IGCSE Physics
Cambridge Survival Kit

This Kit Belongs To:

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Table of Contents

Intro to Cambridge Physics

Welcome to IGCSE Physics! One of our primary goals is to prepare you for the Cambridge test at the end of the year. Before we go into too much of the physics test, here is some general information about Cambridge terminology:

- Paper – test or exam; the physics Cambridge test has 3 “papers” or 3 tests
- Mark – point; instead of earning “points” you earn “marks”
- Mark Scheme – rubric; each of the practice tests have an accompanying “mark scheme” or rubric we can use to assess your progress so far

Also keep in mind that Cambridge will spell things differently (tyre instead of tire) and have other different vocabulary (lift instead of elevator).

Parts of the Cambridge Physics Test:

1. *Multiple Choice (45 minutes)*
   A multiple-choice (A-D) paper consisting of 40 questions. This paper will test assessment objectives AO1 and AO2. This paper will be weighted at 30% of the final total mark.
2. *Free-Response (1 hour 15 minutes)*
   A written paper consisting of short-answer and structured questions. This paper will test assessment objectives AO1 & AO2. This paper will weigh 50% of the total final mark.
3. *Alternative to Practical (1 hour)*
   This paper will test assessment objective AO3. Questions will be based on the experimental skills listed in the “Practical Test” section. You will be taking the Alternative to Practical, which is a lab on paper. This means that instead of doing the experiment yourself, you will be provided with a picture of the set up (for example, a picture of a ruler next to a block), which you will analyze. This paper will be weighted at 20% of the final total mark.

Notice that each paper says which assessment objectives are tested on that paper. For more information, see the “Assessment Objectives” page.

Cambridge Test Levels:

The Cambridge Physics test has two levels: Core and Extended/Supplement. You will be taking the Extended/Supplement portion, which means you are responsible for *both* the Core and Extended/Supplement material. This will be important as you look at the objectives later on.

Number Notation:

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 whole numbers, e.g. 4 256 789.

Mathematical Requirements:
Calculators may be used in all parts of the examination. Note that when Cambridge says "recall" they mean you need to have that memorized and that you can recall that fact at the test. That information will not be given.

Candidates should be able to:

- add, subtract, multiply and divide
- use averages, decimals, fractions, percentages, ratios and reciprocals
- use standard notation, including both positive and negative indices
- understand significant figures and use them appropriately
- recognise and use direct and inverse proportion
- use positive, whole number indices in algebraic expressions
- draw charts and graphs from given data
- interpret charts and graphs
- determine the gradient and intercept of a graph
- select suitable scales and axes for graphs
- make approximate evaluations of numerical expressions
- recall and use equations for the areas of a rectangle, triangle and circle and the volumes of a rectangular block and a cylinder
- use mathematical instruments (ruler, compasses, protractor and set square)
- understand the meaning of angle, curve, circle, radius, diameter, circumference, square, parallelogram, rectangle and diagonal
- solve equations of the form $x = y + z$ and $x = yz$ for any one term when the other two are known
- recognise and use clockwise and anticlockwise directions
- recognise and use points of the compass (N, S, E, W)
- use sines ($\sin \theta$)and inverse sines ($\sin^{-1} \theta$)

Assessment Objectives

AO1: Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

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

Syllabus 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.

Questions testing this objective will often begin with one of the following words: define, state, describe, explain (using your knowledge and understanding) or outline (see the Glossary of terms used in science papers).

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:

1. locate, select, organise and present information from a variety of sources
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, 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.

Questions testing these skills will often begin with one of the following words: predict, suggest, calculate or determine (see the Glossary of terms used in science papers).

AO3: Experimental skills and investigations

Candidates should be able to:

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

Grade Descriptions

The scheme of assessment is intended to encourage positive achievement by all candidates.

A Grade A candidate will be able to:

- recall and communicate precise knowledge and display comprehensive understanding of scientific phenomena, facts, laws, definitions, concepts and theories
- apply scientific concepts and theories to present reasoned explanations of familiar and unfamiliar phenomena, to solve complex problems involving several stages, and to make reasoned predictions and hypotheses
- communicate and present complex scientific ideas, observations and data clearly and logically, independently using scientific terminology and conventions consistently and correctly
- independently select, process and synthesise information presented in a variety of ways, and use it to draw valid conclusions and discuss the scientific, technological, social, economic and environmental implications
- devise strategies to solve problems in complex situations which may involve many variables or complex manipulation of data or ideas through multiple steps
- analyse data to identify any patterns or trends, taking account of limitations in the quality of the data and justifying the conclusions reached
- select, describe, justify and evaluate techniques for a large range of scientific operations and laboratory procedures.

