OCR
RECOGNISING ACHIEVEMENT

AS/A Level GCE

GCE Physics A

OCR Advanced Subsidiary GCE in Physics A H158

OCR Advanced GCE in Physics A H558

version 4 – September 2013

specification

QAN 500/2603/3
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Contents

Vertical black lines indicate a significant change to the previous printed version.

1 About these Qualifications

This booklet contains OCR's Advanced Subsidiary (AS) GCE and Advanced GCE specifications in Physics A for teaching from September 2013.

These specifications have been developed for students who wish to continue with a study of physics after GCSE. Some students may wish to follow a physics course for only one year as an AS GCE, in order to broaden their curriculum. Others will continue their course for a further year extending their course to Advanced GCE. Such a course will prepare students to progress into further education, to follow courses in physics, engineering, one of the other sciences or related subjects, or to enter employment where a knowledge of physics would be useful.

For assessment purposes, knowledge and understanding of key concepts are treated separately at AS; important links between different areas of physics are largely assessed synoptically at A2. While the teaching of practical skills may be integrated with the theoretical topics, they are assessed separately. This allows skills to be developed in a way suited to an individual centre.

1.1 The Three-Unit AS

The AS GCE is both a 'stand-alone' qualification and also the first half of the corresponding Advanced GCE. The AS GCE is assessed at a standard appropriate for candidates who have completed the first year of study (both in terms of teaching time and content) of the corresponding two-year Advanced GCE course, ie between GCSE and Advanced GCE.

From September 2013 the AS GCE is made up of **three** mandatory units, of which **two** are externally assessed and **one** is internally assessed and will include the assessment of practical skills. These units form 50% of the corresponding six-unit Advanced GCE.

1.2 The Six-Unit Advanced GCE

From September 2013 the Advanced GCE is made up of **three** mandatory units at AS and **three** further mandatory units at A2.

Two of the AS and **two** of the A2 units are externally assessed.

The third AS unit and the third A2 unit are internally assessed and will include the assessment of practical skills.

1.3 Qualification Titles and Levels

These qualifications are shown on a certificate as:

- OCR Advanced Subsidiary GCE in Physics.
- OCR Advanced GCE in Physics.

Both qualifications are Level 3 in the National Qualification Framework (NQF).

1.4 Aims

The aims of these specifications are to encourage candidates to:

- develop their interest in, and enthusiasm for physics, including developing an interest in further study and careers in physics;
- appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society;
- develop and demonstrate a deeper appreciation of the skills, knowledge and understanding of *How Science Works*;
- develop essential knowledge and understanding of different areas of Physics and how they relate to each other.

1.5 Prior Learning/Attainment

These specifications have been developed for students who wish to continue with a study of physics at Level 3 in the National Qualifications Framework (NQF). The AS specification has been written to provide progression from GCSE Science and GCSE Additional Science, or from GCSE Physics; achievement at a minimum of grade C in these qualifications should be seen as the normal requisite for entry to AS Physics. However, students who have successfully taken other Level 2 qualifications in science or applied science with appropriate physics content may also have acquired sufficient knowledge and understanding to begin the AS Physics course. Other students without formal qualifications may have acquired sufficient knowledge of physics to enable progression onto the course.

Recommended prior learning for the AS units is shown in the introduction to each AS unit. The A2 units build upon the knowledge and understanding acquired at AS.

Recommended prior learning for the A2 course is successful performance at AS Physics.

2 Summary of Content

2.1 AS Units

Unit G481: *Mechanics*

- Motion
- Forces in action
- Work and energy

Unit G482: *Electrons, Waves and Photons*

- Electric current
- Resistance
- DC circuits
- Waves
- Quantum physics

Unit G483: *Practical Skills in Physics 1*

- This AS (practical skills) unit is teacher assessed and externally moderated by OCR.
- Candidates are assessed on one task from each of the following categories: qualitative, quantitative and evaluative tasks.

2.2 A2 Units

Unit G484: *The Newtonian World*

- Newton's laws and momentum
- Circular motion and oscillations
- Thermal physics

Unit G485: *Fields, Particles and Frontiers of Physics*

- Electric and magnetic fields
- Capacitors and exponential decay
- Nuclear physics
- Medical imaging
- Modelling the universe

Unit G486 *Practical Skills in Physics 2*

- This A2 (practical skills) unit is teacher assessed and externally moderated by OCR.
- Candidates are assessed on one task from each of the following categories: qualitative, quantitative and evaluative tasks.

3 Unit Content

Each unit is divided into a number of teaching modules. Within each module, the content is divided into two columns: **Context and exemplification** and **Assessable learning outcomes**. Only the statements in the right hand column will be examined; statements in the left hand column are included to provide guidance on delivery. References to HSW (How Science Works) are to Appendix B.

3.1 AS Unit G481: *Mechanics*

This unit consists of three teaching modules:

Module 1: **Motion**

- 1.1.1 Physical quantities and units
- 1.1.2 Scalars and vectors
- 1.1.3 Kinematics
- 1.1.4 Linear motion

Module 2: **Forces in action**

- 1.2.1 Force
- 1.2.2 Nonlinear motion
- 1.2.3 Equilibrium
- 1.2.4 Car safety

Module 3: **Work and energy**

- 1.3.1 Work and conservation of energy
- 1.3.2 Kinetic and potential energies
- 1.3.3 Power
- 1.3.4 Behaviour of springs and materials

Candidates are expected to apply knowledge, understanding and other skills gained in this unit to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should:

have achieved Grade C or above in both GCSE Science and GCSE Additional Science, or GCSE Physics, or an equivalent standard in other appropriate Level 2 qualifications.

Links

3.9 GCSE Additional Science

(iii) Physics

(a) Forces and motion

Forces arise from interaction between objects. The balance, or otherwise, of these forces on an object affects its movement. Energy transfers can occur due to these interactions though the total energy remains constant.

G481 Module 1: 1.1 Motion

This module provides knowledge and understanding of key ideas used to describe the motion of objects. The module is essential in the understanding of safety features of cars covered in the *Forces in action* module. It also provides students with opportunities to develop both analytical and experimental skills. The motion of a variety of objects can be analysed using graphical, ICT or data-logging techniques. The work of Galileo on falling objects can be used to illustrate how scientific ideas are modified and also the tentative nature of scientific knowledge.

Links

Unit G481: Module 2 – *Forces in action*

Unit G484: Module 1 – *Newton's laws and momentum*

Module 2 – *Circular motion and oscillations*

Context and exemplification	Assessable learning outcomes
1.1.1 Physical quantities and units	Candidates should be able to: (a) explain that some physical quantities consist of a numerical magnitude and a unit; (b) use correctly the named units listed in this specification as appropriate; (c) use correctly the following prefixes and their symbols to indicate decimal sub-multiples or multiples of units: pico (p), nano (n), micro (μ), milli (m), centi (c), kilo (k), mega (M), giga (G), tera (T); (d) Make suitable estimates of physical quantities included within this specification.
1.1.2 Scalars and vectors Students can carry out practical work to investigate the rule for addition of coplanar forces.	Candidates should be able to: (a) define *scalar* and *vector* quantities and give examples; (b) draw and use a vector triangle to determine the resultant of two coplanar vectors such as displacement, velocity and force; (c) calculate the resultant of two perpendicular vectors such as displacement, velocity and force; (d) resolve a vector such as displacement, velocity and force into two perpendicular components.

1.1.3 Kinematics

Compare and contrast average speed cameras and GATSOs.

Candidates should be able to:

(a) define *displacement*, *instantaneous speed*, *average speed*, *velocity and acceleration*;

(b) select and use the relationships

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

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

to solve problems;

(c) apply graphical methods to represent displacement, speed, velocity and acceleration;

(d) determine velocity from the gradient of a displacement against time graph;

(e) determine displacement from the area under a velocity against time graph;

(f) determine acceleration from the gradient of a velocity against time graph.

1.1.4 Linear motion

There are opportunities to investigate the motion of objects using light gates, ticker timers and motion sensors.

Use a spreadsheet to analyse data and plot graphs to find relationships between displacement and time (eg power law). (HSW 3)

The work done by Galileo can be used to illustrate how scientific models develop through the use of experimental data. (HSW 1,2, 7ab)

Students can record and analyse the projectile motion of balls and water jets using digital cameras.

Candidates should be able to:

(a) derive the equations of motion for constant acceleration in a straight line from a velocity against time graph;

(b) Select and use the equations of motion for constant acceleration in a straight line:

$$v = u + at\ ,\ s = \frac{1}{2}(u + v)t\ ,$$

$$s = ut + \frac{1}{2}at^2 \text{ and } v^2 = u^2 + 2as\ ;$$

(c) apply the equations for constant acceleration in a straight line, including the motion of bodies falling in the Earth's uniform gravitational field without air resistance;

(d) explain how experiments carried out by Galileo overturned Aristotle's ideas of motion;

(e) describe an experiment to determine the acceleration of free fall *g* using a falling body;

(f) apply the equations of constant acceleration to describe and explain the motion of an object due to a uniform velocity in one direction and a constant acceleration in a perpendicular direction.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for candidates to investigate the motion of objects (gliders, trolleys, etc) using ticker timers, light gates, data-loggers and video techniques. There are also opportunities for candidates to develop skills in recording, analysing and evaluating primary data.

Study vector addition of two coplanar forces using force-meters and masses.

Determine the average speed of cars and people.

Use a motion sensor to analyse displacement-time graphs.

Use a trolley on a ramp and either light-gates or ticker tape to find acceleration or to show displacement $\propto$ time^2.

Determine the acceleration of free fall using trapdoor and electromagnet arrangement or video technique.

Use a ball bearing and a ramp to study projectile motion.

Determine the initial speed of water from a water hose or jet using the physics of projectiles.

G481 Module 2: 1.2 Forces in action

What happens when several forces act on an object? This important question is of paramount importance to a civil engineer building a bridge or to a car designer aiming to break the world speed record. The material covered in this and the earlier module on motion is used to understand the safety features and navigation systems (GPS) used in modern cars. There are opportunities for students to appreciate societal benefits from scientific innovations. The work of Newton on the motion of objects can be used to illustrate how scientific ideas need to be modified and also the tentative nature of scientific knowledge.

Links

Links to GCSE: 3.9(iii)(a)

Unit G481: Module 1 – *Motion* and Module 3 – *Work and energy*

Unit G484: Module 1 – *Newton's laws and momentum* and Module 2 – *Circular motion and oscillations*

Context and exemplification	Assessable learning outcomes
1.2.1 Force	Candidates should be able to:
Students can investigate the motion of a trolley or a glider when a net force acts. A spreadsheet can be used to find the relationship between force and mass or force and acceleration. (HSW 3)	(a) Solve problems using the relationship: net force = mass × acceleration ($F = ma$) appreciating that acceleration and the net force are always in the same direction;
	(b) define the *newton*;
	(c) apply the equations for constant acceleration and $F = ma$ to analyse the motion of objects;
There are opportunities for either class discussion or Internet research on the limitations of $F = ma$. The use of theories, models and ideas to develop and modify scientific explanations can be discussed. (HSW 1,2, 7ab)	(d) recall that according to the special theory of relativity, $F = ma$ cannot be used for a particle travelling at very high speeds because its mass increases.

1.2.2 Non-linear motion

Students can be challenged to design a parachute to take the longest time to fall a given distance.

Students can discuss how fast-moving jet aircraft are decelerated using parachutes.

Candidates should be able to:

(a) explain that an object travelling in a fluid experiences a resistive or a frictional force known as drag;

(b) state the factors that affect the magnitude of the drag force;

(c) determine the acceleration of an object in the presence of drag;

(d) state that the weight of an object is the gravitational force acting on the object;

(e) select and use the relationship:

weight = mass × acceleration of free fall

($W = mg$);

(f) describe the motion of bodies falling in a uniform gravitational field with drag;

(g) use and explain the term *terminal velocity*.

1.2.3 Equilibrium

Experiments can be carried out on triangles of forces using force meters and weights.

The centre of gravity of various objects can be determined and discussed.

Students can apply the principle of moments to determine the weight of an object such as a clamp stand.

Candidates should be able to:

(a) draw and use a triangle of forces to represent the equilibrium of three forces acting at a point in an object;

(b) state that the *centre of gravity* of an object is a point where the entire weight of an object appears to act;

(c) describe a simple experiment to determine the centre of gravity of an object;

(d) explain that a couple is a pair of forces that tends to produce rotation only;

(e) define and apply the *torque of a couple*;

(f) define and apply the *moment of force*;

(g) explain that both the net force and net moment on an extended object in equilibrium is zero;

(h) apply the principle of moments to solve problems, including the human forearm;

(i) select and use the equation for density:

$$\rho = \frac{m}{V};$$

(j) select and use the equation for pressure

$$p = \frac{F}{A},$$

where F is the force normal to the area A.

1.2.4 Car safety

Students can obtain the Highway Code from the Internet.

Small group work can be carried out on the safety features in cars and how GPS is used in navigation. (HSW 6a)

A ball-bearing attracted to one of the poles of a magnet mounted onto a trolley can be used to illustrate deceleration by crashing the trolley into ‘soft’ and ‘hard’ targets. The ball-bearing flies off when it hits a solid wall but stays attached when the impact time of the trolley is longer.

