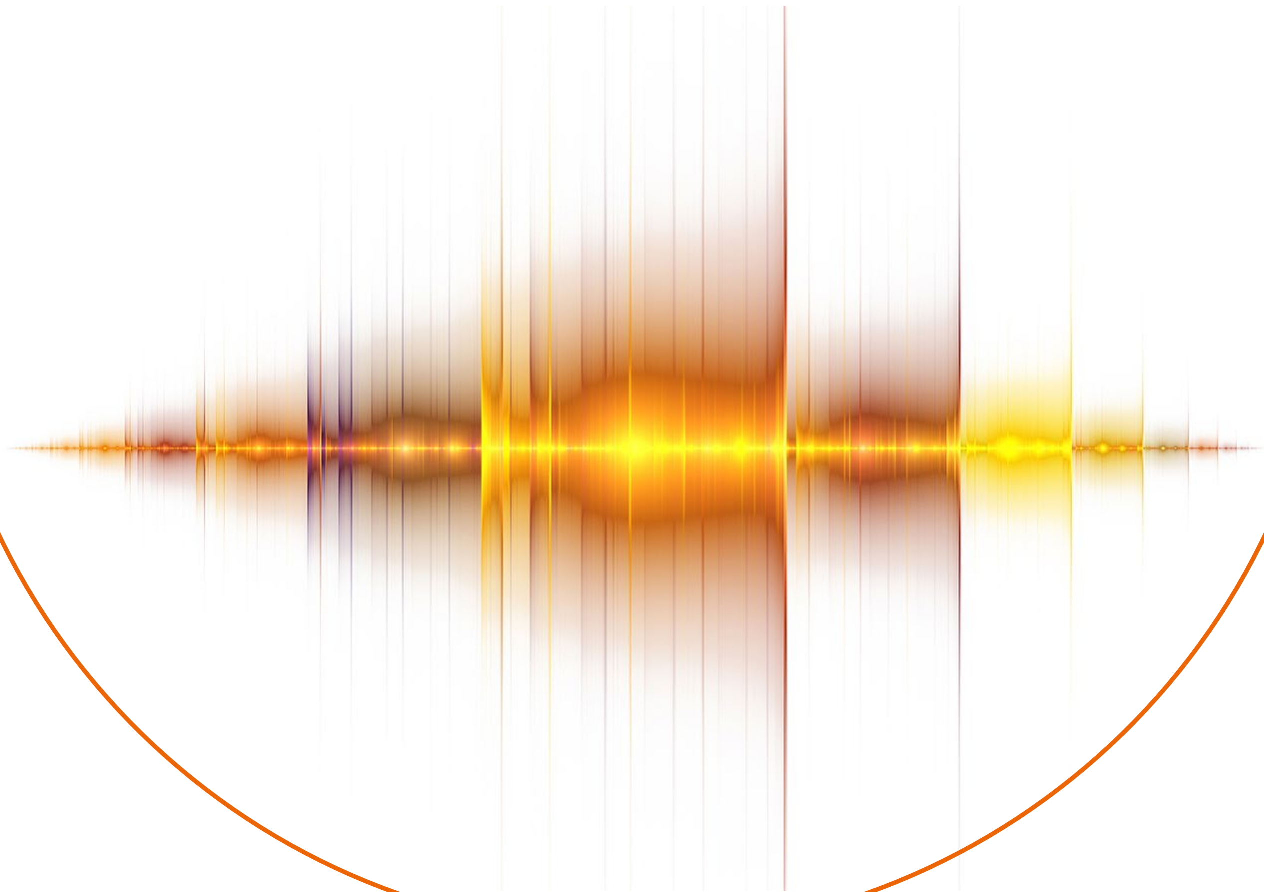
Cambridge Assessment International Education

Syllabus

Cambridge O Level Physics 5054

For examination in June and November 2020 and 2021.



Cambridge Pathway

Version 1

Changes to the syllabus for 2020 and 2021

The latest syllabus is version 1, published September 2017.

There are no significant changes which affect teaching.

You are strongly advised to read the whole syllabus before planning your teaching programme.

Any textbooks endorsed to support the syllabus for examination from 2017 are still suitable for use with this syllabus.

Contents

1. Introduction

1.1 Why choose Cambridge International?

Cambridge Assessment International Education 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 international qualifications are recognised by the world's best universities and employers, giving students a wide range of options in their education and career. As a not-for-profit organisation, we devote our resources to delivering high-quality educational programmes that can unlock learners' potential.

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 students to progress from one stage to the next, and are well supported by teaching and learning resources.

Every year, nearly a million Cambridge learners from 10 000 schools in 160 countries prepare for their future with an international education from Cambridge International.

Cambridge learners

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** in working with information and ideas – their own and those of others
- **responsible** for themselves, responsive to and respectful of others
- **reflective** as learners, developing their ability to learn
- **innovative** and equipped for new and future challenges
- **engaged** intellectually and socially, ready to make a difference.

Recognition

Cambridge O Level is internationally recognised by schools, universities and employers as equivalent in demand to Cambridge IGCSE® (International General Certificate of Secondary Education). There are over 700 000 entries a year in nearly 70 countries. Learn more at **www.cambridgeinternational.org/recognition**

Support for teachers

A wide range of materials and resources is available to support teachers and learners in Cambridge schools. Resources suit a variety of teaching methods in different international contexts. Through subject discussion forums and training, teachers can access the expert advice they need for teaching our qualifications. More details can be found in Section 2 of this syllabus and at **www.cambridgeinternational.org/teachers**

Support for exams officers

Exams officers can trust in reliable, efficient administration of exams entries and excellent personal support from our customer services. Learn more at **www.cambridgeinternational.org/examsofficers**

Our systems for managing the provision of international qualifications and education programmes for learners aged 5 to 19 are certified as meeting the internationally recognised standard for quality management, ISO 9001:2008. Learn more at **www.cambridgeinternational.org/ISO9001**

1.2 Why choose Cambridge O Level?

Cambridge O Levels have been designed for an international audience and are sensitive to the needs of different countries. These qualifications are designed for students whose first language may not be English and this is acknowledged throughout the examination process. The Cambridge O Level syllabus also allows teaching to be placed in a localised context, making it relevant in varying regions.

Our aim is to balance knowledge, understanding and skills in our programmes and qualifications to enable students to become effective learners and to provide a solid foundation for their continuing educational journey.

Through our professional development courses and our support materials for Cambridge O Levels, we provide the tools to enable teachers to prepare students to the best of their ability and work with us in the pursuit of excellence in education.

