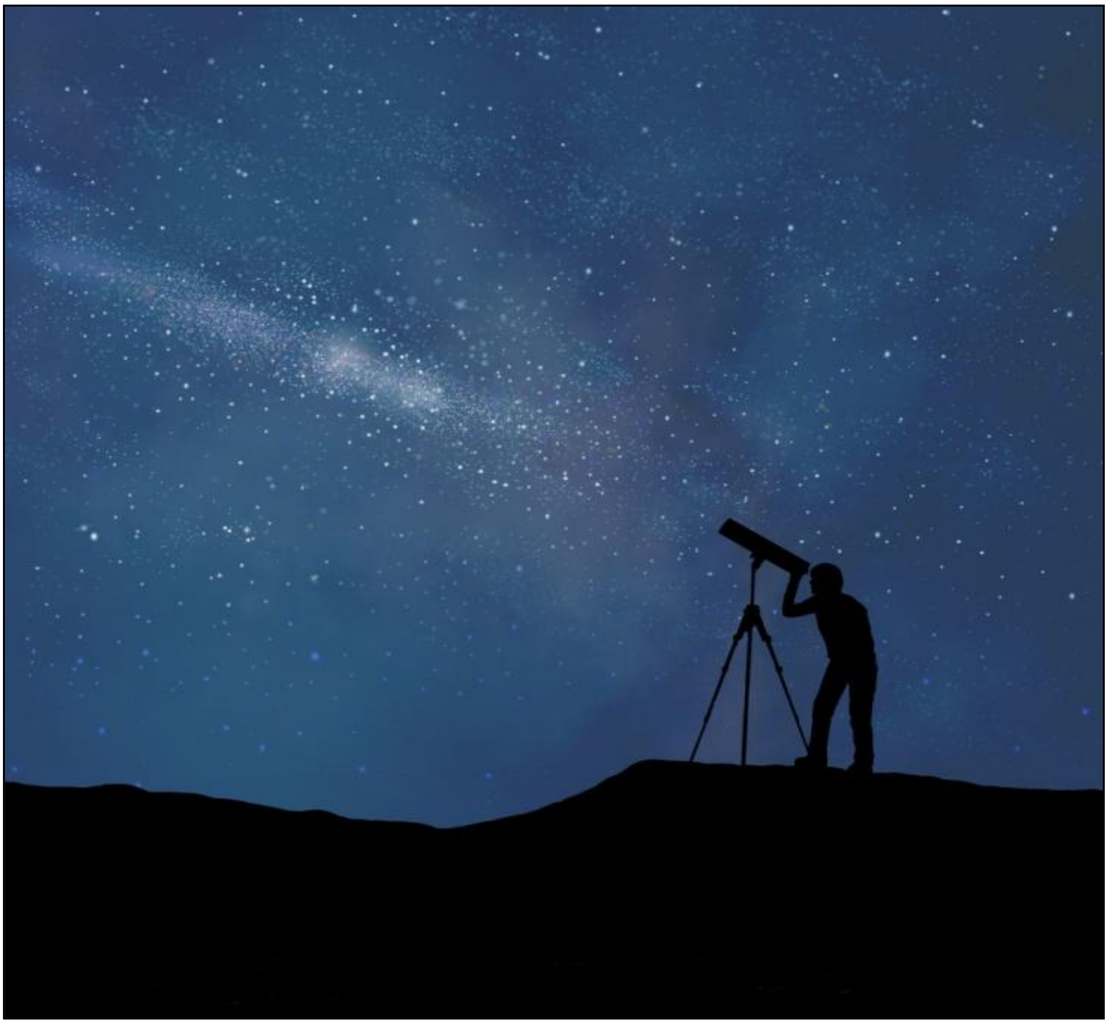
Course/Unit Support Notes

Advanced Higher Physics
Course/Unit Support Notes



Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

Contents

Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing the Advanced Higher Physics Course. They are intended for teachers and lecturers who are delivering the Course and its Units. They should be read in conjunction with the *Course Specification*, the *Course Assessment Specification* and the *Unit Specifications* for the Units in the Course.

These support notes cover both the Advanced Higher Course and the Units in it.

General guidance on the Course/Units

Aims

The aims of the Course are to enable learners to:

- develop a critical understanding of the role of physics in scientific issues and relevant applications, including the impact these could make on the environment/ society
- extend and apply knowledge, understanding and skills of physics
- develop and apply the skills to carry out complex practical scientific activities, including the use of risk assessments, technology, equipment and materials
- develop and apply scientific inquiry and investigative skills, including planning and experimental design
- develop and apply scientific analytical thinking skills, including critical evaluation of experimental procedures in a physics context
- extend and apply problem-solving skills in a physics context
- further develop an understanding of scientific literacy, using a wide range of resources, in order to communicate complex ideas and issues and to make scientifically informed choices
- extend and apply skills of independent/autonomous working in physics

Progression

In order to do this Course, learners should have achieved the Higher Physics Course.

Learners who have achieved this Advanced Higher Course may progress to further study, employment and/or training. Opportunities for progression include:

- Progression to further/higher education
  - For many learners a key transition point will be to further or higher education, for example to Professional Development Awards (PDAs), Higher National Certificates (HNCs) or Higher National Diplomas (HNDs) or degree programmes. Examples of further and higher education programmes that learners doing the Course might progress to include engineering, electronics, computing, design, architecture or medicine.

  - Advanced Higher Courses provide good preparation for learners progressing to further and higher education as learners doing Advanced Higher Courses must be able to work with more independence and less supervision. This eases their transition to further/higher education. Advanced Higher Courses may also allow ‘advanced standing’ or partial credit towards the first year of study of a degree programme.

- — Advanced Higher Courses are challenging and testing qualifications — learners who have achieved multiple Advanced Higher Courses are regarded as having a proven level of ability which attests to their readiness for education in higher education institutions (HEIs) in other parts of the UK as well as in Scotland.

- ♦ Progression to employment
  - — For many learners progression will be directly to employment or work-based training programmes. Examples of employment opportunities and training programmes are careers in oil and gas exploration, construction, transport or telecommunications.

