SCQF level 6
Unit Specification

Physics: Particles and Waves

SCQF: level 6 (6 SCQF credit points)

Unit code: J20C 76

Unit outline

The general aim of this Unit is to develop skills of scientific inquiry, investigation, analytical thinking, and independent working, along with knowledge and understanding of particles and waves. Learners will apply these skills when considering the applications of particles and waves on our lives. This can be done by using a variety of approaches, including investigation and problem solving.

The Unit covers the key areas of the Standard Model; forces on charged particles; nuclear reactions; wave particle duality; interference and diffraction; refraction of light; spectra.

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:

- National 5 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 an experiment/practical investigation
1.2 Following procedures safely
1.3 Making and recording observations/measurements correctly
1.4 Presenting results in an appropriate format
1.5 Drawing valid conclusions
1.6 Evaluating experimental procedures

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
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:

- the Standard Model
- forces on charged particles
- nuclear reactions
- wave particle duality
- interference and diffraction
- refraction of light
- spectra

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 ♦ measurements and/or observations 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	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 6 Units Physics: Our Dynamic Universe (J20B 76) and Physics: Electricity (J20A 76).

Evidence for the achievement of Outcome 2 for this Unit is **not** transferable between the SCQF level 6 Units Physics: Our Dynamic Universe (J20B 76) and Physics: Electricity (J20A 76).

Re-assessment

SQA's guidance on re-assessment is that there should be 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/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
1.2 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 of 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 developing 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 information provides details of skills, knowledge and understanding sampled in the Unit Assessment.

The Standard Model

- Use of orders of magnitude and awareness of the range of orders of magnitude of length from the very small (sub-nuclear) to the very large (distance to furthest known celestial objects).
- Knowledge of the Standard Model of fundamental particles and interactions.
- Knowledge of evidence supporting the existence of sub-nuclear particles and the existence of antimatter.
- Knowledge that fermions, the matter particles, consist of quarks (six types: up, down, strange, charm, top, bottom) and leptons (electron, muon, and tau, together with their neutrinos).
- Knowledge that hadrons are composite particles made of quarks, that baryons are made of three quarks, and that mesons are made of quark-antiquark pairs.
- Knowledge that the force-mediating particles are bosons (photons, W- and Z-bosons, and gluons).
- Description of beta decay as the first evidence for the neutrino.

Forces on charged particles

- Knowledge that charged particles experience a force in an electric field.
- Knowledge that fields exist around charged particles and between charged parallel plates.
- Sketch of electric field patterns for single-point charges, systems of two-point charges, and between two charged parallel plates.
  Knowledge of the direction of movement of charged particles in an electric field.
- Knowledge that the relationship between potential difference, work, and charge gives the definition of the volt.
- Use of appropriate relationships to solve problems involving the charge, mass, speed, and energy of a charged particle in an electric field and the potential difference through which it moves.

  $$W = QV$$

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

- Knowledge that a moving charge produces a magnetic field.
- Determination of the direction of the force on a charged particle moving in a magnetic field for negative and positive charges (for example, by using the right hand rule for negative charges).
- Knowledge of the basic operation of particle accelerators in terms of acceleration, deflection, and collision of charged particles.

Nuclear reactions

- Use of nuclear equations to describe radioactive decay, fission, and fusion reactions, with reference to mass and energy equivalence.
- Use of an appropriate relationship to solve problems involving the mass loss and the energy released by a nuclear reaction.

$$E = mc^2$$

- Knowledge of coolant and containment issues in nuclear fusion reactors.

Wave particle duality

- Knowledge of the photoelectric effect as evidence supporting the particle model of light.
- Knowledge that photons of sufficient energy can eject electrons from the surface of materials.Use of an appropriate relationship to solve problems involving the frequency and energy of a photon.

$$E = hf$$

- Knowledge that the threshold frequency is the minimum frequency of a photon required for photoemission.
- Knowledge that the work function of a material is the minimum energy of a photon required to cause photoemission.
- Use of appropriate relationships to solve problems involving the maximum kinetic energy of photoelectrons, the threshold frequency of the material, and the frequency of the photon.

$$E_k = hf - hf_0$$
$$E_k = \tfrac{1}{2}mv^2$$
$$v = f\lambda$$

Interference and diffraction

- Knowledge that coherent waves have a constant phase relationship and have the same frequency, wavelength, and velocity.
- Description of the conditions for constructive and destructive interference in terms of the phase difference between two waves.
  Knowledge that maxima and minima are produced when the path difference between waves is a whole number of wavelengths or an odd number of half-wavelengths respectively.
- Use of an appropriate relationship to solve problems involving the path difference between waves, wavelength, and order number.

