**Learner Guide**

Cambridge International AS & A Level

# Cambridge International AS & A Level Physics

## 9702

Cambridge Advanced

CAMBRIDGE
International Examinations

Version 2.0
Updated: 17.02.16

# Contents

# How to use this guide

The guide describes what you need to know about your Cambridge International AS and A Level Physics examination.

It will help you to plan your revision programme for the written examinations and will explain what we are looking for in the answers that you write. It will also help you to revise more effectively using the table given in Section 4, 'What do you need to know'.

The guide contains the following sections:

## Section 1: How will you be tested?

This section gives you information about the written papers and practical tests that will be available for physics. It briefly describes the rules for AS and A Level certifications. It contains a table that summaries the examination papers you will take and the duration of each paper.

## Section 2: Examination advice

This section gives you advice to help you do as well as you can. Some of the ideas are general advice and some are based on the common mistakes that learners make in exams.

## Section 3: What will be tested?

We take account of the following areas in your examination papers:

- Knowledge with understanding
- Handling, applying and evaluating information
- Experimental skills and investigations

This section describes the assessment objectives we use to test you in the examination. It also contains a table showing the percentage of marks allocated to the three assessment objectives.

## Section 4: What you need to know

There are 26 topics in the syllabus. The details of what you need to know are given in this section. You can use it to make notes, check your progress, and as a revision aid.

# Section 1: How will you be tested?

## About the examinations

Find out from your teacher what papers you are going to take.

If you have been entered for AS Level Physics, then you will be taking Papers 1, 2 and 3 in a **single** examination session.

After having received AS Level certification, if you wish to continue your studies to the full A Level qualification, then your AS Level marks will be carried forward and you just take Papers 4 and 5 in the examination session in which you require certification.

If you are taking the full A Level qualification at the end of your course, you have to take all the papers in a single examination session.

## About the papers

The table below gives you information about the physics papers.

| Paper | How long is the paper and how many marks? | What is in the papers? | What is the paper worth as a percentage of the AS examination? | What is the paper worth as a percentage of the A Level examination? |
|---|---|---|---|---|
| Paper 1<br><br>Multiple Choice | 1 hour 15 minutes (40 marks) | The paper will have 40 multiple-choice questions all based on the AS syllabus. You have to answer all the questions. | 31% | 15% |
| Paper 2<br><br>AS Structured Questions | 1 hour 15 minutes (60 marks) | You will have a variable number of structured questions of variable value. You have to answer all the questions and you write on the question paper. | 46% | 23% |
| Paper 3<br><br>Advanced Practical Skills | 2 hours (40 marks) | Each paper will consist of two experiments drawn from different areas of physics.<br>You will be allowed to use the apparatus for each experiment for a maximum of 1 hour. The examiners will not be restricted by the subject content. You have to answer both questions and you write on the question paper. | 23% | 12% |

| Paper | How long is the paper and how many marks? | What is in the papers? | What is the paper worth as a percentage of the AS examination? | What is the paper worth as a percentage of the A Level examination? |
|---|---|---|---|---|
| Paper 4<br><br>A Level Structured Questions | 2 hours<br>(100 marks) | This paper will consist of a variable number of structured questions of variable mark value. All questions will be based on the A Level syllabus, but may include material first encountered in the AS Level syllabus. You have to answer all the questions and you write on the question paper. | | 38% |
| Paper 5<br><br>Planning, Analysis and Evaluation | 1 hour 15 minutes<br>(30 marks) | This paper will consist of two questions of equal mark value based on the practical skills of planning, analysis and evaluation. The examiners will not be restricted by the subject content. You have to answer both questions and you write on the question paper. | | 12% |

# Section 2: Examination advice

## How to use this advice

This advice highlights some common mistakes made by learners. They are collected under various subheadings to help you when you revise a particular topic.