This Advanced Higher is part of the Scottish Baccalaureate in Science. The Scottish Baccalaureates in Expressive Arts, Languages, Science and Social Sciences consist of coherent groups of subjects at Higher and Advanced Higher level. Each award consists of two Advanced Highers, one Higher and an Interdisciplinary Project which adds breadth and value and helps learners to develop generic skills, attitudes and confidence that will help them make the transition into higher education or employment.

Hierarchies

Hierarchy is the term used to describe Courses and Units which form a structured progression involving two or more SCQF levels.

It is important that any content in a Course and/or Unit at one particular SCQF level is not repeated if a learner progresses to the next level of the hierarchy. The skills and knowledge should be able to be applied to new content and contexts to enrich the learning experience. This is for centres to manage.

- ♦ Physics Courses from National 3 to Advanced Higher are hierarchical.
- ♦ Courses from National 3 to National 5 have Units with the same structure and titles.

Skills, knowledge and understanding covered in this Course

Teachers and lecturers should refer to the *Course Assessment Specification* for mandatory information about the skills, knowledge and understanding to be covered in this Course.

Approaches to learning and teaching

The purpose of this section is to provide you with advice on learning and teaching. It is essential that you are familiar with the mandatory information within the Advanced Higher Physics *Course Assessment Specification*.

Advanced Higher Courses place more demands on learners as there will be a higher proportion of independent study and less direct supervision. Some of the approaches to learning and teaching suggested for other levels (in particular, Higher) may also apply at Advanced Higher level but there will be a stronger emphasis on independent learning.

As with the Higher Physics Course, learning at Advanced Higher level is still expected to be experiential, active, challenging and enjoyable. It should include appropriate practical experiments/activities and could be learner led. A variety of active learning approaches is encouraged, including peer teaching and assessment, individual and group presentations, and game-based learning with learner-generated questions.

For Advanced Higher Courses, a significant amount of learning may be self-directed and require learners to demonstrate a more mature approach to learning and the ability to work on their own initiative. This can be very challenging for some learners, who may feel isolated at times, and teachers and lecturers should have strategies for addressing this. These could include, for example, planning time for regular feedback sessions/discussions on a one-to-one basis and on a group basis led by the teacher or lecturer (where appropriate).

Centres should be aware that although the mandatory knowledge and skillset may be similar in Higher and Advanced Higher Courses, there are differences in the:

- depth of underpinning knowledge and understanding
- complexity and sophistication of the applied skills
- ways in which learners will learn: namely, they will take more responsibility for their learning at Advanced Higher and work more autonomously

All learning and teaching should offer opportunities for learners to work collaboratively. Practical activities and investigative work can offer opportunities for group work, which should be encouraged. Laboratory work should include the use of technology and equipment that reflects current scientific use in physics.

Learners, especially at Advanced Higher, would be expected to contribute a significant portion of their own time in addition to programmed learning time.

Effective partnership working can enhance the science experience. Where feasible, locally relevant contexts should be studied, with visits where this is possible. Guest speakers from eg industry, further and higher education could be used to bring the world of physics into the classroom.

An investigatory approach is encouraged in physics, with learners actively involved in developing their skills, knowledge and understanding by investigating a range of relevant physics-related applications and issues. A holistic approach should be adopted to encourage simultaneous development of learners' conceptual understanding and skills. Where appropriate, investigative work/experiments, in physics, should allow learners the opportunity to select activities and/or carry out extended study. Investigative and experimental work is part of the scientific method of working and can fulfil a number of educational purposes.

Teachers and lecturers should encourage learners to use an enquiring, critical and problem-solving approach to their learning. Learners should also be given the opportunity to practise and develop research and investigation skills and higher order evaluation and analytical skills.

The use of information and communications technology (ICT) can make a significant contribution to the development of these higher order skills as research and investigation activities become more sophisticated. ICT can make a significant contribution to practical work in Advanced Higher Physics, in addition to the use of computers as a learning tool. Computer interfacing equipment can detect and record small changes in variables allowing experimental results to be recorded over long or short periods of time. Results can also be displayed in real-time helping to improve understanding. Datalogging equipment and video cameras can be set up to record data and make observations over periods of time longer than a class lesson that can then be downloaded and viewed for analysis.

Skills of scientific experimentation, investigation and inquiry

Learners should acquire scientific skills through a series of learning experiences, investigations and experimental work set in the contexts described in the content statements and supplementary notes of the *Course Specification*. These skills should be developed throughout the Course using a variety of case studies, practical activities and other learning experiences as appropriate. Some activities and experiences will lend themselves to developing particular skills more than others. For example, some practical activities will be particularly suitable for developing planning and designing skills, some for presenting and analysing data skills and others for the skill of drawing conclusions. In selecting appropriate activities and experiences, teachers and lecturers should identify which skills are best developed in each activity to ensure the progressive development of all skills and to support candidates' learning.

Learners will engage in a variety of learning activities as appropriate to the subject. Details of approaches and contexts are suggested in Appendix 1.

Teachers and lecturers should support learners by having regular discussions with them and giving regular feedback. Some learning and teaching activities may be carried out on a group basis and, where this applies, learners could also receive feedback from their peers.

Teachers and lecturers should, where possible, provide opportunities to personalise learning for learners, and to enable them to have choices in approaches to learning and teaching. The flexibility in Advanced Higher Courses and the independence with which learners carry out the work lend themselves to this. Teachers and lecturers should also create opportunities for, and use, inclusive approaches to learning and teaching. This can be achieved by encouraging the use of a variety of learning and teaching strategies which suit the needs of all learners. Innovative and creative ways of using technology can also be valuable in creating inclusive learning and teaching approaches.

Centres are free to sequence the teaching of the Course, Units, key areas and Outcomes in any order they wish. For example:

- Each Unit could be delivered separately in any sequence.

  And/or

- All Units may be delivered in a combined way as part of the Course. If this approach is used, the Outcomes within Units may either be partially or fully combined.

