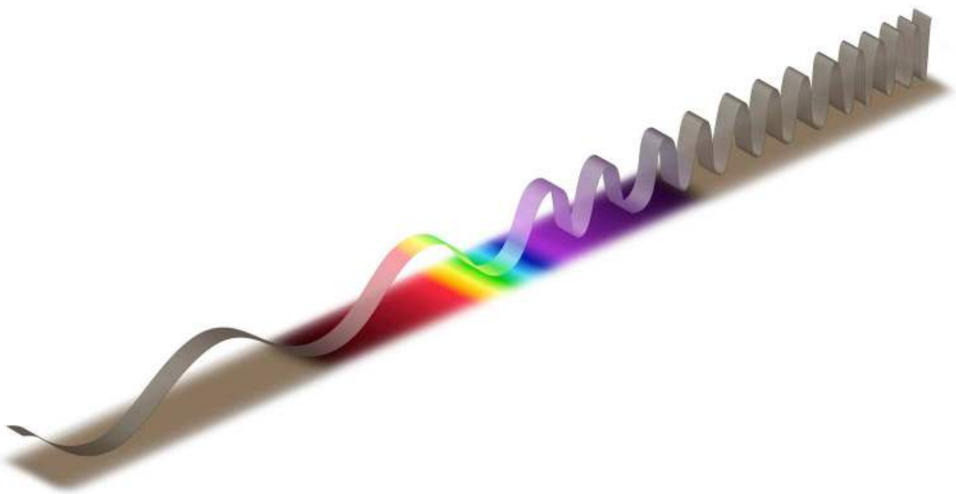
Cambridge Assessment
International Education

Syllabus

Cambridge O Level
Physics 5054

Use this syllabus for exams in 2023, 2024 and 2025.
Exams are available in the June and November series.



Version 1

Please check the syllabus page at **www.cambridgeinternational.org/5054** to see if this syllabus is available in your administrative zone.

Cambridge Pathway

Why choose Cambridge International?

Cambridge International prepares school students for life, helping them develop an informed curiosity and a lasting passion for learning. We are part of the University of Cambridge.

Our Cambridge Pathway gives students a clear path for educational success from age 5 to 19. Schools can shape the curriculum around how they want students to learn – with a wide range of subjects and flexible ways to offer them. It helps students discover new abilities and a wider world, and gives them the skills they need for life, so they can achieve at school, university and work.

Our programmes and qualifications set the global standard for international education. They are created by subject experts, rooted in academic rigour and reflect the latest educational research. They provide a strong platform for learners to progress from one stage to the next, and are well supported by teaching and learning resources.

Our mission is to provide educational benefit through provision of international programmes and qualifications for school education and to be the world leader in this field. Together with schools, we develop Cambridge learners who are confident, responsible, reflective, innovative and engaged – equipped for success in the modern world.

Every year, nearly a million Cambridge students from 10 000 schools in 160 countries prepare for their future with the Cambridge Pathway.

'We think the Cambridge curriculum is superb preparation for university.'

Christoph Guttentag, Dean of Undergraduate Admissions, Duke University, USA

Quality management

Cambridge International is committed to providing exceptional quality. In line with this commitment, our quality management system for the provision of international qualifications and education programmes for students aged 5 to 19 is independently certified as meeting the internationally recognised standard, ISO 9001:2015. Learn more at **www.cambridgeinternational.org/ISO9001**

Contents

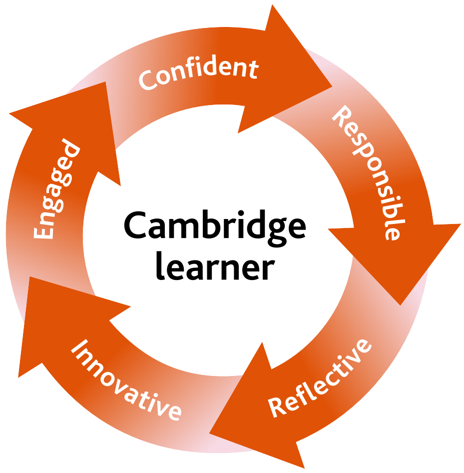
Important: Changes to this syllabus

For information about changes to this syllabus for 2023, 2024 and 2025, go to page 48.

1 Why choose this syllabus?

Key benefits

Cambridge O Level is typically for 14 to 16 year olds and is an internationally recognised qualification. It has been designed especially for an international market and is sensitive to the needs of different countries. Cambridge O Level is designed for learners whose first language may not be English, and this is acknowledged throughout the examination process.



Our programmes balance a thorough knowledge and understanding of a subject and help to develop the skills learners need for their next steps in education or employment.

Cambridge O Level Physics develops a set of transferable skills including handling data, practical problem-solving and applying the scientific method. Learners develop relevant attitudes, such as concern for accuracy and precision, objectivity, integrity, enquiry, initiative and inventiveness. They acquire the essential scientific skills required for progression to further studies or employment.

Our approach in Cambridge O Level Physics encourages learners to be:

confident, interested in learning about science, questioning ideas and using scientific language to communicate their views and opinions

responsible, working methodically and safely when working alone or collaboratively with others

reflective, learning from their experiences and interested in scientific issues that affect the individual, the community and the environment

innovative, solving unfamiliar problems confidently and creatively

engaged, keen to develop scientific skills, curious about scientific principles and their application in the world.

'Cambridge O Level has helped me develop thinking and analytical skills which will go a long way in helping me with advanced studies.'

Kamal Khan Virk, former student at Beaconhouse Garden Town Secondary School, Pakistan, who went on to study Actuarial Science at the London School of Economics

International recognition and acceptance

Our expertise in curriculum, teaching and learning, and assessment is the basis for the recognition of our programmes and qualifications around the world. The combination of knowledge and skills in Cambridge O Level Physics gives learners a solid foundation for further study. Candidates who achieve grades A* to C are well prepared to follow a wide range of courses including Cambridge International AS & A Level Physics.

Cambridge O Levels are accepted and valued by leading universities and employers around the world as evidence of academic achievement. Many universities require a combination of Cambridge International AS & A Levels and Cambridge O Levels or equivalent to meet their entry requirements.

Learn more at **www.cambridgeinternational.org/recognition**

Supporting teachers

We provide a wide range of resources, detailed guidance and innovative training and professional development so that you can give your students the best possible preparation for Cambridge O Level. To find out which resources are available for each syllabus go to our School Support Hub.

The School Support Hub is our secure online site for Cambridge teachers where you can find the resources you need to deliver our programmes. You can also keep up to date with your subject and the global Cambridge community through our online discussion forums.

Find out more at **www.cambridgeinternational.org/support**

Support for Cambridge O Level

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- Next step guides
- Schemes of work
- Specimen papers
- Syllabuses
- Teacher guides

Teaching and assessment
- Endorsed resources
- Online forums
- Support for coursework and speaking tests

Learning and revision
- Example candidate responses
- Learner guides
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Results
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Supporting exams officers

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2 Syllabus overview

Aims

The aims describe the purposes of a course based on this syllabus.

You can deliver some of the aims using suitable local, international or historical examples and applications, or through collaborative practical work.

The aims are to enable students to:

- acquire scientific knowledge and understanding of scientific theories and practice
- develop a range of experimental skills, including handling variables and working safely
- use scientific data and evidence to solve problems and discuss the limitations of scientific methods
- communicate effectively and clearly, using scientific terminology, notation and conventions
- understand that the application of scientific knowledge can benefit people and the environment
- enjoy science and develop an informed interest in scientific matters which support further study.

Cambridge Assessment International Education is an education organisation and politically neutral. The contents of this syllabus, examination papers and associated materials do not endorse any political view. We endeavour to treat all aspects of the exam process neutrally.

Content overview

Candidates study the following topics:

1 Motion, forces and energy
2 Thermal physics
3 Waves
4 Electricity and magnetism
5 Nuclear physics
6 Space physics

Assessment overview

All candidates take three components. Candidates will be eligible for grades A* to E.

Paper 1: Multiple Choice			Paper 2: Theory	
1 hour			1 hour 45 minutes	
40 marks	30%	**AND**	80 marks	50%
40 four-option multiple-choice questions			Short-answer and structured questions	
Externally assessed			Externally assessed	

Practical assessment

All candidates take one practical paper from a choice of two:

Paper 3: Practical Test			Paper 4: Alternative to Practical	
1 hour 30 minutes			1 hour	
40 marks	20%		40 marks	20%
Questions will be based on the experimental skills in Section 4		**OR**	Questions will be based on the experimental skills in Section 4	
Externally assessed			Externally assessed	

Information on availability is in the **Before you start** section.

Assessment objectives

The assessment objectives (AOs) are:

AO1 Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

- scientific phenomena, facts, laws, definitions, concepts and theories
- scientific vocabulary, terminology and conventions (including symbols, quantities and units)
- scientific instruments and apparatus, including techniques of operation and aspects of safety
- scientific and technological applications with their social, economic and environmental implications.

Subject content defines the factual material that candidates may be required to recall and explain.

Candidates will also be asked questions which require them to apply this material to unfamiliar contexts and to apply knowledge from one area of the syllabus to another.