Cambridge O Levels are considered to be an excellent preparation for Cambridge International AS & A Levels, the Cambridge AICE (Advanced International Certificate of Education) Diploma, Cambridge Pre-U, and other education programmes, such as the US Advanced Placement program and the International Baccalaureate Diploma programme. Learn more about Cambridge O Levels at **www.cambridgeinternational.org/olevel**

Guided learning hours

Cambridge O Level syllabuses are designed on the assumption that learners have about 130 guided learning hours per subject over the duration of the course, but this is for guidance only. The number of hours required to gain the qualification may vary according to local curricular practice and the students' prior experience of the subject.

1.3 Why choose Cambridge O Level Physics?

Cambridge O Levels are established qualifications that keep pace with educational developments and trends. The Cambridge O Level curriculum places emphasis on broad and balanced study across a wide range of subject areas. The curriculum is structured so that students attain both practical skills and theoretical knowledge.

Cambridge O Level Physics is recognised by universities and employers throughout the world as proof of knowledge and understanding. Successful Cambridge O Level Physics candidates gain lifelong skills, including:

- confidence in a technological world, with an informed interest in scientific matters
- an understanding of how scientific theories and methods have developed, and continue to develop, as a result of groups and individuals working together
- an understanding that the study and practice of science are affected and limited by social, economic, technological, ethical and cultural factors
- an awareness that the application of science in everyday life may be both helpful and harmful to the individual, the community and the environment

- knowledge that science overcomes national boundaries and that the language of science, used correctly and thoroughly, is universal
- an understanding of the usefulness (and limitations) of scientific method, and its application in other subjects and in everyday life
- a concern for accuracy and precision
- an understanding of the importance of safe practice
- improved awareness of the importance of objectivity, integrity, enquiry, initiative and inventiveness
- an interest in, and care for, the environment
- an excellent foundation for advanced study in pure sciences, in applied science or in science-dependent vocational courses.

Candidates may also study for a Cambridge O Level in a number of other science subjects including chemistry and biology. In addition to Cambridge O Levels, Cambridge International also offers Cambridge IGCSE and Cambridge International AS and A Levels for further study in both physics as well as other science subjects.

See **www.cambridgeinternational.org** for a full list of the qualifications you can take.

Prior learning

We recommend that candidates who are beginning this course should have previously studied a science curriculum such as that of the Cambridge Lower Secondary Programme or equivalent national educational frameworks. Candidates should also have adequate mathematical skills for the content contained in this syllabus.

Progression

Cambridge O Levels are general qualifications that enable candidates to progress either directly to employment, or to proceed to further qualifications.

Candidates who are awarded grades C to A* in Cambridge O Level Physics are well prepared to follow courses leading to Cambridge International AS and A Level Physics, or the equivalent.

1.4 How can I find out more?

If you are already a Cambridge school

You can make entries for this qualification through your usual channels. If you have any questions, please contact us at **info@cambridgeinternational.org**

If you are not yet a Cambridge school

Learn about the benefits of becoming a Cambridge school at **www.cambridgeinternational.org/startcambridge**
Email us at **info@cambridgeinternational.org** to find out how your organisation can register to become a Cambridge school.

2. Teacher support

2.1 Support materials

You can go to our public website at **www.cambridgeinternational.org/olevel** to download current and future syllabuses together with specimen papers or past question papers, examiner reports and grade threshold tables from one series.

For teachers at registered Cambridge schools a range of additional support materials for specific syllabuses is available online from the School Support Hub. Go to **www.cambridgeinternational.org/support** (username and password required). If you do not have access, speak to the Teacher Support coordinator at your school.

2.2 Endorsed resources

We work with publishers who provide a range of resources for our syllabuses including print and digital materials. Resources endorsed by Cambridge International go through a detailed quality assurance process to make sure they provide a high level of support for teachers and learners.

We have resource lists which can be filtered to show all resources, or just those which are endorsed by Cambridge International. The resource lists include further suggestions for resources to support teaching. See **www.cambridgeinternational.org/i-want-to/resource-centre** for further information.

2.3 Training

We offer a range of support activities for teachers to ensure they have the relevant knowledge and skills to deliver our qualifications. See **www.cambridgeinternational.org/events** for further information.

3. Assessment at a glance

For the Cambridge O Level in physics, candidates take **three** components: Paper 1 **and** Paper 2 and either Paper 3 **or** Paper 4.

Paper 1: Multiple Choice	**1 hour**
40 compulsory multiple-choice questions of the direct choice type. The questions involve four response items. 40 marks	

Paper 2: Theory	**1 hour 45 minutes**
This paper has two sections: Section A has a small number of compulsory, structured questions of variable mark value. 45 marks in total are available for this section. Section B has three questions. Each question is worth 15 marks. Candidates must answer **two** questions from this section. There is no compulsory question on Section 25 of the syllabus (Electronic systems). Questions set on topics within Section 25 appear only in Paper 2 and are always set as an alternative within a question. 75 marks	

Paper 3: Practical Test	**2 hours**	**Paper 4: Alternative to Practical**	**1 hour**
This paper has two sections. Section A has three compulsory questions each carrying five marks and each of 20 minutes duration. Section B has one question of 15 marks and is of one hour's duration. 30 marks		A written paper of compulsory short-answer and structured questions designed to test familiarity with laboratory practical procedures. 30 marks	

Availability

This syllabus is examined in the June and November examination series.

This syllabus is available to private candidates. However, it is expected that private candidates learn in an environment where practical work is an integral part of the course. Candidates will not be able to perform well in this assessment or successfully progress to further study without this necessary and important aspect of science education.

Detailed timetables are available from **www.cambridgeinternational.org/timetables**

Cambridge O Levels are available to centres in Administrative Zones 3, 4 and 5. Centres in Administrative Zones 1, 2 or 6 wishing to enter candidates for Cambridge O Level examinations should contact Cambridge International Customer Services.

Combining this with other syllabuses

Candidates can combine this syllabus in an examination series with any other Cambridge International syllabus, except:

- Cambridge IGCSE Physical Science (0652)
- Cambridge IGCSE Combined Science (0653)
- Cambridge IGCSE Co-ordinated Sciences (Double) (0654)
- Cambridge O Level Combined Science (5129)
- syllabuses with the same title at the same level.

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

4. Syllabus aims and assessment objectives

4.1 Syllabus aims

The aims of the syllabus, which are not listed in order of priority, are to:

1. provide, through well-designed studies of experimental and practical science, a worthwhile educational experience for all candidates, whether or not they go on to study science beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge
   - 1.1 to become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific import;
   - 1.2 to recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life;
   - 1.3 to be suitably prepared for studies beyond Cambridge O Level in pure sciences, in applied sciences or in science-dependent vocational courses.
2. develop abilities and skills that
   - 2.1 are relevant to the study and practice of science;
   - 2.2 are useful in everyday life;
   - 2.3 encourage efficient and safe practice;
   - 2.4 encourage effective communication.
3. develop attitudes relevant to science such as
   - 3.1 concern for accuracy and precision;
   - 3.2 objectivity;
   - 3.3 integrity;
   - 3.4 enquiry;
   - 3.5 initiative;
   - 3.6 inventiveness.
4. stimulate interest in and care for the local and global environment.
5. promote an awareness that:
   - 5.1 the study and practice of science are co-operative and cumulative activities, that are subject to social, economic, technological, ethical and cultural influences and limitations;
   - 5.2 the applications of sciences may be both beneficial and detrimental to the individual, the community and the environment.