Learning about Scotland and Scottish culture will enrich the learners' learning experience and help them to develop the skills for learning, life and work they will need to prepare them for taking their place in a diverse, inclusive and participative Scotland and beyond. Where there may be opportunities to contextualise approaches to learning and teaching to Scottish contexts in this Course, this could be done through mini-projects or case studies.

Developing skills for learning, skills for life and skills for work

It is important that learners are aware of the skills for learning, skills for life and skills for work that they are developing in the Course and the activities they are involved in that provide realistic opportunities to practise and/or improve these skills. Teachers and lecturers should ensure that learners have opportunities to develop these skills as an integral part of their learning experience.

At Advanced Higher level it is expected that learners will be using a range of higher order thinking skills. They will also develop skills in independent and autonomous learning.

Learners are expected to develop broad generic skills as an integral part of their learning experience. The *Course Specification* lists the skills for learning, skills for life and skills for work that learners should develop through this Course. These are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work* and must be built into the Course where there are appropriate opportunities. The level of these skills will be appropriate to the level of the Course.

For this Course, it is expected that the following skills for learning, skills for life and skills for work will be significantly developed:

Literacy
Writing means the ability to create texts which communicate ideas, opinions and information, to meet a purpose and within a context. In this context, 'texts' are defined as word-based materials (sometimes with supporting images) which are written, printed, Braille or displayed on screen. These will be technically accurate for the purpose, audience and context.

1.1 Reading
Learners will understand and interpret a variety of scientific texts.

1.2 Writing
Learners use skills to effectively communicate key areas of physics, make informed decisions and explain, clearly, physics issues in various media forms. Learners will have the opportunity to communicate applied knowledge and understanding throughout the Course.

There will be opportunities to develop the literacy skills of listening and reading, when gathering and processing information in Physics.

Numeracy
This is the ability to use numbers in order to solve problems by counting, doing calculations, measuring, and understanding graphs and charts. This is also the ability to understand the results.

Learners will have opportunities to extract, process and interpret information presented in numerous formats including tabular and graphical. Practical work will provide opportunities to develop time and measurement skills.

2.1 Number processes
Number processes means solving problems arising in everyday life through carrying out calculations, when dealing with data and results from experiments/investigations and everyday class work, making informed decisions based on the results of these calculations and understanding these results.

2.2 Money, time and measurement
The accuracy of measurements is important when handling data in a variety of physics contexts, including practical and investigative. Consideration should be given to uncertainties.

2.3 Information handling
Information handling means being able to gather and interpret physics data in tables, charts and other graphical displays to draw sensible conclusions throughout the Course. It involves interpreting the data and considering its reliability in making reasoned deductions and informed decisions. It also involves an awareness and understanding of the chance of events happening.

Thinking skills
This is the ability to develop the cognitive skills of remembering and identifying, understanding and applying.

The Course will allow learners to develop skills of applying, analysing and evaluating. Learners can analyse and evaluate practical work and data by reviewing the process, identifying issues and forming valid conclusions. They can demonstrate understanding and application of key areas and explain and interpret information and data.

5.3 Applying
Applying is the ability to use existing information to solve physics problems in different contexts, and to plan, organise and complete a task such as an investigation.

5.4 Analysing and evaluating
This covers the ability to identify and weigh-up the features of a situation or issue in physics and to draw valid conclusions. It includes reviewing and considering any potential solutions.

5.5 Creating
This is the ability to design something innovative or to further develop an existing thing by adding new dimensions or approaches. Learners can demonstrate their creativity, in particular, when planning and designing physics experiments or investigations. Learners have the opportunity to be innovative in their approach. Learners also have opportunities to make, write, say or do something new.

In addition, learners will also have opportunities to develop working with others and citizenship.

Working with others
Learning activities provide many opportunities, in all areas of the Course, for learners to work with others. Practical activities and investigations, in particular, offer opportunities for group work, which is an important aspect of physics and should be encouraged.

Citizenship
Learners will develop citizenship skills, when considering the applications of physics on our lives, as well as the implications for the environment/society.

Approaches to assessment

Assessment in Advanced Higher Courses will generally reflect the investigative nature of Courses at this level, together with high-level problem-solving and critical thinking skills and skills of analysis and synthesis.

This emphasis on higher order skills, together with the more independent learning approaches that learners will use, distinguishes the added value at Advanced Higher level from the added value at other levels.

There are different approaches to assessment, and teachers and lecturers should use their professional judgement, subject knowledge and experience, as well as understanding of their learners and their varying needs, to determine the most appropriate ones and, where necessary, to consider workable alternatives.

Assessments must be fit for purpose and should allow for consistent judgements to be made by all teachers and lecturers. They should also be conducted in a supervised manner to ensure that the evidence provided is valid and reliable.

Unit assessment

Units will be assessed on a pass/fail basis. All Units are internally assessed against the requirements shown in the *Unit Specification*. Each Unit can be assessed on an individual Outcome-by-Outcome basis or via the use of combined assessment for some or all Outcomes.

Assessments must ensure that the evidence generated demonstrates, at the least, the minimum level of competence for each Unit. Teachers and lecturers preparing assessment methods should be clear about what that evidence will look like.

Sources of evidence likely to be suitable for Advanced Higher Units could include:

- meaningful contributions to group work and/or discussions (making use of log books, blogs, question and answer sessions to confirm individual learners have met the required standards)
- presentation of information to other groups and/or recorded oral evidence
- exemplification of concepts using, for example, a diagram
- interpretation of numerical data
- practical demonstration with commentary/explanation/narrative
- investigations
- answers to objective questions
- short written responses
- extended response essay-type questions

Evidence should include the use of appropriate subject-specific terminology as well as the use of real-life examples where appropriate.

Flexibility in the method of assessment provides opportunities for learners to demonstrate attainment in a variety of ways and so reduce barriers to attainment.