AO2 Handling information and problem-solving

Candidates should be able, in words or using other written forms of presentation (i.e. symbolic, graphical and numerical), to:

- locate, select, organise and present information from a variety of sources
- translate information from one form to another
- manipulate numerical and other data
- use information to identify patterns, report trends and form conclusions
- present reasoned explanations for phenomena, patterns and relationships
- make predictions based on relationships and patterns
- solve problems, including some of a quantitative nature.

Questions testing these skills may be based on information that is unfamiliar to candidates, requiring them to apply the principles and concepts from the syllabus to a new situation, in a logical, deductive way.

AO3 Experimental skills and investigations

Candidates should be able to:

- demonstrate knowledge of how to select and safely use techniques, apparatus and materials (including following a sequence of instructions where appropriate)
- plan experiments and investigations
- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data
- evaluate methods and suggest possible improvements.

Weighting for assessment objectives

The approximate weightings allocated to each of the assessment objectives (AOs) are summarised below.

Assessment objectives as a percentage of the qualification

Assessment objective	Weighting in O Level %
AO1 Knowledge with understanding	50
AO2 Handling information and problem-solving	30
AO3 Experimental skills and investigations	20
Total	100

Assessment objectives as a percentage of each component

Assessment objective	Weighting in components %		
	Paper 1	Paper 2	Papers 3 and 4
AO1 Knowledge with understanding	63	63	–
AO2 Handling information and problem-solving	37	37	–
AO3 Experimental skills and investigations	–	–	100
Total	100	100	100

3 Subject content

This syllabus gives you the flexibility to design a course that will interest, challenge and engage your learners. Where appropriate you are responsible for selecting resources and examples to support your learners' study. These should be appropriate for the learners' age, cultural background and learning context as well as complying with your school policies and local legal requirements.

Scientific subjects are, by their nature, experimental. Learners should pursue a fully integrated course which allows them to develop their experimental skills by doing practical work and investigations.

Practical work helps students to:

- use equipment and materials accurately and safely
- develop observational and problem-solving skills
- develop a deeper understanding of the syllabus topics and the scientific approach
- appreciate how scientific theories are developed and tested
- transfer the experimental skills acquired to unfamiliar contexts
- develop positive scientific attitudes such as objectivity, integrity, cooperation, enquiry and inventiveness
- develop an interest and enjoyment in science.

1 Motion, forces and energy

1.1 Physical quantities and measurement techniques

1 Describe how to measure a variety of lengths with appropriate precision using tapes, rulers and micrometers (including reading the scale on an analogue micrometer)

2 Describe how to use a measuring cylinder to measure the volume of a liquid and to determine the volume of a solid by displacement

3 Describe how to measure a variety of time intervals using clocks and digital timers

4 Determine an average value for a small distance and for a short interval of time by measuring multiples (including the period of oscillation of a pendulum)

5 Understand that a scalar quantity has magnitude (size) only and that a vector quantity has magnitude and direction

6 Know that the following quantities are scalars: distance, speed, time, mass, energy and temperature

7 Know that the following quantities are vectors: displacement, force, weight, velocity, acceleration, momentum, electric field strength and gravitational field strength

8 Determine, by calculation or graphically, the resultant of two vectors at right angles

1.2 Motion

1 Define speed as distance travelled per unit time and define velocity as change in displacement per unit time

2 Recall and use the equation

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

$$v = \frac{s}{t}$$

3 Recall and use the equation

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

4 Define acceleration as change in velocity per unit time; recall and use the equation

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

$$a = \frac{\Delta v}{\Delta t}$$

5 State what is meant by, and describe examples of, uniform acceleration and non-uniform acceleration

6 Know that a deceleration is a negative acceleration and use this in calculations

7 Sketch, plot and interpret distance–time and speed–time graphs

8 Determine from the shape of a distance–time graph when an object is:
(a) at rest
(b) moving with constant speed
(c) accelerating
(d) decelerating

9 Determine from the shape of a speed–time graph when an object is:
(a) at rest
(b) moving with constant speed
(c) moving with constant acceleration
(d) moving with changing acceleration

10 State that the acceleration of free fall *g* for an object near to the surface of the Earth is approximately constant and is approximately $9.8\,\text{m/s}^2$

11 Calculate speed from the gradient of a distance–time graph

12 Calculate the area under a speed–time graph to determine the distance travelled for motion with constant speed or constant acceleration

13 Calculate acceleration from the gradient of a speed–time graph

1.3 Mass and weight

1 State that mass is a measure of the quantity of matter in an object at rest relative to the observer

2 State that the mass of an object resists change from its state of rest or motion (inertia)

3 Know that weights, and therefore masses, may be compared using a beam balance or equal-arm balance

4 Describe how to determine mass using an electronic balance

5 Describe how to measure weight using a force meter

6 Define gravitational field strength as force per unit mass; recall and use the equation

$$\text{gravitational field strength} = \frac{\text{weight}}{\text{mass}}$$

$$g = \frac{W}{m}$$

and know that this is equivalent to the acceleration of free fall

7 State that a gravitational field is a region in which a mass experiences a force due to gravitational attraction

1.4 Density

1 Define density as mass per unit volume; recall and use the equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

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

2 Describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in a liquid (volume by displacement), including appropriate calculations

1.5 Forces

1.5.1 Balanced and unbalanced forces

1 Identify and use different types of force, including weight (gravitational force), friction, drag, air resistance, tension (elastic force), electrostatic force, magnetic force, thrust (driving force) and contact force

2 Identify forces acting on an object and draw free-body diagram(s) representing the forces

3 State Newton's first law as 'an object either remains at rest or continues to move in a straight line at constant speed unless acted on by a resultant force'

4 State that a force may change the velocity of an object by changing its direction of motion or its speed

5 Determine the resultant of two or more forces acting along the same straight line

6 Recall and use the equation

resultant force = mass × acceleration

$F = ma$

7 State Newton's third law as 'when object A exerts a force on object B, then object B exerts an equal and opposite force on object A'

8 Know that Newton's third law describes pairs of forces of the same type acting on different objects

1.5 Forces continued

1.5.2 Friction

1 Describe friction as a force that may impede motion and produce heating
2 Understand the motion of objects acted on by a constant weight or driving force, with and without drag (including air resistance or resistance in a liquid)
3 Explain how an object reaches terminal velocity
4 Define the thinking distance, braking distance and stopping distance of a moving vehicle
5 Explain the factors that affect thinking and braking distance including speed, tiredness, alcohol, drugs, load, tyre surface and road conditions

1.5.3 Elastic deformation

1 Know that forces may produce a change in size and shape of an object
2 Define the spring constant as force per unit extension; recall and use the equation

$$\text{spring constant} = \frac{\text{force}}{\text{extension}}$$

$$k = \frac{F}{x}$$

3 Sketch, plot and interpret load–extension graphs for an elastic solid and describe the associated experimental procedures
4 Define and use the term 'limit of proportionality' for a load–extension graph and identify this point on the graph (an understanding of the elastic limit is **not** required)

1.5.4 Circular motion

1 Describe, qualitatively, motion in a circular path due to a force perpendicular to the motion as:
- (a) speed increases if force increases, with mass and radius constant
- (b) radius decreases if force increases, with mass and speed constant
- (c) an increased mass requires an increased force to keep speed and radius constant

($F = \frac{mv^2}{r}$ is **not** required)

1.5.5 Turning effect of forces

1 Describe the moment of a force as a measure of its turning effect and give everyday examples
2 Define the moment of a force as moment = force × perpendicular distance from the pivot; recall and use this equation
3 State and use the principle of moments for an object in equilibrium
4 Describe an experiment to verify the principle of moments

1.5.6 Centre of gravity

1 State what is meant by centre of gravity
2 Describe how to determine the position of the centre of gravity of a plane lamina using a plumb line
3 Describe, qualitatively, the effect of the position of the centre of gravity on the stability of simple objects

1.6 Momentum

1 Define momentum as mass × velocity; recall and use the equation

$p = mv$

2 Define impulse as force × time for which force acts; recall and use the equation

impulse $= F\Delta t = \Delta(mv)$

3 Apply the principle of the conservation of momentum to solve simple problems in one dimension

4 Define resultant force as the change in momentum per unit time; recall and use the equation

$$\text{resultant force} = \frac{\text{change in momentum}}{\text{time taken}}$$

$$F = \frac{\Delta p}{\Delta t}$$

1.7 Energy, work and power

1.7.1 Energy

1 State that energy may be stored as kinetic, gravitational potential, chemical, elastic (strain), nuclear, electrostatic and internal (thermal)

2 Describe how energy is transferred between stores during events and processes, including examples of transfer by forces (mechanical work done), electrical currents (electrical work done), heating, and by electromagnetic, sound and other waves

3 Know the principle of the conservation of energy and apply this principle to the transfer of energy between stores during events and processes

4 Recall and use the equation for kinetic energy

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

5 Recall and use the equation for the change in gravitational potential energy

$\Delta E_p = mg\Delta h$

1.7.2 Work

1 Recall and use the equation

work done = force × distance moved in the direction of the force

$W = Fd$

1.7 Energy, work and power continued

1.7.3 Energy resources

1 List renewable and non-renewable energy sources

2 Describe how useful energy may be obtained, or electrical power generated, from:

(a) chemical energy stored in fossil fuels
(b) chemical energy stored in biofuels
(c) hydroelectric resources
(d) solar radiation
(e) nuclear fuel
(f) geothermal resources
(g) wind
(h) tides
(i) waves in the sea

including references to a boiler, turbine and generator where they are used

3 Describe advantages and disadvantages of each method limited to whether it is renewable, when and whether it is available, and its impact on the environment

