	420	360	300	240

Candidates who do not achieve the standard required for a grade E will receive a uniform mark in the range 0–239.

Language of assessment

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

Quality of written communication

Candidates will be assessed on their ability to:

- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate.

Quality of written communication will be tested in each unit.

Assessment objectives and weighting

		% in AS	% in A2	% in GCE
A01	Knowledge and understanding of science and of '*How Science Works*'	40%	30%	35%
A02	Application of knowledge and understanding of science and of '*How Science Works*'	40%	50%	45%
A03	'*How Science Works*'	20%	20%	20%
	TOTAL	100%	100%	100%

Synoptic assessment

In synoptic assessment there should be a concentration on the quality of assessment to ensure that it encourages the development of the holistic understanding of the subject.

Synopticity requires students to connect knowledge, understanding and skills acquired in different parts of the Advanced GCE course.

Synoptic assessment in the context of physics requires students to use the skills, knowledge and understanding they have aquired in one part of a unit and apply them to another part of the same unit or to a different unit. For example, Unit 4 builds on the concepts involving forces and motion that are studied in Unit 1.

Stretch and challenge

Students can be stretched and challenged in A2 units through the use of different assessment strategies, for example:

- using a variety of stems in questions — for example analyse, evaluate, discuss, compare
- ensuring connectivity between sections of questions
- use of a wider range of question types to address different skills — for example open-ended questions, case studies, etc
- solving problems that consist of two or more stages.

Additional information

Malpractice and plagiarism

For up-to-date advice on malpractice and plagiarism, please refer to the Joint Council for Qualifications — Suspected Malpractice in Examinations: Policies and Procedures document on the JCQ website www.jcq.org.uk.

Access arrangements and special requirements

Edexcel's policy on access arrangements and special considerations for GCE, GCSE, and Entry Level aims to enhance access to the qualifications for learners with disabilities and other difficulties (as defined by the Disability Discrimination Act 1995 and the amendments to the Act) without compromising the assessment of skills, knowledge, understanding or competence.

Please see the Edexcel website (www.edexcel.com) for:

- the JCQ policy Access Arrangements and Special Considerations, Regulations and Guidance Relating to Students who are Eligible for Adjustments in Examinations.
- the forms to submit for requests for access arrangements and special considerations
- dates for submission of the forms.

Requests for access arrangements and special considerations must be addressed to:

Special Requirements
Edexcel
One90 High Holborn
London
WC1V 7BH

Disability Discrimination Act

Please see *Appendix 11* for the Advanced GCE in Physics Disability Discrimination Act information.

Prior learning and progression

Prior learning

Students who would benefit most from studying a GCE in Physics are likely to have a Level 2 qualification such as a GCSE in Additional Science at grades A*–C. Students should also have achieved GCSE Mathematics at grade C or an equivalent qualification.

Progression

This qualification supports progression into further education such as embarking on a degree-level courses in physic, engineering, electronics, medicine or environmental science, or a BTEC Higher National Certificate in Applied Physics.

Combinations of entry

There are no forbidden combinations.

Student recruitment

Edexcel's access policy concerning recruitment to our qualifications is that:

- they must be available to anyone who is capable of reaching the required standard
- they must be free from barriers that restrict access and progression
- equal opportunities exist for all students.

Key skills

This qualification provides opportunities for developing and generating evidence for assessing the key skills listed below:

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

Further details are available in *Appendices 2 and 3*.

This qualification will be mapped to functional skills once they are finalised. Information will be available on our website (www.edexcel.com/gce2008) at a later date.

The wider curriculum

This qualification provides opportunities for developing an understanding of spiritual, moral, ethical, social, citizenship and cultural issues, together with an awareness of environmental issues, health and safety considerations, and European developments consistent with relevant international agreements appropriate as applied to physics. *Appendix 4*: *Wider curriculum* maps the opportunities available.

E Resources, support and training

Resources to support the specification

In addition to the resources available on the e-Spec and in the 'Getting Started' and Internal Assessment Guide books, Edexcel produces a wide range of resources to support this specification.

Edexcel's own published resources

Edexcel aims to provide the most comprehensive support for our qualifications. We have therefore published our own dedicated suite of resources for teachers and students written by qualification experts.

The resources for the concept approach include:

- AS Students' Book
- A2 Students' Book
- AS ActiveTeach CD ROM
- A2 ActiveTeach CD ROM
- AS Teacher Support Pack
- A2 Teacher Support Pack.

The resources for the context (Salters Horners) approach include:

- AS Students' Book
- A2 Students' Book
- AS Student Website
- A2 Student Website.

For more information on our complete range of products and services for GCE in Physics, visit www.edexcel.com/gce2008.

Edexcel publications

You can order further copies of the specification and Sample Assessment Materials (SAMS) documents from:

Edexcel Publications
Adamsway
Mansfield
Notts NG18 4FN

Telephone:	01623 467467
Fax:	01623 450481
Email:	publications@linney.com
Website:	www.edexcel.com

Additional resources endorsed by Edexcel

Edexcel also endorses additional materials written to support this qualification.

Any resources bearing the 'Endorsed by Edexcel' logo have been through a rigorous quality assurance process to ensure complete and accurate support for the specification. For up-to-date information about endorsed resources, please visit www.edexcel.com/endorsed

Please note that while resources are checked at the time of publication, materials may be withdrawn from circulation and website locations may change.

The resources listed on the Edexcel website are intended to be a guide for teachers and not a comprehensive list. Further suggestions can be found in *Appendix 10*: *Further resources and support*.

Please see www.edexcel.com/gce2008 for up-to-date information.

Support from the University of York

The Salters Horners Advanced Physics project team in the University of York Science Education Group runs in-service courses for teachers and technicians from centres that are following, or preparing to follow, this GCE Physics specification.

The project team also runs an advice service to help with questions concerning the teaching of the course.

For further information please contact the project secretary:

Salters Horners Advanced Physics Project
Science Education Group
Alcuin College
University of York
Heslington
York YO10 5DD

Telephone: 01904 432537
Fax: 01904 432605
Email: slw5@york.ac.uk

The Salters Horners Advanced Physics website contains some general information about the project: www.york.ac.uk/org/seg/salters/physics.

Enquiries concerning assessment and administration should be addressed to the Qualifications and Delivery and Awards Manager for Physics at Edexcel.

Support

Edexcel support services

Edexcel has a wide range of support services to help you implement this qualification successfully.