The structure of an assessment used by a centre can take a variety of forms, for example:

- individual pieces of work could be collected in a folio as evidence for Outcomes and Assessment Standards
- assessment of each complete Outcome
- assessment that combines the Outcomes of one or more Units
- assessment that requires more than the minimum competence, which would allow learners to prepare for the Course assessment

Teachers and lecturers should note that learners' day-to-day work may produce evidence which satisfies assessment requirements of a Unit, or Units, either in full or partially. Such naturally-occurring evidence may be used as a contribution towards Unit assessment. However, such naturally-occurring evidence must still be recorded and evidence such as written reports, recording forms, PowerPoint slides, drawings/graphs, video footage or observational checklists provided.

Combining assessment across Units

A combined approach to assessment will enrich the assessment process for the learner, avoid duplication of tasks and allow more emphasis on learning and teaching. Evidence could be drawn from a range of activities for a combined assessment. Care must be taken to ensure that combined assessments provide appropriate evidence for all the Outcomes that they claim to assess.

Combining assessment will also give centres more time to manage the assessment process more efficiently. When combining assessments across Units, teachers/lecturers should use e-assessment wherever possible. Learners can easily update portfolios, electronic or written diaries and recording sheets.

For some Advanced Higher Courses, it may be that a strand of work which contributes to a Course assessment method is started when a Unit is being delivered and is completed in the Course assessment. In these cases, it is important that the evidence for the Unit assessment is clearly distinguishable from that required for the Course assessment.

Preparation for Course assessment

Each Course has additional time which may be used at the discretion of the teacher or lecturer to enable learners to prepare for Course assessment. This time may be used at various points throughout the Course for consolidation and support. It may also be used for preparation for Unit assessment, and, towards the end of the Course, for further integration, revision and preparation and/or gathering evidence for Course assessment.

For this Advanced Higher Course, the assessment methods for Course assessment are question paper and project. Learners should be given opportunities to practise these methods and prepare for them.

Examples of activities to include within this preparation time include:

- Preparing for the components of Course assessment, for example:
  - preparing for non-question paper components — selecting topics, gathering and researching information/data, evaluating and analysing findings, developing and justifying conclusions, presenting the information/data (as appropriate)
  - practising question paper techniques and revising for the question paper

In relation to preparing for the project, teachers and lecturers should explain requirements to learners and the amount and nature of the support they can expect. However, at Advanced Higher level it is expected that learners will work with more independence and less supervision and support.

Authenticity

In terms of authenticity, there are a number of techniques and strategies to ensure that learners present work that is their own.

In Advanced Higher Courses, because learners will take greater responsibility for their own learning and work more independently, teachers and lecturers need to have measures in place to ensure that work produced is the learner's own work.

For example:

- regular checkpoint/progress meetings with learners
- short spot-check personal interviews
- checklists which record activity/progress
- photographs, films or audio records

Group work approaches are acceptable as part of the preparation for assessment, where appropriate. However, there must be clear evidence for each learner to show that the learner has met the Evidence Requirements.

For more information, please refer to SQA's *Guide to Assessment.*

Added Value

Advanced Higher Courses include assessment of added value which is assessed in the Course assessment.

Information given in the *Course Specification* and the *Course Assessment Specification* about the assessment of added value is mandatory.

In Advanced Higher Courses, added value involves the assessment of higher order skills such as high-level and more sophisticated investigation and research skills, critical thinking skills and skills of analysis and synthesis. Learners may be required to analyse and reflect upon their assessment activity by commenting on it and/or drawing conclusions with commentary/justification. These skills contribute to the uniqueness of Advanced Higher Courses and to the overall higher level of performance expected at this level.

In the assessment for this Course, added value will focus on the following:

- breadth – requiring demonstration of breadth of learning across the Units of the Course, drawing on knowledge and skills from across the Units, requiring retention and/or integration as appropriate
- challenge — requiring greater depth or extension of knowledge and/or skills
- application — requiring application of knowledge and/or skills in practical or theoretical contexts as appropriate

In this Course, added value will be assessed by a question paper and a project:

- The question paper is used to assess whether the learner can retain and consolidate the knowledge and skills gained in individual Units. It requires learners to demonstrate aspects of challenge and application; learners will apply breadth and depth of skills, and the various applications of knowledge
  — such as reasoning, analysing, evaluating and solving problems from across the Course to answer questions in physics.

- The project is used to assess a wide range of high-order cognitive and practical skills and to bring them together, such as skills relating to planning, analysis, synthesis and evaluation. The project requires learners to apply skills of scientific inquiry, using related knowledge, to carry out a meaningful and appropriately challenging task in physics and communicate findings. The learner will carry out a significant part of the work for the project independently with minimal supervision.

Equality and inclusion

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in these *Course/Unit Support Notes* is designed to sit alongside these duties but is specific to the delivery and assessment of the Course.

It is important that centres are aware of and understand SQA's assessment arrangements for disabled learners, and those with additional support needs, when making requests for adjustments to published assessment arrangements. Centres will find more guidance on this in the series of publications on Assessment Arrangements on SQA's website: www.sqa.org.uk/sqa/14977.html.

The greater flexibility and choice in Advanced Higher Courses provide opportunities to meet a range of learners' needs and may remove the need for learners to have assessment arrangements. However, where a disabled learner needs a reasonable adjustment/assessment arrangements to be made, you should refer to the guidance given in the above link.

The following should be taken into consideration:

Situation	**Reasonable adjustment**
Carrying out practical activities	Use could be made of practical helpers for learners with: ♦ physical disabilities, especially manual dexterity, when carrying out practical activities ♦ visual impairment who have difficulty distinguishing colour changes or other visual information
Reading, writing and presenting text, symbolic representation, tables, graphs and diagrams	Use could be made of ICT, enlarged text, alternative paper and/or print colour and/or practical helpers for learners with visual impairment, specific learning difficulties and physical disabilities
Process information using calculations	Use could be made of practical helpers for learners with specific cognitive difficulties (eg dyscalculia)
Draw a valid conclusion, giving explanations and making predictions	Use could be made of practical helpers for learners with specific cognitive difficulties or autism

Appendix 1: Further information on Units in the Course

Advanced Higher Physics: Rotational Motion and Astrophysics

Suggestions for possible contexts and learning activities, to support and enrich learning and teaching, are detailed in the table below. The **Mandatory Course key areas** are from the *Course Assessment Specification*. The **Suggested learning** activities are not mandatory. It is not expected that all will be covered. Centres may also devise their own learning activities. **Exemplification of key areas** is not mandatory. It provides an outline of the level of demand and detail of the key areas.