A Grade C candidate will be able to:

- recall and communicate secure knowledge and understanding of scientific phenomena, facts, laws, definitions, concepts and theories
- apply scientific concepts and theories to present simple explanations of familiar and some unfamiliar phenomena, to solve straightforward problems involving several stages, and to make detailed predictions and simple hypotheses
- communicate and present scientific ideas, observations and data using a wide range of scientific terminology and conventions
- select and process information from a given source, and use it to draw simple conclusions and state the scientific, technological, social, economic or environmental implications
- solve problems involving more than one step, but with a limited range of variables or using familiar methods
- analyse data to identify a pattern or trend, and select appropriate data to justify a conclusion
- select, describe and evaluate techniques for a range of scientific operations and laboratory procedures.

Glossary of Terms

This glossary (which is relevant only to science subjects) will prove helpful to candidates as a guide, but it is neither exhaustive nor definitive. The glossary has been deliberately kept brief, not only with respect to the number 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* only a formal statement or equivalent paraphrase being required.
2. *What do you understand by/What is meant by* (the term(s)…) 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 readily be obtained 'by inspection').
4. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified this should not be exceeded.
5.
    a. *Explain* may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to give reasons. The candidate needs to leave the examiner in no doubt why something happens.
    b. *Give a reason/Give reasons* is another way of asking candidates to explain why something happens.
6. *Describe* requires the candidate to state in words (using diagrams where appropriate) the main points. *Describe and explain* may be coupled, as may *state and explain*.
7. *Discuss* requires the candidate to give a critical account of the points involved.
8. *Outline* implies brevity (i.e. restricting the answer to giving essentials).
9. *Predict* implies that the candidate is expected to make a prediction not by recall but by making a logical connection between other pieces of information.
10. *Deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information.
11. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in physics there are several examples of energy resources from which electricity, or other useful forms of energy, may be obtained), or to imply that candidates are expected to apply their general knowledge of the subject to a 'novel' situation, one that may be formally 'not in the syllabus' – many data response and problem solving questions are of this type.
12. *Find* is a general term that may variously be interpreted as calculate, measure, determine, etc.
13. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.
14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument (e.g. length using a rule, or mass using a balance).
15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained from a graph or by calculation.
16. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.
17. *Sketch,* when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but 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). In diagrams, *sketch* implies that simple, freehand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.

Practical Test

This paper is based on testing experimental skills. The questions do not assess specific syllabus content. Any information required to answer these questions is contained within the question paper or from the experimental context and skills listed below. Questions are structured to assess across the grade range A* – G. You will be taking the Alternative to Practical, which is a lab on paper. This means that instead of doing the experiment yourself, you will be provided with a picture of the set up (for example, a picture of a ruler next to a block), which you will analyze. The Alternative to Practical will typically consist of four questions, three of which require the use of apparatus.

Candidates may be asked questions on the following experimental contexts:

- measurement of physical quantities such as length or volume or force
- cooling and heating
- springs and balances
- timing motion or oscillations
- electric circuits
- optics equipment such as mirrors, prisms and lenses
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate.

Candidates may be required to do the following:

- use, or describe the use of, common techniques, apparatus and materials, for example ray-tracing equipment or the connection of electric circuits
- select the most appropriate apparatus or method for a task and justify the choice made
- draw, complete or label diagrams of apparatus
- explain the manipulation of the apparatus to obtain observations or measurements, for example:
  - when determining a derived quantity, such as the extension per unit load for a spring
  - when testing/identifying the relationship between two variables, such as between the p.d. across a wire and its length
  - when comparing physical quantities, such as two masses using a balancing method
- make estimates or describe outcomes which demonstrate their familiarity with an experiment, procedure or technique
- take readings from an appropriate measuring device or from an image of the device (for example thermometer, rule, protractor, measuring cylinder, ammeter, stopwatch), including:
  - reading analogue and digital scales with accuracy and appropriate precision
  - interpolating between scale divisions when appropriate
  - correcting for zero errors, where appropriate
- plan to take a sufficient number and range of measurements, repeating where appropriate to obtain an average value
- describe or explain precautions taken in carrying out a procedure to ensure safety or the

accuracy of observations and data, including the control of variables
- identify key variables and describe how, or explain why, certain variables should be controlled
- record observations systematically, for example in a table, using appropriate units and to a consistent and appropriate degree of precision
- process data, using a calculator where necessary
- present and analyse data graphically, including the use of best-fit lines where appropriate, interpolation and extrapolation, and the determination of a gradient, intercept or intersection
- draw an appropriate conclusion, justifying it by reference to the data and using an appropriate explanation
- comment critically on a procedure or point of practical detail and suggest an appropriate improvement
- evaluate the quality of data, identifying and dealing appropriately with any anomalous results
- identify possible causes of uncertainty, in data or in a conclusion
- plan an experiment or investigation including making reasoned predictions of expected results and suggesting suitable apparatus and techniques.