ResultsPlus — ResultsPlus is a new application launched by Edexcel to help subject teachers, senior management teams, and students by providing detailed analysis of examination performance. Reports that compare performance between subjects, classes, your centre and similar centres can be generated in 'one-click'. Skills maps that show performance according to the specification topic being tested are available for some subjects. For further information about which subjects will be analysed through ResultsPlus, and for information on how to access and use the service, please visit www.edexcel.com/resultsplus.

Ask the Expert — Ask the Expert is a new service, launched in 2007, that provides direct email access to senior subject specialists who will be able to answer any questions you might have about this or any other specification. All of our specialists are senior examiners, moderators or verifiers and they will answer your email personally. You can read a biography for all of them and learn more about this unique service on our website at www.edexcel.com/asktheexpert.

Ask Edexcel — Ask Edexcel is Edexcel's online question and answer service. You can access it at www.edexcel.com/ask or by going to the main website and selecting the Ask Edexcel menu item on the left.

The service allows you to search through a database of thousands of questions and answers on everything Edexcel offers. If you don't find an answer to your question, you can choose to submit it straight to us. One of our customer services team will log your query, find an answer and send it to you. They'll also consider adding it to the database if appropriate. This way the volume of helpful information that can be accessed via the service is growing all the time.

Examzone — The examzone site is aimed at students sitting external examinations and gives information on revision, advice from examiners and guidance on results, including re-marking, re-sitting and progression opportunities. Further services for students — many of which will also be of interest to parents — will be available in the near future. Links to this site can be found on the main homepage at www.edexcel.com.

Training

A programme of professional development and training courses, covering various aspects of the specification and examination, will be arranged by Edexcel each year on a regional basis. Full details can be obtained from:

Professional Development and Training
Edexcel
One90 High Holborn
London WC1V 7BH

Telephone:	0844 576 0025
Fax:	0845 359 1909
Email:	trainingenquiries@edexcel.org.uk
Website:	www.edexcel.com

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Appendix 1 Performance descriptions

Introduction

Performance descriptions have been created for all GCE subjects. They describe the learning outcomes and levels of attainment likely to be demonstrated by a representative candidate performing at the A/B and E/U boundaries for AS and A2.

In practice most candidates will show uneven profiles across the attainments listed, with strengths in some areas compensating in the award process for weaknesses or omissions elsewhere. Performance descriptions illustrate expectations at the A/B and E/U boundaries of the AS and A2 as a whole; they have not been written at unit level.

Grade A/B and E/U boundaries should be set using professional judgement. The judgement should reflect the quality of candidates' work, informed by the available technical and statistical evidence. Performance descriptions are designed to assist examiners in exercising their professional judgement. They should be interpreted and applied in the context of individual specifications and their associated units. However, performance descriptions are not designed to define the content of specifications and units.

The requirement for all AS and A level specifications to assess candidates' quality of written communication will be met through one or more of the assessment objectives.

The performance descriptions have been produced by the regulatory authorities in collaboration with the awarding bodies.

AS performance descriptions for Physics

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	**Knowledge and understanding of science and of How science works** Candidates should be able to: ■ recognise, recall and show understanding of scientific knowledge ■ select, organise and communicate relevant information in a variety of forms.	**Application of knowledge and understanding of science and of How science works** Candidates should be able to: ■ analyse and evaluate scientific knowledge and processes ■ apply scientific knowledge and processes to unfamiliar situations including those related to issues ■ assess the validity, reliability and credibility of scientific information.	**How science works** Candidates should be able to: ■ demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods ■ make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy ■ analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.
A/B boundary performance descriptions	Candidates characteristically: a demonstrate knowledge of most principles, concepts and facts from the AS specification b show understanding of most principles, concepts and facts from the AS specification c select relevant information from the AS specification d organise and present information clearly in appropriate forms using scientific terminology.	Candidates characteristically: a apply principles and concepts in familiar and new contexts involving only a few steps in the argument b describe significant trends and patterns shown by data presented in tabular or graphical form and interpret phenomena with few errors and present arguments and evaluations clearly c explain and interpret phenomena with few errors and present arguments and evaluations clearly d carry out structured calculations with few errors and demonstrate good understanding of the underlying relationships between physical quantities.	Candidates characteristically: a devise and plan experimental and investigative activities, selecting appropriate techniques b demonstrate safe and skilful practical techniques c make observations and measurements with appropriate precision and record these methodically d interpret, explain, evaluate and communicate the results of their own and others experimental and investigative activities, in appropriate contexts.

	Assessment objective 1	Assessment objective 2	Assessment objective 3
E/U boundary performance descriptions	Candidates characteristically: a demonstrate knowledge of some principles and facts from the AS specification b show understanding of some principles and facts from the AS specification c select some relevant information from the AS specification d present information using basic terminology from the AS specification.	Candidates characteristically: a apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument b describe some trends or patterns shown by data presented in tabular or graphical form c provide basic explanations and interpretations of some phenomena, presenting very limited evaluations d carry out some steps within calculations.	Candidates characteristically: a devise and plan some aspects of experimental and investigative activities b demonstrate safe practical techniques c make observations and measurements, and record them d interpret, explain and communicate some aspects of the results of their own and others experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for Physics

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	**Knowledge and understanding of science and of How science works** Candidates should be able to: ■ recognise, recall and show understanding of scientific knowledge ■ select, organise and communicate relevant information in a variety of forms.	**Application of knowledge and understanding of science and of How science works** Candidates should be able to: ■ analyse and evaluate scientific knowledge and processes ■ apply scientific knowledge and processes to unfamiliar situations including those related to issues ■ assess the validity, reliability and credibility of scientific information.	**How science works** Candidates should be able to: ■ demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods ■ make, record and communicate reliable ■ and valid observations and measurements with appropriate precision and accuracy ■ analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.
A/B boundary performance descriptions	Candidates characteristically: a demonstrate detailed knowledge of most principles, concepts and facts from the A2 specification b show understanding of most principles, concepts and facts from the A2 specification c select relevant information from the A2 specification d organise and present information clearly in appropriate forms using scientific terminology.	Candidates characteristically: a apply principles and concepts in familiar and new contexts involving several steps in the argument b describe significant trends and patterns shown by complex data presented in tabular or graphical form, interpret phenomena with few errors, and present arguments and evaluations clearly and logically c explain and interpret phenomena effectively, presenting arguments and evaluations d carry out extended calculations, with little or no guidance, and demonstrate good understanding of the underlying relationships between physical quantities e select a wide range of facts, principles and concepts from both AS and A2 specifications f link together appropriate facts principles and concepts from different areas of the specification.	Candidates characteristically: a devise and plan experimental and investigative activities, selecting appropriate techniques b demonstrate safe and skilful practical techniques c make observations and measurements with appropriate precision and record these methodically d interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

	Assessment objective 1	Assessment objective 2	Assessment objective 3
E/U boundary performance descriptions	Candidates characteristically: a demonstrate knowledge of some principles and facts from the A2 specification b show understanding of some principles and facts from the A2 specification c select some relevant information from the A2 specification d present information using basic terminology from the A2 specification.	Candidates characteristically: a apply given principles or concepts in familiar and new contexts involving a few steps in the argument b describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form c provide basic explanations and interpretations of some phenomena, presenting very limited arguments and evaluations d carry out routine calculations, where guidance is given e select some facts, principles and concepts from both AS and A2 specifications f put together some facts, principles and concepts from different areas of the specification.	Candidates characteristically: a devise and plan some aspects of experimental and investigative activities b demonstrate safe practical techniques c make observations and measurements and record them d interpret, explain and communicate some aspects of the results of their own and others experimental and investigative activities, in appropriate contexts.