Key areas: kinematic relationships, angular motion, rotational dynamics, angular momentum, rotational kinetic energy, gravitation, general relativity and stellar physics

Mandatory Course key area	Suggested learning activities	Exemplification of key areas
Kinematic relationships Calculus methods with the kinematic relationships for straight line motion with a constant acceleration. Gradient represents instantaneous rate of change for displacement-time and velocity-time graphs. Area under a graph, between limits, obtained by integration.	Kinematic relationships for motion in a straight line. Motion sensors, data logging and video analysis to enable graphical representation of motion.	Calculus methods applied to the kinematic relationships for acceleration in a straight line. Gradients of *s-t* graphs can yield instantaneous velocity. Gradients of *v-t* graphs can yield instantaneous acceleration. Integration of area under a *v-t* graph between limits to calculate displacement.
	Derivation of equations of motion using calculus.	$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$ $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$

Angular motion Angular displacement, velocity and acceleration	Measurement of average angular velocity of a rotating object. Measurement of angular acceleration of an object rotating with constant angular acceleration.	The radian as a measure of angular displacement. Rotational equivalents of linear equations of motion. $s = r\theta$ $\quad \omega = \frac{d\theta}{dt}$ $\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$ $\omega = \omega_0 + \alpha t$ $\omega^2 = \omega_0^2 + 2\alpha\theta$ $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ $v = r\omega$ $\quad \omega = \frac{2\pi}{T}$
Centripetal force and acceleration	Derivation of centripetal acceleration. Investigate factors that determine size of centripetal (central) force required to maintain circular motion.	Distinction between angular acceleration and radial (centripetal) acceleration. $a_t = r\alpha$ $a_r = \frac{v^2}{r} = r\omega^2$ $F = \frac{mv^2}{r} = mr\omega^2$ 'Loop the loop' experiments, conical pendulum, aircraft banking, velodromes, funfair rides, etc.

Rotational dynamics Torque, moment of inertia and angular acceleration	Investigation of torque applied to a turntable and the angular acceleration.	$T = Fr$, $T = I\alpha$ Nm as a unit of torque. Torque wrench, engine torque.
	Calculation of I of different shapes — rod, sphere, solid cylinder, hollow cylinder — give absolute uncertainty in value. (Refer to data sheet for formulae). Measurement of I from the graph of torque vs angular acceleration.	Moment of inertia of an object is a measure of its resistance to angular acceleration about a given axis. For discrete masses: $I = \sum mr^2$ I depends on the mass of the object and its distribution of the mass about a fixed axis.
Angular momentum Conservation of angular momentum	Demonstrate the angular momentum of a point mass m rotating at velocity v and distance r about an axis. (Mass on end of string.)	$L = mvr = mr^2\omega = I\omega$ $L = I\omega =$ const (no external torque).
Rotational kinetic energy	Demonstration using rotating platform, added mass, data logger to plot graph of angular velocity against time. Pupil rotating on computer stool, arms extended etc. Determine I of cylinder rolling down slope. Determine I of flywheel. Account for the increase in rotational kinetic energy when a spinning system increases angular velocity (eg work done by a skater pulling their arms inwards).	Gyroscopes, bicycle wheels, spinning tops, ice skaters, divers, gymnasts, etc $E = \frac{1}{2}I\omega^2$ $E_p = E_k$ (linear) + E_k (rotational)

Gravitation Gravitational field strength	Cavendish/Boys experiment. Maskelyne — Schiehallion experiment. Gravity and orbital motion. Calculations involving period of orbit and distance from centre of Earth. Satellites in (circular) orbit. Data-gathering satellites: weather, telecommunications, mapping, surveying, etc.	Field lines and gravitational field patterns around a planet and a planet–moon system. $F = \frac{GMm}{r^2}$ Tides, tidal forces, tidal energy. $F = \frac{GMm}{r^2} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$
Gravitational potential and potential energy	Work done in moving unit mass from infinity to a point in space.	$V = -\frac{GM}{r}$ $E_p = Vm = -\frac{GMm}{r}$ Gravitational potential and gravitational potential energy have the value zero at infinity. Gravitational potential 'well'.
Escape velocity	Consideration of changes in both potential and kinetic energy when a satellite alters orbit. Minimum velocity required to allow a mass to escape a gravitational field, achieving zero kinetic energy and maximum (zero) gravitational potential energy at infinity.	$E_k = \frac{1}{2}mv^2 = -\frac{GMm}{2r}$ $v = \sqrt{\frac{2GM}{r}}$ Planetary atmospheric composition. Implications for space flight.

General relativity Equivalence principle and its consequences Spacetime diagrams Black holes Stellar physics Properties of stars Hydrogen and helium fusion reactions — production of deuterium, helium 3, helium 4, positrons, neutrinos and gamma rays. Stellar evolution The Hertzsprung-Russell (H-R) diagram	Comparison of general and special relativity. Simulations to aid understanding. Spacetime as a representation of four dimensional space Rubber sheet analogy. Simulations Exercises on the H-R diagram — websites. Position of a star in the H-R diagram determined by luminosity and surface temperature.	General — motion in non-inertial (accelerating) frames of reference. Consideration of clocks in non-inertial frames of reference eg accelerating spacecraft. Effect of altitude on clocks — GPS clock adjustment. Precession of Mercury's orbit. World line of a motion; spacetime diagrams; accelerations represented by world line of changing gradient. Gravity as spacetime curvature; curvature of spacetime by mass. Schwarzchild radius of black holes. $r = \frac{2GM}{c^2}$ Gravitational lensing of light. Radius, surface temperature, mass, luminosity and apparent brightness. $b = \frac{L}{4\pi r^2}$ Power per unit area $= \sigma T^4$ $L = 4\pi r^2 \sigma T^4$ Gravitational equilibrium – balance between inward gravitational pull and outward thermal pressure. Formation of stars due to gravitational effects on cold dense interstellar clouds. Classification of stars. Life cycle of stars — supernovae, neutron stars and black holes.

