SCQF level 7
Unit Specification

Physics: Quanta and Waves

SCQF: level 7 (8 SCQF credit points)

Unit code: J2B7 77

Unit outline

The general aim of this Unit is to develop skills of scientific inquiry, investigation, and analytical thinking, along with knowledge and understanding of quanta and waves. Learners will use these skills when considering how applications of quanta and waves can have impacts on our lives. This application and development of skills can be achieved using a variety of approaches, including investigation and problem solving.

This Unit covers the key areas of introduction to quantum theory, particles from space, simple harmonic motion, waves, interference, and polarisation.

Learners will research issues, apply scientific skills and communicate information related to their findings, which will develop skills of scientific literacy.

Learners who complete this Unit will be able to:

1 Apply skills of scientific inquiry and draw on knowledge and understanding of the key areas of this Unit to carry out an experiment/practical investigation.

2 Draw on knowledge and understanding of the key areas of this Unit and apply scientific skills.

This Unit is available as a free-standing Unit. The Unit Specification should be read in conjunction with the *Unit Support Notes*, which provide advice and guidance on delivery, assessment approaches and development of skills for learning, skills for life and skills for work. Exemplification of the standards in this Unit is given in *Unit Assessment Support*.

Recommended entry

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained the skills, knowledge and understanding required by one or more of the following or equivalent qualifications and/or experience:

- Higher Physics Course or relevant Units

Equality and inclusion

This Unit Specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence. For further information please refer to the *Unit Support Notes.*

Standards

Outcomes and Assessment Standards

Outcome 1

The learner will:

1 Apply skills of scientific inquiry and draw on knowledge and understanding of the key areas of this Unit to carry out an experiment/practical investigation by:

1.1 Planning/designing an experiment/practical investigation
1.2 Following procedures safely
1.3 Making and recording observations/measurements correctly
1.4 Analysing and presenting results in an appropriate format
1.5 Drawing valid conclusions and giving explanations supported by evidence
1.6 Evaluating experimental procedures with justification

Outcome 2

The learner will:

2 Draw on knowledge and understanding of the key areas of this Unit and apply scientific skills by:

2.1 Making accurate statements and giving clear descriptions/explanations
2.2 Solving problems

Evidence Requirements for the Unit

Assessors should use their professional judgement, subject knowledge and experience, and understanding of their learners to determine the most appropriate ways to generate evidence, and the conditions and contexts in which they are used.

The key areas covered in this Unit are:

- introduction to quantum theory
- particles from space
- simple harmonic motion
- waves
- interference
- polarisation

The *Unit Support Notes* (Appendix) provide details of skills, knowledge and understanding sampled in the Unit assessment.

The following table describes the evidence for the Assessment Standards.

Assessment Standard	Evidence Requirements
Planning an experiment or practical investigation	A plan that must include: ♦ a clear statement of the aim ♦ a dependent and independent variable ♦ variables to be kept constant ♦ observations and measurements to be made ♦ necessary equipment and/or materials ♦ a clear and detailed description of how the experiment or practical investigation should be carried out, including safety considerations
Following procedures safely	A record showing the learner was observed following procedures safely
Making and recording observations/measurements correctly	Raw data recorded in a relevant format; for example, a table Repeated measurements, where appropriate Where measurements are repeated, averages must be calculated.
Presenting results in an appropriate format	Results presented in a scatter graph
Drawing a valid conclusion	A conclusion that includes reference to the aim, and is supported by the data
Evaluating experimental procedures	Two evaluative statements, with justifications, about the procedures used
Making accurate statements and solving problems	Achievement of at least 50% of the total marks available in a holistic assessment The assessment must **not** be split into smaller sections, such as individual key areas.

Exemplification of assessment is provided in *Unit Assessment Support*.

Assessment Standard Thresholds

Outcome 1
Learners are not required to show full mastery of the Assessment Standards to achieve Outcome 1. Instead, five out of the six Assessment Standards for Outcome 1 must be met to achieve a pass. Learners must be given the opportunity to meet all Assessment Standards.

Outcome 2
Learners are assessed using a holistic test that covers Assessment Standards 2.1 and 2.2. For Outcome 2, learners must achieve 50% or more of the total marks available in the assessment.