1.7.4 Efficiency

1 Define efficiency as:

(a) $(\%)\ \text{efficiency} = \dfrac{\text{(useful energy output)}}{\text{(total energy input)}}\ (\times 100\%)$

(b) $(\%)\ \text{efficiency} = \dfrac{\text{(useful power output)}}{\text{(total power input)}}\ (\times 100\%)$

and recall and use these equations

1.7.5 Power

1 Define power as work done per unit time and also as energy transferred per unit time; recall and use the equations

(a) $\text{power} = \dfrac{\text{work done}}{\text{time taken}}$

$P = \dfrac{W}{t}$

(b) $\text{power} = \dfrac{\text{energy transferred}}{\text{time taken}}$

$P = \dfrac{\Delta E}{t}$

1.8 Pressure

1 Define pressure as force per unit area; recall and use the equation

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

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

2 Describe how pressure varies with force and area in the context of everyday examples

3 State that the pressure at a surface produces a force in a direction at right angles to the surface and describe an experiment to show this

4 Describe how the height of a liquid column in a liquid barometer may be used to determine the atmospheric pressure

5 Describe, quantitatively, how the pressure beneath the surface of a liquid changes with depth and density of the liquid

6 Recall and use the equation for the change in pressure beneath the surface of a liquid

change in pressure = density × gravitational field strength × change in height

$$\Delta p = \rho g \Delta h$$

2 Thermal physics

2.1 Kinetic particle model of matter

2.1.1 States of matter

1 Know the distinguishing properties of solids, liquids and gases

2 Know the terms for the changes in state between solids, liquids and gases (gas to solid and solid to gas transfers are **not** required)

2.1.2 Particle model

1 Describe, qualitatively, the particle structure of solids, liquids and gases, relating their properties to the forces and distances between particles and to the motion of the particles (atoms, molecules, ions and electrons)

2 Describe the relationship between the motion of particles and temperature, including the idea that there is a lowest possible temperature (–273 °C), known as absolute zero, where the particles have least kinetic energy

3 Describe the pressure and the changes in pressure of a gas in terms of the forces exerted by particles colliding with surfaces, creating a force per unit area

4 Explain qualitatively, in terms of particles, the relationship between:

(a) pressure and temperature at constant volume

(b) volume and temperature at constant pressure

(c) pressure and volume at constant temperature

5 Recall and use the equation $p_1V_1 = p_2V_2$, including a graphical representation of the relationship between pressure and volume for a gas at constant temperature

2.2 Thermal properties and temperatuare

2.2.1 Thermal expansion of solids, liquids and gases

1 Explain applications and consequences of thermal expansion in the context of common examples, including the liquid-in-glass thermometer

2 Explain, in terms of the motion and arrangement of particles, the thermal expansion of solids, liquids and gases, and state the relative order of magnitudes of the expansion of solids, liquids and gases

3 Convert temperatures between kelvin and degrees Celsius; recall and use the equation

T (in K) = θ (in °C) + 273

2.2.2 Specific heat capacity

1 Know that an increase in the temperature of an object increases its internal energy

2 Describe an increase in temperature of an object in terms of an increase in the average kinetic energies of all of the particles in the object

3 Define specific heat capacity as the energy required per unit mass per unit temperature increase; recall and use the equation

$$\text{specific heat capacity} = \frac{\text{change in energy}}{\text{mass} \times \text{change in temperature}}$$

$$c = \frac{\Delta E}{m \Delta \theta}$$

4 Describe experiments to measure the specific heat capacity of a solid and of a liquid

2.2.3 Melting, boiling and evaporation

1 Describe melting, solidification, boiling and condensation in terms of energy transfer without a change in temperature

2 Know the melting and boiling temperatures for water at standard atmospheric pressure

3 Describe the differences between boiling and evaporation

4 Describe evaporation in terms of the escape of more energetic particles from the surface of a liquid

5 Describe how temperature, surface area and air movement over a surface affect evaporation

6 Explain how evaporation causes cooling

7 Describe latent heat as the energy required to change the state of a substance and explain it in terms of particle behaviour and the forces between particles

2.3 Transfer of thermal energy

2.3.1 Conduction

1 Describe experiments to distinguish between good and bad thermal conductors

2 Describe thermal conduction in all solids in terms of atomic or molecular lattice vibrations and also in terms of the movement of free (delocalised) electrons in metallic conductors

2.3.2 Convection

1 Explain convection in liquids and gases in terms of density changes and describe experiments to illustrate convection

2.3.3 Radiation

1 Describe the process of thermal energy transfer by infrared radiation and know that it does not require a medium

2 Describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of infrared radiation

3 Describe how the rate of emission of radiation depends on the surface temperature and surface area of an object

4 Describe experiments to distinguish between good and bad emitters of infrared radiation

5 Describe experiments to distinguish between good and bad absorbers of infrared radiation

2.3.4 Consequences of thermal energy transfer

1 Explain everyday applications using ideas about conduction, convection and radiation, including:
   (a) heating objects such as kitchen pans
   (b) heating a room by convection
   (c) measuring temperature using an infrared thermometer
   (d) using thermal insulation to maintain the temperature of a liquid and to reduce thermal energy transfer in buildings

3 Waves

3.1 General properties of waves

1 Know that waves transfer energy without transferring matter

2 Describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by experiments using water waves

3 Describe the features of a wave in terms of wavefront, wavelength, frequency, crest (peak), trough, amplitude and wave speed

4 Define the terms:
   (a) frequency as the number of wavelengths that pass a point per unit time
   (b) wavelength as the distance between two consecutive, identical points such as two consecutive crests
   (c) amplitude as the maximum distance from the mean position

continued

3.1 General properties of waves continued

5 Recall and use the equation

wave speed = frequency × wavelength

$v = f\lambda$

6 Know that for a transverse wave, the direction of vibration is at right angles to the direction of the energy transfer, and give examples such as electromagnetic radiation, waves on the surface of water, and seismic S-waves (secondary)

7 Know that for a longitudinal wave, the direction of vibration is parallel to the direction of the energy transfer, and give examples such as sound waves and seismic P-waves (primary)

8 Describe how waves can undergo:

(a) reflection at a plane surface

(b) refraction due to a change of speed

(c) diffraction through a gap

9 Describe how wavelength and gap size affects diffraction through a gap

10 Describe the use of a ripple tank to show:

(a) reflection at a plane surface

(b) refraction due to a change in speed caused by a change in depth

(c) diffraction due to a gap

(d) diffraction due to an edge

11 Describe how wavelength affects diffraction at an edge

3.2 Light

3.2.1 Reflection of light

1 Define and use the terms normal, angle of incidence and angle of reflection

2 Describe an experiment to illustrate the law of reflection

3 Describe an experiment to find the position and characteristics of an optical image formed by a plane mirror (same size, same distance from mirror as object and virtual)

4 State that for reflection, the angle of incidence is equal to the angle of reflection and use this in constructions, measurements and calculations

3.2.2 Refraction of light

1 Define and use the terms normal, angle of incidence and angle of refraction

2 Define refractive index n as $n = \frac{\sin i}{\sin r}$; recall and use this equation

3 Describe an experiment to show refraction of light by transparent blocks of different shapes

4 Define the terms critical angle and total internal reflection; recall and use the equation

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

5 Describe experiments to show internal reflection and total internal reflection

6 Describe the use of optical fibres, particularly in telecommunications, stating the advantages of their use in each context

3.2 Light continued

3.2.3 Thin lenses

1 Describe the action of thin converging and thin diverging lenses on a parallel beam of light
2 Define and use the terms focal length, principal axis and principal focus (focal point)
3 Draw ray diagrams to illustrate the formation of real and virtual images of an object by a converging lens and know that a real image is formed by converging rays and a virtual image is formed by diverging rays
4 Define linear magnification as the ratio of image length to object length; recall and use the equation

$$\text{linear magnification} = \frac{\text{image length}}{\text{object length}}$$

5 Describe the use of a single lens as a magnifying glass
6 Draw ray diagrams to show the formation of images in the normal eye, a short-sighted eye and a long-sighted eye
7 Describe the use of converging and diverging lenses to correct long-sightedness and short-sightedness

3.2.4 Dispersion of light

1 Describe the dispersion of light as illustrated by the refraction of white light by a glass prism
2 Know the traditional seven colours of the visible spectrum in order of frequency and in order of wavelength

3.3 Electromagnetic spectrum

1 Know the main regions of the electromagnetic spectrum in order of frequency and in order of wavelength
2 Know that the speed of all electromagnetic waves in:
   (a) a vacuum is 3.0×10^8 m/s
   (b) air is approximately the same as in a vacuum
3 Describe the role of the following components in the stated applications:
   (a) radio waves – radio and television communications, astronomy
   (b) microwaves – satellite television, mobile (cell) phone, Bluetooth, microwave ovens
   (c) infrared – household electrical appliances, remote controllers, intruder alarms, thermal imaging, optical fibres
   (d) visible light – photography, vision
   (e) ultraviolet – security marking, detecting counterfeit bank notes, sterilising water
   (f) X-rays – hospital use in medical imaging, security scanners, killing cancerous cells, engineering applications such as detecting cracks in metal
   (g) gamma rays – medical treatment in detecting and killing cancerous cells, sterilising food and medical equipment, engineering applications such as detecting cracks in metal
4 Describe the damage caused by electromagnetic radiation, including:
   (a) excessive exposure causing heating of soft tissues and burns
   (b) ionising effects caused by ultraviolet (skin cancer and cataracts), X-rays and gamma rays (cell mutation and cancer)