Presentation of Data

During portions of the test (especially during the Practical Exam) you will need to display data in the form of a table, graph, etc.

The solidus (/) is to be used for separating the quantity and the unit in tables, graphs and charts, e.g. time / s for time in seconds.

1. Tables
   - Each column of a table should be headed with the physical quantity and the appropriate unit, e.g. time / s.
   - The column headings of the table can then be directly transferred to the axes of a constructed graph.
2. Graphs
   - Unless instructed otherwise, the independent variable should be plotted on the x -axis (horizontal axis) and the dependent variable plotted on the y -axis (vertical axis).
   - Each axis should be labelled with the physical 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.
   - The graph is the whole diagrammatic presentation, including the best-fit line when appropriate. It may have one or more sets of data plotted on it.
   - Points on the graph should be clearly marked as crosses (x) or encircled dots (⊙).
   - Large 'dots' are penalised. Each data point should be plotted to an accuracy of better than one half of each of the smallest squares on the grid.
   - A best-fit line (trend line) should be a single, thin, smooth straight-line or curve. 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 should be ignored when drawing the best-fit line.
   - The gradient of a straight line should be taken using a triangle whose hypotenuse extends over at least half of the length of the best-fit line, and this triangle should be marked on the graph.
3. Bar charts
   - These are drawn when one of the variables is not numerical.
4. Numerical results
   - Data should be recorded so as to reflect the precision of the measuring instrument.
   - The number of significant figures given for calculated quantities should be appropriate to the least number of significant figures in the raw data used.

Syllabus Objectives

You will be taking the Extended version of the Cambridge test. This means that you will be mastering the Core and the Supplement content. Where possible, Cambridge will test you on the Supplement content instead of the Core material.

1. General physics	
1.1 Length and time **Core** • Use and describe the use of rules and measuring cylinders to find a length or a volume • Use and describe the use of clocks and devices, both analogue and digital, for measuring an interval of time • Obtain an average value for a small distance and for a short interval of time by measuring multiples (including the period of a pendulum)	**Supplement** • Understand that a micrometer screw gauge is used to measure very small distances
1.2 Motion **Core** • Define speed and calculate average speed from $\frac{\text{total distance}}{\text{total time}}$ • Plot and interpret a speed-time graph or a distance-time graph • Recognise from the shape of a speed-time graph when a body is – at rest – moving with constant speed – moving with changing speed • Calculate the area under a speed-time graph to work out the distance travelled for motion with constant acceleration • Demonstrate understanding that acceleration and deceleration are related to changing speed including qualitative analysis of the gradient of a speed-time graph	**Supplement** • Distinguish between speed and velocity • Define and calculate acceleration using $\frac{\text{change of velocity}}{\text{time taken}}$ • Calculate speed from the gradient of a distance-time graph • Calculate acceleration from the gradient of a speed-time graph • Recognise linear motion for which the acceleration is constant • Recognise motion for which the acceleration is not constant • Understand deceleration as a negative acceleration *cont.*
• State that the acceleration of free fall for a body near to the Earth is constant	• Describe qualitatively the motion of bodies falling in a uniform gravitational field with and without air resistance (including reference to terminal velocity)

1.3 Mass and weight **Core** • Show familiarity with the idea of the mass of a body • State that weight is a gravitational force • Distinguish between mass and weight • Recall and use the equation $W = mg$ • Demonstrate understanding that weights (and hence masses) may be compared using a balance	**Supplement** • Demonstrate an understanding that mass is a property that 'resists' change in motion • Describe, and use the concept of, weight as the effect of a gravitational field on a mass
1.4 Density **Core** • Recall and use the equation $\rho = \frac{m}{V}$ • Describe an experiment to determine the density of a liquid and of a regularly shaped solid and make the necessary calculation • Describe the determination of the density of an irregularly shaped solid by the method of displacement • Predict whether an object will float based on density data	
1.5 Forces	
1.5.1 Effects of forces **Core** • Recognise that a force may produce a change in size and shape of a body • Plot and interpret extension-load graphs and describe the associated experimental procedure • Describe the ways in which a force may change the motion of a body • Find the resultant of two or more forces acting along the same line • Recognise that if there is no resultant force on a body it either remains at rest or continues at constant speed in a straight line • Understand friction as the force between two surfaces which impedes motion and results in heating • Recognise air resistance as a form of friction	**Supplement** • State Hooke's Law and recall and use the expression $F = kx$, where k is the spring constant • Recognise the significance of the 'limit of proportionality' for an extension-load graph • Recall and use the relation between force, mass and acceleration (including the direction), $F = ma$ • Describe qualitatively motion in a circular path due to a perpendicular force ($F = mv^2/r$ is *not* required)