4.2 Assessment objectives

The assessment objectives describe the knowledge, skills and abilities that candidates are expected to demonstrate at the end of the course. They reflect those aspects of the aims that are assessed.

AO1 Knowledge with understanding

Candidates should be able to demonstrate knowledge with understanding in relation to:

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

The subject content defines the factual knowledge that candidates may be required to recall and explain. Questions testing these objectives will often begin with one of the following words: *define, state, describe, explain* or *outline* (see the glossary of terms in section 6.2).

AO2 Handling information and solving problems

Candidates should be able, in words using symbolic, graphical and numerical forms of presentation, to:

1. locate, select, organise and present information from a variety of sources, including everyday experience;
2. translate information from one form to another;
3. manipulate numerical and other data;
4. use information to identify patterns, report trends and draw inferences;
5. present reasoned explanations for phenomena, patterns and relationships;
6. make predictions and hypotheses;
7. solve problems.

These assessment objectives cannot readily be fully specified in the syllabus content. Questions testing skills in physics may be based on information (given in the question paper) that is unfamiliar to the candidates or is based on everyday experience. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and to apply them in a logical manner. Questions testing these objectives will often begin with one of the following words: *predict*, *suggest*, *calculate* or *determine* (see the glossary of terms in section 6.2).

AO3 Experimental skills and investigations

Candidates should be able to:

1. follow instructions;
2. carry out techniques, use apparatus, handle measuring devices and materials effectively and safely;
3. make and record observations, measurements and estimates with due regard to precision, accuracy and units;
4. interpret, evaluate and report upon observations and experimental data;
5. identify problems, plan and carry out investigations, including the selection of techniques, apparatus, measuring devices and materials;
6. evaluate methods and suggest possible improvements.

4.3 Weighting for assessment objectives

Theory papers (Papers 1 and 2)

AO1 Knowledge with understanding is weighted at approximately 65 per cent of the marks for each paper, with approximately half allocated to recall.

AO2 Handling information and solving problems is weighted at approximately 35 per cent of the marks for each paper.

Practical assessment (Papers 3 and 4)

This is designed to test appropriate skills in assessment objective AO3 and will carry approximately 20 per cent of the marks for the qualification.

4.4 Nomenclature, units and significant figures

Nomenclature

The proposals in 'Signs, Symbols and Systematics (The Association for Science Education Companion to 16–19 Science, 2000)' will generally be adopted. 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.

Reference should also be made to the summary of key quantities, symbols and units in section 7.1.

It is intended that, in order to avoid difficulties arising out of the use of l as the symbol for litre, use of dm^3 in place of l or litre will be made.

Units, significant figures

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 in the SI brochure at **http://www.bipm.org**. The use of imperial/customary units such as the inch and degree Fahrenheit is 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.

Candidates should give all answers to an appropriate number of significant figures and quantities should have an appropriate unit.

5. Syllabus content

It is expected that any course in physics will be based on experimental work. Teachers are encouraged to develop appropriate practical work for candidates to facilitate a greater understanding of the subject. Candidates should be aware of the appropriate safety precautions to follow when carrying out practical work.

Certain learning outcomes of the syllabus have been marked with an asterisk (*) to indicate the possibility of the application of IT.

Section I: General Physics

1. Physical Quantities, Units and Measurement

Content

1.1 Scalars and vectors

1.2 Measurement techniques

1.3 Units and symbols

Learning outcomes

Candidates should be able to:

(a) define the terms *scalar* and *vector*.

(b) determine the resultant of two vectors by a graphical method.

(c) list the vectors and scalars from distance, displacement, length, speed, velocity, time, acceleration, mass and force.

(d) describe how to measure a variety of lengths with appropriate accuracy using tapes, rules, micrometers and calipers. (The use of a vernier scale is **not** required.)

(e) describe how to measure a variety of time intervals using clocks and stopwatches.

(f) recognise and use the conventions and symbols contained in 'Signs, Symbols and Systematics', Association for Science Education, 2000.

Section II: Newtonian Mechanics

2. Kinematics

Content

2.1 Speed, velocity and acceleration

2.2 Graphical analysis of motion

2.3 Free-fall

Learning outcomes

Candidates should be able to:

(a) state what is meant by *speed* and *velocity*.

(b) recall and use *average speed = distance travelled/time taken*.

(c) state what is meant by *uniform acceleration* and recall and use *acceleration = change in velocity/time taken*.

(d) discuss non-uniform acceleration.

(e) recall that deceleration is a negative acceleration.

(f) *plot and *interpret speed-time and distance-time graphs.

(g) *recognise from the shape of a speed-time graph when a body is

(1) at rest,

(2) moving with uniform speed,

(3) moving with uniform acceleration,

(4) moving with non-uniform acceleration.

(h) calculate the area under a speed-time graph to determine the distance travelled for motion with uniform speed or uniform acceleration.

(i) state that the acceleration of free-fall for a body near to the Earth is constant and is approximately $10\ m/s^2$.

(j) describe qualitatively the motion of bodies with constant weight falling with and without air resistance (including reference to terminal velocity).

3. Dynamics

Content

3.1 Balanced and unbalanced forces

3.2 Friction

3.3 Circular motion

Learning outcomes

Candidates should be able to:

(a) state Newton's third law.

(b) describe the effect of balanced and unbalanced forces on a body.

(c) describe the ways in which a force may change the motion of a body.

(d) recall and use the equation *force* = *mass* × *acceleration*.

(e) explain that friction is a force that impedes motion and produces heating.

(f) discuss the effect of friction on the motion of a vehicle in the context of tyre surface, road conditions (including skidding), braking force, braking distance, thinking distance and stopping distance.

(g) describe qualitatively motion in a circular path due to a constant perpendicular force, including electrostatic forces on an electron in an atom and gravitational forces on a satellite. ($F = mv^2/r$ is **not** required.)

(h) discuss how ideas of circular motion are related to the motion of planets in the solar system.

4. Mass, Weight and Density

Content

4.1 Mass and weight

4.2 Gravitational fields

4.3 Density

Learning outcomes

Candidates should be able to:

(a) state that mass is a measure of the amount of substance in a body.

(b) state that the mass of a body resists change from its state of rest or motion.