3.4 Sound

1 Describe the production of sound by vibrating sources
2 Describe the longitudinal nature of sound waves and describe compressions and rarefactions
3 State the approximate range of frequencies audible to humans as 20 Hz to 20 000 Hz
4 Explain why sound waves cannot travel in a vacuum and describe an experiment to demonstrate this
5 Describe how changes in amplitude and frequency affect the loudness and pitch of sound waves
6 Describe how different sound sources produce sound waves with different qualities (timbres), as shown by the shape of the traces on an oscilloscope
7 Describe an echo as the reflection of sound waves
8 Describe simple experiments to show the reflection of sound waves
9 Describe a method involving a measurement of distance and time for determining the speed of sound in air
10 Know that the speed of sound in air is approximately 330–350 m / s
11 Know that, in general, sound travels faster in solids than in liquids and faster in liquids than in gases
12 Define ultrasound as sound with a frequency higher than 20 kHz
13 Describe the uses of ultrasound in cleaning, prenatal and other medical scanning, and in sonar (including calculation of depth or distance from time and wave speed)

4 Electricity and magnetism

4.1 Simple magnetism and magnetic fields

1 Describe the forces between magnetic poles and between magnets and magnetic materials, including the use of the terms north pole (N pole), south pole (S pole), attraction and repulsion, magnetised and unmagnetised
2 Describe induced magnetism
3 State the difference between magnetic and non-magnetic materials
4 State the differences between the properties of temporary magnets (made of soft iron) and the properties of permanent magnets (made of steel)
5 Describe a magnetic field as a region in which a magnetic pole experiences a force
6 Describe the plotting of magnetic field lines with a compass or iron filings and the use of a compass to determine the direction of the magnetic field
7 Draw the pattern and direction of the magnetic field lines around a bar magnet
8 State that the direction of the magnetic field at a point is the direction of the force on the N pole of a magnet at that point
9 Know that the relative strength of a magnetic field is represented by the spacing of the magnetic field lines
10 Describe uses of permanent magnets and electromagnets

4.2 Electrical quantities

4.2.1 Electrical charge

1 State that there are positive and negative charges and that charge is measured in coulombs
2 State that unlike charges attract and like charges repel
3 Describe experiments to show electrostatic charging by friction
4 Explain that charging of solids by friction involves only a transfer of negative charge (electrons)
5 Describe an electric field as a region in which an electric charge experiences a force
6 State that the direction of an electric field line at a point is the direction of the force on a positive charge at that point
7 Describe simple electric field patterns, including the direction of the field:
(a) around a point charge
(b) around a charged conducting sphere
(c) between two oppositely charged parallel conducting plates (end effects will **not** be examined)
8 State examples of electrical conductors and insulators
9 Describe an experiment to distinguish between electrical conductors and insulators
10 Recall and use a simple electron model to explain the difference between electrical conductors and insulators

4.2.2 Electrical current

1 Define electric current as the charge passing a point per unit time; recall and use the equation

$$\text{electric current} = \frac{\text{charge}}{\text{time}}$$

$$I = \frac{Q}{t}$$

2 Describe electrical conduction in metals in terms of the movement of free electrons
3 Know that current is measured in amps (amperes) and that the amp is given by coulomb per second (C / s)
4 Know the difference between direct current (d.c.) and alternating current (a.c.)
5 State that conventional current is from positive to negative and that the flow of free electrons is from negative to positive
6 Describe the use of ammeters (analogue and digital) with different ranges

4.2.3 Electromotive force and potential difference

1 Define e.m.f. (electromotive force) as the electrical work done by a source in moving a unit charge around a complete circuit; recall and use the equation

$$\text{e.m.f.} = \frac{\text{work done (by a source)}}{\text{charge}}$$

$$E = \frac{W}{Q}$$

continued

4.2 Electrical quantities continued

4.2.3 Electromotive force and potential difference continued

2 Define p.d. (potential difference) as the work done by a unit charge passing through a component; recall and use the equation

$$\text{p.d.} = \frac{\text{work done (on a component)}}{\text{charge}}$$

$$V = \frac{W}{Q}$$

3 Know that e.m.f. and p.d. are measured in volts and that the volt is given by joule per coulomb (J / C)

4 Describe the use of voltmeters (analogue and digital) with different ranges

5 Calculate the total e.m.f. where several sources are arranged in series

6 State that the e.m.f of identical sources connected in parallel is equal to the e.m.f. of one of the sources

4.2.4 Resistance

1 Recall and use the equation

$$\text{resistance} = \frac{\text{p.d.}}{\text{current}}$$

$$R = \frac{V}{I}$$

2 Describe an experiment to determine resistance using a voltmeter and an ammeter and do the appropriate calculations

3 Recall and use, for a wire, the direct proportionality between resistance and length, and the inverse proportionality between resistance and cross-sectional area

4 State Ohm's law, including reference to constant temperature

5 Sketch and explain the current–voltage graphs for a resistor of constant resistance, a filament lamp and a diode

6 Describe the effect of temperature increase on the resistance of a resistor, such as the filament in a filament lamp

4.3 Electric circuits

4.3.1 Circuit diagrams and circuit components

1 Draw and interpret circuit diagrams with cells, batteries, power supplies, generators, oscilloscopes, potential dividers, switches, resistors (fixed and variable), heaters, thermistors (NTC only), light-dependent resistors (LDRs), lamps, motors, ammeters, voltmeters, magnetising coils, transformers, fuses, relays, diodes and light-emitting diodes (LEDs), and know how these components behave in the circuit

4.3 Electric circuits continued

4.3.2 Series and parallel circuits

1 Recall and use in calculations, the fact that:
   (a) the current at every point in a series circuit is the same
   (b) the sum of the currents entering a junction in a parallel circuit is equal to the sum of the currents that leave the junction
   (c) the total p.d. across the components in a series circuit is equal to the sum of the individual p.d.s across each component
   (d) the p.d. across an arrangement of parallel resistances is the same as the p.d. across one branch in the arrangement of the parallel resistances

2 Calculate the combined resistance of two or more resistors in series

3 Calculate the combined resistance of two resistors in parallel

4 Calculate current, voltage and resistance in parts of a circuit or in the whole circuit

4.3.3 Action and use of circuit components

1 Describe the action of negative temperature coefficient (NTC) thermistors and light-dependent resistors and explain their use as input sensors

2 Describe the action of a variable potential divider

3 Recall and use the equation for two resistors used as a potential divider

$$\frac{R_1}{R_2} = \frac{V_1}{V_2}$$

4.4 Practical electricity

4.4.1 Uses of electricity

1 State common uses of electricity, including heating, lighting, battery charging and powering motors and electronic systems

2 State the advantages of connecting lamps in parallel in a lighting circuit

3 Recall and use the equation

   power = current × voltage

   $P = IV$

4 Recall and use the equation

   energy = current × voltage × time

   $E = IVt$

5 Define the kilowatt-hour (kW h) and calculate the cost of using electrical appliances where the energy unit is the kW h

4.4 Practical electricity continued

4.4.2 Electrical safety

1 State the hazards of:
  (a) damaged insulation
  (b) overheating cables
  (c) damp conditions
  (d) excess current from overloading of plugs, extension leads, single and multiple sockets

  when using a mains supply

2 Explain the use and operation of trip switches and fuses and choose appropriate fuse ratings and trip switch settings

3 Explain what happens when a live wire touches a metal case that is earthed

4 Explain why the outer casing of an electrical appliance must be either non-conducting (double-insulated) or earthed

5 Know that a mains circuit consists of a live wire (line wire), a neutral wire and an earth wire and explain why a switch must be connected into the live wire for the circuit to be switched off safely

6 Explain why fuses and circuit breakers are connected into the live wire

4.5 Electromagnetic effects

4.5.1 Electromagnetic induction

1 Describe an experiment to demonstrate electromagnetic induction

2 State that the magnitude of an induced e.m.f. is affected by:
  (a) the rate of change of the magnetic field or the rate of cutting of magnetic field lines
  (b) the number of turns in a coil

3 State and use the fact that the effect of the current produced by an induced e.m.f. is to oppose the change producing it (Lenz's law) and describe how this law may be demonstrated

4.5.2 The a.c. generator

1 Describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings and brushes where needed

2 Sketch and interpret graphs of e.m.f. against time for simple a.c. generators and relate the position of the generator coil to the peaks, troughs and zeros of the e.m.f.

