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INTERNATIONAL ADVANCED LEVEL

Physics

SPECIFICATION

Pearson Edexcel International Advanced Subsidiary in Physics (XPH01)

Pearson Edexcel International Advanced Level in Physics (YPH01)

For first teaching in September 2013
First examination January 2014

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ALWAYS LEARNING

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Acknowledgements
This specification has been produced by Pearson on the basis of consultation with teachers, examiners, consultants and other interested parties. Pearson would like to thank all those who contributed their time and expertise to the specification's development.

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All information in this specification is correct at time of going to publication.

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About this specification

Pearson Edexcel International Advanced Level in Physics is designed for use in schools and colleges outside the United Kingdom. It is part of a suite of International Advanced Level qualifications offered by Pearson.

This qualification has been approved by Pearson Education Limited as meeting the criteria for Pearson's Self-regulated Framework.

Pearson's Self-regulated Framework is designed for qualifications that have been customised to meet the needs of a particular range of learners and stakeholders. These qualifications are not accredited or regulated by any UK regulatory body.

Structure: flexible, modular structure comprising six units.

Content: engaging and relevant to international customers.

Assessment: 100% external assessment, with January and June assessment opportunities.

Approach: use of contemporary contexts and a choice of two distinct, flexible, teaching and learning approaches within one common assessment structure.

Specification updates

This specification is Issue 1 and is valid for the Pearson Edexcel International Advanced Subsidiary and International Advanced Level examination from 2014. If there are any significant changes to the specification Pearson will write to centres to let them know. Changes will also be posted on our website.

For more information please visit: www.edexcel.com/ial

Using this specification

The specification content has been designed to give guidance to teachers and encourage effective delivery of the qualification. The following information will help you get the most out of the content and guidance.

The specification content has been designed to engage and inspire students who have different needs and abilities by providing two 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 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 and finishes with an exploration of their practical applications.

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.

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 International Advanced 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.

Depth and breadth of content: teachers should prepare students to respond to assessment questions. Teachers should use the full range of content and all the assessment objectives given in *Section B: Specification Overview*.

Qualification abbreviations

International Advanced Level – IAL

International Advanced Subsidiary – IAS

International Advanced Level 2 (the additional content required for an IAL) – IA2

Contents

Contents

A Specification at a glance

Unit overview

IAS Unit 1: Physics on the Go	*Unit code WPH01	
■ Externally assessed ■ Availability: January and June ■ First assessment: January 2014	40% of the total IAS raw marks	20% of the total IAL raw 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 30 minutes duration, which will consist of objective, short-answer and long-answer questions.		

IAS Unit 2: Physics at Work	*Unit code WPH02	
■ Externally assessed ■ Availability: January and June ■ First assessment: January 2014	40% of the total IAS raw marks	20% of the total IAL raw 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 30 minutes duration, which will consist of objective, short-answer and long-answer questions.		

* See *Appendix 2* for description of this code and all other codes relevant to this qualification.

IAS Unit 3: Exploring Physics	*Unit code WPH03	
■ Externally assessed ■ Availability: January and June ■ First assessment: January 2014	20% of the total IAS raw marks	10% of the total IAL raw marks
Content summary: Students are expected to develop experimental skills, and a knowledge and understanding of experimental techniques, by carrying out a range of practical experiments and investigations while they study Units 1 and 2. This unit will assess students' knowledge and understanding of experimental procedures and techniques that were developed in Units 1 and 2.		
Assessment: This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration, which will consist of objective, short-answer and long-answer questions.		

IA2 Unit 4: Physics on the Move	*Unit code WPH04	
■ Externally assessed ■ Availability: January and June ■ First assessment: January 2014	40% of the total IA2 raw marks	20% of the total IAL raw 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, short-answer and long-answer questions.		

* See *Appendix 2* for description of this code and all other codes relevant to this qualification.

IA2 Unit 5: Physics from Creation to Collapse	*Unit code WPH05	
■ Externally assessed ■ Availability: January and June ■ First assessment: January 2014	40% of the total IA2 raw marks	20% of the total IAL raw 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, short-answer and long-answer questions.		