1.5.2 Turning effect **Core** • Describe the moment of a force as a measure of its turning effect and give everyday examples • Understand that increasing force or distance from the pivot increases the moment of a force • Calculate moment using the product force × perpendicular distance from the pivot • Apply the principle of moments to the balancing of a beam about a pivot	**Supplement** • Apply the principle of moments to different situations
1.5.3 Conditions for equilibrium **Core** • Recognise that, when there is no resultant force and no resultant turning effect, a system is in equilibrium	**Supplement** • Perform and describe an experiment (involving vertical forces) to show that there is no net moment on a body in equilibrium
1.5.4 Centre of mass **Core** • Perform and describe an experiment to determine the position of the centre of mass of a plane lamina • Describe qualitatively the effect of the position of the centre of mass on the stability of simple objects	
1.5.5 Scalars and vectors	**Supplement** • Understand that vectors have a magnitude and direction • Demonstrate an understanding of the difference between scalars and vectors and give common examples • Determine graphically the resultant of two vectors
1.6 Momentum	**Supplement** • Understand the concepts of momentum and impulse • Recall and use the equation momentum = mass × velocity, $p=mv$ • Recall and use the equation for impulse $Ft = mv - mu$ • Apply the principle of the conservation of momentum to solve simple problems in one dimension

1.7 Energy, work and power	
1.7.1 Energy **Core** • Identify changes in kinetic, gravitational potential, chemical, elastic (strain), nuclear and internal energy that have occurred as a result of an event or process • Recognise that energy is transferred during events and processes, including examples of transfer by forces (mechanical working), by electrical currents (electrical working), by heating and by waves • Apply the principle of conservation of energy to simple examples	**Supplement** • Recall and use the expressions kinetic energy = $\frac{1}{2}mv^2$ and change in gravitational potential energy = $mg\Delta h$ • Apply the principle of conservation of energy to examples involving multiple stages • Explain that in any event or process the energy tends to become more spread out among the objects and surroundings (dissipated)
1.7.2 Energy resources **Core** • Describe how electricity or other useful forms of energy may be obtained from: – chemical energy stored in fuel – water, including the energy stored in waves, in tides, and in water behind hydroelectric dams – geothermal resources – nuclear fission – heat and light from the Sun (solar cells and panels) – wind • Give advantages and disadvantages of each method in terms of renewability, cost, reliability, scale and environmental impact • Show a qualitative understanding of efficiency	**Supplement** • Understand that the Sun is the source of energy for all our energy resources except geothermal, nuclear and tidal • Show an understanding that energy is released by nuclear fusion in the Sun • Recall and use the equation: efficiency = $\frac{\text{useful energy output}}{\text{energy input}} \times 100\%$ • efficiency = $\frac{\text{useful power output}}{\text{power input}} \times 100\%$
1.7.3 Work **Core** • Demonstrate understanding that work done = energy transferred • Relate (without calculation) work done to the magnitude of a force and the distance moved in the direction of the force	**Supplement** • Recall and use $W = Fd = \Delta E$

1.7.4 Power **Core** • Relate (without calculation) power to work done and time taken, using appropriate examples	**Supplement** • Recall and use the equation $P = \Delta E/t$ in simple systems
1.8 Pressure **Core** • Recall and use the equation $p = F/A$ • Relate pressure to force and area, using appropriate examples • Describe the simple mercury barometer and its use in measuring atmospheric pressure • Relate (without calculation) the pressure beneath a liquid surface to depth and to density, using appropriate examples • Use and describe the use of a manometer	**Supplement** • Recall and use the equation $p = h\rho g$
2. Thermal physics	
2.1 Simple kinetic molecular model of matter	
2.1.1 States of matter **Core** • State the distinguishing properties of solids, liquids and gases	
2.1.2 Molecular model **Core** • Describe qualitatively the molecular structure of solids, liquids and gases in terms of the arrangement, separation and motion of the molecules • Interpret the temperature of a gas in terms of the motion of its molecules • Describe qualitatively the pressure of a gas in terms of the motion of its molecules • Show an understanding of the random motion of particles in a suspension as evidence for the kinetic molecular model of matter • Describe this motion (sometimes known as Brownian motion) in terms of random molecular bombardment	**Supplement** • Relate the properties of solids, liquids and gases to the forces and distances between molecules and to the motion of the molecules • Explain pressure in terms of the change of momentum of the particles striking the walls creating a force • Show an appreciation that massive particles may be moved by light, fast-moving molecules
2.1.3 Evaporation **Core** • Describe evaporation in terms of the escape of more-energetic molecules from the surface of a liquid • Relate evaporation to the consequent cooling of the liquid	**Supplement** • Demonstrate an understanding of how temperature, surface area and draught over a surface influence evaporation • Explain the cooling of a body in contact with an evaporating liquid

