GCSE

WJEC GCSE in

PHYSICS

APPROVED BY QUALIFICATIONS WALES

SPECIFICATION

Teaching from 2016
For award from 2018

Version 2 March 2019

This Qualifications Wales regulated qualification is not available to centres in England.

SUMMARY OF AMENDMENTS

Version	Description	Page number
2	'Making entries' section has been amended to clarify resit rules, carry forward of Practical Assessment (NEA) marks and the terminal rule.	39

WJEC GCSE in PHYSICS

For teaching from 2016
For award from 2018

This specification meets the GCSE Qualification Principles which set out the requirements for all new or revised GCSE specifications developed to be taught in Wales from September 2016.

GCSE PHYSICS (Wales)

SUMMARY OF ASSESSMENT

There are two tiers of entry for this qualification:
Higher Tier – Grades A* - D
Foundation Tier – Grades C - G

This GCSE qualification in Physics offers assessment at foundation and higher tier. In most cases, we would expect candidates to be assessed within the same tier. Exceptionally, it may be appropriate to enter some candidates for a combination of higher and foundation tier units.

Unit 1: ELECTRICITY, ENERGY and WAVES Written examination: 1 hour 45 minutes 45% of qualification	80 marks
A mix of short answer questions, structured questions, extended writing and data response questions with some set in a practical context. A tiered assessment.	
Unit 2: FORCES, SPACE and RADIOACTIVITY Written examination: 1 hour 45 minutes 45% of qualification	80 marks
A mix of short answer questions, structured questions, extended writing and data response questions with some set in a practical context. A tiered assessment.	
Unit 3: PRACTICAL ASSESSMENT 10% of qualification	30 marks
Practical assessment that will be carried out in centres, but will be externally marked by WJEC. It will take place in the first half of the spring term (January – February). It is recommended that this should be in the final year of study. An untiered assessment.	

This unitised qualification will be available in the summer series each year. It will be awarded for the first time in Summer 2018.

Qualification Number listed on The Register: 601/8235/0

Qualifications Wales Approval Number listed on QiW: C00/0780/0

GCSE PHYSICS

1 INTRODUCTION

1.1 Aims and objectives

This WJEC GCSE Physics specification provides a broad, coherent, satisfying and worthwhile course of study. It encourages learners to develop confidence in, and a positive attitude towards, science and to recognise its importance in their own lives and to society.

Studying GCSE Physics provides the foundations for understanding the material world. Scientific understanding is changing our lives and is vital to the world's future prosperity, and all learners should be taught essential aspects of the knowledge, methods, processes and uses of science. They should be helped to appreciate how the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas relating to the sciences which are both inter-linked, and are of universal application. These key ideas include:

- the use of conceptual models and theories to make sense of the observed diversity of natural phenomena
- the assumption that every effect has one or more cause
- that change is driven by differences between different objects and systems when they interact
- that many such interactions occur over a distance without direct contact
- that science progresses through a cycle of hypothesis, practical experimentation, observation, theory development and review
- that quantitative analysis is a central element both of many theories and of scientific methods of inquiry.

This specification is intended to promote a variety of styles of teaching and learning so that the course is enjoyable for all participants. Learners will be introduced to a wide range of scientific principles which will allow them to enjoy a positive learning experience. Practical work is an intrinsic part of science. It is imperative that practical skills are developed throughout this course and that an investigatory approach is promoted.

1.2 Prior learning and progression

There are no previous learning requirements for this specification. Any requirements set for entry to a course based on this specification are at the school/college's discretion.

This specification builds on subject content which is typically taught at key stage 3 and provides a suitable foundation for the study of Physics at either AS or A level. In addition, the specification provides a coherent, satisfying and worthwhile course of study for learners who do not progress to further study in this subject.

1.3 Equality and fair access

This specification may be followed by any learner, irrespective of gender, ethnic, religious or cultural background. It has been designed to avoid, where possible, features that could, without justification, make it more difficult for a learner to achieve because they have a particular protected characteristic.

The protected characteristics under the Equality Act 2010 are age, disability, gender reassignment, pregnancy and maternity, race, religion or belief, sex and sexual orientation.

The specification has been discussed with groups who represent the interests of a diverse range of learners, and the specification will be kept under review.

Reasonable adjustments are made for certain learners in order to enable them to access the assessments (e.g. candidates are allowed access to a Sign Language Interpreter, using British Sign Language). Information on reasonable adjustments is found in the following document from the Joint Council for Qualifications (JCQ): *Access Arrangements and Reasonable Adjustments: General and Vocational Qualifications.*

This document is available on the JCQ website (www.jcq.org.uk). As a consequence of provision for reasonable adjustments, very few learners will have a complete barrier to any part of the assessment.

1.4 Welsh Baccalaureate

In following this specification, learners should be given opportunities, where appropriate, to develop the skills that are being assessed through the Core of the Welsh Baccalaureate:

- Literacy
- Numeracy
- Digital Literacy
- Critical Thinking and Problem Solving
- Planning and Organisation
- Creativity and Innovation
- Personal Effectiveness.

1.5 Welsh perspective

In following this specification, learners must consider a Welsh perspective if the opportunity arises naturally from the subject matter and if its inclusion would enrich learners' understanding of the world around them as citizens of Wales as well as the UK, Europe and the world.

2 SUBJECT CONTENT

This section outlines the knowledge, understanding and skills to be developed by learners studying GCSE Physics.

Learners should be prepared to apply the knowledge, understanding and skills specified in a range of theoretical, practical, industrial and environmental contexts. Practical work is an intrinsic part of this specification. It is vitally important in developing a conceptual understanding of many topics and it enhances the experience and enjoyment of science. The practical skills developed are also fundamentally important to learners going on to further study in science and related subjects, and are transferable to many careers.

All of the content present in the Physics units of the Science (Double Award) specification (i.e. Units 3 and 6) is covered in this specification. In addition some of the content covered in Unit 1 of this specification overlaps with the content of Unit 1 of the Applied Science (Double Award) specification. This will allow learners if necessary to transfer between the different qualifications on offer in the GCSE Science suite in the first term of study.

This section includes specified practical work that must be undertaken by learners in order that they are suitably prepared for all assessments. The completion of this practical work will develop the practical skills listed in Appendix A.

Appendix B lists the mathematical requirements. A list of equations will be included at the start of each examination paper. Foundation tier learners will not be expected to change the subject of an equation, however they may be expected to recognise and use them in other formats.

