Qualification Accredited

Oxford Cambridge and RSA

A LEVEL

Specification

PHYSICS B (ADVANCING PHYSICS)

H557

For first assessment in 2017

Version 2.7 (October 2024)

ocr.org.uk/alevelphysicsb

Disclaimer

Specifications are updated over time. Whilst every effort is made to check all documents, there may be contradictions between published resources and the specification, therefore please use the information on the latest specification at all times. Where changes are made to specifications these will be indicated within the document, there will be a new version number indicated, and a summary of the changes. If you do notice a discrepancy between the specification and a resource please contact us at: resources.feedback@ocr.org.uk

We will inform centres about changes to specifications. We will also publish changes on our website. The latest version of our specifications will always be those on our website (ocr.org.uk) and these may differ from printed versions.

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Contents

Introducing…
A Level Physics B (Advancing Physics) (from September 2015)

Our vision for Science is to create specifications with content that will be up to date, scientifically accurate, developed by subject experts, and allow clear progression pathways (from GCSE to AS/A Level through to higher education, or other post-16 courses and employment). Courses will provide a rewarding experience across the ability range, genuinely challenging the most able learners. The assessment burden will be reduced as much as possible for centres through:

- Carefully designed assessments (straightforward to use for all centre types, large to small)
- Well-laid-out specifications and question papers
- Friendly and prompt support from our team of Subject Advisors
- Quality resource materials that help support a variety of good teaching approaches, drawing on expertise from across the subject community.

Our **A Level Physics B specification** takes a context-led approach to the course. Learners study physics within the distinctive 'Advancing Physics' approach. Learners are introduced to a wide variety of topics showing physics in action early in the course to encourage curiosity in the subject. They learn about fundamental physical concepts and how to apply these in everyday and technological settings. The course demonstrates the usefulness of the subject and illustrates the impact that discoveries in physics have had on the way people live.

We're striving for good science that's straightforward and engaging to teach, with fair, challenging and relevant assessment that works well in centres and promotes practical activity.

Contact the team

We have a dedicated team of people working on our A Level Physics qualifications.

If you need specialist advice, guidance or support, get in touch as follows:

- **01223 553998**
- **scienceGCE@ocr.org.uk**
- **@OCR_Science**

Teaching and learning resources

We recognise that the introduction of a new specification can bring challenges for implementation and teaching. Our aim is to help you at every stage and we're working hard to provide a practical package of support in close consultation with teachers and other experts, so we can help you to make the change.

Designed to support progression for all

Our resources are designed to provide you with a range of teaching activities and suggestions so you can select the best approach for your particular students. You are the experts on how your students learn and our aim is to support you in the best way we can.

We want to…

- Support you with a body of knowledge that grows throughout the lifetime of the specification
- Provide you with a range of suggestions so you can select the best activity, approach or context for your particular students
- Make it easier for you to explore and interact with our resource materials, in particular to develop your own schemes of work
- Create an ongoing conversation so we can develop materials that work for you.

Plenty of useful resources

You'll have four main types of subject specific teaching and learning resources at your fingertips:

- Delivery Guides
- Transition Guides
- Topic Exploration Packs
- Lesson Elements.

Along with subject-specific resources, you'll also have access to a selection of generic resources that focus on skills development and professional guidance for teachers.

Skills Guides – we've produced a set of Skills Guides that are not specific to Physics, but each covers a topic that could be relevant to a range of qualifications – for example, communication, legislation and research. Download the guides at **ocr.org.uk/skillsguides**.

Active Results – a free online results analysis service to help you review the performance of individual students or your whole school. It provides access to detailed results data, enabling more comprehensive analysis of results in order to give you a more accurate measurement of the achievements of your centre and individual students. For more details refer to **ocr.org.uk/activeresults**.

Professional Development

Take advantage of our improved Professional Development Programme, designed with you in mind. Whether you want to come to face-to-face events, look at our new digital training or search for training materials, you can find what you're looking for all in one place at the CPD Hub.

An introduction to the new specifications

We'll be running events to help you get to grips with our A Level Physics B (Advancing Physics) qualification.

These events are designed to help prepare you for first teaching and to support your delivery at every stage.

Watch out for details at **cpdhub.ocr.org.uk**.

To receive the latest information about the training we'll be offering, please register for A Level email updates at **ocr.org.uk/updates**.

1 Why choose an OCR A Level in Physics B (Advancing Physics)?

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1a. Why choose an OCR qualification?

Choose OCR and you've got the reassurance that you're working with one of the UK's leading exam boards. Our new A Level in Physics B (Advancing Physics) course has been developed in consultation with teachers, employers and Higher Education to provide students with a qualification that's relevant to them and meets their needs.

We're part of the Cambridge Assessment Group, Europe's largest assessment agency and a department of the University of Cambridge. Cambridge Assessment plays a leading role in developing and delivering assessments throughout the world, operating in over 150 countries.

We work with a range of education providers, including schools, colleges, workplaces and other institutions in both the public and private sectors. Over 13,000 centres choose our A levels, GCSEs and vocational qualifications including Cambridge Nationals and Cambridge Technicals.

Our Specifications

We believe in developing specifications that help you bring the subject to life and inspire your students to achieve more.

We've created teacher-friendly specifications based on extensive research and engagement with the teaching community. They're designed to be straightforward and accessible so that you can tailor the delivery of the course to suit your needs. We aim to encourage learners to become responsible for their own learning, confident in discussing ideas, innovative and engaged.

We provide a range of support services designed to help you at every stage, from preparation through to the delivery of our specifications. This includes:

- A wide range of high-quality creative resources including:
  - delivery guides
  - transition guides
  - topic exploration packs
  - lesson elements
  - …and much more.
- Access to Subject Advisors to support you through the transition and throughout the lifetime of the specifications.
- CPD/Training for teachers to introduce the qualifications and prepare you for first teaching.
- Active Results – our free results analysis service to help you review the performance of individual students or whole schools.
- ExamBuilder – our free online past papers service that enables you to build your own test papers from past OCR exam questions.

All A level qualifications offered by OCR are accredited by Ofqual, the Regulator for qualifications offered in England. The accreditation number for OCR's A Level in Physics B (Advancing Physics) is QN: 601/4745/3.

1b. Why choose an OCR A Level in Physics B (Advancing Physics)?

We appreciate that one size doesn't fit all so we offer two suites of qualifications in each science:

Physics A – a content-led approach. A flexible approach where the specification is divided into topics, each covering different key concepts of physics. As learners progress through the course they will build on their knowledge of the laws of Physics, applying their understanding to solve problems on topics ranging from sub-atomic particles to the entire universe. For A level only, the Practical Endorsement will also support the development of practical skills.

Physics B (Advancing Physics) – a context-led approach. Learners study physics in a range of different contexts, conveying the excitement of contemporary physics. The course provides a distinctive structure within which candidates learn about fundamental physical concepts and about physics in everyday and technological settings. Practical skills are embedded within the specification and learners are expected to carry out practical work in preparation for a written examination that will specifically test these skills.

All of our specifications have been developed with subject and teaching experts. We have worked in close consultation with teachers and representatives from Higher Education (HE) with the aim of including up-to-date relevant content within a framework that is interesting to teach and administer within all centres (large and small).

Our new A Level in Physics B (Advancing Physics) qualification builds on our existing popular course. We've based the redevelopment of our A level sciences on an understanding of what works well in centres large and small and have updated areas of content and assessment where stakeholders have identified that improvements could be made. We've undertaken a significant amount of consultation through our science forums (which include representatives from learned societies, HE, teaching and industry) and through focus groups with teachers. Our papers and specifications have been trialled in centres during development to make sure they work well for all centres and learners.

The content changes are an evolution of our legacy offering and will be familiar to centres already following our courses, but are also clear and logically laid out for centres new to OCR, with assessment models that are straightforward to administer. We have worked closely with teachers and HE representatives to provide high quality support materials to guide you through the new qualifications.

Aims and learning outcomes

OCR's A Level in Physics B (Advancing Physics) specification aims to encourage learners to:

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

1c. What are the key features of this specification?

Our Physics B specification has been designed so learners study physics within the distinctive 'Advancing Physics' context-based approach. The specification:

- will enable learners to learn about fundamental physical concepts and how to apply these in everyday and technological settings
- is laid out clearly in a series of teaching modules with additional guidance added where required to clarify assessment requirements
- is co-teachable with the AS level
- embeds practical requirements within the teaching modules
- identifies practical endorsement requirements and how these can be integrated into teaching of content (see Section 5h)
- exemplifies the mathematical requirements of the course (see Section 5e)
- highlights opportunities for the introduction of key mathematical requirements (see Section 5e and the additional guidance column for each module) into your teaching
- identifies, within the additional guidance, how the skills, knowledge and understanding of How Science Works (HSW) can be incorporated within teaching.

Teacher support

The extensive support offered alongside this specification includes:

- **delivery guides –** providing information on assessed content, the associated conceptual development and contextual approaches to delivery
- **transition guides –** identifying the levels of demand and progression for different key stages for a particular topic and going on to provide links to high quality resources and 'checkpoint tasks' to assist teachers in identifying learners 'ready for progression'
- **lesson elements –** written by experts, providing all the materials necessary to deliver creative classroom activities
- **Active Results** (see Section 1a)
- **ExamBuilder** (see Section 1a)
- **mock examinations service –** a free service offering a practice question paper and mark scheme (downloadable from a secure location).

Along with:

- Subject Advisors within the OCR science team to help with course queries
- teacher training
- *Science Spotlight* (our termly newsletter)
- OCR Science community
- a consultancy service (to advise on Practical Endorsement requirements)
- Practical Skills Handbook
- Maths Skills Handbook.

1d. How do I find out more information?

Whether new to our specifications, or continuing from our legacy offerings, you can find more information on our webpages at: **www.ocr.org.uk**

Visit our Subject pages to find out more about the assessment package and resources available to support your teaching. The science team also release a termly newsletter *Science Spotlight* (despatched to centres and available from our subject pages).

Find out more?

Contact the Subject Advisors: **ScienceGCE@ocr.org.uk**, 01223 553998.

Visit our Online Support Centre at **support.ocr.org.uk**

Check what CPD events are available: **www.cpdhub.ocr.org.uk**

Follow us on Twitter: **@ocr_science**

2 The specification overview

2a. Overview of A Level in Physics B (Advancing Physics) (H557)

Learners must complete all components (01, 02, 03 and 04) to be awarded the OCR A Level in Physics B.

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Content Overview	Assessment Overview	
Content is split into six teaching modules: • Module 1 – Development of practical skills in physics • Module 2 – Fundamental data analysis • Module 3 – Physics in action • Module 4 – Understanding processes • Module 5 – Rise and fall of the clockwork universe • Module 6 – Field and particle physics Components 01– 03 assess content from all six modules.	Fundamentals of physics (01) 110 marks 2 hours 15 minutes written paper	**41%** of total A level
	Scientific literacy in physics (02) 100 marks 2 hours 15 minutes written paper	**37%** of total A level
	Practical skills in physics (03) 60 marks 1 hour 30 minutes written paper	**22%** of total A level
	Practical Endorsement in physics (04) (non exam assessment)	Reported separately (see Section 5h)

All components include synoptic assessment.

2b. Content of A Level in Physics B (Advancing Physics) (H557)

The A Level in Physics B specification content is divided into six teaching modules. Each module is introduced with a summary of the physics it contains and each topic is also introduced with a short summary text. The assessable content is divided into two columns: **Learning outcomes** and **Additional guidance**.

The Learning outcomes may all be assessed in the examinations (with the exception of some of the skills in module **1.2** which will be assessed directly through the Practical Endorsement). The Additional guidance column is included to provide further advice on delivery and the expected skills required from learners.

References to HSW (Section 5d) are included in the guidance to highlight opportunities to encourage a wider understanding of science.

The mathematical requirements in Section 5e are also referenced by the prefix *M* to link the mathematical skills required for A Level Physics to examples of the physics content where those mathematical skills could be linked to learning.

The specification has been designed to be co-teachable with the standalone AS Level in Physics B (Advancing Physics) qualification. The first four modules comprise the AS in Physics B (Advancing Physics) course and learners studying the A level continue with the content of modules 5 and 6 in year 13.

The Data, Formulae and Relationships booklet in Section 5c will be available in examinations and learners are expected to become familiar with this booklet throughout the course.

A summary of the content for the A level course is as follows:

Module 1 – Development of practical skills in physics

1.1 Practical skills assessed in a written examination
1.2 Practical skills assessed in the practical endorsement

Module 2 – Fundamental data analysis

Module 3 – Physics in action

3.1.1 Imaging and signalling
3.1.2 Sensing
3.2 Mechanical properties of materials

Module 4 – Understanding processes

4.1 Waves and quantum behaviour
4.2 Space, time and motion

Module 5 – Rise and fall of the clockwork universe

5.1.1 Creating models
5.1.2 Out into space
5.1.3 Our place in the universe
5.2.1 Matter: very simple
5.2.2 Matter: hot or cold

Module 6 – Field and particle physics

6.1.1 Electromagnetism
6.1.2 Charge and field
6.2.1 Probing deep into matter
6.2.2 Ionising radiation and risk.

Assessment of practical skills and the Practical Endorsement

Module 1 of the specification content relates to the practical skills learners are expected to gain throughout the course, which are assessed throughout the written examinations and also through the Practical Endorsement (see Section 5h).

Practical activities are embedded within the learning outcomes of the course to encourage practical activities in the classroom which contribute to the achievement of the Practical Endorsement (Section 5h) as well as enhancing learners' understanding of physics theory and practical skills.

Opportunities for carrying out activities that could count towards the Practical Endorsement (Section 5h) are indicated throughout the specification. These are shown in the Additional guidance column as **PAG1** to **PAG10** (Practical Activity Group, see Section 5h). There are a wide variety of opportunities to assess **PAG11** and **PAG12** throughout the qualification.

2c. Content of modules 1 to 6

Learners are expected to be able to demonstrate and apply their knowledge and understanding of all the learning outcomes in this specification. The learning outcomes in modules 2 – 6 are split into four categories, labelled **(a)**, **(b)**, **(c)**, and **(d)**, to order the specification in a helpful way for planning teaching programmes and to help identify the knowledge required of learners taking the course.

The headings for these categories are:

- **(a)** Describe and explain
- **(b)** Make appropriate use of
- **(c)** Make calculations and estimates involving
- **(d)** Demonstrate and apply knowledge and understanding of the following practical activities.