(c) state that a gravitational field is a region in which a mass experiences a force due to gravitational attraction.

(d) recall and use the equation *weight* = *mass* × *gravitational field strength*.

(e) explain that weights, and therefore masses, may be compared using a balance.

(f) describe how to measure mass and weight by using appropriate balances.

(g) describe how to use a measuring cylinder to measure the volume of a liquid or solid.

(h) describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in water (volume by displacement).

(i) define density and recall and use the formula *density* = *mass/volume*.

5. Turning Effect of Forces

Content

5.1 Moments

5.2 Centre of mass

5.3 Stability

Learning outcomes

Candidates should be able to:

(a) describe the moment of a force in terms of its turning effect and relate this to everyday examples.

(b) state the principle of moments for a body in equilibrium.

(c) define *moment of a force* and recall and use the formula *moment* = *force* × *perpendicular distance from the pivot* and the principle of moments.

(d) describe how to verify the principle of moments.

(e) describe how to determine the position of the centre of mass of a plane lamina.

(f) describe qualitatively the effect of the position of the centre of mass on the stability of simple objects.

6. Deformation

Content

6.1 Elastic deformation

Learning outcomes

Candidates should be able to:

(a) state that a force may produce a change in size and shape of a body.

(b) *plot, draw and interpret extension-load graphs for an elastic solid and describe the associated experimental procedure.

(c) *recognise the significance of the term "limit of proportionality" for an elastic solid (an understanding of the elastic limit is **not** required).

(d) calculate extensions for an elastic solid using proportionality.

7. Pressure

Content

7.1 Pressure

7.2 Pressure changes

Learning outcomes

Candidates should be able to:

(a) define the term *pressure* in terms of force and area, and do calculations using the equation *pressure = force/area*.

(b) explain how pressure varies with force and area in the context of everyday examples.

(c) describe how the height of a liquid column may be used to measure the atmospheric pressure.

(d) explain quantitatively how the pressure beneath a liquid surface changes with depth and density of the liquid in appropriate examples.

(e) recall and use the equation for hydrostatic pressure $p = \rho gh$.

(f) describe the use of a manometer in the measurement of pressure difference.

(g) describe and explain the transmission of pressure in hydraulic systems with particular reference to the hydraulic press and hydraulic brakes on vehicles.

(h) describe how a change in volume of a fixed mass of gas at constant temperature is caused by a change in pressure applied to the gas.

(i) recall and use $p_1V_1 = p_2V_2$.

Section III: Energy and Thermal Physics

8. Energy Sources and Transfer of Energy

Content

8.1 Energy forms

8.2 Major sources of energy

8.3 Work

8.4 Efficiency

8.5 Power

Learning outcomes

Candidates should be able to:

(a) list the different forms of energy with examples in which each form occurs.

(b) state the principle of the conservation of energy and apply this principle to the conversion of energy from one form to another.

(c) state that kinetic energy is given by $E_k = ½mv^2$ and that gravitational potential energy is given by $E_P = mgh$, and use these equations in calculations.

(d) list renewable and non-renewable energy sources.

(e) describe the processes by which energy is converted from one form to another, including reference to

(1) chemical/fuel energy (a re-grouping of atoms),

(2) hydroelectric generation (emphasising the mechanical energies involved),

(3) solar energy (nuclei of atoms in the Sun),

(4) nuclear energy,

(5) geothermal energy,

(6) wind energy.

(f) explain nuclear fusion and fission in terms of energy-releasing processes.

(g) describe the process of electricity generation and draw a block diagram of the process from fuel input to electricity output.

(h) discuss the environmental issues associated with power generation.

(i) define work done and use the formula *work* = *force* × *distance moved in the line of action of the force*.

(j) recall and use the formula *efficiency* = *energy converted to the required form/total energy input* for an energy conversion.

(k) discuss the efficiency of energy conversions in common use, particularly those giving electrical output.

(l) discuss the usefulness of energy output from a number of energy conversions.

(m) define power and recall and use the formula *power* = *work done/time taken.*

9. Transfer of Thermal Energy

Content

9.1 Conduction

9.2 Convection

9.3 Radiation

Learning outcomes

Candidates should be able to:

(a) describe how to distinguish between good and bad conductors of heat.

(b) describe, in terms of the movement of molecules or free electrons, how heat transfer occurs in solids.

(c) describe convection in fluids in terms of density changes.

(d) describe the process of heat transfer by radiation.

(e) describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of radiation.

(f) describe how to distinguish between good and bad emitters and good and bad absorbers of infra-red radiation.

(g) describe how heat is transferred to or from buildings and to or from a room.

(h) state and explain the use of the important practical methods of thermal insulation for buildings.

10. Temperature

Content

10.1 Principles of thermometry

10.2 Practical thermometers

Learning outcomes

Candidates should be able to:

(a) explain how a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties.

(b) explain the need for fixed points and state what is meant by the *ice point* and *steam point*.

(c) discuss sensitivity, range and linearity of thermometers.

(d) describe the structure and action of liquid-in-glass thermometers (including clinical) and of a thermocouple thermometer, showing an appreciation of its use for measuring high temperatures and those which vary rapidly.

(e) describe and explain how the structure of a liquid-in-glass thermometer affects its sensitivity, range and linearity.

11. Thermal Properties of Matter

Content

11.1 Specific heat capacity

11.2 Melting and boiling

11.3 Thermal expansion of solids, liquids and gases

Learning outcomes

Candidates should be able to:

(a) describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy).

(b) define the terms *heat capacity* and *specific heat capacity*.

(c) recall and use the formula *thermal energy* = *mass* × *specific heat capacity* × *change in temperature*.

(d) describe melting/solidification and boiling/condensation in terms of energy transfer without a change in temperature.

(e) state the meaning of *melting point* and *boiling point*.

(f) explain the difference between boiling and evaporation.

(g) define the terms *latent heat* and *specific latent heat*.

(h) explain latent heat in terms of molecular behaviour.

(i) calculate heat transferred in a change of state using the formula *thermal energy* = *mass* × *specific latent heat*.

(j) describe qualitatively the thermal expansion of solids, liquids and gases.

(k) describe the relative order of magnitude of the expansion of solids, liquids and gases.

(l) list and explain some of the everyday applications and consequences of thermal expansion.

(m) describe qualitatively the effect of a change of temperature on the volume of a gas at constant pressure.

12. Kinetic Model of Matter

Content

12.1 States of matter

12.2 Molecular model

12.3 Evaporation

Learning outcomes

Candidates should be able to:

(a) state the distinguishing properties of solids, liquids and gases.

(b) describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces and distances between molecules and to the motion of the molecules.

(c) describe the relationship between the motion of molecules and temperature.

(d) explain the pressure of a gas in terms of the motion of its molecules.

