GCSE

Rewarding Learning

CCEA GCSE Specification in

Physics

For first teaching from September 2017
For first assessment in Summer 2018
For first award in Summer 2019
Subject Code: 1210

Contents

Subject Code	1210
QAN	603/1383/3

This specification is available online at www.ccea.org.uk

1 Introduction

This specification sets out the content and assessment details for our GCSE course in Physics. We have designed this specification to meet the requirements of:

- Northern Ireland GCSE Design Principles; and
- Northern Ireland GCE and GCSE Qualifications Criteria.

First teaching is from September 2017. We will make the first award based on this specification in Summer 2019.

This specification is a unitised course. The guided learning hours, as for all our GCSEs, are 120 hours.

The specification supports the aim of the Northern Ireland Curriculum to empower young people to achieve their potential and to make informed and responsible decisions throughout their lives, as well as its objectives:

- to develop the young person as an individual;
- to develop the young person as a contributor to society; and
- to develop the young person as a contributor to the economy and environment.

If there are any major changes to this specification, we will notify centres in writing. The online version of the specification will always be the most up to date; to view and download this please go to www.ccea.org.uk

1.1 Aims

This specification aims to encourage students to:

- appreciate the value of physics in their lives and in the wider world around them;
- develop their knowledge and understanding of physics;
- develop their understanding of the effects of physics on society;
- develop an understanding of the importance of scale in physics;
- develop and apply their knowledge and understanding of the nature of physics and of the scientific process;
- develop their understanding of the relationships between hypotheses, evidence, theories and explanations;
- develop their awareness of risk and the ability to assess potential risk in the context of potential benefits;
- develop and apply their observational, practical, modelling, enquiry and problem-solving skills;
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions both qualitatively and quantitatively; and
- develop their skills in communication, mathematics and the use of technology in scientific contexts.

1.2 Key features

The following are important features of this specification.

- It provides a broad, coherent and practical course that develops confidence in physics and offers students a positive view of science.
- It offers opportunities to build on the skills and capabilities developed through the delivery of the Northern Ireland Curriculum at Key Stage 3.
- The GCSE Physics specification is divided into three units.
- Units 1 and 2 each contain prescribed practicals, with a total of nine practicals to be carried out over the two years of this course.
- Students must carry out these investigations in order to develop their skills and knowledge of practical science.
- Units 1 and 2 are each assessed by a written examination either at Foundation Tier (grades C*–G) or Higher Tier (grades A*–D/E).
- Unit 3 is a practical skills unit that is externally assessed. It is divided into two parts: Booklet A and Booklet B.
- Booklet A consists of two practicals based on two from the prescribed practical list. From 2019, centres will be sent a Materials and Apparatus list in December. A Booklet A for each student will be sent to centres in January. All students will be required to complete these by May. They are marked externally.
- Booklet B is a written, externally assessed examination taken at the end of the final year of study. It consists of questions about planning and carrying out any of the prescribed practical activities, together with more general questions about any practical situation that arises from within the specification.
- From Summer 2019, students may take Unit 1 or Unit 2 at the end of their first year of study. (Please note that in Summer 2018, only Unit 1 is available.)

- Students can resit each unit once, with the better result contributing to their final grade.
- The specification provides a thorough preparation for the study of physics and related courses at GCE Advanced level and Advanced Subsidiary level. It also allows students to develop transferable skills that will benefit them in vocational training and employment.
- There is a range of support available for both teachers and students, including specimen papers, mark schemes and planning frameworks. These resources can be downloaded from our Physics microsite at www.ccea.org.uk
- Details of the mathematical skills expected of students are given in the Appendix.

1.3 Prior attainment

Students do not need to have reached a particular level of attainment before beginning to study this specification.

However, the specification builds on the knowledge, skills and understanding developed through the Northern Ireland Curriculum for science at Key Stage 3.

Before studying this specification, we expect students to have a level of skills in science, numeracy, literacy and communication that is commensurate with having studied science to Key Stage 3.

1.4 Classification codes and subject combinations

Every specification has a national classification code that indicates its subject area. The classification code for this qualification is 1210.

Please note that if a student takes two qualifications with the same classification code, schools, colleges and universities that they apply to may take the view that they have achieved only one of the two GCSEs. The same may occur with any two GCSE qualifications that have a significant overlap in content, even if the classification codes are different. Because of this, students who have any doubts about their subject combinations should check with the schools, colleges and universities that they would like to attend before beginning their studies.

2 Specification at a Glance

The table below summarises the structure of this GCSE course.

Content	Assessment	Weightings	Availability
Unit 1: Motion, Force, Density and Kinetic Theory, Energy, and Atomic and Nuclear Physics	External written examination There are two tiers of entry. Foundation Tier: 1 hour 15 mins Higher Tier: 1 hour 30 mins Students answer compulsory structured questions that include short responses, extended writing and calculations.	37.5%	Summer from 2018
Unit 2: Waves, Light, Electricity, Magnetism, Electromagnetism and Space Physics	External written examination There are two tiers of entry. Foundation Tier: 1 hour 15 mins Higher Tier: 1 hour 30 mins Students answer compulsory structured questions that include short responses, extended writing and calculations.	37.5%	Summer from 2019

Content	Assessment	Weightings	Availability
Unit 3: **Practical Skills**	**Booklet A** Practical skills assessment Externally marked Students carry out two pre-release practical tasks in the final year of study. There are two tiers of entry. Students must take both Booklet A and Booklet B at the same tier. Foundation and Higher Tiers: 2 hours	7.5%	Between 1 January and 1 May from 2019
	Booklet B External written examination Students answer compulsory structured questions that include short responses, extended writing and calculations, all set in a practical context. Foundation Tier: 1 hour Higher Tier: 1 hour 15 mins	17.5%	Summer from 2019

Students must take at least 40 percent of the assessment (based on unit weightings) at the end of the course as terminal assessment.

3 Subject Content

We have divided this course into three units. The content of each unit and the respective learning outcomes appear below.

Content for the **Higher Tier only** is in **bold**.
Questions in Higher Tier papers may be set on any content in the specification.

Content for the Foundation Tier is in normal type.
Questions in Foundation Tier papers will only be set on this content.

The nine prescribed practicals are shown in *italics*. These are assessed in Booklets A and B of Unit 3: Practical Skills.

3.1 Unit 1: Motion, Force, Density and Kinetic Theory, Energy, and Atomic and Nuclear Physics

Motion

In this section, students investigate motion. They establish the relationships between distance, average speed, time and rate of change of speed through practical work. They are introduced to graphical methods of describing motion.
At the Higher Tier, students are introduced to the concept of vectors and scalars and they learn about the terms displacement, velocity and acceleration.

Content	Learning Outcomes
1.1 **Motion**	Students should be able to: 1.1.1 investigate and use the quantitative relationships between initial speed, final speed, average speed, distance moved, rate of change of speed and time, to: • calculate the average speed from linear distance–time graphs; • define that distance is measured in metres (m), speed in metres per second (m/s) and rate of change of speed in metres per second squared (m/s^2); and • recall and use the equations: $\textit{average speed} = \dfrac{\textit{distance moved}}{\textit{time taken}}$ $\textit{average speed} = \dfrac{\textit{initial speed} + \textit{final speed}}{2}$ $\textit{rate of change of speed} = \dfrac{\textit{final speed} - \textit{initial speed}}{\textit{time taken}}$

Content	Learning Outcomes
1.1 **Motion (cont.)**	Students should be able to: 1.1.2 *use simple apparatus, including trolleys, ball-bearings, metre rules, stopclocks and ramps, to investigate experimentally how the average speed of an object moving down a runway depends on the slope of the runway measured as the height of one end of the runway (ICT resources could be used to process the measurements and analyse the data) (Prescribed Practical P1)*;
Vectors and scalars	1.1.3 **demonstrate an understanding that:** • **a vector is a quantity that depends on direction and scalar is a quantity that does not;** • **displacement is a vector and distance is a scalar but both are measured in metres (m);** • **velocity is a vector and speed is scalar but both are measured in metres per second (m/s); and** • **acceleration is a vector and rate of change of speed is a scalar but both are measured in metres per second squared (m/s^2);**
Motion, displacement, velocity and acceleration	1.1.4 **recall and use the quantitative relationships between:** • **displacement, time and average velocity:** $\textit{average velocity} = \dfrac{\textit{displacement}}{\textit{time}}$ • **initial velocity, final velocity, acceleration and time:** $\textit{average velocity} = \dfrac{\textit{initial velocity + final velocity}}{2}$ • **initial velocity, final velocity and average velocity (problems will only be set on motion in one direction):** $\textit{acceleration} = \dfrac{\textit{final velocity - initial velocity}}{\textit{time taken}}$ 1.1.5 **explain that negative acceleration is called retardation.**