Some areas of content have been selected for assessment at higher tier only. This content is shown in bold type in the relevant content sections. All content may therefore be examined at higher tier but that in bold will not be examined on foundation tier papers.

All content in the specification should be introduced in such a way that it develops learners' ability to:

- understand scientific concepts through the specific discipline of physics
- understand the nature, processes and methods of science, through different types of scientific enquiries that help them to answer scientific questions about the world around them
- apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory, in the field and in other learning environments
- evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.

2.1 Unit 1

ELECTRICITY, ENERGY and WAVES

Written examination: 1 hour 45 minutes
45% of qualification

This unit includes the following topics:

1.1 Electric circuits

1.2 Generating electricity

1.3 Making use of energy

1.4 Domestic electricity

1.5 Features of waves

1.6 The total internal reflection of waves

1.7 Seismic waves

1.8 Kinetic theory

1.9 Electromagnetism

1.1 ELECTRIC CIRCUITS

Overview

This topic explores the relationship between current and potential difference and develops the idea of resistance. It investigates how potential differences and currents are related in series and parallel circuits and how the total resistance in series and parallel circuits can be calculated. It introduces the concept of power in an electrical circuit as the energy transferred per unit time and introduces the equations which enable the power transferred by an appliance to be calculated.

Working Scientifically

The specified practical work within this topic gives learners the opportunity to plan and devise investigative approaches and methods to practical work; to safely and correctly use a range of practical equipment and materials; to keep appropriate records of experimental observations and measurements; to correctly construct circuits from circuit diagrams using d.c. power supplies, cells and a range of circuit components. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific explanations. Learners can carry out experimental and investigative activities, such as the design and use of circuits to explore the variation of resistance in devices such as lamps, diodes, thermistors and LDRs, selecting techniques, instruments, apparatus and materials appropriate to the experiment. They can then make informed decisions on the use of energy saving devices in their homes. Learners can investigate electrical circuits and use this experience to learn about the risk management issues involved when handling sources of power and the safety aspects involved in the domestic use of electricity.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the equations relating potential difference, resistance, power, energy and time to solve problems for circuits which include components in series, using the concept of equivalent resistance; using graphs to explore whether circuit elements are linear or non-linear and relate the curves produced to their function and properties. These topics afford learners the opportunity to use ratios, fractions and percentages; **to change the subject of an equation**; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; to plot two variables from experimental or other data; to interpret the slope and intercept of a linear graph; to **draw and use the slope of a tangent to a curve as a measure of rate of change.**

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the symbols of components (cell, switch, lamp, voltmeter, ammeter, resistor, variable resistor, fuse, LED, thermistor, LDR, diode) used in electrical circuits

(b) series circuits in which the current is the same throughout a circuit and voltages add up to the supply voltage; parallel circuits in which the voltage is the same across each branch and the sum of the currents in each branch is equal to the current in the supply

(c) voltmeters and ammeters to measure the voltage across and current in electrical components in electrical circuits

(d) circuits to investigate how current changes with voltage for a component e.g. for a resistor (or wire) at constant temperature, a filament lamp and a diode

(e) the significance of and the relationship between current, voltage and resistance, $I = \frac{V}{R}$

(f) how adding components in series increases total resistance in a circuit; adding components in parallel decreases total resistance in a circuit

(g) how to calculate total resistance and total current in a series circuit, **a parallel circuit and circuits consisting of combinations of series and parallel connections**;

$R = R_1 + R_2$; $\quad \boldsymbol{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}}$

(h) power as energy transferred per unit time: $E = Pt$

(i) the power transferred using:

power = voltage × current $\quad P = VI$

power = current² × resistance $\boldsymbol{P = I^2 R}$

(j) explain the design and use of circuits to explore the variation of resistance – including for lamps, diodes, ntc thermistors and LDRs

SPECIFIED PRACTICAL WORK

- Investigation of the current-voltage (I-V) characteristics for a component

1.2 GENERATING ELECTRICITY

Overview

This topic begins by looking at the advantages and disadvantages of renewable and non-renewable technologies for the generation of electrical power. It discusses the need for the National Grid as a nationwide electrical distribution system and the use of step-up and step-down transformers in the transmission of electricity from the power station to the home.

Working Scientifically

This unit contains opportunities for learners to explain every day and technological applications of science; to evaluate personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments. Learners can be helped to understand how, through the ideas of physics, physical laws and models are expressed in mathematical form. Learners can apply the conservation of energy to many different situations, including investigating data to be able to compare the efficiency of power stations and explain why transmitting energy from power stations at high voltage is an efficient way of transferring energy.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include expressing in quantitative form the overall redistribution of energy within a system e.g. Sankey diagrams; applying the relationship between power, voltage and current to calculate the current flowing when electrical power is transmitted at different voltages. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation;** to substitute numerical values into algebraic equations using appropriate units for physical quantities.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the advantages and disadvantages of renewable energy technologies (e.g. hydroelectric, wind power, wave power, tidal power, waste, crops, solar and wood) for generating electricity on a national scale using secondary information

(b) the advantages and disadvantages of non-renewable energy technologies (fossil fuels and nuclear) for generating electricity

(c) the processes involved in generating electricity in a fuel based power station

(d) Sankey diagrams to show energy transfers; energy efficiency in terms of input energy and energy usefully transferred in a range of contexts including electrical power generation and transmission:

$$\%\ \text{efficiency} = \frac{\text{energy [or power] usefully transferred}}{\text{total energy [or power] supplied}} \times 100$$

(e) the need for the National Grid as an electricity distribution system including monitoring power use and responding to changing demand

(f) advantages and disadvantages of using different voltages of electricity at different points in the National Grid to include transmission of electricity and use in the home, selecting and using the equation:

power = voltage × current; $P = VI$

(g) the use of step-up and step-down transformers used in the transmission of electricity from the power station to the user in qualitative terms (they should be treated as voltage changers without any reference to how they perform this function)

(h) efficiency, reliability, carbon footprint and output to compare different types of power stations in the UK including those fuelled by fossil fuels, nuclear fuel and renewable sources of energy

1.3 MAKING USE OF ENERGY

Overview

This topic explores the idea that temperature differences can lead to the transfer of thermal energy by conduction, convection and radiation. It uses the molecular model of matter to explain the differences in the mechanism of thermal energy transfer by these three methods. It uses the ideas developed to discuss the efficiency and cost effectiveness of different methods of reducing thermal energy losses in the domestic situation.