(e) describe evaporation in terms of the escape of more energetic molecules from the surface of a liquid.

(f) describe how temperature, surface area and draught over a surface influence evaporation.

(g) explain that evaporation causes cooling.

Section IV: Waves

13. General Wave Properties

Content

13.1 Describing wave motion

13.2 Wave terms

13.3 Wave behaviour

Learning outcomes

Candidates should be able to:

(a) describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by experiments using a ripple tank.

(b) state what is meant by the term *wavefront*.

(c) define the terms *speed*, *frequency*, *wavelength* and *amplitude* and recall and use the formula *velocity* = *frequency* × *wavelength*.

(d) describe transverse and longitudinal waves in such a way as to illustrate the differences between them.

(e) describe the use of a ripple tank to show

(1) reflection at a plane surface,

(2) refraction due to a change of speed at constant frequency.

(f) describe simple experiments to show the reflection of sound waves.

14. Light

Content

14.1 Reflection of light

14.2 Refraction of light

14.3 Thin converging and diverging lenses

Learning outcomes

Candidates should be able to:

(a) define the terms used in reflection including *normal*, *angle of incidence* and *angle of reflection*.

(b) describe an experiment to illustrate the law of reflection.

(c) describe an experiment to find the position and characteristics of an optical image formed by a plane mirror.

(d) state that for reflection, the angle of incidence is equal to the angle of reflection and use this in constructions, measurements and calculations.

(e) define the terms used in refraction including *angle of incidence*, *angle of refraction* and *refractive index*.

(f) describe experiments to show refraction of light through glass blocks.

(g) recall and use the equation $\sin i / \sin r = n$.

(h) define the terms *critical angle* and *total internal reflection* and recall and use the formula $\sin c = 1/n$.

(i) describe experiments to show total internal reflection.

(j) describe the use of optical fibres in telecommunications and state the advantages of their use.

(k) describe the action of thin lenses (both converging and diverging) on a beam of light.

(l) define the term *focal length*.

(m) *draw ray diagrams to illustrate the formation of real and virtual images of an object by a converging lens, and the formation of a virtual image by a diverging lens.

(n) define the term *linear magnification* and *draw scale diagrams to determine the focal length needed for particular values of magnification (converging lens only).

(o) describe the use of a single lens as a magnifying glass and in a camera, projector and photographic enlarger and draw ray diagrams to show how each forms an image.

(p) draw ray diagrams to show the formation of images in the normal eye, a short-sighted eye and a long-sighted eye.

(q) describe the correction of short-sight and long-sight.

15. Electromagnetic Spectrum

Content

15.1 Dispersion of light

15.2 Properties of electromagnetic waves

15.3 Applications of electromagnetic waves

Learning outcomes

Candidates should be able to:

(a) describe the dispersion of light as illustrated by the action on light of a glass prism.

(b) state the colours of the spectrum and explain how the colours are related to frequency/wavelength.

(c) state that all electromagnetic waves travel with the same high speed in air and state the magnitude of that speed.

(d) describe the main components of the electromagnetic spectrum.

(e) discuss the role of the following components in the stated applications:

(1) radio waves – radio and television communications,

(2) microwaves – satellite television and telephone,

(3) infra-red – household electrical appliances, television controllers and intruder alarms,

(4) light – optical fibres in medical uses and telephone,

(5) ultra-violet – sunbeds, fluorescent tubes and sterilisation,

(6) X-rays – hospital use in medical imaging and killing cancerous cells, and engineering applications such as detecting cracks in metal,

(7) gamma rays – medical treatment in killing cancerous cells, and engineering applications such as detecting cracks in metal.

16. Sound

Content

16.1 Sound waves

16.2 Speed of sound

16.3 Ultrasound

Learning outcomes

Candidates should be able to:

(a) describe the production of sound by vibrating sources.

(b) describe the longitudinal nature of sound waves and describe compression and rarefaction.

(c) state the approximate range of audible frequencies for the healthy human ear as 20 Hz to 20 000 Hz.

(d) explain why a medium is required in order to transmit sound waves and describe an experiment to demonstrate this.

(e) describe a direct method for the determination of the speed of sound in air and make the necessary calculation.

(f) state the order of magnitude of the speeds of sound in air, liquids and solids.

(g) explain how the loudness and pitch of sound waves relate to amplitude and frequency.

(h) describe how the reflection of sound may produce an echo.

(i) describe how the shape of a sound wave as demonstrated by an oscilloscope is affected by the quality (timbre) of the sound wave.

(j) define *ultrasound*.

(k) describe the uses of ultrasound in cleaning, quality control and pre-natal scanning.

Section V: Electricity and Magnetism

17. Magnetism and Electromagnetism

Content

17.1 Laws of magnetism

17.2 Magnetic properties of matter

17.3 Electromagnetism

Learning outcomes

Candidates should be able to:

(a) describe the forces between magnetic poles and between magnets and magnetic materials.

(b) describe induced magnetism.

(c) state the differences between magnetic, non-magnetic and magnetised materials.

(d) describe electrical methods of magnetisation and demagnetisation and other methods of demagnetisation.

(e) describe the plotting of magnetic field lines with a compass.

(f) state the differences between the properties of temporary magnets (e.g. iron) and permanent magnets (e.g. steel).

(g) describe uses of permanent magnets and electromagnets.

(h) explain the choice of material for, and use of, magnetic screening.

(i) describe the use of magnetic materials in a computer hard disk drive.

(j) describe the pattern 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.

(k) describe applications of the magnetic effect of a current in relays, circuit-breakers and loudspeakers.

18. Static Electricity

Content

18.1 Laws of electrostatics

18.2 Principles of electrostatics

18.3 Applications of electrostatics

Learning outcomes

Candidates should be able to:

(a) describe experiments to show electrostatic charging by friction.

(b) explain that charging of solids involves a movement of electrons.

(c) state that there are positive and negative charges and that charge is measured in coulombs.

(d) state that unlike charges attract and like charges repel.

(e) describe an electric field as a region in which an electric charge experiences a force.

(f) state the direction of lines of force and describe simple field patterns.

(g) describe the separation of charges by induction.

(h) discuss the differences between electrical conductors and insulators and state examples of each.

(i) state what is meant by *"earthing"* a charged object.

(j) describe examples where charging could be a problem, e.g. lightning.

(k) describe examples where charging is helpful, e.g. photocopier and electrostatic precipitator.

19. Current Electricity

Content

19.1 Current

19.2 Electromotive force

19.3 Potential difference

19.4 Resistance

Learning outcomes

Candidates should be able to:

(a) state that a current is a flow of charge and that current is measured in amperes.

(b) recall and use the equation *charge* = *current* × *time*.

(c) describe the use of an ammeter with different ranges.