Module 1: Development of practical skills in physics

Physics is a practical subject and the development of practical skills is fundamental to understanding the nature of physics. Physics B gives learners many opportunities to develop the fundamental skills needed to collect and analyse empirical data. Skills in planning, implementing, analysing and evaluating, as outlined in **1.1**, will be assessed in the written papers.

1.1 Practical skills assessed in a written examination

Practical skills are embedded throughout the content of this specification.

Learners will be required to develop a range of practical skills throughout their course in preparation for the written examinations.

1.1.1 Planning

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	experimental design, including to solve problems set in a practical context	Including selection of suitable apparatus, equipment and techniques for the proposed experiment. Learners should be able to apply scientific knowledge based on the content of the specification to the practical context. HSW3
(b)	identification of variables that must be controlled, where appropriate	
(c)	evaluation that an experimental method is appropriate to meet the expected outcomes.	HSW6

1.1.2 Implementing

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how to use a wide range of practical apparatus and techniques correctly	As outlined in the content of the specification and the skills required for the practical endorsement. HSW4
(b)	appropriate units for measurements	*M0.1*
(c)	presenting observations and data in an appropriate format.	HSW8

1.1.3 Analysis

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	processing, analysing and interpreting qualitative and quantitative experimental results	Including reaching valid conclusions, where appropriate. HSW5
(b)	use of appropriate mathematical skills for analysis of quantitative data	Refer to Section 5e for a list of mathematical skills that learners should have acquired competence in as part of their course. HSW3
(c)	appropriate use of significant figures	*M1.1*
(d)	plotting and interpreting suitable graphs from experimental results, including:	
	(i) selection and labelling of axes with appropriate scales, quantities and units	*M3.2,*
	(ii) measurement of gradients and intercepts.	*M3.3, M3.4, M3.5*

1.1.4 Evaluation

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how to evaluate results and draw conclusions	HSW6
(b)	the identification of anomalies in experimental measurements	
(c)	the limitations in experimental procedures	
(d)	precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus	*M1.5*
(e)	the refining of experimental design by suggestion of improvements to the procedures and apparatus.	HSW3

1.2 Practical skills assessed in the Practical Endorsement

A range of practical experiences is a vital part of a learner's development as part of this course.

Learners should develop and practise a wide range of practical skills throughout the course as preparation for the Practical Endorsement, as well as for the written examinations.

The experiments and skills required for the Practical Endorsement will allow learners to develop and practise their practical skills, preparing learners for the written examinations.

Please refer to Section 5h (the Practical Endorsement) of this specification to see the list of practical experiences all learners should cover during the course. Further advice and guidance on the Practical Endorsement can be found in the Practical Skills Handbook support booklet.

1.2.1 Practical skills

	Learning outcomes	Additional guidance
	Practical work carried out throughout the course will enable learners to develop the following skills:	
Independent thinking		
(a)	apply investigative approaches and methods to practical work	Including how to solve problems in a practical context. HSW3
Use and application of scientific methods and practices		
(b)	safely and correctly use a range of practical equipment and materials	See Section 5h. Including identification of potential hazards. Learners should understand how to minimise the risks involved. HSW4
(c)	follow written instructions	
(d)	make and record observations/measurements	HSW8
(e)	keep appropriate records of experimental activities	See Section 5h.
(f)	present information and data in a scientific way	HSW8
(g)	use appropriate software and tools to process data, carry out research and report findings	*M3.1* HSW3
Research and referencing		
(h)	use online and offline research skills including websites, textbooks and other printed scientific sources of information	
(i)	correctly cite sources of information	The Practical Skills Handbook provides guidance on appropriate methods for citing information.

	Learning outcomes	Additional guidance
Instruments and equipment		
(j)	use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification.	See Section 5h. HSW4

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1.2.2 Use of apparatus and techniques

	Learning outcomes	Additional guidance
	Through use of the apparatus and techniques listed below, and a minimum of 12 assessed practicals (see Section 5h), learners should be able to demonstrate all of the practical skills listed within 1.2.1 and CPAC (Section 5h, ***Table 2****) as exemplified through:*	
(a)	use of appropriate analogue apparatus to record a range of measurements (to include length/ distance, temperature, pressure, force, angles and volume) and to interpolate between scale markings	HSW4
(b)	use of appropriate digital instruments, including electrical multimeters, to obtain a range of measurements (to include time, current, voltage, resistance and mass)	HSW4
(c)	use of methods to increase accuracy of measurements, such as timing over multiple oscillations, or use of fiducial marker, set square or plumb line	HSW4
(d)	use of a stopwatch or light gates for timing	HSW4
(e)	use of calipers and micrometers for small distances, using digital or vernier scales	HSW4
(f)	correctly constructing circuits from circuit diagrams using DC power supplies, cells, and a range of circuit components, including those where polarity is important	HSW4
(g)	designing, constructing and checking circuits using DC power supplies, cells, and a range of circuit components	HSW4
(h)	use of a signal generator and oscilloscope, including volts/division and time-base	HSW4
(i)	generating and measuring waves, using microphone and loudspeaker, or ripple tank, or vibration transducer, or microwave/radio wave source	HSW4

(j)	use of a laser or light source to investigate characteristics of light, including interference and diffraction	HSW4
(k)	use of ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data	HSW3, HSW4
(l)	use of ionising radiation, including detectors.	HSW4

Module 2: Fundamental data analysis

Physics B gives learners many opportunities to analyse data collected in practical sessions or provided for them. Learners should be exposed and trained in the techniques of analysis and the handling of experimental uncertainties throughout the course. In particular, the early parts of the course give learners the chance to practise the handling and analysing data. The Physics B approach to data analysis builds on the practical skills in module **1.1** as detailed below.

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	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) factors affecting accuracy and uncertainty of measurements	
	(ii) the importance of recognising the largest source of uncertainty in a measurement.	
(b)	*Make appropriate use of:*	
	(i) SI units and their prefixes, standard form, angles in degrees and radians	Learners may be required to convert degrees to radians and *vice versa M0.1, M0.6, M4.7*
	(ii) the terms: accuracy, precision, resolution, sensitivity, response time, uncertainty, systematic error including zero error	as discussed in *The Language of Measurement* (ASE 2010)
	by sketching and interpreting:	
	(iii) simple plots of the distribution of measured values to estimate the mean (or median) value and the spread and to identifying potential outlying values and to suggest reasons to account for them	use of 'dot-plots' to estimate uncertainty
	(iv) a variety of different kinds of graphical plot and use of uncertainty bars to help establish the validity of measured data.	Including scatter graphs, pie-charts, log graphs
(c)	*Make calculations and estimates involving:*	
	(i) uncertainty of experimental data, the mean of results, range, spread and percentage uncertainties. Estimate of best fit gradients and intercepts with uncertainty	*M0.3, M1.2*
	(ii) estimating uncertainties when data are combined by addition, subtraction, multiplication, division and raising to powers	As set out in the ASE publication *Signs, Symbols and Systematics* (*The ASE Companion to 16–19 Science*, 2000). A rigorous statistical treatment is not required; learners will be expected to re-calculate values of the required quantity using extreme values of the variable(s) with the greatest uncertainty *M1.5*
	(iii) estimated magnitudes of everyday quantities.	

Module 3: Physics in action

This module is intended to provide a graduated path from GCSE work into A level work, develop the skills and habits of independent working and show a wide range of ways in which physics is put to use. It includes many opportunities for practical work that will develop experimental and analytical skills. The module covers a number of techniques and concepts from different areas of physics. This gives learners an early opportunity to appreciate the breadth of the subject and its practical, conceptual and mathematical demands.

3.1 Communication

These sections are about waves, images, simple optics and electric circuits. The physics of the imaging and signalling section is approached through how information is gathered, processed, transmitted and presented. Learners have opportunities to develop IT skills through the use of image processing, data capture and data analysis software. The material can be taught using contexts such as smart phones, data streaming, medical scanning and remote sensing. There are opportunities to address human and social concerns, for example, consequences of the growth of worldwide digital communications (HSW9) and the ethical issues of sharing information (HSW10).

The sensing section covers the ideas involved in understanding electrical circuits, especially charge, current, potential difference, resistance, conductance and potential dividers. Some of this work will be in the context of sensors and instrumentation. There are many opportunities for gaining experimental experience and skills in these sections of the course.

3.1.1 Imaging and signalling

		Learning outcomes	Additional guidance
(a)		*Describe and explain:*	
	(i)	the formation of a real image by a thin converging lens, understood as the lens changing the curvature of the incident wave-front	HSW9
	(ii)	the storage of images in a computer as an array of numbers that may be manipulated to enhance the image (vary brightness and contrast, reduce noise, detect edges and use false colour)	Learners are not expected to carry out numerical manipulations in the examination; an understanding of the nature of the processes will be sufficient
	(iii)	digitising a signal (which may contain noise); advantages and disadvantages of digital signals	HSW12
	(iv)	evidence of the polarisation of electromagnetic waves.	

	Learning outcomes	Additional guidance
(b)	*Make appropriate use of:*	
	(i) the terms: pixel, bit, byte, focal length and power, magnification, resolution, sampling, signal, noise, polarisation	HSW8
	by sketching and interpreting:	
	(ii) diagrams of the passage of light through a converging lens	using both wave-fronts and rays
	(iii) diagrams of wave-forms.	
(c)	*Make calculations and estimates involving:*	
	(i) the amount of information in an image = no. of pixels × bits per pixel	
	(ii) power of a converging lens $P = 1/f$, as change of curvature of wave-fronts produced by the lens	HSW10
	(iii) use of $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$ (Cartesian convention)	restricted to thin converging lenses and real images; *M0.3, M1.1, M2.2, M2.4, M3.2*
	(iv) linear magnification $m = \frac{\text{image height}}{\text{object height}} = \frac{v}{u}$	
	(v) $v = f\lambda$ including the use of $f = 1/T$	
	(vi) number of bits, b, provides $N = 2^b$ alternatives; $b = \log_2 N$	*M0.5*
	(vii) minimum rate of sampling > 2 × maximum frequency of signal	*M2.1*
	(viii) rate of transmission of digital information = samples per second × bits per sample	
	(ix) the graphical representation of the digitisation of an analogue signal for a given number of levels of resolution	*M3.1*
	(x) use of $b = \log_2 \frac{V_{\text{total}}}{V_{\text{noise}}}$.	
(d)	*Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*	
	(i) determination of power or focal length of converging lenses using **3.1.1c(iii)**	links to **3.1.1c(ii)(iii)** **PAG6**
	(ii) observing polarising effects using microwaves and light.	links to **3.1.1a(iv)** **PAG6**

3.1.2 Sensing

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) current as the flow of charged particles	HSW1, 7
	(ii) potential difference as energy per unit charge	
	(iii) resistance and conductance, including series and parallel combinations	
	(iv) the effect of internal resistance and the meaning of e.m.f.	HSW9, 12
	(v) dissipation of power in electric circuits	HSW9, 10, 12
	(vi) the relationship between potential difference and current in ohmic resistors (Ohm's law)	
	(vii) the action of a potential divider	
	(viii) simple electrical behaviour of metals, semiconductors and insulators in terms of the number density of mobile charge carriers	
	(ix) conservation of charge and energy.	as represented by Kirchhoff's first and second law HSW1
(b)	*Make appropriate use of:*	
	(i) the terms: e.m.f, potential difference, current, charge, resistance, conductance, series, parallel, internal resistance, load, resistivity, conductivity, charge carrier number density	
	(ii) and recognise standard circuit symbols	
	by sketching and interpreting:	
	(iii) graphs of current against potential difference and graphs of resistance or conductance against temperature for ohmic and non-ohmic devices or components.	*M3.12* HSW11
(c)	*Make calculations and estimates involving:*	
	(i) $R = \frac{V}{I}$, $G = \frac{I}{V}$, $V = \frac{W}{Q} = \frac{P}{I}$, $P = IV = I^2R$, $W=VIt$, $V = \mathcal{E} - Ir_{\text{internal}}$	Learners will also be expected to recall the equations for R and G *M0.4, M0.1, M0.5, M1.1, M2.3* Epsilon is used as the symbol for e.m.f. to avoid confusion with E which is used for energy and electric field. The ASE guide 'Signs symbols and systematics' details E as the correct symbol for e.m.f. and this will be credited in all examinations.

(ii) $I = \dfrac{\Delta Q}{\Delta t}$,

$\dfrac{1}{G} = \dfrac{1}{G_1} + \dfrac{1}{G_2} + \ldots \quad G = G_1 + G_2 + \ldots$

$R = R_1 + R_2 + \ldots \quad \dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

(iii) $R = \dfrac{\rho L}{A}; G = \dfrac{\sigma A}{L}$ — *M1.4, M2.3, M4.3*

(iv) simple cases of a potential divider in a circuit using:

$V_{out} = \dfrac{R_2}{R_1 + R_2} \times V_{in}$ and $\dfrac{V_1}{V_2} = \dfrac{R_1}{R_2}$.

Learners will be expected to recall the proportionality of potential difference and resistance in a series circuit

(d) *Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*

(i) investigating electrical characteristics for a range of ohmic and non-ohmic components using voltmeters and ammeters	links to **3.1.2a(vi), b(iii)** **PAG3**
(ii) determining the resistivity or conductivity of a metal	links to **3.1.2c(iii)** **PAG3**
(iii) use of potential divider circuits, which may include sensors such as thermistor, LDR	links to **3.1.2a(vii)** **PAG4**
(iv) the calibration of a sensor or instrument	links to **3.1.2a(vii), c(iii)** **PAG3**
(v) determining the internal resistance of a chemical cell or other source of e.m.f.	links to **3.1.2a(iv)** **PAG3**

3.2 Mechanical properties of materials

This section is about materials and how their mechanical properties (and hence their applications) are related to their structures. The physics may be put into context through a study of materials in medicine and engineering. Human and cultural issues arise in considering the impact of materials on technology and society (HSW7, 9, 10, 11, 12).

It is not intended that learners acquire a detailed knowledge of a range of materials. Learners should have a reading comprehension of terms needed to understand accounts of structure, uses and properties of materials. Examples should include: a metal, a ceramic and a long-chain polymer. Learners should be given opportunities to discuss and share their understanding of the uses and properties of these materials (HSW8).