## General advice

- Don't give up if you think that you have calculated the answer to the first part of a question incorrectly. You can still score marks for your follow-on answers in the remaining parts of the question provided that your follow-on calculations are correct.
- Always show your working when answering a question. This will allow you to score marks for your method, even if you make a mistake with the final answer.
- When you have calculated an answer always ask yourself if it is sensible and realistic.
- If it isn't, go back and check your working.
- Ensure that you are fully aware of what data and formulae are given at the front of the question paper. Learn those formulae that are not given.
- During the examination you should monitor your rate of progression through the paper and adjust your rate of working accordingly. This will ensure that towards the end of the examination you will have sufficient time to complete the paper. Completing past papers under timed conditions will allow you to develop an appropriate speed of working.
- Be careful with powers of 10 and take deliberate care if you are keying these into your calculator; make sure that you do not neglect the minus sign of any negative powers and check that your final answer is reasonable.
- All answers should have their correct unit. Pay particular attention to questions that ask you to give the units of your answer and any that do not give a unit in the answer space.

## Advice for the theory papers

### Paper 1 Multiple Choice

- Attempt all questions – a mark is not deducted for a wrong answer.
- Use the space on the examination paper to write down clear working for each question. If you try to do too much working solely on your calculator or in your head, you will make mistakes – many of the *wrong* answers to a question can be reached by manipulating the data in a plausible, but incorrect, way.
- Carefully consider every one of the four possible answers before making your final decision as to which one is correct – although you may initially think that the first or second option is the right answer you will need to look at all four before the correct answer becomes clear.

### Paper 2 and Paper 4 Structured Questions

- If you are asked to sketch a diagram, this implies that a simple, freehand drawing is acceptable. However, care should be taken over proportions and you should clearly show and label any important details.

- If you are asked to sketch a graph, you should give as much information on your sketch as possible. Label each axis with the appropriate quantity and unit. Then draw on the shape of the graph, ensuring that it is correctly positioned relative to the axes and that the different parts of the graph line are in proportion to each other. Don't forget to put on your sketch graph the value of any applicable intercept, asymptote, discontinuity or end point (if these are known).
- Memorise all definitions – you will need to be as precise as possible when quoting them in the examination. Quantities are defined in terms of quantities. Units are defined in terms of units. Remember to use "per" if a ratio is essential to the definition; for example, "pressure" should be defined as "force per unit area" (not "force on unit area").
- A non-numerical answer can sometimes be made clearer by adding a sketch, but remember to ensure that it is clearly labelled and shows all the relevant information.
- Always give your answer to an appropriate number of significant figures. This can be judged from the number of significant figures of the data given in the question.
- Occasionally a question will tell you the number of significant figures that are to be used in your answer and in this case your answer must have exactly the number of significant figures specified.
- Do not prematurely round up figures at an intermediate stage during a calculation – wait until the answer is reached and only then express it to an appropriate number of significant figures.
- When doing algebra ensure that the terms on either side of an "=" sign do in fact equal each other. It is bad practice to write down a string of terms all on the same line and all connected by an "=" sign as any error can result in the first element being of an entirely different nature and/or order to the last. This often leads to errors when calculating the total resistance of a number of resistors connected in parallel.
- Any explanations that you give should be as clear and precise as possible. For example, saying "A increases as B increases" would be insufficient if what is meant is "A is proportional to B".
- When substituting in the value of $g$ use $9.81\,\mathrm{m\,s^{-2}}$ (not $10\,\mathrm{m\,s^{-2}}$).

## Advice for the practical papers

### Paper 3 Practical skills

- Do not panic if the context of the practical experiment appears unfamiliar. Where appropriate the question paper will tell you exactly what to do and how to do it.
- If you find yourself in real difficulty setting up your practical equipment you may ask your supervisor for help. You will only lose one or two marks for this.
- There are a number of things that you can do to save time: Draw a single table for your results in advance of taking any readings and enter your readings in the table as you take them (so that you do not waste time having to copy them up later). This is also important because you must record all your raw readings before you calculate and record any average readings. If the number of readings that you need to take is indicated in the question paper, do not waste time by exceeding this number. Repeat your readings, but remember that it is only necessary to repeat them once (so that you have two sets of values) – do not waste time repeating them more than once.
- All the raw readings of a particular quantity should be recorded to the same number of decimal places which should in turn be consistent with the precision of the measuring instrument.
- The uncertainty in a measurement can sometimes be larger than the smallest interval that can be measured by the measuring equipment. For example, a stopwatch can measure time to a hundredth of a second, but human reaction times will mean that the uncertainty in the reading given by a stopwatch is (typically) 0.1 s to 0.4 s.