Appendix 2 Key skills mapping

Key skills (Level 3)	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Application of number						
N3.1	✓	✓	✓	✓	✓	✓
N3.2	✓	✓	✓	✓	✓	✓
N3.3	✓	✓	✓	✓	✓	✓
Communication						
C3.1a	✓	✓		✓	✓	
C3.1b	✓	✓		✓	✓	
C3.2	✓	✓	✓	✓	✓	✓
C3.3	✓	✓	✓	✓	✓	✓
Information and communication technology						
ICT3.1	✓	✓		✓	✓	
ICT3.2	✓	✓		✓	✓	
ICT3.3	✓	✓		✓	✓	
Improving own learning and performance						
LP3.1	✓	✓		✓	✓	
LP3.2	✓	✓		✓	✓	
LP3.3	✓	✓		✓	✓	
Problem solving						
PS3.1	✓	✓	✓	✓	✓	✓
PS3.2	✓	✓	✓	✓	✓	✓
PS3.3	✓	✓	✓	✓	✓	✓
Working with others						
WO3.1	✓	✓		✓	✓	
WO3.2	✓	✓		✓	✓	
WO3.3	✓	✓		✓	✓	

Appendix 3 Key skills development

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions for opportunities for the generation of Level 3 key skills evidence are given here.

Application of number — Level 3

Plan and carry out one or more activities that each includes tasks for all three of N3.1, N3.2 (a or b or c or d) and N3.3.

Overall, through one or more activities students must:

- use two different types of sources, including a large data set, ie over 50 items of data (N3.1)
- carry out calculations to do with a, b, c and d (N3.2)
- present findings in two different ways using charts, graphs or diagrams (N3.3).

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
N3.1	Plan an activity and get relevant information from relevant sources.		Students are required to plan how to get 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 and justify their choice. Students should plan an experiment or an investigation that involves practical work by referring to relevant sources. Most experiments and investigations will readily produce a large set of results, ie a large data set. Sources include textbooks containing data for comparison, or physical laws and principles to apply. The internet may also be used to gain information — this may also provide evidence for ICT3.1 Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 40, 60 82, 89, 92, 95, 109, 115, 121, 124. 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.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained).
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		3 and 6	Planning an experiment for the assessment of these units
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*.
		5	Investigations include: the measurement of specific heat capacity; penetrating and ionising power of radiation; displacement-time graphs for oscillating objects; forced vibrations.
N3.2	Use this information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae.		Students must carry out their calculations, which could relate to volumes, powers, averages, formulae, etc, to appropriate levels of accuracy 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 opportunities occur in the following outcomes of the specification content: 2, 98, 114, 117. It may also be possible to perform a statistical analysis on the reliability results obtained in an investigation. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 40, 60 82, 89, 92, 95, 109, 115,121, 124. 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. Activities involving estimation and measurement as appropriate will require competence at scales and proportions.

Key skills portfolio evidence requirement		AS/A2 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; factors affecting acceleration using an air track; 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: estimate then measure the weight of familiar 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.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor. These provide opportunities for dealing with amounts and sizes and re-arranging and using formulae.
		3 and 6	Processing experimental data.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with N and rate of change of B. These provide opportunities for dealing with amounts and sizes and re-arranging and using formulae.
		5	Investigations include: the measurement of specific heat capacity; penetrating and ionising power of radiation; displacement-time graphs for oscillating objects; forced vibrations. These provide opportunities for dealing with amounts and sizes and re-arranging and using formulae. 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.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
N3.3	Interpret the results of your calculations, present your findings and justify your methods.		Based on their findings, students must select appropriate and effective methods of presentation using, as appropriate, charts, diagrams, and tables. Students should justify why they have chosen a particular methods of presentation. They should draw relevant conclusions from their findings and discuss possible sources of error in their work to decide whether the results meet their purpose. 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 their findings.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained).
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor.
		3 and 6	Interpreting experimental data.
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*.
		5	Investigations include: the measurement of specific heat capacity; penetrating and ionising power of radiation; displacement-time graphs for oscillating objects; forced vibrations.

Communication — Level 3

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
C3.1a	Take part in a group discussion.		Topics in the physics specification will often lend themselves to form the basis of a group discussion. Complex subjects may involve 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 that 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. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 40, 60 82, 89, 92, 95, 109, 115,121, 124. Other suitable areas for a group discussion would be discussing issues in physics or discoveries and concept development, or the work of scientists eg in outcomes 43, 49, 71, 72, 95, 98, 108, 118.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). The work of the scientists Galileo and Newton can be discussed.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor. Suitable issues include: use of energy and sustainable growth, including environmental considerations.
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*. The work of the scientist Rutherford can be discussed. 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 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.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		5	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth, radioactivity safety issues including implications of long half-lives, protection and environmental considerations. The role of scientists in the development of the ideal gas law can be discussed.
C3.1b	Make a formal presentation of at least eight minutes using an image or other support material.		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 purpose, and the situation, audience and subject. The presentation should have a logical structure which allows the audience to follow the sequence of information and ideas. Where appropriate, images or other material should be used to both support and enhance points made. Images could include graphs or charts and diagrams. At least one image should be used to illustrate and help convey a point and this will readily be achievable using a graph for experiments and investigations. If ICT is used to produce materials for a presentation it can also provide evidence for ICT3.3.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). A presentation could be made about the work of the scientists Galileo and Newton.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; R v T for a thermistor. 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. 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 the model of wave-particle duality.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*. 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. A presentation could be made about the work of the scientists Faraday and Lenz.
		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 purpose and validity of modelling in the context of modelling radioactive decay by throwing dice. Suitable issues include: radioactivity safety issues including implications of long half-lives, protection and environmental considerations. Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. Suitable issues include: the formation, age and ultimate fate of the Universe: indefinite expansion or final contraction.
C3.2	Read and synthesise information from at least two documents about the same subject. Each document must be a minimum of 1000 words long.		Students will have a number of opportunities to read and synthesise information from at least two 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. Documents may include textbooks and reports and articles such as those found in scientific journals. Students will need to select and read material that contains relevant information. From this information they will need to identify accurately, and compare, the ideas, lines of reasoning and main points. Students will then need to synthesise this information to present their own interpretation of the subject in a coherent form, for example, for a presentation, discussion or an essay. Appropriate topics which could form the basis of this research are given below.