Candidates should be able to:

(a) define *thinking distance, braking distance* and *stopping distance*;
(b) analyse and solve problems using the terms thinking distance, braking distance and stopping distance;
(c) describe the factors that affect thinking distance and braking distance;
(d) describe and explain how air bags, seat belts and crumple zones in cars reduce impact forces in accidents;
(e) describe how air bags work, including the triggering mechanism;
(f) describe how the trilateration technique is used in GPS (global positioning system) for cars.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for candidates to investigate the motion of objects (gliders, trolleys, etc) using ticker timers, light gates, data-loggers and video techniques. There are also opportunities for the candidates to develop skills in recording, analysing and evaluating primary data.

Use a falling mass to find the acceleration of a trolley or a glider using light-gates, motion sensor or ticker tape.

Use a video camera or a data-logger to analyse the motion of a falling parachute or a glider with a ‘sail’ on a linear air track.

Investigate force against time or acceleration against time graphs (for crashing toy cars or trolleys) using a spreadsheet.

Investigate the motion of a ball bearing falling vertically in oil or water. The data can be analysed using a spreadsheet.

Determine the terminal velocity of parachutes of different size and mass.

Locate the centre of gravity of various objects.

Apply the principle of moments for a horizontally loaded ‘bridge’ (metre rule).

Use two bathroom scales and a plank to determine the centre of gravity of a person.

Design an effective crumple zone for a trolley using paper and cardboard.

Words like energy, power and work have very precise interpretation in physics. In this module the important link between work and energy is explored. The important principle of conservation of energy is applied to a range of situations including a rollercoaster. All around us we have building structures under tension or compression. Such forces alter the shape and dimensions of objects. If the force per unit area for a particular material exceeds a certain value, then there is a danger of the material breaking apart and this is the last thing an engineer would want. Using the appropriate materials in construction is important. In this module we explore the properties of materials.

Links

Unit G481: Module 2 – *Forces in action*

Unit G484: Module 1 – *Newton's laws and momentum* and Module 2 – *Circular motion and oscillations*

Context and exemplification	**Assessable learning outcomes**
1.3.1 Work and conservation of energy Students can carry out an experiment to determine the work done to lift various weights through different heights.	Candidates should be able to: (a) define *work done* by a force; (b) define the *joule*; (c) calculate the work done by a force using $W = Fx$ and $W = Fx \cos \theta$; (d) state the principle of conservation of energy; (e) describe examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples; (f) apply the idea that work done is equal to the transfer of energy to solve problems.
1.3.2 Kinetic and potential energies Students can use the internet to find the speed and mass of various objects (meteorites, cars, people, jets, etc), and then calculate their kinetic energy. Students can discuss the energy transfers for a rollercoaster. (HSW 1) Students can apply $E_k = E_p$ to predict the speed of a pendulum bob falling through a certain vertical distance. The speed can be independently worked out using a light gate and a timer.	Candidates should be able to: (a) select and apply the equation for kinetic energy $E_k = \frac{1}{2}mv^2$; (b) apply the definition of work done to derive the equation for the change in gravitational potential energy; (c) select and apply the equation for the change in gravitational potential energy near the Earth's surface $E_p = mgh$; (d) analyse problems where there is an exchange between gravitational potential energy and kinetic energy; (e) apply the principle of conservation of energy to determine the speed of an object falling in the Earth's gravitational field.

1.3.3 Power Students can calculate the average power of a person running up a flight of stairs.	Candidates should be able to: (a) define *power* as the rate of work done; (b) define the *watt*; (c) calculate power when solving problems; (d) state that the efficiency of a device is always less than 100% because of heat losses; (e) select and apply the relationship for efficiency $efficiency = \frac{useful\ output\ energy}{total\ input\ energy} \times 100\%$; (f) interpret and construct Sankey diagrams.
1.3.4 Behaviour of springs and materials Students can carry out experiments to find the relationship between force and extension for a single spring, springs in series or parallel, rubber band, polythene strip, etc. Students can use a spring operated toy-gun to find the speed of the emergent dart using the principle of conservation of energy. (HSW 1, 5a) Students can use a long thin copper (or steel) wire to find its Young modulus. Students can discuss how engineers use specific materials for their physical properties. (HSW 6a)	Candidates should be able to: (a) describe how deformation is caused by a force in one dimension and can be tensile or compressive; (b) describe the behaviour of springs and wires in terms of force, extension, elastic limit, Hooke's law and the force constant (ie force per unit extension or compression); (c) select and apply the equation $F = kx$, where k is the force constant of the spring or the wire; (d) determine the area under a force against extension (or compression) graph to find the work done by the force; (e) select and use the equations for elastic potential energy $E = \frac{1}{2}Fx$ and $E = \frac{1}{2}kx^2$; (f) define and use the terms *stress*, *strain*, *Young modulus* and *ultimate tensile strength* (*breaking stress*); (g) describe an experiment to determine the Young modulus of a metal in the form of a wire; (h) define the terms *elastic deformation* and *plastic deformation* of a material; (i) describe the shapes of the stress against strain graphs for typical ductile, brittle and polymeric materials.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for the candidates to develop skills in recording, analysing and evaluating primary data.

Use the principle of conservation of energy to find the speed of a toy car rolling down a plastic track.

Determine the average power of a person climbing a flight of stairs.

Determine the power generated by arm muscles when repeatedly lifting known weights through a certain vertical distance.

Find the relationship between force and extension for a single spring, springs in series and springs in parallel.

Plot force against extension graphs for a rubber band, polythene strip, etc.

Determine the Young modulus of metal, eg copper or steel.

Determine the ultimate tensile strength (UTS) or the breaking stress of a metal such as copper or aluminium.

Design a safe rollercoaster.

3.2 AS Unit G482: *Electrons, Waves and Photons*

This unit consists of five teaching modules:

Module 1: **Electric current**

- 2.1.1 Electric current

Module 2: **Resistance**

- 2.2.1 Circuit symbols
- 2.2.2 E.m.f. and p.d.
- 2.2.3 Resistance
- 2.2.4 Resistivity
- 2.2.5 Power

Module 3: **DC circuits**

- 2.3.1 Series and parallel circuits
- 2.3.2 Practical circuits

Module 4: **Waves**

- 2.4.1 Wave motion
- 2.4.2 Electromagnetic waves
- 2.4.3 Interference
- 2.4.4 Stationary waves

Module 5: **Quantum physics**

- 2.5.1 Energy of a photon
- 2.5.2 The photoelectric effect
- 2.5.3 Wave-particle duality
- 2.5.4 Energy levels in atoms

Candidates are expected to apply knowledge, understanding and other skills gained in this unit to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should:

Have achieved Grade C or above in both GCSE Science and GCSE Additional Science, or GCSE Physics, or an equivalent standard in other appropriate Level 2 qualifications.

Links

3.7 GCSE Science

(iii) Energy, electricity and radiations

(b) electrical power is readily transferred and controlled, and can be used in a range of different situations.

(c) radiations, including ionising radiations, can transfer energy.

This short module introduces the ideas of charge and current. Understanding electric current is essential when dealing with circuits in Modules 2 and 3. This module does not lend itself to practical work but to introducing fundamental ideas. The continuity equation is developed using these fundamental ideas. The module concludes with categorising all materials in terms of their ability to electrically conduct.

There are opportunities to discuss how theories and models develop with the history of the electron.

Links

Unit G482: Module 2 – *Resistance*

Unit G482: Module 3 – *DC circuits*

Unit G485: Module 1 & 2 – *Electric and magnetic fields*, *Capacitors and exponential decay*

Context and exemplification	Assessable learning outcomes
2.1.1 Charge and current The students can carry out practical work on conduction using coloured salts. The teacher can demonstrate an electron beam in a vacuum as a flow of charge. The teacher can demonstrate flow of charge by ionising air between plates using a candle and a radioactive source. An historical theme can be introduced here with the discovery of the electron in 1897 and the quantisation of charge. (HSW 1) There are opportunities for discussion of the model of traffic flow and/or water in a pipe including the effect of constrictions.	Candidates should be able to: (a) explain that electric current is a net flow of charged particles; (b) explain that electric current in a metal is due to the movement of electrons, whereas in an electrolyte the current is due to the movement of ions; (c) explain what is meant by conventional current and electron flow; (d) select and use the equation $\Delta Q = I\Delta t$; (e) define the *coulomb*; (f) describe how an ammeter may be used to measure the current in a circuit; (g) recall and use the elementary charge $e = 1.6 \times 10^{-19}$ C; (h) describe Kirchhoff's first law and appreciate that this is a consequence of conservation of charge; (i) state what is meant by the term *mean drift velocity* of charge carriers; (j) select and use the equation $I = Anev$; (k) describe the difference between conductors, semiconductors and insulators in terms of the number density n.

Possible class experiment and demonstrations are:

observing an electron beam in a vacuum as a flow of charge;

verifying Kirchhoff's first law using ammeters;

observing the conduction of coloured salts;

measuring the current in a circuit caused by ionising of air between two charged plates.

The aim of this module is to introduce or consolidate the basic concepts required for describing, using and designing electrical circuits. It is vital for a scientist to be able to recall, use and apply scientific vocabulary. Hence, it is important to learn key definitions within this module.

Electromotive force and potential difference are defined and distinguished in terms of the energy transferred by charges moving round the circuit. This leads to considering the rate of energy transfer, the power, in each component of the circuit. How current varies with potential difference for a range of components is investigated. The characteristics and uses of light-emitting diodes are also explored. The module closes with an investigation of how the resistivity of metals and semiconductors varies with temperature.

Links

Unit G482: Module 1 – *Electric current*

Unit G482: Module 3 – *DC circuits*

Unit G485: Module 1

Context and exemplification	Assessable learning outcomes
2.2.1 Circuit symbols	Candidates should be able to:
Students can draw circuit symbols on the whiteboard.	(a) recall and use appropriate circuit symbols as set out in SI Units, Signs, Symbols and Abbreviations (ASE, 1981) and Signs, Symbols and Systematics (ASE, 1995); (b) interpret and draw circuit diagrams using these symbols.
2.2.2 E.m.f. and p.d.	Candidates should be able to:
Students can use a simple circuit consisting of a cell and filament lamp to illustrate the differences between p.d. and e.m.f.	(a) define *potential difference* (p.d.); (b) select and use the equation $W = VQ$; (c) define the *volt*; (d) describe how a voltmeter may be used to determine the p.d. across a component; (e) define *electromotive force* (e.m.f.) of a source such as a cell or a power supply; (f) describe the difference between e.m.f. and p.d. in terms of energy transfer.
2.2.3 Resistance	Candidates should be able to:
Students can carry out practical work to investigate the I–V characteristics of a resistor, lamp and different coloured LEDs.	(a) define *resistance*; (b) select and use the equation for resistance $R = \frac{V}{I}$; (c) define the *ohm*; (d) state and use Ohm's law;

Students can discuss low-energy lighting, eg LED torches.	(e) describe the I–V characteristics of a resistor at constant temperature, filament lamp and light-emitting diode (LED); (f) describe an experiment to obtain the I–V characteristics of a resistor at constant temperature, filament lamp and light-emitting diode (LED); (g) describe the uses and benefits of using light-emitting diodes (LEDs).
2.2.4 Resistivity There are opportunities for discussion of the factors that determine resistance including temperature, leading to superconductivity in some materials.	Candidates should be able to: (a) define *resistivity* of a material; (b) select and use the equation $R = \frac{\rho L}{A}$; (c) describe how the resistivities of metals and semiconductors are affected by temperature; (d) describe how the resistance of a pure metal wire and of a negative temperature coefficient (NTC) thermistor is affected by temperature.
2.2.5 Power A joulemeter or a data-logger may be used to determine energy transfer. The teacher can challenge the students to make a list of devices in the home that use a fuse. A utilities statement can be used to illustrate the use of the kW h by electricity companies.	Candidates should be able to: (a) describe power as the rate of energy transfer; (b) select and use power equations $P = VI$, $P = I^2R$ and $P = \frac{V^2}{R}$; (c) explain how a fuse works as a safety device (HSW 6a); (d) determine the correct fuse for an electrical device; (e) select and use the equation $W = IVt$; (f) define the kilowatt-hour (kW h) as a unit of energy; (g) calculate energy in kW h and the cost of this energy when solving problems (HSW 6a).

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for students to improve their electrical measuring skills by investigating the I–V characteristics of various components. Students are given practice at developing skills in recording, analysing and evaluating data.

Investigate the factors that determine resistance including the effect of temperature.

Determine the resistivity of a metal.

Use the resistivity equation to estimate the thickness of a pencil line.

Find the most suitable material to use as a fuse.

Carry out an experiment to investigate the variation of resistance of a thermistor with temperature.

Investigate energy transferred by components using a joulemeter or data-logger.

The work from Modules 1 and 2 is brought together in this module. At the end of this module, students should have the confidence to connect up circuits and predict the outcome in terms of current or potential difference.

To monitor changes in the intensity of light or temperature, passive components are needed like light-dependent resistors and thermistors in electrical circuits. The module explores how this may be done using potential divider circuits.

There are opportunities to encourage students to use appropriate scientific vocabulary and make them aware of how data-loggers or computers can be used to monitor physical changes.