- Each column heading in your table must contain both a quantity and its unit. For instance if you have measured time *t* in seconds, your column heading would be written as "t/s" ("t in s" or "t(s)" would also be acceptable). The quantity or unit or both may also be written in words rather than symbols.
- The number of significant figures used in a derived quantity that you calculate from your raw readings should be equal in number to (or possibly one more than) the number of significant figures in the raw readings. For example, if you measure potential difference and current to 2 and 3 significant figures respectively, then the corresponding value of resistance calculated from them should be given to 2 or 3 significant figures, but not 1 or 4. If both were measured to 3 significant figures, then the resistance could be given to 3 (or 4) significant figures.
- When drawing your graph, do not forget to label each axis with the appropriate quantity and unit, using the same format for expressing column headings in a table. Choose a scale such that the plotted points occupy at least half the graph grid in both the *x* and *y* directions. The *x*-axis scale should increase positively to the right and the *y*-axis scale should increase positively upwards. Use a convenient scale such as 1, 2 or 5 units to a 2 cm square as you will then be less likely to make a mistake with the position of your plotted points and it will be easier for you to read off points from your graph if you are calculating the gradient or finding an intercept. Similarly, it is good practice to mark values on at least every other 2 cm square.
- All your plotted points should be on the grid; points in the white margin area will be ignored. Plot all your observations and ensure that they are accurate to half a small square. A fine cross (or an encircled dot) drawn with a sharp pencil is acceptable, but be careful not to obscure the position of your points by your line of best fit or other working.
- When drawing your line of best fit, ensure you have an even balance of points about the line along its whole length. If it is a straight line, use a clear plastic ruler so that you can see points on both sides of the line as it is being drawn.
- Show all your working when calculating a gradient. It is helpful to draw the triangle used to calculate the gradient on the graph and to clearly label the coordinates of the vertices (accurate to half a small square). These values can then be used in the gradient calculation. The length of the hypotenuse of the triangle should be greater than half the length of the graph line.
- If you are required to give a value for the *y*-intercept, it may be possible to directly read it off from your graph from an axis where $x=0$. If this is not possible you can instead calculate the *y*-intercept by using the equation of a straight line. In this case you should substitute into this equation a pair of *x* and *y* values from your line of best fit along with your calculated value of gradient.

## Paper 5 Planning, Analysis and Evaluation

### Planning question

- Do not panic if the context of the question appears unfamiliar to you. During your A Level studies you will have used or learnt about suitable apparatus for completing the task. If you are asked to 'use' any unfamiliar apparatus the question will supply you with all the details that you need to know about.
- Read the question very carefully – it may give you guidance on those aspects of your plan to which you need to pay particular attention. It will also help you to identify the independent and the dependent variables.
- When writing your answer you will need to consider some or all of the following:
  - what apparatus you will use
  - what experimental arrangement will be used
  - what procedure will be followed

  - the independent and dependent variables
  - the means of keeping other variables constant – use the word 'constant' when identifying these variables, saying you will 'control' them is insufficient
  - how the raw data readings will be processed to give the desired result, e.g. what derived quantities you might calculate or what graph you might plot
  - what *relevant* safety precautions should be in place

- The relationship to be tested, given to you in the introduction to the task, will suggest the type of graph to be expected. You will need to describe it as precisely as possible. For example, is it linear, does it pass through the origin? If you choose a logarithmic graph, you will be expected to predict its slope from the given expression.
- When writing your answer you must write down all the information clearly and *explicitly* – the examiner cannot give you marks for things that are vaguely implied.
- Many of the marks can often be scored by having a good working diagram (even if the accompanying explanation is weak) and so you should spend time making sure that your diagram shows all the relevant details and is fully labelled. For example, make clear the exact points between which measurements, such as distance, are to be made.
- The equipment and procedures that you describe in your answer should be realistic and workable.
- One mark is available for describing safe working. This must relate specifically to the apparatus being used. It is not sufficient to write, for example, 'keep all bags and coats out of the way'.
- Additional marks are available for detailed descriptions of apparatus/techniques. There are always more possible answers than marks available, so if you write your plan carefully, then some these marks should be gained as you go along. It is not expected that you write a separate section solely for the detail marks.
- As part of your preparation for this question you should plan some of your own experiments, but this should be done under the close supervision of your teacher. Also practise answering past papers.
- A sketch graph is not necessary, but if drawn it should be consistent with your description of the graph.