Transfer of evidence

Evidence for the achievement of Outcome 1 for this Unit can be used as evidence for the achievement of Outcome 1 in the SCQF level 7 Units: *Physics: Rotational Motion and Astrophysics* (J2B6 77) and *Physics: Electromagnetism* (J2B8 77).

Evidence for the achievement of Outcome 2 for this Unit is **not** transferable between the SCQF level 7 Units: *Physics: Rotational Motion and Astrophysics* (J286 77) and *Physics: Electromagnetism* (J2B8 77).

Re-assessment

SQA's guidance on re-assessment is that there should be only one or, in exceptional circumstances, two re-assessment opportunities. Re-assessment must be carried out under the same conditions as the original assessment and must be of equal demand.

Outcome 1
Learners can either re-draft their original Outcome 1 report or carry out a new experiment and/or practical investigation.

Outcome 2
Learners must have a full re-assessment opportunity that consists of a holistic assessment. For Outcome 2, learners must achieve 50% of the total marks available in the re-assessment.

Development of skills for learning, skills for life and skills for work

It is expected that learners will develop broad, generic skills through this Unit. The skills that learners will be expected to improve on and develop through the Unit are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work* and drawn from the main skills areas listed below. These must be built into the Unit where there are appropriate opportunities.

1 Literacy
1.1 Reading
1.2 Writing

2 Numeracy
2.1 Number processes
2.2 Money, time and measurement
2.3 Information handling

5 Thinking skills
5.3 Applying
5.4 Analysing and evaluating
5.5 Creating

Amplification of these is given in SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work.* The level of these skills should be at the same SCQF level as the Unit and be consistent with the SCQF level descriptor. Further information on building in skills for learning, skills for life and skills for work is given in the *Unit Support Notes.*

Appendix: Unit Support Notes

Introduction

These support notes provide advice and guidance on skills, knowledge and understanding for the unit assessment. They should be read in conjunction with:

- *Unit Assessment Support*

Developing skills, knowledge and understanding

Teachers and lecturers are free to select the skills, knowledge and understanding, and contexts that are most appropriate for delivery in their centres.

Skills, knowledge and understanding for the unit assessment

The following provides details of skills, knowledge and understanding sampled in the Unit assessment.

Introduction to quantum theory

- Understanding of the challenges to classical theory.
- Black body radiation.
- Photoelectric effect.
- Use of an appropriate relationship to solve problems involving photon energy and frequence.

  $E = hf$

- Knowledge of the Bohr model of the atom.
- Use of an appropriate relationship to solve problems involving the angular momentum of an electron and its principal quantum number.

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

- Wave particle duality.
- Description of experimental evidence for wave particle duality.
- De Broglie waves.
- Use of an appropriate relationship to solve problems involving the de Broglie wavelength of a particle and its momentum.

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

- Uncertainty principle.
- Use of appropriate relationships to solve problems involving the uncertainties in position, momentum, energy, and time.

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

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

- Understanding of implications of quantum mechanics and the uncertainty principle.

Particles from space

- Cosmic rays.
  Knowledge of the origin and composition of cosmic rays, the interaction of cosmic rays with Earth's atmosphere, and the helical motion of charged particles in the Earth's magnetic field.

- Use of appropriate relationships to solve problems involving the force on a charged particle, its charge, its mass, its velocity, the radius of its path, and the magnetic induction of a magnetic field.

  $F = qvB$

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

- Solar wind.

  Knowledge of the interaction of the solar wind with Earth's magnetic field and the composition of the solar wind as charged particles (for example, protons and electrons) in the form of plasma.

Simple harmonic motion

- Definition of SHM in terms of the restoring force and acceleration proportional to and in the opposite direction to the displacement from the rest position.

  $F = -ky$

- Use of appropriate relationships to solve problems involving the displacement, velocity, acceleration, angular frequency, period, and energy of an object executing SHM.

  $\omega = 2\pi f = \frac{2\pi}{T}$

  $a = \frac{d^2y}{dt^2} = -\omega^2 y$

  $y = A\cos\omega t$ or $y = A\sin\omega t$

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

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

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

- Derivation of the relationships

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

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

- Knowledge of the effects of damping in SHM (to include underdamping, critical damping, and overdamping).