2.1.4 Pressure changes **Core** • Describe qualitatively, in terms of molecules, the effect on the pressure of a gas of: – a change of temperature at constant volume – a change of volume at constant temperature	**Supplement** • Recall and use the equation pV = constant for a fixed mass of gas at constant temperature
2.2 Thermal properties and temperature	
2.2.1 Thermal expansion of solids, liquids and gases **Core** • Describe qualitatively the thermal expansion of solids, liquids, and gases at constant pressure • Identify and explain some of the everyday applications and consequences of thermal expansion	**Supplement** • Explain, in terms of the motion and arrangement of molecules, the relative order of the magnitude of the expansion of solids, liquids and gases
2.2.2 Measurement of temperature **Core** • Appreciate how a physical property that varies with temperature may be used for the measurement of temperature, and state examples of such properties • Recognise the need for and identify fixed points • Describe and explain the structure and action of liquid-in-glass thermometers	**Supplement** • Demonstrate understanding of sensitivity, range and linearity • Describe the structure of a thermocouple and show understanding of its use as a thermometer for measuring high temperatures and those that vary rapidly • Describe and explain how the structure of a liquid-in-glass thermometer relates to its sensitivity, range and linearity
2.2.3 Thermal capacity (heat capacity) **Core** • Relate a rise in the temperature of a body to an increase in its internal energy • Show an understanding of what is meant by the thermal capacity of a body	**Supplement** • Give a simple molecular account of an increase in internal energy • Recall and use the equation thermal capacity = mc • Define specific heat capacity • Describe an experiment to measure the specific heat capacity of a substance • Recall and use the equation change in energy = $mc\Delta T$
2.2.4 Melting and boiling **Core** • Describe melting and boiling in terms of energy input without a change in temperature • State the meaning of melting point and boiling point • Describe condensation and solidification in terms of molecules	**Supplement** • Distinguish between boiling and evaporation • Use the terms latent heat of vaporisation and latent heat of fusion and give a molecular interpretation of latent heat • Define specific latent heat • Describe an experiment to measure specific latent heats for steam and for ice • Recall and use the equation energy = ml

2.3 Thermal processes	
2.3.1 Conduction **Core** • Describe experiments to demonstrate the properties of good and bad thermal conductors	**Supplement** • Give a simple molecular account of conduction in solids including lattice vibration and transfer by electrons
2.3.2 Convection **Core** • Recognise convection as an important method of thermal transfer in fluids • Relate convection in fluids to density changes and describe experiments to illustrate convection	
2.3.3 Radiation **Core** • Identify infra-red radiation as part of the electromagnetic spectrum • Recognise that thermal energy transfer by radiation does not require a medium • Describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of radiation	**Supplement** • Describe experiments to show the properties of good and bad emitters and good and bad absorbers of infra-red radiation • Show understanding that the amount of radiation emitted also depends on the surface temperature and surface area of a body
2.3.4 Consequences of energy transfer **Core** • Identify and explain some of the everyday applications and consequences of conduction, convection and radiation	
3. Properties of waves, including light and sound	
3.1 General wave properties **Core** • Demonstrate understanding that waves transfer energy without transferring matter • Describe what is meant by wave motion as illustrated by vibration in ropes and springs and by experiments using water waves • Use the term wavefront • Give the meaning of speed, frequency, wavelength and amplitude • Distinguish between transverse and longitudinal waves and give suitable examples • Describe how waves can undergo: – reflection at a plane surface – refraction due to a change of speed – diffraction through a narrow gap • Describe the use of water waves to demonstrate reflection, refraction and diffraction	**Supplement** • Recall and use the equation $v = f\lambda$ • Describe how wavelength and gap size affects diffraction through a gap • Describe how wavelength affects diffraction at an edge