Content	Learning Outcomes
Distance–time graphs and speed–time graphs	Students should be able to: 1.1.6 use graphical methods to determine speed, distance and rate of change of speed, applying knowledge that: • the slope of a distance–time graph is the speed; • the slope of a speed–time graph is the rate of change of speed; and • the area under a speed–time graph is the distance moved; **and**
Displacement–time graphs and velocity–time graphs	1.1.7 **use graphical methods to determine velocity, acceleration and displacement, applying knowledge that:** • **the slope of a displacement–time graph is the velocity;** • **the slope of a velocity–time graph is the acceleration; and** • **the area under a velocity–time graph is the displacement.**

Force

In this section, students are introduced to the idea of forces between objects existing as pairs. They learn about the unit of force and the concept of a resultant force. Students investigate Newton's first and second laws through practical investigation or computer simulation. They carry out calculations based on the second law and establish the difference between mass and weight. Experimental investigation of Hooke's law introduces students to the idea of proportionality and teaches them that experimental laws are only valid provided certain conditions are met. They are introduced to the idea of pressure, along with applications that are dependent on the concept. Students find out how to calculate the moment of a force and how to establish the Principle of Moments through practical investigation. They are introduced to the meaning of centre of gravity and learn how it affects the stability of an object.

Content	Learning Outcomes
1.2 **Force**	Students should be able to: 1.2.1 demonstrate understanding that forces arise between objects, that the forces on these objects are equal and opposite, and that friction is a force that always opposes motion; 1.2.2 demonstrate understanding that: • force is measured in newtons (N); and • a force acting in one direction can be given a positive value and one acting in the opposite direction can be given a negative value; 1.2.3 calculate the resultant of two one-dimensional forces using the rule stated in 1.2.2;
Newton's laws	1.2.4 recall that Newton's first law states that in the absence of unbalanced forces an object will continue to move in a straight line at constant speed (i.e. move with constant velocity); and 1.2.5 investigate experimentally Newton's first and second laws, for example using an air track and data logger, or a computer simulation, to study the effect of balanced and unbalanced forces on an object, and through mathematical modelling derive the relationship between resultant force, mass and acceleration.

Content	Learning Outcomes
Mass and weight	Students should be able to: 1.2.6 explain that Newton's second law states that a resultant force will cause an object to accelerate and that the acceleration is proportional to the size of the resultant force; 1.2.7 recall and use the equation: *resultant force = mass × acceleration* 1.2.8 demonstrate understanding that: • mass is defined as the amount of matter in an object and is measured in kilograms (kg); • weight is a force due to the pull of gravity on the object; and • on the Earth the pull of gravity is 10 N on a mass of 1 kg; 1.2.9 use the equation $W = mg$ to calculate the weight W of an object in newtons when given the mass m in kilograms and the value of g in N/kg; 1.2.10 explain that: • all objects in the absence of air resistance (friction) fall at the same rate regardless of their mass; and • due to gravity the speed of an object dropped from rest from a height will increase at the rate of 10 m/s every second as it falls; 1.2.11 **recall that due to gravity an object allowed to fall freely from rest will accelerate at the rate of 10 m/s^2 and this is known as the acceleration of free fall, 'g';** 1.2.12 recall that an object fired vertically upwards will experience a retardation of 10 m/s^2; and
Hooke's law	1.2.13 *investigate experimentally the extension of a spring and how it is related to the applied force, and recall that the extension of a spring is directly proportional to the force applied, provided that the limit of proportionality is not exceeded (Prescribed Practical P2).*

Content	Learning Outcomes
Hooke's law (cont.)	Students should be able to: 1.2.14 recall and use the equation $F = ke$, where F is the applied force, e is the extension of the spring and k is called the spring constant; 1.2.15 demonstrate understanding that the gradient of the graph of force (y-axis) and extension (x-axis) is numerically equal to the spring constant;
Pressure	1.2.16 demonstrate understanding that pressure is the force exerted per m^2 and that the unit of pressure is the pascal (Pa), where $1\ Pa = 1\ N/m^2$; 1.2.17 recall and use the equation $P = \frac{F}{A}$ to calculate pressure, force or area (questions may be set in which cm^2 and mm^2 are used but students will not be expected to convert mm^2 or cm^2 to m^2); 1.2.18 interpret the importance of pressure in a range of everyday situations, for example: • when using a sharp knife, the small area of the blade creates a large pressure, making cutting easier; and • having caterpillar tracks on vehicles means their weight acts over a large area, so reducing the pressure they exert on the ground; and
Moment of a force	1.2.19 define the moment of a force and recall and use the equation *moment = force × perpendicular distance from the pivot* (problems will only be set in which the force and distance are perpendicular to each other).

Content	Learning Outcomes
Principle of Moments	Students should be able to: 1.2.20 *plan and carry out experiments to verify the Principle of Moments using a suspended metre rule and attached weights or a pivoted beam and square weights (Prescribed Practical P3);* 1.2.21 use the Principle of Moments to carry out a practical task to find the weight of an object; 1.2.22 use the Principle of Moments to calculate the size of a force, or its distance from the pivot, when an object is balanced under the turning effects of no more than two forces, one of which could be the object's weight;
Centre of gravity	1.2.23 investigate that the centre of gravity of an object is the point where all of the weight of the object can be considered as acting; 1.2.24 identify the position of the centre of gravity for a disc, a ring and a rectangle; 1.2.25 explain how the position of the centre of gravity and the width of an object's base affect the stability of the object; and 1.2.26 demonstrate understanding of when the weight of an object will have a turning effect.

Density and Kinetic Theory

In this section, students investigate the relationship between the volume of a material and its mass, leading to the concept of density. They are introduced to simple kinetic theory and this is used to explain the differences between the densities of solids, liquids and gases.

Content	Learning Outcomes
1.3 **Density and kinetic theory**	Students should be able to: 1.3.1 *investigate experimentally the relationship between the mass and volume of liquids and regular solids, and analyse and interpret the data gathered (Prescribed Practical P4);* 1.3.2 measure the density of an irregular solid (that sinks in water), and use the displacement method to measure the volume using either a measuring cylinder or a eureka can; 1.3.3 recall and use the equation $density = \frac{mass}{volume}$ to solve simple problems, and recall and use the units of density as g/cm^3 and kg/m^3; 1.3.4 demonstrate understanding that kinetic theory describes matter as a large number of particles and that this theory explains the properties of the different states of matter; and 1.3.5 recall that: • in solids the particles are in fixed positions; • the only motion allowed to them is vibration; • the particles are held in the solid by strong forces; and • this explains why solids have a fixed shape and volume.

Content	Learning Outcomes
1.3 **Density and kinetic theory (cont.)**	Students should be able to: 1.3.6 explain that: • in liquids the particles are mainly touching, but some gaps have appeared in the structure; • these gaps allow the particles to move and, although there are also forces between them, the particles have enough energy to prevent the forces holding them in a fixed arrangement; and • this behaviour of particles explains why liquids have a fixed volume but take on the shape of the container; 1.3.7 demonstrate understanding that: • in a gas, the particles have larger gaps between them and are entirely free to move; and • the forces between particles are weak and this explains why gases completely fill their container; and 1.3.8 use kinetic theory to explain qualitatively that the difference between the densities of solids, liquids and gases is due to the distance between the particles in each state of matter.

Energy

In this section, students examine the various forms of energy and apply the Principle of Conservation of Energy to a range of situations. They study the difference between renewable and non-renewable energy resources, along with their impact on the environment. Students also study the concepts of work, power, and kinetic and gravitational potential energy. They examine heat transfer and its importance in a range of applications.

Content	Learning Outcomes
1.4 Energy	Students should be able to:
Forms of energy	1.4.1 recall that energy can exist in many forms such as chemical, heat, electrical, sound, light, magnetic, strain energy, kinetic and gravitational potential;
Principle of Conservation of Energy	1.4.2 recall that the Principle of Conservation of Energy states that energy can be changed from one form to another but the total amount of energy does not change;
	1.4.3 demonstrate understanding that energy is measured in joules (J) and that 1 J is approximately the energy needed to lift an apple vertically 1 m;
	1.4.4 draw energy transfer diagrams for the energy conversions that occur in a range of common devices found in everyday life and interpret them using the Principle of Conservation of Energy;
Renewable energy resources	1.4.5 explain that renewable energy is defined as energy that is collected from resources that will never run out or which are naturally replenished within a human lifetime;
	1.4.6 evaluate examples of renewable energy such as sunlight, wind, hydroelectricity, tidal, waves, wood and geothermal heat; and
	1.4.7 demonstrate knowledge of how using renewable energy resources can affect the environment, for example causing habitat destruction or visual pollution.