IA2 Unit 6: Experimental Physics	*Unit code WPH06	
■ Externally assessed ■ Availability: January and June ■ First assessment: January 2014	20% of the total IA2 raw marks	10% of the total IAL raw marks
Content summary: Students are expected to further develop the experimental skills and the knowledge and understanding of experimental techniques that they acquired in Units 1 and 2 by carrying out a range of practical experiments and investigations while they study Units 4 and 5. This unit will assess students' knowledge and understanding of the experimental procedures and techniques that were developed in Units 4 and 5.		
Assessment: This unit is assessed by means of a written examination paper of 1 hour 20 minutes duration, which will consist of short-answer and long-answer questions.		

* See *Appendix 2* 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 raw marks allocated in the unit
Unit 1 Physics on the Go	IAS	Examination length: 1 hour 30 minutes. The paper will consist of objective questions, short-answer questions and long-answer 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 5 Formulae*. Any other physics formulae that are required will be stated in the question paper.	80
Unit 2 Physics at Work	IAS	Examination length: 1 hour 30 minutes. The paper will consist of objective questions, short-answer questions and long-answer 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 5 Formulae*. Any other physics formulae that are required will be stated in the question paper.	80
Unit 3 Exploring Physics	IAS	Examination length: 1 hour and 20 minutes. The paper will consist of objective questions, short-answer questions and long-answer questions.	40
Unit 4 Physics on the Move	IA2	Examination length: 1 hour 35 minutes duration. The paper will consist of objective questions, short-answer questions and long-answer 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 5 Formulae*. Any other physics formulae that are required will be stated in the question paper.	80

Unit number and unit title	Level	Assessment information	Number of raw marks allocated in the unit
Unit 5 Physics from Creation to Collapse	IA2	Examination length: 1 hour 35 minutes duration. The paper will consist of objective questions, short-answer questions and long-answer 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 5 Formulae*. Any other physics formulae that are required will be stated in the question paper.	80
Unit 6 Experimental Physics	IA2	Examination length: 1 hour and 20 minutes. The paper will consist of short-answer questions and long-answer questions.	40

Assessment objectives and weightings

		% in IAS	% in IA2	% in IAL
AO1	Knowledge and understanding of science and of *How Science Works*	40%	30%	35%
AO2	Application of knowledge and understanding of science and of *How Science Works*	40%	50%	45%
AO3	*How Science Works*	20%	20%	20%
		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 International Advanced Level	35%	45%	20%	100%

Qualification summary

Aims

The aims of the International Advanced Level in Physics are to enable students to:

- progress 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 including *How Science Works*
- demonstrate the importance of physics as a human endeavour that interacts with social, philosophical, economic and industrial matters
- prepare for higher educational courses in physics and related courses.

IAS/IA2 knowledge and understanding

The International Advanced Level qualifications in Physics require 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.

IAS/IA2 skills

The International Advanced Level qualifications in Physics require 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

Course structure

- The Pearson Edexcel International Advanced Level in Physics comprises six units and contains an International Advanced Subsidiary subset of three IAS units.
- The International Advanced Subsidiary is the first half of the International Advanced Level course and consists of Units 1, 2 and 3. It may be awarded as a discrete qualification or contribute 50 per cent of the total International Advanced Level marks.
- The full International Advanced Level award consists of the three IAS units (Units 1, 2 and 3), plus three IA2 units (Units 4, 5 and 6) which make up the other 50 per cent of the International Advanced Level. Students wishing to take the full International Advanced Level must, therefore, complete all six units.
- The structure of this qualification allows teachers to construct a course of study that 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.

Introduction to the concept and context approaches

Each unit may be taught based on either a concept approach or a context approach:

1. Concept-led approach – starts on page 13.

This approach begins with a study of the laws, theories and models of physics and finishes with an exploration of their practical applications.

2. Context-led approach – starts on page 45.

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 and finishes with an exploration of their practical applications.

Teachers may select the approach that best meets the needs of their students. Centres may use both approaches, for example, by allowing one group of students to follow one approach and another group of students to follow the other approach. These different approaches lead to the same assessment for each unit. A mix of approaches can be used, if desired.

Concept-led approach

The following sections show how the specification may be taught using the concept-led appoach.

1.1 Unit description

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 47 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

How Science Works – Appendix 3 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 to make predictions.

The word 'investigate' indicates where students should develop their practical skills for *How Science Works*, numbers 1–6 as detailed in *Appendix 3*.