3.2 Light	
3.2.1 Reflection of light **Core** • Describe the formation of an optical image by a plane mirror, and give its characteristics • Recall and use the law angle of incidence = angle of reflection	**Supplement** • Recall that the image in a plane mirror is virtual • Perform simple constructions, measurements and calculations for reflection by plane mirrors
3.2.2 Refraction of light **Core** • Describe an experimental demonstration of the refraction of light • Use the terminology for the angle of incidence *i* and angle of refraction *r* and describe the passage of light through parallel-sided transparent material • Give the meaning of critical angle • Describe internal and total internal reflection	**Supplement** • Recall and use the definition of refractive index *n* in terms of speed • Recall and use the equation $\frac{\sin i}{\sin r} = n$ • Recall and use $n = \frac{1}{\sin c}$ • Describe and explain the action of optical fibres particularly in medicine and communications technology
3.2.3 Thin converging lens **Core** • Describe the action of a thin converging lens on a beam of light • Use the terms principal focus and focal length • Draw ray diagrams for the formation of a real image by a single lens • Describe the nature of an image using the terms enlarged/same size/diminished and upright/inverted	**Supplement** • Draw and use ray diagrams for the formation of a virtual image by a single lens • Use and describe the use of a single lens as a magnifying glass • Show understanding of the terms real image and virtual image
3.2.4 Dispersion of light **Core** • Give a qualitative account of the dispersion of light as shown by the action on light of a glass prism including the seven colours of the spectrum in their correct order	**Supplement** • Recall that light of a single frequency is described as monochromatic

Core	Supplement
3.3 Electromagnetic spectrum **Core** • Describe the main features of the electromagnetic spectrum in order of wavelength • State that all e.m. waves travel with the same high speed in a vacuum • Describe typical properties and uses of radiations in all the different regions of the electromagnetic spectrum including: – radio and television communications (radio waves) – satellite television and telephones (microwaves) – electrical appliances, remote controllers for televisions and intruder alarms (infra-red) – medicine and security (X-rays) • Demonstrate an awareness of safety issues regarding the use of microwaves and X-rays	**Supplement** • State that the speed of electromagnetic waves in a vacuum is 3.0×10^8 m/s and is approximately the same in air
3.4 Sound **Core** • Describe the production of sound by vibrating sources • Describe the longitudinal nature of sound waves • State that the approximate range of audible frequencies for a healthy human ear is 20 Hz to 20 000 Hz • Show an understanding of the term ultrasound • Show an understanding that a medium is needed to transmit sound waves • Describe an experiment to determine the speed of sound in air • Relate the loudness and pitch of sound waves to amplitude and frequency • Describe how the reflection of sound may produce an echo	**Supplement** • Describe compression and rarefaction • State typical values of the speed of sound in gases, liquids and solids

4. Electricity and magnetism	
4.1 Simple phenomena of magnetism **Core** • Describe the forces between magnets, and between magnets and magnetic materials • Give an account of induced magnetism • Distinguish between magnetic and non-magnetic materials • Describe methods of magnetisation, to include stroking with a magnet, use of d.c. in a coil and hammering in a magnetic field • Draw the pattern of magnetic field lines around a bar magnet • Describe an experiment to identify the pattern of magnetic field lines, including the direction • Distinguish between the magnetic properties of soft iron and steel • Distinguish between the design and use of permanent magnets and electromagnets	**Supplement** • Explain that magnetic forces are due to interactions between magnetic fields • Describe methods of demagnetisation, to include hammering, heating and use of a.c. in a coil
4.2 Electrical quantities	
4.2.1 Electric charge **Core** • State that there are positive and negative charges • State that unlike charges attract and that like charges repel • Describe simple experiments to show the production and detection of electrostatic charges • State that charging a body involves the addition or removal of electrons	**Supplement** • State that charge is measured in coulombs • State that the direction of an electric field at a point is the direction of the force on a positive charge at that point • Describe an electric field as a region in which an electric charge experiences a force • Describe simple field patterns, including the field around a point charge, the field around a charged conducting sphere and the field between two parallel plates (not including end effects) • Give an account of charging by induction
• Distinguish between electrical conductors and insulators and give typical examples	• Recall and use a simple electron model to distinguish between conductors and insulators