[Likely HSW aspects covered: 3, 4, 6a]

Links

Unit G482: Module 1 – *Electric current*

Unit G482: Module 2 – *Resistance*

Context and exemplification	Assessable learning outcomes
2.3.1 Series and parallel circuits	Candidates should be able to:
An example of more than one source of e.m.f. is a battery charger. (HSW 6a)	(a) state Kirchhoff's second law and appreciate that this is a consequence of conservation of energy; (b) apply Kirchhoff's first and second laws to circuits;
Students can verify the rules for resistors experimentally. This can be done using a multimeter as an ohmmeter.	(c) select and use the equation for the total resistance of two or more resistors in series; (d) select and use the equation for the total resistance of two or more resistors in parallel; (e) solve circuit problems involving series and parallel circuits with one or more sources of e.m.f.; (f) explain that all sources of e.m.f. have an internal resistance; (g) explain the meaning of the term *terminal p.d.*;
Students can carry out practical work to measure the internal resistance and e.m.f. of a cell.	(h) select and use the equations e.m.f. = $I(R + r)$, and e.m.f. = $V + Ir$.
2.3.2 Practical circuits	Candidates should be able to: (a) draw a simple potential divider circuit;
Students can set up and investigate a potential divider using two fixed resistors or a variable resistor or a rotary potentiometer.	(b) explain how a potential divider circuit can be used to produce a variable p.d.; (c) select and use the potential divider equation $V_{out} = \frac{R_2}{R_1 + R_2} \times V_{in}$;
Students can investigate how to use a potential divider as a source of variable p.d.	(d) describe how the resistance of a light-dependent resistor (LDR) depends on the

Students can construct potential divider circuits for a simple light-sensor and a temperature-sensor.	intensity of light; (e) describe and explain the use of thermistors and light-dependent resistors in potential divider circuits; (f) describe the advantages of using data-loggers to monitor physical changes (HSW 3).

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

In this module, there is much potential for experimental work and improving instrumentation skills.

Use a multimeter as an ohmmeter to ‘verify’ the rules for total resistance for series and parallel circuits.

Use a calibrated light-meter to plot the variation of resistance of an LDR against intensity.

Determine the internal resistance of a chemical cell.

Use a potential divider circuit to show the validity of the potential divider equation

$$V_{\text{out}} = \frac{R_2}{R_1 + R_2} \times V_{\text{in}}.$$

Design a light-sensing circuit based on a potential divider with a light-dependent resistor.

Design a temperature-sensor based on a potential divider with a thermistor.

Monitor the output potential difference from either light-sensors or temperature-sensors using a data-logger.

The module begins by reviewing and consolidating students' prior knowledge about waves and wave properties. This is followed by a short section on electromagnetic waves also reinforcing and amplifying prior knowledge of the electromagnetic spectrum.

Students then gain an understanding of superposition effects. The wavelength of light is too small to be measured directly using a ruler; however, experiments can be done in the laboratory to determine wavelength of visible light using a laser and a double slit. The module concludes by considering stationary waves formed on strings and in pipes.

There are opportunities to discuss how theories and models develop with the Young's double-slit experiment. The dangers of over-exposure to ultraviolet radiation are well known. This module explores which type of ultraviolet radiation is most dangerous to us and illustrates how scientific knowledge can be used to reduce risks for society.

[Likely HSW aspects covered: 1, 4, 6a]

Links

Unit G481: Module 1 – *Motion*

Unit G484: Module 2 – *Circular motion and oscillations*

Context and exemplification	**Assessable learning outcomes**
2.4.1 Wave motion Students can determine the frequency of alternating electrical signals and sound using an oscilloscope.	Candidates should be able to: (a) describe and distinguish between progressive longitudinal and transverse waves; (b) define and use the terms *displacement*, *amplitude*, *wavelength*, *period*, *phase difference*, *frequency* and *speed of a wave*; (c) derive from the definitions of speed, frequency and wavelength, the wave equation $v = f\lambda$; (d) select and use the wave equation $v = f\lambda$; (e) explain what is meant by reflection, refraction and diffraction of waves such as sound and light.
2.4.2 Electromagnetic waves Students can discuss the purpose of using sunscreen. (HSW 6a) The teacher can demonstrate polarisation using a metal grill for microwave and polarising filter for light.	Candidates should be able to: (a) state typical values for the wavelengths of the different regions of the electromagnetic spectrum from radio waves to γ-rays; (b) state that all electromagnetic waves travel at the same speed in a vacuum; (c) describe differences and similarities between different regions of the electromagnetic spectrum;

Students can observe light reflected from a glass surface through a polarising sheet. Students can discuss the use of polarising filters in photography and in sun glasses to reduce glare. (HSW 6a)	(d) describe some of the practical uses of electromagnetic waves; (e) describe the characteristics and dangers of UV-A, UV-B and UV-C radiations and explain the role of sunscreen (HSW 6a); (f) explain what is meant by plane polarised waves and understand the polarisation of electromagnetic waves; (g) explain that polarisation is a phenomenon associated with transverse waves only; (h) state that light is partially polarised on reflection; (i) recall and apply Malus's law for transmitted intensity of light from a polarising filter.
2.4.3 Interference Superposition effects can be discussed and demonstrated using a slinky or computer simulations (applets). Show how the wavelength of microwaves can be determined using double slit apparatus. Determine the wavelength of light from different LEDs using a diffraction grating.	Candidates should be able to: (a) state and use the principle of superposition of waves; (b) apply graphical methods to illustrate the principle of superposition; (c) explain the terms *interference*, *coherence*, *path difference* and *phase difference*; (d) state what is meant by constructive interference and destructive interference; (e) describe experiments that demonstrate two-source interference using sound, light and microwaves; (f) describe constructive interference and destructive interference in terms of path difference and phase difference; (g) use the relationships intensity = power/cross-sectional area intensity $\propto$ amplitude^2; (h) describe the Young double-slit experiment and explain how it is a classical confirmation of the wave-nature of light (HSW 1); (i) Select and use the equation $\lambda = \frac{ax}{D}$ for electromagnetic waves; (j) describe an experiment to determine the wavelength of monochromatic light using a laser and a double slit (HSW 1); (k) describe the use of a diffraction grating to determine the wavelength of light (the structure and use of a spectrometer are not required); (l) select and use the equation $d\sin\theta = n\lambda$; (m) explain the advantages of using multiple slits in an experiment to find the wavelength of light.

2.4.4 Stationary waves

Students can carry out experiments that demonstrate stationary waves for stretched strings, air columns and microwaves.

Invite students to bring along their musical instruments and discuss the formation of stationary waves.

In experiments, students should be aware of the end correction at the open end.

Candidates should be able to:

(a) explain the formation of stationary (standing) waves using graphical methods;

(b) describe the similarities and differences between progressive and stationary waves;

(c) define the terms *nodes* and *antinodes*;

(d) describe experiments to demonstrate stationary waves using microwaves, stretched strings and air columns;

(e) determine the standing wave patterns for stretched string and air columns in closed and open pipes;

(f) use the equation:

separation between adjacent nodes (or antinodes) = $\lambda/2$;

(g) define and use the terms *fundamental mode of vibration* and *harmonics*;

(h) determine the speed of sound in air from measurements on stationary waves in a pipe closed at one end.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

Students should gain a qualitative understanding of superposition effects together with confidence in handling experimental data. Students should be able to discuss superposition effects and perform experiments leading to measurements of wavelength and wave velocity.

Use an oscilloscope to determine the frequency of sound.

Observe polarising effects using microwaves and light.

Investigate polarised light when reflected from glass or light from LCD displays.

Study diffraction by a slit using laser light.

Study hearing superposition using a signal generator and two loudspeakers.

Study superposition of microwaves.

Determine the wavelength of laser light with a double-slit.

Determine the wavelength of light from an LED using a diffraction grating.

Demonstrate stationary waves using a slinky spring, tubes and microwaves.

Determine the speed of sound in air by formation of stationary waves in a resonance tube.

The aim of this module is to introduce the concept of quantum behaviour. How do we know that light is a wave? The evidence for this comes from diffraction of light. However, this wave-like behaviour cannot explain how light interacts with electrons in a metal. A revolutionary model of light (photon model), developed by Max Planck and Albert Einstein, is needed to describe the interaction of light with matter.

Physicists expect symmetry in nature. If light can have a dual nature, then surely particles like the electron must also have a dual nature. We study the ideas developed by de Broglie. The final section looks briefly at the idea that electrons in atoms have discrete bond energies and they move between energy levels by either absorbing or by emitting photons.

There are many opportunities to discuss how theories and models develop with the history of wave-particle duality.

[Likely HSW aspects covered: 1, 2, 4, 7a]

Links

Unit G481: Module 3 *Work and energy*

Unit G482: Module 2 and 4 *Resistance*, *Waves*

Unit G485: Module 3 and 4 *Nuclear physics*, *Modelling the universe*

Context and exemplification	**Assessable learning outcomes**
2.5.1 Energy of a photon The teacher can carry out a demonstration using a GM tube to ‘count’ gamma ray photons. Students can carry out an experiment to determine h using LEDs.	Candidates should be able to: (a) describe the particulate nature (photon model) of electromagnetic radiation; (b) state that a photon is a quantum of energy of electromagnetic radiation; (c) select and use the equations for the energy of a photon: $E = hf$ and $E = \frac{hc}{\lambda}$ (d) define and use the electronvolt (eV) as a unit of energy; (e) use the transfer equation $eV = \frac{1}{2}mv^2$ for electrons and other charged particles; (f) describe an experiment using LEDs to estimate the Planck constant *h* using the equation $eV = \frac{hc}{\lambda}$ (no knowledge of semiconductor theory is expected).

2.5.2 The photoelectric effect

The teacher can demonstrate the photoelectric effect using a photocell or a negatively charged zinc plate exposed to ultraviolet radiation.

As another example for the historical theme, Einstein's theory in 1905 gave the first strong evidence for Max Planck's ideas about the quantisation of electromagnetic energy.

(HSW 1, 2, 7a)

Candidates should be able to:

(a) describe and explain the phenomenon of the photoelectric effect;

(b) explain that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provide evidence for a wave nature;

(c) define and use the terms *work function* and *threshold frequency*;

(d) state that energy is conserved when a photon interacts with an electron;

(e) select, explain and use Einstein's photoelectric equation $hf = \phi + \mathrm{KE}_{\mathrm{max}}$;

(f) explain why the maximum kinetic energy of the electrons is independent of intensity and why the photoelectric current in a photocell circuit is proportional to intensity of the incident radiation.

2.5.3 Wave–particle duality

Students can show diffraction of visible light using narrow slits or tiny holes. They can compare the diffraction pattern for electrons travelling through a thin piece of graphite.

Candidates should be able to:

(a) explain electron diffraction as evidence for the wave nature of particles like electrons;

(b) explain that electrons travelling through polycrystalline graphite will be diffracted by the atoms and the spacing between the atoms;

(c) select and apply the de Broglie equation $\lambda = \dfrac{h}{mv}$;

(d) explain that the diffraction of electrons by matter can be used to determine the arrangement of atoms and the size of nuclei.

2.5.4 Energy levels in atoms

Students can use a diffraction grating to observe the emission spectral lines from different gas discharge tubes.

Students can discuss how different elements can be identified in stars using spectra. (HSW 2)

Candidates should be able to:

(a) explain how spectral lines are evidence for the existence of discrete energy levels in isolated atoms, ie in a gas discharge lamp;

(b) describe the origin of emission and absorption line spectra;

(c) use the relationships $hf = E_1 - E_2$ and $\dfrac{hc}{\lambda} = E_1 - E_2$.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

This module does not lend itself to many experiments carried by the students. However, it does contain many revolutionary ideas and engaging students in discussions is vital when demonstrating some of the experiments.

Use a GM tube to ‘count’ gamma ray photons.

Determine the wavelength of light from different LEDs using the equation $eV = \frac{hc}{\lambda}$.

Demonstrate the photoelectric effect using a photocell or a negatively charged zinc plate connected to an electroscope.

Observe ‘diffraction rings’ for light passing through a tiny hole.

Demonstrate the diffraction of electrons by graphite.

Observe emission line spectra from different discharge tubes. (A hand-held optical spectrometer can be used to observe Fraunhofer lines in daylight. Caution: Do not look directly at the Sun.)

3.3 AS Unit G483: *Practical Skills in Physics 1*

This unit develops practical and investigative skills developed within contexts encountered during AS Physics.

Candidates are required to carry out **three** tasks:

1.	Qualitative task	[10 marks]
2.	Quantitative task	[20 marks]
3.	Evaluative task	[10 marks]

Tasks will be chosen from a selection provided by OCR.

The qualitative and quantitative tasks will test skills of observation and measurement.

Candidates will carry out these tasks under controlled conditions.

Each task will be internally assessed using a mark scheme provided by OCR.

Candidates may attempt more than one task from each category with the best mark from each category being used to make up the overall mark.

Centres will supply OCR with a single mark out of 40.

How Science Works

5a Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.

5b Analyse and interpret data to provide evidence, recognising correlations and causal relationships.

5c Evaluate methodology, evidence and data, and resolve conflicting evidence.

The mark schemes supplied by OCR will be based on the following generic criteria.

1. Qualitative task	
	Candidates should be able to:
Candidates carry out a practical task using instructions supplied by OCR.	(a) Demonstrate skilful and safe practical techniques using suitable qualitative methods. (b) Make, record and communicate valid observations; organise results suitably.