4.5.3 Magnetic effect of a current

1 Describe the pattern and direction of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and direction of the current

2 Describe how the magnetic effect of a current is used in relays and loudspeakers and give examples of their application

4.5 Electromagnetic effects continued

4.5.4 Forces on a current-carrying conductor

1. Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing:
   (a) the current
   (b) the direction of the field
2. Recall and use the relative directions of force, magnetic field and current
3. Describe the magnetic field patterns between currents in parallel conductors and relate these to the forces on the conductors (excluding the Earth's field)

4.5.5 The d.c. motor

1. Know that a current-carrying coil in a magnetic field may experience a turning effect and that the turning effect is increased by increasing:
   (a) the number of turns on the coil
   (b) the current
   (c) the strength of the magnetic field
2. Describe the operation of an electric motor, including the action of a split-ring commutator and brushes

4.5.6 The transformer

1. Describe the structure and explain the principle of operation of a simple iron-cored transformer
2. Use the terms primary, secondary, step-up and step-down
3. Recall and use the equation

   $$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

   where P and S refer to primary and secondary
4. State the advantages of high-voltage transmission and explain why power losses in cables are smaller when the voltage is greater

4.6 Uses of an oscilloscope

1. Describe the use of an oscilloscope to display waveforms (the structure of an oscilloscope is **not** required)
2. Describe how to measure p.d. and short intervals of time with an oscilloscope using the Y-gain and timebase

5 Nuclear physics

5.1 The nuclear model of the atom

5.1.1 The atom

1 Describe the structure of the atom in terms of a positively charged nucleus and negatively charged electrons in orbit around the nucleus

2 Describe how alpha-particle scattering experiments provide evidence for:
- (a) a very small nucleus surrounded by mostly empty space
- (b) a nucleus containing most of the mass of the atom
- (c) a nucleus that is positively charged

5.1.2 The nucleus

1 Describe the composition of the nucleus in terms of protons and neutrons

2 Describe how atoms form positive ions by losing electrons or negative ions by gaining electrons

3 Define the terms proton number (atomic number) *Z* and nucleon number (mass number) *A* and be able to calculate the number of neutrons in a nucleus

4 Explain the term nuclide and use the nuclide notation ${}^{A}_{Z}\mathrm{X}$

5 Explain what is meant by an isotope and state that an element may have more than one isotope

5.2 Radioactivity

5.2.1 Detection of radioactivity

1 Describe the detection of alpha particles (α-particles) using a cloud chamber or spark counter and the detection of beta particles (β-particles) (β-particles will be taken to refer to β^-) and gamma radiation (γ-radiation) by using a Geiger-Müller tube and counter

2 Use count rate measured in counts / s or counts / minute

3 Know what is meant by background radiation

4 Know the sources that make a significant contribution to background radiation including:
- (a) radon gas (in the air)
- (b) rocks and buildings
- (c) food and drink
- (d) cosmic rays

5 Use measurements of background radiation to determine a corrected count rate

5.2.2 The three types of emission

1 Describe the emission of radiation from a nucleus as spontaneous and random in direction

2 Describe α-particles as two protons and two neutrons (helium nuclei), β-particles as high-speed electrons from the nucleus and γ-radiation as high-frequency electromagnetic waves

3 State, for α-particles, β-particles and γ-radiation:
- (a) their relative ionising effects
- (b) their relative penetrating powers

4 Describe the deflection of α-particles, β-particles and γ-radiation in electric fields and magnetic fields

5.2 Radioactivity continued

5.2.3 Radioactive decay

1 Know that radioactive decay is a change in an unstable nucleus that can result in the emission of α-particles or β-particles and/or γ-radiation and know that these changes are spontaneous and random

2 Use decay equations, using nuclide notation, to show the emission of α-particles, β-particles and γ-radiation

5.2.4 Fission and fusion

1 Describe the process of fusion as the formation of a larger nucleus by combining two smaller nuclei with the release of energy, and recognise fusion as the energy source for stars

2 Describe the process of fission when a nucleus, such as uranium-235 (U-235), absorbs a neutron and produces daughter nuclei and two or more neutrons with the release of energy

3 Explain how the neutrons produced in fission create a chain reaction and that this is controlled in a nuclear reactor, including the action of coolant, moderators and control rods

5.2.5 Half-life

1 Define the half-life of a particular isotope as the time taken for half the nuclei of that isotope in any sample to decay; recall and use this definition in calculations, which may involve information in tables or decay curves

2 Describe the dating of objects by the use of ^{14}C

3 Explain how the type of radiation emitted and the half-life of the isotope determine which isotope is used for applications including:

(a) household fire (smoke) alarms

(b) irradiating food to kill bacteria

(c) sterilisation of equipment using gamma rays

(d) measuring and controlling thicknesses of materials with the choice of radiations used linked to penetration and absorption

(e) diagnosis and treatment of cancer using gamma rays

5.2.6 Safety precautions

1 State the effects of ionising nuclear radiations on living things, including cell death, mutations and cancer

2 Explain how radioactive materials are moved, used and stored in a safe way, with reference to:

(a) reducing exposure time

(b) increasing distance between source and living tissue

(c) use of shielding to absorb radiation

6 Space physics

6.1 Earth and the Solar System

6.1.1 The Earth

1 Know that:
- (a) the Earth is a planet that orbits the Sun once in approximately 365 days
- (b) the orbit of the Earth around the Sun is an ellipse which is approximately circular
- (c) the Earth rotates on its axis, which is tilted, once in approximately 24 hours
- (d) it takes approximately one month for the Moon to orbit the Earth
- (e) it takes approximately 500 s for light from the Sun to reach the Earth

2 Define average orbital speed from the equation

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

where r is the average radius of the orbit and T is the orbital period; recall and use this equation

6.1.2 The Solar System

1 Describe the Solar System as containing:
- (a) one star, the Sun
- (b) the eight named planets and know their order from the Sun
- (c) minor planets that orbit the Sun, including dwarf planets such as Pluto and asteroids in the asteroid belt
- (d) moons, that orbit the planets
- (e) smaller Solar System bodies, including comets and natural satellites

2 Analyse and interpret planetary data about orbital distance, orbital period, density, surface temperature and uniform gravitational field strength at the planet's surface

3 Know that the strength of the gravitational field:
- (a) at the surface of a planet depends on the mass of the planet
- (b) around a planet decreases as the distance from the planet increases

4 Know that the Sun contains most of the mass of the Solar System and that the strength of the gravitational field at the surface of the Sun is greater than the strength of the gravitational field at the surface of the planets

5 Know that the force that keeps an object in orbit around the Sun is the gravitational attraction of the Sun

6 Know that the strength of the Sun's gravitational field decreases and that the orbital speeds of the planets decrease as the distance from the Sun increases

6.2 Stars and the Universe

6.2.1 The Sun as a star

1 Know that the Sun is a star of medium size, consisting mostly of hydrogen and helium, and that it radiates most of its energy in the infrared, visible and ultraviolet regions of the electromagnetic spectrum

2 Know that stars are powered by nuclear reactions that release energy and that in stable stars the nuclear reactions involve the fusion of hydrogen into helium

6.2.2 Stars

1 State that:

(a) galaxies are each made up of many billions of stars

(b) the Sun is a star in the galaxy known as the Milky Way

(c) other stars that make up the Milky Way are much further away from the Earth than the Sun is from the Earth

(d) astronomical distances can be measured in light-years, where one light-year is the distance travelled in a vacuum by light in one year

2 Describe the life cycle of a star:

(a) a star is formed from interstellar clouds of gas and dust that contain hydrogen

(b) a protostar is an interstellar cloud collapsing and increasing in temperature as a result of its internal gravitational attraction

(c) a protostar becomes a stable star when the inward force of gravitational attraction is balanced by an outward force due to the high temperature in the centre of the star

(d) all stars eventually run out of hydrogen as fuel for the nuclear reaction

(e) most stars expand to form red giants and more massive stars expand to form red supergiants when most of the hydrogen in the centre of the star has been converted to helium

(f) a red giant from a less massive star forms a planetary nebula with a white dwarf at its centre

(g) a red supergiant explodes as a supernova, forming a nebula containing hydrogen and new heavier elements, leaving behind a neutron star or a black hole at its centre

(h) the nebula from a supernova may form new stars with orbiting planets

6.2.3 The Universe

1 Know that the Milky Way is one of many billions of galaxies making up the Universe and that the diameter of the Milky Way is approximately 100 000 light-years

2 Describe redshift as an increase in the observed wavelength of electromagnetic radiation emitted from receding stars and galaxies

3 Know that the light from distant galaxies shows redshift and that the further away the galaxy, the greater the observed redshift and the faster the galaxy's speed away from the Earth

4 Describe, qualitatively, how redshift provides evidence for the Big Bang theory

4 Details of the assessment

All candidates take three papers. All papers assess grades A* to E.

Paper 1: Multiple Choice		Paper 2: Theory
1 hour 40 marks 40 compulsory multiple-choice items of the four-choice type This paper tests assessment objectives AO1 and AO2 Externally assessed	**AND**	1 hour 45 minutes 80 marks Compulsory short-answer and structured questions This paper tests assessment objectives AO1 and AO2 Externally assessed

Practical assessment

All candidates take one practical paper from a choice of two:

Paper 3: Practical Test		Paper 4: Alternative to Practical
1 hour 30 minutes 40 marks All items are compulsory This paper tests assessment objective AO3 Candidates will be required to do experiments in a laboratory as part of this test Externally assessed	**OR**	1 hour 40 marks All items are compulsory This paper tests assessment objective AO3 Candidates will not be required to do experiments as part of this test Externally assessed

The Practical Test and Alternative to Practical:

- require the same experimental skills to be developed and learned
- require an understanding of the same experimental contexts
- test the same assessment objective, AO3.