4.2.2 Current **Core** • State that current is related to the flow of charge • Use and describe the use of an ammeter, both analogue and digital • State that current in metals is due to a flow of electrons	**Supplement** • Show understanding that a current is a rate of flow of charge and recall and use the equation $I = Q/t$ • Distinguish between the direction of flow of electrons and conventional current
4.2.3 Electromotive force **Core** • State that the e.m.f. of an electrical source of energy is measured in volts	**Supplement** • Show understanding that e.m.f. is defined in terms of energy supplied by a source in driving charge round a complete circuit
4.2.4 Potential difference **Core** • State that the potential difference (p.d.) across a circuit component is measured in volts • Use and describe the use of a voltmeter, both analogue and digital	**Supplement** • Recall that 1 V is equivalent to 1 J/C
4.2.5 Resistance **Core** • State that resistance = p.d./current and understand qualitatively how changes in p.d. or resistance affect current • Recall and use the equation $R = V/I$ • Describe an experiment to determine resistance using a voltmeter and an ammeter • Relate (without calculation) the resistance of a wire to its length and to its diameter	**Supplement** • Sketch and explain the current-voltage characteristic of an ohmic resistor and a filament lamp • Recall and use quantitatively the proportionality between resistance and length, and the inverse proportionality between resistance and cross-sectional area of a wire
4.2.6 Electrical working **Core** • Understand that electric circuits transfer energy from the battery or power source to the circuit components then into the surroundings	**Supplement** • Recall and use the equations $P = IV$ and $E = IVt$
4.3 Electric circuits	
4.3.1 Circuit diagrams **Core** • Draw and interpret circuit diagrams containing sources, switches, resistors (fixed and variable), heaters, thermistors, light-dependent resistors, lamps, ammeters, voltmeters, galvanometers, magnetising coils, transformers, bells, fuses and relays	**Supplement** • Draw and interpret circuit diagrams containing diodes

4.3.2 Series and parallel circuits **Core** • Understand that the current at every point in a series circuit is the same • Give the combined resistance of two or more resistors in series • State that, for a parallel circuit, the current from the source is larger than the current in each branch • State that the combined resistance of two resistors in parallel is less than that of either resistor by itself • State the advantages of connecting lamps in parallel in a lighting circuit	**Supplement** • Calculate the combined e.m.f. of several sources in series • Recall and use the fact that the sum of the p.d.s across the components in a series circuit is equal to the total p.d. across the supply • Recall and use the fact that the current from the source is the sum of the currents in the separate branches of a parallel circuit • Calculate the effective resistance of two resistors in parallel
4.3.3 Action and use of circuit components **Core** • Describe the action of a variable potential divider (potentiometer) • Describe the action of thermistors and light-dependent resistors and show understanding of their use as input transducers • Describe the action of a relay and show understanding of its use in switching circuits	**Supplement** • Describe the action of a diode and show understanding of its use as a rectifier • Recognise and show understanding of circuits operating as light-sensitive switches and temperature-operated alarms (to include the use of a relay)
4.4 Digital electronics	**Supplement** • Explain and use the terms analogue and digital in terms of continuous variation and high/low states • Describe the action of NOT, AND, OR, NAND and NOR gates • Recall and use the symbols for logic gates • Design and understand simple digital circuits combining several logic gates • Use truth tables to describe the action of individual gates and simple combinations of gates
4.6.3 Transformer **Core** • Describe the construction of a basic transformer with a soft-iron core, as used for voltage transformations • Recall and use the equation $(V_p/V_s) = (N_p/N_s)$ • Understand the terms step-up and step-down • Describe the use of the transformer in high-voltage transmission of electricity • Give the advantages of high-voltage transmission	**Supplement** • Describe the principle of operation of a transformer • Recall and use the equation $I_p V_p = I_s V_s$ (for 100% efficiency) • Explain why power losses in cables are lower when the voltage is high

4.6.4 The magnetic effect of a current **Core** • Describe the pattern of the magnetic field (including direction) due to currents in straight wires and in solenoids • Describe applications of the magnetic effect of current, including the action of a relay	**Supplement** • State the qualitative variation of the strength of the magnetic field over salient parts of the pattern • State that the direction of a magnetic field line at a point is the direction of the force on the N pole of a magnet at that point • Describe the effect on the magnetic field of changing the magnitude and direction of the current
4.6.5 Force on a current-carrying conductor **Core** • Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing: – the current – the direction of the field	**Supplement** • State and use the relative directions of force, field and current • Describe an experiment to show the corresponding force on beams of charged particles
4.6.6 d.c. motor **Core** • State that a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by: – increasing the number of turns on the coil – increasing the current – increasing the strength of the magnetic field	**Supplement** • Relate this turning effect to the action of an electric motor including the action of a split-ring commutator
5. Atomic physics	
5.1 The nuclear atom	
5.1.1 Atomic model **Core** • Describe the structure of an atom in terms of a positive nucleus and negative electrons	**Supplement** • Describe how the scattering of α-particles by thin metal foils provides evidence for the nuclear atom
5.1.2 Nucleus **Core** • Describe the composition of the nucleus in terms of protons and neutrons • State the charges of protons and neutrons • Use the term proton number Z • Use the term nucleon number A • Use the term nuclide and use the nuclide notation ${}^{A}_{Z}X$ • Use and explain the term isotope	**Supplement** • State the meaning of nuclear fission and nuclear fusion • Balance equations involving nuclide notation