Working Scientifically

There are opportunities within this topic for learners to use models, as in the particle model of matter to develop an understanding of the different methods of the transfer of thermal energy. There are also opportunities for learners to use scientific knowledge and understanding to pose scientific questions and present scientific arguments and ideas. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific explanations. For example, the use of the particle model of matter to explain the different properties and behaviour of solids, liquids and gases. There are also opportunities within this topic for learners to carry out experimental activities, using appropriate risk management.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the relationship between density, mass and volume; calculating the cost effectiveness and efficiency of different methods of reducing energy loss from the home. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation**; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to calculate areas of rectangles and volumes of cubes.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) how temperature differences lead to the transfer of energy thermally by conduction, convection and radiation

(b) the equation: $\text{density} = \frac{\text{mass}}{\text{volume}}$ and explain the differences in density between the three states of matter in terms of the arrangements of the atoms or molecules

(c) **conduction using a model of molecular motion and account for the better conduction in metals by the presence of mobile electrons**

(d) **convection in liquids and gases in terms of molecular behaviour and variations in volume and density**

(e) how energy loss from houses can be restricted e.g. loft insulation, double glazing, cavity wall insulation and draught excluders

(f) the cost effectiveness and efficiency of different methods of reducing energy loss from the home, to compare their effectiveness; use data to compare the economics of domestic insulation techniques, including calculating the payback time; the economic and environmental issues surrounding controlling energy loss

(g) how data can be obtained and used to investigate the cost of using a variety of energy sources for heating and transport

SPECIFIED PRACTICAL WORK

- Investigation of the methods of heat transfer
- Determination of the density of liquids and solids (regular and irregular)

1.4 DOMESTIC ELECTRICITY

Overview

This topic covers the functions of fuses and other devices which are designed to prevent current flow when faults develop in domestic circuits. It introduces the concept of the ring main circuit and explains the functions of the live, neutral and earth wires. It compares the cost effectiveness of using different renewable energy sources such as solar and wind energy to supplement the user's needs in the domestic situation.

Working Scientifically

Learners can carry out experimental and investigative activities, such as the efficiency of energy transfer of an electric kettle. They will develop the skill of carrying out experiments appropriately, having due regard for the manipulation of apparatus, the accuracy of the measurements and health and safety considerations. They can then make informed decisions on the use of energy saving devices in their homes. Learners can investigate electrical circuits and use this experience to learn about the risk management issues involved when handling sources of power and the safety aspects involved in the domestic use of electricity.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the equations relating units used, power and time to calculate the cost of electrical energy; determining the efficiency of energy transfer, e.g. whilst using an electric kettle. These topics afford learners the opportunity to use ratios, fractions and percentages; **to change the subject of an equation**; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; to construct and interpret tables and diagrams.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the kilowatt (kW) as a convenient unit of power in the domestic context and the kilowatt hour (kWh) as a unit of energy

(b) the cost of electricity using the equations:

units used (kWh) = power (kW) × time (h)
cost = units used × cost per unit

(c) how data can be obtained either directly or using secondary sources (e.g. through the energy banding (A-G) and the power ratings of domestic electrical appliances) to investigate the cost of using them

(d) the difference between alternating current (a.c.) and direct current (d.c.)

(e) the functions of fuses, miniature circuit breakers (mcb) and residual current circuit breakers (rccb) including calculations of appropriate fuse ratings

(f) the ring main, including the functions of the live, neutral and earth wires

(g) the cost effectiveness of introducing domestic solar and wind energy equipment, including fuel cost savings and payback time by using data

(h) how to investigate energy transfers in a range of contexts including interpreting and analysing data; evaluation of validity of the data and methods, e.g.

- the energy output from a renewable source (e.g. wind turbine: construction and location)
- efficiency of energy transfer (e.g. using an electric kettle)

1.5 FEATURES OF WAVES

Overview

This topic covers the basic properties of transverse and longitudinal waves and the differences between them. It introduces the wave equation and gives learners the fundamental ideas and skills they need to study both electromagnetic and sound waves.

Working Scientifically

Questions set on this topic will assess learners' abilities to apply scientific knowledge to practical contexts; to present data in appropriate ways; to evaluate results and draw conclusions. The specified practical work in this topic gives learners the opportunity to make and record observations; to keep appropriate records of experimental activities; to apply the cycle of collecting, presenting and analysing data. There are opportunities within this topic for learners to carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying formulae relating velocity, frequency and wavelength; showing how changes in velocity and wavelength in refraction from one medium to another are inter-related. These topics afford learners the opportunity to use ratios, fractions and percentages; to substitute numerical values into algebraic equations using appropriate units for physical quantities; **to change the subject of an equation.**

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the difference between transverse and longitudinal waves

(b) the description of a wave in terms of amplitude, wavelength (λ), frequency (f) and wave speed (v)

(c) the graphical representation of a transverse wave, including labelling the wavelength and amplitude

(d) diagrams showing plane wave fronts being reflected or refracted, e.g. as shown by water waves in a ripple tank

(e) refraction in terms of the speed of waves on either side of a refracting boundary and the effect on the wavelength of the waves

(f) the term "radiation" to both electromagnetic waves and to energy given out by radioactive materials

(g) the characteristics of radioactive emissions and short wavelength parts of the electromagnetic spectrum (ultraviolet, X-ray and gamma ray) as ionising radiation, able to interact with atoms and to damage cells by the energy they carry

(h) the difference between the different regions of the electromagnetic spectrum [radio waves, microwaves, infra-red, visible light, ultraviolet, X-rays and gamma rays] in terms of their wavelength and frequency and know that they all travel at the same speed in a vacuum

(i) the fact that all regions of the electromagnetic spectrum transfer energy and certain regions are commonly used to transmit information

(j) waves in terms of their wavelength, frequency, speed and amplitude

(k) the equations:
wave speed = wavelength × frequency; $v = \lambda f$ and

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

applied to the motion of waves, including electromagnetic waves

(l) communication using satellites in geosynchronous/geostationary orbit

SPECIFIED PRACTICAL WORK

- Investigation of the speed of water waves

1.6 THE TOTAL INTERNAL REFLECTION OF WAVES

Overview

This topic studies the conditions necessary for the total internal reflection of light. It introduces both medical and communications applications of total internal reflection using optical fibres.

