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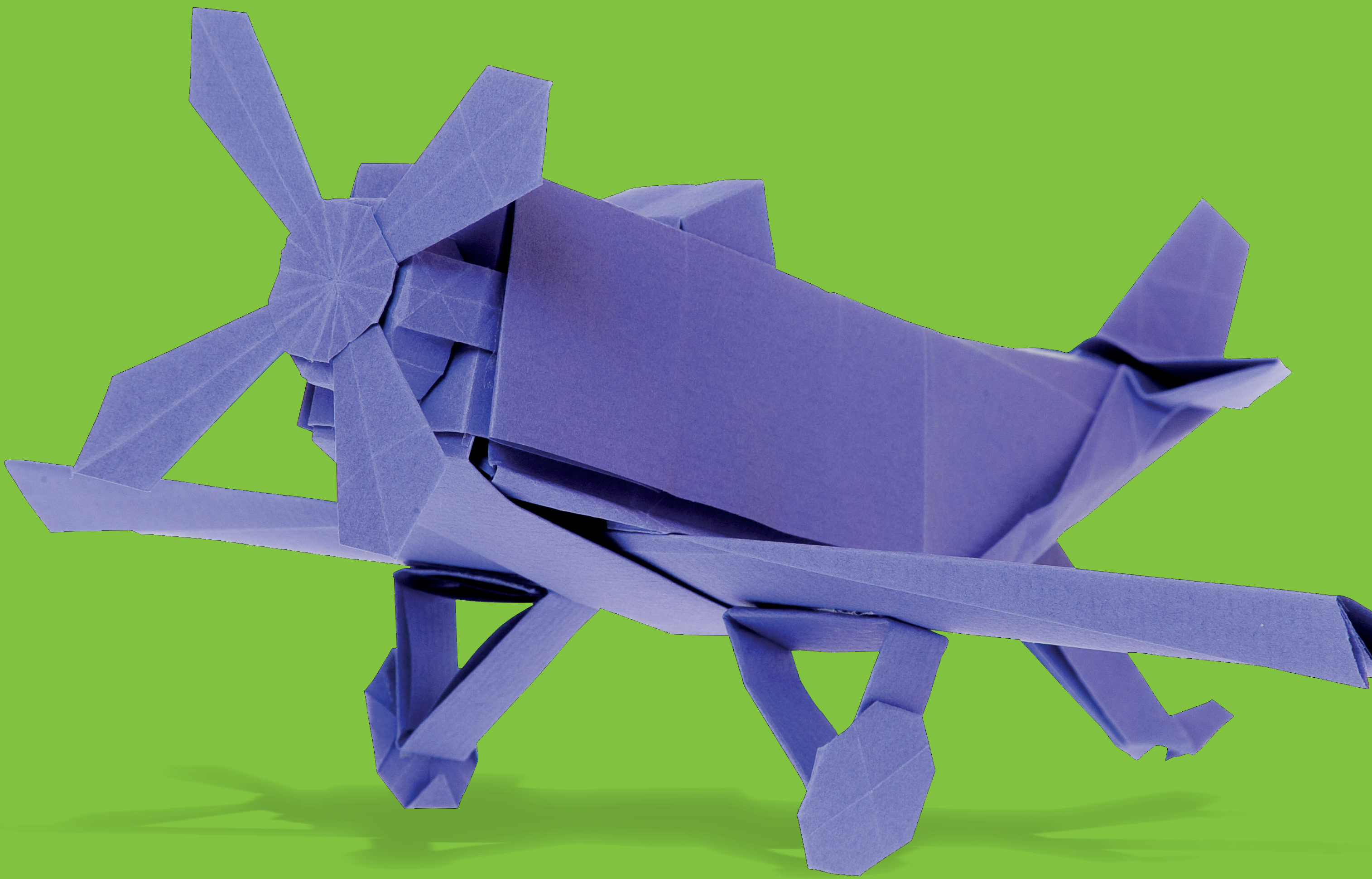

Specification

Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics (8PH0)

First teaching from September 2015

First certification from 2016

Issue 2

ALWAYS LEARNING

PEARSON

Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics (8PH0)

Specification

First certification 2016

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ALWAYS LEARNING

PEARSON

Edexcel, BTEC and LCCI qualifications

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This specification is Issue 2. Key changes are sidelined. We will inform centres of any changes to this issue. The latest issue can be found on the Pearson website: qualifications.pearson.com

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

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From Pearson's Expert Panel for World Class Qualifications

"The reform of the qualifications system in England is a profoundly important change to the education system. Teachers need to know that the new qualifications will assist them in helping their learners make progress in their lives.

When these changes were first proposed we were approached by Pearson to join an 'Expert Panel' that would advise them on the development of the new qualifications.

We were chosen, either because of our expertise in the UK education system, or because of our experience in reforming qualifications in other systems around the world as diverse as Singapore, Hong Kong, Australia and a number of countries across Europe.

We have guided Pearson through what we judge to be a rigorous qualification development process that has included:

- Extensive international comparability of subject content against the highest-performing jurisdictions in the world
- Benchmarking assessments against UK and overseas providers to ensure that they are at the right level of demand
- Establishing External Subject Advisory Groups, drawing on independent subject-specific expertise to challenge and validate our qualifications
- Subjecting the final qualifications to scrutiny against the DfE content and Ofqual accreditation criteria in advance of submission.

Importantly, we have worked to ensure that the content and learning is future oriented. The design has been guided by what is called an 'Efficacy Framework', meaning learner outcomes have been at the heart of this development throughout.

We understand that ultimately it is excellent teaching that is the key factor to a learner's success in education. As a result of our work as a panel we are confident that we have supported the development of qualifications that are outstanding for their coherence, thoroughness and attention to detail and can be regarded as representing world-class best practice."

Sir Michael Barber (Chair)
Chief Education Advisor, Pearson plc

Professor Sing Kong Lee
Director, National Institute of Education, Singapore

Bahram Bekhradnia
President, Higher Education Policy Institute

Professor Jonathan Osborne
Stanford University

Dame Sally Coates
Principal, Burlington Danes Academy

Professor Dr Ursula Renold
Federal Institute of Technology, Switzerland

Professor Robin Coningham
Pro-Vice Chancellor, University of Durham

Professor Bob Schwartz
Harvard Graduate School of Education

Dr Peter Hill
Former Chief Executive ACARA

Introduction

The Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics is designed for use in schools and colleges. It is part of a suite of GCE qualifications offered by Pearson.

Purpose of the specification

This specification sets out:

- the objectives of the qualification
- any other qualifications that a student must have completed before taking the qualification
- any prior knowledge and skills that the student is required to have before taking the qualification
- any other requirements that a student must have satisfied before they will be assessed or before the qualification will be awarded
- the knowledge and understanding that will be assessed as part of the qualification
- the method of assessment and any associated requirements relating to it
- the criteria against which a student’s level of attainment will be measured (such as assessment criteria).

Rationale

The Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics meets the following purposes, which fulfil those defined by the Office of Qualifications and Examinations Regulation (Ofqual) for GCE qualifications in their *GCE Qualification Level Conditions and Requirements* document, published in April 2014.

The purposes of this qualification are to:

- provide evidence of students' achievements in a robust and internationally comparable post-16 course of study that is a sub-set of Advanced GCE content
- enable students to broaden the range of subjects they study.

Qualification aims and objectives

The aims and objectives of the Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics are to enable students to develop:

- essential knowledge and understanding of different areas of the subject and how they relate to each other
- a deep appreciation of the skills, knowledge and understanding of scientific methods
- competence and confidence in a variety of practical, mathematical and problem-solving skills
- their interest in and enthusiasm for the subject, including developing an interest in further study and careers associated with the subject
- an understanding of how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society.

The context for the development of this qualification

All our qualifications are designed to meet our World Class Qualification Principles[1] and our ambition to put the student at the heart of everything we do.

We have developed and designed this qualification by:

- reviewing other curricula and qualifications to ensure that it is comparable with those taken in high-performing jurisdictions overseas
- consulting with key stakeholders on content and assessment, including subject associations, higher education academics, teachers and employers to ensure this qualification is suitable for a UK context
- reviewing the legacy qualification and building on its positive attributes.

This qualification has also been developed to meet criteria stipulated by Ofqual in their document *GCE Qualification Level Conditions and Requirements* and by the Department for Education (DfE) in their *GCE AS and A level regulatory requirements for biology, chemistry, physics and psychology* document, published in April 2014.

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[1] Pearson's World Class Qualification principles ensure that our qualifications are:

- **demanding**, through internationally benchmarked standards, encouraging deep learning and measuring higher-order skills
- **rigorous**, through setting and maintaining standards over time, developing reliable and valid assessment tasks and processes, and generating confidence in end users of the knowledge, skills and competencies of certified students
- **inclusive**, through conceptualising learning as continuous, recognising that students develop at different rates and have different learning needs, and focusing on progression
- **empowering**, through promoting the development of transferable skills, see *Appendix 1*.

Contents

Qualification at a glance

The Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics consists of two externally examined papers.

Students must complete both assessments in May/June in any single year.

The content for this qualification is presented in two different ways to provide two distinct, flexible, teaching and learning approaches to suit the needs of different types of student:

- 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
- the Salters Horners context-led approach. This approach begins with the consideration of situations and applications that each draws on one or more areas of physics, and then moves on to the underlying physics laws, theories and models. This approach is based on the Salters Horners Advanced Physics (SHAP) Project.

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

Paper 1: Core Physics I	***Paper code: 8PH0/01**
• Externally assessed • Availability: May/June • First assessments: 2016	**50% of the total qualification**

Overview of content

This paper will consist of two sections, A and B. Section A will assess the topics listed below. Section B will include a data analysis question, possibly within an experimental context, and will draw on topics from the whole specification.

Concept approach

- Working as a Physicist
- Mechanics
- Electric Circuits

Salters Horners approach

- Working as a Physicist
- Higher, Faster, Stronger (HFS)
- Technology in Space (SPC) (except items 70 and 92–95)
- Digging up the Past (DIG) (except items 83–87)

Overview of assessment

- Assessment is 1 hour 30 minutes.
- The paper consists of 80 marks. Section A will consist of 56–60 marks and Section B will consist of 20–24 marks.
- The paper may include multiple-choice, short open, open-response, calculation and extended writing questions.
- The paper will include questions that target mathematics at level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*). Overall, a minimum of 40% of the marks across both papers will be awarded for mathematics at level 2 or above.
- Students will be expected to apply their knowledge and understanding to familiar and unfamiliar contexts.