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		Learning outcomes	Additional guidance
(a)	*Describe and explain:*		
	(i)	simple mechanical behaviour: elastic and plastic deformation and fracture	
	(ii)	direct evidence of the size of particles and their spacing	Examples: Scanning Tunnelling Microscope images; Rayleigh's oil drop experiment HSW7, 11
	(iii)	behaviour/structure of classes of materials, limited to metals, ceramics and polymers; dislocations leading to slip in metals with brittle materials not having mobile dislocations; polymer behaviour in terms of chain entanglement/unravelling	HSW12
	(iv)	one method of measuring Young modulus and fracture stress.	*M1.2*
(b)	*Make appropriate use of:*		
	(i)	the terms: stress, strain, Young modulus, tension, compression, fracture stress and yield stress, stiff, elastic, plastic, ductile, hard, brittle, tough, strong, dislocation	HSW8
	by sketching and interpreting:		
	(ii)	force–extension and stress–strain graphs up to fracture	*M3.1, M3.2, M3.12*
	(iii)	tables and diagrams comparing materials by properties	*M3.1, M3.10*
	(iv)	images showing structures of materials.	HSW7, 11

(c) *Make calculations and estimates involving:*

(i) Hooke's Law, $F = kx$; energy stored in an elastic material (elastic strain energy) $= \frac{1}{2}kx^2$; energy as area under Force–extension graph for elastic materials	*M0.5, M2.2, M2.3, M3.8* (loading only)
(ii) stress $= \frac{\text{tension}}{\text{cross-sectional area}}$, strain $= \frac{\text{extension}}{\text{original length}}$, Young modulus $E = \frac{\text{stress}}{\text{strain}}$	*M0.3, M1.1, M1.4*

(d) *Demonstrate and apply knowledge and understanding of the following practical activities:*

(i) plotting force–extension characteristics for arrangements of springs, rubber bands, polythene strips, etc.	links to **3.2a(iii)**, **b(ii)**, **c(i)** HSW4 **PAG2**
(ii) determining Young modulus for a metal such as copper, steel or other wire.	links to **3.2a(iv)**, **c(ii)** **PAG2**

Module 4: Understanding processes

This module provides progression from the application-oriented work in Physics in Action. Understanding Processes is organised around different ways of describing and understanding processes of change: motion in space and time, wave motion, quantum behaviour. It provides a sound foundation in the classical physics of mechanics and waves and takes the story further, touching on the quantum probabilistic view.

Physical variables are extended from scalars to quantities that add like vectors.

Either section may be covered first. Some teachers may wish to introduce work on vector addition from **4.2** before embarking on work on combining phasors.

The first section of the module is mainly about superposition phenomena of waves with a brief account of the quantum behaviour of photons. This is a rich field for practical physics and learners will have many opportunities to extend their experimental and analytical skills. In addition, the topics provide a picture of the development of theories and understanding over time (HSW1, HSW2, HSW7). Quantum behaviour is discussed through considering possible photon paths, avoiding the wave/particle dichotomy.

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4.1 Waves and quantum behaviour

		Learning outcomes	Additional guidance
(a)		*Describe and explain:*	
	(i)	production of standing waves by waves travelling in opposite directions	Including graphical treatment HSW1, 2
	(ii)	interference of waves from two slits	
	(iii)	refraction of light at a plane boundary in terms of the changes in the speed of light and explanation in terms of the wave model of light	*M0.2*
	(iv)	diffraction of waves passing through a narrow aperture	HSW6
	(v)	diffraction by a grating	
	(vi)	evidence that photons exchange energy in quanta $E = hf$ (for example, one of light-emitting diodes, photoelectric effect and line spectra)	limitations of particle and wave models HSW7, 11 *M3.1, M3.2, M3.3, M3.4*
	(vii)	quantum behaviour: quanta have a certain probability of arrival; the probability is obtained by combining amplitude and phase for all possible paths	*M1.3*
	(viii)	evidence from electron diffraction that electrons show quantum behaviour.	HSW7, 11

(b)	*Make appropriate use of:*	
(i)	the terms: phase, phasor, amplitude, probability, interference, diffraction, superposition, coherence, path difference, intensity, electronvolt, refractive index, work function, threshold frequency.	
(c)	*Make calculations and estimates involving:*	
(i)	wavelength of standing waves	end corrections not required
(ii)	Snell's Law, $n = \frac{\sin i}{\sin r} = \frac{c_{\text{1st medium}}}{c_{\text{2nd medium}}}$	*M03, M0.6, M4.5*
(iii)	path differences for double slits and diffraction grating, for constructive interference $n\lambda = d \sin \theta$ (both limited to the case of a distant screen)	angles may be given in degrees or radians, the use of the small angle approximation is expected. *M0.6, M4.6, M4.7*
(iv)	the energy carried by photons across the spectrum, $E = hf$	*M0.2, M2.3*
(v)	the wavelength of a particle of momentum p, $\lambda = \frac{h}{p}$	As given by the de Broglie relationship *M0.2, M2.3*
(d)	*Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*	
(i)	using an oscilloscope to determine frequencies	links to **4.1a(i)** **PAG5**
(ii)	determining refractive index for a transparent block	links to **4.1c(ii)** **PAG6**
(iii)	superposition experiments using vibrating strings, sound waves, light and microwaves	links to **4.1a(i), b(i), c(i)** **PAG5**
(iv)	determining the wavelength of light with a double-slit and diffraction grating	links to **4.1a(ii), a(v), c(iii)** **PAG5**
(v)	determining the speed of sound in air by formation of stationary waves in a resonance tube	links to **4.1a(i), c(i)** **PAG5**
(vi)	determining the Planck constant using different coloured LEDs.	links to **4.1a(vi), c(iv)** **PAG6**

4.2 Space, time and motion

This section develops classical mechanics, including vectors. The conservation of momentum, the kinematics of uniformly accelerated motion and the dynamics of motion in two dimensions under a constant force are covered. IT skills may be developed through a variety of data capture techniques and simple mathematical modelling (HSW3).

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) the use of vectors to represent displacement, velocity and acceleration	
	(ii) the trajectory of a body moving under constant acceleration, in one or two dimensions	
	(iii) the independent effect of perpendicular components of a force	
	(iv) calculation of work done, including cases where the force is not parallel to the displacement	
	(v) the principle of conservation of energy	HSW1
	(vi) power as rate of transfer of energy	
	(vii) measurement of displacement, velocity and acceleration	
	(viii) Newton's laws of motion	HSW7
	(ix) The principle of conservation of momentum; Newton's Third Law as a consequence.	HSW2, 7
(b)	*Make appropriate use of:*	
	(i) the terms: displacement, speed, velocity, acceleration, force, mass, vector, scalar, work, energy, power, momentum, impulse	
	by sketching and interpreting:	
	(ii) graphs of accelerated motion; slope of displacement–time and velocity–time graphs; area underneath the line of a velocity–time graph	*M3.3, M3.4, M3.5, M3.6, M3.7, M3.12* HSW5
	(iii) graphical representation of addition of vectors and changes in vector magnitude and direction.	

(c) *Make calculations and estimates involving:*

(i)	the resolution of a vector into two components at right angles to each other	*M4.5*
(ii)	the addition of two vectors, graphically and algebraically	algebraic calculations restricted to two perpendicular vectors *M4.1, M4.2, M4.4*
(iii)	the kinematic equations for constant acceleration derivable from: $a = \frac{v - u}{t}$ and average velocity $= \frac{v + u}{2}$: $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$	*M2.2, M2.4*
(iv)	momentum $p = mv$	*M2.3*
(v)	the equation $F = ma = \frac{\Delta(mv)}{\Delta t}$ where the mass is constant	Learners will also be expected to recall the equation $F = ma$ *M2.1*
(vi)	the principle of conservation of momentum	one-dimensional problems only
(vii)	work done $\Delta E = F\Delta s$	If displacement is at an angle θ to the force $\Delta E = F\Delta \cos\theta$ *M2.1*
(viii)	kinetic energy $= \frac{1}{2}mv^2$	Learners will also be expected to recall this equation *M0.5*
(ix)	gravitational potential energy = mgh	Learners will also be expected to recall this equation *M2.3*
(x)	force, energy and power: power $= \frac{\Delta E}{t}$, power = Fv	*M2.3*
(xi)	modelling changes of displacement and velocity in small discrete time steps, using a computational model or graphical representation of displacement and velocity vectors.	calculations restricted to zero or constant resultant force *M3.9*

(d) *Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*

(i)	investigating the motion and collisions of objects using trolleys, air-track gliders etc. with data obtained from ticker timers, light gates, data-loggers and video techniques	links to **4.2a(vii), b(ii), c** **PAG1**
(ii)	determining the acceleration of free fall, using trapdoor and electromagnet arrangement, lightgates or video technique	links to **4.2a(vii), b(ii), c** **PAG1**
(iii)	investigating terminal velocity with experiments such as dropping a ball-bearing in a viscous liquid or dropping paper cones in air.	links to **4.2a(vii), b(ii), c** **PAG1**

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Module 5: Rise and fall of the clockwork universe

5.1 Models and rules

This module builds upon the work covered earlier in the course. The first section (**5.1.1**) uses simple techniques to model radioactive decay, capacitor charging and discharging and simple harmonic motion. In this framework, the formalism of the differential equation is developed along with the concept of field. There are many opportunities for practical work and empirical data can be compared and contrasted to the predictions made by the simple mathematical models. The field model is developed through consideration of gravitational fields.

The section raises questions about simplification in models, their usefulness and limitations (HSW7, HSW11). The difference can be highlighted between those models in which well-determined behaviour is due to exact rules operating on variables (as in the harmonic oscillator) and those in which well-determined behaviour is due to smooth averages over many particles (as in radioactive decay).

The second section (**5.1.2**) develops ideas about gravitational field strength and potential. Space flight and astronomical data can provide a context and there are further opportunities to consider the development of the modern view of the universe (HSW1, HSW6, HSW7, HSW11).

The third section (**5.1.3**) covers a descriptive and mainly qualitative outline of the main features of the observable universe consistent with the hot big bang model of its origin. The ideas of the universality of the speed of light and the relativistic consequence of time dilation are introduced.

5.1.1 Creating models

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) capacitance as the ratio $C = \dfrac{Q}{V}$	
	(ii) the energy on a capacitor $E = \frac{1}{2}QV$	HSW6
	(iii) the exponential form of the decay of charge on a capacitor as due to the rate of removal of charge being proportional to the charge remaining $\dfrac{dQ}{dt} = -\dfrac{Q}{RC}$	exponential relationship as shown, explained using constant ratio property *M3.9*
	(iv) the exponential form of radioactive decay as a random process with a fixed probability, the number of nuclei decaying being proportional to the number remaining $\dfrac{dN}{dt} = -\lambda N$	*M1.3*
	(v) simple harmonic motion of a mass with a restoring force proportional to displacement such that $\dfrac{d^2x}{dt^2} = -\dfrac{k}{m}x$	

(vi)	simple harmonic motion of a system where $a = -\omega^2 x$, where $\omega = 2\pi f$, and two possible solutions are $x = A\sin(\omega t)$ and $x = A\cos(\omega t)$	
(vii)	kinetic and potential energy changes in simple harmonic motion	example of conservation of energy HSW1
(viii)	free and forced vibrations, damping and resonance.	qualitative treatment only HSW9

(b) *Make appropriate use of:*

(i)	for a capacitor: the term: time constant τ	
(ii)	for radioactive decay: the terms: activity, decay constant λ, half-life $T_{\frac{1}{2}}$, probability, randomness	HSW8
(iii)	for oscillating systems: the terms: simple harmonic motion, period, frequency, free and forced oscillations, resonance, damping	HSW8

by expressing in words:

(iv)	relationships of the form $\frac{dx}{dt} = -kx$, where rate of change is proportional to amount present	Learners are expected to be able to transfer relationships from words, formulae and diagrams, converting from any one form to another

by sketching, plotting from data and interpreting:

(v)	exponential curves plotted with linear or logarithmic scales	Capacitor charging and discharging curves plotted against linear scales *M2.5, M3.10, M3.11, M3.12*
(vi)	energy of capacitor as area below a Q–V graph	*M3.8* HSW5
(vii)	x–t, v–t and a–t graphs of simple harmonic motion including their relative phases	*M3.12* HSW5
(viii)	amplitude of a resonator against driving frequency.	

(c) *Make calculations and estimates involving:*

(i)	calculating activity and half-life of a radioactive source from data, $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$	HSW10

(ii)	solving equations of the form $\frac{\Delta N}{\Delta t} = -\lambda N$ by iterative numerical or graphical methods	$N = N_0 e^{-\lambda t}$ as the analytic solution *M3.9* HSW3
(iii)	calculating time constant τ of a capacitor circuit from data; $\tau = RC; Q = Q_0 e^{-t/RC}$	*M0.5*
(iv)	solving equations of the form $\frac{\Delta Q}{\Delta t} = -\frac{Q}{RC}$ discharging $Q = Q_0\, e^{-t/RC}$; charging $Q = Q_0(1 - e^{-t/RC})$; corresponding equations for V and I	by iterative numerical/graphical methods *M0.5, M3.9*
(v)	$C = \frac{Q}{V}, I = \frac{\Delta Q}{\Delta t}, E = \frac{1}{2}QV = \frac{1}{2}CV^2$	*M2.3*
(vi)	$T = 2\pi\sqrt{\frac{m}{k}}$ with $f = 1/T$ for a mass oscillating on a spring	*M2.2*
(vii)	$T = 2\pi\sqrt{\frac{L}{g}}$ for a simple pendulum	*M2.2*
(viii)	$F = kx; E = \frac{1}{2}kx^2$	
(ix)	solving equations of the form $\frac{\Delta^2 x}{\Delta t^2} = -\frac{k}{m}x$ by iterative numerical or graphical methods	*M3.9*
(x)	$x = A\sin 2\pi ft$ or $x = A\cos 2\pi ft$	*M0.6, M4.5*
(xi)	$E_{total} = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$.	