Working Scientifically

Questions set on this unit will assess learners' abilities to explain every day and technological applications of science; to process and analyse data using appropriate mathematical skills; to present data in appropriate ways. There are opportunities within this topic for learners to consider applications and implications of science and to evaluate their associated risks.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the conditions for total internal reflection of light

(b) how optical fibres rely on total internal reflection for their operation

(c) comparison of the advantages and disadvantages of optical fibres and geosynchronous / geostationary satellites for long distance communication

(d) the use of optical fibres for remote imaging, including endoscopic medical examinations and a comparison of endoscopy with CT scans for obtaining medical information

1.7 SEISMIC WAVES

Overview

This topic explores the properties of seismic P, S and surface waves and how these properties enable seismic records to locate the epicentres of earthquakes. This builds upon the properties of waves studied in topic 1.5.

Working Scientifically

There are opportunities within this topic for learners to use models to explain the passage of P and S waves through the Earth and to deduce the epicentre of an earthquake by using seismic records. There are also opportunities for learners to use scientific knowledge and understanding to pose scientific questions and to present scientific arguments and ideas. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific explanations. For example, how the existence of the S wave shadow zone has led geologists to a model of the Earth with a solid mantle and a liquid core.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying formulae relating speed, distance and time to calculate the lag time between the arrival of P and S waves from the epicentre of an earthquake. These topics afford learners the opportunity to use ratios, fractions and percentages; to substitute numerical values into algebraic equations using appropriate units for physical quantities; **to change the subject of an equation**.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the properties of seismic P waves, S waves and surface waves, in terms of their nature, speed and ability to penetrate different materials

(b) the fact that P waves are longitudinal and S waves are transverse

(c) simplified seismic records, to allow for the identification of the lag time between the arrival of the P and S waves to occur and to use the seismic records from several stations to locate the epicentre of an earthquake.

(d) the path of P and S waves through the Earth (the dependence of the speed of seismic waves on the density and stiffness of the material will not be examined)

(e) how existence of the S wave shadow zone as shown on seismic records has led geologists to a model of the Earth with a solid mantle and a liquid core

1.8 KINETIC THEORY

Overview

This topic introduces the concept of pressure and uses this to discuss the behaviour of a fixed mass of gas under different conditions of pressure, volume and temperature. It develops the idea of absolute zero and how this can define an absolute scale of temperature. The equations relating heat transfer to changes in temperature and state are also introduced.

Working Scientifically

There are opportunities within this topic for learners to use models, as in the particle model of matter to develop the idea that differences between pressure and temperature are the drivers of change. There are also opportunities for learners to use scientific knowledge and understanding to pose scientific questions and to present scientific arguments and ideas. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific explanations. For example, the use of the particle model of matter to explain the variation of pressure in gases with volume and temperature. There are also opportunities within this topic for learners to carry out experimental activities, using appropriate risk management.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the relationship between pressure and volume for a fixed mass of gas at constant temperature and in other circumstances where one of the other variables remains constant; using the equations relating heat transfer to changes of temperature and state. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation;** to substitute numerical values into algebraic equations using appropriate units for physical quantities; to calculate areas of rectangles.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the concept of pressure qualitatively and select and use the relationship:

$$\text{pressure} = \frac{\text{force}}{\text{area}}; \quad p = \frac{F}{A}$$

(b) the behaviour of a fixed quantity of gas under conditions of varying pressure, volume and temperature

(c) how the behaviour of gases leads to the concepts of absolute zero and an absolute scale of temperature

(d) temperatures in kelvin and **use the relationship:**

$$\frac{pV}{T} = \textbf{constant}$$

for gases including circumstances in which one of the three variables remains constant

(e) the variation of the pressure of gases with volume and temperature qualitatively by applying a model of molecular motion and collisions

(f) the equations:

$Q = mc\Delta\theta$ and $Q = mL$

relating the heat transfer to changes of temperature and state respectively

(g) **the explanation of changes in temperature and state of a substance, resulting from heat transfer, in terms of the behaviour of molecules**

SPECIFIED PRACTICAL WORK

- Determination of the specific heat capacity of a material

1.9 ELECTROMAGNETISM

Overview

This topic covers the concept of magnetic fields and investigates the forces on current carrying conductors in magnetic fields and how this effect is used in simple motors. It also explores the production of induced potential differences produced by changing magnetic fields and how this effect is used in generators and transformers.

Working Scientifically

The specified practical work in this topic gives learners the opportunity to investigate the output of a transformer; to make and record observations; to keep appropriate records of experimental activities. There are opportunities within this topic for learners to communicate information and ideas in appropriate ways using appropriate terminology; to consider applications and implications of science and to evaluate their associated benefits and risks. Learners can consider the applications and implications of science and the associated benefits to society by studying the changing flux through a coil rotating in a magnetic field. They can also consider how the invention of devices such as the a.c. generator has benefited society.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the equation linking field strength, current and length of conductor, to calculate the force on a conductor placed at right angles to a magnetic field; applying the equations linking the potential differences and numbers of turns in the two coils of a transformer, to the currents and power transfer involved. These topics afford learners the opportunity to use ratios, fractions and percentages; **to change the subject of an equation;** to substitute numeric values into algebraic equations using appropriate units for physical quantities.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the magnetic field patterns of bar magnets, straight wires and solenoids

(b) how a magnet and a current carrying conductor exert a force on one another (the motor effect) and use Fleming's left hand rule to predict the direction of one of the following: force on the conductor, the current and the magnetic field when two are provided

(c) **the equation that links the force (F) on a conductor to the strength of the field (B), the current (I) and the length of conductor (l), when the field and current are at right angles:**
$$F = BIl$$

(d) a simple d.c. motor, by predicting its direction of rotation and understand qualitatively the effect on increasing the current, magnetic field strength and number of turns

(e) the conditions in which a current is induced in circuits by changes in magnetic fields and the movement of wires

(f) electromagnetic induction to explain the operation of a simple a.c. electric generator including the factors upon which its output depends

(g) the direction of the induced current in a generator to the direction of the magnetic field and the direction of rotation of the coil

(h) the operation of a transformer qualitatively by reference to electromagnetic induction

(i) how the output of a 100% efficient transformer depends upon the number of turns on the coils:

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

SPECIFIED PRACTICAL WORK

- Investigation of the output of an iron-cored transformer

2.2 Unit 2

FORCES, SPACE and RADIOACTIVITY

Written examination: 1 hour 45 minutes
45% of qualification

This unit includes the following topics:

2.1 Distance, speed and acceleration

2.2 Newton's laws

2.3 Work and energy

2.4 Further motion concepts

2.5 Stars and planets

2.6 The Universe

2.7 Types of radiation

2.8 Half-life

2.9 Nuclear decay and nuclear energy

2.1 DISTANCE, SPEED AND ACCELERATION

Overview

This topic introduces the ideas of distance, speed, velocity, acceleration and their definitions. Learners will use velocity-time graphs to determine the acceleration of a moving body, and the distance the body travels in a given time. These basic principles will be applied to the safe stopping distances of vehicles and the factors upon which this depends.