*See *Appendix 3: Codes* for a description of this code and all other codes relevant to this qualification.

Paper 2: Core Physics II	***Paper code: 8PH0/02**
• Externally assessed • Availability: May/June • First assessments: 2016	**50% of the total qualification**

Overview of content

This paper will consist of two sections, A and B. Section A will assess the topics listed below. Section B will include a short article, questions in this section will draw on topics from the whole specification.

Concept approach

- Working as a Physicist
- Materials
- Waves and Particle Nature of Light

Salters Horners approach

- Working as a Physicist
- The Sound of Music (MUS)
- Good Enough to Eat (EAT)
- Technology in Space (SPC) (only items 70 and 92–95)
- Digging up the Past (DIG) (only items 83–87)
- Spare-part Surgery (SUR)

Overview of assessment

- Assessment is 1 hour 30 minutes.
- The paper consists of 80 marks. Section A will consist of 56–60 marks and Section B will consist of 20-24 marks.
- The paper may include multiple-choice, short open, open-response, calculations and extended writing questions.
- The paper will include questions that target mathematics at level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*). Overall, a minimum of 40% of the marks across both papers will be awarded for mathematics at level 2 or above.
- Students will be expected to apply their knowledge and understanding to familiar and unfamiliar contexts.

*See *Appendix 3: Codes* for a description of this code and all other codes relevant to this qualification.

Knowledge, skills and understanding

Overview

This qualification may be taught using either a concept approach or a context-led (SHAP) approach. The concept approach begins with a study of the laws, theories and models of physics and then explores their practical applications. The SHAP context-led approach begins with the consideration of applications that draw on one or more areas of physics, and moves on to the underlying laws, theories and models of physics.

These different approaches lead to the same common assessment papers for this qualification.

The content in this section has been arranged to match the concept approach. The same content, reordered for the context-led (SHAP) approach starts on page 17.

Content overview

Students are expected to demonstrate and apply the knowledge, understanding and skills described in the content. They are also expected to analyse, interpret and evaluate a range of scientific information, ideas and evidence using their knowledge, understanding and skills.

To demonstrate their knowledge, students should be able to undertake a range of activities, including the ability to recall, describe and define, as appropriate.

To demonstrate their understanding, students should be able to explain ideas and to use their knowledge to apply, analyse, interpret and evaluate, as appropriate.

Students should consider ethical issues relating to the environment, evaluate risks and benefits of applications of physics, and evaluate ways in which society uses physics to inform decision making.

Students should develop their ability to apply their mathematical skills to physics throughout the course. These skills include the ability to change the subject of an equation, substitute numerical values and solve algebraic equations using decimal and standard form, ratios, fractions and percentages. Further details of the skills that should be developed are given in *Appendix 6: Mathematical skills and exemplifications*. They should also be familiar with Système Internationale d'Unités (SI) units and their prefixes, be able to estimate physical quantities and know the limits of physical measurements.

Core practicals will be assessed in the examination.

Students should be encouraged to use ICT throughout the course.

Practical assessment

Practical work is central to any study of physics. For this reason, the specification includes 8 core practical activities that form a thread linking theoretical knowledge and understanding to practical scenarios. By following this thread, students will build on practical skills learned at GCSE, becoming confident practical physicists and handling apparatus competently and safely. Using a variety of apparatus and techniques, they should be able to design and carry out both the core practical activities and their own investigations, collecting data that can be analysed and used to draw valid conclusions.

One important aspect of practical work is being able to evaluate and manage potential risks. The variety of different practical techniques and scenarios in the core practical activities give students scope to consider risk management in different contexts.

Students should also consider the ethical issues presented by their work which, in the laboratory might include the safe use of apparatus in ways that do not degrade that apparatus. Students should consider the other people involved in their work and those working nearby and consider any waste products that their work might produce. These issues should be part of students' understanding across the breadth of applications of the subject. Questions on these issues will be included in written examination papers.

Central to the development of practical skills is the ability to communicate information and ideas through the use of appropriate terminology and ICT. Being able to communicate the findings of practical work clearly is arguably as important as the collection of accurate data.

In carrying out practical activities, students will be expected to use their knowledge and understanding to pose scientific questions that can be investigated through experimental activities. These activities will enable students to collect data, analyse it for correlations and causal relationships, and to develop solutions to the problems posed. Questions in written examination papers will aim to assess the knowledge and understanding that students will gain while carrying out practical activities, in the context of the 8 core practical activities, as well as in novel practical scenarios. The written papers will test the skills of students in planning practical work – both in familiar and unfamiliar applications – including risk management and the selection of apparatus, with reasons. As part of data handling, students will be expected to use significant figures appropriately to process data and to plot graphs. In analysing outcomes and drawing valid conclusions, students should critically consider methods and data, including assessing measurement uncertainties and errors.

Examination papers will give students the opportunity to evaluate the wider role of the scientific community in validating new knowledge and the ways in which society as a whole uses science to inform decision making. Within this, students could be asked to consider the implications and applications of physics in terms of associated benefits and risks. Students may be asked to evaluate methodology, evidence and data, and resolve the issue of conflicting evidence.

Success in questions that indirectly assess practical skills in written papers will come more naturally to those candidates who have a solid foundation of laboratory practice and who, having carried them out, have a thorough understanding of practical techniques. Therefore, where possible, teachers should consider adding additional experiments to the core practical activities.

Concept-led approach

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

Topic 1: Working as a Physicist

Throughout their study of physics at this level, students should develop their knowledge and understanding of what it means to work scientifically. They should also develop their competence in manipulating quantities and their units, including making estimates.

Students should gain experience of a wide variety of practical work that gives them opportunities to develop their practical and investigative skills by planning, carrying out and evaluating experiments. Through studying a range of examples, contexts and applications of physics, students should become increasingly knowledgeable of the ways in which the scientific community and society as a whole use scientific ideas and methods, and how the professional scientific community functions.

Students should develop their ability to communicate their knowledge and understanding of physics in ways that are appropriate to the content and to the audience.

It is not intended that this part of the specification be taught as a discrete topic. Rather, the knowledge and skills specified here should pervade the entire course and should be taught using examples and applications from the rest of the specification.

Students should:	
1.	know and understand the distinction between base and derived quantities and their SI units
2.	demonstrate their knowledge of practical skills and techniques for both familiar and unfamiliar experiments
3.	be able to estimate values for physical quantities and use their estimate to solve problems
4.	understand the limitations of physical measurement and apply these limitations to practical situations
5.	be able to communicate information and ideas in appropriate ways using appropriate terminology
6.	understand applications and implications of science and evaluate their associated benefits and risks
7.	understand the role of the scientific community in validating new knowledge and ensuring integrity
8.	understand the ways in which society uses science to inform decision making

Topic 2: Mechanics

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include strobe photography or the use of a video camera to analyse projectile motion, determine the centre of gravity of an irregular rod, investigate the conservation of momentum using light gates and air track.

Mathematical skills that could be developed in this topic include plotting two variables from experimental data, calculating rate of change from a graph showing a linear relationship, drawing and using the slope of a tangent to a curve as a measure of rate of change, distinguishing between instantaneous rate of change and average rate of change and identifying uncertainties in measurements, using simple techniques to determine uncertainty when data are combined, using angles in regular 2D and 3D structures with force diagrams and using sin, cos and tan in physical problems.

This topic may be studied using applications that relate to mechanics, for example, sports.

Students should:	
9.	be able to use the equations for uniformly accelerated motion in one dimension: $s = \frac{(u+v)t}{2}$ $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
10.	be able to draw and interpret displacement-time, velocity-time and acceleration-time graphs
11.	know the physical quantities derived from the slopes and areas of displacement-time, velocity-time and acceleration-time graphs, including cases of non-uniform acceleration and understand how to use the quantities
12.	understand scalar and vector quantities and know examples of each type of quantity and recognise vector notation
13.	be able to resolve a vector into two components at right angles to each other by drawing and by calculation
14.	be able to find the resultant of two coplanar vectors at any angle to each other by drawing, and at right angles to each other by calculation
15.	understand how to make use of the independence of vertical and horizontal motion of a projectile moving freely under gravity
16.	be able to draw and interpret free-body force diagrams to represent forces on a particle or on an extended but rigid body

Students should:	
17.	be able to use the equation $\sum F = ma$, and understand how to use this equation in situations where *m* is constant (Newton's second law of motion), including Newton's first law of motion where $a = 0$, objects at rest or travelling at constant velocity *Use of the term terminal velocity is expected*
18.	be able to use the equations for gravitational field strength $g = \frac{F}{m}$ and weight $W = mg$
19.	**CORE PRACTICAL 1: Determine the acceleration of a freely-falling object.**
20.	know and understand Newton's third law of motion and know the properties of pairs of forces in an interaction between two bodies
21.	understand that momentum is defined as $p = mv$
22.	know the principle of conservation of linear momentum, understand how to relate this to Newton's laws of motion and understand how to apply this to problems in one dimension
23.	be able to use the equation for the moment of a force, moment of force = Fx where x is the perpendicular distance between the line of action of the force and the axis of rotation
24.	be able to use the concept of centre of gravity of an extended body and apply the principle of moments to an extended body in equilibrium
25.	be able to use the equation for work $\Delta W = F\Delta s$, including calculations when the force is not along the line of motion
26.	be able to use the equation $E_k = \frac{1}{2}mv^2$ for the kinetic energy of a body
27.	be able to use the equation $\Delta E_{grav} = mg\Delta h$ for the difference in gravitational potential energy near the Earth's surface
28.	know, and understand how to apply, the principle of conservation of energy including use of work done, gravitational potential energy and kinetic energy
29.	be able to use the equations relating power, time and energy transferred or work done $P = \frac{E}{t}$ and $P = \frac{W}{t}$
30.	be able to use the equations $\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$ and $\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$

Topic 3: Electric Circuits

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include estimating power output of an electric motor, using a digital voltmeter to investigate the output of a potential divider and investigating current/voltage graphs for a filament bulb, thermistor and diode.

Mathematical skills that could be developed in this topic include substituting numerical values into algebraic equations using appropriate units for physical quantities and applying the equation $y = mx + c$ to experimental data.

