Higher National Unit specification

General information

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Unit code: H93K 35

Superclass: RC

Publication date: May 2015

Source: Scottish Qualifications Authority

Version: 03

Unit purpose

This Unit is designed to enable learners to understand key aspects of relativity and quantum mechanics, and to develop research skills. The Unit is suitable for learners studying at HND level, and will provide the necessary underpinning knowledge to enable progression to further study of relativity and quantum mechanics at degree level or to seek employment in science based industries.

Outcomes

On successful completion of the Unit the learner will be able to:

1 Explain and apply concepts of the Special Theory of Relativity.
2 Describe the General Theory of Relativity.
3 Describe and apply concepts of quantum mechanics.
4 Produce a report on an application of relativity or quantum mechanics.

Credit points and level

1 Higher National Unit credit at SCQF level 8: (8 SCQF credit points at SCQF level 8)

Recommended entry to the Unit

Entry is at the discretion of the centre, however it is recommended that learners should have completed the HN Units H8XP 33 *Mathematics for Science 1* and H93H 34 *Physics Principles: Mechanics* or equivalent, or have experience of Physics and Mathematics at Higher level.

Higher National Unit Specification: General information (cont)

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Core Skills

Achievement of this Unit gives automatic certification of the following Core Skills component:

Complete Core Skill	None
Core Skill component	Critical Thinking at SCQF level 6 Using Number at SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the Support Notes of this Unit specification.

Context for delivery

If this Unit is delivered as part of a Group Award, it is recommended that it should be taught and assessed within the subject area of the Group Award to which it contributes.

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.

Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**.

Higher National Unit specification: Statement of standards

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Where evidence for Outcomes is assessed on a sample basis, the whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Explain and apply concepts of the Special Theory of Relativity.

Knowledge and/or Skills

- Inertial frame of reference, inertial observer
- Einstein's two postulates
- Time dilation
- Length contraction
- The Lorentz transformations for length, time and velocity
- Relativistic momentum
- The Doppler effect for electromagnetic waves
- Relativistic rest mass energy
- Relativistic kinetic energy
- Total energy

Outcome 2

Describe the General Theory of Relativity.

Knowledge and/or Skills

- The equivalence principle
- Tidal effect
- Curvature of spacetime
- Gravitational waves
- The gravitational deflection of light
- Gravitational lensing

Higher National Unit specification: Statement of standards (cont)

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Outcome 3

Describe and apply concepts of quantum mechanics.

Knowledge and/or Skills

- Dual wave-particle nature of matter
- Particle energy
- Particle momentum
- De Broglie wavelength
- Heisenberg Uncertainty Principle, for position and momentum
- Schrödinger's General 1D wave equation
- Particle in a box: energy level and wave function
- Particle in a box: tunnelling
- Standard particle model, including Higgs boson
- Simple Feynman diagrams

Outcome 4

Produce a report on an application of relativity or quantum mechanics.

Knowledge and/or Skills

- Researching relevant topic
- Collation of sources of information
- Research findings
- Referencing

Higher National Unit specification: Statement of standards (cont)

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Evidence Requirements for this Unit

Written and/or oral recorded evidence for Outcomes 1−3 should be assessed using a holistic closed-book assessment under supervised conditions. The assessment will use a sampling approach to the Knowledge and/or Skills as detailed below. It is recommended that the assessment be completed within two hours. Learners can only have access to the *SQA Databook for HN Physics* or any suitable replacement when sitting the assessment.

Written and/or oral recorded evidence for Outcome 4 should be assessed using an open-book assessment in unsupervised conditions.

Outcome 1

The assessment will sample 6 of the 10 Knowledge and/or Skills items. Learners will not have prior knowledge of which items are being assessed. Those items which are not sampled must be covered in the alternative (re-sit) assessment.

Where an item is sampled, a learner's response will be judged satisfactory where the evidence shows that the learner can:

- Explain the term inertial frame of reference or inertial observer.
- State Einstein's two postulates of Special Relativity; explain that a consequence of the second postulate is that it is impossible for an inertial observer to travel at c, the speed of light in a vacuum.
- Derive and apply the formula for time dilation.
- Derive and apply the formula for length contraction.
- Solve a problem using a Lorentz transformation.
- Apply the relativistic momentum formula.
- Describe the Doppler effect; apply the Doppler equation for light moving either towards or away from an observer.
- Perform calculations to determine relativistic rest mass energy.
- Perform calculations to determine relativistic kinetic energy.
- Solve an energy problem using total energy, rest mass energy and kinetic energy relationship or total energy, rest mass energy and momentum relationship.