(d) explain that electromotive force (e.m.f.) is measured by the energy dissipated by a source in driving a unit charge around a complete circuit.

(e) state that e.m.f. is work done/charge.

(f) state that the volt is given by J / C.

(g) calculate the total e.m.f. where several sources are arranged in series and discuss how this is used in the design of batteries.

(h) discuss the advantage of making a battery from several equal voltage sources of e.m.f. arranged in parallel.

(i) state that the potential difference (p.d.) across a circuit component is measured in volts.

(j) state that the p.d. across a component in a circuit is given by the work done in the component/charge passed through the component.

(k) describe the use of a voltmeter with different ranges.

(l) state that *resistance* = *p.d./current* and use the equation *resistance* = *voltage/current* in calculations.

(m) describe an experiment to measure the resistance of a metallic conductor using a voltmeter and an ammeter and make the necessary calculations.

(n) state Ohm's Law and discuss the temperature limitation on Ohm's Law.

(o) *use quantitatively the proportionality between resistance and the length and the cross-sectional area of a wire.

(p) calculate the net effect of a number of resistors in series and in parallel.

(q) describe the effect of temperature increase on the resistance of a resistor and a filament lamp and draw the respective sketch graphs of current/voltage.

(r) describe the operation of a light-dependent resistor.

20. D.C. Circuits

Content

20.1 Current and potential difference in circuits

20.2 Series and parallel circuits

Learning outcomes

Candidates should be able to:

(a) *draw circuit diagrams with power sources (cell, battery or a.c. mains), switches (closed and open), resistors (fixed and variable), light-dependent resistors, thermistors, lamps, ammeters, voltmeters, magnetising coils, bells, fuses, relays, diodes and light-emitting diodes.

(b) state that the current at every point in a series circuit is the same, and use this in calculations.

(c) state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and use this in calculations.

(d) state that the current from the source is the sum of the currents in the separate branches of a parallel circuit.

(e) do calculations on the whole circuit, recalling and using formulae including $R = V/I$ and those for potential differences in series, resistors in series and resistors in parallel.

21. Practical Electricity

Content

21.1 Uses of electricity

21.2 Dangers of electricity

21.3 Safe use of electricity in the home

Learning outcomes

Candidates should be able to:

(a) describe the use of electricity in heating, lighting and motors.

(b) recall and use the equations *power* = *voltage* × *current*, and *energy* = *voltage* × *current* × *time*.

(c) define the kilowatt-hour (kW h) and calculate the cost of using electrical appliances where the energy unit is the kW h.

(d) state the hazards of damaged insulation, overheating of cables and damp conditions.

(e) explain the use of fuses and circuit breakers, and fuse ratings and circuit breaker settings.

(f) explain the need for earthing metal cases and for double insulation.

(g) state the meaning of the terms *live*, *neutral* and *earth*.

(h) describe how to wire a mains plug safely. (Candidates will **not** be expected to show knowledge of the colours of the wires used in a mains supply.)

(i) explain why switches, fuses and circuit breakers are wired into the live conductor.

22. Electromagnetism

Content

22.1 Force on a current-carrying conductor

22.2 The d.c. motor

Learning outcomes

Candidates should be able to:

(a) describe experiments to show the force on a current-carrying conductor, and on a beam of charged particles, in a magnetic field, including the effect of reversing (1) the current, (2) the direction of the field.

(b) state the relative directions of force, field and current.

(c) describe the field patterns between currents in parallel conductors and relate these to the forces which exist between the conductors (excluding the Earth's field).

(d) explain how a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by increasing (1) the number of turns on the coil, (2) the current.

(e) discuss how this turning effect is used in the action of an electric motor.

(f) describe the action of a split-ring commutator in a two-pole, single-coil motor and the effect of winding the coil onto a soft-iron cylinder.

23. Electromagnetic Induction

Content

23.1 Principles of electromagnetic induction

23.2 The a.c. generator

23.3 The transformer

Learning outcomes

Candidates should be able to:

(a) describe an experiment which shows that a changing magnetic field can induce an e.m.f. in a circuit.

(b) state the factors affecting the magnitude of the induced e.m.f.

(c) state that the direction of a current produced by an induced e.m.f. opposes the change producing it (Lenz's Law) and describe how this law may be demonstrated.

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

(e) *sketch a graph of voltage output against time for a simple a.c. generator.

(f) describe the structure and principle of operation of a simple iron-cored transformer.

(g) recall and use the equation $(V_p / V_s) = (N_p / N_s)$

(h) state the advantages of high voltage transmission.

(i) discuss the environmental and cost implications of underground power transmission compared to overhead lines.

24. Introductory Electronics

Content

24.1 Thermionic emission and cathode-rays

24.2 Uses of an oscilloscope

24.3 Action and use of circuit components

Learning outcomes

Candidates should be able to:

(a) state that electrons are emitted by a hot metal filament.

(b) explain that to cause a continuous flow of emitted electrons requires (1) high positive potential and (2) very low gas pressure.

(c) describe the deflection of an electron beam by electric fields and magnetic fields.

(d) state that the flow of electrons (electron current) is from negative to positive and is in the opposite direction to conventional current.

(e) describe the use of an oscilloscope to display waveforms and to measure p.d.s and short intervals of time (the structure of the oscilloscope is **not** required).

(f) explain how the values of resistors are chosen according to a colour code and why widely different values are needed in different types of circuit.

(g) discuss the need to choose components with suitable power ratings.

(h) describe the action of thermistors and light-dependent resistors and explain their use as input sensors (thermistors will be assumed to be of the negative temperature coefficient type).

(i) describe the action of a variable potential divider (potentiometer).

(j) describe the action of a diode in passing current in one direction only.

(k) describe the action of a light-emitting diode in passing current in one direction only and emitting light.

(l) describe and explain the action of relays in switching circuits.

(m) describe and explain circuits operating as light-sensitive switches and temperature-operated alarms (using a relay or other circuits).

25. Electronic Systems

Note: There is no compulsory question set on Section 25 of the syllabus. Questions set on topics within Section 25 are always set as an alternative within a question.

Content

25.1 Switching and logic circuits

25.2 Bistable and astable circuits

Learning outcomes

Candidates should be able to:

(a) describe the action of a bipolar npn transistor as an electrically operated switch and explain its use in switching circuits.

(b) state in words and in truth table form, the action of the following logic gates, AND, OR, NAND, NOR and NOT (inverter).

(c) state the symbols for the logic gates listed above (American ANSI Y 32.14 symbols will be used).

(d) describe the use of a bistable circuit.

(e) discuss the fact that bistable circuits exhibit the property of memory.