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

This unit is assessed by means of a written examination paper of 1 hour 30 minutes duration. The paper will consist of objective, short-answer and long-answer 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 IAS and 20% to the IAL in Physics.

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 5*. Any other physics formulae that are required will be stated in the question paper.

The quality of written communication will be assessed in the context of this unit through questions which are labelled with an asterisk (*). Students should take particular care with spelling, punctuation and grammar, as well as the clarity of expression, on these questions.

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	
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

Students will be assessed on their ability to:		Suggested experiments
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 $E_k = \frac{1}{2}mv^2$ 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 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.

Content 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' 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, 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 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	

Students will be assessed on their ability to:		Suggested experiments
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 that the elastic strain energy E_{el} is a deformed material sample, using the expression $E_{el} = ½F\Delta x$, and from the area under its force/extension graph	

2.1 Unit description

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 53 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

How Science Works – Appendix 3 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 to 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 3*.

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.

2.2 Assessment information

This unit is assessed by means of a written examination paper of 1 hour 30 minutes duration. The paper will consist of objective, short-answer and long-answer 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 IAS and 20% to the IAL in Physics.

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 5*. Any other physics formulae that are required will be stated in the question paper.

The quality of written communication will be assessed in the context of this unit through questions which are labelled with an asterisk (*). Students should take particular care with spelling, punctuation and grammar, as well as the clarity of expression, on these questions.

2.3 Waves

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

This topic should be studied by exploring the 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 (stationary) 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
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

Concept approach

Students will be assessed on their ability to:		Suggested experiments
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	
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, e.g. when developing and trialing 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 an ohmmeter to measure total resistance of series/parallel circuits
53	investigate and use the expressions $P = VI$, $W = VIt$. Recognise and use related expressions, e.g. $P = I^2R$ and $P = V^2/R$	Measure the efficiency of an electric motor (see 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
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

Students will be assessed on their ability to:		Suggested experiments
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, e.g. 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 the 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 $hf = \phi + ½mv^2_{max}$	
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]	
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

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 61 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

How Science Works – Appendix 3 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 to 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 3*.

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.

3.2 Assessment information

This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective, short-answer and long-answer 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 IA2 and 20% to the IAL in Physics.

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 5*. Any other physics formulae that are required will be stated in the question paper.

The quality of written communication will be assessed in the context of this unit through questions which are labelled with an asterisk (*). Students should take particular care with spelling, punctuation and grammar, as well as the clarity of expression, on these questions.

3.3 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	
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

3.4 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 $W = \frac{1}{2}QV$ 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, $W = \frac{1}{2}CV^2$	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	
90	recognise and use the expression $Q = Q_0e^{-t/RC}$ and derive and use related expressions, for exponential discharge in RC circuits, for example, $I = I_0\, e^{-t\backslash RC}$	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

Students will be assessed on their ability to:		Suggested experiments
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	

3.5 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	
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	

Concept approach

Students will be assessed on their ability to:		Suggested experiments
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 to 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 (e.g. neutrons and protons) are made from three quarks, and mesons (e.g. 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 (e.g. π^+, e^-)	
108	use de Broglie's wave equation $\lambda = h/p$	

4.1 Unit description

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 69 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

How Science Works – Appendix 3 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 to 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 3*.

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.

4.2 Assessment information

This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective, short-answer and long-answer 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 IA2 and 20% to the IAL in Physics.

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 5*. Any other physics formulae that are required will be stated in the question paper.

The quality of written communication will be assessed in the context of this unit through questions which are labelled with an asterisk (*). Students should take particular care with spelling, punctuation and grammar, as well as the clarity of expression, on these questions.

4.3 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 $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	
113	use the expression $pV = NkT$ as the equation of state for an ideal gas	Use temperature and pressure sensors to investigate the relationship between p and T Experimental investigation of the relationship between p and V

4.4 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	

4.5 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

4.6 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 $L = \sigma T^4 \times$ 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	
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 $v = H_0 d$ 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	

Students will be assessed on their ability to:	Suggested experiments
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	

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

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

5.1 Unit description

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 15 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

How Science Works – Appendix 3 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 to 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 3.

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.

5.2 Assessment information

This unit is assessed by means of a written examination paper of 1 hour 30 minutes duration. The paper will consist of objective, short-answer and long-answer 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 IAS and 20% to the IAL in Physics.