### Analysis and Evaluation question

- See advice for Paper 3: the comments regarding significant figures, plotting graphs and calculating gradients and intercepts apply equally for this paper.
- It is particularly important that the rules previously given for significant figures are followed.
- You will be expected to use the uncertainty given in the raw data to find the uncertainty in calculated data. The latter will often involve a function such as a logarithm. This requires plenty of practice, if you are to be able do it with confidence in the examination.
- You will need to be able to translate the calculated uncertainties into error bars on your graph and then to draw the worst acceptable line. Again, this requires plenty of practice.
- Once the graph has been drawn, you will be expected to find uncertainties in both the gradient and the intercept – using your line of best fit and your worst acceptable line. A lot of marks depend on your being able to calculate the uncertainties in the calculated data.
- Every candidate is provided with the same data and so the final values calculated should be very similar.

# Section 3: What will be tested?

## Assessment objectives

The areas of knowledge and skills are called assessment objectives. The theory papers test mainly AO1 (Knowledge with understanding) and AO2 (Handling, applying and evaluating information). The practical papers are used to test you on the AO3 (Experimental skills and investigations). Your teacher will be able to provide you with more detailed information on the assessment objectives.

### AO1: Knowledge with understanding

Questions testing these objectives will often begin questions with one of the following words:

- Define
- State
- Describe
- Explain

| **You should demonstrate knowledge and understanding of:** |
|---|
| • Scientific phenomena<br>• Facts<br>• Laws<br>• Definitions<br>• Concepts<br>• Theories |
| • Scientific vocabulary<br>• Terminology<br>• Conventions (including symbols, quantities and units) |
| • Scientific instruments and apparatus, including techniques of operation and aspects of safety |
| • Scientific quantities and their determination |
| • Scientific and technological applications with their social, economic and environmental implications |

## AO2: Handling, applying and evaluating information

Questions testing these objectives will often begin questions with one of the following words:

- Predict
- Suggest
- Deduce
- Calculate
- Determine

| **You should be able, in words or by using written, symbolic, graphical and numerical forms of presentation, to:** |
|---|
| • Locate information from a variety of sources<br>• Select information from a variety of sources<br>• Organise information from a variety of sources<br>• Present information from a variety of sources |
| • Translate information from one form to another |
| • Manipulate numerical and other data |
| • Use information to identify<br>– patterns<br>– report trends<br>– draw inferences<br>– report conclusions |
| • Present reasoned explanations for<br>– phenomena<br>– patterns<br>– relationships |
| • Make predictions and put forward hypotheses |
| • Apply knowledge, including principles, to new situations |
| • Evaluate information and hypotheses |
| • Demonstrate an awareness of the limitations of physical theories and models |

## AO3: Experimental skills and investigations

Experimental skills are tested in Paper 3 and Paper 5.

| **You should be able to:** |
|---|
| • plan experiments and investigations |
| • collect, record and present observations, measurements and estimates |
| • analyse and interpret data to reach conclusions |
| • evaluate methods and quality of data, and suggest improvements |

## Marks allocated to the assessment objectives

The table below gives a general idea of the allocation of marks to the assessment objectives across the whole assessment, though the balance on each paper may vary slightly.

| Assessment objective | Marks allocated |
|---|---|
| AO1 (Papers 1, 2 and 4) | 37% |
| AO2 (Papers 1, 2 and 4) | 40% |
| AO3 (Papers 3 and 5) | 23% |

# Section 4: What you need to know

The table below lists the things that you may be tested on in the examination.

You can use the table throughout your physics course to check the topic areas you have covered. You can also use the table as a **revision aid**. You can make notes to yourself as you go through the table in the comments column. These could be reminders like:

*'Need to go through some more questions on momentum'*
*'See the teacher about more questions on resistivity'*

or simply place a tick in the comments column to show that you have a decent understanding of that particular physics.

Areas shown in bold type are examined only in the full Advanced Level qualification.