Section VI: Atomic Physics

26. Radioactivity

Content

26.1 Detection of radioactivity

26.2 Characteristics of the three types of emission

26.3 Nuclear reactions

26.4 Half-life

26.5 Uses of radioactive isotopes including safety precautions

Learning outcomes

Candidates should be able to:

(a) describe the detection of alpha-particles, beta-particles and gamma rays by appropriate methods.

(b) state and explain the random emission of radioactivity in direction and time.

(c) state, for radioactive emissions, their nature, relative ionising effects and relative penetrating powers.

(d) describe the deflection of radioactive emissions in electric fields and magnetic fields.

(e) explain what is meant by *radioactive decay*.

(f) explain the processes of fusion and fission.

(g) describe, with the aid of a block diagram, one type of fission reactor for use in a power station.

(h) discuss theories of star formation and their energy production by fusion.

(i) explain what is meant by the term *half-life*.

(j) make calculations based on half-life which might involve information in tables or shown by decay curves.

(k) describe how radioactive materials are moved, used and stored in a safe way.

(l) discuss the way in which the type of radiation emitted and the half-life determine the use for the material.

(m) discuss the origins and effect of background radiation.

(n) discuss the dating of objects by the use of ^{14}C.

27. The Nuclear Atom

Content

27.1 Atomic model

27.2 Nucleus

Learning outcomes

Candidates should be able to:

(a) describe the structure of the atom in terms of nucleus and electrons.

(b) describe how the Geiger-Marsden alpha-particle scattering experiment provides evidence for the nuclear atom.

(c) describe the composition of the nucleus in terms of protons and neutrons.

(d) define the terms *proton number* (atomic number), Z and *nucleon number* (mass number), A.

(e) explain the term *nuclide* and use the nuclide notation $^{A}_{Z}X$ to construct equations where radioactive decay leads to changes in the composition of the nucleus.

(f) define the term *isotope*.

(g) explain, using nuclide notation, how one element may have a number of isotopes.

6. Practical assessment

Scientific subjects are, by their nature, experimental. It is therefore important that an assessment of a candidate's knowledge and understanding of physics should contain a practical component. Two alternative means of assessment are provided: a formal practical written test and a written alternative-to-practical paper. Both papers assess the skills outlined in Assessment Objective AO3.

6.1 Paper 3: Practical Test

Introduction

This paper is designed to assess a candidate's competence in those practical skills which can realistically be assessed within the context of a formal test of limited duration. The best preparation for this paper is for candidates to pursue a comprehensive course in practical physics throughout the time during which they are being taught the theoretical content. It is not expected that all the experiments and exercises will follow the style of the Practical Test, but candidates should regularly be made aware of the points examiners will be looking for when marking this paper.

The questions in the Practical Test cover most of the objectives outlined above. In particular, candidates should be prepared to make measurements or determinations of physical quantities such as mass, length, area, volume, time, current and potential difference. Candidates should be aware of the need to take simple precautions for safety and/or accuracy. The questions are not necessarily restricted to topics in the curriculum content. The test does not involve the use of textbooks, nor will candidates need access to their own records of laboratory work carried out during the course. Candidates are required to follow instructions given in the question paper. Candidates may use an electronic calculator, which complies with the current version of the Regulations. Examiners assume that an electronic calculator will be used when they are setting the papers and judging the length of time required for each question. Candidates answer on the question paper.

Apparatus requirements

Instructions are sent to centres several months in advance of the date of the Practical Test. Every effort is made to minimise the cost to centres by designing experiments around basic apparatus which should be available in most school physics laboratories. For guidance, a list of the items used in recent papers is included at the end of this section. It is not intended to be exhaustive, but should be taken as a guide to the requirements.

Candidates should have:

- 20 minutes with the apparatus for each of the three questions in Section A
- 60 minutes with the apparatus for the question in Section B.

Candidates may be instructed as to the order in which they are to attempt the questions. To reduce the number of sets of apparatus required, a 'circus' arrangement may be used for Section A, and some candidates may be told to do Section B first. It is essential that candidates are warned of these arrangements in advance.

Centres should provide a seating plan of each stage of the examination, as indicated on the instructions.

Supervisors should check every set of apparatus before the examination, and spare sets of apparatus must be available to allow for breakage and malfunction. If any significant deviations from the specified apparatus are necessary, the Product Manager at Cambridge International must be consulted well in advance of the date on which the paper is set, by fax or e-mail. For some centres, communication must be through the appropriate Ministry of Education. Specimen results must be provided in the envelope which is sent to the examiner containing the scripts.

Apparatus

- adhesive tape (e.g. Sellotape)
- ammeter FSD 1 A, or 1.5 A*
- beaker, 100 cm^3, 250 cm^3, 1 litre
- Blu-tack
- boiling tube, 150 mm × 25 mm
- card
- cells, 1.5 V
- connecting leads
- crocodile clips
- d.c. power supply – variable to 12 V
- filament lamp, 12 V, 24 W
- G-clamp
- half-metre rule
- lens, converging f = 15 cm
- low voltage (2.5 V) filament lamps in holders
- masses, 50 g, 100 g
- measuring cylinder 100 cm^3, 250 cm^3
- metre rule
- microscope slides
- mirror, plane, 50 mm × 10 mm
- modelling clay (e.g. Plasticine)
- newton meter, max. reading 1.0 N
- nichrome wire 28 swg (0.38 mm diameter), 30 swg (0.32 mm diameter)
- pendulum bob
- pin board
- pivot (to fit a hole in metre rule)
- plastic or polystyrene cup, 200 cm^3
- protractor
- pulley
- ray box
- resistors, various
- retort stand, boss and clamp
- springs
- stopwatch reading to 0.1 s or better
- switch
- thermometer –10 °C–110 °C (by 1 °C)
- thread
- tracing paper
- voltmeter FSD 1 V, 5 V*
- wooden board

*Digital multimeters may be suitable as a flexible, low-cost alternative to both ammeters and voltmeters.

General marking points

Setting up apparatus

Candidates are expected to be able to follow written instructions for the assembly and use of apparatus, for example, an electrical circuit or ray-tracing equipment. They may be expected to make a sensible choice of measuring instrument.

Taking readings

During the course of their preparation for this paper, candidates should be taught to observe the following points of good practice, which often feature in the mark scheme.

- A measuring instrument should be used to its full precision.
- Thermometers are often marked with intervals of 1 °C. It is appropriate to record a reading which coincides exactly with a mark as, for example, 22.0 °C, rather than as a bald 22 °C.
- Interpolation between scale divisions should be to one half of a division or better. For example, consider a thermometer with scale divisions of 1 °C. A reading of 22.3 °C might best be recorded as 22.5 °C, since '0.3' is nearer '0.5' than '0'. That is, where a reading lies between two scale marks, an attempt should be made to interpolate between those two marks, rather than simply rounding to the nearest mark.
- The length of an object measured on a rule with a centimetre and millimetre scale should be recorded as 12.0 cm rather than a bald 12 cm, if the ends of the object coincide exactly with the 0 and 12 cm marks.
- A measurement or calculated quantity must be accompanied by a correct unit, where appropriate.
- Candidates should be able to make allowance for zero errors.