2. Quantitative task

Candidates carry out a practical task using instructions supplied by OCR.

(a) Demonstrate and describe safe and skilful practical techniques for a quantitative experiment.

(b) Make, record and communicate reliable measurements with appropriate precision and accuracy.

(c) Analyse the experimental results.

(d) Interpret and explain the experimental results.

3. Evaluative task

This task will extend the quantitative task.

Candidates will evaluate the quality of the data and procedures. Evaluative tasks will **not** require additional data collection.

Candidates should be able to:

(a) Evaluate the results and their impact on the experimental methodology.

(b) Assess the reliability and accuracy of the experiment by calculating percentage differences and uncertainties.

(c) Evaluate the methodology with a view to improving experimental precision and accuracy.

(d) Identify weaknesses in the experimental methodology and measurements.

(e) Understand and suggest improvements to the experimental procedures and measurements.

The tasks

Tasks, mark schemes and guidance for teachers and technicians can be downloaded from the OCR Interchange site.

3.4 A2 Unit G484: *The Newtonian World*

This unit consists of three teaching modules:

Module 1: Newton's laws and momentum

- 4.1.1 Newton's laws of motion
- 4.1.2 Collisions

Module 2: Circular motion and oscillations

- 4.2.1 Circular motion
- 4.2.2 Gravitational Fields
- 4.2.3 Simple harmonic oscillations

Module 3: Thermal Physics

- 4.3.1 Solid, liquid and gas
- 4.3.2 Temperature
- 4.3.3 Thermal properties of materials

Recommended Prior Knowledge

Candidates should:

- have studied AS Physics

G484 Module 1: 4.1 Newton's laws and momentum

The ideas developed by Newton underpin work in a number of the units and modules at A2. The second law in particular has impact on several topics including the behaviour of gases in the module on thermal physics.

This module provides the opportunity to discuss the use of models to explain the elaborate physical world around us. It is also important to remember that a fundamental law such as Newton's second law is valid as long as a single experiment does not contradict it. For objects travelling at relatively slow speeds, its success is truly phenomenal, but strange things start to happen when objects travel at speeds close to the speed of light.

There are many opportunities for students to carry out experimental work and analyse data using ICT or data-logging techniques.

Links

Links to GCSE: 3.9(iii)a

Unit G481: Module 1 – *Motion*

Unit G484: Module 2 – *Circular motion and oscillations* and Module 3 – *Thermal physics*

Unit G485: Module 3 – *Nuclear physics*

Context and exemplification	Assessable learning outcomes
4.1.1 Newton's laws of motion Small groups of students can research and present the three laws. Students can carry out experiments with trolleys or gliders on a linear air track and either light gates, ticker timers or a motion sensor to show the validity of $F = \frac{\Delta p}{\Delta t}$. The data can be analysed using a spreadsheet. (HSW 3)	Candidates should be able to: (a) state and use each of Newton's three laws of motion; (b) define *linear momentum* as the product of mass and velocity and appreciate the vector nature of momentum; (c) define *net force on a body* as equal to rate of change of its momentum; (d) select and apply the equation $F = \frac{\Delta p}{\Delta t}$ to solve problems; (e) explain that $F = ma$ is a special case of Newton's second law when mass *m* remains constant; (f) define *impulse of a force*; (g) recall that the area under a force against time graph is equal to impulse; (h) recall and use the equation impulse = change in momentum.
4.1.2 Collisions Students can carry out an experiment to find the initial velocity of a dart (or pellet from an air pistol) using a glider and light gates. Gliders with repelling magnets or Blu-tac can be used to show elastic and inelastic collisions. (HSW 5)	Candidates should be able to: (a) state the principle of conservation of momentum; (b) apply the principle of conservation of momentum to solve problems when bodies interact in one dimension; (c) define a *perfectly elastic collision* and an *inelastic collision*; (d) explain that whilst the momentum of a system is always conserved in the interaction between bodies, some change in kinetic energy usually occurs.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for candidates to investigate collisions between objects (gliders, trolleys, etc) using ticker timers, light gates and data-logging techniques. There are also opportunities for the candidates to develop skills in recording, analysing and evaluating primary data (HSW 5).

Use a motion sensor to demonstrate $F = \frac{\Delta p}{\Delta t}$.

Carry out an experiment to show *total initial momentum* = *total final momentum* using trolleys or gliders.

Find the initial velocity of an air-gun pellet or a dart using a glider and light gates.

Demonstrate elastic and inelastic collisions using plastic 'super balls' and squash balls.

Carry out experiments involving collisions of trolleys or gliders.

There are many examples of objects travelling at constant speed in circles, eg planets, artificial satellites, charged particles in a magnetic field, etc. The physics in all these cases can be described using the ideas developed by Newton. We can use the models created by Newton to understand and predict the motion of artificial satellites around the Earth and the planets in our own solar system.

The atoms in a solid and the piston of a car both show oscillatory motion. In this module, we develop the physics behind oscillatory motion and illustrate its beneficial and detrimental effects.

This module provides ample opportunities to show how theories are developed. Newton's thought experiment on the cannon ball fired at right angles to the Earth's gravitational field can be used to show how scientific ideas and models can be developed to describe the motion of satellites in geostationary orbits.

Links

Links to GCSE: 3.7(iv)(c), 3.9(iii)a

Unit G481: Module 1 – *Motion* and Module 3 – *Work and energy*
Unit G484: Module 1 – *Newton's laws* and *momentum*
Unit G485: Module 1 – *Electric and magnetic fields*

Context and exemplification	Assessable learning outcomes

4.2.1 Circular motion

Students can suggest examples of objects moving in a circle and in each case state the origin of the centripetal force.

An experiment on a whirling rubber bung can be used to illustrate $F \propto v^2$. The data can be analysed using a spreadsheet. (HSW 3)

Candidates should be able to:

(a) define the *radian*;
(b) convert angles from degrees into radians and vice versa;
(c) explain that a force perpendicular to the velocity of an object will make the object describe a circular path;
(d) explain what is meant by centripetal acceleration and centripetal force;
(e) select and apply the equations for speed

$$v = \frac{2\pi r}{T}$$

and centripetal acceleration $a = \frac{v^2}{r}$;

(f) select and apply the equation for centripetal force

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

4.2.2 Gravitational fields

Working in small groups, students can use textbooks or the Internet to find the masses and separation to estimate the magnitude of the gravitational force.

Students can use a science data book or the internet to find the surface gravitational field strength and the diameter of the planets in our solar system. The data can be used to find the mass of the planets.

Students can discuss Newton's thought experiment on a cannon ball fired at right angles to the Earth's gravitational field. (HSW 1, 2)

Students can use the Internet or an astronomy data book to find the distance *r* and period *T* for satellites of Jupiter or Saturn or of planets in our solar system and use a spreadsheet to determine the mass of the gravitating object.

Students can use the Internet to find the history of some of the geostationary artificial satellites. (HSW 1, 6a)

Candidates should be able to:

(a) describe how a mass creates a gravitational field in the space around it;

(b) define *gravitational field strength* as force per unit mass;

(c) use gravitational field lines to represent a gravitational field;

(d) state Newton's law of gravitation;

(e) select and use the equation $F = -\frac{GMm}{r^2}$ for the force between two point or spherical objects;

(f) select and apply the equation $g = -\frac{GM}{r^2}$ for the gravitational field strength of a point mass;

(g) select and use the equation $g = -\frac{GM}{r^2}$ to determine the mass of the Earth or another similar object;

(h) explain that close to the Earth's surface the gravitational field strength is uniform and approximately equal to the acceleration of free fall;

(i) analyse circular orbits in an inverse square law field by relating the gravitational force to the centripetal acceleration it causes;

(j) define and use the *period* of an object describing a circle;

(k) derive the equation $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$ from first principles;

(l) select and apply the equation $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$ for planets and satellites (natural and artificial);

(m) select and apply Kepler's third law $T^2 \propto r^3$ to solve problems;

(n) define *geostationary orbit* of a satellite and state the uses of such satellites.

4.2.3 Simple harmonic oscillations

Students can find examples of some isochronous oscillators that keep steady time.

Students can use a simple pendulum or a child on a swing to demonstrate the exchange between gravitational and kinetic energy.

The forced oscillations of a small mass tethered between two suspended springs can be used to demonstrate unwanted effects of resonance.

One use for resonance is cooking food using microwaves and one unwanted example of resonance is in suspension bridges. (HSW 6a)

Candidates should be able to:

(a) describe simple examples of free oscillations;

(b) define and use the terms *displacement*, *amplitude*, *period*, *frequency*, *angular frequency* and *phase difference*;

(c) select and use the equation

period = 1/frequency;

(d) define *simple harmonic motion*;

(e) select and apply the equation $a = -(2\pi f)^2 x$ as the defining equation of simple harmonic motion;

(f) select and use $x = A\cos(2\pi ft)$ or $x = A\sin(2\pi ft)$ as solutions to the equation $a = -(2\pi f)^2 x$;

(g) select and apply the equation $v_{max} = (2\pi f)A$ for the maximum speed of a simple harmonic oscillator;

(h) explain that the period of an object with simple harmonic motion is independent of its amplitude;

(i) describe, with graphical illustrations, the changes in displacement, velocity and acceleration during simple harmonic motion;

(j) describe and explain the interchange between kinetic and potential energy during simple harmonic motion;

(k) describe the effects of damping on an oscillatory system;

(l) describe practical examples of forced oscillations and resonance;

(m) describe graphically how the amplitude of a forced oscillation changes with frequency near to the natural frequency of the system;

(n) describe examples where resonance is useful and other examples where resonance should be avoided.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for the candidates to develop skills in recording, analysing and evaluating primary data.

Carry out an experiment to show *force* $\propto$ *speed*^{2} for a whirling bung.

A ball on a rotating turntable and a projector can be used to illustrate simple harmonic motion.

Barton's pendulums can be used to show resonance.

Investigate the forced oscillations of a spring-mass system.

In physics, the terms 'internal energy' and 'temperature' have very precise meanings. The amount of internal energy within an object is the total random kinetic and potential energy of all the atoms within the object whereas temperature is used to determine in which direction energy will flow when two objects are close to one another. The flow of energy from one object at a higher temperature to another object at a lower temperature is called heating.

This module uses the ideas of Newtonian mechanics to explain how gas atoms exert pressure on container walls.

It provides an opportunity to discuss how scientific models in the form of Newtonian mechanics can be developed to explain the behaviour of gases.

Links

Links to GCSE: 3.7(iii)d

Unit G481: Module 1 – *Motion* and Module 3 – *Work and energy*

Unit G484: Module 1 – *Newton's laws and momentum*

Context and exemplification	Assessable learning outcomes
4.3.1 Solid, liquid and gas You can tell that someone has just sprayed some perfume by the smell. This simple observation can be used to discuss the movement of molecules. A smoke cell can be used to show Brownian motion. Discuss how Newtonian laws are used to show how pressure is exerted by a gas. (HSW 1) A melting cube of ice can be used to discuss the change in internal energy.	Candidates should be able to: (a) describe solids, liquids and gases in terms of the spacing, ordering and motion of atoms or molecules; (b) describe a simple kinetic model for solids, liquids and gases; (c) describe an experiment that demonstrates Brownian motion and discuss the evidence for the movement of molecules provided by such an experiment; (d) define the term *pressure* and use the kinetic model to explain the pressure exerted by gases; (e) define *internal energy* as the sum of the random distribution of kinetic and potential energies associated with the molecules of a system; (f) explain that the rise in temperature of a body leads to an increase in its internal energy; (g) explain that a change of state for a substance leads to changes in its internal energy but not its temperature; (h) describe using a simple kinetic model for matter the terms melting, boiling and evaporation.
4.3.2 Temperature	Candidates should be able to: (a) explain that thermal energy is transferred from a region of higher temperature to a region of lower temperature; (b) explain that regions of equal temperature are in thermal equilibrium;

(c) describe how there is an absolute scale of temperature that does not depend on the property of any particular substance (ie the thermodynamic scale and the concept of absolute zero);

(d) convert temperatures measured in kelvin to degrees Celsius (or vice versa):

$$T\ (\text{K}) = \theta\ (^\circ\text{C}) + 273.15;$$

(e) state that absolute zero is the temperature at which a substance has minimum internal energy.

4.3.3 Thermal properties of materials

Students can carry out experiments to find specific heat capacities of liquids (water) and solids.

A data-logger with a temperature sensor can be used to show the steady temperature rise of a solid when electrically heated by a constant power heater.

Candidates should be able to:

(a) define and apply the concept of specific heat capacity;

(b) select and apply the equation $E = mc\Delta\theta$;

(c) describe an electrical experiment to determine the specific heat capacity of a solid or a liquid;

(d) describe what is meant by the terms *latent heat of fusion* and *latent heat of vaporisation*.

4.3.4 Ideal gases

Experiment on Boyle's Law.

Candidates should be able to:

(a) state Boyle's law;

(b) select and apply $p\dfrac{V}{T}$ = constant;

(c) state the basic assumptions of the kinetic theory of gases;

(d) state that one mole of any substance contains 6.02×10^{23} particles and that $6.02 \times 10^{23}\ \text{mol}^{-1}$ is the Avogadro constant N_A;

(e) select and solve problems using the ideal gas equation expressed as

$$pV = NkT \text{ and } pV = nRT,$$

where N is the number of atoms and n is the number of moles;

(f) explain that the mean translational kinetic energy of an atom of an ideal gas is directly proportional to the temperature of the gas in kelvin;

(g) select and apply the equation $E = \dfrac{3}{2}kT$ for the mean translational kinetic energy of atoms.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for the candidates to develop skills in recording, analysing and evaluating primary data.