Key skills portfolio evidence requirement		AS/A2 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; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). A presentation could be developed about the work of the scientists Galileo and Newton.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor. 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 the model of wave-particle duality.
		3 and 6	Using information for planning an experiment.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with N and rate of change of B. 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. A presentation could be developed about the work of Rutherford, Faraday and Lenz. 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.
		5	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be developed about the purpose and validity of modelling in the context of modelling radioactive decay by throwing dice. A presentation could be developed about the role of scientists in the development of the kinetic theory. Suitable issues include: the formation, age and ultimate fate of the universe: indefinite expansion or final contraction.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
C3.3	Write two different types of documents, each one giving different information about complex subjects. One document must be at least 1000 words long.		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 appropriate for its purpose and the complexity of the subject matter covered. Specialist vocabulary should be used where appropriate and the information in the document should be clearly and coherently organised, for example, through the use of headings, paragraphs, etc, to suit the length, complexity and purpose of the document. Students should ensure that the text is legible and that spelling, punctuation and grammar are accurate.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). A document could be written about the work of the scientists Galileo and Newton.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; R v T for a thermistor. 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 the model of wave-particle duality.
		3 and 6	Producing reports.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with N and rate of change of B. 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. A document could be written about the work of the scientists, Rutherford, Faraday and Lenz. 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.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		5	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth, 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 and development of ideas on gravitation, the kinetic theory of gases and radiation. A document could be written about the purpose and validity of modelling in the context of modelling radioactive decay by throwing dice.

Information and communication technology — Level 3

Show that students can **plan** and carry through a number of different tasks, one of which must be a major task covering ICT3.1, ICT3.2 and ICT3.3.

Each component, ICT3.1, ICT3.2 and ICT3.3, must be covered at least twice, and ICT3.3 must be covered for at least two different audiences. Smaller tasks may be used to ensure each component is covered.

Overall, through at least two activities students must:

- include at least one ICT-based information source
- include at least one non-ICT-based information source
- use at least one example of text, one example of image and one example of number
- use one example of combined information such as text and number, or image and number or text and image
- present evidence of purposeful use of email; one of these emails must have an attachment related to the task.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
ICT3.1	Search for information, using different sources, and multiple search criteria in at least one case.		Students will need to plan and document how they are to use ICT as part of the activity, including how they will search for and use relevant information from different electronic sources. These may include the internet and CD ROM. Information selected must be based on judgements of relevance and quality. Suitable data may be obtained from investigations or experiments. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 40, 60 82, 89, 92, 95, 109, 115,121, 124. Students could also conduct research using ICT for a presentation on a physics topic. Suitable areas for research would be issues in physics, for example, in outcomes 43, 49, 71, 72, 95, 98, 108, 118.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). A presentation could be produced about the work of the scientists Galileo and Newton.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be produced about the role of scientists in the development of the model of wave-particle duality.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*. A presentation could be produced 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. A presentation could be produced about the work of the scientists, Rutherford, Faraday and Lenz. A presentation could be produced 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.
		5	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth, the formation, age and ultimate fate of the universe: indefinite expansion or final contraction. A presentation could be produced about the role of scientists in the discovery and development of ideas on gravitation, the kinetic theory of gases and radiation. A presentation could be produced about the purpose and validity of modelling in the context of modelling radioactive decay by throwing dice.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
ICT3.2	Enter and develop the information and derive new information.		Students are required to bring together in a consistent format their selected information. They should use software features to improve the efficiency of their work, eg automatic page numbering, styles and templates. Students should sort and group the information generated, produce graphs and charts if appropriate, to allow them to draw conclusions. Evidence to show that students understood processes followed and took into account views of others. Students could work 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. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 40, 60 82, 89, 92, 95, 109, 115,121, 124. Students could also develop a presentation on a physics topic using ICT. Suitable areas for research would be issues in physics, for example in outcomes 43, 49, 71, 72, 95, 98, 108, 118. Students may also use ICT for modelling in physics. Suitable opportunities are found in outcomes 98, 121, 124.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). A presentation could be produced about the work of the scientists Galileo and Newton.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be produced about the role of scientists in the development of the model of wave-particle duality.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*. ICT could be used in modelling alpha particle scattering with ball bearings on collision with a $1/r$ hill. A presentation could be produced about the work of the scientists, Rutherford, Faraday and Lenz. A presentation could be produced 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.
		5	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. ICT 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. 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. A presentation could be produced about the role of scientists in the discovery and development of ideas on gravitation, the kinetic theory of gases and radiation.
ICT3.3	Present combined information such as text with image, text with number, image with number.		In combining information students will need to ensure that the presentation is accurate, clear and consistent. It should take into account the views of others. 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 and style 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 proofread. A presentation may be based on 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, for example graphs and numbers, for example 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 ICT to model behaviour are presented, a presented spreadsheet will be an example of numbers.

Key skills portfolio evidence requirement		AS/A2 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; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). A presentation could be produced about the work of the scientists Galileo and Newton.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor. Suitable issues include: use of energy and sustainable growth, including environmental considerations. A presentation could be produced about the role of scientists in the development of the model of wave-particle duality.
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*. A presentation could be produced about the work of the scientists, Rutherford, Faraday and Lenz. A presentation could be produced 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.
		5	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. A presentation could be produced about the role of scientists in the discovery and development of ideas on gravitation, the kinetic theory of gases and radiation.