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 5*. Any other physics formulae that are required will be stated in the question paper.

The quality of written communication will be assessed in the context of this unit through questions which are labelled with an asterisk (*). Students should take particular care with spelling, punctuation and grammar, as well as the clarity of expression, on these questions.

5.3 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	
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 $E_k = \frac{1}{2}mv^2$ 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	
17	investigate and calculate power from the rate at which work is done or energy transferred	Estimate power output of electric motor (see 53)
16	understand some applications of mechanics, for example to safety or to sports	

5.4 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	

5.5 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 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
27	calculate the elastic strain energy E_{el} is a deformed material sample, using the expression $E_{el} = \frac{1}{2}F\Delta x$, and from the area under its force/extension graph	

6.1 Unit description

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 21 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

How Science Works – Appendix 3 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 to 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 3*.

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.

6.2 Assessment information

This unit is assessed by means of a written examination paper of 1 hour 30 minutes duration. The paper will consist of objective, short-answer and long-answer 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 IAS and 20% to the IAL in Physics.

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 5*. Any other physics formulae that are required will be stated in the question paper.

The quality of written communication will be assessed in the context of this unit through questions which are labelled with an asterisk (*). Students should take particular care with spelling, punctuation and grammar, as well as the clarity of expression, on these questions.

6.3 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 should 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 (stationary) 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	
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

6.4 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 should 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	
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

Students will be assessed on their ability to:		Suggested experiments
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, e.g. $P = I^2R$ and $P = V^2/R$	Measure the efficiency of an electric motor (see 17)
54	use the fact that resistance is defined by $R = V/I$ and that Ohm's law is a special case when $I \alpha V$	
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
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, e.g. a solar cell

Students will be assessed on their ability to:		Suggested experiments
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	
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, e.g. when developing and trialing 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	

6.5 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 for sudents 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
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	Demonstration using a ripple tank or computer simulation
43	discuss how scientific ideas may change over time, for example, our ideas on the particle/wave nature of electrons	

7.1 Unit description

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.

Concept approach

This unit is presented in a different format on page 29 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

How Science Works – Appendix 3 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 3*.

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

This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective, short-answer and long-answer 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 IA2 and 20% to the IAL in Physics.

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 5*. Any other physics formulae that are required will be stated in the question paper.

The quality of written communication will be assessed in the context of this unit through questions which are labelled with an asterisk (*). Students should take particular care with spelling, punctuation and grammar, as well as the clarity of expression, on these questions.

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

There are opportunities for students 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 $C = Q/V$	Use a Coulometer to measure charge stored
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, $I = I_0 e^{-t/RC}$	Use of data logger to obtain I–t graph

Context approach

Students will be assessed on their ability to:		Suggested experiments
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	

7.4 The Medium is the Message (MDM)

Students will 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 for students to develop information and communication technology skills using computer simulations.

In studying various types of display technology, students will 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	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
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 $W = \frac{1}{2}QV$ 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, $W = \frac{1}{2}CV^2$	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 $N\Phi$	

Students will be assessed on their ability to:		Suggested experiments
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	

7.5 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 will 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 for students to develop ICT skills using the internet and computer simulations.

Students will 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 $T = 2\pi/\omega$	
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

Students will be assessed on their ability to:		Suggested experiments
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	
105	be aware of relativistic effects and that these need to be taken into account at speeds near to 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 (e.g. π^+, e^-)	
106	recall that in the standard quark-lepton model each particle has a corresponding antiparticle, that baryons (e.g. neutrons and protons) are made from three quarks, and mesons (e.g. 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 $\lambda = h/p$	

8.1 Unit description

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 37 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

How Science Works – Appendix 3 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 3*.

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.

8.2 Assessment information

This unit is assessed by means of a written examination paper of 1 hour 35 minutes duration. The paper will consist of objective, short-answer and long-answer 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 IA2 and 20% to the IAL in Physics.

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 5*. Any other physics formulae that are required will be stated in the question paper.

The quality of written communication will be assessed in the context of this unit through questions which are labelled with an asterisk (*). Students should take particular care with spelling, punctuation and grammar, as well as the clarity of expression, on these questions.