(d) *Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*

(i)	measuring the period/frequency of simple harmonic oscillations for example mass on a spring or simple pendulum and relating this to parameters such as mass and length	links to **5.1.1a(v), (vi), (vii), b(iii), (iv), c(vi), (vii), (viii), (ix), (x), (xi)** **PAG10**
(ii)	qualitative observations of forced and damped oscillations for a range of systems	links to **5.1.1a(viii), b(iii)** **PAG10**
(iii)	investigating the charging and discharging of a capacitor using both meters and data loggers	links to **5.1.1a(iii), b(v), c(iii), c(iv)** **PAG9**
(iv)	determining the half-life of an isotope such as protactinium.	links to **5.1.1c(i)** **PAG7**

5.1.2 Out into space

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) changes of gravitational and kinetic energy	
	(ii) motion in a uniform gravitational field	
	(iii) the gravitational field and potential of a point mass	modelling the mass of a spherical object as a point mass at its centre
	(iv) angular velocity in rad s^{-1}	
	(v) motion in a horizontal circle and in a circular gravitational orbit.	
(b)	*Make appropriate use of:*	
	(i) the terms: force, kinetic and potential energy, gravitational field, gravitational potential, equipotential surface	HSW2, 8
	by sketching and interpreting:	
	(ii) graphs showing gravitational potential as area under a graph of gravitational field versus distance, graphs showing changes in gravitational potential energy as area under a graph of gravitational force versus distance between two distance values	*M3.8, M3.12* HSW5
	(iii) graphs showing force as related to the tangent of a graph of gravitational potential energy versus distance, graphs showing field strength as related to the tangent of a graph of gravitational potential versus distance	*M3.6* HSW5
	(iv) diagrams of gravitational fields and the corresponding equipotential surfaces.	
(c)	*Make calculations and estimates involving:*	
	(i) uniform gravitational field, gravitational potential energy change = *mgh*	Learners will also be expected to recall this equation
	(ii) energy exchange, work done, $\Delta E = F\Delta s$; no work done when the force is perpendicular to the displacement, resulting in no work being done whilst moving along equipotentials	*M2.1*
	(iii) $a = v^2/r$, $F = mv^2/r = mr\omega^2$	
	(iv) the radial components: $F_{grav} = -\frac{GmM}{r^2}$, $g = \frac{F_{grav}}{m} = -\frac{GM}{r^2}$	
	(v) gravitational potential energy $E_{grav} = -\frac{GMm}{r}$	
	(vi) gravitational potential $V_{grav} = \frac{E_{grav}}{m} = -\frac{GM}{r}$.	

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5.1.3 Our place in the universe

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) the use of radar-type measurements to determine distances within the solar system; how distance is measured and defined in units of time, assuming the relativistic principle of the invariance of the speed of light	HSW3, 11, 12
	(ii) effect of relativistic time dilation using the relativistic factor $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$	*M2.4*
	(iii) the measurement of relative velocities by radar observation	
	(iv) evidence for a 'hot big bang' origin of the universe from cosmological red-shifts (Hubble's law); cosmological microwave background.	HSW7,11 Development of the 'hot big bang' model
(b)	*Make appropriate use of, by sketching and interpreting:*	
	(i) logarithmic scales of magnitudes of quantities: distance, size, mass, energy, power, brightness.	*M2.5*
(c)	*Make calculations and estimates of:*	
	(i) distances and ages of astronomical objects	HSW7, 10
	(ii) distances and relative velocities from radar-type measurements.	HSW3

5.2 Matter

This part of the module considers how kinetic theory explains the behaviour of matter in probabilistic and mechanical terms. The beginnings of the basis of thermodynamic thinking appear in the study of the Boltzmann factor.

The first section (**5.2.1**) explains ideal gas behaviour in terms of the kinetic theory.

The second section (**5.2.2**) introduces the Boltzmann factor as the link between energy and temperature. The important idea that differences drive change is introduced here.

5.2.1 Matter: very simple

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) energy transfer producing a change in temperature and the concept of specific thermal capacity c	HSW1, 2, 8
	(ii) the behaviour of ideal gases	
	(iii) impulse $F\Delta t = \Delta p$	
	(iv) the kinetic theory of ideal gases	assumptions are that the particles (atoms or molecules) occupy negligible volume, that all collisions are perfectly elastic, and that there are negligible forces between particles except during collision HSW2
	(v) temperature as proportional to average energy per particle; average energy = 3/2 kT $\approx kT$ as a useful approximation	
	(vi) random walk of molecules in a gas: displacement in N steps related to $\sqrt{N}$.	
(b)	*Make appropriate use of:*	
	(i) the terms: ideal gas, root mean square speed, absolute temperature, internal energy, Avogadro constant, Boltzmann constant, gas constant, mole	
	by sketching and interpreting:	
	(ii) relationships between p, V, N and T for an ideal gas	*M3.12*
	(iii) force–time graph for an interaction with area under line representing the impulse.	

(c)	*Make calculations and estimates of:*		
	(i)	temperature and energy change using $\Delta E = mc\Delta\theta$	*M2.1* HSW5 **PAG11**
	(ii)	$pV = NkT$ where $N = nN_A$ and $Nk = nR$	number of moles n and Avogadro constant N_A
	(iii)	$pV = \frac{1}{3}Nm\overline{c^2}$	*M2.2* **PAG8**
(d)	*Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*		
	(i)	using an electrical method to find the specific thermal capacity of a metal block or liquid	links to **5.2.1a(i), c(i)** **PAG11**
	(ii)	using appropriate apparatus to investigate the gas laws including determining absolute zero	links to **5.2.1a(ii)** **PAG8**
	(iii)	using apparatus to investigate the relationship of volume with pressure, measured either by pressure gauge or differential pressure monitor and data logger.	links to **5.2.1b(ii)** **PAG8**

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5.2.2 Matter: hot or cold

		Learning outcomes	Additional guidance
(a)	*Describe and explain:*		
	(i)	ratios of numbers of particles in quantum states of different energy, at different temperatures (classical approximation only)	*M0.3*
	(ii)	qualitative effects of temperature in processes with an activation energy (for example, changes of state, thermionic emission, ionisation, conduction in semiconductors, viscous flow).	HSW7, 8
(b)	*Make appropriate use of, by sketching and interpreting:*		
	(i)	graphs showing the variation of the Boltzmann factor with energy and temperature.	*M3.12*
(c)	*Make calculations and estimates of:*		
	(i)	ratios of characteristic energies to the energy kT	*M0.3*
	(ii)	Boltzmann factor $e^{-\frac{E}{kT}}$.	links to **5.2.2a(i) and (ii)**

Module 6: Field and particle physics

This module introduces the modern picture of fields and particle interactions as fundamental mechanisms of nature.

6.1 Fields

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The idea of field has been met in the earlier module. The first section (**6.1.1**) treats the electromagnetic field in a practical context. The electric field, as the interaction between charges at rest, links back to the mathematically analogous model of the gravitational field. There are opportunities for discussing the social impact of the widespread distribution and use of electrical power and its influence on industrial societies. (HSW9, HSW12).

The second section (**6.1.2**) covers interactions between charged particles and ideas about electric field and potential.

6.1.1 Electromagnetism

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) the action of a transformer: magnetic flux from a coil; induced e.m.f = rate of change of flux linkage	HSW2
	(ii) the action of a dynamo: change of flux linked produced by relative motion of flux and conductor	
	(iii) electromagnetic forces; qualitatively as arising from tendency of flux lines to contract or interaction of induced poles; quantitative calculation limited to force on a straight current-carrying wire in a uniform field	
	(iv) simple linked electric and magnetic circuits: flux produced by current turns, need for large conductance and permeance and the effect of increasing the dimensions of an electromagnetic machine; qualitative effect of iron and air gap.	permeance is understood as a magnetic equivalent to electrical conductance and with analogous dependence on the dimensions and nature of the magnetic medium
(b)	*Make appropriate use of:*	
	(i) the terms: **B**-field, magnetic field, flux, flux linkage, induced e.m.f, eddy currents	
	by sketching and interpreting:	
	(ii) graphs of variations of currents, flux and induced e.m.f	
	(iii) diagrams of lines of flux in magnetic circuits; continuity of lines of flux.	

(c) *Make calculations and estimates involving:*

(i)	$\phi = BA, \mathcal{E} = -\frac{\mathrm{d}(\phi N)}{\mathrm{d}t}$	In the context of Faraday's and Lenz's laws HSW1, 2, 8
(ii)	$F = ILB$	Calculations restricted to current perpendicular to uniform magnetic field
(iii)	$\frac{V_1}{V_2} = \frac{N_1}{N_2}$ for an ideal transformer	i.e. no energy losses for an ideal transformer Learners will also be expected to recall the equation relating V and N
(iv)	$\frac{I_2}{I_1} = \frac{N_1}{N_2}$ for an ideal transformer	Learners will also be expected to recall the equation relating I and N HSW12

(d) *Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*

(i)	observing induced e.m.fs produced under varying conditions such as dropping a magnet through a coil attached to a data logger or oscilloscope	links to **6.1.1a(ii), 6.1.1c(i)**
(ii)	determining the uniform magnetic flux density between the poles of a magnet using a rigid current carrier and digital balance.	links to **6.1.1a(iii), c(ii)**
(iii)	investigate transformers.	links to **6.1.1a(i), c(iii)(iv)**

6.1.2 Charge and field

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
(i)	uniform electric field $E = V/d$	*M2.3*
(ii)	the electric field of a charged object, and the force on a charge in an electric field; inverse square law for point charge	Spherically symmetrical charged conductor is equivalent to a point charge at its centre
(iii)	electrical potential energy and electric potential due to a point charge; $1/r$ relationship	
(iv)	evidence for discreteness of charge on electron	Such as the Millikan oil drop experiment HSW2, 7, 11
(v)	the force on a moving charged particle due to a uniform magnetic field	
(vi)	similarities and differences between electric and gravitational fields.	HSW2, 8

(b) *Make appropriate use of:*

(i) the terms: charge, electric field, electric potential, equipotential surface, electronvolt

by sketching and interpreting:

(ii) graphs showing electric potential as area under a graph of electric field versus distance, graphs showing changes in electric potential energy as area under a graph of electric force versus distance between two distance values. *M3.8*

(iii) graphs showing force as related to the tangent of a graph of electric potential energy versus distance, graphs showing field strength as related to the tangent of a graph of electric potential versus distance *M3.8*

(iv) diagrams of electric fields and the corresponding equipotential surfaces.

(c) *Make calculations and estimates involving:*

(i) for radial components

$F_{electric} = \frac{kqQ}{r^2}$, $E_{electric} = \frac{F_{electric}}{q}$

$= \frac{kQ}{r^2}\left[k = \frac{1}{4\pi\varepsilon_0}\right]$

(ii) $E_{electric} = -\frac{\mathrm{d}V_{electric}}{\mathrm{d}r}$,

$E_{electric} = \frac{V}{d}$ (for a uniform field)

(iii) electrical potential energy $= \frac{kQq}{r}$,

$V_{electric} = \frac{kQ}{r}$

(iv) $F = qvB$. *M2.3*

2

6.2 Fundamental particles

The work here concerns the structure and binding of atoms and nuclei and the nature of fundamental particles. The practical implications of radioactivity are considered, introducing the idea of risk.

The first section (**6.2.1**) considers scattering experiments as a source of evidence about the structure of atoms and nucleons. Ideas from earlier in the module are used to consider particle paths in magnetic and electric fields in the context of particle accelerators. Evidence for discrete energy levels leads on to a crude model of the atom as a particle in a box. This section gives more opportunities to discuss the development of models in physics and the international cooperation needed to fund large experiments (HSW11).

The second section (**6.2.2**) sees changes in nuclear binding energy per nucleon as driving different types of decay. This leads to a consideration of nuclear power generation. The biological effects of ionising radiation are also considered, giving more opportunity to consider issues of ethics, decision making and the risks and benefits of technology (HSW9, HSW10, HSW12).

2

6.2.1 Probing deep into matter

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) use of particle accelerators to generate high-energy beams of particles for scattering	HSW7, 11
	(ii) evidence from scattering for a small massive nucleus within the atom	Development of the nuclear model HSW7, HSW11
	(iii) evidence of discrete energy levels in atoms	For example from collisions with electrons or from line spectra, HSW12
	(iv) a simple model of the atom as the quantum behaviour of electrons in a confined space	HSW7
	(v) simple picture of the quark structure of protons and neutrons	
	(vi) application of conservation of mass/energy, charge and lepton number in balanced nuclear equations	
	(vii) relativistic calculations for particles travelling at very high speed, for example in particle accelerators or cosmic rays.	
(b)	*Make appropriate use of:*	
	(i) the terms: energy level, scattering, nucleus, proton, neutron, nucleon, electron, positron, quark, gluon, neutrino, hadron, lepton, antiparticle, lepton number	HSW8
	by sketching and interpreting:	
	(ii) paths of scattered particles	
	(iii) electron standing waves in simple models of an atom.	

(c)	*Make calculations and estimates involving:*	
	(i) motion of a charged particle in magnetic field using $F = qvB$	*M2.3*
	(ii) kinetic and potential energy of a scattered charged particle	
	(iii) $E_{rest} = mc^2$ and relativistic factor	*M2.2* HSW11, 12
	(iv) $E_{total} = \gamma E_{rest}$.	

6.2.2 Ionising radiation and risk

	Learning outcomes	Additional guidance
(a)	*Describe and explain:*	
	(i) the nature and effects of ionising radiations: differences in ionising and penetrating power, effects on living tissue	
	(ii) the stability and decay of nuclei in terms of binding energy; transformation of nucleus on emission of radiation; qualitative variation of binding energy with proton and neutron number ("Nuclear Valley")	HSW2, 8
	(iii) nuclear fission; chain reaction; nuclear fusion; nuclear power generation.	Benefits and concerns over nuclear power HSW12
(b)	*Make appropriate use of:*	
	(i) the terms: nucleon number, proton number, isotope, binding energy, atomic mass unit, absorbed and effective dose, risk	
	by sketching and interpreting:	
	(ii) plots of binding energy per nucleon of nuclei against nucleon number.	
(c)	*Make calculations and estimates involving:*	
	(i) activity of a sample of radioactive material (related to half-life or decay constant)	
	(ii) absorbed dose in gray = energy deposited per unit mass	HSW9, 10
	(iii) effective dose in sievert = absorbed dose in gray × quality factor	HSW9, 10
	(iv) energy changes from nuclear transformations: $E_{rest} = mc^2$.	

(d)	*Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*	
	(i) studying the absorption of α-particles, β-particles and γ-rays by appropriate materials	Possible use of simulation software links to **6.2.2a(i)**
	(ii) determining the half-life of an isotope such as protactinium.	Possible use of simulation software links to **6.2.2c(i)**

2

2d. Prior knowledge, learning and progression

This specification has been developed for learners who wish to continue with a study of physics at Level 3. The A level specification has been written to provide progression from GCSE Science, GCSE Additional Science, GCSE Further Additional Science, GCSE Physics or from AS Level Physics. Learners who have successfully taken other Level 2 qualifications in Science or Applied Science with appropriate physics content may also have acquired sufficient knowledge and understanding to begin the A Level Physics course.

There is no formal requirement for prior knowledge of physics for entry onto this qualification. Other learners without formal qualifications may have acquired sufficient knowledge of physics to enable progression onto the course.