Higher National Unit specification: Statement of standards (cont)

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Outcome 2

The assessment will sample 4 of the 6 Knowledge and/or Skills items. Learners will not have prior knowledge of which items are being assessed. Those items which are not sampled must be covered in the alternative (re-sit) assessment.

Where an item is sampled, a learner's response will be judged satisfactory where the evidence shows that the learner can:

- Describe the equivalence principle; describe an example of the equivalence principle.
- Describe the tidal effect; describe an example of the tidal effect.
- Explain in General Relativity that space is curved, over long distances parallel lines meet at a point.
- Describe gravitational waves; describe how gravitational waves are produced; describe how gravitational waves are indirectly detected.
- Describe the gravitational deflection of light and the effect it can have on a planet's orbit.
- Explain the effect of gravitational lensing; explain the cause of gravitational lensing; describe the effect gravitational lensing has on the image of a cosmic body, as viewed by an observer.

Outcome 3

The assessment will sample 6 of the 10 Knowledge and/or Skills items. Learners will not have prior knowledge of which items are being assessed. Those items which are not sampled must be covered in the alternative (re-sit) assessment.

Where an item is sampled, a learner's response will be judged satisfactory where the evidence shows that the learner can:

- Describe the dual wave-particle nature of matter.
- Perform calculations to determine particle energy.
- Perform calculations to determine particle momentum.
- Perform calculations to determine the De Broglie wavelength of a particle.
- Apply Heisenberg's Uncertainty Principle to a particle for position and momentum.
- Describe what is represented by each of the 3 main building blocks of Schrödinger's General 1D wave equation.
- Apply Schrödinger's equation to a particle in a box to determine energy and wave functions at different specified levels.
- Describe an application of tunnelling.
- Describe the Standard particle model including: quarks and lepton particles, Gauge bosons, Higgs boson; describe how bosons act as force carriers.
- Analyse simple Feynman diagrams, applying conservation of charge.

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Outcome 4

The assessment will cover all of the Knowledge and/or Skills items. A learner's response will be judged satisfactory where the evidence shows that the learner can:

- Select a relevant research topic.
- Use a range of reliable sources to obtain relevant information.
- Present research findings.
- Include references for all sources used.

Learners will be required to produce a 1,500−2,000 word report on an application of relativity or quantum mechanics. The report must contain a title, introduction, critical discussion and conclusions.

The report should be concise, appropriately structured, correctly referenced, and the past tense and the impersonal voice should be used. The work should be relevant, original, and contain a substantial scientific content.

Where a report does not meet required standard, then the learner will be given a single opportunity to re-draft. If the required standard is still not attained, then an alternative application to research will be set.

Higher National Unit Support Notes

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Unit Support Notes are offered as guidance and are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

This Unit is intended as part of the framework for HNC/D Applied Sciences, but may be suitable for inclusion in other HN Science awards. It is designed to develop the theoretical aspects of relativity and quantum mechanics introduced in the HN Units H8XP 33 *Mathematics for Science 1* and H93H 34 *Physics Principles: Mechanics*.

Outcome 1 — Explain and apply concepts of the Special Theory of Relativity

- Principle of Relativity states; the laws of physics are the same in all inertial frames of reference. The speed of light in a vacuum is the same in all inertial frames and is independent of the motion of the source.

- Events that appear simultaneous to one observer may not appear simultaneous to another observer. Variation in length, time measurements and velocity, depending on inertial frame of reference. Moving clocks run slower. In order for the principles of conservation of momentum and energy to be valid in all inertial frames, then Newton's second law and the equations for momentum and energy need to be revised. Second postulate implies the speed of light, c is the maximum possible speed.

- Describe thought experiments, to demonstrate simultaneity, time dilation, length contraction. Show derivations of $t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$ and $l = l_0\sqrt{1 - \frac{v^2}{c^2}}$

  Solve problems using these formulae.