Content	Learning Outcomes
Non-renewable energy resources	Students should be able to: 1.4.8 explain that: • a non-renewable energy resource is one that has a finite supply and it will run out some time; and • fossil fuels such as oil, natural gas and coal are considered non-renewable because they cannot be replaced within a human lifetime;
	1.4.9 demonstrate knowledge that nuclear energy based on fission is also non-renewable since supplies of uranium ore will not last forever;
	1.4.10 demonstrate understanding of how using non-renewable energy resources can affect the environment, for example causing acid rain or global warming;
Efficiency	1.4.11 demonstrate understanding that: • not all of the energy used in a particular process or device is useful; and • the efficiency is a measure of how much of the input energy to a process or device appears as useful output energy;
	1.4.12 recall, demonstrate understanding of and use the equation $efficiency = \frac{useful\ output\ energy}{total\ input\ energy}$ quoting the efficiency as a decimal or a percentage;
Work	1.4.13 demonstrate understanding that work is said to be done when energy changes from one form to another and that the amount of work can be calculated by the equation $work = force \times distance$ and
	1.4.14 recall that work is measured in joules (J), the force in newtons (N) and the distance in metres (m).

Content	Learning Outcomes
Power	Students should be able to: 1.4.15 demonstrate understanding that: • power is the amount of energy transferred in one second or the amount of work done in one second; and • power is measured in watts (W) so 1 W = 1 joule per second (1 W = 1 J/s); 1.4.16 recall and use the equations $power = \frac{energy\ transferred}{time\ taken}$ $power = \frac{work\ done}{time\ taken}$ to calculate power, work done, time taken or energy transferred; 1.4.17 *plan and carry out experiments to measure personal power, either by measuring the time taken to climb a staircase or performing a number of step-ups to a platform (Prescribed Practical P5);* 1.4.18 plan an experiment (or watch a demonstration) to measure the output power of an electric motor, and take measurements to calculate the power of the motor; and
Kinetic energy, E_k	1.4.19 explain that kinetic energy E_k is the energy possessed by a moving object and recall and use the equation $E_k = \frac{1}{2}mv^2$ to calculate kinetic energy in joules, where m is the mass of the object in kg and v is the speed of the object in m/s.

Content	Learning Outcomes
Gravitational potential energy, E_p	Students should be able to: 1.4.20 demonstrate understanding that an object has gravitational potential energy E_p because of its position above the ground; 1.4.21 recall and use the equation $E_p = mgh$ to calculate the potential energy in joules, where m is the mass in kilograms, h is the vertical height in metres and g is 10 N/kg;
Heat transfer by conduction, convection and radiation	1.4.22 investigate by experimentation or demonstration: • that heat can be transferred from place to place by conduction and that metals are the best conductors of heat; • convection in liquids and gases; and • that dark matt surfaces are better at absorbing and radiating heat energy than light shiny surfaces; 1.4.23 demonstrate understanding: • that the transfer of energy by conduction and convection involves particles; • of how this transfer takes place; • in simple terms how the arrangement and movement of particles determine whether a material is a conductor or an insulator; and • of the role of free electrons in the conduction of heat through a metal; 1.4.24 explain everyday applications of heat transfer and the role each transfer method plays; and 1.4.25 demonstrate understanding that heat energy can be lost from homes mainly through conduction and convection, and recall ways of reducing these heat losses.

Atomic and Nuclear Physics

In this section, students explore the particle structure of both the atom and the nucleus. They examine radioactivity as a consequence of unstable nuclei and study the properties of alpha, beta and gamma radiation. They are introduced to the terms background and half-life and discuss the damaging effect that nuclear radiations have on our bodies. They also learn about fusion and fission as sources of energy.

Content	**Learning Outcomes**
1.5 Atomic and nuclear physics	Students should be able to:
Structure of the atom	1.5.1 research the historical development of the model of atomic structure from the Plum Pudding model to the present Rutherford–Bohr model;
	1.5.2 **describe, in outline, the Rutherford alpha-particle scattering experiment and its principal results;**
	1.5.3 **explain how the evidence provided by the Rutherford alpha-particle scattering experiment led to the Plum Pudding model of the atom being replaced by the Rutherford–Bohr model;**
	1.5.4 describe the structure of atoms in terms of protons, neutrons and electrons;
	1.5.5 recall the relative charge and relative mass of protons, neutrons and electrons;
Structure of the nucleus	1.5.6 describe a nucleus in terms of atomic number Z and mass number A, using the notation ${}^{A}_{Z}X$;
	1.5.7 explain what an isotope is;
Radioactive decay	1.5.8 recall that some nuclei are unstable and disintegrate, emitting alpha, beta or gamma radiation randomly and spontaneously, and that such nuclei are described as radioactive; and
	1.5.9 explain that alpha particles are helium nuclei consisting of two protons and two neutrons, beta particles are fast electrons, and gamma radiation is an electromagnetic wave of high energy.

Content	Learning Outcomes
Radioactive decay (cont.)	Students should be able to: 1.5.10 **describe nuclear disintegrations in terms of equations involving mass numbers and atomic numbers, and complete the equations by balancing the mass numbers and atomic numbers:** ***alpha decay*** $^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$ (or $^{4}_{2}\alpha$) ***beta decay*** $^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$ (or $^{0}_{-1}\beta$) ***gamma decay*** $^{A}_{Z}X \rightarrow {}^{A}_{Z}X + \gamma$ 1.5.11 investigate: • through demonstrations or computer simulations, the range of alpha, beta and gamma radiations; • how alpha radiation is stopped by a few centimetres of air or a thin sheet of paper; • how beta radiation is stopped by several metres of air or a thin sheet of aluminium; and • how gamma radiation easily passes through all of these but can be blocked by lead; and 1.5.12 recall that: • background activity is detected when no radioactive sources are present; and • the measured activity from a radioactive source has to be corrected by subtracting the background activity.

Content	Learning Outcomes
Radioactive decay (cont.)	Students should be able to: 1.5.13 demonstrate understanding that: • most radioactive background activity comes from natural sources such as cosmic rays from space, rocks and soil, some of which contain radioactive elements such as radon; • gas, living things and plants absorb radioactive materials from the soil, which are then passed along the food chain; • there is little we can do about natural background radiation, although people who live in areas with a high background due to radon gas require homes to be well ventilated to remove the gas; and • human behaviour also adds to the background activity that we are exposed to through medical X-rays, radioactive waste from nuclear power plants and the radioactive fallout from nuclear weapons testing;
Dangers of radioactivity	1.5.14 recall that radioactive emissions cause dangerous ionisations by removing electrons from atoms and, when this happens with molecules in living cells, the genetic material of a cell is damaged and the cell may become cancerous; and 1.5.15 recall that: • alpha radiation is not as dangerous if the radioactive source is outside the body, because it cannot pass through the skin and is unlikely to reach cells inside the body; • beta and gamma radiation can penetrate the skin and cause damage to cells; and • alpha radiation will damage cells if the radioactive source has been breathed in or swallowed.

Content	Learning Outcomes
Dangers of radioactivity (cont.)	Students should be able to: 1.5.16 explain that steps should be taken when handling radioactive sources to minimise the risk to those using them, such as: • wearing protective clothing; • keeping the source as far away as possible by using tongs; • being exposed to the source for as short a time as possible; and • keeping radioactive materials in lead-lined containers;
Half-life	1.5.17 explain the meaning of the term half-life, carry out simple calculations involving half-life and determine half-life from appropriate graphs; and
Uses of radioactivity	1.5.18 describe some uses of radioactivity in industry, medicine and agriculture, and recall that: • radioactive isotopes are used as tracers to find out what is happening inside an object without the need to break into the object; • radioactive isotopes are used in industry to find the route of underground pipes using a gamma ray emitter, or to control the thickness of metal as it is rolled into thin sheets; • gamma rays are used in medicine to sterilise plastic objects such as syringes, and different radioactive isotopes are used to monitor the function of organs by injecting a small amount into the bloodstream and detecting the emitted radiation; • gamma rays are used in agriculture to kill the bacteria on food, prolonging its shelf life; and • alpha radiation is used in the home in smoke alarms.