Some learners may wish to follow a physics course for only one year as an AS, in order to broaden their curriculum, and to develop their interest and understanding of different areas of the subject. Others may follow a co-teachable route, completing the one-year AS course and/or then moving to the two-year A level developing a deeper knowledge and understanding of physics and its applications.

The A Level Physics course will prepare learners for progression to undergraduate study, enabling them to enter a range of academic and vocational careers in mathematics-related courses, physical sciences, engineering, medicine, computing and related sectors. For learners wishing to follow an apprenticeship route or those seeking direct entry into physical science careers, this A level provides a strong background and progression pathway.

There are a number of Science specifications at OCR. Find out more at www.ocr.org.uk.

3 Assessment of OCR A Level in Physics B (Advancing Physics)

3a. Forms of assessment

All three externally assessed components (01–03) contain some synoptic assessment, some extended response questions and some stretch and challenge questions.

Stretch and challenge questions are designed to allow the most able learners the opportunity to demonstrate the full extent of their knowledge and skills.

Stretch and challenge questions will support the awarding of A* grade at A level, addressing the need for greater differentiation between the most able learners.

3

Fundamentals of physics (Component 01)

This component is worth 110 marks and assesses content from across all teaching modules. Learners answer all questions.

Section A contains multiple choice questions. This section of the paper is worth 30 marks.

Section B includes short answer question styles (structured questions, problem solving, calculations, practical). This section of the paper is worth approximately 20 marks.

Section C includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response question styles. This section of the paper is worth approximately 60 marks.

Scientific literacy in physics (Component 02)

This component is worth 100 marks and assesses content from across all teaching modules and places a particular emphasis on scientific literacy. Learners answer all questions. This component includes a pre-release Advance Notice article (see Section 5f).

Section A includes short answer question styles (structured questions, problem solving, calculations, practical). This section of the paper is worth approximately 30 marks.

Section B includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response question styles. This section of the paper is worth approximately 45 marks.

Section C includes short answer question styles and extended response question styles based on the Advance Notice article. This section of the paper is worth approximately 25 marks.

Practical skills in physics (Component 03)

This component is worth 60 marks and assesses content from across all teaching modules, placing a particular emphasis on practical skills. Learners answer all questions.

Section A includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response questions. This section is worth approximately 40 marks.

Section B takes the form of a longer structured question (practical, problem solving, calculations, extended response) focusing on data analysis. This section is worth approximately 20 marks.

Practical Endorsement in physics (Component 04)

Performance in this component is reported separately to the performance in the A level as measured through externally assessed components 01 to 03. This non-exam assessment component rewards the development of practical competency in physics and is teacher assessed. Learners demonstrate competence in the range of skills and techniques specified in Section 1.2 of the specification by carrying out a minimum of 12 assessed practical activities. The Practical Endorsement is teacher assessed against the Common Practical Assessment Criteria as specified in Section 5h.

Learners may work in groups but must demonstrate and record independent evidence of their competency. Teachers who award a pass to their learners must be confident that each learner consistently and routinely exhibits the competencies listed in Section 5 and has demonstrated competence in all the skills detailed in Section 1.2.1 and all the apparatus and techniques detailed in Section 1.2.2 before completion of the A level course. The practical activities provided by OCR are all mapped against the specification and assessment criteria.

3b. Assessment objectives (AO)

There are three assessment objectives in OCR's A Level in Physics B (Advancing Physics). These are detailed in the table below.

Learners are expected to demonstrate their ability to:

	Assessment Objective
AO1	Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures.
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.
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.

AO weightings in A Level in Physics B

The relationship between the assessment objectives and the components are shown in the following table:

Component	% of A level Physics B (H557)		
	AO1	AO2	AO3
Fundamentals of physics (H557/01)	15–17	16–17	8–9
Scientific literacy in physics (H557/02)	11–12	15–17	10–11
Practical skills in physics (H557/03)	4–6	9–10	7–8
Practical Endorsement in physics (H557/04)*	N/A	N/A	N/A
Total	**30–35**	**40–44**	**25–28**

* The Practical Endorsement is assessed and reported separately from the overall A level grade (see Section 5h).

3

3c. Total qualification time

Total qualification time (TQT) is the total amount of time, in hours, expected to be spent by a learner to achieve a qualification. It includes both guided learning hours and hours spent in preparation, study, and assessment. The total qualification time for A Level Physics B is 360 hours. The total guided learning time is 360 hours.

3d. Qualification availability outside of England

This qualification is available in England. For Wales and Northern Ireland please check the Qualifications in Wales Portal (QIW) or the Northern Ireland Department of Education Performance Measures / Northern Ireland Entitlement Framework Qualifications Accreditation Number (NIEFQAN) list to see current availability.

3e. Language

This qualification is available in English only. All assessment materials are available in English only and all candidate work must be in English.

3f. Assessment availability

There will be one examination series available each year in May/June for **all** learners.

All examined components must be taken in the same examination series at the end of the course.

This specification will be certificated from the June 2017 examination series onwards.

3g. Retaking the qualification

Learners can retake the qualification as many times as they wish. Learners must retake all examined components but they can choose to either retake the Practical Endorsement or carry forward their most recent result (see Section 4d).

Candidates can choose either to retake the Practical Endorsement or to carry forward their result for the Practical Endorsement by using the carry forward entry option (see Section 4a). The result for the Practical Endorsement may be carried forward for the lifetime of the specification.

A candidate who is retaking A Level Physics B (Advancing Physics) may re-use a previous result for the Practical Endorsement, even if it was awarded by another awarding organisation or if it was awarded for an alternative suite [e.g. a Practical Endorsement pass result from A Level Physics B (Advancing Physics) could be re-used for retaking A Level Physics A].

3h. Assessment of extended responses

The assessment materials for this qualification provide learners with the opportunity to demonstrate their ability to construct and develop a sustained and coherent line of reasoning and the marks for extended responses are integrated into the marking criteria.

3i. Synoptic assessment

Synoptic assessment tests the learners' understanding of the connections between different elements of the subject.

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the A level course. The emphasis of synoptic assessment is to encourage the development of the understanding of the subject as a discipline. All components within Physics B (Advancing Physics) contain an element of synoptic assessment.

Synoptic assessment requires learners to make and use connections within and between different areas of physics, for example, by:

- applying knowledge and understanding of more than one area to a particular situation or context
- using knowledge and understanding of principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

3j. Calculating qualification results

A learner's overall qualification grade for A Level in Physics B will be calculated by adding together their marks from the three examined components taken to give their total weighted mark.

This mark will then be compared to the qualification level grade boundaries for the entry option taken by the learner and for the relevant exam series to determine the learner's overall qualification grade.

A learner's result for their Practical Endorsement in physics component will not contribute to their overall qualification grade.

4 Admin: what you need to know

The information in this section is designed to give an overview of the processes involved in administering this qualification so that you can speak to your exams officer. All of the following processes require you to submit something to OCR by a specific deadline.

More information about the processes and deadlines involved at each stage of the assessment cycle can be found in the Administration area of the OCR website.

OCR's *Admin overview* is available on the OCR website at http://www.ocr.org.uk/administration.

4a. Pre-assessment

Estimated entries

Estimated entries are your best projection of the number of learners who will be entered for a qualification in a particular series. Estimated entries should be submitted to OCR by the specified deadline. These do not incur a cost and do not commit your centre in any way.

Updated arrangements for monitoring the Practical Endorsement

Full details on the monitoring and the implementation of the practical endorsement are available on the Positive about Practical pages at https://www.ocr.org.uk/subjects/science/positive-about-practical. Lead teachers are required to have undertaken the free online training for A level science teachers, available here: https://practicalendorsement.ocr.org.uk/login/index.php. The lead teacher should also ensure that all other teachers of that science within the centre are familiar with the requirements so that standards are applied consistently.

The awarding organisations (AOs) use information from centre entries for the A levels in biology, chemistry and physics from the previous summer examination series to jointly plan monitoring visits for the current two-year cycle and the subsequent cycles. Most centres will be monitored for a different science than that which was monitored in the previous monitoring cycle. Large centres will continue to be monitored for biology, chemistry and physics in each cycle. The first contact with a centre will be from the AO with which the science to be monitored was entered in the prior summer series. This first contact will be with the exams officer (or other nominated school contact).

It is the responsibility of a centre that is new, or is switching exam boards, or that only offers one or two science A levels to let AOs know, so that appropriate monitoring can be scheduled.

Final entries

Final entries provide OCR with detailed data for each learner, showing each assessment to be taken. It is essential that you use the correct entry code, considering the relevant entry rules.

Final entries must be submitted to OCR by the published deadlines or late entry fees will apply.

All learners taking A Level in Physics B must be entered for one of the entry options shown on the following table:

Entry option		Component		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
H557	Physics B (Advancing Physics)	01	Fundamentals of physics	External assessment
		02	Scientific literacy in physics	External assessment
		03	Practical skills in physics	External assessment
		04	Practical Endorsement in physics	Non-exam assessment (Visiting monitoring)
H557C	Physics B (Advancing Physics)	01	Fundamentals of physics	External assessment
		02	Scientific literacy in physics	External assessment
		03	Practical skills in physics	External assessment
		80	Practical Endorsement in physics – Carried Forward*	Non-exam assessment (Carried Forward)

*The carry forward option will be available for the first time from June 2018.

Private candidates

Private candidates may enter for OCR assessments.

A private candidate is someone who pursues a course of study independently but takes an examination or assessment at an approved examination centre. A private candidate may be a part-time student, someone taking a distance learning course, or someone being tutored privately. They must be based in the UK.

The A Level Physics B (Advancing Physics) qualification requires learners to complete a Practical Endorsement incorporating a minimum of 12 practical activities, allowing them to demonstrate a range of practical skills, use of apparatus and techniques to fulfil the Common Practical Assessment Criteria.

The Practical Endorsement is an essential part of the course and will allow learners to develop skills for further study or employment, as well as imparting important knowledge that is part of the specification.

Private candidates need to contact OCR approved centres to establish whether they are prepared to host them as a private candidate. The centre may charge for this facility and OCR recommends that the arrangement is made early in the course.

Further guidance for private candidates may be found on the OCR website: http://www.ocr.org.uk

Head of Centre Annual Declaration

The practical science statement is contained within the NEA Centre Declaration form which can be found on the OCR website at www.ocr.org.uk/formsfinder. By signing the form, the centre is confirming that they are meeting all the requirements detailed in the specification, including that they have provided all candidates the opportunity to undertake the prescribed practical activities.

Please see the JCQ publication *Instructions for conducting non-examination assessments* for further information.

Any failure by a centre to provide a practical science statement to OCR in a timely manner (by means of an NEA Centre Declaration form) will be treated as malpractice and/or maladministration [under General Condition A8 (*Malpractice and maladministration*)].

NEA Centre Declaration Form: Practical Science Statement

Centres must provide a written **practical science statement** confirming that reasonable opportunities have been provided to all learners being submitted for entry for assessment to undertake at least **twelve** appropriate practical activities.

The practical science statement is contained within the NEA Centre Declaration Form, this form can be found on the OCR website at www.ocr.org.uk/formsfinder.

By signing the form, the centre is confirming that:

(a) At least twelve practical activities have been completed by each candidate enabling them to demonstrate competence in all skills, apparatus and techniques as specified in OCR's A Level science specifications.

(b) Whilst undertaking the practical activities, all candidates have written and retained a record of their work.

Centres should have records confirming points (a) to (b) above available as they may be requested as part of the monitoring process.

Any failure by a centre to provide a practical science statement to OCR in a timely manner (by means of an NEA Centre Declaration Form) will be treated as malpractice and/or maladministration [under General Condition A8 (*Malpractice and maladministration*)].

Collecting evidence of student performance to ensure resilience in the qualifications system

Regulators have published guidance on collecting evidence of student performance as part of long-term contingency arrangements to improve the resilience of the qualifications system. You should review and consider this guidance when delivering this qualification to students at your centre.

For more detailed information on collecting evidence of student performance please visit our website at: https://www.ocr.org.uk/administration/general-qualifications/assessment/

4b. Accessibility and special consideration

Reasonable adjustments and access arrangements allow learners with special educational needs, disabilities or temporary injuries to access the assessment and show what they know and can do, without changing the demands of the assessment.

Applications for these should be made before the examination series. Detailed information about eligibility for access arrangements can be found in the JCQ *Access Arrangements and Reasonable Adjustments.*

Special consideration is a post-assessment adjustment to marks or grades to reflect temporary injury, illness or other indisposition at the time the assessment was taken. Detailed information about eligibility for special consideration can be found in the JCQ *A guide to the special consideration process* and JCQ *Reasonable Adjustments for GCE A-level sciences – Endorsement of practical skills.*

4c. External assessment arrangements

Regulations governing examination arrangements are contained in the JCQ publication *Instructions for conducting examinations*.

Learners are permitted to use a scientific or graphical calculator for components 01, 02 and 03. Calculators are subject to the rules in the document *Instructions for Conducting Examinations* published annually by JCQ (www.jcq.org.uk).

4d. Admin of non-exam assessment

Regulations governing arrangements for internal assessments are contained in the JCQ *Instructions for conducting non-examination assessments*. Appendix 1 of this document gives specific details for the Practical Skills Endorsement for A Level sciences designed for use in England.

OCR's *Admin overview* is available on the OCR website at http://www.ocr.org.uk/administration.

Carrying forward the Practical Endorsement in Physics

4

Learners who are retaking the qualification can choose to either retake the endorsement or carry forward their most recent result for that component (even if it was awarded by another awarding organisation or if it was awarded for an alternative suite).

To carry forward the result, you must use the carry forward entry option (see table in Section 4a).

Learners must decide at the point of entry whether they are going to carry forward the endorsement or not.

The result for the endorsement may be carried forward for the lifetime of the specification and there is no restriction on the number of times the result may be carried forward. However, only the most recent non-absent result may be carried forward.

4e. Results and certificates

Grade scale

A level qualifications are graded on the scale: A*, A, B, C, D, E, where A* is the highest. Learners who fail to reach the minimum standard for E will be Unclassified (U). Only subjects in which grades A* to E are attained will be recorded on certificates.

Results for the A Level Sciences Practical Endorsements will be shown independently of the qualification grade on the certificate. Candidates who fulfil the requirements and reach the minimum standard will be awarded a Pass grade. Candidates who fail to reach the minimum standard will be recorded as 'Not Classified' and this will also be reported on the certificate.