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

Students should:	
31.	understand that electric current is the rate of flow of charged particles and be able to use the equation $I = \frac{\Delta Q}{\Delta t}$
32.	understand how to use the equation $V = \frac{W}{Q}$
33.	understand that resistance is defined by $R = \frac{V}{I}$ and that Ohm's law is a special case when $I \propto V$ for constant temperature
34.	understand how the distribution of current in a circuit is a consequence of charge conservation
35.	understand how the distribution of potential differences in a circuit is a consequence of energy conservation
36.	be able to derive the equations for combining resistances in series and parallel using the principles of charge and energy conservation, and be able to use these equations
37.	be able to use the equations $P = VI$, $W = VIt$ and be able to derive and use related equations, e.g. $P = I^2R$ and $P = \frac{V^2}{R}$
38.	understand how to sketch, recognise and interpret current-potential difference graphs for components, including ohmic conductors, filament bulbs, thermistors and diodes
39.	be able to use the equation $R = \frac{\rho l}{A}$

Students should:	
40.	**CORE PRACTICAL 2: Determine the electrical resistivity of a material.**
41.	be able to use $I = nqvA$ to explain the large range of resistivities of different materials
42.	understand how the potential along a uniform current-carrying wire varies with the distance along it
43.	understand the principles of a potential divider circuit and understand how to calculate potential differences and resistances in such a circuit
44.	be able to analyse potential divider circuits where one resistance is variable including thermistors and light dependent resistors (LDRs)
45.	know the definition of *electromotive force (e.m.f.)* and understand what is meant by *internal resistance* and know how to distinguish between e.m.f. and *terminal potential difference*
46.	**CORE PRACTICAL 3: Determine the e.m.f. and internal resistance of an electrical cell.**
47.	understand how changes of resistance with temperature may be modelled in terms of lattice vibrations and number of conduction electrons and understand how to apply this model to metallic conductors and negative temperature coefficient thermistors
48.	understand how changes of resistance with illumination may be modelled in terms of the number of conduction electrons and understand how to apply this model to LDRs.

Topic 4: Materials

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic.

Mathematical skills that could be developed in this topic include determining the slope of a linear graph and calculating or estimating, by graphical methods as appropriate, the area between a curve and the *x*-axis and realising the physical significance of the area that has been determined.

This topic may be studied using applications that relate to materials, for example spare-part surgery.

Students should:
49. be able to use the equation density $\rho = \frac{m}{V}$
50. understand how to use the relationship upthrust = weight of fluid displaced
51. a. be able to use the equation for viscous drag (Stokes' Law), $F = 6\pi\eta rv$. b. understand that this equation applies only to small spherical objects moving at low speeds with *laminar flow* (or in the absence of *turbulent flow*) and that viscosity is temperature dependent
52. **CORE PRACTICAL 4: Use a falling-ball method to determine the viscosity of a liquid.**
53. be able to use the Hooke's law equation, $\Delta F = k\Delta x$, where k is the stiffness of the object
54. understand how to use the relationships • (*tensile or compressive*) *stress = force/cross-sectional area* • (*tensile or compressive*) *strain = change in length/original length* • *Young modulus = stress/strain*
55. a. be able to draw and interpret force-extension and force-compression graphs b. understand the terms *limit of proportionality, elastic limit, yield point, elastic deformation* and *plastic deformation* and be able to apply them to these graphs
56. be able to draw and interpret tensile or compressive stress-strain graphs, and understand the term *breaking stress*
57. **CORE PRACTICAL 5: Determine the Young modulus of a material**
58. be able to calculate the elastic strain energy E_{el} in a deformed material sample, using the equation $\Delta E_{el} = \frac{1}{2}F\Delta x$, and from the area under the force-extension graph *The estimation of area and hence energy change for both linear and non-linear force-extension graphs is expected*.

Topic 5: Waves and Particle Nature of Light

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include determining the refractive index of solids and liquids, measuring the focal length of a lens, and using models of structures to investigate stress concentrations.

Mathematical skills that could be developed in this topic include using calculators to handle sin *x*, identifying uncertainties in measurements and using simple techniques to determine uncertainty when data are combined.

This topic may be studied using applications that relate to waves and light, for example medical physics.

Students should:	
59.	understand the terms *amplitude*, *frequency*, *period*, *speed* and *wavelength*
60.	be able to use the wave equation $v = f\lambda$
61.	be able to describe longitudinal waves in terms of pressure variation and the displacement of molecules
62.	be able to describe transverse waves
63.	be able to draw and interpret graphs representing transverse and longitudinal waves including standing/stationary waves
64.	**CORE PRACTICAL 6: Determine the speed of sound in air using a 2-beam oscilloscope, signal generator, speaker and microphone.**
65.	know and understand what is meant by *wavefront*, *coherence*, *path difference*, *superposition*, *interference* and *phase*
66.	be able to use the relationship between *phase difference* and *path difference*
67.	know what is meant by a *standing/stationary* wave and understand how such a wave is formed, know how to identify nodes and antinodes
68.	be able to use the equation for the speed of a transverse wave on a string $v = \sqrt{\frac{T}{\mu}}$
69.	**CORE PRACTICAL 7: Investigate the effects of length, tension and mass per unit length on the frequency of a vibrating string or wire.**
70.	be able to use the equation intensity of radiation $I = \frac{P}{A}$
71.	know and understand that at the interface between medium 1 and medium 2 $n_1 \sin\theta_1 = n_2 \sin\theta_2$ where refractive index is $n = \frac{c}{v}$
72.	be able to calculate *critical angle* using $\sin C = \frac{1}{n}$
73.	be able to predict whether total internal reflection will occur at an interface

Students should:
74. understand how to measure the refractive index of a solid material
75. understand the term *focal length* of converging and diverging lenses
76. be able to use ray diagrams to trace the path of light through a lens and locate the position of an image
77. be able to use the equation power of a lens $P = \frac{1}{f}$
78. understand that for thin lenses in combination $P = P_1 + P_2 + P_3 + \ldots$
79. know and understand the terms *real image* and *virtual image*
80. be able to use the equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ for a thin converging or diverging lens with the real is positive convention
81. know and understand that magnification = image height/object height and $m = \frac{v}{u}$
82. understand what is meant by *plane polarisation*
83. understand what is meant by *diffraction* and use Huygens' construction to explain what happens to a wave when it meets a slit or an obstacle
84. be able to use $n\lambda = dsin\theta$ for a diffraction grating
85. **CORE PRACTICAL 8: Determine the wavelength of light from a laser or other light source using a diffraction grating.**
86. understand how diffraction experiments provide evidence for the wave nature of electrons
87. be able to use the de Broglie equation $\lambda = \frac{h}{p}$
88. understand that waves can be transmitted and reflected at an interface between media
89. understand how a pulse-echo technique can provide information about the position of an object and how the amount of information obtained may be limited by the wavelength of the radiation or by the duration of pulses
90. understand how the behaviour of electromagnetic radiation can be described in terms of a wave model and a photon model, and how these models developed over time
91. be able to use the equation $E = hf$, that relates the photon energy to the wave frequency

Students should:	
92.	understand that the absorption of a photon can result in the emission of a photoelectron
93.	understand the terms *threshold frequency* and *work function* and be able to use the equation $hf = \phi + \frac{1}{2}mv^2_{\text{max}}$
94.	be able to use the *electronvolt* (eV) to express small energies
95.	understand how the photoelectric effect provides evidence for the particle nature of electromagnetic radiation
96.	understand atomic line spectra in terms of transitions between discrete energy levels and understand how to calculate the frequency of radiation that could be emitted or absorbed in a transition between energy levels.

Salters Horners approach

The following section shows how the course may be taught using the Salters Horners (SHAP) context-led approach.

Working as a Physicist

Throughout their study of physics at this level, students should develop their knowledge and understanding of what it means to work scientifically. They should also develop their competence in manipulating quantities and their units, including making estimates. They should experience a wide variety of practical work, giving them opportunities to develop their practical and investigative skills by planning, carrying out and evaluating experiments. Through studying a range of examples, contexts and applications of physics, students should become increasingly knowledgeable of the ways in which the scientific community, and society as a whole, use scientific ideas and methods, and how the professional scientific community functions. They should develop their abilities to communicate their knowledge and understanding of physics in ways that are appropriate to the content and to the audience.

It is not intended that this part of the specification is taught as a discrete topic. Rather, the knowledge and skills specified here should pervade the entire course and should be taught using examples and applications from throughout the rest of the specification.

Students should:	
1.	know and understand the distinction between base and derived quantities and their SI units
2.	demonstrate their knowledge of practical skills and techniques for both familiar and unfamiliar experiments
3.	be able to estimate values for physical quantities and use their estimate to solve problems
4.	understand the limitations of physical measurement and apply these limitations to practical situations
5.	be able to communicate information and ideas in appropriate ways using appropriate terminology
6.	understand applications and implications of science and evaluate their associated benefits and risks
7.	understand the role of the scientific community in validating new knowledge and ensuring integrity
8.	understand the ways in which society uses science to inform decision making.

Higher, Faster, Stronger (HFS)

An exploration of the physics behind a variety of sports, using use video clips, ICT and laboratory practical activities:

- graphs and equations of motion in sprinting and jogging
- work and power in weightlifting
- forces and equilibrium in rock climbing
- moments and equilibrium in gymnastics
- forces and projectiles in tennis and ski-jumping
- 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 should:	
9.	be able to use the equations for uniformly accelerated motion in one dimension: $s = \frac{(u+v)t}{2}$ $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
10.	be able to draw and interpret displacement-time, velocity-time and acceleration-time graphs
11.	know the physical quantities derived from the slopes and areas of displacement-time, velocity-time and acceleration-time graphs, including cases of non-uniform acceleration, and understand how to use the quantities
12.	understand scalar and vector quantities, and know examples of each type of quantity and recognise vector notation
13.	be able to resolve a vector into two components at right angles to each other by drawing and by calculation
14.	be able to find the resultant of two coplanar vectors at any angle to each other by drawing, and at right angles to each other by calculation
15.	understand how to make use of the independence of vertical and horizontal motion of a projectile moving freely under gravity
16.	be able to draw and interpret free-body force diagrams to represent forces on a particle or on an extended but rigid body
17.	be able to use the equation $\sum F = ma$, and understand how to use this equation in situations where m is constant (Newton's second law of motion), including Newton's first law of motion where a = 0, objects at rest or travelling at constant velocity Use of the term *terminal velocity* is expected

Students should:	
18.	be able to use the equations for gravitational field strength $g = \frac{F}{m}$ and weight $W = mg$
19.	**CORE PRACTICAL 1: Determine the acceleration of a freely-falling object.**
20.	know and understand Newton's third law of motion, and know the properties of pairs of forces in an interaction between two bodies
21.	understand that momentum is defined as $p = mv$
22.	know the principle of conservation of linear momentum, understand how to relate this to Newton's laws of motion and understand how to apply this to problems in one dimension
23.	be able to use the equation for the moment of a force, moment of force $= Fx$ where x is the perpendicular distance between the line of action of the force and the axis of rotation
24.	be able to use the concept of centre of gravity of an extended body and apply the principle of moments to an extended body in equilibrium
25.	be able to use the equation for work $\Delta W = F\Delta s$, including calculations when the force is not along the line of motion
26.	be able to use the equation $E_k = \frac{1}{2}mv^2$ for the kinetic energy of a body
27.	be able to use the equation $\Delta E_{\text{grav}} = mg\Delta h$ for the difference in gravitational potential energy near the Earth's surface
28.	know, and understand how to apply, the principle of conservation of energy, including use of work done, gravitational potential energy and kinetic energy
29.	be able to use the equations relating power, time and energy transferred or work done $P = \frac{E}{t}$ and $P = \frac{W}{t}$
30.	be able to use the equations $\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$ and $\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$

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/DVD player:

- synthesised and 'natural' sounds
- travelling waves and standing/stationary waves in string and wind instruments
- reading a CD/DVD 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 investigation and to communication.