Physics: Quanta and Waves

Suggestions for possible contexts and learning activities, to support and enrich learning and teaching, are detailed in the table below. The **Mandatory Course key areas** are from the ***Course Assessment Specification***. Activities in the **Suggested learning activities** are not mandatory. This offers examples of suggested activities, from which you could select a range of suitable activities. It is not expected that all will be covered. Centres may also devise their own learning activities. **Exemplification of key areas** is not mandatory. It provides an outline of the level of demand and detail of the key areas.

Key areas: introduction to quantum theory, particles from space, simple harmonic motion, waves, interference and polarisation

Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
Introduction to quantum theory Challenges to classical theory Black body radiation Photoelectric effect	Analysis of black body radiation curves (graphs of irradiance versus λ).	Black body radiation curves and the photoelectric effect cannot be predicted by classical theory. The ultraviolet catastrophe. Absorption and emission of radiation by quantum leaps – Planck. Quantisation of energy of e-m waves — Einstein. $E = hf$
Bohr model of the atom	Observation and examination of line emission and line absorption spectra. Use of spectrometer.	Quantisation of angular momentum — Bohr. $mvr = \frac{nh}{2\pi}$
Wave particle duality	Double-slit experiments with single particles (photons and electrons). Evidence of wave/particle duality — eg electron diffraction.	Atomic spectra in terms of electron energy states.
De Broglie waves	Observation of stationary waves in wire loops.	Wave properties of electrons — de Broglie. $\lambda = \frac{h}{p}$

Uncertainty principle	Mathematical statements of the uncertainty principle in terms of Planck's constant. Quantum mechanics — qualitative description.	Uncertainty principle in terms of location and momentum — Heisenberg. $\Delta x \Delta p_x \geq \frac{h}{4\pi}$ $\Delta E \Delta t \geq \frac{h}{4\pi}$
Particles from space Cosmic rays Solar wind	 Investigate parabolic and helical motion of charged particles in a magnetic field. Research how aurorae are produced in the upper atmosphere. Research the solar cycle and solar flares.	 $F = Bqv$ Origin and composition of cosmic rays. Comparison of variety and energies of cosmic rays with particles generated by particle accelerators. Interaction of cosmic rays with Earth's atmosphere. Interaction of the solar wind with Earth's magnetic field. Composition of the solar wind as charged particles in the form of plasma.
Simple harmonic motion Dynamics of simple harmonic motion (SHM) Angular frequency and period Solutions of the SHM equation	 Investigate different oscillating SHM systems (pendulums, mass on spring, loaded test tube, etc). Relationship between force applied and extension of a spring. Demonstration of link between circular motion and SHM. Investigate the factors affecting the period of oscillation of an object moving with SHM.	 Criteria for SHM. $F = -ky$ (or x can be used throughout) $\omega = 2\pi f$ $a = \frac{d^2y}{dt^2} = -\omega^2 y$ $y = A\sin\omega t$ or $x = A\cos\omega t$ $v = \pm\omega\sqrt{(A^2 - y^2}$

Kinetic and potential energy in SHM	Investigate relationship between kinetic and potential for an object with SHM. Investigate damped and undamped systems — use of motion sensor or mobile device for use as an accelerometer.	$E_k = \frac{1}{2}m\omega^2(A^2 - y^2)$ $E_p = \frac{1}{2}m\omega^2 y^2$ Car shock absorbers, bridges, bungee cords, trampolines, diving boards, etc. $E = kA^2$ $y = A\sin 2\pi(ft - \frac{x}{\lambda})$ $\phi = \frac{2\pi x}{\lambda}$ The displacement y is given by the combination of the particle's transverse SHM and the phase angle between each particle.
Waves Energy transferred by a wave is directly proportional to the square of the amplitude. Mathematical representation of travelling waves. Phase difference and phase angle Superposition of waves Stationary waves	Simulation of a transverse wave leading to understanding of the mathematical representation. Stationary waves simulation/Slinky. Nodes/antinodes — investigating stationary waves using vibrator and elastic string. Measurement of wavelength of sound and microwaves using standing waves. Resonance tube to measure the speed of sound.	Synthesisers related to addition of waves — Fourier analysis. Musical instruments — wind and string. Fundamental and harmonic frequencies. Beats — tuning of musical instruments.

Interference Conditions for constructive and destructive interference Coherence Division of amplitude Optical path length, geometrical path length, phase difference and optical path difference Thin-film interference	Phase change of λ at boundary — Slinky demonstration. Investigate thin-film interference using an extended light source — oil films, soap bubbles.	Optical path difference = $n \times$ geometrical path difference Optical path difference = $m\lambda$ or $\left(m+\frac{1}{2}\right)\lambda$ $d = \frac{\lambda}{4n}$ Blooming of lenses. $\Delta x = \frac{\lambda l}{2d}$ $\Delta x = \frac{\lambda D}{d}$
Wedge fringes	Determine the thickness of sheet of paper using wedge fringes.	Liquid crystal displays, computer/phone displays, polarising lenses, optical activity, photoelasticity and saccharimetry. Stress analysis of perspex models of structures.
Division of wavelength Young's slits interference	Determine the wavelength of laser light using Young's slits.	
Polarisation Plane polarisation of transverse waves Brewster's angle	Observe the difference between linearly (plane) polarised and unpolarised waves. Investigate polarisation of microwaves and light. Investigate reflected laser (polarised) light from a glass surface through a polarising filter as the angle of incidence is varied. Investigate reflected white light through a polarising filter.	$n = \tan i_p$

Physics: Electromagnetism

Suggestions for possible contexts and learning activities, to support and enrich learning and teaching, are detailed in the table below. The **Mandatory Course key areas** are from the ***Course Assessment Specification***. Activities in the **Suggested learning activities** are not mandatory. This offers examples of suggested activities, from which you could select a range of suitable activities. It is not expected that all will be covered. Centres may also devise their own learning activities. **Exemplification of key areas** is not mandatory. It provides an outline of the level of demand and detail of the key areas.