Improving own learning and performance — Level 3

Provide at least **one** example of meeting the standard for LP3.1, LP3.2 and LP3.3 (the example should cover at least three targets). Overall, students must show they can use at least **two** different ways of learning to improve your performance.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
LP3.1	Set targets using information from appropriate people and plan how these will be met.	1, 2, 4 and 5	Students could plan how they are to perform experimental work and investigations. This will require the setting of targets and clear action points. Difficulties will need top be identified and dealt with. Progress should be reviewed and support obtained where necessary. Opportunities for investigations that may be used as a context for developing this aspect of key skils are to be found in the following outcomes of the specification content: 2, 9, 14, 59, 60 82, 120, 92, 95.
LP3.2	Take responsibility for your learning, using your plan to help meet targets and improve your performance.	1, 2, 4 and 5	Students should use their time effectively when they perform experimental work and investigations. This will involve prioritising action and revising their development plan as necessary. They should select appropriate ways of learning to improve performance and adapt their plans to meet new demands. Students should reflect on their progress, seek and use feedback and support to help them meet targets. Opportunities for investigations that may be used as a context for developing this aspect of this key skill are to be found in the following outcomes of the specification content: 2, 9, 14, 40, 60 82, 89, 92, 95, 109, 115,121, 124.
LP3.3	Review progress and establish evidence of your achievements.	1, 2, 4 and 5	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 consult with others, for example tutors, to agree further actions for improving their performance at experimental work and investigations. Opportunities for investigations that may be used as a context for developing this aspect of this key skill are to be found in the following outcomes of the specification content: 2, 9, 14, 59, 60 82, 120, 92, 95.

Problem solving — Level 3

Provide at least **one** example of meeting the standard for PS3.1, PS3.2 and PS3.3. The example should include exploring at least **three** different ways of tackling a problem (for PS3.1).

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
PS3.1	Explore a problem and identify different ways of tackling it.		Students will need to identify, analyse and accurately describe a problem, and agree standards that have to be met to show successful resolution of the problem. Different ways of tackling the problem should be explored; the main features and risks of these approaches need to be considered. The method selected to solve the problem must be justified. The solution of the problem could be achieved by an investigation. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 40, 60 82, 89, 92, 95, 109, 115,121, 124.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained).
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor.
		3 and 6	Considering alternative ways of doing an experiment.
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*.
		5	Investigations include: the measurement of specific heat capacity; penetrating and ionising power of radiation; displacement-time graphs for oscillating objects; forced vibrations. These provide opportunities for dealing with amounts and sizes and re-arranging and using formulae.
PS3.2	Plan and implement at least one way of solving the problem.		The plan to solve the problem should be put into action after it has been approved by the tutor. Support and feedback should be obtained when necessary. Progress should be checked at appropriate times and the plan revised as necessary. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 59, 60 82, 120, 92, 95.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained).

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor.
		3 and 6	Plan an experiment.
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*.
		5	Investigations include: the measurement of specific heat capacity; penetrating and ionising power of radiation; displacement-time graphs for oscillating objects; forced vibrations. These provide opportunities for dealing with amounts and sizes and re-arranging and using formulae.
PS3.3	Check if the problem has been solved and review your approach to problem solving.		On completion the outcomes need to be checked against the standards agreed at the start and the approach taken reviewed. Examples of investigations that meet this key skill are to be found in the following sections of the specification content: 2, 9, 14, 40, 60 82, 89, 92, 95, 109, 115,121, 124.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained).
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor.
		3 and 6	Evaluating outcomes from experiments.
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*.
		5	Investigations include: the measurement of specific heat capacity; penetrating and ionising power of radiation; displacement-time graphs for oscillating objects; forced vibrations. These provide opportunities for dealing with amounts and sizes and re-arranging and using formulae.

Working with others — Level 3

Provide at least **one** example of meeting the standard for WO3.1, WO3.2 and WO3.3, to include work in a group or team situation. Students must check progress on two occasions (for WO3.2).

Key skills portfolio evidence requirement		**AS/A2 unit**	**Opportunities for development or internal assessment**
WO3.1	Plan work with others.		Students could work in groups of six to eigth and be asked to investigate a given topic. Initial work will require agreeing objectives and planning how to meet these, including any necessary action and resources required. The group needs to agree responsibilities and working arrangements. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 59, 60 82, 120, 92, 95. Suitable areas for research would be issues in physics, for example in outcomes 43, 49, 71, 72, 95, 98, 108, 118.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). A presentation could be planned about the work of the scientists Galileo and Newton.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor. 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 the model of wave-particle duality.
		4	Investigations include: effect of m, υ and r of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with N and rate of change of B. 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. A presentation could be planned about the work of the scientists, Rutherford, Faraday and Lenz.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		5	Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth, the formation, age and ultimate fate of the universe: indefinite expansion or final contraction. Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be planned about the role of scientists in the discovery and development of ideas on gravitation, the kinetic theory of gases and radiation.
WO3.2	Seek to develop co-operation and check progress towards your agreed objectives.		When developing co-operation, students could work in pairs with each pair undertaking a particular role, for example the use of textbooks or other written sources; the use of ICT; 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 plan and organise their work effectively so that they meet agreed responsibilities and maintain appropriate working relationships. They need to check their progress and agree changes to their plan if necessary. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 40, 60, 82, 89, 92, 95, 109, 115,121, 124. Suitable areas for research would be issues in physics, for example in outcomes 43, 49, 71, 72, 95, 98, 108, 118.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained). A presentation could be developed about the work of the scientists Galileo and Newton.
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor. 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 the model of wave-particle duality.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*. 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. A presentation could be developed about the work of the scientists, Rutherford, Faraday and Lenz.
		5	Investigations include: the measurement of specific heat capacity; penetrating and ionising power of radiation; displacement-time graphs for oscillating objects; forced vibrations. These provide opportunities for dealing with amounts and sizes and re-arranging and using formulae. Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth. A presentation could be developed about the role of scientists in the discovery and development of ideas on gravitation, the kinetic theory of gases and radiation.
WO3.3	Review work with others and agree ways of improving collaborative work in the future.		Once completed, the full group needs to review work against the agreed objectives. In doing this they should identify factors that have influenced the outcome and agree on the ways in which they could have collaborated more effectively. Opportunities for investigations are to be found in the following outcomes of the specification content: 2, 9, 14, 59, 60, 82, 120, 92, 95. Suitable areas for research would be issues in physics, for example in outcomes 43, 49, 71, 72, 95, 98, 108, 118.
		1	Investigations into motion include: light gates to measure speed and acceleration of a trolley rolling down a slope; factors affecting acceleration using an air track; speed of a falling object (GPE lost and KE gained).
		2	Investigations include: measuring the rotation of the plane of polarisation for light; *R* v *T* for a thermistor.
		4	Investigations include: effect of *m*, υ and *r* of orbit on centripetal force; growth and decay curves for RC circuits; effect of current and length on the force on a current-carrying conductor in a magnetic field; Faraday's law — variation of ε with *N* and rate of change of *B*.