- Show the derivation of the Lorenz co-ordinate and velocity transformation equations. Carry out calculations using the Lorenz velocity transformation equations. Lorentz velocity transforms, where u is relative constant velocity between frames.

$$v' = \frac{v_x - u}{\sqrt{1 - \frac{uv_x}{c^2}}}$$

$$v_x = \frac{v'_x + u}{1 + \frac{uv'_x}{c^2}}$$

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- Explain that to preserve conservation of linear momentum, the linear momentum formula must be modified. Relativistic momentum, $\vec{p}$ is given by

$$\vec{p} = \frac{m\vec{v}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

- Describe the Doppler effect for electromagnetic waves; light from a source changes its frequency depending on the relative movement between the source and observer. Carry out calculations for light sources moving towards and away from observer, using

$f = \sqrt{\frac{c+u}{c-u}}\, f_0$ when source is moving towards the observer

$f = \sqrt{\frac{c-u}{c+u}}\, f_0$ when source is moving away from the observer

- Use rest energy, $E = mc^2$

- Show derivation of and relativistic kinetic energy K

$$K = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} - mc^2$$

- Show total energy E = sum of kinetic energy + rest energy

$$E = K + mc^2 = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

  Show relationship between total energy E and momentum

  $E^2 = (mc^2)^2 + (pc)^2$

  Solve problems using these equations.

Higher National Unit Support Notes (cont)

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Outcome 2 — Describe the General Theory of Relativity

- Special Relativity is incompatible with Newton's laws of gravity, the General theory addresses these. Description of the equivalence principle: observers who perform experiments in free fall produce the same results as those of an inertial observer. Examples include — if you are in an isolated lift cabin and drop an object, the object falls to the ground — this could occur either as expected on earth, or in deep space, where gravity is zero, but frame is accelerating at 9.81 ms^{-2}.

- Explanation of tidal effect with examples — real gravitational fields are inhomogeneous, eg two spheres are dropped in an enormous lift that is free falling from a great height, towards earth's centre. To an observer in the lift, the spheres do not fall, but will be observed to move towards each other. If this happened in a lift on earth, at a distance of 1 metre, the effect is practically undetectable.

- Explanation that in Special theory, inertial frames move in gravity-free space, in straight lines, at constant speed relative to observers, parallel lines never meet. In general theory, space is curved, parallel lines meet, however over short distances, curved lines appear linear. If a mass is placed in empty space, it will lead to a curvature of space-time, it will cause a distortion of space-time. Empty space is flat.

- Explanation that gravitational waves are small distortions of space-time geometry that are propagated through space as waves. Compare to sound waves; a distortion in one area of space causes distortions in neighbouring regions, results in a moving distortion, at the speed of light.

- Explanation of distortions of geometry: gravitational waves act by rhythmically distorting distances between free falling objects; objects simultaneously stretch in one direction and shrink in the perpendicular direction. Describe what produces gravitational waves, eg heavenly bodies orbiting in space, eg two orbiting neutron stars, or, a neutron star orbiting a black hole, collisions, stellar matter jettisoned into space during explosions. Describe how they are indirectly detected; observed decrease in orbital period of neutron stars 'PSR913+16'; as gravitational waves take away energy, orbit becomes closer and faster.

- Einstein predicted that light is deflected by gravity. First observed in 1919, the observed position of a star apparently changes slightly, when light from the star passes close to the sun; the sun deflects starlight. Describe Mercury's orbit (closest planet to the sun) — Kepler's laws predicted an elliptical orbit, Einstein predicted a relativistic perihelion shift; the points closest (perihelion) and furthest (aphelion) from the sun in each orbit, shift slightly during each orbit. Show diagrams.

- Gravitational lensing is a consequence of the deflection of light. Light that passes close to a massive body is deflected. Light from a cosmic body may reach the observer through multiple paths simultaneously; consequently the observer sees multiple images of the cosmic body, in different positions. Show images of effect.

Higher National Unit Support Notes (cont)

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Outcome 3 — Describe and apply concepts of quantum mechanics

- Dual wave-particle properties of light, giving examples: diffraction, photoelectric effect, emission/absorption spectra and lasers. Planck's hypothesis E = hf
- Particle energy $E = hf = \frac{hc}{\lambda}$
- Photon momentum $p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$
- De Broglie's wavelength formula: $\lambda = \frac{h}{p} = \frac{h}{mv}$. Apply this formula to solve problems.
- Heisenberg's Uncertainty Principle: description of the two slit interference experiment for electrons and associated results. Heisenberg Uncertainty Principle (1927):

  $\Delta x \Delta p_x \geq \frac{\hbar}{2}$ $\quad (Position\ and\ momentum)$

  $\Delta t \Delta E \geq \frac{\hbar}{2}$ $\quad (energy\ and\ time)$

  Where $\hbar = \frac{h}{2\pi}$
- Apply these formulas to solve problems.