Results

Results are released to centres and learners for information and to allow any queries to be resolved **before** certificates are issued.

Centres will have access to the following results information for each learner:

- the grade for the qualification
- the raw mark for each component
- the total weighted mark for the qualification.

The following supporting information will be available:

- raw mark grade boundaries for each component
- weighted mark grade boundaries for each entry option.

Until certificates are issued, results are deemed to be provisional and may be subject to amendment. A learner's final results will be recorded on an OCR certificate.

The qualification title will be shown on the certificate as 'OCR Level 3 Advanced GCE in Physics B (Advancing Physics)'.

4f. Post-results services

A number of post-results services are available:

- **Review of results** – If you are not happy with the outcome of a learner's results, centres may request a review of marking.
- **Missing and incomplete results** – This service should be used if an individual subject result for a learner is missing, or the learner has been omitted entirely from the results supplied.
- **Access to scripts** – Centres can request access to marked scripts.
- **Practical Endorsement** – Since monitoring and any potential request for further visits take place throughout the period of the qualification, there is no post-results service provided.

4g. Malpractice

Any breach of the regulations for the conduct of examinations and coursework may constitute malpractice (which includes maladministration) and must be reported to OCR as soon as it is detected.

Detailed information on malpractice can be found in the *Suspected Malpractice in Examinations and Assessments: Policies and Procedures* published by JCQ.

5 Appendices

5a. Overlap with other qualifications

There is a small degree of overlap between the content of this specification and those for other AS level/A level Sciences.

Examples of overlap include:

Geology

- Half-life.

Chemistry

- Atomic structure.

Science

- Atomic structure.
- Electromagnetic spectrum.

5b. Avoidance of bias

The A level qualification and subject criteria have been reviewed in order to identify any feature which could disadvantage learners who share a protected characteristic as defined by the Equality Act 2010. All reasonable steps have been taken to minimise any such disadvantage.

5c. Physics B data sheet

Data, Formulae and Relationships

The data, formulae and relationships in this data sheet will be printed for distribution with the examination papers.

Data

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

Physical constants

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

Other data

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

Conversion factors

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

5

Mathematical constants and equations

e = 2.72 π = 3.14 1 radian = 57.3°

arc = $r\theta$

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

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

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

circumference of circle = $2\pi r$

area of circle = πr^2

surface area of cylinder = $2\pi rh$

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

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

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

Prefixes

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

Formulae and relationships

Imaging and signalling

focal length	$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$
linear magnification	$m = \frac{v}{u}$
refractive index	$n = \frac{\sin i}{\sin r} = \frac{c_{\text{1st medium}}}{c_{\text{2nd medium}}}$
noise limitation on maximum bits per sample	$b = \log_2\left(\frac{V_{\text{total}}}{V_{\text{noise}}}\right)$
alternatives, N, provided by b bits	$N = 2^b$, $b = \log_2 N$

Electricity

current	$I = \frac{\Delta Q}{\Delta t}$
potential difference	$V = \frac{W}{Q}$
power and energy	$P = IV = I^2R$, $W = VIt$
e.m.f and potential difference	$V_{\text{load}} = \mathcal{E} - Ir$
conductors in series and parallel	$\frac{1}{G} = \frac{1}{G_1} + \frac{1}{G_2} + \ldots$ $\quad G = G_1 + G_2 + \ldots$
resistors in series and parallel	$R = R_1 + R_2 + \ldots$ $\quad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
potential divider	$V_{\text{out}} = \frac{R_2}{R_1 + R_2} V_{\text{in}}$
conductivity and resistivity	$G = \frac{\sigma A}{L}$ $\quad R = \frac{\rho L}{A}$
capacitance	$C = \frac{Q}{V}$
energy stored in a capacitor	$E = \frac{1}{2}QV = \frac{1}{2}CV^2$
discharge of capacitor	$\frac{dQ}{dt} = -\frac{Q}{RC}$ $\quad Q = Q_0 e^{-t/RC}$ $\quad \tau = RC$

Materials

Hooke's law — $F = kx$

elastic strain energy — $\frac{1}{2}kx^2$

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

$\text{stress} = \frac{\text{tension}}{\text{cross-sectional area}}, \ \text{strain} = \frac{\text{extension}}{\text{original length}}$

Gases

kinetic theory of gases — $pV = \frac{1}{3}Nm\overline{c^2}$

ideal gas equation — $pV = nRT = NkT$

Motion and forces

momentum — $p = mv$

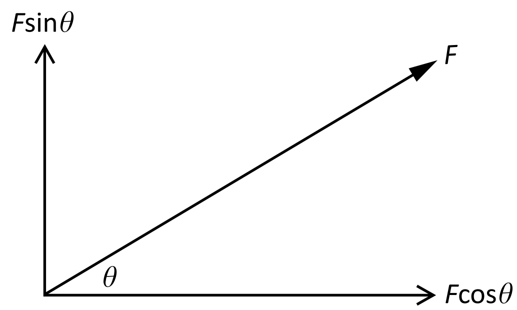
impulse — $F\Delta t$

force — $F = \frac{\Delta(mv)}{\Delta t}$

work done — $W = Fx \quad \Delta E = F\Delta s$

power — $P = Fv, \ P = \frac{\Delta E}{t}$

components of a vector in two perpendicular directions



equations for uniformly accelerated motion

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

$v = u + at$

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

for circular motion — $a = \frac{v^2}{r}, \ F = \frac{mv^2}{r} = mr\omega^2$

Energy and thermal effects

energy — $\Delta E = mc\Delta\theta$

average energy approximation — average energy ~ kT

Boltzmann factor	$e^{-\frac{E}{kT}}$
Waves	
wave formula	$v = f\lambda$
frequency and period	$f = \frac{1}{T}$
diffraction grating	$n\lambda = d \sin \theta$
Oscillations	
simple harmonic motion	$\frac{\mathrm{d}^2 x}{\mathrm{d}t^2} = a = -\left(\frac{k}{m}\right)x = -\omega^2 x$
	$x = A \cos(\omega t)$
	$x = A \sin(\omega t)$
	$\omega = 2\pi f$
periodic time	$T = 2\pi\sqrt{\frac{m}{k}}$
	$T = 2\pi\sqrt{\frac{L}{g}}$
total energy	$E = \frac{1}{2}kA^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$
Atomic and nuclear physics	
radioactive decay	$\frac{\Delta N}{\Delta t} = -\lambda N$ $N = N_0 e^{-\lambda t}$
half life	$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$
radioactive dose and risk	absorbed dose = energy deposited per unit mass effective dose = absorbed dose × quality factor risk = probability × consequence
mass–energy relationship	$E_{\text{rest}} = mc^2$
relativistic factor	$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$
relativistic energy	$E_{\text{total}} = \gamma E_{\text{rest}}$
energy–frequency relationship for photons	$E = hf$

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de Broglie $\lambda = \frac{h}{p}$

Field and potential

for all fields field strength $= -\frac{\mathrm{d}V}{\mathrm{d}r} \approx -\frac{\Delta V}{\Delta r}$

gravitational fields $g = \frac{F}{m}$, $E_{\text{grav}} = -\frac{GmM}{r}$

$V_{\text{grav}} = -\frac{GM}{r}$, $F = -\frac{GmM}{r^2}$

electric fields $E = \frac{F}{q} = \frac{V}{d}$, electrical potential energy = $\frac{kQq}{r}$

$V_{\text{elec}} = \frac{kQ}{r}$, $F = \frac{kQq}{r^2}$

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Electromagnetism

magnetic flux $\phi = BA$

force on a current carrying conductor $F = ILB$

force on a moving charge $F = qvB$

induced e.m.f $\mathcal{E} = -\frac{\mathrm{d}(N\phi)}{\mathrm{d}t}$

Symbols and units used in question papers

The following list illustrates the symbols and units which are used in the A level question papers.

Quantity	Usual symbol	Usual unit
mass	m	kg
length	L or l	m
time	t	s
electric current	I	A
thermodynamic temperature	T	K
amount of substance	n	mol
distance	d	m
displacement	x or s	m
area	A	m^2
volume	V	m^3
density	ρ	kg m^{-3}
speed	u, v, c	m s^{-1}
velocity	u, v, c	m s^{-1}
acceleration	a	m s^{-2}
acceleration of free fall	g	m s^{-2}
force	F	N
momentum	p	N s
work	W	J
energy	W, E	J
potential energy	E_P	J
kinetic energy	E_K	J
energy transferred thermally (heating)	Q	J
power	P	W
pressure	p	Pa
gravitational constant	G	N kg^{-2} m^2
gravitational field strength	g	N kg^{-1}
angle	θ	°, rad

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Quantity	Usual symbol	Usual unit
angular displacement	θ	°, rad
angular velocity	ω	rad s^{-1}
period	T	s
frequency	f	Hz
angular frequency	ω	rad s^{-1}
wavelength	λ	m
speed of electromagnetic waves	c	m s^{-1}
electric charge	Q, q	C
elementary charge	e	C
electric potential	V	V
electric potential difference	V	V
electromotive force (e.m.f)	$\mathcal{E}$, E	V
resistance	R	Ω
conductance	G	S
resistivity	ρ	Ω m
conductivity	σ	S m^{-1}
electric field strength	E	N C^{-1}, V m^{-1}
permittivity of free space	ε_0	F m^{-1}
capacitance	C	F
time constant	τ	s
magnetic flux	Φ	Wb
magnetic flux density	B	T
permeability of free space	μ_0	H m^{-1}
stress		Pa
strain		fraction or percent
spring constant	k	N m^{-1}
Young modulus	E	Pa
Celsius temperature	θ	°C
specific heat capacity	c	J kg^{-1} K^{-1}

Quantity	Usual symbol	Usual unit
specific latent heat	L	J kg^{-1}
molar gas constant	R	J K^{-1} mol^{-1}
Boltzmann constant	k	J K^{-1}
Avogadro constant	L, N_A	mol^{-1}
number	N, n	
number density (number per unit volume)	n	m^{-3}
Planck constant	h	J s
work function energy	W	J, eV
activity of radioactive source	A	Bq
decay constant	λ	s^{-1}
half-life	$T_{\frac{1}{2}}$	s
atomic mass	m_{a}	kg, u
electron mass	m_{e}	kg, u
neutron mass	m_{n}	kg, u
proton mass	m_{p}	kg, u
proton number	Z	
nucleon number	A	
neutron number	N	

5d. How Science Works (HSW)

Incorporating Section 8 (the skills, knowledge and understanding of *How Science Works*) of the DfE criteria for science into the specification.

How Science Works (HSW) was conceived as being a wider view of science in context, rather than just straightforward scientific enquiry. It was intended to develop learners as critical and creative thinkers, able to solve problems in a variety of contexts.

Developing ideas and theories to explain the operation of the entirety of our existence, from the sub-atomic particles to the Universe, is the basis of Physics. How Science Works develops the critical analysis and linking of evidence to support or refute ideas and theories. Learners should be aware of the importance that peer review and repeatability have in giving confidence to this evidence.

Learners are expected to understand the variety of sources of data available for critical analysis to provide evidence and the uncertainty involved in its measurement. They should also be able to link that evidence to contexts influenced by culture, politics and ethics.

Understanding How Science Works requires an understanding of how scientific evidence can influence ideas and decisions for individuals and society, which is linked to the necessary skills of communication for audience and for purpose with appropriate scientific terminology.

The examples and guidance within the specification are not exhaustive but give a flavour of opportunities for integrating HSW within the course. These references, written in the form HSW1, link to the statements as detailed below:

- **HSW1** Use theories, models and ideas to develop scientific explanations
- **HSW2** Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas
- **HSW3** Use appropriate methodology, including information and communication technology (ICT), to answer scientific questions and solve scientific problems
- **HSW4** Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts
- **HSW5** Analyse and interpret data to provide evidence, recognising correlations and causal relationships
- **HSW6** Evaluate methodology, evidence and data, and resolve conflicting evidence
- **HSW7** Know that scientific knowledge and understanding develops over time
- **HSW8** Communicate information and ideas in appropriate ways using appropriate terminology
- **HSW9** Consider applications and implications of science and evaluate their associated benefits and risks
- **HSW10** Consider ethical issues in the treatment of humans, other organisms and the environment
- **HSW11** Evaluate the role of the scientific community in validating new knowledge and ensuring integrity
- **HSW12** Evaluate the ways in which society uses science to inform decision making.

5e. Mathematical requirements

In order to be able to develop their skills, knowledge and understanding in A Level Physics, learners 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 40% Level 2 (or above) mathematical skills for physics (see later for a definition of Level 2 mathematics).

These skills will be applied in the context of the relevant physics.

All mathematical content will be assessed within the lifetime of the specification. Skills shown in **bold** type will only be tested in the full A level course, not the standalone AS level course.

This list of examples is not exhaustive and is not limited to Level 2 examples. These skills could be developed in other areas of specification content from those indicated.