Content	Learning Outcomes
Uses of radioactivity (cont.)	Students should be able to: 1.5.19 demonstrate understanding that: • gamma radiation of food has many opponents but would be valuable in hot climates where refrigeration is not always possible; and • the half-life of the radioactive material used in all applications needs to be considered to ensure that the application works but minimal harm is done to the environment or to people;
Nuclear fission	1.5.20 describe nuclear fission in simple terms and be aware that it is a form of energy used to generate electricity (fission equations are not required); 1.5.21 demonstrate knowledge that: • for fission to occur, the uranium nucleus must first absorb a neutron and then split into two smaller nuclei, releasing energy and several neutrons; and • these fission neutrons go on to cause further fissions, creating a chain reaction; and 1.5.22 discuss and debate some of the political, social, environmental and ethical issues relating to using nuclear energy to generate electricity, demonstrating understanding that: • although using nuclear power produces employment opportunities for many people, many are still concerned about living close to nuclear power plants and the storage facilities used for radioactive waste; • incidents at nuclear power plants in Ukraine and Japan have caused huge economic, health and environmental damage to the area surrounding the power plant; and • although nuclear fission does not release carbon dioxide, the mining, transport and purification of the uranium ore releases significant amounts of greenhouse gases into the atmosphere.

Content	Learning Outcomes
Nuclear fusion	Students should be able to: 1.5.23 describe nuclear fusion in simple terms and be aware that it is the source of a star's energy; 1.5.24 demonstrate understanding: • of the potential of nuclear fusion to solve the world's energy needs, provided the technological difficulties of fusion reactors can be overcome; • that the isotopes of hydrogen, deuterium and tritium are widely available as the constituents of seawater and so are nearly inexhaustible; and • that fusion does not emit carbon dioxide or other greenhouse gases into the atmosphere as its major by-product is helium, an inert, non-toxic gas; 1.5.25 recall that: • fusing nuclei together in a controlled way releases four million times more energy per kg than a chemical reaction such as burning coal, oil or gas; and • fusing nuclei together in a controlled way releases four times as much energy as nuclear fission reactions per kg; 1.5.26 explain that: • there are many difficulties to overcome before nuclear fusion provides electricity on a commercial scale and it may be another 50 years before that happens; and • nuclear fusion reactors will be expensive to build, and the system used to contain them will be equally expensive because of the very high temperatures needed for the nuclei to fuse; and 1.5.27 demonstrate an appreciation of the work being carried out at the ITER project (International Thermonuclear Experimental Reactor) and an understanding that such research requires international co-operation.

3.2 Unit 2: Waves, Light, Electricity, Magnetism, Electromagnetism and Space Physics

Waves

In this section, students are introduced to the two main categories of waves, as well as the terms used to describe their various properties. They study echoes and their applications. They explore the electromagnetic spectrum and examine the use of the various types of electromagnetic wave.

Content	Learning Outcomes
2.1 Waves	Students should be able to: 2.1.1 recall that waves transfer energy from one point to another through vibrations;
Transverse and longitudinal waves	2.1.2 distinguish between transverse and longitudinal waves in terms of the motion of the particles of the medium, recalling: • sound and ultrasound as examples of longitudinal waves; and • water waves and electromagnetic waves as examples of transverse waves;
Frequency, wavelength and amplitude	2.1.3 explain the meaning of frequency, wavelength and amplitude of a wave, and extract details of these quantities from graphs of displacement of the particles against time and displacement of the particles against distance;
	2.1.4 recall and use the equation $v = f\lambda$ to calculate the velocity of the wave in m/s, the frequency of the wave in hertz (Hz) and the wavelength of the wave in metres (m);
Reflection and refraction of waves	2.1.5 describe, using simple wavefront diagrams, how plane waves are reflected at plane barriers and refracted at plane boundaries, based on their observations using ripple tanks, video or computer simulations; and
	2.1.6 explore and recall the analogy between the reflection and refraction of water waves and the reflection and refraction of light (see also 2.2.1–2.2.7).

Content	**Learning Outcomes**
Echoes, sonar and radar	Students should be able to: 2.1.7 describe some applications of echoes and carry out calculations on the echo principle; 2.1.8 recall that ultrasound is the name given to sound waves that have frequencies greater than 20 000 Hz, and is used in medicine to measure foetal head diameter and in industry to detect defects in metals; 2.1.9 demonstrate knowledge that sonar uses sound pulses to detect objects under water and electromagnetic waves are used in radar to detect aircraft and ships;
Electromagnetic waves	2.1.10 distinguish between the different regions of the electromagnetic spectrum (radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays) in terms of their wavelength and frequency, arrange them in order of wavelength and recall that they all travel at the same speed in a vacuum; and 2.1.11 recall that overexposure to certain types of electromagnetic radiation can be harmful and that the higher the frequency of the radiation, the more damage it is likely to cause to the body, for example: • microwaves cause internal heating of body tissues; • infrared radiation is felt as heat and causes skin burns; • certain wavelengths of ultraviolet can damage skin cells and lead to skin cancer; • intense visible light can damage eyes; • large doses of radio waves are believed to cause cancer, leukaemia and other disorders, and some people claim the very low frequency radio waves from overhead power cables near their homes has affected their health, although this has not been reliably proven; and • X-rays and gamma rays damage cells, which may lead to cancer.

Light

In this section, students investigate the reflection and refraction of light. They relate refraction to a change of speed as light moves from one medium to another. They study how a prism disperses white light and also investigate total internal reflection of light and relate it to the idea of a critical angle.

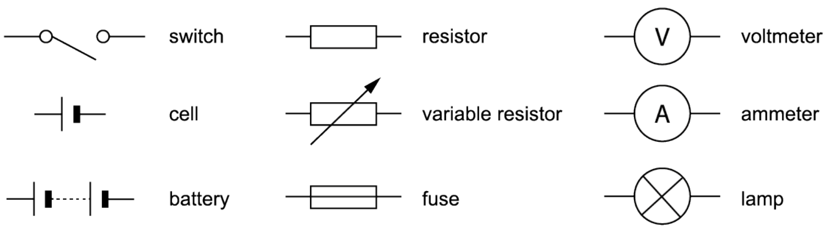
Content	Learning Outcomes
2.2 Light **Reflection of light**	Students should be able to: 2.2.1 investigate how light is reflected by a plane mirror, and recall that: • angles of incidence and reflection are measured from a line at right angles to the mirror known as the normal; and • the angle of incidence equals the angle of reflection, and apply this rule in practical situations; 2.2.2 investigate the properties of an image seen in a plane mirror through ray tracing and use the properties to solve simple problems;
Refraction of light	2.2.3 observe the refraction of light as it passes from air into glass and air into water and vice versa; 2.2.4 *carry out practical work:* • *to use ray tracing to measure the angles of incidence and refraction when light is refracted by a glass block;* • *to demonstrate understanding that the angles of incidence and refraction are measured from a line at right angles to the glass surface known as the normal; and* • *to use the measurements taken to plot a graph of angle of incidence against angle of refraction to show that they are related but not proportional (Prescribed Practical P6); and* 2.2.5 recall and demonstrate understanding that when light slows it bends towards the normal and the converse.

Content	Learning Outcomes
Refraction of light (cont.)	Students should be able to: 2.2.6 relate the amount of refraction to the change of speed, so that the greater the refraction, the larger the change of speed of the light (a knowledge of Snell's law is not expected);
Dispersion of white light	2.2.7 investigate how prisms disperse white light and recall that: • a spectrum can be produced because different colours of light travel at different speeds in the glass; • the greater the amount of refraction, the greater the change of speed; and • since red is refracted the least, it is slowed the least, and violet is refracted the most because it has been slowed the most;
Critical angle and total internal reflection	2.2.8 **investigate experimentally the critical angle and the conditions under which total internal reflection occurs within a semi-circular glass block, and recall that:** • **when the angle of incidence in the glass reaches the critical angle, the angle of refraction in the air becomes 90°; and** • **when the angle of incidence in the glass is greater than the critical angle, total internal reflection occurs;** 2.2.9 **apply the principle of total internal reflection to parallel-sided glass blocks and triangular prisms;** 2.2.10 **explain in terms of total internal reflection how optical fibres enable long distance communication and apply their knowledge to other situations or applications that involve this effect;** and
Lenses	2.2.11 distinguish between the action of converging and diverging lenses (qualitative treatment only) through practical investigation, and define the focal length of a converging lens.

Content	Learning Outcomes
Lenses (cont.)	Students should be able to: 2.2.12 recall that: • short sight usually occurs when the eyes grow slightly too long so that light doesn't focus on the light-sensitive tissue (retina) at the back of the eye properly; and • for a short-sighted person, the light rays focus just in front of the retina, resulting in distant objects appearing blurred; 2.2.13 draw a simple ray diagram to show: • how light is refracted by an eye that is short-sighted; and • how short sight is corrected using a diverging lens; 2.2.14 recall that: • long sight usually occurs when the eyeball is too short or the lens cannot be made thick enough to focus the light rays on the retina; and • for a long-sighted person, the light rays would focus behind the retina so that nearby objects appear blurred; 2.2.15 draw a simple ray diagram to show: • how light is refracted by an eye that is long-sighted; and • how long sight is corrected using a converging lens; 2.2.16 carry out and describe an experiment that uses a distant object to measure the focal length of a converging lens; 2.2.17 draw ray diagrams to show how converging lenses form real images; 2.2.18 use ray diagrams to explain the principle of the simple camera and the projector (details of the construction of these are not required); **and** 2.2.19 **draw a ray diagram to show how a converging lens is used as a magnifying glass, forming a virtual image.**

Electricity

In this section, students investigate electrical circuits and draw circuit diagrams using the correct symbols. They examine series and parallel circuits and investigate the rule for currents and voltages in each type of circuit. They also study the transfer of electrical energy and electricity in the home.