Candidates are expected to be familiar with and may be asked questions using the following experimental contexts:

- measurement of physical quantities such as length, volume or force
- measurement of small distances or short intervals of time
- determining a derived quantity such as the extension per unit load for a spring, the value of a known resistance or the acceleration of an object
- testing and identifying the relationship between two variables such as between the potential difference across a wire and its length
- comparing measured quantities such as angles of reflection
- comparing derived quantities such as density
- cooling and heating, including measurement of temperature
- experiments using springs and balances
- timing motion or oscillations
- electric circuits, including the connection and reconnection of these circuits, and the measurement of current and potential difference
- optics experiments using equipment such as optics pins, mirrors, prisms, lenses, glass or Perspex blocks (both rectangular and semi-circular), including the use of transparent, translucent and opaque substances to investigate the transmission of light
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate.

Candidates may be required to do the following:

- **demonstrate knowledge of how to select and safely use techniques, apparatus and materials (including following a sequence of instructions where appropriate):**
  - identify apparatus from diagrams or descriptions
  - draw, complete or label diagrams of apparatus
  - use, or explain the use of, common techniques, apparatus and materials
  - select the most appropriate apparatus or method for the task and justify the choice made
  - describe and explain hazards and identify safety precautions
  - describe and explain techniques used to ensure the accuracy of observations and data

- **plan experiments and investigations:**
  - identify the independent variable and dependent variable
  - describe how and explain why variables should be controlled
  - suggest an appropriate number and range of values for the independent variable
  - suggest the most appropriate apparatus or technique and justify the choice made
  - describe experimental procedures
  - identify risks and suggest appropriate safety precautions
  - describe how to record the results of an experiment
  - describe how to process the results of an experiment to form a conclusion or to evaluate a prediction
  - make reasoned predictions of expected results

- **make and record observations, measurements and estimates:**
  - take readings from apparatus (analogue and digital) or from diagrams of apparatus
  - take readings with appropriate precision, reading to the nearest half-scale division where required
  - correct for zero errors where required
  - make observations, measurements or estimates that are in agreement with expected results or values
  - take sufficient observations or measurements
  - repeat observations or measurements where appropriate
  - record qualitative observations from tests
  - record observations and measurements systematically, for example in a suitable table, to an appropriate degree of precision and using appropriate units

- **interpret and evaluate experimental observations and data:**
  - process data, including for use in further calculations or for graph plotting, using a calculator as appropriate
  - present data graphically, including the use of best-fit lines where appropriate
  - analyse and interpret observations and data, including data presented graphically
  - use interpolation and extrapolation graphically to determine a gradient or intercept
  - form conclusions justified by reference to observations and data and with appropriate explanation
  - evaluate the quality of observations and data, identifying any anomalous results and taking appropriate action
  - comment on and explain whether results are equal within the limits of experimental accuracy (assumed to be ± 10% at this level of study)

- **evaluate methods and suggest possible improvements:**
  - evaluate experimental arrangements, methods and techniques, including the control of variables
  - identify sources of error, including measurement error, random error and systematic error
  - identify possible causes of uncertainty in data or in a conclusion
  - suggest possible improvements to the apparatus, experimental arrangements, methods or techniques

Language of measurement

The following definitions have been taken or adapted from *The Language of Measurement* (2010), a guide from the Association for Science Education (ASE).
www.ase.org.uk

The definitions in the table below should be used by teachers during the course to encourage students to use the terminology correctly and consistently.

Candidates will **not** be required to recall the specific definition of these terms in the examinations.

true value	the value that would be obtained in an ideal measurement
measurement error	the difference between a measured value and the true value of a quantity
accuracy	a measurement result is described as accurate if it is close to the true value
precision	how close the measured values of a quantity are to each other
repeatability	a measurement is repeatable if the same or similar result is obtained when the measurement is repeated under the same conditions, using the same method, within the same experiment
reproducibility	a measurement is reproducible if the same or similar result is obtained when the measurement is made under either different conditions or by a different method or in a different experiment
validity of experimental design	an experiment is valid if the experiment tests what it says it will test. The experiment must be a fair test where only the independent variable and dependent variable may change, and controlled variables are kept constant
range	the maximum and minimum value of the independent or dependent variables
anomaly	an anomaly is a value in a set of results that appears to be outside the general pattern of the results, i.e. an extreme value that is either very high or very low in comparison to others
independent variable	independent variables are the variables that are changed in a scientific experiment by the scientist. Changing an independent variable may cause a change in the dependent variable
dependent variable	dependent variables are the variables that are observed or measured in a scientific experiment. Dependent variables may change based on changes made to the independent variables

Apparatus

These lists give items that candidates should be familiar with using, whether they are taking the Practical Test or the Alternative to Practical.

These items should be available for use in the Practical Test. These lists are not exhaustive and we may also require other items to be sourced for specific examinations. The Confidential Instructions we send before the Practical Test will give the detailed requirements for the examination.

Every effort is made to minimise the cost to and resources required by centres. Experiments will be designed around basic apparatus and materials which should be available in most school laboratories or are easily obtainable.

Appropriate safety equipment must be provided to students and should at least include eye protection.

The following suggested equipment has been categorised, but equipment can be used in any topic.

General

- adhesive putty (e.g. Patafix, Blu Tack®)
- adhesive tape (e.g. Sellotape®)
- card
- dropping pipette (2.5 cm^3) or small plastic syringe (e.g. 5 cm^3)
- pair of compasses
- ruler, 30 cm, graduated in mm
- S-hook
- scissors
- set square
- string
- thread
- top pan (electronic) balance to measure up to 500 g, with precision of at least 0.1 g
- tracing paper
- wooden board, rigid, 150 cm × 20 cm × 1.5 cm

Mechanics

- expendable steel springs, with spring constant of approx. 0.25 N / cm
- force meter, with maximum reading or full scale deflection of between 1.0 N and 10.0 N
- G-clamp
- glass ball (marble), ball bearing (approx. 10 mm in diameter) and table tennis ball
- half-metre rule, graduated in mm
- masses, 10 × 10 g, 10 × 100 g, including holders
- metre rule, graduated in mm
- modelling clay (e.g. Plasticine®)
- pendulum bob
- pivots (e.g. 15 cm nails, triangular wooden blocks)
- retort stand, boss and clamp
- single-wheel pulley, with facilities for attaching to a bench or to a clamp stand
- stopwatch, reading to 0.1 s or better

Thermal physics

- beakers, glass (borosilicate), 100 cm^3, 250 cm^3, 400 cm^3
- boiling tube, approx. 150 mm × 25 mm
- measuring cylinders, constant diameter, 50 cm^3, 100 cm^3, 250 cm^3
- plastic or polystyrene cup, approx. 200 cm^3
- thermometer, –10 °C to +110 °C, with 1 °C graduations

Optics

- converging lens, spherical, +10D (f = 10 cm)
- converging lens, spherical, +6.7D (f = 15 cm)
- diverging lens, spherical, -6.7D (f = –15 cm)
- glass or Perspex 60° prism
- glass or Perspex blocks, rectangular and semi-circular
- optics pins, minimum length 75 mm
- plane mirror, approx. 75 mm × 25 mm
- pin board
- protractor

Electricity

Candidates or centres may need to join components, meters and cells together to make circuits. Connectors used will be 3.5 mm or 4 mm in diameter.

- ammeter, with full scale deflection 1 A or 1.5 A and precision of at least 0.05 A (analogue, dedicated digital or multimeter)
- voltmeter, with full scale deflection 5 V and precision of at least 0.1 V (analogue, dedicated digital or multimeter)
- cells, 1.5 V and holders to enable several cells to be joined
- connecting leads, 3.5 mm or 4 mm connectors
- crocodile clips
- d.c. power supply, variable to 12 V
- diodes, including LEDs
- filament lamps, low voltage (e.g. 2.5 V) and holders
- filament lamp, 12 V, 24 W and holder
- LDRs (suitable for use in 1–5 V circuits)
- switches, including push switches
- selection of resistors, values within range 5–50 Ω , power rating of 1–2 W
- thermistors (NTC only)
- wire, constantan (eureka), 0.38 mm diameter (28 swg), 0.32 mm diameter (30 swg)
- wire, nichrome, 0.38 mm diameter (28 swg), 0.32 mm diameter (30 swg)

Safety in the laboratory

Teachers should make sure that they do not contravene any school, education authority or government regulations. Responsibility for safety matters rests with centres.

Further information can be found from the following UK associations, publications and regulations.