Students should:	
59.	understand the terms *amplitude*, *frequency*, *period*, *speed* and *wavelength*
60.	be able to use the wave equation $v = f\lambda$
61.	be able to describe longitudinal waves in terms of pressure variation and the displacement of molecules
62.	be able to describe transverse waves
63.	be able to draw and interpret graphs representing transverse and longitudinal waves including standing/stationary waves
64.	**CORE PRACTICAL 6: Determine the speed of sound in air using a 2-beam oscilloscope, signal generator, speaker and microphone.**
65.	know and understand what is meant by *wavefront*, *coherence*, *path difference*, *superposition*, *interference* and *phase*
66.	be able to use the relationship between *phase difference* and *path difference*
67.	know what is meant by a *standing/stationary wave* and understand how such a wave is formed, know how to identify nodes and antinodes
68.	be able to use the equation for the speed of a transverse wave on a string $v = \sqrt{\frac{T}{\mu}}$
69.	**CORE PRACTICAL 7: Investigate the effects of length, tension and mass per unit length on the frequency of a vibrating string or wire.**
90.	understand how the behaviour of electromagnetic radiation can be described in terms of a wave model and a photon model, and how these models developed over time
91.	be able to use the equation $E = hf$, that relates the photon energy to the wave frequency
96.	understand atomic line spectra in terms of transitions between discrete energy levels and understand how to calculate the frequency of radiation that could be emitted or absorbed in a transition between energy levels.

Good Enough to Eat (EAT)

A case study of the production of sweets and biscuits:

- measuring and controlling the flow of a viscous liquid
- mechanical testing of products
- using refractometry and polarimetry to monitor sugar concentration.

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

Students should:		
49.	be able to use the equation density $\rho = \frac{m}{V}$	
50.	understand how to use the relationship upthrust = weight of fluid displaced	
51.	a.	be able to use the equation for viscous drag (Stokes' Law), $F = 6\pi\eta rv$.
	b.	understand that this equation applies only to small spherical objects moving at low speeds with *laminar flow* (or in the absence of *turbulent flow*) and that viscosity is temperature dependent
52.	**CORE PRACTICAL 4: Use a falling-ball method to determine the viscosity of a liquid.**	
53.	be able to use the Hooke's law equation, $\Delta F = k\Delta x$, where k is the stiffness of the object	
55.	a.	be able to draw and interpret force-extension and force-compression graphs
	b.	understand the terms *limit of proportionality, elastic limit, yield point, elastic deformation* and *plastic deformation* and be able to apply them to these graphs
71.	know and understand that at the interface between medium 1 and medium 2 $n_1 \sin\theta_1 = n_2 \sin\theta_2$ where refractive index is $n = \frac{c}{v}$	
72.	be able to calculate *critical angle* using $\sin C = \frac{1}{n}$	
73.	be able to predict whether total internal reflection will occur at an interface	
74.	understand how to measure the refractive index of a solid material	
82.	understand what is meant by *plane polarisation*.	

Technology in Space (SPC)

The focus is on a satellite whose instruments are run from a solar power supply:

- illuminating solar cells
- operation of photocells
- design and operation of dc circuits
- combining sources of e.m.f.

Mathematical models are developed to describe ohmic behaviours 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 and there is some discussion of the historical development of the photoelectric effect.

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

Students should:	
31.	understand that electric current is the rate of flow of charged particles and be able to use the equation $I = \frac{\Delta Q}{\Delta t}$
32.	understand how to use the equation $V = \frac{W}{Q}$
33.	understand that resistance is defined by $R = \frac{V}{I}$ and that Ohm's law is a special case when $I \propto V$ for constant temperature
34.	understand how the distribution of current in a circuit is a consequence of charge conservation
35.	understand how the distribution of potential differences in a circuit is a consequence of energy conservation
36.	be able to derive the equations for combining resistances in series and parallel using the principles of charge and energy conservation, and be able to use these equations
37.	be able to use the equations $P = VI$, $W = VIt$ and be able to derive and use related equations, e.g. $P = I^2R$ and $P = \frac{V^2}{R}$
38.	understand how to sketch, recognise and interpret current-potential difference graphs for components, including ohmic conductors, filament bulbs, thermistors and diodes
45.	know the definition of *electromotive force (e.m.f.)* and understand what is meant by *internal resistance* and know how to distinguish between e.m.f. and *terminal potential difference*
46.	**CORE PRACTICAL 3: Determine the e.m.f. and internal resistance of an electrical cell.**

Students should:	
47.	understand how changes of resistance with temperature may be modelled in terms of lattice vibrations and number of conduction electrons and understand how to apply this model to metallic conductors and negative temperature coefficient thermistors
48.	understand how changes of resistance with illumination may be modelled in terms of the number of conduction electrons and understand how to apply this model to LDRs
70.	be able to use the equation intensity of radiation $I = \frac{P}{A}$
92.	understand that the absorption of a photon can result in the emission of a photoelectron
93.	understand the terms *threshold frequency* and *work function* and be able to use the equation $hf = \phi + \frac{1}{2}mv_{\text{max}}^2$
94.	be able to use the *electronvolt* (eV) to express small energies
95.	understand how the photoelectric effect provides evidence for the particle nature of electromagnetic radiation.

Digging up the Past (DIG)

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

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

Waves are used to model the behaviour of electromagnetic radiation and electrons.

Through a variety of practical and ICT activities, there are opportunities to revisit, review and build on work from previous topics.

Students should:	
39.	be able to use the equation $R = \frac{\rho l}{A}$
40.	**CORE PRACTICAL 2: Determine the electrical resistivity of a material.**
41.	be able to use $I = nqvA$ to explain the large range of resistivities of different materials
42.	understand how the potential along a uniform current-carrying wire varies with the distance along it
43.	understand the principles of a potential divider circuit and understand how to calculate potential differences and resistances in such a circuit
44.	be able to analyse potential divider circuits where one resistance is variable including thermistors and light dependent resistors (LDRs)
83.	understand what is meant by *diffraction* and use Huygens' construction to explain what happens to a wave when it meets a slit or an obstacle
84.	be able to use $n\lambda = dsin\theta$ for a diffraction grating
85.	**CORE PRACTICAL 8: Determine the wavelength of light from a laser or other light source using a diffraction grating.**
86.	understand how diffraction experiments provide evidence for the wave nature of electrons
87.	be able to use the de Broglie equation $\lambda = \frac{h}{p}$

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
- lens implants and the optical system of the eye
- 'designer' materials for medical use
- ultrasound imaging.

Through a variety of practical and ICT activities, there are opportunities to revisit, review and build on work from previous topics.

Students should:	
54.	understand how to use the relationships: • *(tensile or compressive) stress = force/cross-sectional area* • *(tensile or compressive) strain = change in length/original length* • *Young modulus = stress/strain*
56.	be able to draw and interpret tensile or compressive stress-strain graphs, and understand the term *breaking stress*
57.	**CORE PRACTICAL 5: Determine the Young modulus of a material.**
58.	be able to calculate the elastic strain energy E_{el} in a deformed material sample, using the equation $\Delta E_{el} = \frac{1}{2} F \Delta x$, and from the area under the force-extension graph *The estimation of area and hence energy change for both linear and non-linear force-extension graphs is expected*
75.	understand the term *focal length* of converging and diverging lenses
76.	be able to use ray diagrams to trace the path of light through a lens and locate the position of an image
77.	be able to use the equation power of a lens $P = \dfrac{1}{f}$
78.	understand that for thin lenses in combination $P = P_1 + P_2 + P_3 + \ldots$
79.	know and understand the terms *real image* and *virtual image*
80.	be able to use the equation $\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$ for a thin converging or diverging lens with the real-is-positive convention
81.	know and understand that magnification = image height/object height and $m = \dfrac{v}{u}$

Students should:
88. understand that waves can be transmitted and reflected at an interface between media
89. understand how a pulse-echo technique can provide information about the position of an object and how the amount of information obtained may be limited by the wavelength of the radiation or by the duration of pulses.

Assessment

Assessment summary

Summary of table of assessment

Students must complete both assessments in May/June in any single year.

Paper 1: Core Physics I	***Paper code: 8PH0/ 01**
• Questions draw on content from the topics listed in the section *Qualification at a glance.* • Questions are broken down into a number of parts. • Availability: May/June • First assessment: 2016 • The assessment is 1 hour 30 minutes. • The assessment consists of 80 marks.	**50% of the total qualification**

Paper 2: Core Physics II	***Paper code: 8PH0/02**
• Questions draw on content from the topics listed in the section *Qualification at a glance.* • Questions are broken down into a number of parts. • Availability: May/June • First assessment: 2016 • The assessment is 1 hour 30 minutes. • The assessment consists of 80 marks.	**50% of the total qualification**

The sample assessment materials can be found in the *Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics Sample Assessment Materials* document.

*See *Appendix 3: Codes* for a description of this code and all other codes relevant to this qualification.