Working Scientifically

There are opportunities within this topic for learners to use appropriate methodology, including ICT to answer scientific questions and to solve scientific problems. Learners can carry out experimental and investigative activities using stopwatches, light gates and data loggers to measure the acceleration of a moving body, to investigate factors affecting stopping distances and to measure the speed of a moving body. Learners can apply these factors to explain the factors which affect the braking distances of moving vehicles and the related safety considerations and to explain the dangers caused by large decelerations. Learners can evaluate risks in the wider social context, including perception of risk in relation to given data and discuss traffic control arising from the above.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include making calculations using ratios and proportional reasoning to convert units and compute rates; relating changes and differences in motion to appropriate distance-time and velocity-time graphs; interpreting enclosed areas of such graphs; applying formulae relating distance, time and speed for uniform motion; estimating how the distances required for road vehicles to stop in an emergency varies over a range of typical speeds. These topics afford learners the opportunity to use expressions in decimal form; to use ratios, fractions and percentages; to make estimates of the results of simple calculations, without using a calculator; **to change the subject of an equation;** to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; to translate information between graphical and numeric form; **to understand that $y = mx + c$ represents a linear relationship;** to plot two variables from experimental or other data; to interpret the slope of a linear graph; **to understand the physical significance of the area between a curve and the x-axis and to measure it by counting squares as appropriate.**

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) motion using speed, velocity and acceleration

(b) speed-time and distance-time graphs

(c) the equations: $\text{speed} = \dfrac{\text{distance}}{\text{time}}$ and

$$\text{acceleration (or deceleration)} = \frac{\text{change in velocity}}{\text{time}}$$

(d) velocity-time graphs to determine acceleration **and distance travelled**

(e) the principles of forces and motion to the safe stopping of vehicles, including knowledge of the terms reaction time, thinking distance, braking distance and overall stopping distance and discuss the factors which affect these distances

(f) the physics of motion together with presented data and opinions to discuss traffic control arising from the above, e.g. the need for speed limits and seat belts

2.2 NEWTON'S LAWS

Overview

This topic introduces the concepts of inertia, mass and weight and the relationship between them. The relationship between force, mass and acceleration is developed. Newton's laws of motion are used to explain the behaviour of objects moving through the air, and the concept of terminal speed.

Working Scientifically

The specified practical work in this topic gives learners the opportunity to know and understand a range of techniques, practical instruments and equipment appropriate to the knowledge and understanding included in the specification; to safely and correctly use practical equipment and materials; to make and record observations; to present information and data in a scientific way.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the relationship between resultant force, mass and acceleration; calculating the weight of a mass in a given gravitational field. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation;** to substitute numerical values into algebraic equations using appropriate units for physical quantities.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the concept of inertia, that mass is an expression of the inertia of a body

(b) Newton's first law of motion **and be able to state it**

(c) how unbalanced forces produce a change in a body's motion and that the acceleration of a body is directly proportional to the resultant force and inversely proportional to the body's mass

(d) Newton's second law of motion, **and be able to state it**, in the form:

resultant force = mass × acceleration; $F = ma$

(e) the distinction between the weight and mass of an object, the approximation that the weight of an object of mass 1 kg is 10 N on the surface of the Earth and use data on gravitational field strength in calculations involving weight ($W = mg$) and gravitational potential energy:

weight (N) = mass (kg) × gravitational field strength (N/kg)

(f) forces and their effects to explain the behaviour of objects moving through the air, including the concept of terminal speed

(g) Newton's third law of motion **and be able to state it**

SPECIFIED PRACTICAL WORK

- Investigation of the terminal speed of a falling object

2.3 WORK AND ENERGY

Overview

This topic explores the relationship between work and energy. The equations for kinetic energy and change in gravitational potential energy are developed. The principles of force, energy and motion are used to analyse such safety features of cars as air bags and crumple zones.

Working Scientifically

This unit contains opportunities for learners to apply scientific knowledge to practical contexts. It gives learners the opportunity to understand how to use a range of experimental and practical instruments with due consideration for safety. It presents the opportunity for learners to apply the cycle of collecting, presenting and analysing data and presenting observations and other data using appropriate methods. There are opportunities within this topic for learners to carry out experimental activities in a range of topics. Learners can be helped to understand how, through the ideas of physics, physical laws and models are expressed in mathematical form. Learners can investigate the elastic and inelastic behaviour of a spring by carrying out experimental and investigative activities, including appropriate risk management.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include performing calculations using compatible units for energy transfers associated with energy changes in a system; recalling or selecting and applying the relevant equations for work done, kinetic energy and change in gravitational potential energy; calculating the energy stored in a stretched spring. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation;** to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; **to understand the physical significance of the area between a curve and the x-axis and to measure it by counting squares as appropriate.**

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the fact that, when a force acts on a moving body, energy is transferred although the total amount of energy remains constant

(b) the equation: work = force × distance moved in the direction of the force ; $W = Fd$

(c) the fact that work is a measure of the energy transfer, i.e. that work = energy transfer (in the absence of thermal transfer)

(d) the fact that an object can possess energy because of its motion (kinetic energy) and position (gravitational potential energy) and deformation (elastic energy)

(e) **the equations for kinetic energy and changes in gravitational potential energy:**

kinetic energy $= \frac{\text{mass} \times \text{velocity}^2}{2}$ **;** $\mathbf{KE} = \frac{1}{2} \boldsymbol{mv}^2$

change in potential energy = mass × gravitational field strength × change in height ; $\mathbf{PE} = \boldsymbol{mgh}$

(f) the relationship between force and extension for a spring and other simple systems;
force = spring constant × extension; $F = kx$

(g) **the work done in stretching by finding the area under the force-extension (*F*-*x*) graph**;
$\boldsymbol{W} = \frac{1}{2}\boldsymbol{Fx}$ **for a linear relationship**

(h) how energy efficiency of vehicles can be improved (e.g. by reducing aerodynamic losses/air resistance and rolling resistance, idling losses and inertial losses)

(i) the principles of forces and motion to an analysis of safety features of cars e.g. air bags and crumple zones

SPECIFIED PRACTICAL WORK

- Investigation of the force-extension graph for a spring

2.4 FURTHER MOTION CONCEPTS

Overview

This topic covers rectilinear motion. The equations of uniformly accelerated motion in a straight line are studied. The effects of forces upon objects and the concept of momentum and its conservation are explored.