	Mathematical skill to be assessed	**Exemplification of the mathematical skill in the context of A Level Physics (assessment is not limited to the examples below)**	**Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)**
M0 – Arithmetic and numerical computation			
M0.1	Recognise and make use of appropriate units in calculations	Learners 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.	1.1.2(b), 2 (b)(i), 3.1.2 (c)(i)
M0.2	Recognise and use expressions in decimal and standard form	Learners may be tested on their ability to: • use physical constants expressed in standard form such as $c = 3.00 \times 10^8 \text{ m s}^{-1}$.	1.1.3(c), 4.1(a)(iii), 4.1(c)(iv), 4.1(c)(v)
M0.3	Use ratios, fractions and percentages	Learners may be tested on their ability to: • calculate efficiency of devices; • calculate percentage uncertainties in measurements.	2(c)(i), 3.1.1(c)(iii), 3.2(c)(ii), 5.2.2(a)(i), 5.2.2(c)(i)

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	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Physics (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M0.4	Estimate results	Learners may be tested on their ability to: • estimate the effect of changing experimental parameters on measurable values.	1.1.1(b), 1.1.3(a), 3.1.2(c)(i)
M0.5	Use calculators to find and use power functions **exponential and logarithmic functions**	Learners may be tested on their ability to: • **solve for unknowns in decay problems such as** $\boldsymbol{N = N_0 e^{-\lambda t}}$.	3.1.1(c)(vi), 3.1.2(c)(i), 3.2(c)(i), 3.2(c)(ii), 4.2(c)(viii), 5.1.1(c)(iii)
M0.6	Use calculators to handle sin *x,* cos *x* and tan *x* when *x* is expressed in degrees or radians	Learners may be tested on their ability to: • calculate the direction of resultant vectors.	2(b)(i), 4.1(c)(ii), 4.1(c)(iii), 5.1.1(c)(x)
M1 – Handling data			
M1.1	Use an appropriate number of significant figures	Learners 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 only be reported to the limits of the least accurate measurement.	3.1.1(c)(iii), 3.1.2(c)(i), 3.2(c)(ii)
M1.2	Find arithmetic means	Learners may be tested on their ability to: • calculate a mean value for repeated experimental readings.	1.1.3(c), 2(c)(i), 3.2(a)(iv)
M1.3	Understand simple probability	Learners may be tested on their ability to: • understand probability in the context of radioactive decay.	4.1(a)(vii), 5.1(a)(iv)

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	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Physics (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M1.4	Make order of magnitude calculations	Learners may be tested on their ability to: • evaluate equations with variables expressed in different orders of magnitude.	3.1.2(c)(iii), 3.2(c)(ii)
M1.5	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers	Learners may be tested on their ability to: • determine the uncertainty where two readings for length need to be added together.	1.1.4(d), 2(c)(ii)
M2 – Algebra			
M2.1	Understand and use the symbols: $=, <, \ll, \gg, >, \propto, \approx, \Delta$	Learners may be tested on their ability to: • recognise the significance of the symbols in the expression $F \propto \Delta p/\Delta t$.	3.1.1(c)(vii), 4.2(c)(v), 4.2(c)(vi), 5.1.2 (c)(ii), 5.2.1(c)(i)
M2.2	Change the subject of an equation, including non-linear equations	Learners may be tested on their ability to: • rearrange $E = mc^2$ to make *m* the subject.	3.1.1(c)(iii), 3.2(c)(i), 4.2(c)(iii), 5.1.1(c)(vi), 5.1.1 (c)(vii), 6.2.1(c)(iii)
M2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Learners 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 $p = mv$.	3.1.1(c)(iii), 3.1.2(c)(i), 3.2(c)(i), 4.1(c)(iv), 4.1(c)(v), 4,2(c)(iv), 4.2(c)(ix) 5.1.1(c)(v), 6.1.2(a)(i), 6.1.2(c)(iv), 6.2.1(c)(i)
M2.4	Solve algebraic equations, including quadratic equations	Learners may be tested on their ability to: • solve kinematic equations for constant acceleration such as $v = u + at$ and $s = ut + \frac{1}{2}at^2$.	3.1.1(c)(iii), 3.1.2(c)(iii), 4.2(c)(iii) 5.1.3(a)(ii)

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Physics (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	**Learners may be tested on their ability to:** • **recognise and interpret real world examples of logarithmic scales.**	**5.1.1(b)(v), 5.1.3(b)(i)**
M3 – Graphs			
M3.1	Translate information between graphical, numerical and algebraic forms	Learners may be tested on their ability to: • calculate Young modulus for materials using stress–strain graphs.	1.1.3(d), 3.1.1(c)(ix), 3.2(b)(ii), 4.1(a)(vi)
M3.2	Plot two variables from experimental or other data	Learners may be tested on their ability to: • plot graphs of extension of a wire against force applied.	1.1.3(d), 3.1.1(c)(iii), 3.2(b)(ii), 4.1(a)(vi)
M3.3	Understand that $y = mx + c$ represents a linear relationship	Learners may be tested on their ability to: • rearrange and compare $v = u + at$ with $y = mx + c$ for velocity–time graphs in constant acceleration problems.	1.1.3(d), 4.2(b)(ii), 4.1(a)(vi)
M3.4	Determine the slope and intercept of a linear graph	Learners 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.	1.1.3(d), 4.1(a)(vi), 4.2(b)(ii)
M3.5	Calculate rate of change from a graph showing a linear relationship	Learners may be tested on their ability to: • calculate acceleration from a linear velocity–time graph.	4.2(b)(ii)
M3.6	Draw and use the slope of a tangent to a curve as a measure of rate of change	Learners 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.	4.2(b)(ii), 5.1.2(b)(iii)

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Physics (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M3.7	Distinguish between instantaneous rate of change and average rate of change	Learners 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.	4.2(b)(ii)
M3.8	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	Learners 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.	3.2(c)(i), 5.1.1(b)(vi), 5.1.2(b)(ii), 6.1.2(b)(i), 6.1.2(b)(ii)
M3.9	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	Learners may be tested on their ability to: • determine *g* from distance–time plot, projectile motion. •	4.2(c)(xi), 5.1.1(a)(iii), 5.1.1(c)(ii), 5.1.1(c)(iv), 5.1.1(c)(ix)
M3.10	**Interpret logarithmic plots**	**Learners may be tested on their ability to:** • **obtain time constant for capacitor discharge by interpreting plot of log *V* against time.**	**3.2(b)(iii), 5.1.1(b)(v)**
M3.11	**Use logarithmic plots to test exponential and power law variations**	**Learners may be tested on their ability to:** • **use logarithmic plots with decay law of radioactivity / charging and discharging of a capacitor.**	**5.1.1(b)(v)**

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	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Physics (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M3.12	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 $y = \sin^2 x$, $y = \cos^2 x$ as applied to physical relationships**	Learners may be tested on their ability to: • **sketch relationships between pressure and volume for an ideal gas.**	3.1.2(b)(iii), 3.2(b)(ii), 4.2(b)(ii), 5.1.1(b)(v), 5.1.1(b)(vii), 5.1.2(b)(ii), 5.2.1(b)(ii), 5.2.2(b)(i)
M4 – Geometry and trigonometry			
M4.1	Use angles in regular 2D and 3D structures	Learners may be tested on their ability to: • interpret force diagrams to solve problems.	4.2(c)(ii)
M4.2	Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Learners may be tested on their ability to: • draw force diagrams to solve mechanics problems.	4.2(c)(ii)
M4.3	Calculate areas of triangles, circumferences and areas of circles, surface areas and volumes of rectangular blocks, cylinders and spheres	Learners 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.	3.1.2(c)(iii)
M4.4	Use Pythagoras' theorem, and the angle sum of a triangle	Learners may be tested on their ability to: • calculate the magnitude of a resultant vector, resolving forces into components to solve problems.	4.2(c)(ii)
M4.5	Use sin, cos and tan in physical problems	Learners may be tested on their ability to: • resolve forces into components.	4.1(c)(ii), 4.2(c)(i), 5.1.1(c)(x)
M4.6	Use of small angle approximations including $\sin\theta \approx \theta$, $\tan\theta \approx \theta$, $\cos\theta \approx 1$ for small θ where appropriate	Learners may be tested on their ability to: • calculate fringe separations in interference patterns.	4.1(c)(iii)

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Physics (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M4.7	Understand the relationship between degrees and radians and translate from one to the other	Learners may be tested on their ability to: • convert angle in degrees to angle in radians.	2(b)(i), 4.1(c)(iii)

Definition of Level 2 mathematics

Within A Level Physics, 40% of the marks available within written examinations will be for assessment of mathematics (in the context of physics) at a Level 2 standard, or higher. Lower level mathematical skills will still be assessed within examination papers but will not count within the 40% weighting for physics.

The following will be counted as Level 2 (or higher) mathematics:

- application and understanding requiring choice of data or equation to be used
- problem solving involving use of mathematics from different areas of maths and decisions about direction to proceed
- questions involving use of A level mathematical content (as of 2012), e.g. use of logarithmic equations.

The following will not be counted as Level 2 mathematics:

- simple substitution with little choice of equation or data
- structured question formats using GCSE mathematics (based on 2012 GCSE mathematics content).

Additional guidance on the assessment of mathematics within physics is available on the OCR website as a separate resource, the Maths Skills Handbook.

5f. Advance Notice for component 02

The A Level Physics B (Advancing Physics) specification places a particular emphasis on the development of scientific literacy skills, which are assessed at the end of the course using a pre-release Advance Notice article (also included as part of the examination paper for component H557/02). The Advance Notice will be a scientific article/s related to the content within the specification and questions related to the Advance Notice will be worth 20–25 marks.

The Advance Notice will be available for download *via* the OCR website on 13 March each year (starting from 13 March 2017 for the first A level assessment in June 2017) to enable teachers and learners sufficient time to work through the information provided.

The instructions for teachers and candidates that will accompany the Advance Notice article are summarised below:

Notes for guidance (candidates)

1. This leaflet contains an article/s which is needed in preparation for questions in the externally assessed examination H557/02 Scientific literacy in physics.

2. You will need to read the article carefully and also have covered the Learning outcomes for A Level in Physics B (Advancing Physics). The examination paper will contain questions on the article/s. You will be expected to apply your knowledge and understanding of the work covered in A Level in Physics B (Advancing Physics) to answer these questions. There are 20–25 marks available on the question paper for these questions.

3. You can seek advice from your teacher about the content of the article and you can discuss it with others in your class. You may also investigate the topic yourself using any resources available to you.

4. You will not be able to bring your copy of the article, or other materials, into the examination. The examination paper will contain a fresh copy of the article as an insert.

5. You will not have time to read this article for the first time in the examination if you are to complete the examination paper within the specified time. However, you should refer to the article when answering the questions.

Notes for guidance (teachers)

1. This Advance Notice material should be issued to candidates on or after the date shown on the front cover of the candidate instructions sheet at the discretion and convenience of the centre. Candidates can be given the material at any point, but it is suggested that this should be at least four weeks before the examination date.

2. Candidates will need to read the article carefully. Time can be built into the teaching programme to introduce the article content. Candidates should be able to discuss the article freely and be given support and advice in the interpretation of the content so that they are able to answer the questions based on the article in the externally assessed examination. Candidates should also be encouraged to investigate the topics covered in the article for themselves.

3. Candidates will be expected to apply their knowledge and understanding of the content in A Level Physics B (Advancing Physics) to questions based on the article. There are 20–25 marks available on the paper for these questions.

The Advance Notice material must not be taken into the examination. The examination paper H557/02 will contain a fresh copy of the article, as an insert. Candidates should be reminded that they do not have sufficient time during the examination to read the article for the first time. They should, however, refer to the article printed in the insert in the examination paper to help them to answer the questions.

5g. Health and Safety

In UK law, health and safety is primarily the responsibility of the employer. In a school or college the employer could be a local education authority, the governing body or board of trustees. Employees (teachers/lecturers, technicians etc.), have a legal duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 (as amended) and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful microorganisms is carried out, or hazardous chemicals are used or made, the employer must carry out a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at **http://www.ase.org.uk/resources/health-and-safety-resources/risk-assessments/**

For members, the CLEAPSS® guide, *PS90*, *Making and recording risk assessments in school science*[1] offers appropriate advice.

Most education employers have adopted nationally available publications as the basis for their Model Risk Assessments.

Where an employer has adopted model risk assessments an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded in a "*point of use text*", for example on schemes of work, published teachers' guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed for each practical activity, although a minority of employers may require this.

Where project work or investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or microorganisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS®.

[1] These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications website **www.cleapss.org.uk**. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to **www.cleapss.org.uk**.

5h. Practical endorsement

The Practical Endorsement is common across Chemistry A and Chemistry B (Salters)/Biology A and Biology B (Advancing Biology) /Physics A and Physics B (Advancing Physics). It requires a minimum of 12 practical activities to be completed from the Practical Activity Groups (PAGs) defined below (**Fig. 1**).

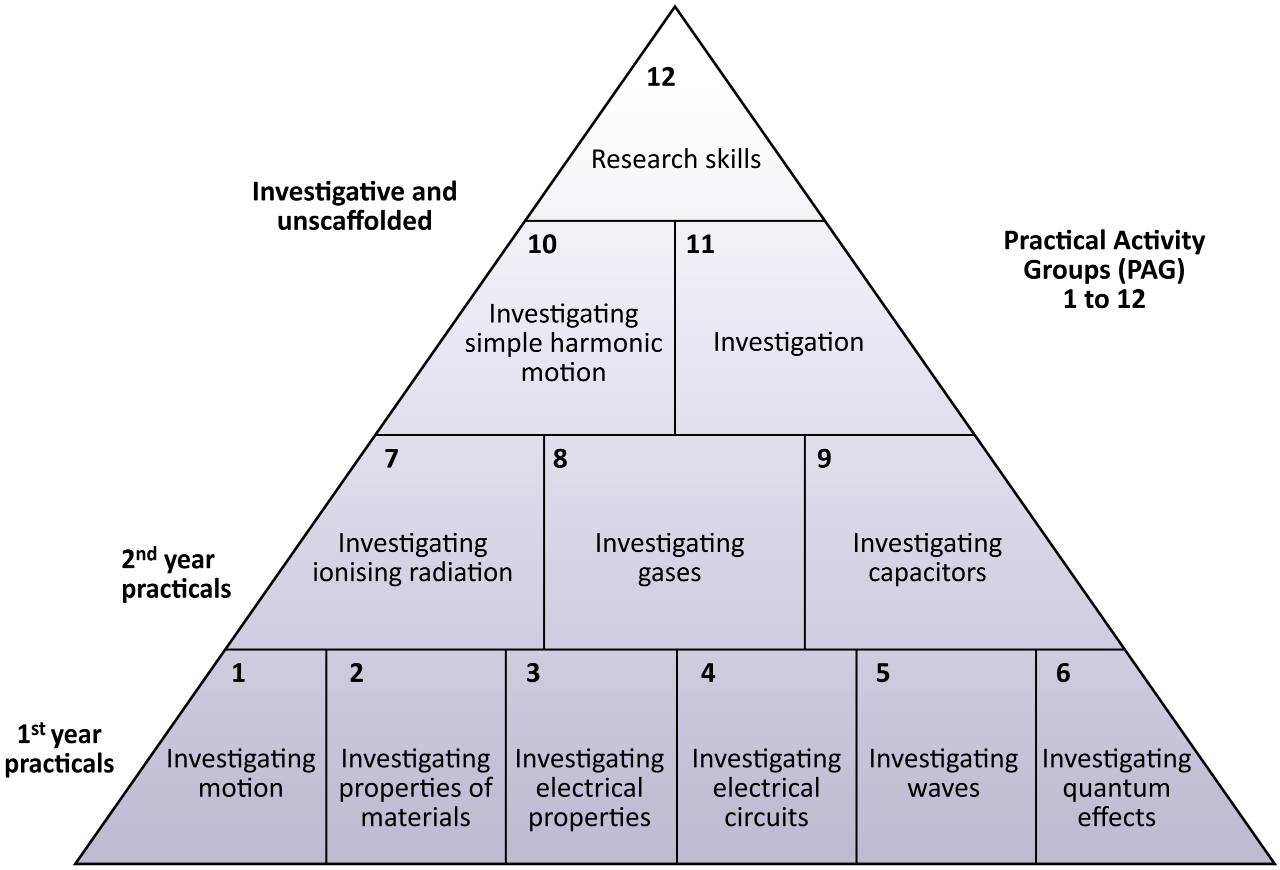

Fig. 1 OCR's Practical Activity Groups (PAGs), also see **Table 1**

Table 1 Practical requirements for the OCR Physics Practical Endorsement

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity (a range of examples will be available from the OCR website and centres can devise their own activity)	Specification reference (examples)
1 Investigating motion	• Use of appropriate analogue apparatus to measure distance, angles[1], mass[2] and to interpolate between scale markings[3] • Use of a stopwatch or light gates for timing • Use of ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data[4] • Use of methods to increase accuracy of measurements, such as set square or plumb line	Acceleration of free fall	4.2(d)(ii)
2 Investigating properties of materials	• Use of calipers and micrometers for small distances, using digital or vernier scales[5] • Use of appropriate analogue apparatus to measure length[6] and to interpolate between scale markings[3] • Use of appropriate digital instruments to measure mass[2]	Determining Young's Modulus for a metal	3.2(d)(ii)
3 Investigating electrical properties	• Use of appropriate digital instruments, including multimeters[7], to measure current[8], voltage[9], resistance[10] • Use calipers and micrometers for small distances, using digital or vernier scales[5] • Correctly constructing circuits from circuit diagrams using DC power supplies, cells, and a range of circuit components	Determining the resistivity/ conductivity of a metal	3.1.2(a)(ix), 3.1.2(d)(ii)