Assessment Objectives and weightings

Students must:		% in GCE
AO1	Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures	35–37
AO2	Apply knowledge and understanding of scientific ideas, processes, techniques and procedures: • in a theoretical context • in a practical context • when handling qualitative data • when handling quantitative data	41–43
AO3	Analyse, interpret and evaluate scientific information, ideas and evidence, including in relation to issues, to: • make judgements and reach conclusions • develop and refine practical design and procedures	20–23
	Total	**100%**

Breakdown of Assessment Objectives

Paper	AO1	AO2	AO3	Total for all Assessment Objectives
Paper 1: Core Physics I	17–19%	20–22%	10–12%	50%
Paper 2: Core Physics II	17–19%	20–22%	10–12%	50%
Total for this qualification	**35–37%**	**41–43%**	**20–23%**	**100%**

Entry and assessment information

Student entry

Details of how to enter students for the examinations for this qualification can be found in our *UK Information Manual*. A copy is made available to all examinations officers and is available on our website at: www.edexcel.com/iwantto/Pages/uk-information-manual.aspx

Forbidden combinations and discount code

Centres should be aware that students who enter for more than one GCE qualification with the same discount code will have only one of the grades they achieve counted for the purpose of the School and College Performance Tables – normally the better grade (please see *Appendix 3: Codes*).

Students should be advised that if they take two qualifications with the same discount code, colleges, universities and employers are very likely to take the view that they have achieved only one of the two GCEs. The same view may be taken if students take two GCE qualifications that have different discount codes but have significant overlap of content. Students or their advisers who have any doubts about their subject combinations should check with the institution to which they wish to progress before embarking on their programmes.

Access arrangements, reasonable adjustments and special consideration

Access arrangements are agreed before an assessment. They allow students with special educational needs, disabilities or temporary injuries to:

- access the assessment
- show what they know and can do without changing the demands of the assessment.

The intention behind an access arrangement is to meet the particular needs of an individual disabled student without affecting the integrity of the assessment. Access arrangements are the principal way in which awarding bodies comply with the duty under the Equality Act 2010 to make 'reasonable adjustments'.

Access arrangements should always be processed at the start of the course. Students will then know what is available and have the access arrangement(s) in place for assessment.

Reasonable adjustments

The Equality Act 2010 requires an awarding organisation to make reasonable adjustments where a person with a disability would be at a substantial disadvantage in undertaking an assessment. The awarding organisation is required to take reasonable steps to overcome that disadvantage.

A reasonable adjustment for a particular person may be unique to that individual and therefore might not be in the list of available access arrangements.

Whether an adjustment will be considered reasonable will depend on a number of factors, which will include:

- the needs of the student with the disability
- the effectiveness of the adjustment
- the cost of the adjustment; and
- the likely impact of the adjustment on the student with the disability and other students.

An adjustment will not be approved if it involves unreasonable costs to the awarding organisation, timeframes or affects the security or integrity of the assessment. This is because the adjustment is not 'reasonable'.

Special consideration

Special consideration is a post-examination adjustment to a student's mark or grade to reflect temporary injury, illness or other indisposition at the time of the examination/assessment, which has had, or is reasonably likely to have had, a material effect on a candidate's ability to take an assessment or demonstrate their level of attainment in an assessment.

Further information

Please see our website for further information about how to apply for access arrangements and special consideration.

For further information about access arrangements, reasonable adjustments and special consideration, please refer to the JCQ website: www.jcq.org.uk.

Malpractice

Candidate malpractice

Candidate malpractice refers to any act by a candidate that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

Candidate malpractice in examinations **must** be reported to Pearson using a *JCQ M1 Form* (available at www.jcq.org.uk/exams-office/malpractice). The form can be emailed to pqsmalpractice@pearson.com or posted to Investigations Team, Pearson, 190 High Holborn, London, WC1V 7BH. Please provide as much information and supporting documentation as possible. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice constitutes staff or centre malpractice.

Staff/centre malpractice

Staff and centre malpractice includes both deliberate malpractice and maladministration of our qualifications. As with candidate malpractice, staff and centre malpractice is any act that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

All cases of suspected staff malpractice and maladministration **must** be reported immediately, before any investigation is undertaken by the centre, to Pearson on a *JCQ M2(a) Form* (available at www.jcq.org.uk/exams-office/malpractice). The form, supporting documentation and as much information as possible can be emailed to pqsmalpractice@pearson.com or posted to Investigations Team, Pearson, 190 High Holborn, London, WC1V 7BH. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice itself constitutes malpractice.

More-detailed guidance on malpractice can be found in the latest version of the document *JCQ General and Vocational Qualifications Suspected Malpractice in Examinations and Assessments,* available at www.jcq.org.uk/exams-office/malpractice.

Equality Act 2010 and Pearson's equality policy

Equality and fairness are central to our work. Our equality policy requires all students to have equal opportunity to access our qualifications and assessments, and our qualifications to be awarded in a way that is fair to every student.

We are committed to making sure that:

- students with a protected characteristic (as defined by the Equality Act 2010) are not, when they are undertaking one of our qualifications, disadvantaged in comparison to students who do not share that characteristic
- all students achieve the recognition they deserve for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

You can find details on how to make adjustments for students with protected characteristics in the policy document *Access Arrangements, Reasonable Adjustments and Special Considerations*, which is on our website, www.edexcel.com/Policies.

Synoptic assessment

Synoptic assessment requires students to work across different parts of a qualification and to show their accumulated knowledge and understanding of a topic or subject area.

Synoptic assessment enables students to show their ability to combine their skills, knowledge and understanding with breadth and depth of the subject.

Awarding and reporting

This qualification will be graded, awarded and certificated to comply with the requirements of the current *Code of Practice* published by the Office of Qualifications and Examinations Regulation (Ofqual).

This qualification will be graded and certificated on a five-grade scale from A to E using the total subject mark. Individual papers are not graded.

The first certification opportunity for the Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics will be 2016.

Students whose level of achievement is below the minimum judged by Pearson Edexcel to be of sufficient standard to be recorded on a certificate will receive an unclassified U result.

Language of assessment

Assessment of this qualification will be available in English. All student work must be in English.

Other information

Student recruitment

Pearson follows the JCQ policy concerning recruitment to our qualifications in 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.

Prior learning and other requirements

There are no prior learning or other requirements for this qualification.

Students who would benefit most from studying this qualification are likely to have a Level 2 qualification such as a GCSE in Additional Science or Physics.

Progression

Students can progress from this qualification to:

- a range of different, relevant academic or vocational higher education qualifications
- employment in a relevant sector
- further training.

Relationship between Advanced Subsidiary GCE and Advanced GCE

The content for Advanced GCE in Physics includes all the content studied at Advanced Subsidiary GCE. Advanced GCE in Physics builds on the knowledge, skills, and understanding achieved when studying the Advanced Subsidiary GCE in Physics.

Progression from Advanced Subsidiary GCE to Advanced GCE

Students who have achieved the Advanced Subsidiary GCE in Physics can progress to the Advanced GCE in Physics. They would have covered content common to both qualifications but the Advanced GCE has additional content which will need to be covered and then all the assessment for the Advanced GCE qualification must be taken at the end of the course.

Relationship between GCSE and Advanced Subsidiary GCE

Students cover Key Stage 4 fundamental core concepts in sciences at GCSE and continue to cover these concepts and additional subject material in the Advanced Subsidiary GCE at Key Stage 5.

Progression from GCSE to Advanced Subsidiary GCE

Students will draw on knowledge and understanding achieved in GCSE Additional Science or GCSE Physics to progress on to an Advanced Subsidiary GCE in Physics qualification.

Appendices

Appendix 1: Transferable skills

The need for transferable skills

In recent years, higher education institutions and employers have consistently flagged the need for students to develop a range of transferable skills to enable them to respond with confidence to the demands of undergraduate study and the world of work.

The Organisation for Economic Co-operation and Development (OECD) defines skills, or competencies, as 'the bundle of knowledge, attributes and capacities that can be learned and that enable individuals to successfully and consistently perform an activity or task and can be built upon and extended through learning.'[1]

To support the design of our qualifications, the Pearson Research Team selected and evaluated seven global 21st-century skills frameworks. Following on from this process, we identified the National Research Council's (NRC) framework as the most evidence-based and robust skills framework. We adapted the framework slightly to include the Program for International Student Assessment (PISA) ICT Literacy and Collaborative Problem Solving (CPS) Skills.

The adapted National Research Council's framework of skills involves:[2]

Cognitive skills

- **Non-routine problem solving** – expert thinking, metacognition, creativity.
- **Systems thinking** – decision making and reasoning.
- **Critical thinking –** definitions of critical thinking are broad and usually involve general cognitive skills such as analysing, synthesising and reasoning skills.
- **ICT literacy** — access, manage, integrate, evaluate, construct and communicate[3].

Interpersonal skills

- **Communication** – active listening, oral communication, written communication, assertive communication and non-verbal communication.
- **Relationship-building skills** – teamwork, trust, intercultural sensitivity, service orientation, self-presentation, social influence, conflict resolution and negotiation.
- **Collaborative problem solving** – establishing and maintaining shared understanding, taking appropriate action, establishing and maintaining team organisation.

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[1] OECD (2012), Better Skills, Better Jobs, Better Lives (2012):http://skills.oecd.org/documents/OECDSkillsStrategyFINALENG.pdf

[2] Koenig, J. A. (2011) Assessing 21st Century Skills: Summary of a Workshop, National Research Council

[3] PISA (2011) The PISA Framework for Assessment of ICT Literacy, PISA

Intrapersonal skills

- **Adaptability** – ability and willingness to cope with the uncertain, handling work stress, adapting to different personalities, communication styles and cultures, and physical adaptability to various indoor and outdoor work environments.
- **Self-management and self-development** – ability to work remotely in virtual teams, work autonomously, be self-motivating and self-monitoring, willing and able to acquire new information and skills related to work.

Transferable skills are the skills that enable young people to face the demands of further and higher education, as well as the demands of the workplace, and are important in the teaching and learning of this qualification. We will provide teaching and learning materials, developed with stakeholders, to support our qualifications.

Appendix 2: Level 3 Extended Project qualification

What is the Extended Project qualification?

The Extended Project is a stand-alone qualification that can be taken alongside GCEs. It supports the development of independent learning skills and helps to prepare students for their next step – whether that be university study or employment. The qualification:

- is recognised by universities for the skills it develops
- is worth half of an Advanced GCE qualification at grades to A*–E
- carries UCAS points for university entry.

The Extended Project encourages students to develop skills in the following areas: research, critical thinking, extended writing and project management. Students identify and agree a topic area of their choice (which may or may not be related to a GCE subject they are already studying), guided by their teacher.