Key skills portfolio evidence requirement		AS/A2 unit	Opportunities for development or internal assessment
		5	Investigations include: the measurement of specific heat capacity; penetrating and ionising power of radiation; displacement-time graphs for oscillating objects; forced vibrations. These provide opportunities for dealing with amounts and sizes and re-arranging and using formulae. Suitable issues include: research into nuclear energy with respect to environmental considerations and sustainable growth, the formation, age and ultimate fate of the universe: indefinite expansion or final contraction.

Appendix 4 Wider curriculum

Signposting

Issue	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Spiritual	✓	✓		✓	✓	
Moral	✓	✓		✓	✓	
Ethical	✓	✓		✓	✓	
Social	✓	✓		✓	✓	
Cultural	✓	✓		✓	✓	
Citizenship	✓	✓		✓	✓	
Environmental	✓	✓	✓	✓	✓	✓
European initiatives	✓	✓	✓	✓	✓	✓
Health and safety	✓	✓	✓	✓	✓	✓

Development suggestions

Issue	AS/A2 units	Opportunities for development or internal assessment
Spiritual	1, 2, 4 and 5	■ Working with others when carrying out practical work ■ Appreciating the mathematical nature of the universe
Moral	1, 2, 4 and 5	■ Discussing the development and trialling of new medical techniques/spare parts on patients ■ Discussing the funding of space missions and research into particle physics ■ Discussing applications of radioactive materials
Ethical	1, 2, 4 and 5	■ Discussing the development and trialling of new medical techniques/spare parts on patients ■ Discussing the funding of space missions and research into particle physics ■ Discussing decisions to place mobile phone masts near schools ■ Discussing applications of radioactive materials
Social	1, 2, 4 and 5	■ The use of ICT introduces social issues of access and equality ■ Discussing the use of science to make informed decisions
Cultural	1, 2, 4 and 5	■ Discussing the impact of cultural beliefs and values on scientific developments
Citizenship	1, 2, 4 and 5	■ Discussing bias in scientific articles ■ Discussing the role of the media in providing scientific information
Environmental	1, 2, 3, 4, 5 and 6	■ Environmental issues can arise from the disposal of materials and equipment, for example NiCd batteries and nuclear materials. There are also concerns about emissions from telecommunications masks for mobile phones
European initiatives	1, 2, 3, 4, 5 and 6	■ Discussing laws concerning health and safety and disposal of materials ■ Investigating the sharing of costs for large projects, for example particle physics accelerators, and space programmes
Health and safety	1, 2, 3, 4, 5 and 6	■ Health and safety issues will arise naturally in practical work.

Appendix 5 Codes

Type of code	Use of code	Code number
National classification codes	Every qualification is assigned to a national classification code indicating the subject area to which it belongs. 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.	1210
National Qualifications Framework (NQF) codes	Each qualification title is allocated a QCA National Qualifications Framework (NQF) code. The QCA National Qualifications Framework (NQF) code is known as a Qualification Accreditation Number (QAN). This is the code that features in the DfES Funding Schedule, Sections 96 and 97, and is to be used for all qualification funding purposes. The QCA QAN is the number that will appear on the candidate's final certification documentation.	The QANs for the qualifications in this publication are: AS — 500/2554/5 Advanced GCE — 500/2435/8
Unit codes	Each unit is assigned a unit code. This unit code is used as an entry code to indicate that a student wishes to take the assessment for that unit. Centres will need to use the entry codes only when entering students for their examination.	Unit 1 — 6PH01 Unit 2 — 6PH02 Unit 3 — 6PH03 Unit 4 — 6PH04 Unit 5 — 6PH05 Unit 6 — 6PH06
Cash-in codes	The cash-in code is used as an entry code to aggregate the student's unit scores to obtain the overall grade for the qualification. Centres will need to use the entry codes only when entering students for their qualification.	AS — 8PH01 Advanced GCE — 9PH01
Entry codes	The entry codes are used to: 1 enter a student for the assessment of a unit 2 aggregate the student's unit scores to obtain the overall grade for the qualification.	Please refer to the Edexcel Information Manual available on the Edexcel website.

Appendix 6 How Science Works

How Science Works requires that students explore how scientific knowledge is developed, validated and communicated by the scientific community. It also requires that students consider the risks, benefits, ethical and environmental implications of science and that students appreciate ways in which society uses science to inform decision making.

How Science Works is an important aspect of the QCA's new GCE Science Criteria and should be embedded within the GCE Physics programme of study.

The first column in the table below lists the criteria for *How Science Works*. The second column provides some guidance on *How Science Works* may be applied to the GCE Physics programme of study.

How science works **statement in the QCA's GCE Science Criteria**	**How it may be applied to GCE Physics**
1 Use theories, models and ideas to develop and modify scientific explanations.	a Explain how the development of scientific theories involves collecting and interpreting data and using creative thinking. b Explain the importance of using models to develop scientific understanding.
2 Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas.	a Distinguish between questions that science can address, and those which science can't address. b Identify scientific questions or problems within a given context. c Use scientific theories to answer scientific questions or address scientific problems.
3 Use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems.	a Justify methods, techniques and processes used during scientific investigations, including the use of ICT, to collect valid and reliable data and produce scientific theories for a chosen question or problem. b Use, for example, spreadsheets to develop scientific models.
4 Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.	a Produce a risk assessment before carrying out a range of practical work.
5 Analyse and interpret data to provide evidence, recognising correlations and causal relationships.	a Analyse data, including the use of graphs, to identify patterns and relationships (for example, correlation and cause). b Interpret data with reference to the analytical methods used.
6 Evaluate methodology, evidence and data, and resolve conflicting evidence.	a Evaluate the validity of conclusions derived from primary and secondary data in terms of the methods, techniques and processes used to collect and analyse the data. b Recognise any systematic or random errors present. c Recognise conflicting evidence.

How science works statement in the QCA's GCE Science Criteria	How it may be applied to GCE Physics
7 Appreciate the tentative nature of scientific knowledge.	a Explain how scientific theories are developed, refined, supported or refuted as new data or new interpretations of data become available.
8 Communicate information and ideas in appropriate ways using appropriate terminology.	a Present scientific information: ■ using text, graphics and other media as appropriate ■ using scientific terminology ■ with reference to data and credible sources.
9 Consider applications and implications of science and appreciate their associated benefits and risks.	a Evaluate activities in terms of their associated benefits and risks to humans and the environment. b Discuss the risk associated with an activity in terms of the actual level of the risk and its potential consequences, associated uncertainties and the factors affecting people's perception of the risk.
10 Consider ethical issues in the treatment of humans, other organisms and the environment.	a Identify ethical issues arising from the application of science as it impacts on humans and the environment. b Discuss scientific solutions from a range of ethical viewpoints.
11 Appreciate the role of the scientific community in validating new knowledge and ensuring integrity.	a Discuss the importance of critical evaluation of new data or new interpretations of data which challenge established scientific theories or propose new theories. b Describe how the process of communication through journals and conferences, and peer review contribute to validation of new scientific theories by the scientific community.
12 Appreciate the ways in which society uses science to inform decision making.	a Discuss how science influences decisions on an individual, local, national or international level.