Working Scientifically

The specified practical work in this topic gives learners the opportunity to use apparatus to record a range of measurements; to use analogue apparatus to record a range of measurements. Learners have the opportunity to follow written instructions, to make and record observations, keep appropriate records and to present information and data in a scientific way. There are opportunities within this topic for learners to use appropriate methodology, including ICT to answer scientific questions and solve scientific problems. Learners can carry out experimental and investigative activities using stopwatches, light gates and data loggers to measure the acceleration of a moving body.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include making calculations using ratios and proportional reasoning to convert units and compute rates; applying formulae relating mass, velocity and momentum to investigate the conservation of momentum; using the equations of uniformly accelerated motion to study how the motion of objects can be modelled; applying the principle of moments to systems involving a pivot and parallel forces. These topics afford learners the opportunity to use expressions in decimal form; to use ratios, fractions and percentages; to make estimates of the results of simple calculations, without using a calculator; **to change the subject of an equation;** to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; to translate information between graphical and numeric form.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) qualitatively how the momentum of a body depends upon its mass and its velocity, and select and use the equation:

momentum = mass × velocity ; $p = mv$

(b) Newton's second law of motion in the form: $\text{force} = \frac{\text{change in momentum}}{\text{time}}$

(c) the law of conservation of momentum and relate it to Newton's third law of motion and to use it quantitatively to perform calculations involving collisions **or explosions**, including selecting **and using the kinetic energy equation: to compare the kinetic energy before and after an interaction**

(d) how the motion of objects can be modelled using the equations:

$v = u + at$ $\qquad$ $x = \frac{u+v}{2}t$

$\boldsymbol{x} = \boldsymbol{ut} + \frac{1}{2}\boldsymbol{at}^2$ $\qquad$ $\boldsymbol{v}^2 = \boldsymbol{u}^2 + 2\boldsymbol{ax}$

(e) the Principle of Moments, limited to situations involving a pivot and parallel forces, e.g. a balanced metre rule

(f) describe examples in which forces cause rotation; define and calculate the moment of the force in such examples (moment = force × distance (normal to the direction of the force) [$M = F d$])

SPECIFIED PRACTICAL WORK

- Investigation of the Principle of Moments

2.5 STARS AND PLANETS

Overview

This topic covers the main features of our solar system and the circular orbits of planets, their moons and artificial satellites. It looks at the main observable stages in the life cycle of stars of different masses and discusses the stability of stars and explains the origin of the solar system as being due to the collapse of a cloud of gas and dust.

Working Scientifically

There are opportunities within this topic for learners to understand how scientific methods and theories develop over time. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific questions, define scientific problems, present scientific arguments and ideas; to know that scientific knowledge and understanding develops over time; to communicate information and ideas in appropriate ways using appropriate terminology. Learners can be given the opportunity to understand how scientific knowledge and understanding developed over time and how the theory that the origin of the solar system from the collapse of a cloud of gas and dust was accepted.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the main features of our solar system: their order, size, orbits and composition to include the Sun, terrestrial planets and gaseous giant planets, dwarf planets, comets, moons and asteroids

(b) the features of the observable universe (planets, planetary systems, stars and galaxies) and the use of appropriate units of distance: kilometres, astronomical units (AU) and light years (l-y)

(c) the main observable stages in the life cycle of stars of different masses, using the terms: protostar, main sequence star, red giant, supergiant, white dwarf, supernova, neutron star and black hole

(d) the fact that the stability of stars depends upon a balance between gravitational force and a combination of gas and radiation pressure and that stars generate their energy by the fusion of increasingly heavier elements

(e) the return of material, including heavy elements, into space during the final stages in the life cycle of giant stars

(f) the origin of the solar system from the collapse of a cloud of gas and dust, including elements ejected in supernovae

(g) **the Hertzsprung-Russell (H-R) diagram as a means of displaying the properties of stars, depicting the evolutionary path of a star**

2.6 THE UNIVERSE

Overview

This topic explores the evidence which leads to the concept of an expanding universe and links this evidence to the Big Bang model. It discusses the role played by the cosmological red shift in supporting the Big Bang model.

Working Scientifically

There are opportunities within this topic for learners to understand how scientific methods and theories develop over time. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific questions, define scientific problems, present scientific arguments and ideas; to know that scientific knowledge and understanding develops over time; to communicate information and ideas in appropriate ways using appropriate terminology. Learners can be given the opportunity to understand how scientific knowledge and understanding developed over time and how the Big Bang theory developed until its acceptance.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) how atomic absorption spectra can be used to identify gases from a given absorption spectrum and additional data and explain how scientists in the nineteenth century were able to reveal the chemical composition of stars

(b) how the "cosmological red shift", revealed initially by Sir Edwin Hubble's measurements on the spectra of distant galaxies, revealed that the wavelengths of the absorption lines are increased and that this effect increases with distance

(c) cosmological red shift in terms of the expansion of the Universe since the radiation was emitted

(d) the role played by the cosmological red shift in supporting the Big Bang model of the origin of the Universe

(e) how the existence of the Cosmic Microwave Background Radiation supports the hot Big Bang model of the origin of the Universe.

2.7 TYPES OF RADIATION

Overview

This topic covers the structure of the nuclear atom and its representation using atomic notation. It covers the spontaneous nature of nuclear decay and the nature of alpha, beta and gamma radiation. Learners will produce and balance nuclear equations for radioactive decay.