Content	Learning Outcomes
2.3 **Electricity** **Conductors and insulators**	Students should be able to: 2.3.1 demonstrate understanding of the difference between conductors and insulators in terms of free electrons;
	2.3.2 recall that an electric current in a metal is a flow of electrons and that the electrons move in the opposite direction to that of a conventional current;
Simple circuits	2.3.3 demonstrate understanding of the role of conductors, insulators and switches in simple series and parallel circuits;
Standard symbols	2.3.4 interpret and draw circuit diagrams using the standard symbols illustrated below: 
	2.3.5 explain the meaning of cell polarity and relate it to the symbol for a cell;
Electric charge flow	2.3.6 recall and use the quantitative relationship between current, charge and time *charge = current × time* and recall that charge is measured in coulombs; and
	2.3.7 demonstrate understanding that the voltage provided by cells connected in series is the sum of the voltages of each cell, having regard to their polarity.

Content	**Learning Outcomes**
Ohm's law	Students should be able to: 2.3.8 *use a voltmeter to measure the voltage across a metal wire and an ammeter to measure the current passing through the wire, and:* • *demonstrate understanding that the temperature of the wire is kept constant using a switch and small currents;* • *demonstrate understanding of the need to obtain sufficient values of voltage and current so that a voltage–current characteristic graph (V-I graph) can be plotted, with voltage on the y-axis and current on the x-axis;* • *recall that the V-I graph is a straight line that passes through the origin; and* • *recall that this shows that the current and voltage are proportional for a metal wire at constant temperature, and that this is known as Ohm's law (Prescribed Practical P7);*
Resistance	2.3.9 recall and use the equation *voltage = current × resistance* where voltage is measured in volts, current in amperes and resistance in ohms;
Filament lamp	2.3.10 **describe and carry out an experiment to obtain the voltage–current characteristic graph (V-I graph) for a filament lamp with voltage on the y-axis and current on the x-axis, and show that the resistance of a filament lamp increases as the current through the filament increases by taking the ratio of the voltage to the current at different values of the current;** and
Series and parallel circuits	2.3.11 investigate how for components connected in series: • the current through each component is the same; and • the voltage of the supply is equal to the sum of the voltages across the separate components.

Content	Learning Outcomes
Series and parallel circuits (cont.)	Students should be able to: 2.3.12 recall that for components connected in parallel: • the voltage across each component is the same as that of the supply; and • the total current taken from the supply is the sum of the currents through the separate components;
Calculating resistance	2.3.13 calculate the total resistance of resistors in series; 2.3.14 calculate the resistance of two equal resistors in parallel; 2.3.15 **calculate the combined resistance of any number of resistors in parallel;** 2.3.16 **calculate the combined resistance of circuits with series and parallel sections;**
Factors affecting resistance	2.3.17 *investigate experimentally how the resistance of a metallic conductor at constant temperature depends on length and obtain sufficient values to plot a graph of resistance (y-axis) and length (x-axis), recalling that:* • *the graph is a straight line that passes through the origin; and* • *this shows that for a metal wire at constant temperature the resistance and length of wire are proportional (Prescribed Practical P8);* 2.3.18 solve simple problems using the knowledge that the resistance of a metal wire at constant temperature is proportional to its length; 2.3.19 **investigate experimentally how the resistance of a metallic conductor at constant temperature depends on the area of cross section and the material it is made from; and** 2.3.20 **recall that the resistance of a metallic conductor at constant temperature depends on the area of cross section and the material it is made from and solve simple problems using this knowledge (knowledge of resistivity is not required).**

Content	Learning Outcomes
Electrical energy and power	Students should be able to: 2.3.21 demonstrate understanding of why an electrical current flowing through a metal wire generates heat in terms of free electron–atom collisions; 2.3.22 recall and use the quantitative relationships *energy = power × time* *power = current × voltage* to calculate energy in joules (J), power in watts (W), current in amps (A), voltage in volts (V) and the time in seconds (s);
Electricity in the home	2.3.23 recall that the unit used in the cost of electricity to the consumer is the kilowatt-hour, and demonstrate understanding of the meaning of the kilowatt- hour and use of the power rating of electrical appliances to calculate their cost; 2.3.24 demonstrate understanding that in one-way switching the switch basically operates as a make or break switch, because: • when it is turned on, the two terminals are connected, and when it is turned off, the contact between the two terminals is broken; and • the switch is always placed on the positive or live side of a circuit; 2.3.25 demonstrate understanding that in a two-way switch two one-way switches are joined by wires to make one switch, recalling that: • there is no defined position for the off or on states when used in this way, as flipping either switch would turn the light on or off; and • a two-way switch can be used to control a light from two locations, for example on a staircase or in a long hallway; and 2.3.26 draw the circuit diagram to show two-way switching.

Content	Learning Outcomes
Electricity in the home (cont.)	Students should be able to: 2.3.27 recall the wiring inside a fused three-pin plug and demonstrate understanding of the function of the live, neutral and earth wires; 2.3.28 recall that appliances with metal cases are usually earthed and demonstrate understanding of how the earth wire and fuse together protect the user from electric shock and the apparatus from potential damage; 2.3.29 demonstrate understanding of how double insulation protects the user; and 2.3.30 recall the equation *power = current × voltage* and use this in calculations to select the appropriate rating of a fuse.

Magnetism and Electromagnetism

In this section, students plot the magnetic field around a bar magnet and a current-carrying coil. They investigate factors affecting the strength of a magnetic field. They are introduced to Fleming's Left Hand Rule to determine the direction of the force that acts on a current-carrying wire in a magnetic field. They examine the difference between alternating and direct current. They also study the generation of electricity and its transmission to the consumer.

Content	Learning Outcomes
2.4 Magnetism and electromagnetism	Students should be able to:
Magnetic field of a bar magnet	2.4.1 use plotting compasses to investigate, describe and recall the shape and direction of the magnetic field around a bar magnet;
Magnetic field of a current-carrying coil	2.4.2 use plotting compasses to investigate, describe and recall the shape and direction of the magnetic field produced by the current in a coil of wire, and relate the polarity to the direction of the current in the coil;
Factors affecting the strength of an electromagnet	2.4.3 *investigate, describe and recall how the strength of the magnetic field depends on the current in the coil, the number of turns in the coil and the material used as the core of the coil (Prescribed Practical P9);*
Force on a current-carrying conductor in a magnetic field and Fleming's Left Hand Rule	2.4.4 **investigate the force on a current-carrying conductor in a magnetic field, recall that the force is perpendicular to the direction of both the current and the magnetic field, use Fleming's Left Hand Rule to determine the direction of the force, current or magnetic field, and recall how this forms the basis of the electric motor (details of the split ring commutator are not required); and**
a.c. and d.c.	2.4.5 describe the difference between a.c. and d.c. and identify sources for each, and recognise the waveforms of a.c. and d.c. supplies from diagrams of cathode ray oscilloscope (CRO) traces.

Content	Learning Outcomes
Electromagnetic induction	Students should be able to: 2.4.6 investigate electromagnetic induction by moving a magnet in and out of a coil connected to a centre-zero meter, and also: • observe the relationship between the direction of movement of the bar and the direction of the induced current; • observe the relationship between the size of the induced current and speed of the moving magnet; • observe that when the magnet is stationary, either inside or outside the coil, there is no induced current; • observe that alternating current can be induced by rotating the bar magnet close to the coil; and • recall that this is the basis for generating electricity; 2.4.7 investigate electromagnetic induction using two coils of wire, one connected to a power supply and switch and the neighbouring coil connected to a centre-zero meter, then: • observe the direction of the induced current on the meter when switching the current in one coil wire on and then off; and • recall that this is the basis for transformers; and
Generation and transmission of electricity	2.4.8 recall that a.c. generators are used in the generation of electricity and in their simplest form consist of a coil of wire rotated between the poles of a magnet.