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity	Specification Reference
4 Investigating electrical circuits	• Use of appropriate digital instruments, including multimeters[7], to measure current[8], voltage[9], resistance[10] • Correctly constructing circuits from circuit diagrams using DC power supplies, cells, and a range of circuit components, including those where polarity is important • Designing, constructing and checking circuits using DC power supplies, cells, and a range of circuit components	Investigation of potential divider circuits	3.1.2(a)(ix), 3.1.2(d)(iii)
5 Investigating waves	• Use of appropriate analogue apparatus to measure length[6], angles[1] and to interpolate between scale markings[3] • Use of a signal generator and oscilloscope, including volts/division and time-base • Generating and measuring waves, using microphone and loudspeaker, or ripple tank, or vibration transducer, or microwave/radio wave source • Use of a laser or light source to investigate characteristics of light, including interference and diffraction • Use of ICT such as computer modelling	Determination of the wavelength of light and sound by two source superposition with a double-slit and diffraction grating	4.1(d)(iii), 4.1(d)(iv)

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity	Specification Reference
6 Investigating quantum effects	• Use of appropriate digital instruments, including multimeters[7], to measure current[8], voltage[9] • Correctly constructing circuits from circuit diagrams using DC power supplies, cells, and a range of circuit components, including those where polarity is important • Use of a laser or light source to investigate characteristics of light, including interference and diffraction • Use of methods to increase accuracy of measurements	Determination of Planck's constant using LEDs	4.1(d)(vi)
7 Investigating ionising radiation	• Safe use of ionising radiation, including detectors • Use of ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data[4]	Absorption of α or β or γ radiation	6.2.2(d)(i)
8 Investigating gases	• Use of appropriate analogue apparatus to measure pressure, volume, temperature and to interpolate between scale markings[3]	Determining an estimate of absolute zero using variation of gas temperature with pressure	5.2.1(d)(ii)
9 Investigating capacitors	• Use of appropriate digital instruments, including multimeters[7], to measure current[8], voltage[9], resistance[10] • Use of appropriate digital instruments to measure time • Designing, constructing and checking circuits using DC power supplies, cells, and a range of circuit components • Use of ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data[4]	Determining time constant using the gradient of ln V or ln I–time graph	5.1.1(c)(iii), 5.1.1(d)(iii)

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity	Specification Reference
10 Investigating simple harmonic motion	• Use of appropriate digital instruments to measure time • Use of appropriate analogue apparatus to measure distance and to interpolate between scale markings[3] • Use of methods to increase accuracy of measurements, such as timing over multiple oscillations, or use of fiducial marker, set square or plumb line • Use of ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data[4]	Investigating the factors affecting the period of a simple harmonic oscillator	5.1.1(d)(i)
11 Investigation	• Apply investigative approaches and methods to practical work	Determination of the specific heat capacity of a material	5.2.1(d)(i)
12 Research skills	• Use online and offline research skills • Correctly cite sources of information	The principles behind the operation of the Global Positioning System The use of radioactive materials as tracers in medical imaging	Opportunities throughout specification

[1,2,3,4,5,6,7,8,9,10] These techniques/skills may be covered in any of the groups indicated.

It is expected that the following skills will be developed across all activities, regardless of the exact selection of activities. The ability to:

- safely and correctly use a range of practical equipment and materials **(1.2.1 b)**
- follow written instructions **(1.2.1 c)**
- make and record observations/measurements **(1.2.1 d)**
- keep appropriate records of experimental activities **(1.2.1 e)**
- present information and data in a scientific way **(1.2.1 f)**
- use a wide range of experimental and practical instruments, equipment and techniques **(1.2.1 j)**.

The practical activities can be completed at any point during the two year A level course at the discretion of the centre. Candidates starting from a standalone AS can count A level practical activities carried out during the AS year towards the A level Practical Endorsement provided that they are appropriately recorded. It is recommended therefore that candidates starting AS maintain a record of practical activities carried out (e.g. this could be in the form of a 'log book' or 'practical portfolio') that could be counted towards the Practical Endorsement. For candidates who then decide to follow a full A level, having started from AS, they can carry this record with them into their A level study.

The assessment of practical skills is a compulsory requirement of the course of study for A level qualifications in physics. It will appear on all students' certificates as a separately reported result, alongside the overall grade for the qualification. The arrangements for the assessment of practical skills are common to all awarding organisations. These arrangements include:

- A minimum of 12 practical activities to be carried out by each student which, together, meet the requirements of Appendices 5b (*Practical skills identified for direct assessment and developed through teaching and learning,* covered in Section **1.2.1**) and 5c (*Use of apparatus and techniques*, covered in Section **1.2.2**) from the prescribed subject content, published by the Department for Education. The required practical activities are defined by each awarding organisation (see **Fig. 1** and **Table 1**)
- Teachers will assess students against Common Practical Assessment Criteria (CPAC) issued by the awarding organisations. The CPAC (see **Table 2**) are based on the requirements of Appendices 5b and 5c of the subject content requirements published by the Department for Education, and define the minimum standard required for the achievement of a pass.
- Each student will keep an appropriate record of their practical work, including their assessed practical activities
- Students who demonstrate the required standard across all the requirements of the CPAC, incorporating all the skills, apparatus and techniques (as defined in Sections 1.2.1 and 1.2.2), will receive a 'Pass' grade (note that the practical activity tracker available from OCR allows confirmation that the activities selected cover all the requirements).
- There will be no direct assessment of practical skills for AS qualifications
- Students will answer questions in the AS and A level examination papers that assess the requirements of Appendix 5a (*Practical skills identified for indirect assessment and developed through teaching and learning*, covered in Section **1.1**) from the prescribed subject content, published by the Department for Education. These questions may draw on, or range beyond, the practical activities included in the specification.

In order to achieve a pass, students will need to:

- develop these competencies by carrying out a minimum of 12 practical activities (**PAG1** to **PAG12**), which allow acquisition of all the skills, apparatus and techniques outlined in the requirements of the specification (Sections 1.2.1 and 1.2.2)
- consistently and routinely exhibit the competencies listed in the CPAC (**Table 2**) before the completion of the A-level course
- keep an appropriate record of their practical work, including their assessed practical activities
- be able to demonstrate and/or record independent evidence of their competency, including evidence of independent application of investigative approaches and methods to practical work.

The practical activities prescribed in the subject specification (**PAG1** to **PAG12**) will provide opportunities for demonstrating competence in all the skills identified, together with the use of apparatus and techniques for each subject. However, students can also demonstrate these competencies in any additional practical activity undertaken throughout the course of study which covers the requirements of appendix 5b and 5c (covered in Sections 1.2.1 and 1.2.2).

Students may work in groups but teachers who award a pass to their students need to be confident of individual students' competence.

Table 2 Common Practical Assessment Criteria (CPAC) for the assessment of practical competency in A Level sciences

Competency	Practical Mastery
	In order to be awarded a Pass a Learner must, by the end of the practical science assessment, consistently and routinely meet the criteria in respect of each competency listed below. A Learner may demonstrate the competencies in any practical activity undertaken as part of that assessment throughout the course of study. Learners may undertake practical activities in groups. However, the evidence generated by each Learner must demonstrate that he or she independently meets the criteria outlined below in respect of each competency. Such evidence – **a)** will comprise both the Learner's performance during each practical activity and his or her contemporaneous record of the work that he or she has undertaken during that activity, and **b)** must include evidence of independent application of investigative approaches and methods to practical work.
(1) Follows written procedures	**a)** Correctly follows instructions to carry out experimental techniques or procedures.
(2) Applies investigative approaches and methods when using instruments and equipment	**a)** Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. **b)** Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. **c)** Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. **d)** Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.
(3) Safely uses a range of practical equipment and materials	**a)** Identifies hazards and assesses risks associated with these hazards, making safety adjustments as necessary, when carrying out experimental techniques and procedures in the lab or field. **b)** Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.
(4) Makes and records observations	**a)** Makes accurate observations relevant to the experimental or investigative procedure. **b)** Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.
(5) Researches, references and reports	**a)** Uses appropriate software and/or tools to process data, carry out research and report findings. **b)** Cites sources of information, demonstrating that research has taken place, supporting planning and conclusions.

Choice of activity

Centres can include additional skills, apparatus and techniques within an activity (PAG) beyond those listed as the minimum in **Table 1** or in the published practical activities. They may also carry out more than the minimum 12 practical activities required to meet the Practical Endorsement.

To achieve a Pass within the Practical Endorsement, candidates must have demonstrated competence in all the skills, apparatus and techniques detailed in Sections 1.2.1 and 1.2.2 of the specification by carrying out a minimum of 12 assessed practical activities (covering all of **PAG1** to **PAG12**) and achieved the level of competence defined within the Common Practical Assessment Criteria (**Table 2**).

The minimum of 12 activities can be met by:

(i) using OCR suggested activities (provided as resources from Interchange, or by contacting pass@ocr.org.uk should you be unable to access Interchange)

(ii) modifying OCR suggested activities to match available equipment whilst fulfilling the same skills, apparatus and techniques and CPAC

(iii) using activities devised by the centre and mapped against Section 1.2 of the specification and the CPAC

(iv) using activities from external sources such as the learned societies, mapped against Section 1.2 of the specification and the CPAC

Centres can receive guidance on the suitability of their own practical activities or against any of the options within **(ii)** to **(iv)** above through our free practical assessment support service by emailing pass@ocr.org.uk.

Where centres devise their own practical activity or use an alternative activity, that practical activity must be of a level of demand appropriate for A level.

Practical Activity Groups 1 to 12 can be achieved through more than one centre devised practical activity, and centres are not limited to 12 practical activities such that a centre could, for instance, split **PAG3** into two activities of their own (rather than one) with the two activities fulfilling the requirements. Alternatively it could be possible that an extended activity may cover the requirements of more than one group, in which case the centre could then select an additional activity from another group to achieve the required minimum of 12 practical activities.

5i. Revision of the requirements for practical work

OCR will review the Practical Endorsement detailed in Section 5h of this specification following any revision by the Secretary of State of the skills, apparatus or techniques specified in respect of A Level Physics B (Advancing Physics).

OCR will revise the Practical Endorsement if appropriate.

If any revision to the Practical Endorsement is made, OCR will produce an amended specification which will be published on the OCR website. OCR will then use the following methods to communicate the amendment to centres: subject information update emailed sent to all Examinations Officers, e-alerts to centres that have registered to teach the qualification and social media.

Summary of updates

Date	Version	Section	Title of section	Change
December 2017	2	Multiple		Changes to generic wording and OCR website links throughout the specification. No changes have been made to any assessment requirements.
April 2018	2.1	Front Cover	Disclaimer	Addition of Disclaimer
May 2018	2.2	4a	Head of Centre Annual Declaration	Update in line with new NEA Centre Declaration form.
August 2018	2.3	3d 4d	Retaking the qualification Admin of non-exam assessment	Update to the wording for carry foward rules.
May 2020	2.4	1d 4f	How do I find out more information? Post-results services	Insertion of Online support centre link Enquiries about results changed to Review of results Update to specification covers to meet digital accessibility standards.
December 2020	2.5	4a	Pre-assessment	Changes to practical endorsement requirements and advice Update to specification covers to meet digital accessibility standards.
February 2024	2.6	3	Assessment of OCR A Level in Physics A	Insertion of new section 3c. Total qualification time.
		3d, 3e	Qualification availability, Language	Inclusion of disclaimer regarding availability and language
		4a	Assessment	Update to include resilience guidance
		5c	Physics B Data Sheet	Typographical Correction
		Checklist		inclusion of Teach Cambridge
October 2024	2.7	5c	Physics B Data Sheet	Correction of typographical errors

YOUR CHECKLIST

Our aim is to provide you with all the information and support you need to deliver our specifications.

- [ ] Bookmark OCR website for all the latest information and news on AS and A Level Physics B (Advancing Physics)
- [ ] Sign up for Teach Cambridge: our personalised and secure website that provides teachers with access to all planning, teaching and assessment support materials
- [ ] Be among the first to hear about support materials and resources as they become available – register for Physics updates
- [ ] Find out about our professional development
- [ ] View our range of skills guides for use across subjects and qualifications
- [ ] Discover our new online past paper service
- [ ] Learn more about Active Results
- [ ] Visit our Online Support Centre

Download high-quality, exciting and innovative AS and A Level Physics resources from ocr.org.uk/alevelphysicsb

Free resources and support for our A Level Physics qualification, developed through collaboration between our Physics Subject Advisors, teachers and other subject experts, are available from our website. You can also contact our Physics Subject Advisors for specialist advice, guidance and support, giving you individual service and assistance whenever you need it.

Contact the team at:

01223 553998

scienceGCE@ocr.org.uk

@OCR_science

To stay up to date with all the relevant news about our qualifications, register for email updates at **ocr.org.uk/updates**

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