Students can choose from one of four approaches to produce:

- a dissertation (for example an investigation based on predominately secondary research)
- an investigation/field study (for example a practical experiment)
- a performance (for example in music, drama or sport)
- an artefact (for example a creating a sculpture in response to a client brief or solving an engineering problem).

The qualification is coursework based and students are assessed on the skills of managing, planning and evaluating their project. Students will research their topic, develop skills to review and evaluate the information, and then present the final outcome of their project.

Students: what they need to do

The Extended Project qualification requires students to:

- select a topic of interest for an in-depth study and negotiate the scope of the project with their teacher
- identify and draft an objective for their project (for example in the form of a question, hypothesis, challenge, outline of proposed performance, issue to be investigated or commission for a client) and provide a rationale for their choice
- produce a plan for how they will deliver their intended objective
- conduct research as required by the project brief, using appropriate techniques
- carry out the project using tools and techniques safely
- share the outcome of the project using appropriate communication methods, including a presentation.

Teachers: key information

- The Extended Project has 120 guided learning hours (GLH) consisting of:
  - a taught 40-GLH element that includes teaching the technical skills (for example research skills)
  - a guided 80-GLH element that includes mentoring students through the project work.
- Group work is acceptable, however it is important that each student provides evidence of their own contribution and produces their own report.
- 100% externally moderated.
- Four Assessment Objectives: manage, use resources, develop and realise, review.
- Can be run over 1, 1½ or 2 years.
- Can be submitted in January or June.

What is the Extended Project for physics?

The Extended Project creates the opportunity to develop transferable skills for progression to higher education and to the workplace through the exploration of either an area of personal interest, or a topic of interest, from within the physics qualification content.

For example, physics students could choose to carry out an investigation that would give them an opportunity to develop their skills in data collection, the development and testing of hypotheses and the application of mathematical models in data analysis. Alternatively, they could work on the design of an artefact or a dissertation as a way of exploring the use of physics in engineering contexts.

Skills developed

Through the Extended Project, students will develop skills in the following areas:

- independent research skills, including skills in primary research and the selection of appropriate methods for data collection
- extended reading and academic writing, including reading scientific literature and writing about trends or patterns in data sets
- planning/project management, including the refining of hypotheses to be tested in investigations
- data handling and evaluation, including the comparison of data from primary research with published data and exploration of the significance of results
- evaluation of arguments and processes, including arguments in favour of alternative interpretations of data and evaluation of experimental methodology
- critical thinking.

In the context of the Extended Project, critical thinking refers to the ability to identify and develop arguments for a point of view or hypothesis and to consider and respond to alternative arguments.

The Extended Project is an ideal vehicle to support the development of skills identified in *Appendix 1*.

Using the Extended Project to support breadth and depth

There is no specified material that students are expected to study and, in the Extended Project, students are assessed on the quality of the work they produce and the skills they develop and demonstrate through completing this work. Students can use the Extended Project to demonstrate *extension* in one or more dimensions:

- ***deepening understanding***: where a student explores a topic in greater depth than in the specification content
- ***broadening skills***: the student learns a new skill. In a physics-based project, this might involve learning to assemble and manipulate an unfamiliar piece of apparatus or learning advanced data-handling techniques
- ***widening perspectives***: the student's project spans different subjects. This might involve discussing historical, philosophical or ethical aspects of a physics-based topic or making links with other subject areas such as chemistry or economics.

Choosing topics and narrowing down to a question

A dissertation, typically around 6000 words in length, involves addressing a research question through a literature review and argumentative discussion while an investigation/field study involves data collection and analysis, leading to a written report of around 5000 words.

For example, consider a student with an interest in acoustics who decided to carry out an investigation to explore the effect of different variables such as the volume, density and stiffness of foam on sound absorption. The investigation involved secondary research to establish the theoretical background to the project and to find out how absorption is measured, what techniques can be used to gather data and to explore the context in which such physics is used (for example in industry). The student collected data using appropriately designed experiments. The student's own data were compared with published data, and the trends and patterns in data analysed, with consideration of the significance of the results obtained, and an attempt to interpret them in the light of the mathematical models that the student had learned about through research. Finally, the student's project ended with a review of the effectiveness of the investigation and an oral presentation of the main findings and arguments considered.

Physics-based dissertation projects can cover a wide variety of topics, as these examples illustrate:

- Why did the Titanic sink?
- Are wind turbines a good solution to the energy crisis?
- Can we justify human space exploration?
- Is it possible to believe in God and the Big Bang?
- How did the Copernican paradigm shift affect subsequent developments in cosmology?
- Is wi-fi safe?

Examples of possible investigation Extended Project titles include:

- How does solar activity affect weather?
- Do ‘sharkskin’ swimsuits give the wearer an unfair advantage?
- Over its working lifetime, does the energy output from a photovoltaic solar panel exceed the energy required to make, install and operate it?

There is also scope for physics-based artefact Extended Projects. For example a student might set out to design, make and test an item of apparatus such as a sundial or a spectrometer. Extended Projects involving a performance or event can also be physics-based. For example an incident or issue could be explored through drama (as Bertholt Brecht did with the ‘Trial of Galileo’).

Appendix 3: Codes

Type of code	Use of code	Code number
Discount codes	Every qualification is assigned to a discount code indicating the subject area to which it belongs. This code may change. Please go to our website (www.edexcel.com) for details of any changes.	For KS4 performance table: RC1 For 16–18 performance table: 1210
National Qualifications Framework (NQF) codes	Each qualification title is allocated an Ofqual National Qualifications Framework (NQF) code. The NQF code is known as a Qualification Number (QN). This is the code that features in the DfE Section 96 and on the LARA as being eligible for 16–18 and 19+ funding, and is to be used for all qualification funding purposes. The QN is the number that will appear on the student's final certification documentation.	The QN for the qualification in this publication is: 601/4847/0
Subject codes	The subject code is used by centres to enter students for a qualification. Centres will need to use the entry codes only when claiming students' qualifications.	Advanced Subsidiary GCE – 8PH0
Paper code	These codes are provided for reference purposes. Students do not need to be entered for individual papers.	Paper 1: 8PH0/01 Paper 2: 8PH0/02

Appendix 4: Command words used in examination papers

The following table lists the command words used in the external assessments.

Command word	Definition
Add/label	Requires the addition or labelling to a stimulus material given in the question, for example labelling a diagram or adding units to a table.
Assess	Give careful consideration to all the factors or events that apply and identify which are the most important or relevant. Make a judgement on the importance of something, and come to a conclusion where needed.
Calculate	Obtain a numerical answer, showing relevant working. If the answer has a unit, this must be included.
Comment on	Requires the synthesis of a number of variables from data/information to form a judgement.
Compare and contrast	Looking for the similarities **and** differences of two (or more) things. Should not require the drawing of a conclusion. Answer must relate to both (or all) things mentioned in the question. The answer must include at least one similarity and one difference.
Complete	Requires the completion of a table/diagram.
Criticise	Inspect a set of data, an experimental plan or a scientific statement and consider the elements. Look at the merits and/or faults of the information presented and back judgements made.
Deduce	Draw/reach conclusion(s) from the information provided.
Derive	Combine two or more equations or principles to develop a new equation.
Describe	To give an account of something. Statements in the response need to be developed as they are often linked but do not need to include a justification or reason.
Determine	The answer must have an element which is quantitative from the stimulus provided, or must show how the answer can be reached quantitatively.

Command word	Definition
Devise	Plan or invent a procedure from existing principles/ideas
Discuss	• Identify the issue/situation/problem/argument that is being assessed within the question. • Explore all aspects of an issue/situation/problem/ argument. • Investigate the issue/situation etc by reasoning or argument.
Draw	Produce a diagram either using a ruler or using freehand.
Evaluate	Review information then bring it together to form a conclusion, drawing on evidence including strengths, weaknesses, alternative actions, relevant data or information. Come to a supported judgement of a subject's qualities and relation to its context.
Explain	An explanation requires a justification/exemplification of a point. The answer must contain some element of reasoning/justification, this can include mathematical explanations.
Give/state/name	All of these command words are really synonyms. They generally all require recall of one or more pieces of information.
Give a reason/reasons	When a statement has been made and the requirement is only to give the reasons why.
Identify	Usually requires some key information to be selected from a given stimulus/resource.
Justify	Give evidence to support (either the statement given in the question or an earlier answer).
Plot	Produce a graph by marking points accurately on a grid from data that is provided and then drawing a line of best fit through these points. A suitable scale and appropriately labelled axes must be included if these are not provided in the question.
Predict	Give an expected result.
Show that	Prove that a numerical figure is as stated in the question. The answer must be to at least 1 more significant figure than the numerical figure in the question.
Sketch	Produce a freehand drawing. For a graph this would need a line and labelled axis with important features indicated, the axis are not scaled.
State what is meant by	When the meaning of a term is expected but there are different ways of how these can be described.
Write	When the questions ask for an equation.

Appendix 5: Working scientifically

Appendices 5 and *5a* are taken from the document *GCE AS and A level regulatory requirements for biology, chemistry, physics and psychology* published by the DfE in April 2014. Working scientifically is achieved through practical activities.

Specifications in biology, chemistry and physics must encourage the development of the skills, knowledge and understanding in science through teaching and learning opportunities for regular hands-on practical work.

Skills identified in *Appendix 5a* are assessed in the written examinations.

Appendix 5a: Practical skills identified for indirect assessment and developed through teaching and learning

Question papers will assess the following student's abilities:

a) Independent thinking

- solve problems set in practical contexts
- apply scientific knowledge to practical contexts

b) Use and application of scientific methods and practices

- comment on experimental design and evaluate scientific methods
- present data in appropriate ways
- evaluate results and draw conclusions with reference to measurement uncertainties and errors
- identify variables including those that must be controlled

c) Numeracy and the application of mathematical concepts in a practical context

- plot and interpret graphs
- process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science
- consider margins of error, accuracy and precision of data

d) Instruments and equipment

- know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

Appendix 6: Mathematical skills and exemplifications

The information in this appendix has been taken directly from the document *GCE AS and A level regulatory requirements for biology, chemistry, physics and psychology* published by the Department for Education (April 2014).

In order to be able to develop their skills, knowledge and understanding in science, students need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table of coverage below.

The assessment of quantitative skills will include at least 10% level 2 or above mathematical skills for biology and psychology, 20% for chemistry and 40% for physics. These skills will be applied in the context of the relevant science A Level.

All mathematical content must be assessed within the lifetime of the specification.

The following tables illustrate where these mathematical skills may be developed and could be assessed in each of the sciences. Those shown in **bold** type would be tested only in the full A Level course.