Use an electrical method to find the specific heat capacity of a substance like aluminium, or water.

Determine the specific heat capacity of water using method of mixtures.

Determine the specific heat capacity of a metal block by heating the block and immersing it into water.

Investigate the relationship between pressure exerted by a gas and its volume (Boyle’s law).

3.5 A2 Unit G485: *Fields, Particles and Frontiers of Physics*

This unit consists of five teaching modules:

Module 1: Electric and magnetic fields

- 5.1.1 Electric fields
- 5.1.2 Magnetic fields
- 5.1.3 Electromagnetism

Module 2: Capacitors and exponential decay

- 5.2.1 Capacitors

Module 3: Nuclear physics

- 5.3.1 The nuclear atom
- 5.3.2 Fundamental particles
- 5.3.3 Radioactivity
- 5.3.4 Nuclear fission and fusion

Module 4: Medical imaging

- 5.4.1 X-rays
- 5.4.2 Diagnostic methods in medicine
- 5.4.3 Ultrasound

Module 5: Modelling the universe

- 5.5.1 Structure of the universe
- 5.5.2 The evolution of the universe

Recommended Prior Knowledge

Candidates should:

- have studied AS Physics and ideally Unit G484.

G485 Module 1: 5.1 Electric and Magnetic Fields

This module introduces the laws developed by Coulomb, Faraday and Lenz. The application of these laws is used to demonstrate how science has benefited society with important devices such as generators and transformers. Transformers are at the heart of many electrical items in our homes that use mains electricity.

This module demonstrates how scientific theories develop to explain the physical world around us.

Links

Links to GCSE: 3.7(iii)b

Unit G481: Module 1 – *Motion*

Unit G482: Module 2 – *Forces in action*

Unit G484: Module 2 – *Circular motion and gravitational fields*

Context and exemplification	Assessable learning outcomes
5.1.1 Electric fields Show evidence of a uniform electric field between charged parallel plates by using a charged gold foil attached to the end of an insulator.	Candidates should be able to (a) state that electric fields are created by electric charges; (b) define *electric field strength* as force per unit positive charge; (c) describe how electric field lines represent an electric field; (d) select and use Coulomb's law in the form $F = \dfrac{Qq}{4\pi\varepsilon_0 r^2}$; (e) select and apply $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ for the electric field strength of a point charge; (f) select and use $E = \dfrac{V}{d}$ for the magnitude of the uniform electric field strength between charged parallel plates; (g) explain the effect of a uniform electric field on the motion of charged particles; (h) describe the similarities and differences between the gravitational fields of point masses and the electric fields of point charges.
5.1.2 Magnetic fields The magnetic field due to current-carrying conductors can be mapped out using plotting compasses or sealed-iron filings. Students can use a current balance to determine the magnetic flux density between the poles of a magnet. A fine-beam tube can be used to demonstrate the force acting on an electron beam. Students can discuss how the Earth's magnetic field protects us from the dangers of the solar wind and cosmic particles.	Candidates should be able to: (a) describe the magnetic field patterns of a long straight current-carrying conductor and a long solenoid; (b) state and use Fleming's left-hand rule to determine the force on current conductor placed at right angles to a magnetic field; (c) select and use the equations $F = BIL$ and $F = BIL\sin\theta$; (d) define *magnetic flux density* and the *tesla*; (e) select and use the equation $F = BQv$ for the force on a charged particle travelling at right angles to a uniform magnetic field; (f) analyse the circular orbits of charged particles moving in a plane perpendicular to a uniform magnetic field by relating the magnetic force to the centripetal acceleration

it causes;

(g) analyse the motion of charged particles in both electric and magnetic fields;

(h) explain the use of deflection of charged particles in the magnetic and electric fields of a mass spectrometer (HSW 6a).

5.1.3 Electromagnetism

Students can use a magnet and a coil to demonstrate the factors affecting the magnitude and direction of induced e.m.f.

The teacher can demonstrate the operation of a simple transformer.

The students can discuss how transformers and generators are used in power stations. (HSW 6a & 7c)

Candidates should be able to:

(a) define *magnetic flux*;

(b) define the *weber*.

(c) select and use the equation for magnetic flux $\phi = BA\cos\theta$;

(d) define *magnetic flux linkage*;

(e) state and use Faraday's law of electromagnetic induction;

(f) state and use Lenz's law;

(g) select and use the equation:

induced e.m.f. = –rate of change of magnetic flux linkage;

(h) describe the function of a simple ac generator;

(i) describe the function of a simple transformer;

(j) select and use the turns-ratio equation for a transformer;

(k) describe the function of step-up and step-down transformers.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

Data loggers can be used to record the e.m.f. variations when there are changes in the magnetic flux linkage in a circuit.

Investigate factors affecting the magnetic force on a current-carrying conductor placed in a uniform magnetic field.

Use a current-balance to determine the magnetic flux density between the poles of a magnet.

Investigate different ways of inducing an e.m.f. in a coil.

Make a transformer using insulated copper wire and an iron rod.

Use a dual-beam oscilloscope to verify the turns-ratio equation for a transformer.

This module introduces the basic properties of capacitors and how they are used in electrical circuits. The use of capacitors as a source of electrical energy is then developed.

This module also introduces the mathematics of exponential decay that is used when studying the decay of radioactive nuclei in module 3.

[Likely HSW aspects covered: 3, 4 and 6a]

Links

Unit G485: Module 1 – *Electric and magnetic fields* and Module 3 – *Nuclear physics*

Context and exemplification	Assessable learning outcomes
5.2.1 Capacitors	Candidates should be able to:
Practical work to investigate how the charge stored on a capacitor is related to the potential difference across the capacitor.	(a) define *capacitance* and the *farad*; (b) select and use the equation $Q = VC$; (c) state and use the equation for the total capacitance of two or more capacitors in series;
Demonstrate energy stored by a capacitor by discharging it through a small motor or filament lamp.	(d) state and use the equation for the total capacitance of two or more capacitors in parallel;
Practical work to investigate the discharge of a capacitor and using a spreadsheet to 'fit best curve'. (HSW 3)	(e) solve circuit problems with capacitors involving series and parallel circuits; (f) explain that the area under a potential difference against charge graph is equal to energy stored by a capacitor; (g) select and use the equations $W = \frac{1}{2}QV$ and $W = \frac{1}{2}CV^2$ for a charged capacitor; (h) sketch graphs that show the variation with time of potential difference, charge and current for a capacitor discharging through a resistor; (i) define the *time constant* of a circuit; (j) select and use *time constant* = *CR*; (k) analyse the discharge of capacitor using equations of the form $x = x_0 e^{-\frac{t}{CR}}$; (l) explain exponential decays as having a constant-ratio property;

(m) describe the uses of capacitors for the storage of energy in applications such as flash photography, lasers used in nuclear fusion and as back-up power supplies for computers (HSW 6a).

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for students to investigate the discharge of a capacitor using data loggers or stopwatches. There are also opportunities for the students to develop skills in recording, analysing and evaluating primary data.

Use a multimeter set on 'capacitance' to verify the rules: $C = C_1 + C_2 + C_3$ and

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

Use an e.h.t. supply, parallel plates and a coulombmeter to show $Q = VC$.

Plot discharge curves for different values of time constants.

Determine the capacitance of a capacitor from a discharge curve.

Investigate the factors that affect the time constant of a C–R circuit.

This module shows how knowledge and understanding of ideas about the basic structure of the atom lead to an explanation of radioactivity, nuclear fission and fusion. The development of the theory illustrates how scientific ideas are modified and also the tentative nature of scientific knowledge. These ideas are then developed to explore whether fission and fusion are acceptable methods for the production of our electrical power needs in the future.

Links

Links to GCSE: 3.9(iii)(b)

G485: Module 1 – *Electric and magnetic fields* and Module 2 – *Capacitors and exponential decays*

Context and exemplification	Assessable learning outcomes
5.3.1 The nuclear atom Use applets or the 1/r-hill to simulate the α-particle scattering experiment. Discussion around: ‘If a penny represents the nucleus, then where would the outermost electron in the atom be?’ Students can use the internet to search for some isotopes. (HSW 4)	Candidates should be able to: (a) describe qualitatively the alpha-particle scattering experiment and the evidence this provides for the existence, charge and small size of the nucleus (HSW 1, 4c); (b) describe the basic atomic structure of the atom and the relative sizes of the atom and the nucleus; (c) select and use Coulomb’s law to determine the force of repulsion, and Newton’s law of gravitation to determine the force of attraction, between two protons at nuclear separations and hence the need for a short-range, attractive force between nucleons (HSW 1, 2, 4); (d) describe how the strong nuclear force between nucleons is attractive and very short-ranged; (e) estimate the density of nuclear matter; (f) define *proton* and *nucleon number*; (g) state and use the notation ${}^{A}_{Z}\mathrm{X}$ for the representation of nuclides; (h) define and use the term *isotopes*; (i) use nuclear decay equations to represent simple nuclear reactions; (j) state the quantities conserved in a nuclear decay.

5.3.2 Fundamental particles

Students can use a science data book or the internet to identify some of the isotopes that emit β^+ or β^- particles.

Candidates should be able to:

(a) explain that since protons and neutrons contain charged constituents called quarks they are, therefore, not fundamental particles;

(b) describe a simple quark model of hadrons in terms of up, down and strange quarks and their respective antiquarks, taking into account their charge, baryon number and strangeness;

(c) describe how the quark model may be extended to include the properties of charm, topness and bottomness;

(d) describe the properties of neutrons and protons in terms of a simple quark model;

(e) describe how there is a weak interaction between quarks and that this is responsible for β decay;

(f) state that there are two types of β decay;

(g) describe the two types of β decay in terms of a simple quark model;

(h) state that (electron) neutrinos and (electron) antineutrinos are produced during β^+ and β^- decays, respectively;

(i) state that a β^- particle is an electron and a β^+ particle is a positron;

(j) state that electrons and neutrinos are members of a group of particles known as leptons.

5.3.3 Radioactivity

Use a GM tube and a counter to show the absorption and range of the radiations.

Use dice to simulate exponential decay of radioactive nuclei.

Teachers can show the insides of a smoke detector.

Candidates should be able to:

(a) describe the spontaneous and random nature of radioactive decay of unstable nuclei;

(b) describe the nature, penetration and range of α-particles, β-particles and γ-rays;

(c) define and use the quantities *activity* and *decay constant*;

(d) select and apply the equation for activity $A = \lambda N$;

(e) select and apply the equations

$A = A_0 e^{-\lambda t}$ and $N = N_0 e^{-\lambda t}$

where A is the activity and N is the number of undecayed nuclei;

(f) define and apply the term *half-life*;

(g) select and use the equation $\lambda t_{1/2} = 0.693$;

(h) compare and contrast decay of radioactive nuclei and decay of charge on a capacitor in a C–R circuit (HSW 5b);

(i) describe the use of radioactive isotopes in smoke alarms (HSW 6a);

(j) describe the technique of radioactive dating

	(ie carbon-dating).
5.3.4 Nuclear fission and fusion Discuss how scientific theories stand or fall on the strength of their predictions and experiments. (HSW 1, 7a) Student can do a presentation on the possibilities of nuclear fusion as an energy source in Europe.	Candidates should be able to: (a) select and use Einstein's mass–energy equation $\Delta E = \Delta mc^2$; (b) define *binding energy* and *binding energy per nucleon*; (c) use and interpret the binding energy per nucleon against nucleon number graph; (d) determine the binding energy of nuclei using $\Delta E = \Delta mc^2$ and masses of nuclei; (e) describe the process of induced nuclear fission; (f) describe and explain the process of nuclear chain reaction; (g) describe the basic construction of a fission reactor and explain the role of the fuel rods, control rods and the moderator (HSW 6a and 7c); (h) describe the use of nuclear fission as an energy source (HSW 4 and 7c); (i) describe the peaceful and destructive uses of nuclear fission (HSW 4 and 7c); (j) describe the environmental effects of nuclear waste (HSW 4, 6a and b, 7c); (k) describe the process of nuclear fusion; (l) describe the conditions in the core of stars that make fusion possible; (m) calculate the energy released in simple nuclear reactions.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities for students to develop skills in recording, analysing and evaluating primary data.

Study the absorption of α-particles, β-particles and γ-rays by appropriate materials.

Deflect beta-particles in magnetic field.

Deflect beta-particles in an electric field.

Carry out a simulation of radioactive decay of nuclei using small cubes or dice.

Determine the half-life of an isotope such as protactinium.

Use a spreadsheet to simulate exponential-decay.

This module shows how the development of the application of physics in medical imaging has led to a number of non-invasive techniques. The nature of X-rays is considered to explain the operation of CAT scans. The basic operation of MRI scanners and the principles behind ultrasound scans are used to show the applications of physics in the medical world.

This module shows how science has benefited society and informs decision making.