Appendix 7 Data

The value of the following constants will be provided in each examination paper.

Acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9} \text{ N m}^{2} \text{ C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19} \text{ C}$	
Electron mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$	
Electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	
Gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^{2} \text{ kg}^{-2}$	
Gravitational field strength	$g = 9.81 \text{ N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27} \text{ kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8} \text{ m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27} \text{ kg}$	

Appendix 8 Formulae

Students need not memorise formulae for this specification.

The formulae below will be supplied in each examination. Any other physics formulae that are required will be provided in the question. Symbols used comply with ASE guidelines (which are based on IUPAP recommendations).

Unit 1

Mechanics

Kinematic equations of motion	$v = u + at$ $s = ut + ½at^2$ $v^2 = u^2 + 2as$
Forces	$\Sigma F = ma$ $g = F/m$ $W = mg$
Work and energy	$\Delta W = F\Delta s$ $E_k = ½\ mv^2$ $\Delta E_{grav} = mg\Delta h$

Materials

Stokes' law	$F = 6\pi\eta rv$
Hooke's law	$F = k\Delta x$
Density	$\rho = m/V$
Pressure	$p = F/A$
Young's modulus	$E = \sigma/\varepsilon$ where Stress $\sigma = F/A$ Strain $\varepsilon = \Delta x/x$
Elastic strain energy	$E_{el} = ½\ Fx$

Unit 2

Waves

Wave speed	$v = f\lambda$
Refractive index	${}_1\mu_2 = \sin i / \sin r = v_1/v_2$

Electricity

Potential difference	$V = W/Q$
Resistance	$R = V/I$
Electrical power, energy and efficiency	$P = VI$ $P = I^2R$ $P = V^2/R$. $W = VIt$ % efficiency = [useful energy (or power) output/total energy (or power) input] × 100%
Resistivity	$R = \rho l/A$
Current	$I = \Delta Q/\Delta t$ $I = nqvA$

Quantum physics

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2} mv^2_{max}$

Unit 4

Mechanics

Momentum	$p = mv$
Kinetic energy of a non-relativistic particle	$E_k = p^2/2m$
Motion in a circle	$v = \omega r$ $T = 2\pi/\omega$ $F = ma = mv^2/r$ $a = v^2/r$ $a = r\omega^2$

Fields

Coulomb's law	$F = kQ_1Q_2/r^2$ where $k = 1/4\pi\varepsilon_0$
Electric field	$E = F/Q$ $E = kQ/r^2$ $E = V/d$
Capacitance	$C = Q/V$
Energy stored in capacitor	$W = \frac{1}{2} QV$
Capacitor discharge	$Q = Q_0 \mathrm{e}^{-t/RC}$
In a magnetic field	$F = BIl \sin\theta$ $F = Bqv \sin\theta$ $r = p/BQ$
Faraday's and Lenz's Laws	$\varepsilon = -\mathrm{d}(N\Phi)/\mathrm{d}t$

Particle physics

Mass-energy	$\Delta E = c^2\Delta m$
de Broglie wavelength	$\lambda = h/p$

Unit 5

Energy and matter

Heating	$\Delta E = mc\Delta\theta$
Molecular kinetic theory	$\frac{1}{2} m\langle c^2\rangle = {}^3/_2\, kT$
Ideal gas equation	$pV = NkT$

Nuclear physics

Radioactive decay	$\mathrm{d}N/\mathrm{d}t = -\lambda N$
	$\lambda = \ln 2/t_{½}$
	$N = N_0\, \mathrm{e}^{-\lambda t}$

Mechanics

Simple harmonic motion	$a = -\omega^2 x$ $a = -A\omega^2 \cos \omega t$ $v = -A\omega \sin \omega t$ $x = A\cos \omega t$ $T = 1/f = 2\pi/\omega$
Gravitational force	$F = Gm_1m_2/r^2$

Observing the universe

Radiant energy flux	$F = L/4\pi d^2$
Stefan-Boltzmann law	$L = \sigma T^4 A$ $L = 4\pi r^2\sigma T^4$
Wien's law	$\lambda_{max}T = 2.898 \times 10^{-3}$ m K
Redshift of electromagnetic radiation	$z = \Delta\lambda/\lambda \approx \Delta f/f \approx v/c$
Cosmological expansion	$v = H_0 d$

Appendix 9 Glossary

This appendix gives explanations of how keywords that are used in *Section C: Physics unit content* can be related to examination questions.

Keywords	Possible applications in examinations
Discuss	Questions using this keyword will require that students write a few sentences, for example, to describe an application of physics or explain a given situation using principles of physics.
Explore	Students may be required to use information that is provided, together with their own knowledge of physics, to solve a problem or explain a given situation.
Identify	Students may be required to select appropriate formulae, terms or concepts, for example to solve a problem or to explain a given situation. Students may be required to solve the problem or explain the situation. Students may be given equations that include formula that they should be able to recognise, for example an equation for the conservation of energy that contains formulae for different forms of energy.
Investigate	Students are expected to have carried out an experiment to achieve outcomes that use this keyword. Consequently students may be asked to describe experiments or interpret experimental data for outcomes using this keyword. They may also be asked questions related to experimental work, for example, evaluating the validity of conclusions that are based on experimental data.
Recall	Students are expected to retrieve from their memory facts that are relevant to a given situation.
Recognise	Students may be required to realise which formula or concepts in physics are needed to solve a problem or explain a given situation. Students may be required to solve the problem or explain the situation. Students may be given equations that include formulae that they should be able to recognise, for example an equation for the conservation of energy that contains formulae for different forms of energy.
Understand	Students may be required to apply their knowledge of physics to a given situation to show that they understand physics concepts and formulae. For example, students may be required to apply their knowledge of mechanics to a situation that involves sports.
Use	Students may be required to apply their knowledge and understanding of physics, including formulae, to a given situation.