Content	**Learning Outcomes**
The transformer	Students should be able to: 2.4.9 describe the construction of a step-up and a step-down transformer, including the primary coil, secondary coil and the function of the core, then: • recall how the output voltage depends on the number of turns on the secondary compared to the primary coil; and • recall that the input and output voltages are both alternating; 2.4.10 **treat transformers as devices that have an efficiency of 1 (100%), so that electrical power input is the same as electrical power output and state, and use the turns-ratio equation:** $$\frac{N_S}{N_P} = \frac{V_S}{V_P}$$ 2.4.11 describe and explain the role of step-up and step-down transformers in the transmission of electricity.

Space Physics

In this section, students are introduced to the variety of objects that make up our Solar System. They develop understanding of how the objects move and the force that keeps them in orbit. Students are introduced to the life cycle of stars and how the mass of a star determines its final outcome, leading to the idea of a black hole. They study the Big Bang and supporting evidence and discuss the difficulties associated with space travel to other planets.

Content	Learning Outcomes
2.5 **Space physics** **The Earth and Solar System**	Students should be able to: 2.5.1 describe the main features of the Solar System, including the Sun, the rocky and gas planets, moons, asteroids and comets; 2.5.2 recall the order of the eight planets from the Sun outwards; 2.5.3 demonstrate understanding that gravity provides the force needed for the orbital motion of planets, comets, moons and artificial satellites; 2.5.4 explain the use of artificial satellites in the observation of the Earth, weather monitoring, astronomy and communications;
Stars	2.5.5 explain that: • stars form when enough dust and gas from space is pulled together by gravitational attraction; and • smaller masses may also form and be attracted by a larger mass to become planets; 2.5.6 demonstrate understanding that studies of light from stars, including our Sun, show they are composed mainly of hydrogen and helium and that their energy is supplied by the fusion of hydrogen into helium; 2.5.7 **recall that all the naturally occurring elements apart from hydrogen are formed by nuclear fusion in stars; and**
Life cycle of stars	2.5.8 **recall the life cycle of a star with the mass of our Sun from protostar to main sequence to red giant to white dwarf to black dwarf.**

Content	Learning Outcomes
Life cycle of stars (cont.)	Students should be able to: 2.5.9 **recall that a star is stable during the 'main sequence' period of its life cycle because the outward force of thermal expansion is balanced by the inward force of gravity;**
Supernovae	2.5.10 **demonstrate understanding that:** • **more massive stars have a very different life cycle after the main sequence period;** • **they become red supergiants followed by an explosion in which the outer layers of the star are ejected;** • **this is called a supernova and the star will shine for a relatively short time with the brightness of 10 billion suns; and** • **after the supernova the remaining core of the star may collapse more, and some become neutron stars while very massive ones form black holes;**
Black holes	2.5.11 **demonstrate knowledge that there is such a strong gravitational field in a black hole that nothing can escape from it, including electromagnetic radiation such as light;**
The Universe	2.5.12 demonstrate knowledge that the Universe began as a Big Bang which, according to current measurements, occurred 14 billion years ago; **and**
Big Bang model	2.5.13 **describe the Big Bang model for the formation and evolution of the Universe, including:** • **the rapid expansion and cooling of the Universe;** • **the eventual formation of neutrons and protons;** • **how further expansion and cooling allowed nuclei to form; and** • **how eventually, after further expansion and cooling, the temperature had dropped sufficiently for electrons to combine with neutrons and protons to form atoms of hydrogen.**

Content	Learning Outcomes
Red shift	Students should be able to: 2.5.14 describe and explain that evidence for the Big Bang includes that light from other galaxies is shifted to the red end of the spectrum, and that this can be explained by space expanding;
CMBR	2.5.15 **explain that the existence of cosmic microwave background radiation (CMBR) is further evidence of the Big Bang, and that the Big Bang is currently the only model that explains CMBR;**
Space travel and life on other planets	2.5.16 research, discuss and recall the evidence for other planets outside our Solar System; 2.5.17 demonstrate understanding of how the composition of the atmosphere of these planets can be determined by examination of the light passing through their atmospheres, in particular the search for oxygen, which would indicate the possibility of life on the planet; 2.5.18 consider the possibilities and limitations of space exploration in terms of distance and speed of travel; 2.5.19 recall that distances to stars and galaxies are so large that they are measured in light years and that a light year is the distance light travels in one year; **and** 2.5.20 **carry out calculations involving light years and distance.**

3.3 Unit 3: Practical Skills

Units 1 and 2 include a number of practical tasks that students carry out during the course. Nine of these are prescribed practicals. This unit has two parts: Booklet A and Booklet B. We set and mark both booklets.

Booklet A is a practical skills assessment. It assesses students' ability to carry out **two** practical tasks based on but not identical to the nine prescribed practicals listed in this specification.

Booklet B is a written, externally assessed examination taken during the final year of study. It assesses students' knowledge and understanding of practical science. It consists of questions about planning and carrying out any of the prescribed practical tasks, together with more general questions about any practical situation that arises in Units 1 and 2 in this specification.

Content	Learning Outcomes
Planning an investigation	Students should be able to: • identify the dependent, independent and controlled variables in an investigation; • suggest a hypothesis for investigation in the context of How Science Works; • plan a method to allow a hypothesis to be tested; • carry out a risk assessment on all planned practical activities; • select equipment or apparatus that is suitable and will contribute to obtaining accurate results; • produce a results table with appropriate headings and units which allows for the recording of a wide range of appropriate raw data; • draw a diagram of the apparatus used in an experiment; and • demonstrate understanding of the steps that must be taken to ensure the reliability of data collected.

Content	Learning Outcomes
Carrying out an experiment	Students should be able to: • demonstrate the practical skills necessary to use the following apparatus correctly, skilfully and safely: – spring balance and/or top-pan balance (mass); – ruler (length); – graduated cylinder (liquid volume); – stopclock or stopwatch (time); – thermometer or sensor (temperature); – ammeter (electric current); – voltmeter (potential difference); – ohmmeter (resistance); and – protractor (angle); • demonstrate the practical skills necessary to set up simple electric circuits safely;
Analysing experimental data	• demonstrate understanding of the mathematical techniques that can be used to identify the relationships between variables (such as division to find k in $F = kx$ and multiplication to find k in $R = k/A$); • use appropriate scales and axes labels when plotting a graph of experimental data; • demonstrate understanding of what is meant by an anomalous result in a set of experimental data and how it should be treated; and • plot data points accurately and draw the appropriate straight line or curve.

Content	Learning Outcomes
Drawing conclusions from an experiment	Students should be able to: • make reasoned judgements and draw evidence-based conclusions; • analyse, interpret and critically evaluate a broad range of experimental data; • demonstrate understanding that for a graph of y against x, a straight line through (0,0) is an indicator of direct proportion; • demonstrate understanding that for a graph of y against 1/x, a straight line through (0,0) is an indicator of inverse (indirect) proportion; • discuss in detail the areas of an investigation that could affect the reliability of the data or evidence collected; • develop and defend a hypothesis with appropriate and detailed scientific reasoning; and • develop arguments and explanations, taking account of the limitations of the available evidence.

Content	Learning Outcomes
Prescribed practicals	Below is a list of prescribed practicals that may be assessed in Unit 3 Booklet A and/or Booklet B. Students should be able to carry out practical work: • using simple apparatus, including trolleys, ball-bearings, metre rules, stopclocks and ramps, to investigate experimentally how the average speed of an object moving down a runway depends on the slope of the runway measured as the height of one end of the runway (ICT resources could be used to process the measurements and analyse the data) (Prescribed Practical P1); • to investigate experimentally the extension of a spring and how it is related to the applied force, and recall that the extension of a spring is directly proportional to the force applied, provided that the limit of proportionality is not exceeded (Prescribed Practical P2); • to plan and carry out experiments to verify the Principle of Moments using a suspended metre rule and attached weights or a pivoted beam and square weights (Prescribed Practical P3); • to investigate experimentally the relationship between the mass and volume of liquids and regular solids, and analyse and interpret the data gathered (Prescribed Practical P4); • to plan and carry out experiments to measure personal power, either by measuring the time taken to climb a staircase or performing a number of step-ups to a platform (Prescribed Practical P5); and • to use ray tracing to measure the angles of incidence and refraction when light is refracted by a glass block; to demonstrate understanding that the angles of incidence and refraction are measured from a line at right angles to the glass surface known as the normal; and to use the measurements taken to plot a graph of angle of incidence against angle of refraction to show that they are related but not proportional (Prescribed Practical P6).