Associations

CLEAPSS is an advisory service providing support in practical science and technology.
www.cleapss.org.uk

Publications

CLEAPSS Laboratory Handbook, updated 2015 (available to CLEAPSS members only)

CLEAPSS Hazcards, 2019 update of 2016 edition (available to CLEAPSS members only)

UK regulations

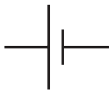
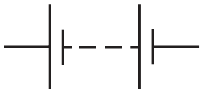
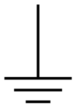
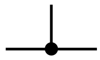
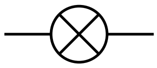
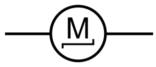
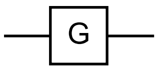
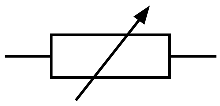
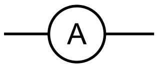
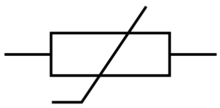
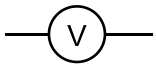
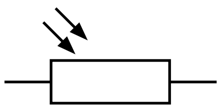
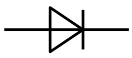
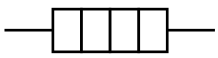
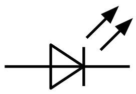
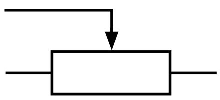
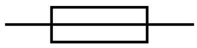
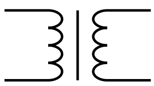
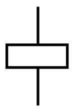
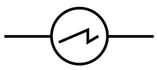
Control of Substances Hazardous to Health Regulations (COSHH) 2002 and subsequent amendment in 2004

www.legislation.gov.uk/uksi/2002/2677/contents/made

www.legislation.gov.uk/uksi/2004/3386/contents/made

A brief guide may be found at
www.hse.gov.uk/pubns/indg136.pdf

Electrical symbols

cell		switch	
battery of cells	 or 	earth or ground	
power supply		junction of conductors	
d.c. power supply		lamp	
a.c. power supply		motor	
fixed resistor		generator	
variable resistor		ammeter	
thermistor		voltmeter	
light-dependent resistor		diode	
heater		light-emitting diode	
potential divider		fuse	
transformer		relay coil	
magnetising coil		oscilloscope	

Symbols and units for physical quantities

Candidates should be able to give the symbols for the following physical quantities and, where indicated, state the units in which they are measured.

Candidates should be able to use the following multipliers: G giga, M mega, k kilo, d deci, c centi, m milli, µ micro, n nano

Quantity	***Usual symbol***	***Usual unit***
length	*l, h, d, s, x*	km, m, cm, mm
area	*A*	m^2, cm^2
volume	*V*	m^3, cm^3, dm^3
weight	*W*	N
mass	*m, M*	kg, g, mg
time	*t*	h, min, s, ms, µs
density	*ρ*	g/cm^3, kg/m^3
speed	*u, v*	km/h, m/s, cm/s
velocity	*u, v*	m/s
acceleration	*a*	m/s^2
acceleration of free fall	*g*	m/s^2
force	*F*	N
gravitational field strength	*g*	N/kg
spring constant	*k*	N/m, N/cm
momentum	*p*	kg m/s
impulse		N s
moment of a force		N m
work done	*W*	J, kJ, MJ
energy	*E*	J, kJ, MJ, kW h
power	*P*	W, kW, MW
pressure	*p*	N/m^2, N/cm^2, Pa
temperature	*θ*, *T*	°C, K
specific heat capacity	*c*	J/(g °C), J/(kg °C)

Quantity	***Usual symbol***	***Usual unit***
frequency	f	Hz, kHz
wavelength	λ	m, cm, nm
focal length	f	m, cm
angle of incidence	i	degree (°)
angle of reflection	r	degree (°)
angle of refraction	r	degree (°)
critical angle	c	degree (°)
refractive index	n	
magnification	M	
potential difference/voltage	V	V, mV, kV
current	I	A, mA
e.m.f.	E	V
resistance	R	Ω
charge	Q	C
count rate		counts / s, counts / minute
half-life		s, minutes, h, days, weeks, years

Mathematical requirements

It is expected that these requirements will be covered as part of a mathematics curriculum at this level of study.

Calculators may be used in all parts of the examination.

Numerical answers should be written as decimals (or percentages if appropriate).

Number

- add, subtract, multiply and divide
- use decimals, fractions, percentages, ratios and reciprocals
- convert between decimals, fractions and percentages
- understand and use the symbols: =, <, >
- understand the meaning of sum, difference and product
- use standard form (scientific notation)
- understand that only the final answer in a calculation should be rounded
- use decimal places and significant figures appropriately
- make approximations and estimates to obtain reasonable answers

Algebra

- use positive, whole number indices in algebraic expressions
- substitute values of quantities into equations, using consistent units
- solve simple algebraic equations for any one term when the other terms are known
- recognise and use direct and inverse proportion
- set up simple algebraic equations as mathematical models of physical situations and to represent information given in words
- use Δ (delta) in algebraic expressions and equations to represent a change in a variable

Geometry and trigonometry

- understand the meaning of angle, curve, circle, radius, diameter, circumference, square, parallelogram, rectangle and diagonal
- recall and use the equation for the circumference of a circle
- recall and use the equations for the area of a rectangle, area of a triangle and area of a circle
- recall and use the equations for the volume of a rectangular block and volume of a cylinder
- use scale diagrams
- apply Pythagoras' theorem to the calculation of a side of a right-angled triangle
- understand that a right angle is 90° and that the sum of the angles on a straight line is 180°
- use trigonometric functions (sine, cosine, tangent and their inverses)
- use mathematical instruments (ruler, pair of compasses, protractor, set square)
- recognise and use the points of the compass (N, S, E, W) and clockwise and anticlockwise directions
- convert between metric units, e.g. cm^3 and m^3; mg, g and kg

Graphs, charts and statistics

- draw graphs and charts from data
- interpret graphs and charts, including interpolation and extrapolation of data
- determine the gradient (slope) of a line on a graph, including by drawing a tangent to a curved line
- determine the intercept of the line on a graph, extending the line graphically (extrapolating) where appropriate
- select suitable scales and axes for graphs
- understand that $y = mx + c$ represents a linear relationship
- recognise direct proportionality from a graph
- calculate and use the average (mean) for a set of data

Presentation of data

Taking readings

- Data values should be read from an instrument to an accuracy of one half of one of the smallest divisions on the scale.
- Interpolation between scale divisions should be to an accuracy of one half of a division. That is, where a reading lies between two scale marks, it should be interpolated to the nearest half division.

Recording readings

- Data should be recorded so as to reflect the precision of the measuring instrument, i.e. the smallest difference that can reliably be detected on the measuring instrument scale should be reflected by the number of decimal places and unit given in the measurement.
- A measurement or calculated quantity must be accompanied by a correct unit, where appropriate.
- Each column of a table should be headed with the name or symbol of the measured or calculated quantity and the appropriate unit, e.g. time / s. The solidus (/) is to be used for separating the quantity and the unit in tables, graphs and charts.
- Units should not be included with data in the body of a table.
- Each reading should be repeated, where appropriate, and recorded.
- The number of significant figures given for measured quantities should be appropriate to the measuring instrument used.
- The number of significant figures given for calculated quantities should be the same as the least number of significant figures in the raw data used in that specific calculation.
- A ratio should be expressed as $x : y$.

Drawing and analysing graphs

- The column headings of a table can be directly transferred to the axes of a constructed graph.
- A graph should be drawn with a sharp pencil.
- The axes should be labelled with the name or symbol of the measured or calculated quantity and the appropriate unit, e.g. time / s.
- Unless instructed otherwise, the scales for the axes should allow more than half of the graph grid to be used in both directions, and be based on sensible ratios, e.g. 2 cm on the graph grid representing 1, 2 or 5 units of the variable (or 10, 20 or 50, etc.)
- Points on the graph should be clearly marked as plus signs (+), crosses (×) or encircled dots (⊙) of appropriate size.
- Each data point should be plotted to an accuracy of one half of one of the smallest squares on the grid.

- A best-fit line (trend line) should be a single, thin, smooth straight-line or curve, drawn by inspection. The line does not need to coincide exactly with any of the points; where there is scatter evident in the data, examiners would expect a roughly even distribution of points either side of the line over its entire length. Points that are clearly anomalous and identified by the candidate should be ignored when drawing the best-fit line.
- Candidates should be able to take readings from the graph by extrapolation or interpolation.
- Data values should be read from a line on a graph to an accuracy of one half of one of the smallest squares on the grid. The same accuracy should be used in reading off an intercept.
- The gradient of a straight line should be taken using a triangle whose hypotenuse extends over at least half the length of the candidate's best-fit line, and this triangle should be marked on the graph.
- Calculation of the gradient should be to two or three significant figures.
- When the gradient or intercept of a graph is used in subsequent calculations, it will be assumed to have units consistent with the graph axes.

Further guidance can be found in the following publications:

ASE, The Language of Mathematics in Science: A Guide for Teachers of 11–16 Science (2016).

ASE, The Language of Mathematics in Science: Teaching Approaches (2016).

www.ase.org.uk/mathsinscience

Conventions (e.g. signs, symbols, terminology and nomenclature)

Candidates are expected to be familiar with the nomenclature used in the syllabus. The syllabus and question papers conform with accepted international practice. In particular, the following document, produced by the Association for Science Education (ASE), should be used as a guideline.

Signs, Symbols and Systematics: The ASE Companion to 16–19 Science (2000).

Decimal markers

In accordance with current ASE convention, decimal markers in examination papers will be a single dot on the line. Candidates are expected to follow this convention in their answers.

Numbers

Numbers from 1000 to 9999 will be printed without commas or spaces. Numbers greater than or equal to 10 000 will be printed without commas. A space will be left between each group of three digits, e.g. 4 256 789.