Appendix 10 Further resources and support

Books

Akrill T and Millar C —*Practice in Physics* (Hodder Murray, 2000) ISBN 978-0340758137

Breithaupt J — *New Understanding Physics for Advanced Level* (Nelson Thornes Ltd, 1999) ISBN 978-0748743148

Lowe T and Rounce J — *Calculations for A-level Physics* (Nelson Thornes Ltd, 2002) ISBN 978-0748767489

Salters Horners Advanced Physics A2 Level Students Book
Authors: University of York Science Education Group
ISBN 9780435628901

Salters Horners Advanced Physics AS Level Students Book
Authors: University of York Science Education Group
ISBN 9780435628901

Useful websites

Web addresses are correct at the time of publication.

www.cpepweb.org — Contemporary Physics Education Project

www.edexcel.com/gce2008

www.iop.org/Our_Activities/Schools_and_Colleges/index.html — Institute of Physics web resource

www.particleadventure.org — a useful resource for particle physics

www.phy.ntnu.edu.tw/ntnujava — A site containing java applets

www.pparc.ac.uk — free publications, advice and resources for astronomy, space and particle physics

www.practicalphysics.org — contains over 500 practical experiments

www.schoolscience.co.uk — An online resource collection schools.matter.org.uk/a-level.html — has online resources for GCE Physics

www.sciencelearningcentres.org.uk — learning centres provide courses for teachers and technicians

www.york.ac.uk/org/seg/salters/physics — the Salters Horners website for this specification

Multimedia

Multimedia Motion and Multimedia Sound CD ROM
Cambridge Science Media
354 Mill Road
Cambridge CB1 3NN

Telephone: 01223 357546
Website: www.csmedia.demon.co.uk

Other support

Focus ISSN 09664270 (BBC)

New Scientist ISSN 0262-4079 (IPC Magazines)

Physics Education ISSN 0031-9120 (Institute of Physics Publishing)

Physics Review ISSN 0959-8472 (Philip Allan Publishers)

Scientific American ISSN 0036-8733 (Scientific American Inc.)

Appendix 11 Disability Discrimination Act

AS/A levels often require assessment of a broad range of competences. This is because they are general qualifications and, as such, prepare candidates for a wide range of occupations and higher level courses.

The revised AS/A level qualification and subject criteria were reviewed to identify whether any of the competences required by the subject presented a potential barrier to any disabled candidates. If this was the case, the situation was reviewed again to ensure that such competences were included only where essential to the subject. The findings of this process were discussed with disability groups and with disabled people.

Reasonable adjustments are made for disabled candidates in order to enable them to access the assessments. For this reason, very few candidates will have a complete barrier to any part of the assessment. For information on reasonable adjustments please see the Edexcel website (www.edexcel.com).

Candidates who are still unable to access a significant part of the assessment, even after exploring all possibilities through reasonable adjustments, may still be able to receive an award. They would be given a grade on the parts of the assessment they have taken and there would be an indication on their certificate that not all of the competencies have been addressed. This will be kept under review and may be amended in the future.

Practical assistants may be used for manipulating equipment and making observations. Technology may help visually impaired students to take readings and make observations.

Appendix 12 General and mathematical requirements

An understanding of the following, as applied to the analysis of physical situations, is expected and may be assessed in relevant units of the specification. These requirements should not be taught separately from their applications within physics; an integrated approach is expected. Bold text indicates requirements that are specific to A2 only.

A familiarity with the layout of a spreadsheet and the nomenclature used is expected.

Physical quantities and their units.	Understand the distinction between base and derived physical quantities and their units in SI. There is no need to memorise derived physical quantities.
Significant figures	Use an appropriate number of significant figures.
Order of magnitude.	Appreciate the order of magnitude of common physical quantities. Make order-of-magnitude calculations.
Rate of change	Use and interpret expressions such as: average $\upsilon = \Delta x/\Delta t$ average $a = \Delta \upsilon/\Delta t$
Vectors and scalars.	Recognise a physical quantity as a vector or a scalar. Resolve a vector into two components at right angles to each other. Combine two perpendicular vectors by calculation. Combine any number of coplanar vectors at any angle to each other by drawing.

Graphs

Translate information between graphical, numerical and algebraic forms.

Plot a graph using two variables from experimental or other data, using appropriate scales for graph plotting.

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

Understand that $y = mx + c$ represents a linear relationship and rearrange relationships into this form where appropriate.

Determine the gradient and intercept of a linear graph by drawing and calculation.

Determine the gradient of a tangent to a non-linear graph by drawing.

Allocate appropriate physical units to quantities deduced from gradient and intercept.

Understand the possible physical significance of the area between a curve and the horizontal axis and be able to calculate it (in the case of a straight-line graph) or measure it by counting squares.

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

Plot data on a log-linear graph and hence determine whether they change exponentially and, if they do, determine the exponent.

Plot data on a log-log graph and hence decide whether data obey a power law and, if they do, determine the exponent.

Arithmetic and computation

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

Use ratios, fractions and percentages.

Recognise and use SI prefixes 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
- finding arithmetic means
- manipulating degrees **and radians**
- **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, $\sin^{-1}$ θ, $\cos^{-1}$ θ, $\tan^{-1}$ θ, $\log_{10} x$ and ln x)**
- finding and using x^n, $1/x$ and $\sqrt{x}$.

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.

Use the terms *accuracy*, *precision* and *sensitivity* appropriately

Estimate the uncertainty (random error) in a single measurement and express it as an absolute value and as a percentage.

Estimate the uncertainty (random error) in a quantity derived by processing a set of experimental data, and express it as an absolute value and as a percentage.

Algebra	Change the subject of an equation by manipulation of the terms, including positive, negative, 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. Formulate and use simple equations as mathematical models of physical situations, and identify inadequacies of such models. **Express quantities with a very large range, eg resistivities of materials, using $\log_{10}$ of those quantities** **Recognise and use the logarithmic forms of expressions such as ab, a/b, x^n and e^{kx}** 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.

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Edexcel, a Pearson company, is the UK's largest awarding body, offering academic and vocational qualifications and testing to more than 25,000 schools, colleges, employers and other places of learning in the UK and in over 100 countries worldwide. Qualifications include GCSE, AS and A Level, NVQ and our BTEC suite of vocational qualifications from entry level to BTEC Higher National Diplomas, recognised by employers and higher education institutions worldwide.

We deliver 9.4 million exam scripts each year, with more than 90% of exam papers marked onscreen annually. As part of Pearson, Edexcel continues to invest in cutting-edge technology that has revolutionised the examinations and assessment system. This includes the ability to provide detailed performance data to teachers and students which helps to raise attainment.

This specification is Issue 4. Key changes are sidelined. We will inform centres of any changes to this issue. The latest issue can be found on the Edexcel website: www.edexcel.com

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