8.3 Reach for the Stars (STA)

The focus of this unit 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 for students 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	
112	recognise and use the expression $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	

Students will be assessed on their ability to:		Suggested experiments
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	
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

Students will be assessed on their ability to:	Suggested experiments
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 $L = \sigma T^4 \times$ 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	
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 $v = H_0 d$ 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	

8.4 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 for students 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	
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

Generic units (concept and context)

The following section contains details of the external assessments for Units 3 and 6. The same external assessments are used for both the concept-led and context-led approaches.

9.1 Unit description

Introduction

Students are expected to develop experimental skills, and a knowledge and understanding of experimental techniques, by carrying out a range of practical experiments and investigations while they study Units 1 and 2.

This unit will assess students' knowledge and understanding of experimental procedures and techniques that were developed when they conducted these experiments.

Development of practical skills, knowledge and understanding

Students should do a variety of practical work during the IAS course to develop their practical skills. This should help them to gain an understanding and knowledge of the practical techniques that are used in experimental work.

Centres should provide opportunities for students to plan experiments, implement their plans, collect data, analyse their data and draw conclusions in order to prepare them for the assessment of this unit.

Experiments should cover a range of different topic areas and require the use of a variety of practical techniques. The specification for Units 1 and 2 contain suggestions for practical work, although these suggestions do not constitute an exhaustive list. This should help students to gain an understanding and knowledge of the practical techniques that are used in experimental work.

How Science Works

Students should be given the opportunity to develop their practical skills for *How Science Works*, numbers 2–6, as detailed in *Appendix 3*, by completing a range of different experiments that require a variety of different practical techniques.

Students should produce laboratory reports on their experimental work using appropriate scientific, technical and mathematical language, conventions and symbols in order to meet the requirements of *How Science Works*, number 8.

9.2 Assessment information

This unit is assessed by means of a written examination paper of 1 hour 20 minutes' duration. The paper will consist of objective, short-answer and long-answer 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 40. It contributes 10 per cent to the International Advanced Level in Physics.

Students will need a scientific calculator, a protractor and a ruler for this paper.

Students are provided with the formulae sheet in *Appendix 5* in the main specification. Any other physics formulae that are required will be stated in the question paper.

9.3 Assessment details

This unit is assessed by means of a written examination paper. The assessment for this unit covers planning an experiment, analysing data and drawing conclusions. A laboratory is not required for this assessment.

Planning

Students will be expected to plan an experiment that is set by Pearson, although they will not be expected to carry it out.

Students may be required to:

- identify the apparatus required
- discuss calibration of instruments, e.g. whether a meter reads zero before measurements are made
- describe how to measure relevant variables using the most appropriate instrument and correct measuring techniques
- identify and state how to control all other relevant variables to make it a fair test
- discuss whether repeat readings are appropriate
- identify health and safety issues and discuss how these may be dealt with
- discuss how the data collected will be used
- identify possible sources of uncertainty and/or systematic error and explain how these may be reduced or eliminated
- comment on the implications of physics (e.g. benefits/risks) and on its context (e.g. social/environmental/historical).

Implementation and measurements

Students will be given details of an experiment carried out by an inexperienced student. Results may be included.

Students may be asked to:

- comment on the number of readings taken
- comment on the range of measurements taken
- comment on significant figures
- check a reading that is inconsistent with other readings, e.g. a point that is not on the line of a graph — students may be shown a diagram of a micrometer that is being used to measure the diameter of a wire and be expected to write down the reading to the correct number of significant figures
- comment on how the experiment may be improved, possibly by using additional apparatus (e.g. to reduce errors) — examples may include using a set square to determine whether a ruler is vertical and to aid the measurement of the extension of a spring.

Processing results

Students will be provided with a set of experimental results that were obtained by a more experienced student conducting an experiment.

Students may be expected to:

- perform calculations, using the correct number of significant figures
- plot results on a graph using an appropriate scale
- use the correct units throughout
- comment on the trend/pattern obtained
- determine the relationship between two variables or determine a constant with the aid of a graph, e.g. by determining the gradient using a large triangle
- suggest realistic modifications to reduce errors
- suggest realistic modifications to improve the experiment
- discuss uncertainties, qualitatively and/or quantitatively (students will be expected to determine the percentage uncertainty of a single measurement).