Working Scientifically

There are opportunities within this topic for learners to process and analyse data using mathematical skills. There are opportunities within this topic for learners to use appropriate methodology to answer scientific questions and to solve scientific problems.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include balancing equations representing alpha, beta or gamma decay in terms of the mass number and atomic number, and charges of the atoms involved. These topics afford learners the opportunity to use ratios, fractions and percentages.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the terms nucleon number (A), proton number (Z) and isotope, and relate them to the number of protons and neutrons in an atomic nucleus

(b) radioactive emissions as arising from unstable atomic nuclei because of an imbalance between the numbers of protons and neutrons

(c) the fact that waste materials from nuclear power stations and nuclear medicine are radioactive and some of them will remain radioactive for thousands of years

(d) background radiation and be able to make an allowance for it in measurements of radiation

(e) the random nature of radioactive decay and that it has consequences when undertaking experimental work, requiring repeat readings to be made or measurements over a lengthy period as appropriate

(f) the differences between alpha, beta and gamma radiation in terms of their penetrating power, relating their penetrating powers to their potential for harm and discussing the consequences for the long term storage of nuclear waste

(g) alpha radiation as a helium nucleus, beta radiation as a high energy electron and gamma radiation as electromagnetic

(h) **producing** and balancing nuclear equations for radioactive decay using the symbols ${}^{4}_{2}\mathrm{He}^{2+}$ or ${}^{4}_{2}\alpha$ for the alpha particle and ${}^{0}_{-1}\mathrm{e}$ and ${}^{0}_{-1}\beta$ for the beta particle respectively

(i) natural and artificial sources of background radiation, respond to information about received dose from different sources (including medical X-rays) and discuss the reasons for the variation in radon levels

2.8 HALF-LIFE

Overview

This topic covers the random nature of radioactive decay and introduces the concept of half-life. Learners will plot decay curves and use them to determine the half-lives of radioactive materials. Different uses of radioactive materials will be studied, the uses being related to their half-lives and their penetrating powers.

Working Scientifically

There are opportunities within this topic for learners to plot and interpret graphs; to process and analyse data using mathematical skills. There are opportunities within this topic for learners to use appropriate methodology to answer scientific questions and to solve scientific problems.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include calculating how the activity of a radioactive source changes after a given number of half-lives. These topics afford learners the opportunity to recognise expressions in standard form; to use ratios, fractions and percentages; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the random nature of radioactive decay and to model the decay of a collection of atoms using a constant probability of decay, e.g. using a large collection of dice, coins or a suitably programmed spreadsheet

(b) how to plot or sketch decay curves for radioactive materials, understand that a given radioactive material has a characteristic half-life and determine the half-life of a material from the decay curve

(c) how to perform simple calculations involving the activity and half-life of radioactive materials in a variety of contexts, e.g. carbon dating

(d) the different uses of radioactive materials, relating to the half-life, penetrating power and biological effects of the radiation e.g. radioactive tracers and cancer treatment

SPECIFIED PRACTICAL WORK

- Determination of the half-life of a model radioactive source, e.g. using dice

2.9 NUCLEAR DECAY AND NUCLEAR ENERGY

Overview

This topic covers the physics of fission and fusion, and the idea that in these processes, some of the mass may be converted into energy. Learners look at an example of a controlled fission reaction and study the roles of the moderator and control rods in a nuclear fission reactor. The problem of containment in reactors is also discussed.

Working Scientifically

There are opportunities within this topic for learners to use appropriate methodology to answer scientific questions and to solve scientific problems. Learners have the opportunity to evaluate methodology, evidence and data and to resolve conflicting evidence to consider ethical issues in the treatment of humans and the environment, to evaluate the ways in which society uses science to inform decision making.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the fact that the absorption of slow neutrons can induce fission in certain nuclei, referred to as fissile nuclei, such as uranium-235 ($^{235}_{92}\mathrm{U}$), and that the emission of neutrons from such fission reactions can lead to a sustainable chain reaction

(b) the roles of the moderator and control rods in a nuclear fission reactor

(c) the radioactive nature of fission products with a large range of half-lives

(d) the fact that high energy collisions between light nuclei, especially the isotopes of hydrogen, $^{2}_{1}\mathrm{H}$ (deuterium) and $^{3}_{1}\mathrm{H}$ (tritium) can result in fusion which releases energy

(e) the nuclear symbol, $^{1}_{0}\mathrm{n}$, for a neutron and use data to **produce and** balance nuclear equations for nuclear fission and fusion

(f) the problems of containment in fission and fusion reactors including neutron and gamma shielding and pressure containment in fission reactors and maintaining a high temperature in fusion reactors

2.3 Unit 3

PRACTICAL ASSESSMENT

10% of qualification

This assessment gives learners the opportunity to demonstrate their ability to work scientifically. This will include experimental skills and strategies and skills in analysis and evaluation.

The practical assessment is untiered and will take place in the first half of the spring term (January – February). It is recommended that this should be in the final year of study. Each year, WJEC will provide two tasks based on the content of GCSE Physics. Learners are only required to submit **one** task so centres can select which one they wish to use with their learners.

The tasks will be externally marked by WJEC and will change on an annual basis.

The details required for the planning and administration of the practical assessment will be provided to centres at appropriate times prior to the assessment.

Each task comprises two sections:

Section A - Obtaining results (6 marks)

Learners will be permitted to work in groups of no more than three, to obtain results from a given experimental method. This will be carried out under a limited level of control i.e. learners may work with others to obtain results but they must provide their own responses to the questions set. Teacher assistance should not normally be required, but may be given if equipment failure occurs. Section A will be completed in one session of 60 minutes duration.

Section B - Analysing and evaluating results (24 marks)

Learners will be assessed on their ability to analyse and evaluate the data obtained in section A. They will require access to their section A assessment in order to complete this. Section B will be carried out under a high level of control i.e. learners must work individually. This section is to be completed with no teacher feedback or assistance allowed and under formal supervision. Section B will be completed in one session of 60 minutes duration.

3 ASSESSMENT

3.1 Assessment objectives and weightings

Below are the assessment objectives for this specification. Learners must:

AO1
Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures

AO2
Apply knowledge and understanding of scientific ideas, processes, techniques and procedures

AO3
Analyse, interpret and evaluate scientific information, ideas and evidence, including in relation to issues, to:

- make judgements and reach conclusions
- develop and refine practical design and procedures

The table below shows the weighting of each assessment objective for each unit and for the qualification as a whole.

	AO1	**AO2**	**AO3**
Unit 1	18%	18%	9%
Unit 2	18%	18%	9%
Unit 3	4%	4%	2%
Overall weighting	**40%**	**40%**	**20%**

For each series:
- the weighting for the assessment of mathematical skills will be a minimum of 30%
- the weighting for the assessment of practical skills will be a minimum of 15%.

The ability to select, organise and communicate information and ideas coherently using scientific convention and vocabulary will be tested across the assessment objectives.