- Consider a free particle, moving in a straight line, with no forces acting on it. State that the 1D Schrödinger equation for a free particle is:

  $$-\frac{\hbar^2}{2m}\frac{\delta^2 \psi(x,t)}{\delta x^2} + U(x)\psi(x,t) = i\hbar\frac{\delta\psi(x,t)}{\delta t}$$

  and

  $$\psi(x,t) = \psi(x)e^{-iEt/\hbar}$$

  Show that this is an energy formula; $E_k + E_p = E_{Total}$
  where

  The $-\frac{\hbar}{2m}\frac{\partial^2\Psi(x,t)}{\partial x^2}$ term is related to the Kinetic energy of the particle,

  The $U(x)\Psi(x,t)$ term relates to Potential energy

  The $i\hbar\frac{\partial\Psi(x,t)}{\partial t}$ term relates to Total energy

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- Consider a particle of mass m, in a box, ie in an infinitely deep square potential well, of width L. Calculate the energy levels using
  $$E_n = \frac{P_n^2}{2m} = \frac{n^2 h^2}{8mL^2} = \frac{n^2 \pi^2 \hbar^2}{2mL^2} \quad (n = 1,2,3 \ldots \ldots)$$

- Potential barriers and tunnelling. Consider a particle in a well of finite depth. Calculate the probability that the particle may penetrate/tunnel through the potential energy barrier, using
  $$T = Ge^{-2kL} \qquad where\ G = 16\frac{E}{U_0}\left(1 - \frac{E}{U_0}\right)\ and\ k = \frac{\sqrt{2m(U_0 - E)}}{\hbar}$$

- Describe the standard model including:

  Matter particles: Quarks and Leptons
  Force Carriers: Gauge bosons + Higgs boson

  The model and its properties are shown below.

Quark types (flavours)			*Charge carried*	*Spin*
Up (u)	*Charm (c)*	*Top (t)*	*2/3*	*½*
Down (d)	*Strange (s)*	*Bottom or beauty (b)*	*-1/3*	*½*

Leptons			*Charge carried*	*Spin*
Electron, e	*Muon, μ*	*Tau, τ*	*-1*	*½*
anti-electron neutrino, ν_e	*Anti-muon neutrino, ν_μ*	*antii-tau neutrino, ν_τ*	*0*	*½*

Gauge bosons	***Forces***	***Charge***	***Spin***
Gluon, g	Strong	0	*1*
Photon, γ	*Electromagnetic*	*0*	*1*
$W^{\pm}$	*Weak*	*±1*	*1*
Z	*Weak*	*0*	*1*

Higgs bosons	***Force***	*Charge*	*Spin*
h	Associated with weak force	0	*0*

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Explain that Gauge bosons act as force carriers, moving between particles.

Show properties of constituent quarks determine charge of bound states, eg proton is a bound state and contains u +u + d quarks, therefore the proton charge is 2/3 + 2/3 -1/3 = 1.

Describe the early prediction of the existence of a missing particle, the long search for the Higgs boson; its discovery completed the standard model.

The Higgs boson is associated with the weak force, it is known to have an energy of 125GeV and disappears immediately. Higgs added an additional force to the mathematical model, shaped like a Mexican hat, that gave the boson mass.

Draw simple Feynman diagrams and show that at each vertex, the total charge is conserved (show that at each vertex, total momentum is also conserved).

Outcome 4 — Produce a report on an application of relativity or quantum mechanics

Outcome 4 could cover any suitable topic areas from Outcomes 1, 2 or 3.

Applications of relativity could include:

- An aspect of General Relativity
- An aspect of Special Relativity
- Experimental results for Special Theory of Relativity
- The Doppler effect
- Black holes
- Big Bang Model

Applications of quantum mechanics could include:

- The discovery/search for the Higgs boson
- The standard particle model
- Research beyond the standard particle model
- Large Hadron Colliders
- Feynman diagrams
- Importance of tunnelling effects

Higher National Unit Support Notes (cont)

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Guidance on approaches to delivery of this Unit

It is recommended that Outcomes 1−3 be taught in order. Outcome 4 requires learners to research a topic and this Outcome may be given early in the delivery of this Unit.