Drawing conclusions

After processing results, students may be asked to provide a final conclusion for the experiment based on their quantitative evidence.

10.1 Unit description

Introduction

Students are expected to further develop the experimental skills that they acquired in Units 1 and 2.

Students are expected to develop these skills, and a knowledge and understanding of experimental techniques, by carrying out a range of practical experiments and investigations while they study Units 4 and 5.

This unit will assess students' knowledge and understanding of experimental procedures and techniques that were developed when they conducted these experiments.

Development of practical skills, knowledge and understanding

Students should do a variety of practical work during the IA2 course to develop their practical skills.

Centres should provide opportunities for students to plan experiments, implement their plans, collect data, analyse their data and draw conclusions in order to prepare them for the assessment of this unit.

Experiments should cover a range of different topic areas and use of a variety of practical techniques. The specification for Units 4 and 5 contain suggestions for practical work, although these suggestions do not constitute an exhaustive list. This should help students to gain an understanding and knowledge of the practical techniques that are used in experimental work.

Students should gain experience of using log graphs to determine the relationship between two variables. The graphs do not always need to be obtained for variables that are related by the exponential function.

For example, students could investigate how the pressure of a fixed mass of gas varies with its volume at constant temperature and plot an appropriate log/log graph to determine the relationship between the pressure and volume of the gas.

How Science Works

Students should be given the opportunity to develop their practical skills for *How Science Works*, numbers 2–6, as detailed in *Appendix 3*, by completing a range of different experiments that require a variety of different practical techniques throughout the International Advanced Level course.

Students should produce laboratory reports on their experimental work using appropriate scientific, technical and mathematical language, conventions and symbols in order to meet the requirements of *How Science Works*, number 8.

10.2 Assessment information

This unit is assessed by means of a written examination paper of 1 hour 20 minutes' duration. The paper will consist of short-answer and long-answer 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 40. It contributes 10 per cent to the International Advanced Level in Physics.

Students will need a scientific calculator, a protractor and a ruler for this paper.

Students are provided with the formulae sheet in *Appendix 5* in the main specification. Any other physics formulae that are required will be stated in the question paper.

10.3 Assessment details

This unit is assessed by means of a written examination paper. The assessment for this unit covers planning an experiment, analysing data and drawing conclusions. A laboratory is not required for this assessment.

Planning

Students will be expected to plan an experiment that is set by Pearson, although they will not be expected to carry it out.

Students may be required to:

- identify the most appropriate apparatus, giving details. These may include the range and precision of instruments and/or relevant dimensions of apparatus (e.g. the length of string used for a pendulum)
- discuss calibration of instruments, e.g. whether a meter reads zero before measurements are made
- describe how to measure relevant variables using the most appropriate instrument(s) and techniques
- identify and state how to control all other relevant variables to make it a fair test
- discuss whether repeat readings are appropriate
- identify health and safety issues and discuss how these may be dealt with
- discuss how the data collected will be used
- identify possible sources of uncertainty and/or systematic error and explain how these may be reduced or eliminated.

Implementation and measurements

Students will be given partial details of how an experiment was carried out. Results may be included.

Students may be asked to:

- comment on how the experiment could have been improved, possibly by using additional apparatus (e.g. to reduce errors) — examples may include using set squares to measure the diameter of a cylinder and using a marker for timing oscillations
- comment on the number of readings taken
- comment on the range of measurements taken
- comment on significant figures — students may be required to identify and/or round up any incorrect figures in a table of results
- identify and/or amend units that are incorrect
- identify and check a reading that is inconsistent with other readings, e.g. a point that is not on the line of a graph.

Analysis

Students will be expected to use the set of experimental results to:

- perform calculations, using the correct number of significant figures
- plot results on a graph using an appropriate scale and units — the graph could be logarithmic in nature
- use the correct units throughout
- comment on the trend/pattern obtained
- determine the relationship between two variables or determine a constant with the aid of the graph, e.g. by determining the gradient using a large triangle
- use the terms *precision, accuracy* and *sensitivity* appropriately
- suggest realistic modifications to reduce errors
- suggest realistic modifications to improve the experiment
- discuss uncertainties qualitatively and quantitatively
- compound percentage uncertainties correctly.

Drawing conclusions

After processing results, students may be asked to provide a final conclusion for the experiment in relation to its original aim and based on their quantitative evidence.