Content	Learning Outcomes
Prescribed practicals (cont.)	Students should be able to carry out practical work: • using a voltmeter to measure the voltage across a metal wire and an ammeter to measure the current passing through the wire, and: – demonstrate understanding that the temperature of the wire is kept constant using a switch and small currents; – demonstrate understanding of the need to obtain sufficient values of voltage and current so that a voltage–current characteristic graph (V-I graph) can be plotted, with voltage on the y-axis and current on the x-axis; – recall that the V-I graph is a straight line that passes through the origin; and – recall that this shows that the current and voltage are proportional for a metal wire at constant temperature, and that this is known as Ohm's law (Prescribed Practical P7); • to investigate experimentally how the resistance of a metallic conductor at constant temperature depends on length and obtain sufficient values to plot a graph of resistance (y-axis) and length (x-axis), recalling that: – the graph is a straight line that passes through the origin; and – this shows that for a metal wire at constant temperature the resistance and length of wire are proportional (Prescribed Practical P8); and • to investigate, describe and recall how the strength of the magnetic field depends on the current in the coil, the number of turns in the coil and the material used as the core of the coil (Prescribed Practical P9).

4 Scheme of Assessment

4.1 Assessment opportunities

For the availability of examinations and assessment, see Section 2.

This is a unitised specification; candidates must complete at least 40 percent of the overall assessment requirements at the end of the course, in the examination series in which they request a final subject grade. This is the terminal rule.

Candidates may resit individual assessment units once before cash-in. The better of the two results will count towards their final GCSE grade unless a unit is required to meet the 40 percent terminal rule. If it is, the more recent mark will count (whether or not it is the better result). Results for individual assessment units remain available to count towards a GCSE qualification until we withdraw the specification.

4.2 Assessment objectives

There are three assessment objectives for this specification. Candidates must:

AO1 demonstrate knowledge and understanding of:
- scientific ideas; and
- scientific techniques and procedures;

AO2 apply knowledge and understanding of and develop skills in:
- scientific ideas; and
- scientific enquiry, techniques and procedures; and

AO3 analyse scientific information and ideas to:
- interpret and evaluate;
- make judgements and draw conclusions; and
- develop and improve experimental procedures.

4.3 Assessment objective weightings

The table below sets out the approximate assessment objective weightings for each assessment component and the overall GCSE qualification.

Assessment Objective	Unit Weighting (%)			Overall Weighting (%)
	Unit 1	Unit 2	Unit 3	
AO1	16	16	8	40
AO2	16	16	8	40
AO3	5.5	5.5	9	20
Total Weighting	37.5	37.5	25	100

4.4 Quality of written communication

In GCSE Physics, candidates must demonstrate their quality of written communication. They need to:

- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- select and use a form and style of writing that suit their purpose and complex subject matter; and
- organise information clearly and coherently, using specialist vocabulary where appropriate.

Quality of written communication is assessed in responses to questions and tasks that require extended writing.

4.5 Reporting and grading

We report the results of individual assessment units on a uniform mark scale that reflects the assessment weighting of each unit.

We determine the grades awarded by aggregating the uniform marks that candidates obtain in individual assessment units. We award GCSE qualifications on a grade scale from A* to G, with A* being the highest. The nine grades available are as follows:

Grade	A*	A	B	C*	C	D	E	F	G

If candidates fail to attain a grade G or above, we report their result as unclassified (U).

5 Grade Descriptions

Grade descriptions are provided to give a general indication of the standards of achievement likely to have been shown by candidates awarded particular grades. The descriptions must be interpreted in relation to the content in the specification; they are not designed to define that content. The grade awarded depends in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of candidates' performance in the assessment may be balanced by better performances in others.

Grade	Description
A	Candidates recall, select and communicate precise knowledge and detailed understanding of physics. They demonstrate a comprehensive understanding of the nature of physics, its laws, principles and applications and the relationship between physics and society. They understand the relationships between scientific advances, their ethical implications and the benefits and risks associated with them. They use scientific and technical knowledge, terminology and conventions appropriately and consistently, showing a detailed understanding of scale in terms of time, size and space. They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models, including mathematical models, to explain abstract ideas, phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses. Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations, taking account of the limitations of the available evidence. They make reasoned judgements consistently and draw detailed, evidence-based conclusions.

Grade	Description
C	Candidates recall, select and communicate secure knowledge and understanding of physics. They demonstrate understanding of the nature of physics, its laws, principles and applications and the relationship between physics and society. They understand that scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space. They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding in a range of practical and other contexts. They show understanding of the relationships between hypotheses, evidence, theories and explanations and use models, including mathematical models, to describe abstract ideas, phenomena, events and processes. They use a range of appropriate methods, sources of information and data, applying their skills to address scientific questions, solve problems and test hypotheses. Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and use evidence and information to develop arguments with supporting explanations. They draw conclusions based on the available evidence.
F	Candidates recall, select and communicate limited knowledge and understanding of physics. They recognise simple interrelationships between physics and society. They show a limited understanding that scientific advances may have ethical implications, benefits and risks. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space. They apply skills, including limited communication, mathematical, technical and observational skills, knowledge and understanding in practical and some other contexts. They show limited understanding of the nature of science and its applications. They can explain straightforward models of phenomena, events and processes. Using a limited range of skills and techniques, they answer scientific questions, solve straightforward problems and test ideas. Candidates interpret and evaluate limited quantitative and qualitative data and information from a narrow range of sources. They can draw elementary conclusions having collected limited evidence.

6 Guidance on Practical Skills Assessment

6.1 Overview

Unit 3 assesses practical skills. It has two parts: Booklet A and Booklet B.

All of the nine prescribed practicals should be taught throughout the course. Booklet A consists of two pre-release practical assessments based on but not identical to those on the list of nine prescribed practicals. We change the two assessed practicals every year to ensure that they continue to set an appropriate challenge and remain valid, reliable and stimulating.

In Booklet A, candidates carry out two practical tasks in the laboratory. Booklet A is a practical skills assessment and should be carried out under high level of control, with teacher and invigilator supervision to comply with health and safety regulations.

We send centres a list of the materials required for Booklet A in the December before the Summer submission. We send Booklet A to centres in January of the final year of study.

Candidates collect qualitative or quantitative results depending on the demands of the practical skills assessment. We will publish a timetabled period for this practical skills assessment on the examinations timetable. Candidates must complete Booklet A by 1 May of the final year of study. Centres must send these booklets to us for marking.

Booklet B is a timetabled, externally assessed examination taken at the end of the final year of study. It consists of questions about planning and carrying out any of the prescribed practical tasks. It also has more general questions about any practical situation that arises from this specification.

6.2 Skills assessed by Unit 3

The following skills are assessed:

- planning an investigation;
- carrying out an experiment;
- analysing experimental data; and
- drawing conclusions from an experiment.

6.3 Task taking in Booklet A

Booklet A is a practical skills assessment and must be carried out under a high level of control.

An appropriate teacher should be present with an invigilator to ensure compliance with health and safety regulations.

Teachers and invigilators should **not** offer direction or guidance to candidates where this would assist them in completing Booklet A.

Candidates may work collaboratively in groups of up to three when carrying out the practical tasks, but they must work individually and independently to complete Booklet A.

Candidates have **2 hours** to complete Booklet A, and it must be completed in a single session.

Foundation and Higher Tier candidates may carry out the practical skills assessment in the same room but can only work with others taking the same tier.

The examinations officer must keep all Booklet A papers (completed and unused) securely at all times.

Centres must return Booklet A papers to us for marking after 1 May.

We will provide additional information relating to Booklet A as a support document.

For Booklet A, the level of control for task taking is **high**. The table below exemplifies high levels of control for this practical skills assessment.

Areas of Control	Details of Control
Authenticity	• Booklet A is an externally set and externally marked practical skills assessment. • Teachers must ensure that all candidates are in direct sight of the supervisor at all times. • Interaction between candidates is tightly prescribed during the practical tasks. • They should not communicate with each other when completing their response in Booklet A. • We will publish a timetabled period for this practical skills assessment on the examinations timetable. • Candidates must carry out the practical tasks and complete Booklet A in 2 hours. • We send an apparatus and materials list to examinations officers in December of the final year of study. They should distribute this list to the relevant head of department.
Feedback	• Teachers should not provide guidance or feedback during the practical skills assessment except to intervene on the grounds of health and safety.
Page limit	• We set Booklet A. It has no prescribed page limit.
Collaboration	• Candidates for the same tier of entry may work collaboratively to carry out the practical tasks, but they must provide an individual response in Booklet A.

For up-to-date advice on plagiarism, or any kind of candidate malpractice, see *Suspected Malpractice in Examinations and Assessments: Policies and Procedures* on the Joint Council for Qualifications website at www.jcq.org.uk

6.4 Task marking

Our examiners mark the tasks.

7 Curriculum Objectives

This specification builds on the learning experiences from Key Stage 3 as required for the statutory Northern Ireland Curriculum. It also offers opportunities for students to contribute to the aim and objectives of the Curriculum at Key Stage 4, and to continue to develop the Cross-Curricular Skills and the Thinking Skills and Personal Capabilities. The extent of the development of these skills and capabilities will be dependent on the teaching and learning methodology used.