5.2 Radioactivity	
5.2.1 Detection of radioactivity **Core** • Demonstrate understanding of background radiation • Describe the detection of α-particles, β-particles and γ-rays (β^+ are not included: β-particles will be taken to refer to β^-)	
5.2.2 Characteristics of the three kinds of emission **Core** • Discuss the random nature of radioactive emission • Identify α, β and γ-emissions by recalling – their nature – their relative ionising effects – their relative penetrating abilities (β^+ are not included, β-particles will be taken to refer to β^-)	**Supplement** • Describe their deflection in electric fields and in magnetic fields • Interpret their relative ionising effects • Give and explain examples of practical applications of α, β and γ-emissions
5.2.3 Radioactive decay **Core** • State the meaning of radioactive decay • State that during α- or β-decay the nucleus changes to that of a different element	**Supplement** • Use equations involving nuclide notation to represent changes in the composition of the nucleus when particles are emitted
5.2.4 Half-life **Core** • Use the term half-life in simple calculations, which might involve information in tables or decay curves	**Supplement** • Calculate half-life from data or decay curves from which background radiation has not been subtracted
5.2.5 Safety precautions **Core** • Recall the effects of ionising radiations on living things • Describe how radioactive materials are handled, used and stored in a safe way	

Symbols and Units

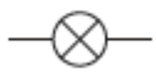
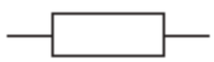
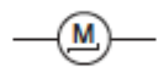
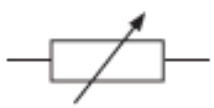
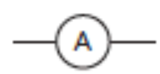
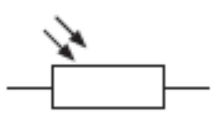
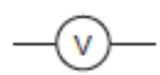
Candidates should be able to give the symbols for the following physical quantities and, where indicated, state the units in which they are measured.

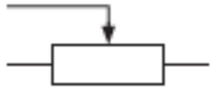
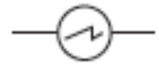
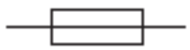
Candidates should be familiar with the following multipliers: M mega, k kilo, c centi, m milli.

Core			Supplement		
Quantity	***Usual symbol***	***Usual unit***	***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	mass	*m*, *M*	mg
time	*t*	h, min, s	time	*t*	ms
density	*ρ*	g/cm^3, kg/m^3			
speed	*u*, *v*	km/h, m/s, cm/s			
acceleration	*a*		acceleration	*a*	m/s^2
acceleration of free fall	*g*		acceleration of free fall	*g*	m/s^2
force	*F*	N			
gravitational field strength	*g*	N/kg			
			momentum	*p*	kg m/s
			impulse		N s
moment of a force		N m			
work done	*W*, *E*	J, kJ, MJ			
energy	*E*	J, kJ, MJ			
power	*P*	W, kW, MW			
pressure	*p*	N/m^2	pressure	*p*	Pa
atmospheric pressure		mm Hg			
temperature	*θ*, *T*	°C			
			thermal capacity (heat capacity)	*C*	J/°C
			specific heat capacity	*c*	J/(g °C), J/(kg °C)

Core			Supplement		
Quantity	***Usual symbol***	***Usual unit***	***Quantity***	***Usual symbol***	***Usual unit***
latent heat	*L*	J			
			specific latent heat	*l*	J/kg, J/g
frequency	*f*	Hz, kHz			
wavelength	*λ*	m, cm			
focal length	*f*	cm			
angle of incidence	*i*	degree (°)			
angle of reflection, refraction	*r*	degree (°)			
critical angle	*c*	degree (°)			
			refractive index	*n*	
potential difference/voltage	*V*	V, mV			
current	*I*	A, mA			
e.m.f.	*E*	V			
resistance	*R*	Ω			
			charge	*Q*	C

Electrical Symbols

cell		switch	
battery of cells	 or 	earth or ground	
power supply		electric bell	
a.c. power supply		buzzer	
junction of conductors		microphone	
lamp		loudspeaker	
fixed resistor		motor	
variable resistor		generator	
thermistor		ammeter	
light dependent resistor		voltmeter	
heater		galvanometer	

potential divider		oscilloscope	
relay coil		AND gate	
transformer		OR gate	
diode		NAND gate	
light-emitting diode		NOR gate	
fuse		NOT gate