For each series, writing accurately will be assessed in specified questions that require extended writing (i.e. QER questions) in Units 1 and 2.
Writing accurately takes into account the candidate's use of specialist language. It also takes into account the candidate's spelling, punctuation and grammar.

4 TECHNICAL INFORMATION

4.1 Making entries

This is a unitised qualification which allows for an element of staged assessment.

Assessment opportunities will be available in the summer assessment period each year, until the end of the life of the specification.

Unit 1 will be available in 2017 (and each year thereafter). Unit 2 and Unit 3 will be available in 2018 (and each year thereafter) and the qualification will be awarded for the first time in Summer 2018.

There are two tiers of entry available for this qualification: Higher Tier (Grades A* - D) and Foundation Tier (Grades C - G). Unit 3 (practical assessment) is untiered. In most cases, we would expect candidates to be assessed within the same tier. Exceptionally, it may be appropriate to enter some candidates for a combination of higher and foundation tier units.

Candidates may resit an individual unit once only. The better uniform mark score from the two attempts will be used in calculating the final overall grade subject to the **terminal rule** being satisfied first i.e. that candidates must complete a minimum amount of the assessment for a qualification in the series in which they are cashing in. The terminal rule is set at 40% of the overall qualification for GCSE Physics. If the assessment being re-taken contributes to the 40% terminal rule requirement, the mark for the new assessment will count.

If any unit has been attempted twice and a candidate wishes to enter the unit for the third time, the candidate will have to re-enter all units and the appropriate cash-in(s). This is referred to as a 'fresh start'. When retaking a qualification (fresh start), a candidate may have up to two attempts at each unit. However, no results from units taken prior to the fresh start can be used in aggregating the new grade(s).

Marks for Practical Assessment (NEA) may be carried forward for the life of the specification.

If a candidate has been entered for but is absent for a unit, the absence does not count as an attempt. The candidate would, however, qualify as a resit candidate.

The entry codes appear below.

	Title	**Entry codes**	
		English-medium	**Welsh-medium**
Unit 1	Electricity, Energy and Waves (Foundation Tier)	3420U1	3420N1
	Electricity, Energy and Waves (Higher Tier)	3420UA	3420NA
Unit 2	Forces, Space and Radioactivity (Foundation Tier)	3420U2	3420N2
	Forces, Space and Radioactivity (Higher Tier)	3420UB	3420NB
Unit 3	Practical Assessment	3420U3	3420N3
GCSE Qualification cash-in		3420QS	3420CS

The current edition of our *Entry Procedures and Coding Information* gives up-to-date entry procedures.

4.2 Grading, awarding and reporting

There are two tiers of entry available for this qualification: Higher Tier (Grades A* - D) and Foundation Tier (Grades C - G). In most cases, we would expect candidates to be assessed within the same tier. Exceptionally, it may be appropriate to enter some candidates for a combination of higher and foundation tier units.

The Uniform Mark Scale (UMS) is used in unitised specifications as a device for reporting, recording and aggregating candidates' unit assessment outcomes. The UMS is used so that candidates who achieve the same standard will have the same uniform mark, irrespective of when the unit was taken.

Individual unit results reported on UMS have the following grade equivalences:

Grade	**MAX.**	**A***	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Units 1 - 2	180	162	144	126	108	90	72	54	36
Unit 3	40	36	32	28	24	20	16	12	8

For Units 1 - 2, which are tiered, the maximum uniform mark available on the foundation tier of the assessment will be 125 (i.e. 1 mark less than the minimum mark needed to achieve a grade B on the unit). As Unit 3 is untiered, the full range of uniform marks is available in the unit.

GCSE qualifications are reported on an eight point scale from A*- G, where A* is the highest grade. Results not attaining the minimum standard for the award will be reported as U (unclassified) and learners will not receive a certificate.

The uniform marks obtained for each unit are added up and the subject grade is based on this total. The total results reported on UMS will have the following grade equivalences:

UMS total	**A***	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Subject Award	360	320	280	240	200	160	120	80

APPENDIX A

Working Scientifically

1. Development of scientific thinking

- understand how scientific methods and theories develop over time
- use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts
- appreciate the power and limitations of science and consider any ethical issues which may arise
- explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments
- evaluate risks both in practical science and the wider societal context, including perception of risk in relation to data and consequences
- recognise the importance of peer review of results and of communicating results to a range of audiences

2. Experimental skills and strategies

- use scientific theories and explanations to develop hypotheses
- plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena
- apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment
- carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations
- make and record observations and measurements using a range of apparatus and methods
- evaluate methods and suggest possible improvements and further investigations

3. Analysis and evaluation

- apply the cycle of collecting, presenting and analysing data, including:
  - presenting observations and other data using appropriate methods
  - translating data from one form to another
  - carrying out and representing mathematical analysis
  - representing distributions of results and make estimations of uncertainty
  - interpreting observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions
  - presenting reasoned explanations including relating data to hypotheses
  - being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error
  - communicating the scientific rationale for investigations, methods used, findings and reasoned conclusions through paper based and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms

4. Scientific vocabulary, quantities, units, symbols and nomenclature

- use scientific vocabulary, terminology and definitions
- recognise the importance of scientific quantities and understand how they are determined
- use SI units (e.g. kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate
- use prefixes and powers of ten for orders of magnitude (e.g. tera, giga, mega, kilo, centi, milli, micro and nano)
- interconvert units
- **use an appropriate number of significant figures in calculation**

APPENDIX B

Mathematical Skills

This table shows the mathematical skills which can be assessed. Skills which will be assessed at higher tier only are shown in bold type.

	Skill
1	*Arithmetic and numerical computation*
	Recognise and use expressions in decimal form
	Recognise expressions in standard form
	Use ratios, fractions and percentages
2	*Handling data*
	Use an appropriate number of significant figures
	Find arithmetic means
	Construct and interpret tables and diagrams
	Understand simple probability
	Make order of magnitude calculations
3	*Algebra*
	Change the subject of an equation
	Substitute numerical values into algebraic equations and solve them using appropriate units for physical quantities
4	*Graphs*
	Translate information between graphical and numeric form
	Understand that $y = mx + c$ represents a linear relationship
	Plot two variables from experimental or other data
	Interpret the slope of a linear graph
	Interpret the intercept of a linear graph
	Draw and use the slope of a tangent to a curve as a measure of rate of change
	Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate
5	*Geometry and trigonometry*
	Use angular measures in degrees
	Calculate areas of triangles and rectangles, surface areas and volumes of cubes