This list of examples is not exhaustive. These skills could be developed in other areas of specification content.

	Mathematical skills	Exemplification of mathematical skill in the context of A Level Physics (assessment is not limited to the examples given below)
(i) C.0 – arithmetic and numerical computation		
C.0.1	Recognise and make use of appropriate units in calculations	Students may be tested on their ability to: • identify the correct units for physical properties such as m s^{-1}, the unit for velocity • convert between units with different prefixes, e.g. cm^3 to m^3
C.0.2	Recognise and use expressions in decimal and standard form	Students may be tested on their ability to: • use physical constants expressed in standard form such as $c = 3.00 \times 10^8$ m s^{-1}
C.0.3	Use ratios, fractions and percentages	Students may be tested on their ability to: • calculate efficiency of devices • calculate percentage uncertainties in measurements
C.0.4	Estimate results	Students may be tested on their ability to: • estimate the effect of changing experimental parameters on measurable values
C.0.5	Use calculators to find and use power, **exponential and logarithmic functions**	Students may be tested on their ability to: • **solve for unknowns in decay problems such as** $N = N_0 e^{-\lambda t}$
C.0.6	Use calculators to handle sin *x*, cos *x*, tan *x* when *x* is expressed in degrees or radians	Students may be tested on their ability to: • calculate the direction of resultant vectors

	Mathematical skills	Exemplification of mathematical skill in the context of A Level Physics (assessment is not limited to the examples given below)
(ii)	**C.1 – handling data**	
C.1.1	Use an appropriate number of significant figures	Students may be tested on their ability to: • report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures • understand that calculated results can be reported only to the limits of the least accurate measurement
C.1.2	Find arithmetic means	Students may be tested on their ability to: • calculate a mean value for repeated experimental readings
C.1.3	Understand simple probability	Students may be tested on their ability to: • understand probability in the context of radioactive decay
C.1.4	Make order of magnitude calculations	Students may be tested on their ability to: • evaluate equations with variables expressed in different orders of magnitude
C.1.5	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers	Students may be tested on their ability to: • determine the uncertainty where two readings for length need to be added together

	Mathematical skills	Exemplification of mathematical skill in the context of A Level Physics (assessment is not limited to the examples given below)
(iii)	**C.2 – algebra**	
C.2.1	Understand and use the symbols: =, <, <<, >>, >, ∝, ≈, Δ	Students may be tested on their ability to: • recognise the significance of the symbols in the expression $F \propto \Delta p/\Delta t$
C.2.2	Change the subject of an equation, including non-linear equations	Students may be tested on their ability to: • rearrange $E = mc^2$ to make m the subject
C.2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Students may be tested on their ability to: • calculate the momentum p of an object by substituting the values for mass m and velocity v into the equation $p = mv$
C.2.4	Solve algebraic equations, including quadratic equations	Students may be tested on their ability to: • solve kinematic equations for constant acceleration such as $v = u + at$ and $s = ut + ½ at^2$
C.2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	Students may be tested on their ability to: • **recognise and interpret real-world examples of logarithmic scales**
(iv)	**C.3 – graphs**	
C.3.1	Translate information between graphical, numerical and algebraic forms	Students may be tested on their ability to: • calculate Young modulus for materials using stress-strain graphs
C.3.2	Plot two variables from experimental or other data	Students may be tested on their ability to: • plot graphs of extension of a wire against force applied
C.3.3	Understand that $y = mx + c$ represents a linear relationship	Students may be tested on their ability to: • rearrange and compare $v = u + at$ with $y = mx + c$ for velocity-time graph in constant acceleration problems
C.3.4	Determine the slope and intercept of a linear graph	Students may be tested on their ability to: • read off and interpret intercept point from a graph, e.g. the initial velocity in a velocity-time graph

	Mathematical skills	Exemplification of mathematical skill in the context of A Level Physics (assessment is not limited to the examples given below)
(iv) C.3 – graphs		
C.3.5	Calculate rate of change from a graph showing a linear relationship	Students may be tested on their ability to: • calculate acceleration from a linear velocity-time graph
C.3.6	Draw and use the slope of a tangent to a curve as a measure of rate of change	Students may be tested on their ability to: • draw a tangent to the curve of a displacement–time graph and use the gradient to approximate the velocity at a specific time
C.3.7	Distinguish between instantaneous rate of change and average rate of change	Students may be tested on their ability to: • understand that the gradient of the tangent of a displacement–time graph gives the velocity at a point in time which is a different measure to the average velocity
C.3.8	Understand the possible physical significance of the area between a curve and the *x* axis and be able to calculate it or estimate it by graphical methods as appropriate	Students may be tested on their ability to: • recognise that for a capacitor the area under a voltage-charge graph is equivalent to the energy stored
C.3.9	Apply the concepts underlying calculus (but without requiring the explicit use of derivatives or integrals) by solving equations involving rates of change, e.g. $\Delta x / \Delta t = -\lambda x$ using a graphical method or spreadsheet modelling	Students may be tested on their ability to: • determine *g* from distance-time plot, projectile motion
C.3.10	**Interpret logarithmic plots**	Students may be tested on their ability to: • **obtain time constant for capacitor discharge by interpreting plot of log *V* against time**

	Mathematical skills	Exemplification of mathematical skill in the context of A Level Physics (assessment is not limited to the examples given below)
(iv) C.3 – graphs		
C.3.11	**Use logarithmic plots to test exponential and power law variations**	Students may be tested on their ability to: • **use logarithmic plots with decay law of radioactivity/charging and discharging of a capacitor**
C.3.12	Sketch relationships which are modelled by $y = k/x$, $y = kx^2$, $y = k/x^2$, $y = kx$, $y = \sin x$, $y = \cos x$, **$y = e^{\pm x}$, and $y = \sin^2 x$, $y = \cos^2 x$ *a* as applied to physical relationships**	Students may be tested on their ability to: • **sketch relationships between pressure and volume for an ideal gas**
(v) C.4 – geometry and trigonometry		
C.4.1	Use angles in regular 2D and 3D structures	Students may be tested on their ability to: • interpret force diagrams to solve problems
C.4.2	Visualise and represent 2D and 3D forms, including two-dimensional representations of 3D objects	Students may be tested on their ability to: • draw force diagrams to solve mechanics problems
C.4.3	Calculate areas of triangles, circumferences and areas of circles, surface areas and volumes of rectangular blocks, cylinders and spheres	Students may be tested on their ability to: • calculate the area of the cross-section to work out the resistance of a conductor given its length and resistivity
C.4.4	Use Pythagoras' theorem, and the angle sum of a triangle	Students may be tested on their ability to: • calculate the magnitude of a resultant vector, resolving forces into components to solve problems
C.4.5	Use sin, cos and tan in physical problems	Students may be tested on their ability to: • resolve forces into components
C.4.6	Use of small angle approximations, including $\sin \theta \approx \theta$, $\tan \theta \approx \theta$, $\cos \theta \approx 1$ for small θ where appropriate	Students may be tested on their ability to: • calculate fringe separations in interference patterns
C.4.7	Understand the relationship between degrees and radians and translate from one to the other	Students may be tested on their ability to: • convert angle in degrees to angle in radians

Appendix 7: Formulae sheet

Students need not memorise formulae for this qualification.

The formulae below will be supplied in each examination. Any other formulae that are required will be provided in the question. Symbols used comply with Association for Science in Education (ASE) guidelines (which are based on International Union of Pure and Applied Physics (IUPAP) recommendations).

Mechanics

Kinematic equations of motion

$$s = \frac{(u+v)t}{2}$$

$$v = u + at$$

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

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

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

$$\text{Moment of force} = Fx$$

Momentum

$$p = mv$$

Work, energy and power

$$\Delta W = F\Delta s$$

$$E_k = \tfrac{1}{2}mv^2$$

$$\Delta E_{\mathrm{grav}} = mg\Delta h$$

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

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

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Electricity

Potential difference $$V = \frac{W}{Q}$$

Resistance $$R = \frac{V}{I}$$

Electrical power, energy and efficiency

$$P = VI$$

$$P = I^2R$$

$$P = \frac{V^2}{R}$$

$$W = VIt$$

Resistivity $$R = \frac{\rho l}{A}$$

Current

$$I = \frac{\Delta Q}{\Delta t}$$

$$I = nqvA$$

Materials

Density $$\rho = \frac{m}{V}$$

Stokes' law $$F = 6\pi\eta rv$$

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

Pressure $$p = \frac{F}{A}$$

Young modulus	Stress $\sigma = \frac{F}{A}$ Strain $\varepsilon = \frac{\Delta x}{x}$ $E = \frac{\sigma}{\varepsilon}$
Elastic strain energy	$\Delta E_{el} = \frac{1}{2} F \Delta x$

Waves and particle nature of light

Wave speed	$v = f\lambda$
Speed of a transverse wave on a string	$v = \sqrt{\frac{T}{\mu}}$
Intensity of radiation	$I = \frac{P}{A}$
Power of a lens	$P = \frac{1}{f}$ $P = P_1 + P_2 + P_3 + \ldots$
Thin lens equation	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
Magnification for a lens	magnification = Image height/Object height $m = \frac{v}{u}$
Diffraction grating	$n\lambda = d\sin\theta$

Refractive index	$n_1 \sin \theta_1 = n_2 \sin \theta_2$ $n = \frac{c}{v}$
Critical angle	$\sin C = \frac{1}{n}$
Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2} m v_{\max}^2$
de Broglie wavelength	$\lambda = \frac{h}{p}$

Appendix 8: Data sheet

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

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

Appendix 9: Uncertainties and practical work

The aim of physics in studying natural phenomena is to develop explanations based on empirical evidence. Hence there is a central concern about the quality of evidence and of the explanations that are based on it. There is no practical examination in this qualification and a set of practical skills has been identified as appropriate for indirect assessment. In doing this it is clearly important that the words used have a precise and scientific meaning as distinct from their everyday usage. Practical skills should be developed by carrying out practical work throughout the course and the assessment of these skills will be through examination questions in both AS papers (see *Appendix 5a: Practical skills identified for indirect assessment and developed through teaching and learning*).

The terms used for this assessment will be those described in the publication by the Association for Science Education (ASE) entitled *The Language of Measurement* (ISBN 9780863574245). In adopting this terminology, it should be noted that certain terms will have a meaning different to that in the previous specification. In accordance with common practice, this qualification will adopt the Uncertainty Approach to measurement. Using this approach assumes that the measurement activity produces an interval of reasonable values together with a statement of the confidence that the true value lies within this interval.