[Likely HSW aspects covered: 1, 2,3, 4c, 6 and 7]

Links

Links to GCSE: 3.7(iii)d

Unit G482: Module 3 – *Waves*

Unit G485: Modules 1 and 3

Context and exemplification	Assessable learning outcomes
5.4.1 X-Rays	Candidates should be able to:
	(a) describe the nature of X-rays;
A simulation of X-ray attenuation can be done with light. A light-meter can be used to show absorption by different thicknesses of paper.	(b) describe in simple terms how X-rays are produced;
	(c) describe how X-rays interact with matter (limited to photoelectric effect, Compton Effect and pair production);
Use the Internet to find images from CAT scans.	(d) define *intensity* as the power per unit cross-sectional area;
	(e) select and use the equation $I = I_0 e^{-\mu x}$ to show how the intensity I of a collimated X-ray beam varies with thickness x of medium;
	(f) describe the use of X-rays in imaging internal body structures including the use of image intensifiers and of contrast media (HSW 3, 4c and 6);
	(g) explain how soft tissues like the intestines can be imaged using barium meal;
	(h) describe the operation of a computerised axial tomography (CAT) scanner;
	(i) describe the advantages of a CAT scan compared with an X-ray image (HSW 4c, 6).

5.4.2 Diagnosis methods in medicine Students can use the internet to show images of MRI and PET scans.	Candidates should be able to: (a) describe the use of medical tracers like technetium-99m to diagnose the function of organs; (b) describe the main components of a gamma camera; (c) describe the principles of positron emission tomography (PET); (d) outline the principles of magnetic resonance, with reference to precession of nuclei, Larmor frequency, resonance and relaxation times; (e) describe the main components of an MRI scanner; (f) outline the use of MRI (magnetic resonance imaging) to obtain diagnostic information about internal organs (HSW 3, 4c and 6a); (g) describe the advantages and disadvantages of MRI (HSW 4c & 6a); (h) describe the need for non-invasive techniques in diagnosis (HSW 6a); (i) explain what is meant by the Doppler effect; (j) explain qualitatively how the Doppler effect can be used to determine the speed of blood.
5.4.3 Ultrasound The piezoelectric effect may be demonstrated using a gas fire lighter. Students can use a signal generator and a loudspeaker to demonstrate that we cannot hear ultrasound but it can be registered by a sensitive microphone.	Candidates should be able to: (a) describe the properties of ultrasound; (b) describe the piezoelectric effect; (c) explain how ultrasound transducers emit and receive high-frequency sound; (d) describe the principles of ultrasound scanning; (e) describe the difference between A-scan and B-scan; (f) calculate the acoustic impedance using the equation $Z = \rho c$; (g) calculate the fraction of reflected intensity using the equation $\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$; (h) describe the importance of impedance matching; (i) explain why a gel is required for effective ultrasound imaging techniques.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

Students have the opportunity to discuss the role of science in society. The internet can be used a resource for medical images.

This module demonstrates how theories are developed as more experimental evidence becomes available. The nature of the origins of the universe and its possible future are studied.

[Likely HSW aspects covered: 1, 2, and 7]

Links

Links to GCSE: 3.7(iv)(c)

Unit G481: Module 1 – *Motion*

Unit G482: Module 3 – *Waves*

Unit G484: Module 3 – *Thermal physics*

Unit G485: Module 3 – *Nuclear physics*

Context and exemplification	Assessable learning outcomes
5.5.1 Structure of the universe	Candidates should be able to:
Students can use the internet to show images of the planets and some of their physical characteristics.	(a) describe the principal contents of the universe, including stars, galaxies and radiation;
	(b) describe the solar system in terms of the Sun, planets, planetary satellites and comets;
Students can obtain some redshift data from the internet to calculate the speed v of galaxies.	(c) describe the formation of a star, such as our Sun, from interstellar dust and gas;
	(d) describe the Sun's probable evolution into a red giant and white dwarf;
	(e) describe how a star much more massive than our Sun will evolve into a super red giant and then either a neutron star or black hole;
	(f) define distances measured in astronomical units (AU), parsecs (pc) and light-years (ly);
	(g) state the approximate magnitudes in metres, of the parsec and light-year;
	(h) state Olbers' paradox;
	(i) interpret Olbers' paradox to explain why it suggests that the model of an infinite, static universe is incorrect (HSW 7);
	(j) select and use the equation $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$;
	(k) describe and interpret Hubble's redshift observations;
	(l) state and interpret Hubble's law (HSW 1 & 2);
	(m) convert the Hubble constant H_0 from its conventional units (km s^{-1} Mpc^{-1}) to SI (s^{-1});
	(n) state the cosmological principle;
	(o) describe and explain the significance of the

3K microwave background radiation (HSW 1).

5.5.2 The evolution of the universe

Candidates should be able to:

(a) explain that the standard (hot big bang) model of the universe implies a finite age for the universe (HSW 1, 2, 7);

(b) select and use the expression

$$\text{age of universe} \approx 1/H_0;$$

(c) describe qualitatively the evolution of universe 10^{-43} s after the big bang to the present;

(d) explain that the universe may be 'open', 'flat' or 'closed', depending on its density (HSW 7);

(e) explain that the ultimate fate of the universe depends on its density;

(f) define the term *critical density*;

(g) select and use the expression for critical density of the universe

$$\rho_0 = \frac{3H_0^2}{8\pi G};$$

(h) explain that it is currently believed that the density of the universe is close to, and possibly exactly equal to, the critical density needed for a 'flat' cosmology (HSW 7).

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

There are opportunities to visit local observatories or invite outside speakers from university research departments. The internet provides a wealth of free images of celestial objects.

3.6 A2 Unit G486: *Practical Skills in Physics 2*

This unit assesses practical and investigative skills within contexts encountered during A Level Physics.

Candidates are required to carry out **three** tasks:

1.	Qualitative task	[10 marks]
2.	Quantitative task	[20 marks]
3.	Evaluative task	[10 marks]

Tasks will be chosen from a selection provided by OCR.

The qualitative and quantitative tasks will test skills of observation and measurement.

Candidates will carry out these tasks under controlled conditions.

Each task will be internally assessed using a mark scheme provided by OCR.

Candidates may attempt more than one task from each category with the best mark from each category being used to make up the overall mark.

Centres will supply OCR with a single mark out of 40.

How Science Works

5a Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.

5b Analyse and interpret data to provide evidence, recognising correlations and causal relationships.

5c Evaluate methodology, evidence and data, and resolve conflicting evidence.

The mark schemes supplied by OCR will be based on the following generic criteria:

1. Qualitative task

Candidates carry out a practical task using instructions supplied by OCR.

Candidates should be able to:

(a) demonstrate skilful and safe practical techniques using suitable qualitative methods;

(b) make, record and communicate valid observations;
organise results suitably.

2. Quantitative task

Candidates carry out a practical task using instructions supplied by OCR.	Candidates should be able to: (a) demonstrate and describe safe and skilful practical techniques for a quantitative experiment; (b) make, record and communicate reliable measurements with appropriate precision and accuracy; (c) analyse the experimental results; (d) interpret and explain the experimental results.

3. Evaluative task

This task will extend the quantitative task. Candidates will evaluate the quality of the data and procedures. Evaluative tasks will **not** require additional data collection.	Candidates should be able to: (a) evaluate the results and their impact on the experimental methodology; (b) assess the reliability and accuracy of the experiment by calculating percentage differences and uncertainties; (c) evaluate the methodology with a view to improving experimental precision and accuracy; (d) identify weaknesses in the experimental methodology and measurements; (e) understand and suggest improvements to the experimental procedures and measurements.

The tasks

Tasks, mark schemes and guidance for teachers and technicians can be downloaded from the OCR Interchange site.

4 Schemes of Assessment

4.1 AS GCE Scheme of Assessment

AS GCE Physics A (H158)	
AS Unit G481: *Mechanics*	
30% of the total AS GCE marks 1 h written paper 60 marks	Candidates answer **all** questions.
AS Unit G482: *Electrons, Waves and Photons*	
50% of the total AS GCE marks 1 h 45 min written paper 100 marks	Candidates answer **all** questions.
AS Unit G483: *Practical Skills in Physics 1*	
20% of the total AS GCE marks Coursework 40 marks	Candidates complete three tasks set by OCR. Tasks are marked by the centre using a mark scheme written by OCR.

4.2 Advanced GCE Scheme of Assessment

Advanced GCE Physics A (H558)	
AS Units as above, Unit G481 being 15% of the total Advanced GCE marks, Unit G482 being 25% of the Advanced GCE marks, and Unit G483 being 10% of the Advanced GCE marks.	
A2 Unit G484: *The Newtonian World*	
15% of the total Advanced GCE marks 1 h 15 min written paper 60 marks	Candidates answer **all** questions. This unit is synoptic.
A2 Unit G485 *Fields, Particles and Frontiers of Physics*	
25% of the total Advanced GCE marks 2 h written paper 100 marks	Candidates answer **all** questions. This unit is synoptic.
A2 Unit G486: *Practical Skills in Physics 2*	
10% of the total Advanced GCE marks Coursework 40 marks	Candidates complete three tasks set by OCR. Tasks are marked by the centre using a mark scheme written by OCR.

4.3 Unit Order

The normal order in which the unit assessments could be taken is AS Units G481, G482 and G483 in the first year of study, leading to an AS GCE award, then A2 Units G484, G485 and G486 leading to the Advanced GCE award.

Alternatively, candidates may take a valid combination of unit assessments at the end of their AS GCE or Advanced GCE course in a 'linear' fashion.

4.4 Unit Options (at AS/A2)

There are no optional units in the AS GCE specification; for AS GCE Physics A candidates must take AS Units G481, G482 and G483.

There are no optional units in the Advanced GCE specification; for Advanced GCE Physics A candidates take AS Units G481, G482 and G483, *and* A2 Units G484, G485 and G486.

4.5 Synoptic Assessment (A Level GCE)

Synoptic assessment tests the candidates' understanding of the connections between different elements of the subject.

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. The emphasis of synoptic assessment is to encourage the development of the understanding of the subject as a discipline. All A2 units, whether internally or externally assessed, contain synoptic assessment.

Synoptic assessment requires candidates to make and use connections within and between different areas of physics at AS and A2, for example, by:

- applying knowledge and understanding of more than one area to a particular situation or context;
- using knowledge and understanding of principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data;
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

All A2 units, G484–G486, contain some synoptic assessment.

4.6 Assessment Availability

There is one examination series each year in June.

From 2014, both AS units and A2 units will be assessed in June only.

4.7 Assessment Objectives

Candidates are expected to demonstrate the following in the context of the content described:

AO1 Knowledge and Understanding

- recognise, recall and show understanding of scientific knowledge;
- select, organise and communicate relevant information in a variety of forms.

AO2 Application of Knowledge and Understanding

- analyse and evaluate scientific knowledge and processes;
- apply scientific knowledge and processes to unfamiliar situations including those related to issues;
- assess the validity, reliability and credibility of scientific information.

AO3 How Science Works

- demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods;
- make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy;
- analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

AO weightings in AS GCE

Unit	% of AS GCE			Total
	AO1	AO2	AO3	
AS Unit G481: *Mechanics*	14	14	2	30%
AS Unit G482: *Electrons, Waves and Photons*	21	24	5	50%
AS Unit G483: *Practical Skills in Physics 1*	3	2	15	20%
	38%	40%	22%	100%

AO weightings in Advanced GCE

Unit	% of Advanced GCE			Total
	AO1	AO2	AO3	
AS Unit G481: *Mechanics*	7	7	1	15%
AS Unit G482: *Electrons, Waves and Photons*	10.5	12	2.5	25%
AS Unit G483: *Practical Skills in Physics 1*	1.5	1	7.5	10%
A2 Unit G484: *The Newtonian World*	5	9	1	15%
A2 Unit G485: *Fields, Particles and Frontiers of Physics*	9	13.5	2.5	25%
A2 Unit G486: *Practical Skills in Physics 2*	1	1.5	7.5	10%
	34%	44%	22%	100%

4.8 Quality of Written Communication

Quality of written communication is assessed in all units and credit may be restricted if communication is unclear.

Candidates will:

- 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 appropriate to purpose and to complex subject matter;
- organise information clearly and coherently, using specialist vocabulary when appropriate.

5 Technical Information

5.1 Making Unit Entries

Please note that centres must be registered with OCR in order to make any entries, including estimated entries. It is recommended that centres apply to OCR to become a registered centre well in advance of making their first entries. Centres must have made an entry for a unit in order for OCR to supply the appropriate forms or moderator details for coursework.

It is essential that unit entry codes are quoted in all correspondence with OCR. See Sections 4.1 and 4.2 for these unit entry codes.

5.2 Making Qualification Entries

Candidates must enter for qualification certification separately from unit assessment(s). If a certification entry is **not** made, no overall grade can be awarded.

Candidates may enter for:

- AS GCE certification (entry code H158).
- Advanced GCE certification (entry code H558).

A candidate who has completed all the units required for the qualification, and who did not request certification at the time of entry, may enter for certification either in the same examination series (within a specified period after publication of results) or at a later series.

AS GCE certification is available from June 2014.
Advanced GCE certification is available from June 2014.

5.3 Grading

All GCE units are awarded a–e. The AS GCE is awarded on the scale A–E. The Advanced GCE is awarded on the scale A–E with access to an A*. To be awarded an A*, candidates will need to achieve a grade A on their full A Level qualification and an A* on the aggregate of their A2 units. Grades are reported on certificates. Results for candidates who fail to achieve the minimum grade (E or e) will be recorded as *unclassified* (U or u) and this is **not** certificated.