Waves

- Use of an appropriate relationship to solve problems involving the energy transferred by a wave and its amplitude.

  $E = kA^2$

- Knowledge of the mathematical representation of travelling waves.

- Use of appropriate relationships to solve problems involving wave motion, phase difference, and phase angle.

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

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

- Knowledge of the superposition of waves and stationary waves.

Interference

- Knowledge of the conditions for constructive and destructive interference in terms of coherence and phase.
- Explanation of interference by division of amplitude, including optical path length, geometrical path length, phase difference, optical path difference, thin film interference, and wedge fringes.
- Derivation of the relationship

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

- Use of appropriate relationships to solve problems involving interference of waves by division of amplitude.

$$opd = n \times gpd$$

$opd = m\lambda$ or $\left(m + \frac{1}{2}\right)\lambda$ where $m = 0, 1, 2...$

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

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

- Explanation of interference by division of wavefront, including Young's slits interference.
- Use of appropriate relationships to solve problems involving interference of waves by division of wavefront.

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

Polarisation

- Explanation of the polarisation of transverse waves, including polarisers, analysers, and Brewster's angle.
- Derivation of the relationship

$$n = \tan i_p$$

- Use of an appropriate relationship to solve problems involving Brewster's angle and refractive index.

$$n = \tan i_p$$

Advanced Higher Physics: Units, prefixes and uncertainties

Mandatory course key area	Exemplification of key areas
Knowledge and use of appropriate units, prefixes and scientific notation, eg electronvolt, light year. 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.
Use of an appropriate number of significant figures in final answers.	The final answer should have no more significant figures than the data with the fewest number of significant figures given in the question.
Knowledge and use, where appropriate, of uncertainties, including systematic uncertainties, scale reading uncertainties, random uncertainties, and calibration uncertainties. Calculations involving absolute uncertainties and fractional/percentage uncertainties	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. Calibration uncertainty is a manufacturer's claim for the accuracy of an instrument compared with an approved standard.
Appropriate use of significant figures in absolute uncertainties.	Absolute uncertainty should be rounded to one significant figure (two if the first number is small).

Mandatory course key area	Exemplification of key areas
Data analysis Combination of various types of uncertainties to obtain the total uncertainty in a measurement. $\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$ Combination of uncertainties in measured values to obtain the total uncertainty in a calculated value. $\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$ $\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$ $\left(\frac{\Delta W^n}{W^n}\right) = n\left(\frac{\Delta W}{W}\right)$	
Graphical interpretation Use of 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, for example linest and trendline functions in Excel.
Understanding the meaning of the terms accuracy and precision with reference to the comparison of an obtained value with a 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.

Administrative information

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Superclass: RC

History of changes to National Unit Specification

Version	Description of change	Authorised by	Date
2.0	Significant changes to Outcomes and Assessment Standards. Significant changes to Evidence Requirements.	Qualifications Development Manager	April 2015
3.0	Level changed from Advanced Higher to SCQF level 7 Unit code updated	Qualifications Manager	July 2019
4.0	Information that had been omitted now added regarding assessment methodologies.	Qualifications Manager	October 2020
5.0	Refined guidance on Evidence Requirements; removed option for assessment-standard-specific evidence for Outcome 2. Added 'Assessment Standards thresholds' heading to existing information. Refined guidance on re-assessment. Content statements and relationships added. Some changes made to the format throughout the document to improve accessibility. **What you need to do differently** ♦ If you are already assessing outcome 2 holistically at the end of the unit, by using the assessment as a single test with marks and a cut-off score, you don't need to do anything differently.	Qualifications Manager	August 2025

Version	Description of change	Authorised by	Date
5.0 (cont)	♦ If you have been assessing outcome 2 atomistically, by assessing each key area and each problem-solving skill separately, you must change to using the holistic approach for outcome 2. You must do this by administering the test in a single sitting, at the end of the unit, and applying the marks and cut-off score in the unit assessment support pack.	Qualifications Manager	August 2025