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

- Use of an appropriate relationship to solve problems involving grating spacing, wavelength, order number and angle to the maximum.

$$d\sin\theta = m\lambda$$

Refraction of light

- Definition of absolute refractive index of a medium as the ratio of the speed of light in a vacuum to the speed of light in the medium.
- Use of an appropriate relationship to solve problems involving absolute refractive index, the angle of incidence, and the angle of refraction.

$$n = \frac{\sin\theta_1}{\sin\theta_2}$$

- Use of appropriate relationships to solve problems involving the angles of incidence and refraction, the wavelength of radiation in each medium, and the speed of the radiation in each medium. (Including situations where light is travelling from a more dense to a less dense medium.)

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

$$v = f\lambda$$

- Knowledge of the variation of refractive index with frequency.
- Knowledge of critical angle and of total internal reflection.
- Use of an appropriate relationship to solve problems involving critical angle and refractive index.

$$\sin\theta_c = \frac{1}{n}$$

Spectra

- Knowledge that irradiance is the power per unit area incident on a surface.
- Use of an appropriate relationship to solve problems involving irradiance, the power of radiation incident on a surface, and the area of the surface.

$$I = \frac{P}{A}$$

- Knowledge that irradiance is inversely proportional to the square of the distance from a point source.
- Use of an appropriate relationship to solve problems involving irradiance and distance from a point source of light.

$$I = \frac{k}{d^2}$$

$$I_1 d_1^2 = I_2 d_2^2$$

- Knowledge of the Bohr model of the atom.
- Knowledge of the terms *ground state, energy levels, ionisation, and zero potential energy* in relation to the Bohr model of the atom.
- Knowledge of the mechanism of production of line emission spectra, continuous emission spectra, and absorption spectra in terms of electron energy level transitions.

- Use of appropriate relationships to solve problems involving energy levels and the frequency of the radiation emitted or absorbed.

  $E_2 - E_1 = hf$

  $E = hf$

- Knowledge that the absorption lines in the spectrum of sunlight provide evidence for the composition of the Sun's upper atmosphere.

Units, prefixes, and uncertainties

Units, prefixes and scientific notation	Notes
Appropriate use of units and prefixes. Use of the appropriate number of significant figures in final answers. Appropriate use of scientific notation.	SI units should be used with all the physical quantities. Prefixes should be used where appropriate. These include pico (p), nano (n), micro (μ), milli (m), kilo (k), mega (M), giga (G) and tera (T). In carrying out calculations and using relationships to solve problems, it is important to give answers to an appropriate number of significant figures. This means that the final answer can have no more significant figures than the value with least number of significant figures used in the calculation. Candidates should be familiar with the use of scientific notation and this may be used as appropriate when large and small numbers are used in calculations.
Uncertainties	
Awareness of random and systematic uncertainties in a measured quantity. Use of an appropriate relationship to determine the random uncertainty in a value using repeated measurements. Appropriate use of uncertainties in data analysis.	All measurements of physical quantities are liable to uncertainty, which should be expressed in absolute or percentage form. Random uncertainties occur when an experiment is repeated and slight variations occur. Scale reading uncertainty is a measure of how well an instrument scale can be read. Random uncertainties can be reduced by taking repeated measurements. 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. The random uncertainty is calculated by dividing the difference between the largest and smallest measured value by the number of trials. $\Delta x = \frac{(\text{max} - \text{min})}{n}$ The mean of a set of readings is the best estimate of a 'true' value of the quantity being measured. When systematic uncertainties are present, the mean value of measurements will be offset. When mean values are used, the approximate random uncertainty should be calculated. When an experiment is being undertaken and more than one physical quantity is measured, the quantity with the largest percentage uncertainty should be identified and this may often be used as a good estimate of the percentage uncertainty in the final numerical result of an experiment. The numerical result of an experiment should be expressed in the form final value $\pm$uncertainty.

Administrative information

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Superclass: RC

History of changes to National Unit Specification

Version	Description of change	Authorised by	Date
2.0	Page 1 – the description of key areas under 'Unit outline' has been revised to give more information Page 3 – in Outcome 1.3, the word 'accurately' has been replaced by 'correctly'. Pages 3-4 – the Evidence requirements have been rewritten to better explain what is required; information has been added on Transfer of Evidence	Qualifications Development Manager	April 2014
3.0	Assessment Standards 2.2 & 2.3 removed	Qualifications Development Manager	June 2014
4.0	Level changed from Higher to SCQF level 6. Assessment standard threshold added.	Qualifications Manager	September 2018
5.0	Unit code updated	Qualifications Manager	July 2019
6.0	Information that had been omitted regarding assessment methodologies now added.	Qualifications Manager	October 2020
7.0	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. Some changes made to the format throughout the document to improve accessibility.	Qualifications Manager	August 2025

Version	Description of change	Authorised by	Date
7.0 (cont)	**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. ♦ 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