A Uniform Mark Scale (UMS) enables comparison of candidates' performance across units and across series. The three-unit AS GCE has a total of 300 *uniform* marks and the six-unit Advanced GCE has a total of 600 *uniform* marks.

OCR converts the candidate's raw mark for each unit to a *uniform* mark. The maximum *uniform* mark for any unit depends on that unit's weighting in the specification. In these Physics A specifications the six units of the Advanced GCE specification have UMS weightings of 15%/25%/10%/15%/25%/10% (and the three units of the AS GCE specification have UMS weightings of 30%/50%/20%). The *uniform* mark totals are 90/150/60/90/150/60 respectively. Each unit's *raw* mark grade boundary equates to the *uniform* mark boundary at the same grade. Intermediate marks are converted on a pro-rata basis.

Uniform marks correspond to *unit* grades as follows:

(Advanced GCE) Unit Weighting	Maximum Unit Uniform Mark	Unit Grade					
		a	b	c	d	e	u
25%	150	150–120	119–105	104–90	89–75	74–60	59–0
15%	90	90–72	71–63	62–54	53–45	44–36	35–0
10%	60	60–48	47–42	41–36	35–30	29–24	23–0

OCR adds together the unit *uniform* marks and compares these to pre-set boundaries (see the table below) to arrive at *qualification* grades.

Qualification	Qualification Grade					
	A	B	C	D	E	U
AS GCE	300–240	239–210	209–180	179–150	149–120	119–0
Advanced GCE	600–480	479–420	419–360	359–300	299–240	239–0

Candidates achieving at least 480 *uniform* marks in their Advanced GCE, ie grade A, and who also gain at least 270 *uniform* marks in their three A2 units will receive an A* grade.

5.4 Result Enquiries and Appeals

Under certain circumstances, a centre may wish to query the grade available to one or more candidates or to submit an appeal against an outcome of such an enquiry. Enquiries about unit results must be made immediately following the series in which the relevant unit was taken.

For procedures relating to enquires on results and appeals, centres should consult the OCR *Administration Guide for General Qualifications* and the document *Enquiries about Results and Appeals – Information and Guidance for Centres* produced by the Joint Council. Copies of the most recent editions of these papers can be obtained from OCR.

5.5 Shelf-life of Units

Individual unit results, prior to certification of the qualification, have a shelf-life limited only by that of the qualification.

5.6 Unit and Qualification Re-sits

There is no restriction on the number of times a candidate may re-sit each unit before entering for certification for an AS GCE or Advanced GCE.

Candidates may enter for the full qualifications an unlimited number of times.

5.7 Guided Learning Hours

AS GCE Physics A requires **180** guided learning hours in total.
Advanced GCE Physics A requires **360** guided learning hours in total.

5.8 Code of Practice/Subject Criteria/Common Criteria Requirements

These specifications comply in all respects with current *GCSE, GCE, GNVQ and AEA Code of Practice* as available on the QCA website, the subject criteria for GCE Physics and *The Statutory Regulation of External Qualifications 2004*.

5.9 Arrangements for Candidates with Particular Requirements

For candidates who are unable to complete the full assessment or whose performance may be adversely affected through no fault of their own, teachers should consult the *Access Arrangements and Special Consideration: Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations* produced by the Joint Council. In such cases advice should be sought from OCR as early as possible during the course.

5.10 Prohibited Qualifications and Classification Code

Candidates who enter for the OCR GCE specifications may not also enter for any other GCE specification with the certification title *Physics* in the same examination series.

Every specification is assigned to a national classification code indicating the subject area to which it belongs.

Centres should be aware that candidates who enter for more than one GCE qualification with the same classification code will have only one grade (the highest) counted for the purpose of the School and College Achievement and Attainment Tables.

The classification code for these specifications is 1210.

5.11 Coursework Administration/Regulations

Supervision and Authentication

As with all coursework, teachers must be able to verify that the work submitted for assessment is the candidate's own work. Sufficient work must be carried out under direct supervision to allow the teacher to authenticate the marks with confidence.

Submitting marks to OCR

Centres must have made an entry for a unit in order for OCR to supply the appropriate forms or moderator details for coursework. Coursework administration documents are sent to centres on the basis of estimated entries. Marks may be submitted to OCR either via Interchange, on the computer-printed Coursework Mark Sheets (MS1) provided by OCR (sending the top copy to OCR and the second copy to their allocated moderator) or by EDI (centres using EDI are asked to print a copy of their file and sign it before sending to their allocated moderator).

The deadline for the receipt of coursework marks is:
15 May for the June series.

The awarding body must require centres to obtain from each candidate a signed declaration that authenticates the work they produce as their own. For regulations governing internally assessed work, centres should consult the OCR *Administration Guide for General Qualifications.* Further copies of the coursework administration documents are available on the OCR website (www.ocr.org.uk).

Standardisation and Moderation

All internally-assessed coursework is marked by the teacher and internally standardised by the centre. Marks must be submitted to OCR by the agreed date, after which postal moderation takes place in accordance with OCR procedures.

The purpose of moderation is to ensure that the standard for the award of marks in internally-assessed coursework is the same for each centre, and that each teacher has applied the standards appropriately across the range of candidates within the centre.

The sample of work which is submitted to the moderator for moderation must show how the marks have been awarded in relation to the marking criteria.

Minimum Coursework Required

If a candidate submits no work for a unit, then the candidate should be indicated as being absent from that unit on the coursework mark sheets submitted to OCR. If a candidate completes any work at all for that unit then the work should be assessed according to the criteria and marking instructions and the appropriate mark awarded, which may be zero.

6 Other Specification Issues

6.1 Overlap with other Qualifications

There is a small degree of overlap between the content of these specifications and those for Advanced GCE Science, Chemistry, Geology and Biology.

Examples of overlap include:

Geology

Unit G485 Nuclear physics: carbon dating

Chemistry

Unit G485 Nuclear physics: the nuclear atom

Unit G482 Quantum physics: spectra

Science

Unit G485 Nuclear physics: the nuclear atom.

6.2 Progression from these Qualifications

Throughout the course, candidates are introduced to the ideas of physics and their application to a variety of contexts, both everyday and more specialised. Their understanding of How Science Works in physics is deepened.

The specification thus provides a valuable education for candidates who take physics or related subjects no further. It is also an excellent foundation for further study of physics, engineering (and related subjects such as metallurgy and materials science) or other sciences.

6.3 Key Skills Mapping

These specifications provide opportunities for the development of the Key Skills of *Communication*, *Application of Number*, *Information Technology*, *Working with Others*, *Improving Own Learning and Performance* and *Problem Solving* at Levels 2 and/or 3. However, the extent to which this evidence fulfils the Key Skills criteria at these levels will be totally dependent on the style of teaching and learning adopted for each unit.

The following table indicates where opportunities *may* exist for at least some coverage of the various Key Skills criteria at Levels 2 and/or 3 for each unit.

Unit	C				AoN			IT			WwO			IoLP			PS		
	.1a	.1b	.2	.3	.1	.2	.3	.1	.2	.3	.1	.2	.3	.1	.2	.3	.1	.2	.3
G481	✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G482	✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G483				✓	✓	✓	✓	✓	✓	✓									
G484	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G485	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G486		✓	✓	✓	✓	✓	✓	✓	✓	✓									

6.4 Spiritual, Moral, Ethical, Social, Legislative, Economic and Cultural Issues

These specifications offer opportunities which can contribute to an understanding of these issues in the following topics:

- the endeavour of physics in describing the structure and functioning of the natural and material world;
- a sense of awe and wonder at the scale and impact of physical processes and phenomena;
- the ethical and moral implications of some of the applications of science and technology;
- developing nuclear power to meet our energy requirements.

6.5 Sustainable Development, Health and Safety Considerations and European Developments

These specifications support these issues, consistent with current EU agreements, in the following topics:

- aspects of environmental education occur in relation to problems associated with reprocessing and storage of radioactive materials;
- there have been many contributions to the understanding of physics by European physicists, including Coulomb, Einstein and Curie, as well as many others;
- many European developments could be drawn into the course, for example European co-operation in joint scientific projects (JET);
- a number of health and safety issues feature in these specifications, including:
    - radioactivity;
    - health physics;
    - safe practice in laboratories;
    - problems associated with reprocessing and storage of radioactive materials.

6.6 Avoidance of Bias

OCR has taken great care in the preparation of these specifications and assessment materials to avoid bias of any kind.

6.7 Language

These specifications and associated assessment materials are in English only.

6.8 Disability Discrimination Act Information Relating to these Specifications

AS/A levels often require assessment of a broad range of competences. This is because they are general qualifications and, as such, prepare candidates for a wide range of occupations and higher level courses.

The revised AS/A level qualification and subject criteria were reviewed to identify whether any of the competences required by the subject presented a potential barrier to any disabled candidates. If this was the case, the situation was reviewed again to ensure that such competences were included only where essential to the subject. The findings of this process were discussed with disability groups and with disabled people.

Reasonable adjustments are made for disabled candidates in order to enable them to access the assessments. For this reason, very few candidates will have a complete barrier to any part of the assessment. Information on reasonable adjustments is found in *Access Arrangements and Special Consideration Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations* produced by the Joint Council (refer to Section 5.9 of this specification).

Candidates who are still unable to access a significant part of the assessment, even after exploring all possibilities through reasonable adjustments, may still be able to receive an award. They would be given a grade on the parts of the assessment they have taken and there would be an indication on their certificate that not all of the competences have been addressed. This will be kept under review and may be amended in the future.

Practical assistants may be used for manipulating equipment and making observations. Technology may help visually impaired students to take readings and make observations.

Appendix A: Performance Descriptions

Performance descriptions have been created for all GCE subjects. They describe the learning outcomes and levels of attainment likely to be demonstrated by a representative candidate performing at the A/B and E/U boundaries for AS and A2.

In practice most candidates will show uneven profiles across the attainments listed, with strengths in some areas compensating in the award process for weaknesses or omissions elsewhere. Performance descriptions illustrate expectations at the A/B and E/U boundaries of the AS and A2 as a whole; they have not been written at unit level.

Grade A/B and E/U boundaries should be set using professional judgement. The judgement should reflect the quality of candidates' work, informed by the available technical and statistical evidence. Performance descriptions are designed to assist examiners in exercising their professional judgement. They should be interpreted and applied in the context of individual specifications and their associated units. However, performance descriptions are not designed to define the content of specifications and units.

The requirement for all AS and A Level specifications to assess candidates' quality of written communication will be met through one or more of the assessment objectives.

The performance descriptions have been produced by the regulatory authorities in collaboration with the awarding bodies.

AS performance descriptions for physics

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
Assessment Objectives	**Knowledge and understanding of science and of How Science Works** Candidates should be able to: • recognise, recall and show understanding of scientific knowledge; • select, organise and communicate relevant information in a variety of forms.	**Application of knowledge and understanding of science and of How Science Works** Candidates should be able to: • analyse and evaluate scientific knowledge and processes; • apply scientific knowledge and processes to unfamiliar situations including those related to issues; • assess the validity, reliability and credibility of scientific information.	**How Science Works** Candidates should be able to: • demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods; • make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy; • analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary Performance Descriptions	Candidates characteristically: a) demonstrate knowledge of most principles, concepts and facts from the AS specification; b) show understanding of most principles, concepts and facts from the AS specification; c) select relevant information from the AS specification; d) organise and present information clearly in appropriate forms using scientific terminology.	Candidates characteristically: a) apply principles and concepts in familiar and new contexts involving only a few steps in the argument; b) describe significant trends and patterns shown by data presented in tabular or graphical form and interpret phenomena with few errors and present arguments and evaluations clearly; c) explain and interpret phenomena with few errors and present arguments and evaluations clearly; d) carry out structured calculations with few errors and demonstrate good understanding of the underlying relationships between physical quantities.	Candidates characteristically: a) devise and plan experimental and investigative activities, selecting appropriate techniques; b) demonstrate safe and skilful practical techniques; c) make observations and measurements with appropriate precision and record these methodically; d) interpret, explain, evaluate and communicate the results of their own and others experimental and investigative activities, in appropriate contexts.
E/U boundary Performance Descriptions	Candidates characteristically: a) demonstrate knowledge of some principles and facts from the AS specification; b) show understanding of some principles and facts from the AS specification; c) select some relevant information from the AS specification; d) present information using basic terminology from the AS specification.	Candidates characteristically: a) apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument; b) describe some trends or patterns shown by data presented in tabular or graphical form; c) provide basic explanations and interpretations of some phenomena, presenting very limited evaluations; d) carry out some steps within calculations.	Candidates characteristically: a) devise and plan some aspects of experimental and investigative activities; b) demonstrate safe practical techniques; c) make observations and measurements, and record them; d) interpret, explain and communicate some aspects of the results of their own and others experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for physics