Outcome 1 could commence with an introduction of the basic terms and principles: inertial frames of reference, constancy of speed of light, laws of physics are the same in all inertial frames. Delivery could then focus on a description of thought experiments to demonstrate simultaneity, time dilation and length contraction. Learners should be able to apply derivation of time dilation and length contraction to solve problems. Learners could then be introduced to the Lorenz co-ordinate and velocity equations, and the concept of relativistic momentum before applying it to solve problems. The Doppler effect for sources moving towards/away from the observer should be described before learners apply it to frequency problems. Learners should be able to use given relativistic energy formula, without having to derive them.

Outcome 2 is purely descriptive and could commence with a description of the limitations of the Special Theory of Relativity — it is incompatible with gravity. Delivery could then focus on a description of the equivalence principle using thought experiments. General theory could then be described and compared to the Special Theory. Demonstrations using a sphere on a rubber sheet or a video of the demonstration could be used to exemplify that empty space is flat, however a large mass causes a disturbance in space-time. Gravitational waves, what they are and how they are produced could then be described. The bending of light by gravity and gravitational lensing could then be described and exemplified by the use of satellite images of these effects. Learners should be encouraged to research, make use of thought experiments and virtual physics to help describe the principles.

A good resource for Outcome 2 is: **www.einstein-online.info**

Outcome 3 could commence with an overview of the dual wave-particle properties of light, before moving on to explain Planck's hypothesis. Delivery could then focus on the derivation of photon energy, momentum and De Broglie's wavelength. The two slit interference experiment for electrons and the associated results could then be discussed before leading to Heisenberg's Uncertainty Principle and his formulae, which learners should use to solve simple problems. Learners should be able to use Schrödinger's wave equation to calculate energy levels of particles in an infinitely deep well, and discuss tunnelling, its significance and calculate probability of tunnelling. The standard particle model could be described and the historical timeline of discoveries discussed. Learners should be able to draw and use simple Feynman diagrams.

A good resource for Outcome 3 is **http://hyperphysics.phy-astr.gsu.edu**

Outcome 4 could cover any suitable topic areas from Outcomes 1, 2 or 3. Learners could be made aware of this Outcome early in the Unit, so that they can think about their essay choice. A selection of suitable topics should be offered to learners, alternatively learners may suggest their own subject, but it should be prior approved by the lecturer.

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Guidance on approaches to assessment of this Unit

Evidence can be generated using different types of assessment. The following are suggestions only. There may be other methods that would be more suitable to learners.

Outcomes 1−3 could be assessed by a single holistic closed-book assessment with an appropriate cut-off score that covers the sampling requirements as detailed in the Evidence Requirements. Assessment should be carried out in supervised conditions, and it is recommended that the assessment be completed within 120 minutes. Learners can only have access to the *SQA Databook for HN Physics* or any suitable replacement when sitting the assessment.

Where evidence of Outcomes 1−3 is assessed by sampling, the whole of the content listed in the Knowledge and/or Skills must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed, and different items should be sampled on each assessment occasion. Any items not sampled in the first assessment, must be included in the alternative (re-sit) assessment.

In Outcome 4 learners are required to produce a 1,500−2,000 word report on an application of relativity or quantum mechanics in open-book, unsupervised conditions. It is the responsibility of the centre to take reasonable steps to ensure that the report is the work of the learner.

An exemplar instrument of assessment with marking guidelines has been produced to indicate the notional standard of achievement at SCQF level 8.

Centres are reminded that prior verification of centre-devised assessments would help to ensure that the national standard is being met. Where learners experience a range of assessment methods, this helps them to develop different skills that should be transferable to work or further and higher education.

Opportunities for e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all learner evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. The most up-to-date guidance on the use of e-assessment to support SQA’s qualifications is available at **www.sqa.org.uk/e-assessment**.

Higher National Unit Support Notes (cont)

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

Opportunities for developing Core and other essential skills

The delivery and assessment of this Unit will provide learners with the opportunity to develop the Core Skills of *Numeracy* and *Problem Solving* at SCQF level 6, and *Information and Communication Technology (ICT)* at SCQF level 5.