They may also be asked to suggest further relevant work, for example to verify their conclusion(s).

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 candidates for the examinations for this qualification can be found in the International Information Manual, copies of which are sent to all examinations officers. The information can also be found at: www.edexcel.com/international

Resitting of units

There is one resit opportunity allowed for each 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 are held in the Pearson unit bank and have a shelf life limited only by the shelf life of this specification.

Awarding and reporting

The IAS qualification will be graded and certificated on a five-grade scale from A to E. The full International Advanced Level will be graded on a six-point scale A* to E. Individual unit results will be reported.

A pass in an International 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 International Advanced Level 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 International Advanced Level qualification and an A* aggregate of the IA2 units. Students whose level of achievement is below the minimum judged by Pearson 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**

Students 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**

Students 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**

Students 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**

Students 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**

Students 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**

Students 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:

International Advanced Subsidiary cash-in code XPH01

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

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

International Advanced Level cash-in code YPH01

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

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

To be awarded an A* students will need to achieve an A on the full International Advanced Level qualification and an A* aggregate of the IA2 units.

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 must be produced in English.
Quality of written communication	Students will be assessed on their ability to: ■ write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear ■ organise relevant information clearly and coherently, using specialist vocabulary when appropriate. Quality of written communication will be tested in each unit.
Synoptic Assessment	In synoptic assessment the focus should be on the quality of assessment to ensure that it encourages the development of an understanding of the subject. Synopticity requires students to connect knowledge, understanding and skills acquired in different parts of the International Advanced Level course. Synoptic assessment in the context of physics requires students to use the skills, knowledge and understanding they have acquired 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.

Additional information

Malpractice	For up-to-date information on malpractice, please refer to the latest Joint Council for Qualifications (JCQ) Suspected Malpractice in Examinations and Assessments: Policies and Procedures document, available on the JCQ website: www.jcq.org.uk
Access arrangements and special requirements	Pearson's policy on access arrangements and special considerations for GCE, GCSE, IAL and Entry Level is designed to ensure equal access to qualifications for all students (in compliance with the Equality Act 2010) without compromising the assessment of skills, knowledge, understanding or competence. Please see the JCQ website (www.jcq.org.uk) for their policy on access arrangements, reasonable adjustments and special considerations. Please see our website (www.edexcel.com) for: ■ the forms to submit for requests for access arrangements and special considerations ■ dates for submissions of the forms.
Equality Act 2010	Please see our website (www.edexcel.com) for information on the Equality Act 2010.
Prior learning and progression	**Prior learning** Students who would benefit most from studying an International Advanced Level in Physics are likely to have a Level 2 qualification such as an International GCSE in Physics at grades A*–C. **Progression** This qualification supports progression into further education, training or employment.
Combinations of entry	Only units achieved from this qualification may contribute to the certification of the International Advanced Subsidiary in Physics or the International Advanced Level in Physics.
Student recruitment	Pearson'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.

E Support, training and resources

Support

Pearson aim to provide the most comprehensive support for our qualifications. Here are just a few of the support services we offer:

- Subject Advisor – subject experts are on-hand to offer their expertise to answer any questions you may have on delivering the qualification and assessment.
- Subject Page – written by our Subject Advisors, the subject pages keep you up to date with the latest information on your subject.
- Subject Communities – exchange views and share information about your subject with other teachers.
- Training – see 'Training' below for full details.

For full details of all the teacher and student support provided by Pearson to help you deliver our qualifications, please visit:
www.edexcel.com/ial/physics/support

Training

Our programme of professional development and training courses, covering various aspects of the specification and examinations, are arranged each year on a regional basis. Pearson training is designed to fit you, with an option of face-to-face, online or customised training so you can choose where, when and how you want to be trained.

Face-to-face training
Our programmes of face-to-face training have been designed to help anyone who is interested in, or currently teaching, a Pearson Edexcel qualification. We run a schedule of events throughout the academic year to support you and help you to deliver our qualifications.

Online training
Online training is available for international centres who are interested in, or currently delivering our qualifications. This delivery method helps us run training courses more frequently to a wider audience.

To find out more information or to book a place please visit:
www.edexcel.com/training

Alternatively, email internationaltfp@pearson.com
or telephone +44 (0) 44 844 576 0025

Resources

Pearson is committed to ensuring that teachers and students have a choice of resources to support their teaching and study.