Glossary

Term	**Meaning and notes**
Validity	A measurement is valid if it measures what it is supposed to be measuring – this depends both on the method and the instruments.
True value	The value that would have been obtained in an ideal measurement – with the exception of a fundamental constant the true value is considered unknowable.
Accuracy	A measurement result is considered accurate if it is judged to be close to the true value. It is a quality denoting the closeness of agreement between measurement and true value – it cannot be quantified and is influenced by random and systematic errors.
Precision	A quality denoting the closeness of agreement (consistency) between values obtained by repeated measurement – this is influenced only by random effects and can be expressed numerically by measures such as standard deviation. A measurement is precise if the values 'cluster' closely together.
Repeatability	The precision obtained when measurement results are obtained by a single operator using a single method over a short timescale. A measurement is repeatable when similar results are obtained by students from the same group using the same method. Students can use the precision of their measurement results to judge this.

Term	Meaning and notes
Reproducibility	The precision obtained when measurement results are obtained by different operators using different pieces of apparatus. A measurement is reproducible when similar results are obtained by students from different groups using different methods or apparatus. This is a harder test of the quality of data.
Uncertainty	The interval within which the true value can be considered to lie with a given level of confidence or probability – any measurement will have some uncertainty about the result, this will come from variation in the data obtained and be subject to systematic or random effects. This can be estimated by considering the instruments and the method and will usually be expressed as a range such as 20°C ± 2°C. The confidence will be qualitative and based on the goodness of fit of the line of best fit and the size of the percentage uncertainty.
Error	The difference between the measurement result and the true value if a true value is thought to exist. This is not a mistake in the measurement. The error can be due to both systematic and random effects and an error of unknown size is a source of uncertainty.
Resolution	The smallest measuring interval and the source of uncertainty in a single reading.
Significant figures (sf)	The number of sf used depends on the resolution of the measuring instruments and should usually be the same as given in the instrument with the fewest sf in its reading.

This is a selection of terms from the list in *The Language of Measurement* published by ASE (ISBN 9780863574245).

Uncertainties in practice

What are uncertainties and why are they important?

When you repeat a measurement you often get different results. There is an *uncertainty* in the measurement that you have taken. It is important to be able to determine the uncertainty in measurements so that their effect can be taken into consideration when drawing conclusions about experimental results. The uncertainty might be the resolution of the instrument or, if the readings were repeated, the uncertainty might be half the range of the repeats.

Calculating uncertainties

Example: A student measures the diameter of a metal canister using a ruler graduated in mm and records three results:

66 mm, 65 mm and 61 mm.

The average diameter is (66 + 65 + 61)/3 = 64 mm.

The uncertainty in the diameter is the difference between the average reading and the biggest or smallest value obtained, whichever is the greater. In this case, the measurement of 61 mm is further from the average value than 66 mm and we take the uncertainty as the greatest distance between the mean and one extreme value.

So the uncertainty in the measurement is 64 – 61 = 3 mm.

Therefore, the diameter of the metal canister is 64 ± 3 mm.

Sometimes it is also helpful to consider half the range of the readings, in this case that is 2.5 mm. Since we are expecting students to produce an *estimate* of the uncertainty any suitable value is acceptable.

Even in situations where the same reading is obtained each time there is still an uncertainty in the measurement because the instrument used to take the measurement has its own limitations.

If the three readings obtained above were all 64 mm, then the value of the diameter being measured lies somewhere between the range of values 63.5 mm and 64.5 mm.

In this case, the uncertainty in the diameter is 0.5 mm.

Therefore, the diameter of the metal canister is 64 ± 0.5 mm.

Calculating percentage uncertainties

The percentage uncertainty in a measurement can be calculated using:

Percentage uncertainty = (Uncertainty of measurement/Measurement taken) × 100%

The percentage uncertainty in the first measurement of the diameter of the metal canister is:

Percentage uncertainty = (3/64) × 100% = 4.7%

The radius of the canister = diameter/2 = 32 mm.

The percentage uncertainty for the radius of the canister is the same as its diameter, i.e. 4.7%. This is one reason why the percentage uncertainty in a measurement is useful. Additionally, the value is less than 5%, which from experience shows the measurement is probably repeatable.

Compounding uncertainties

Calculations often use more than one measurement. Each measurement will have its own uncertainty, so it is necessary to combine the uncertainties for each measurement to calculate the overall uncertainty in the calculation result.

The total percentage uncertainty is calculated by adding together the percentage uncertainties for each measurement if:

(1) all the measured quantities are independent of one another AND

(2) they are multiplied together or divided.

Example 1: A builder calculates the area of a square tile and the percentage uncertainty for it.

Solution 1

He uses a rule to measure the two adjacent sides of a square tile and obtains the following results:

Length of one side = 84 ± 0.5 mm
Length of perpendicular side = 84 ± 0.5 mm

The percentage uncertainty (%U) in the length of each side of this square tile is given by

%U = (0.5/84) %× 100% = 0.59%

The area of the tile A is given by $A = 84 \times 84 = 7100\ \text{mm}^2$ – note that this is to 2 significant figures (SF) since the measurements are to 2 SF.

The percentage uncertainty in the area of the square tile is calculated by adding together the percentage uncertainties for the two measurements.

%U = 2 × 0.59% = 1.2%

Percentage uncertainty in the area of the square tile is: $\Delta A/A = 1.2\%$

So $A = 7100\ \text{mm}^2 \pm 1.2\%$ **or** $A = 7100\ \text{mm}^2 \pm 85\ \text{mm}^2$

Example 2: A metallurgist is determining the purity of a sample of an alloy that is in the shape of a cube by determining the density of the material.

The following readings are taken:

Length of each side of the cube l = 24.0 mm ± 0.5 mm
Mass of cube m = 48.23 ± 0.05 g

The metallurgist calculates (i) the density of the material and (ii) the percentage uncertainty in the density of the material.

Solution 2

(i) Density of alloy = mass/volume

$= (48.23 \times 10^{-3}\ \text{kg})/\ (24.0 \times 10^{-3}\ \text{m})^3 = 3490\ \text{kg m}^{-3}$

(ii) Percentage uncertainty in the length of each side of the cube

$\Delta l/l = 0.5/24.0 \times 100\% = 2.1\%$

Percentage uncertainty in the mass of the cube

$\Delta m/m = 0.05/48.23 \times 100\% = 0.1\%$

Therefore total percentage uncertainty = 2.1% + 2.1% + 2.1% +0.1% = 6.4%

We normally ignore decimal places in calculating uncertainties so the percentage uncertainty in the density of the material is 6%.

So density = $3490\ \text{kg m}^{-3} \pm 6\%$ **or** $3490\ \text{kg m}^{-3} \pm 210\ \text{kg m}^{-3}$

Example 3: A student calculates the volume of a drinks can and the percentage uncertainty for the final value.

Solution 3

The student determines that the radius of the metal can is 33 mm with an uncertainty of 1% so the cross-sectional area A of the canister is:

$A = \pi r^2 = \pi\ (33)^2 = 3.4 \times 10^3\ \text{mm}^2 \pm 2\%$

Notice that the result has been expressed using scientific notation so that we can write down just two significant figures. The calculator answer (3421.1...) gives the impression of far more SF than is justified when the radius is known only to the nearest mm.

The cross-sectional area was calculated by squaring the radius. Since two quantities have in effect been multiplied together, the percentage uncertainty in the value of the cross-sectional area is found by adding the percentage uncertainty of the radius to the percentage uncertainty of the radius – doubling it.

The student measures the length L of the can $L = 115\ \text{mm} \pm 2\ \text{mm}$

The volume V of the can is $V = 3.4 \times 10^3\ \text{mm}^2 \times 115\ \text{mm} = 3.91 \times 10^5\ \text{mm}^3 = 3.91 \times 10^{-4}\ \text{m}^3$

The percentage uncertainty in this value is obtained by adding together an appropriate combination of the uncertainties

$\Delta L/L = (2/115) \times 100\% = 1.7\%$ So $\Delta V/V = 2\% + 1.7\% = 3.7\%$

Volume = $3.91 \times 10^{-4}\ \text{m}^3 \pm 3.7\% = 3.91 \times 10^{-4}\ \text{m}^3 \pm 1.4 \times 10^{-5}\ \text{m}^3$

Again, an overall percentage uncertainty of less than 5% suggests that this determination of the volume of a can is repeatable.

Using error bars to estimate experimental uncertainties

The equation $v = kT^{a}$ relates the speed v of a wave in a string to the tension T. In an experiment to verify this relationship, the data is plotted on a graph of ln (v/ms^{-1}) against ln (T/N) and the gradient of the resulting straight line is the constant a.

To determine the uncertainty in constant *a,* the uncertainties in v and T can be compounded by considering the difference between two lines of best fit that can be drawn through the data using error bars – one is steepest and the other least steep.

To produce error bars in ln(T/N) you need the uncertainty in T. You then calculate the logarithm of your data point with the uncertainty applied (both ways) and draw the error bar to this value.

Suppose you measure T = 3.4N ± 0.2N.

Then the length of the error bar is (ln(3.6N)-ln(3.2N)) = 1.28 – 1.16 = 0.12

This need only be calculated for one data point (one in the middle of the range) and the same size error bar used for each value of T.

The uncertainty in ln (v/ms^{-1}) can be calculated in the same way and error bars drawn in that direction to give, in effect, an error box around each plot. The steepest line of best fit is the line that passes through all the boxes and is steeper than the least steep line of best fit that just passes through all other corners of the error boxes.

It is not intended that this should be a particularly lengthy procedure but it is one way of finding an estimate of the uncertainty in an experiment and is considerably easier than a mathematical treatment.

Appendix 10: Support from the University of York

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

The project team also runs an advice service to help with questions concerning the teaching of the course, and produces newsletters that are distributed to centres using this specification.

Centres following this qualification may be eligible for additional financial support (for example book grants) from the Salters and Horners companies.

There are email support groups for SHAP teachers and technicians.

For further information about the SHAP approach to teaching for this qualification, and about the support available to centres, please visit the SHAP website: www.york.ac.uk/org/seg/salters/physics or contact the project administrator:

Salters Horners Advanced Physics Project
Science Education Group
Alcuin College D Block
University of York
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York
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Telephone:	01904 322601
Fax:	01904 322605
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Enquiries concerning assessment and administration should be addressed to the Qualifications and Delivery and Awards Manager for Physics at Pearson.

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