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
Assessment Objectives	**Knowledge and understanding of science and of How Science Works** Candidates should be able to: • recognise, recall and show understanding of scientific knowledge; • select, organise and communicate relevant information in a variety of forms.	**Application of knowledge and understanding of science and of How Science Works** Candidates should be able to: • analyse and evaluate scientific knowledge and processes; • apply scientific knowledge and processes to unfamiliar situations including those related to issues; • assess the validity, reliability and credibility of scientific information.	**How Science Works** Candidates should be able to: • demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods; • make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy; • analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary Performance Descriptions	Candidates characteristically: a) demonstrate detailed knowledge of most principles, concepts and facts from the A2 specification; b) show understanding of most principles, concepts and facts from the A2 specification; c) select relevant information from the A2 specification; d) organise and present information clearly in appropriate forms using scientific terminology.	Candidates characteristically: a) apply principles and concepts in familiar and new contexts involving several steps in the argument; b) describe significant trends and patterns shown by complex data presented in tabular or graphical form, interpret phenomena with few errors, and present arguments and evaluations clearly and logically; c) explain and interpret phenomena effectively, presenting arguments and evaluations; d) carry out extended calculations, with little or no guidance, and demonstrate good understanding of the underlying relationships between physical quantities; e) select a wide range of facts, principles and concepts from both AS and A2 specifications; f) link together appropriate facts principles and concepts from different areas of the specification.	Candidates characteristically: a) devise and plan experimental and investigative activities, selecting appropriate techniques; b) demonstrate safe and skilful practical techniques; c) make observations and measurements with appropriate precision and record these methodically; d) interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.
E/U boundary Performance Descriptions	Candidates characteristically: a) demonstrate knowledge of some principles and facts from the A2 specification; b) show understanding of some principles and facts from the A2 specification; c) select some relevant information from the A2 specification; d) present information using basic terminology from the A2 specification.	Candidates characteristically: a) apply given principles or concepts in familiar and new contexts involving a few steps in the argument; b) describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form; c) provide basic explanations and interpretations of some phenomena, presenting very limited arguments and evaluations; d) carry out routine calculations, where guidance is given; e) select some facts, principles and concepts from both AS and A2 specifications; f) put together some facts, principles and concepts from different areas of the specification.	Candidates characteristically: a) devise and plan some aspects of experimental and investigative activities; b) demonstrate safe practical techniques; c) make observations and measurements and record them; d) interpret, explain and communicate some aspects of the results of their own and others experimental and investigative activities, in appropriate contexts.

Appendix B: How Science Works

References in this specification to *How Science Works* (HSW) are to the following statements. These have been written by rearranging the statements in Section 3.6 of the QCA Subject Criteria.

1. Use theories, models and ideas to develop and modify scientific explanations.

2. Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas.

3. Use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems.

4. Communicate information and ideas in appropriate ways using appropriate terminology.

5. Obtaining, analysing and evaluation data:

   a. carry out experimental and investigative activities, including appropriate risk management, in a range of contexts;

   b. analyse and interpret data to provide evidence, recognising correlations and causal relationships;

   c. evaluate methodology, evidence and data, and resolve conflicting evidence.

6. Applications, implications and ethical considerations:

   a. consider applications and implications of science and appreciate their associated benefits and risks;

   b. consider ethical issues in the treatment of humans, other organisms and the environment.

7. Scientific knowledge in its social context:

   a. appreciate the tentative nature of scientific knowledge;

   b. appreciate the role of the scientific community in validating new knowledge and ensuring integrity;

   c. appreciate the ways in which society uses science to inform decision-making.

Appendix C Physics Data, Formulae and Relationships

The data, formulae and relationships relevant to each unit will be printed as an insert to the examination paper.

Data

Values are given to three significant figures, except where more are useful.

speed of light in a vacuum	c	3.00×10^{8} m s^{-1}
permittivity of free space	ε_0	8.85×10^{-12} C^{2} N^{-1} m^{-2} (F m^{-1})
elementary charge	e	1.60×10^{-19} C
Planck constant	h	6.63×10^{-34} J s
gravitational constant	G	6.67×10^{-11} N m^{2} kg^{-2}
Avogadro constant	N_A	6.02×10^{23} mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
electron rest mass	m_e	9.11×10^{-31} kg
proton rest mass	m_p	1.673×10^{-27} kg
neutron rest mass	m_n	1.675×10^{-27} kg
alpha particle rest mass	m_α	6.646×10^{-27} kg
acceleration of free fall	g	9.81 m s^{-2}

Conversion factors

unified atomic mass unit	1 u = 1.661×10^{-27} kg
electronvolt	1 eV = 1.60×10^{-19} J
	1 day = 8.64×10^{4} s
	1 year $\approx 3.16 \times 10^{7}$ s
	1 light year $\approx 9.5 \times 10^{15}$ m

Mathematical equations

arc length = $r\theta$

circumference of circle = $2\pi r$

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

volume of cylinder = $\pi r^2 h$

surface area of sphere = $4\pi r^2$

volume of sphere = $\frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

For small angle $\theta \Rightarrow \sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$

$\lg(AB) = \lg(A) + \lg(B)$

$\lg\left(\frac{A}{B}\right) = \lg(A) - \lg(B)$

$\ln(x^n) = n\ln(x)$

$\ln(e^{kx}) = kx$

Formulae and relationships

Unit G481 – Mechanics	Unit G482 – Electrons, waves and photons
$F_x = F\cos\theta$ $F_y = F\sin\theta$	$\Delta Q = I\Delta t$
$a = \dfrac{\Delta v}{\Delta t}$	$I = Anev$
$v = u + at$	$W = VQ$
$s = \dfrac{1}{2}(u+v)t$	$V = IR$
$s = ut + \dfrac{1}{2}at^2$	$R = \dfrac{\rho L}{A}$
$v^2 = u^2 + 2as$	$P = VI \qquad P = I^2R \qquad P = \dfrac{V^2}{R}$
$F = ma$	$W = VIt$
$W = mg$	e.m.f $= V + Ir$
moment $= Fx$	$V_{\text{out}} = \dfrac{R_2}{R_1+R_2} \times V_{\text{in}}$
torque $= Fd$	$v = f\lambda$
$\rho = \dfrac{m}{V}$	$\lambda = \dfrac{ax}{D}$
$p = \dfrac{F}{A}$	$d\sin\theta = n\lambda$
$W = Fx\cos\theta$	$E = hf \qquad E = \dfrac{hc}{\lambda}$
$E_k = \dfrac{1}{2}mv^2$	$hf = \phi + \text{KE}_{\text{max}}$
$E_p = mgh$	$\lambda = \dfrac{h}{mv}$
efficiency $= \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$	$R = R_1 + R_2 + \ldots$
$F = kx$	$1/R = 1/R_1 + 1/R_2 + \ldots$
$E = \dfrac{1}{2}Fx \qquad E = \dfrac{1}{2}kx^2$	
stress $= \dfrac{F}{A}$	
strain $= \dfrac{x}{L}$	

Young modulus = stress/strain

Unit G484 – The Newtonian World	Unit G485 – Fields, Particles and Frontiers of Physics
$F = \frac{\Delta p}{\Delta t}$	$E = \frac{F}{Q}$
$v = \frac{2\pi r}{T}$	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$
$a = \frac{v^2}{r}$	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$
$F = \frac{mv^2}{r}$	$E = \frac{V}{d}$
$F = -\frac{GMm}{r^2}$	$F = BIL\sin\theta$
$g = \frac{F}{m}$	$F = BQv$
$g = -\frac{GM}{r^2}$	$\phi = BA\cos\theta$
$T^2 = (\frac{4\pi^2}{GM})r^3$	induced e.m.f. = – rate of change of magnetic flux linkage
$f = \frac{1}{T}$	$\frac{V_s}{V_p} = \frac{n_s}{n_p}$
$\omega = \frac{2\pi}{T} = 2\pi f$	$Q = VC$
$a = -(2\pi f)^2 x$	$W = \frac{1}{2}QV \quad W = \frac{1}{2}CV^2$
$x = A\cos(2\pi ft)$	time constant = CR
$v_{\max} = (2\pi f)A$	$x = x_0 \, e^{-\frac{t}{CR}}$
$E = mc\Delta\theta$	$C = C_1 + C_2 + C_3$
$pV = NkT$	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
$pV = nRT$	$A = \lambda N$
$E = \frac{3}{2}kT$	$A = A_0 \, e^{-\lambda t}$
	$N = N_0 \, e^{-\lambda t}$
	$\lambda t_{1/2} = 0.693$

	$\Delta E = \Delta mc^2$
	$I = I_0 \, e^{-\mu x}$
	$Z = \rho c$
	$\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$
	$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
	age of universe $\approx \frac{1}{H_0}$
	$\rho_0 = \frac{3H_0^2}{8\pi G}$

Appendix D: Mathematical Requirements

In order to be able to develop their skills, knowledge and understanding in physics, students need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated below.

1 Arithmetic and numerical computation:

(a) recognise and use expressions in decimal and standard form;

(b) use ratios, fractions and percentages;

(c) use calculators to find and use power, exponential and logarithmic functions;

(e) use calculators to handle sin *x*, cos *x*, tan *x* when *x* is expressed in degrees or radians.

2 Handling data:

(a) use an appropriate number of significant figures;

(b) find arithmetic means;

(c) make order of magnitude calculations.

3 Algebra:

(a) understand and use the symbols: =, <, <<, >>, >, ∝, ~;

(b) change the subject of an equation;

(c) substitute numerical values into algebraic equations using appropriate units for physical quantities;

(d) solve simple algebraic equations.

4 Graphs:

(a) translate information between graphical, numerical and algebraic forms;

(b) plot two variables from experimental or other data;

(c) understand that $y = mx + c$ represents a linear relationship;

(d) determine the slope and intercept of a linear graph;

(e) draw and use the slope of a tangent to a curve as a measure of rate of change;

(f) understand the possible physical significance of the area between a curve and the x axis and be able to calculate it or measure it by counting squares as appropriate;

(g) use logarithmic plots to test exponential and power law variations;

(h) sketch simple functions including $y = k/x$, $y = kx^2$, $y = k/x^2$, $y = \sin x$, $y = \cos x$,

$y = e^{-x}$.

5 Geometry and trigonometry:

(a) calculate areas of triangles, circumferences and areas of circles, surface areas and volumes of rectangular blocks, cylinders and spheres;

(b) use Pythagoras' theorem, and the angle sum of a triangle;

(c) use sin, cos and tan in physical problems;

(d) understand the relationship between degrees and radians and translate from one to the other;

(e) use relationship for triangles: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$ and $a^2 = b^2 = c^2 - 2bc\cos A$.

Appendix E: Health and Safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for AS and Advanced GCE, this is likely to be the local education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at www.ase.org.uk/htm/teacher_zone/safety_in_science_education.php.

For members, the CLEAPSS® guide, *Managing Risk Assessment in Science** offers detailed advice. Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

- *Safety in Science Education*, DfEE, 1996, HMSO, ISBN 0 11 270915 X.

  Now out of print but sections are available at:
  www.ase.org.uk/htm/teacher_zone/safety_in_science_education.php;

- *Topics in Safety*, 3rd edition, 2001, ASE ISBN 0 86357 316 9;
- *Safeguards in the School Laboratory*, 11th edition, 2006, ASE ISBN 978 0 86357 408 5;
- CLEAPSS® *Hazcards*, 2007 edition and later updates*;
- CLEAPSS® *Laboratory Handbook**;
- *Hazardous Chemicals*, A Manual for Science Education, 1997, SSERC Limited

  ISBN 0 9531776 0 2 (see www.sserc.org.uk/public/hazcd/whats_new.htm).

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or micro-organisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS® (or, in Scotland, SSERC).

*****These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications CD-ROM issued annually to members. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to www.cleapss.org.uk. In Scotland, SSERC (www.sserc.org.uk) has a similar role to CLEAPSS® and there are some reciprocal arrangements.

Appendix F: Using OCR Interchange to Download Practical Skills Tasks

All materials for the assessment of GCE Physics A Practical Skills can be obtained from OCR Interchange.

How to use OCR Interchange
OCR Interchange is a secure extranet enabling registered users to administer qualifications on-line. Your Examinations Officer is probably using OCR Interchange to administer qualifications already. If this is not the case, then your centre will need to register.

Your Examinations Officer will be able to:*

- download the relevant documents for you by adding the role of 'Science Coordinator' to their other roles or
- create a new user account for you (adding the Science Coordinator role) so that you can access the GCE Physics A pages and download documents when you need them.*

*Note that in order to assign the role of Science Coordinator to others, the Examinations Officer will need to hold the role of Centre Administrator.

The website address for Interchange is:

https://interchange.ocr.org.uk

The teacher who has downloaded these materials is responsible for ensuring that any pages labelled **confidential** are stored securely so that students do not have the opportunity to access them.

It is intended that the circulation of the Practical Tasks is limited to those students who are currently undertaking that task. These materials should be photocopied and issued to students at the start of the task. Numbering the documents may help to keep track of them.

Registering for Interchange

If your Examinations Officer is not already a registered user of Interchange then he/she will need to register before the Physics A Tasks can be downloaded.

This is a straightforward process:

- Go to the website – https://interchange.ocr.org.uk
- The first page has a New User section
- Click on Sign Up to access the OCR Interchange Agreement Form 1
- Download this document and fill in your details
- Return form by post to OCR Customer Contact Centre, Westwood Way, Coventry, CV4 8JQ or fax the form back to 024 76 851633
- OCR will then contact the Head of Centre with the details needed for the Examinations Officer to access OCR Interchange.