Teachers and students can continue to use their existing GCE A level resources for International Advanced Levels.

To search for Pearson GCE resources, please visit: www.pearsonschools.co.uk

To search for endorsed resources from other publishers, please visit: www.edexcel.com/resources

Specifications, Sample Assessment Materials and Teacher Support Materials

Specifications, Sample Assessment Materials (SAMs) and Teacher Support Materials (TSMs) can be downloaded from the International Advanced Level subject pages.

To find a complete list of supporting documents, including the specification, SAMs and TSMs, please visit: www.edexcel.com/ial/physics

F Appendices

Appendix 1 Performance descriptions

Introduction

Performance descriptions describe the outcomes of learning and levels of attainment likely to be demonstrated by a representative candidate performing at the A/B and E/U boundaries for IAS and IA2.

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 IAS and IA2 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.

IAS performance descriptors 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, 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 IAS specification b) show understanding of most principles, concepts and facts from the IAS specification c) select relevant information from the IAS 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 IAS specification b) show understanding of some principles and facts from the IAS specification c) select some relevant information from the IAS specification d) present information using basic terminology from the IAS 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.

IA2 performance descriptors 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 and understanding of most principles, concepts and facts from the IA2 specification b) show understanding of most principles, concepts and facts from the IA2 specification c) select relevant information from the IA2 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 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 IAS and IA2 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, concepts and facts from the IA2 specification b) show understanding of some principles and facts from the IA2 specification c) select some relevant information from the IA2 specification d) present information using basic terminology from the IA2 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 IAS and IA2 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 of the results of their own and others' experimental and investigative activities, in appropriate contexts.

Appendix 2 Codes

Type of code	Use of code	Code number
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 – WPH01 Unit 2 – WPH02 Unit 3 – WPH03 Unit 4 – WPH04 Unit 5 – WPH05 Unit 6 – WPH06
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.	IAS – XPH01 IAL – YPH01
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 *Pearson Information Manual,* available on our website (www.edexcel.com).

Appendix 3 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 should be embedded within the IAL Physics content. 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 IAL Physics content.

***How Science Works* Statements**	**How it may be applied to IAL 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, problems, present arguments and ideas	a) Distinguish between questions that science can address, and those which science cannot 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 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.
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.

How Science Works Statements	How it may be applied to IAL Physics
8 Communicate information and ideas in appropriate ways using appropriate terminology	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, other organisms 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, other organisms 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 4 Data

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

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

Appendix 5 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 are based on IUPAP recommendations.

Unit 1

Mechanics

Kinematic equations of motion	$v = u + at$
	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
Forces	$\Sigma F = ma$
	$g = F/m$
	$W = mg$
Work and energy	$\Delta W = F\Delta s$
	$E_k = \frac{1}{2}mv^2$
	$\Delta E_{grav} = mg\Delta h$

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	$E_{el} = \frac{1}{2}F\Delta x$

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	$hf = \phi + ½mv^2_{max}$

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	$Q = Q_0e^{-t/RC}$
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	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$
Ideal gas equation	$pV = NkT$

Nuclear physics

Radioactive decay	$\mathrm{d}N/\mathrm{d}t = -\lambda N$
	$\lambda = \ln 2/t_{\frac{1}{2}}$
	$N = N_0 e^{-\lambda t}$

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	$\lambda_{max}T = 2.898 \times 10^{-3}\ \mathrm{m\ K}$
Redshift of electromagnetic radiation	$z = \Delta\lambda/\lambda \approx \Delta f/f \approx v/c$
Cosmological expansion	$v = H_o d$

Appendix 6 Glossary

This appendix gives explanations of how keywords that are used in the unit content can be related to examination questions.

Keywords	Possible applications in examinations
Discuss	Questions using this keyword will require students to 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 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 6 Glossary

Appendix 7 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 IA2 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 $v = \Delta x/\Delta t$ average $a = \Delta v/\Delta t$
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.

e.g. 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, $\sin^{-1}\theta$, $\cos^{-1}\theta$, $\tan^{-1}\theta$, $\log_{10} x$ 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, e.g. 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 =, <, >, <<, >>, ≈, α, ~, 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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