Numeracy **— Using Number at SCQF level 6**

Learners will be required to solve complex problems, involving several stages, and requiring a number of sustained complex calculations.

Problem Solving **— Reviewing and Evaluating at SCQF level 6**

Learners will be required to search for information to create a report or poster that will develop their planning and organising skills.

Problem Solving **— Critical Thinking at SCQF level 6**

Learners will be required to evaluate selected information to create a report or poster that will develop their critical thinking skills.

Information and Communication Technology **(ICT) — Accessing Information at SCQF level 5**

Learners will make effective and appropriate use of the internet and/or databases to source information on an application for Outcome 4.

Information and Communication Technology **(ICT) — Providing/Creating Information at SCQF level 5**

Learners will make effective and appropriate use of ICT packages to create a short report or a poster. Packages used will likely include word processing and presentation packages.

This Unit has the Critical Thinking and Using Number components of Problem Solving embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show they have achieved Critical Thinking at SCQF level 6 and Using Number at SCQF level 6.

History of changes to Unit

Version	Description of change	Date
03	Page 7— Word count for report adjusted from 1,000-1,500 words to 1,500-2,000 words.	14/06/2016
03	Page 15— Word count for report adjusted from 1,000-1,500 words to 1,500-2,000 words.	14/06/2016
03	Page 19— Word count for report adjusted from 1,000-1,500 words to 1,500-2,000 words.	14/06/2016
02	Core Skills Components Critical Thinking and Using Number at SCQF level 6 embedded	28/07/2015

Additional copies of this Unit specification can be purchased from the Scottish Qualifications Authority. Please contact the Business Development and Customer Support team, telephone 0303 333 0330.

General information for learners

Unit title: Relativity and Quantum Mechanics (SCQF level 8)

This section will help you decide whether this is the Unit for you by explaining what the Unit is about, what you should know or be able to do before you start, what you will need to do during the Unit and opportunities for further learning and employment.

This is a 1 credit Unit at SCQF level 8, which you are likely to be studying as part of the second year of an HNC/HND Science programme. Before progressing to this Unit it would be beneficial to have completed the HN Units H8XP 33 *Mathematics for Science 1* and H93H 34 *Physics Principles: Mechanics,* where you will have learned underpinning aspects of relativity and quantum mechanics.

On completion of the Unit you should be able to:

1 Explain and apply concepts of the Special Theory of Relativity.
2 Describe the General Theory of Relativity.
3 Describe and apply concepts of quantum mechanics.
4 Produce a report on an application of relativity or quantum mechanics.

Outcome 1

In this Outcome you will learn about Einstein's Special Theory of Relativity, and you will learn to describe and explain basic terms and concepts, including the Doppler effect. You will apply the concepts of time dilation and length contraction, and you will use Lorentz transformation equations, relativistic momentum and energy equations to solve problems.

You will look at Einstein's Special Theory of Relativity in mathematical detail, comparing the motion of objects that are in different inertial frames that are moving at constant speed relative to each other. You will also look at: time dilation, length contraction, relative speed, Doppler effect, energy and momentum.

Outcome 2

In this Outcome you will learn about the key aspects of the General Theory of Relativity, including the equivalence principle, tidal effects, gravitational waves, gravitational deflection of light and gravitational lensing.

Outcome 3

In this Outcome you will learn about the key concepts of quantum mechanics. You will learn to describe and explain the dual wave-particle nature of matter, the standard particle model including the Higgs boson. You will carry out calculations to determine particle energy, momentum and De Broglie wavelength, and you will apply Schrödinger's wave equation to a particle in a box. You will also apply Heisenberg's Uncertainty Principle, and analyse simple Feynman diagrams.

Outcome 4

In Outcome 4 you will describe an application of an aspect of quantum mechanics or relativity. This requires you to research a suitable topic and present your results in either a short report or a poster.

General information for learners (cont)

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Assessment

For Outcomes 1−3 you will take a closed-book, end of Unit assessment.

In Outcome 4 the assessment involves you producing a 1,500−2,000 word report on an application of relativity or quantum mechanics.

Core Skills

You will have opportunities to develop the Core Skills of *Numeracy* and *Problem Solving* at SCQF level 6, and *Information and Communication Technology (ICT)* at SCQF level 5.