Key areas: fields, circuits and electromagnetic radiation

Mandatory Course key area	**Suggested learning activities**	**Exemplification of key areas**
Fields Electric field strength Coulomb's inverse square law Electric potential and electric field strength around a point charge and a system of charges.	Field simulations. Investigate electrostatic spray painting.	An electric field is the space that surrounds electrically charged particles and in which a force is exerted on other electrically charged particles. Force per unit positive charge. $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ $V = \frac{Q}{4\pi\varepsilon_0 r}$
Potential difference and electric field strength for a uniform electric field. Motion of charged particles in uniform electric fields. The electronvolt as a unit of energy. Ferromagnetism Magnetic field patterns	Investigate the motion of charged particles in uniform electric fields Investigate particle accelerators, cosmic rays, Compton scattering, oscilloscope deflecting plates. Investigate field patterns around permanent magnets and electromagnets, for example a straight wire and a coil.	$F = QE$ $V = Ed$ $E_w = qV$ The eV is commonly used in high energy physics. Electrons are in motion around atomic nuclei and individually produce a magnetic effect. Iron, nickel, cobalt and some rare earths exhibit a magnetic effect called ferromagnetism, in which magnetic dipoles can be made to line up, resulting in the material becoming magnetised.

Magnetic induction Magnetic induction at a distance from a long current carrying wire. Force on a current carrying conductor in a magnetic field. Compare gravitational, electrostatic, magnetic and nuclear forces.	Investigate the magnetic induction at a distance from a long current carrying wire. (Use of Hall probe, smartphone or search coil.) Investigate the magnitude of the force on a current carrying conductor in a magnetic field.	$B = \frac{\mu_0 I}{2\pi r}$ $F = IlB\sin\theta$ Electric motor, electromagnetic pump. Millikan's experimental determination of charge of the electron.
Circuits *Capacitors in d.c. circuits* The time constant for a CR circuit. *Capacitors in a.c. circuits* Capacitive reactance. *Inductors in d.c. circuits* Self-inductance of a coil Lenz's law Energy stored by an inductor	Investigate the current and potential difference in CR circuits during charging and discharging — possible use of datalogging to determine the time constant for a CR circuit. Investigate applications of capacitors in d.c. circuits. Experiments to investigate the relationship between current, frequency and capacitive reactance. Investigate the factors affecting the size of the induced emf in a coil. Demonstration — neon bulb lit from 1·5 V cell. Investigate the growth and decay of current in a d.c. circuit containing an inductor. Determine the self-inductance of a coil by use of datalogging or waveform capture	$X_C = \frac{V}{I}$ $X_C = \frac{1}{2\pi fC}$ $\varepsilon = -L\frac{dI}{dt}$

Inductors in a.c. circuits Inductive reactance.	Experiments to investigate the relationship between current, frequency and inductive reactance.	$E = \frac{1}{2}LI^2$ $X_L = \frac{V}{I}$ $X_L = 2\pi fL$ Induction cookers, electromagnetic braking, LC filters, tuned circuits, etc.
Electromagnetic radiation The unification of electricity and magnetism Electromagnetic radiation exhibits wave properties Electric and magnetic field components of electromagnetic radiation Relationship between the speed of light and the permittivity and permeability of free space	Investigate the nature of e-m radiation. Estimate the speed of light by determining permittivity using a parallel plate capacitor and determining permeability using a current balance.	Electromagnetic radiation exhibits wave properties as it transfers energy through space. It has both electric and magnetic field components which oscillate in phase, perpendicular to each other and to the direction of energy propagation. $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$

Physics Investigation Unit
This Unit requires the application of different teaching methods/techniques to the other Advanced Higher Physics Units; the following guidance on learning and teaching approaches for this Unit are suggested methods for assessors.

Candidates are required to record the details of the planning cycle. Planning experimental work is likely to involve a certain amount of trialling, with subsequent amendments being made to the initial plan; at Advanced Higher level candidates are expected to maintain a record of their work including the planning stages and any issues and challenges met, together with reasons for proposed amendments. Formal statements and diagrams of the experimental procedures adopted should be included in the investigation report, and therefore are not needed in the work record or diary. However, any evidence of assessing risks that have been undertaken during the planning stage should be included.

Candidates should have regular discussions with assessors on the difficulties and challenges of carrying out the practical work. By observation and discussion, assessors should attest that the candidate has carried out the experimental procedures effectively. The following may contribute to their judgement:

- Candidates should use equipment properly, taking account of any precautions in setting up the equipment.
- Candidates should take responsibility for collecting and putting away equipment as appropriate.

Candidates are required to prove they can use equipment correctly. Meters and measuring devices should be selected to generate experimental data that is within a suitable range and of a suitable accuracy. Evidence of this Outcome could include candidates work record showing they have repeated and checked spurious results.

While candidates can record experimental data in any suitable format — paper based or electronic. Candidates who maintain an ongoing record of work (and they should be strongly advised to do so) may present this as their evidence for a record of experimental data.

All measurements should be recorded. If a mean value is calculated, the data used to calculate that mean should also be available. Tables should normally include headings and units as appropriate. The uncertainties associated with measurements should be included in the record. Whereas the analysis and combination of uncertainties is not required in the record.

It is good practice for the assessor to check the record of work of each candidate on a regular basis and sign and date any part which is to be used as evidence. Candidates should use the record of work to record aims, planning, risk assessments, observations and results of the Investigation. It is also good practice for the assessor to write appropriate comments and advice in the candidate’s work record.

Advanced Higher Physics: Units, prefixes and uncertainties

This table details the content in which candidates should develop knowledge and skills which should be applied in the context of all the component Units of the Course.