Recording readings

- A table of results should include, in the heading of each column, the name or symbol of the measured or calculated quantity, together with the appropriate unit. Solidus notation is expected.
- Each reading should be repeated, if possible, and recorded. (This is particularly true in Section B.)
- 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.
- A ratio should be calculated as a decimal number, of two or three significant figures.

Drawing graphs

- A graph should be drawn with a sharp pencil.
- The axes should be labelled with quantity and unit.
- The scales for the axes should allow the majority of the graph paper to be used in both directions, and be based on sensible ratios, e.g. 2 cm on the graph paper representing 1, 2 or 5 units of the variable (or 10, 20 or 50, etc.).
- Each data point should be plotted to an accuracy of better than one half of one of the smallest squares on the grid.
- Points should be indicated by a small cross or a fine dot with a circle drawn around it. Large 'dots' are penalised.
- Where a straight line is required to be drawn through the data points, Examiners expect to see an equal number of points either side of the line over its entire length. That is, points should not be seen to lie all above the line at one end, and all below the line at the other end.
- 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 line. Data values should be read from the line to an accuracy better than one half of one of the smallest squares on the grid. The same accuracy should be used in reading off an intercept. Calculation of the gradient should be to two or three significant figures.

- Candidates should be able to determine the intercept of the graph line.
- 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.
- Candidates should be able to take readings from the graph by extrapolation or interpolation.

Conclusion

- Candidates should be able to indicate how they carried out a specific instruction and to describe the precautions taken in carrying out a procedure.
- They should be able to explain the choice of a particular piece of apparatus.
- They should also be able to comment on a procedure and suggest an improvement.

6.2 Paper 4: Alternative to Practical

This paper is designed for those centres for whom the preparation and execution of the Practical Test is impracticable.

The Alternative to Practical Paper consists of four or five questions relating to practical physics: candidates answer on the question paper.

The best preparation for this paper is a thorough course in experimental physics. Candidates are unlikely to demonstrate their full potential on this paper unless they have become fully familiar with the techniques and apparatus involved by doing experiments for themselves. Questions may involve the description of particular techniques, the drawing of diagrams, or the analysis of data. The examiners expect the same degree of detail as for Paper 3 and candidates should be taught to adopt practices which satisfy the same general marking points. In addition, candidates should be able to draw, complete and label diagrams of apparatus and to take readings from diagrams of apparatus given in the question paper. Where facilities permit, demonstration experiments by the teacher can be very useful in the teaching of particular techniques, and can be the source of useful data for candidates to analyse.

7. Appendix

7.1 Summary of key quantities, symbols and units

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

Candidates should be familiar with the following multipliers: M mega, k kilo, c centi, m milli.

Quantity	Usual symbol	Usual unit
length	l, h …	km, m, cm, mm
area	A	m^2, cm^2
volume	V	m^3, cm^3
weight	W	N
mass	m, M	kg, g, mg
time	t	h, min, s, ms
density	ρ	g/cm^3, kg/m^3
speed	u, v	km/h, m/s, cm/s
acceleration	a	m/s^2
acceleration of free fall	g	m/s^2
force	F	N
gravitational field strength	g	N/kg
moment of a force		N m
work done	W, E	J
energy	E	J, kW h
power	P	W
pressure	p, P	Pa, N/m^2
temperature	θ, t, T	°C
heat capacity	C	J/°C
specific heat capacity	c	J/(kg °C), J/(g °C)
latent heat	L	J
specific latent heat	l	J/kg, J/g
frequency	f	Hz
wavelength	λ	m, cm

Quantity	Usual symbol	Usual unit
focal length	f	m, cm
angle of incidence	i	degree (°)
angles of reflection, refraction	r	degree (°)
critical angle	c	degree (°)
refractive index	n	
potential difference/voltage	V	V, mV
current	I	A, mA
charge	Q	C
e.m.f.	E	V
resistance	R	Ω

7.2 Glossary of terms used in science papers

The glossary (which is relevant only to science subjects) will prove helpful to candidates as a guide but it is not exhaustive. The glossary has been deliberately kept brief, not only with respect to the numbers of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend, in part, on its context.

1. *Define (the term(s) ...)* is intended literally. Only a formal statement or equivalent paraphrase, such as the defining equation with symbols identified, being required.
2. *Explain*/*What is meant by* ... normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.
3. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.
4. *List* requires a number of points with no elaboration. Where a given number of points is specified, this should not be exceeded.
5. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. The amount of description intended should be interpreted in the light of the indicated mark value.
6. *Discuss* requires candidates to give a critical account of the points involved in the topic.
7. *Deduce* implies that candidates are not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question.
8. *Suggest* is used in two main contexts. It may either imply that there is no unique answer or that candidates are expected to apply their general knowledge to a 'novel' situation, one that formally may not be 'in the syllabus'.
9. *Calculate* is used when a numerical answer is required. In general, working should be shown.
10. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.
11. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, e.g. the Young modulus, relative molecular mass.
12. *Show* is used when an algebraic deduction has to be made to prove a given equation. It is important that the terms being used by candidates are stated explicitly.
13. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned. Candidates should make such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.
14. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct. However, candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates clearly indicate what is being plotted on each axis.

    Sketch, when applied to diagrams, implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important detail.

8. Other information

Equality and inclusion

We have taken great care in the preparation of this syllabus and assessment materials to avoid bias of any kind. To comply with the UK Equality Act (2010), we have designed this qualification with the aim of avoiding direct and indirect discrimination.

The standard assessment arrangements may present unnecessary barriers for candidates with disabilities or learning difficulties. Arrangements can be put in place for these candidates to enable them to access the assessments and receive recognition of their attainment. Access arrangements will not be agreed if they give candidates an unfair advantage over others or if they compromise the standards being assessed.

Candidates who are unable to access the assessment of any component may be eligible to receive an award based on the parts of the assessment they have taken.

Information on access arrangements is found in the *Cambridge Handbook* which can be downloaded from the website **www.cambridgeinternational.org/examsofficers**

Language

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

Grading and reporting

Cambridge O Level results are shown by one of the grades A*, A, B, C, D or E, indicating the standard achieved, A* being the highest and E the lowest. 'Ungraded' indicates that the candidate's performance fell short of the standard required for grade E. 'Ungraded' will be reported on the statement of results but not on the certificate. The letters Q (result pending), X (no result) and Y (to be issued) may also appear on the statement of results but not on the certificate.

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.

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