7.1 Cross-Curricular Skills at Key Stage 4

Communication
Students should be able to: • communicate meaning, feelings and viewpoints in a logical and coherent manner, *for example use appropriate technical terms*; • make oral and written summaries, reports and presentations, taking account of audience and purpose, *for example describe the process of nuclear fission, explain where and how it is used, and identify the benefits and drawbacks in the form of a written or oral presentation*; • participate in discussions, debates and interviews, *for example discuss and debate some of the political, social, environmental and ethical issues relating to the use of nuclear energy to generate electricity*; and • interpret, analyse and present information in oral, written and ICT formats, *for example carry out practical work using a voltmeter and ammeter to measure the voltage across a metal wire and the current passing through it, interpret and analyse the measurements and use graph plotting software to show the linear relationship between the measured quantities*.

Using Mathematics
Students should be able to: • use mathematical language and notation with confidence, *for example write down and solve linear equations throughout all areas of the specification and enter numbers in standard index form in a scientific calculator (see also the Appendix: Mathematical Content and Skills)*; • use mental computation to calculate, estimate and make predictions in a range of simulated and real-life contexts, *for example estimate the speed of sound given that it is about ten times faster than a typical car on a motorway*; • select and apply mathematical concepts and problem-solving strategies in a range of simulated and real-life contexts, *for example investigate and use quantitative relationships between initial speed, final speed, average speed, distance moved, rate of change of speed and time*; • interpret and analyse a wide range of mathematical data, *for example carry out practical work using simple apparatus to investigate the motion of an object down a slope*; and • present mathematical data in a variety of formats, *such as tables or graphs*, which take account of audience and purpose, *for example plot a graph of extension against force in a Hooke's Law experiment, use it to find the stiffness constant, k, and compare the result with the average value of force/extension in a results table*.
Using ICT
Students should be able to make effective use of information and communications technology in a wide range of contexts to access, manage, select and present information, including mathematical information, *for example use data loggers to record experimental data about the instantaneous velocity of an object in free fall, or use a spreadsheet to calculate the resistance of wires from data relating to voltage and currents and plot a graph of resistance against length*.

7.2 Thinking Skills and Personal Capabilities at Key Stage 4

Self-Management
Students should be able to: • plan work, *for example plan with others how they might carry out one of the prescribed practical tasks*; and • set personal learning goals, *for example learn how to use a scientific calculator to solve the mathematical problems encountered throughout the course*.

Working with Others
Students should be able to: • learn with and from others through co-operation, *for example plan and carry out with others an experiment to measure personal power*; • participate in effective teams and accept responsibility for achieving collective goals, *for example work in small groups for the prescribed practical tasks*; and • listen actively to others and influence group thinking and decision-making, taking account of others' opinions, *for example research the uses and dangers of electromagnetic waves and recall their findings*.
Problem Solving
Students should be able to: • identify and analyse relationships and patterns, *for example investigate experimentally the relationship between the mass and volume of liquids, regular solids and irregular solids, and use ICT to process the data*; • propose justified explanations, *for example use the Big Bang to explain why light from other galaxies is shifted to the red end of the spectrum and the existence of cosmic microwave background radiation (CMBR)*; • reason, form opinions and justify their views, *for example discuss the safety of wi-fi or mobile phones in relation to electromagnetic waves and potential dangers*; • analyse critically and assess evidence to understand how information or evidence can be used to serve different purposes or agendas, *for example describe a range of renewable and non-renewable energy resources and understand their effect on the environment*; • analyse and evaluate multiple perspectives, *for example debate the pros and cons of nuclear power*; • weigh up options and justify decisions, *for example weigh up the advantages of a tidal barrage in Strangford Lough against the destruction of the shoreline habitat and the effect on biodiversity*; and • apply and evaluate a range of approaches to solve problems in familiar and novel contexts, *for example explore the different approaches to understanding half-life*.

Although not referred to separately as a statutory requirement at Key Stage 4 in the Northern Ireland Curriculum, **Managing Information** and **Being Creative** may also remain relevant to learning.

8 Links and Support

8.1 Support

The following resources are available to support this specification:

- our Physics microsite at www.ccea.org.uk and
- specimen assessment materials.

We also intend to provide:

- past papers;
- mark schemes;
- Chief Examiner's reports;
- Principal Moderator's reports;
- guidance on progression from Key Stage 3;
- planning frameworks;
- centre support visits;
- support days for teachers;
- agreement trials;
- practical assessment guidance for teachers;
- practical assessment guidance for candidates;
- a resource list; and
- exemplification of examination performance.

8.2 Examination entries

Entry codes for this subject and details on how to make entries are available on our Qualifications Administration Handbook microsite, which you can access at www.ccea.org.uk

Alternatively, you can telephone our Examination Entries, Results and Certification team using the contact details provided.

8.3 Equality and inclusion

We have considered the requirements of equality legislation in developing this specification and designed it to be as free as possible from ethnic, gender, religious, political and other forms of bias.

GCSE qualifications often require the assessment of a broad range of competences. This is because they are general qualifications that prepare students for a wide range of occupations and higher level courses.

During the development process, an external equality panel reviewed the specification to identify any potential barriers to equality and inclusion. Where appropriate, we have considered measures to support access and mitigate barriers.

We can make reasonable adjustments for students with disabilities to reduce barriers to accessing assessments. For this reason, very few students will have a complete barrier to any part of the assessment.

Students with a physical impairment may instruct a practical assistant to set up equipment but may have difficulty in making observations and in manipulating the equipment to carry out the experiment.

Students with a visual impairment may find elements of the assessment difficult, but technology may help visually impaired students to take readings and make observations. Therefore, the assessments should not pose a difficulty for these students.

It is important to note that where access arrangements are permitted, they must not be used in any way that undermines the integrity of the assessment. You can find information on reasonable adjustments in the Joint Council for Qualifications document *Access Arrangements and Reasonable Adjustments*, available at www.jcq.org.uk

8.4 Contact details

If you have any queries about this specification, please contact the relevant CCEA staff member or department:

- Specification Support Officer: Nuala Tierney
  (telephone: (028) 9026 1200, extension 2292, email: ntierney@ccea.org.uk)

- Subject Officer: Gavin Gray
  (telephone: (028) 9026 1200, extension 2270, email: ggray@ccea.org.uk)

- Examination Entries, Results and Certification
  (telephone: (028) 9026 1262, email: entriesandresults@ccea.org.uk)

- Examiner Recruitment
  (telephone: (028) 9026 1243, email: appointments@ccea.org.uk)

- Distribution
  (telephone: (028) 9026 1242, email: cceadistribution@ccea.org.uk)

- Support Events Administration
  (telephone: (028) 9026 1401, email: events@ccea.org.uk)

- Moderation
  (telephone: (028) 9026 1200, extension 2236, email: moderationteam@ccea.org.uk)

- Business Assurance (Complaints and Appeals)
  (telephone: (028) 9026 1244, email: complaints@ccea.org.uk or appealsmanager@ccea.org.uk).

Appendix

Mathematical Content and Skills

Students need to be familiar with and competent in the following areas of mathematics in order to develop their skills, knowledge and understanding in Physics. Material in **bold** will only be required in Higher Tier papers.

Arithmetic and numerical computation
Recognise and use expressions in decimal form.
Recognise and use expressions in standard form.
Use ratios, fractions and percentages.
Make estimates of the results of simple calculations.
Handling data
Express a physical quantity to an appropriate number of significant figures.
Express a number to one, two or three decimal places.
Find arithmetic means.
Construct and interpret tables, pie charts and bar charts.
Algebra
Understand and use the symbols =, <, <<, >>, >, ∝ and ~.
Change the subject of an equation.
Substitute numerical values into algebraic equations to calculate a physical quantity.
Deduce appropriate units for physical quantities.
Solve simple algebraic equations.
Understand the meaning of direct **and inverse (indirect)** proportion.
Graphs
Translate information between graphical and numeric form.
Understand that $y = mx$ represents a linear relationship, where m is the gradient, and that the graph of y against x is a straight line through the origin.
Understand that $y = mx + c$ represents a linear relationship, where m is the gradient and c is the y-axis intercept.
Plot two variables from experimental or other data.
Determine the slope and intercept of a linear graph.
Geometry and trigonometry
Use angular measures in degrees.
Calculate areas of triangles and rectangles, surface areas and volumes of cuboids.

The mathematics content above will be assessed within the lifetime of the specification.

COUNCIL FOR THE **CURRICULUM, EXAMINATIONS** AND **ASSESSMENT**
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