Mandatory Course key area	Suggested learning activities	Exemplification of key areas
Units, prefixes and scientific notation Electronvolt Light year Significant figures Scientific notation	SI units used for all standard physical quantities. Use of electronvolt (eV) as an alternative unit of energy in appropriate contexts. Light year (ly) as a measure of distance in appropriate contexts. Appropriate use of significant figures when carrying out calculations using mathematical and physics relationships. Appropriate use of scientific notation for large and small numbers in calculations.	pico (p), nano (n), micro (μ), milli (m), mega (M), giga (G) and tera (T). $E_w = qV$ The final answer should have no more significant figures than the value with the least number of significant figures used in the calculation.
Uncertainties Systematic uncertainties	Systematic uncertainty associated with measurement techniques or experimental design.	Systematic uncertainties occur when readings taken are either all too small or all too large. They can arise due to measurement techniques or experimental design.
Scale reading uncertainties	Reading uncertainty associated with instrument scales.	
Random uncertainties	Calculation of random uncertainty associated with repeated measurements.	
Calibration uncertainties	Calibration uncertainty associated with manufacturer's claim for the accuracy of an instrument.	Calibration uncertainty is a manufacturer's claim for the accuracy of an instrument compared with an approved standard.
Absolute uncertainties Fractional/percentage uncertainties	Calculation of absolute and percentage/ fractional uncertainty.	Absolute uncertainty should be rounded to one significant figure.

Mandatory Course key area	Suggested learning activities	Exemplification of key areas
Appropriate use of significant figures	Experimental numerical results expressed as a value plus absolute uncertainty.	
Data analysis Combination of various types of uncertainties to obtain the total uncertainty in a measurement	Appropriate determination of uncertainty in a final value when several measured quantities are combined. Simple experiments to demonstrate appropriate combinations. (Measurements/ calculations for mass, length, time, density, resistance, volume, etc.)	$\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta X^2}$ $\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$ or combination of percentage uncertainties. Sum, difference, product, quotient of quantities and quantities raised to a power.
Graphical interpretation	Error bars to represent absolute uncertainties on graphs. Estimation of uncertainty in the gradient and intercept of a linear graph.	Various methods possible including the use of functions available in graph drawing software eg linest and trendline functions in Excel.
Accuracy and precision	Comparison of obtained value with accepted or 'true' value.	The accuracy of a measurement compares how close the measurement is to the 'true' or accepted value. The precision of a measurement gives an indication of the uncertainty in the measurement.

Relationships required for Advanced Higher Physics

$$v = \frac{ds}{dt}$$

$$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$$

$$v = u + at$$

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

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

$$\omega = \frac{d\theta}{dt}$$

$$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

$$\omega = \omega_o + \alpha t$$

$$\theta = \omega_o t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_o{}^2 + 2\alpha\theta$$

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

$$a_r = \frac{v^2}{r} = r\omega^2$$

$$F = \frac{mv^2}{r} = mr\omega^2$$

$$T = Fr$$

$$T = I\alpha$$

$$L = mvr = mr^2\omega$$

$$L = I\omega$$

$$E_K = \frac{1}{2} I\omega^2$$

$$F = G\frac{Mm}{r^2}$$

$$V = -\frac{GM}{r}$$

$$v = \sqrt{\frac{2GM}{r}}$$

$$\text{apparent brightness}, \ b = \frac{L}{4\pi r^2}$$

$$\text{Power per unit area} = \sigma T^4$$

$$L = 4\pi r^2 \sigma T^4$$

$$r_{Schwarzschild} = \frac{2GM}{c^2}$$

$$E = hf$$

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

$$mvr = \frac{nh}{2\pi}$$

$$\Delta x \, \Delta p_x \geq \frac{h}{4\pi}$$

$$\Delta E \, \Delta t \geq \frac{h}{4\pi}$$

$$F = qvB$$

$$\omega = 2\pi f$$

$$a = \frac{d^2y}{dt^2} = -\omega^2 y \quad y = A\cos\omega t \quad \text{or} \quad y = A\sin\omega t$$

$$v = \pm\omega\sqrt{(A^2 - y^2)}$$

$$E_K = \frac{1}{2}m\omega^2(A^2 - y^2)$$

$$E_P = \frac{1}{2}m\omega^2 y^2$$

$$y = A\sin 2\pi(ft - \frac{x}{\lambda})$$

$$\phi = \frac{2\pi x}{\lambda}$$

optical path difference $= m\lambda$ or $\left(m + \frac{1}{2}\right)\lambda$

where $m = 0, 1, 2....$

$$\Delta x = \frac{\lambda l}{2d}$$

$$d = \frac{\lambda}{4n}$$

$$\Delta x = \frac{\lambda D}{d}$$

$$n = \tan i_P$$

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$$

$$E = \frac{Q}{4\pi\varepsilon_o r^2}$$

$$V = \frac{Q}{4\pi\varepsilon_o r}$$

$$F = QE$$

$$V = Ed$$

$$F = IlB\sin\theta$$

$$B = \frac{\mu_o I}{2\pi r}$$

$$c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$$

$$t = RC$$

$$X_C = \frac{V}{I}$$

$$X_C = \frac{1}{2\pi fC}$$

$$\mathcal{E} = -L\frac{dI}{dt}$$

$$E = \frac{1}{2}LI^2$$

$$X_L = \frac{V}{I}$$

$$X_L = 2\pi fL$$

$$\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$$

$$\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

Appendix 2: Reference documents

The following reference documents will provide useful information and background.

- Assessment Arrangements (for disabled candidates and/or those with additional support needs) — various publications are available on SQA's website at: www.sqa.org.uk/sqa//14977.html.
- Building the Curriculum 4: Skills for Learning, Skills for Life and Skills for Work
- Building the Curriculum 5: A Framework for Assessment
- Course Specifications
- Design Principles for National Courses
- *Guide to Assessment*
- Overview of Qualification Reports
- Principles and practice papers for curriculum areas
- *SCQF Handbook: User Guide* and SCQF level descriptors
- *SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work*
- *Skills for Learning, Skills for Life and Skills for Work: Using the Curriculum Tool*
- *Coursework Authenticity: A Guide for Teachers and Lecturers*

Administrative information

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History of changes to Advanced Higher Course/Unit Support Notes

Course details	Version	Description of change	Authorised by	Date

Note: You are advised to check SQA's website (**www.sqa.org.uk**) to ensure you are using the most up-to-date version.