Units

To avoid any confusion concerning the symbol for litre, the equivalent quantity, the cubic decimetre (dm^3) will be used in place of l or litre. Similarly, the cubic centimetre (cm^3) will be used in place of ml or millilitre.

In practical work, candidates will be expected to use SI units or, where appropriate, units approved by the BIPM for use with the SI (e.g. minute). A list of SI units and units approved for use with the SI may be found at **www.bipm.org**. The use of imperial/customary units such as the inch and degree Fahrenheit are not acceptable and should be discouraged.

In all examinations, where data is supplied for use in questions, candidates will be expected to use units that are consistent with the units supplied and should not attempt conversion to other systems of units unless this is a requirement of the question.

Command words

Command words and their meanings help candidates know what is expected from them in the exam. The table below includes command words used in the assessment for this syllabus. The use of the command word will relate to the subject context.

Command word	What it means
Calculate	work out from given facts, figures or information
Comment	give an informed opinion
Compare	identify/comment on similarities and/or differences
Deduce	conclude from available information
Define	give precise meaning
Describe	state the points of a topic / give characteristics and main features
Determine	establish an answer using the information available
Explain	set out purposes or reasons / make the relationships between things evident / provide why and/or how and support with relevant evidence
Give	produce an answer from a given source or recall/memory
Identify	name/select/recognise
Justify	support a case with evidence/argument
Predict	suggest what may happen based on available information
Sketch	make a simple freehand drawing showing the key features, taking care over proportions
State	express in clear terms
Suggest	apply knowledge and understanding to situations where there are a range of valid responses in order to make proposals / put forward considerations

5 What else you need to know

This section is an overview of other information you need to know about this syllabus. It will help to share the administrative information with your exams officer so they know when you will need their support. Find more information about our administrative processes at **www.cambridgeinternational.org/eoguide**

Before you start

Previous study

We recommend that learners starting this course should have studied a science curriculum such as the Cambridge Lower Secondary programme or equivalent national educational framework.

Guided learning hours

We design Cambridge O Level syllabuses based on learners having about 130 guided learning hours for each subject during the course but this is for guidance only. The number of hours a learner needs to achieve the qualification may vary according to local practice and their previous experience of the subject.

Availability and timetables

Cambridge O Levels are available to centres in administrative zones 3, 4 and 5.

You can enter candidates in the June and November exam series. You can view the timetable for your administrative zone at **www.cambridgeinternational.org/timetables**

Check you are using the syllabus for the year the candidate is taking the exam.

Private candidates can enter for this syllabus. For more information, please refer to the *Cambridge Guide to Making Entries*.

Combining with other syllabuses

Candidates can take this syllabus alongside other Cambridge International syllabuses in a single exam series. The only exceptions are:

- Cambridge IGCSE™ Physics (0625)
- Cambridge IGCSE (9–1) Physics (0972)
- Cambridge IGCSE Physical Science (0652)
- Cambridge IGCSE Combined Science (0653)
- Cambridge IGCSE Co-ordinated Sciences (Double Award) (0654)
- Cambridge IGCSE (9–1) Co-ordinated Sciences (Double Award) (0973)
- Cambridge O Level Combined Science (5129)
- syllabuses with the same title at the same level.

Cambridge O Level, Cambridge IGCSE and Cambridge IGCSE (9–1) syllabuses are at the same level.

Making entries

Exams officers are responsible for submitting entries to Cambridge International. We encourage them to work closely with you to make sure they enter the right number of candidates for the right combination of syllabus components. Entry option codes and instructions for submitting entries are in the *Cambridge Guide to Making Entries*. Your exams officer has a copy of this guide.

Exam administration

To keep our exams secure, we produce question papers for different areas of the world, known as administrative zones. We allocate all Cambridge schools to one administrative zone determined by their location. Each zone has a specific timetable. Some of our syllabuses offer candidates different assessment options. An entry option code is used to identify the components the candidate will take relevant to the administrative zone and the available assessment options.

Support for exams officers

We know how important exams officers are to the successful running of exams. We provide them with the support they need to make your entries on time. Your exams officer will find this support, and guidance for all other phases of the Cambridge Exams Cycle, at **www.cambridgeinternational.org/eoguide**

Retakes

Candidates can retake the whole qualification as many times as they want to. Information on retake entries is at **www.cambridgeinternational.org/entries**

Equality and inclusion

We have taken great care to avoid bias of any kind in the preparation of this syllabus and related assessment materials. In our effort to comply with the UK Equality Act (2010) we have taken all reasonable steps to avoid any direct and indirect discrimination.

The standard assessment arrangements may present barriers for candidates with impairments. Where a candidate is eligible, we may be able to make arrangements to enable that candidate to access assessments and receive recognition of their attainment. We do not agree access arrangements if they give candidates an unfair advantage over others or if they compromise the standards being assessed.

Candidates who cannot access the assessment of any component may be able to receive an award based on the parts of the assessment they have completed.

Information on access arrangements is in the *Cambridge Handbook* at **www.cambridgeinternational.org/eoguide**

Language

This syllabus and the related assessment materials are available in English only.

After the exam

Grading and reporting

Grades A*, A, B, C, D or E indicate the standard a candidate achieved at Cambridge O Level.

A* is the highest and E is the lowest. 'Ungraded' means that the candidate's performance did not meet the standard required for grade E. 'Ungraded' is reported on the statement of results but not on the certificate.

In specific circumstances your candidates may see one of the following letters on their statement of results:

- Q (PENDING)
- X (NO RESULT).

These letters do not appear on the certificate.

On the statement of results and certificates, Cambridge O Level is shown as GENERAL CERTIFICATE OF EDUCATION (GCE O LEVEL).

How students and teachers can use the grades

Assessment at Cambridge O Level has two purposes:

- to measure learning and achievement

  The assessment:
  - confirms achievement and performance in relation to the knowledge, understanding and skills specified in the syllabus, to the levels described in the grade descriptions.
- to show likely future success

  The outcomes:
  - help predict which students are well prepared for a particular course or career and/or which students are more likely to be successful
  - help students choose the most suitable course or career.

Grade descriptions

Grade descriptions are provided to give an indication of the standards of achievement candidates awarded particular grades are likely to show. Weakness in one aspect of the examination may be balanced by a better performance in some other aspect.

Grade descriptions for Cambridge O Level Physics will be published after the first assessment of the syllabus in 2023. Find more information at **www.cambridgeinternational.org/5054**

Changes to this syllabus for 2023, 2024 and 2025

The syllabus has been reviewed and revised for first examination in 2023.

You must read the whole syllabus before planning your teaching programme.

Changes to syllabus content

- The learner attributes have been updated.
- The structure of the subject content has changed to ensure a coherent topic structure.
- The wording in the learning objectives has been updated to provide clarity on the depth to which each topic should be taught. Although the wording will look different in many places, the content to teach remains largely the same.
- Main topics and sub-topics removed:
  - use of a manometer
  - transmission of pressure in hydraulic systems
  - principles of thermometry
  - practical thermometers
  - latent heat (all learning objectives removed except one)
  - methods of magnetisation and demagnetisation
  - magnetic screening
  - applications of electrostatic charging
  - electronics and electronic systems.
- Main topics and sub-topics added:
  - motion (additional learning objectives)
  - balanced and unbalanced forces (additional learning objectives)
  - equation for spring constant
  - momentum
  - the absolute scale of temperature
  - general properties of waves (additional learning objectives)
  - simple magnetism and magnetic fields (additional learning objectives)
  - equation for two resistors used as a potential divider
  - detection of radioactivity (additional learning objectives)
  - using decay equations
  - space physics.
- Other sections have had learning objectives added and removed. However, the overall teaching time still falls within the recommended guided learning hours.
- The learning objectives have been numbered, rather than listed by letters.

continued

Changes to syllabus content continued	• The **Details of the assessment** section has been updated and further explanation has been provided. This includes revisions to the apparatus list, the list of symbols and units for physical quantities and the details for the presentation of data. • A list of mathematical requirements has been provided. • A list of electrical symbols has been provided. • A list of command words used in the assessments has been provided and replaces the previous glossary of terms used in science papers.
Changes to assessment (including changes to specimen papers)	• The syllabus aims have been updated to improve the clarity of wording and the consistency between Cambridge O Level Biology, Chemistry and Physics. • The wording of the assessment objectives (AOs) has been updated to ensure consistency across Cambridge O Level Biology, Chemistry and Physics. The assessment objectives still test the same knowledge and skills as previously. • Section B (optional questions) has been removed from Paper 2 Theory and replaced with short-answer and structured questions. • The number of marks for Paper 2 Theory has increased from 75 marks to 80 marks. • The duration of Paper 3 Practical Test has been reduced from 2 hours to 1 hour 30 minutes. • The number of marks for Paper 3 Practical Test has increased from 30 marks to 40 marks. • The number of marks for Paper 4 Alternative to Practical has increased from 30 marks to 40 marks. • Paper 4 Alternative to Practical will now have a similar structure to Paper 3 Practical Test to ensure consistency between the two papers that assess practical skills.

In addition to reading the syllabus, you should refer to the updated specimen assessment materials. The specimen papers will help your students become familiar with exam requirements and command words in questions. The specimen mark schemes explain how students should answer questions to meet the assessment objectives.

Any textbooks endorsed to support the syllabus for examination from 2023 are suitable for use with this syllabus.

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