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 1 Physical quantities and units | 1.1 Physical quantities | a) understand that all physical quantities consist of a numerical magnitude and a unit<br>b) make reasonable estimates of physical quantities included within the syllabus | |
| 1 Physical quantities and units | 1.2 SI units | a) recall the following SI base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), **amount of substance** (**mol**)<br>b) express derived units as products or quotients of the SI base units and use the named units listed in this syllabus as appropriate<br>c) use SI base units to check the homogeneity of physical equations<br>d) use the following prefixes and their symbols to indicate decimal submultiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)<br>e) understand and use the conventions for labelling graph axes and table columns as set out in the ASE publication *Signs, Symbols and Systematics* (*The ASE Companion to 16–19 Science*, 2000) | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 1 Physical quantities and units | **1.3 The Avogadro constant** | **a) understand that the Avogadro constant $N_A$ is the number of atoms in 0.012 kg of carbon-12**<br>**b) use molar quantities where one mole of any substance is the amount containing a number of particles equal to the Avogadro constant $N_A$** | |
| 1 Physical quantities and units | 1.4 Scalars and vectors | a) distinguish between scalar and vector quantities and give examples of each<br>b) add and subtract coplanar vectors<br>c) represent a vector as two perpendicular components | |
| 2 Measurement techniques | 2.1 Measurements | a) use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the ranges of magnitude implied by the relevant parts of the syllabus. In particular, candidates should be able to:<br>• measure lengths using rulers, calipers and micrometers<br>• measure weight and hence mass using balances<br>• measure an angle using a protractor<br>• measure time intervals using clocks, stopwatches and the calibrated time-base of a cathode-ray oscilloscope (c.r.o.)<br>• measure temperature using a thermometer<br>• use ammeters and voltmeters with appropriate scales<br>• use a galvanometer in null methods<br>• use a cathode-ray oscilloscope (c.r.o.)<br>• **use a calibrated Hall probe**<br>b) use both analogue scales and digital displays<br>c) use calibration curves | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 2 Measurement techniques | 2.2 Errors and uncertainties | a) understand and explain the effects of systematic errors (including zero errors) and random errors in measurements<br>b) understand the distinction between precision and accuracy<br>c) assess the uncertainty in a derived quantity by simple addition of absolute, fractional or percentage uncertainties (a rigorous statistical treatment is not required) | |
| 3 Kinematics | 3.1 Equations of motion | a) define and use distance, displacement, speed, velocity and acceleration<br>b) use graphical methods to represent distance, displacement, speed, velocity and acceleration<br>c) determine displacement from the area under a velocity-time graph<br>d) determine velocity using the gradient of a displacement-time graph<br>e) determine acceleration using the gradient of a velocity-time graph<br>f) derive, from the definitions of velocity and acceleration, equations that represent uniformly accelerated motion in a straight line<br>g) solve problems using equations that represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitational field without air resistance<br>h) describe an experiment to determine the acceleration of free fall using a falling body<br>i) describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 4 Dynamics | 4.1 Momentum and Newton's laws of motion | a) understand that mass is the property of a body that resists change in motion<br>b) recall the relationship $F = ma$ and solve problems using it, appreciating that acceleration and resultant force are always in the same direction<br>c) define and use linear momentum as the product of mass and velocity<br>d) define and use force as rate of change of momentum<br>e) state and apply each of Newton's laws of motion | |
| 4 Dynamics | 4.2 Non-uniform motion | a) describe and use the concept of weight as the effect of a gravitational field on a mass and recall that the weight of a body is equal to the product of its mass and the acceleration of free fall<br>b) describe qualitatively the motion of bodies falling in a uniform gravitational field with air resistance | |
| 4 Dynamics | 4.3 Linear momentum and its conservation | a) state the principle of conservation of momentum<br>b) apply the principle of conservation of momentum to solve simple problems, including elastic and inelastic interactions between bodies in both one and two dimensions (knowledge of the concept of coefficient of restitution is not required)<br>c) recognise that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation<br>d) understand that, while momentum of a system is always conserved in interactions between bodies, some change in kinetic energy may take place | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 5 Forces, density and pressure | **5.1 Types of force** | a) describe the force on a mass in a uniform gravitational field and on a charge in a uniform electric field<br>b) understand the origin of the upthrust acting on a body in a fluid<br>c) show a qualitative understanding of frictional forces and viscous forces including air resistance (no treatment of the coefficients of friction and viscosity is required)<br>d) understand that the weight of a body may be taken as acting at a single point known as its centre of gravity | |
| 5 Forces, density and pressure | **5.2 Turning effects of forces** | a) define and apply the moment of a force<br>b) understand that a couple is a pair of forces that tends to produce rotation only<br>c) define and apply the torque of a couple | |
| 5 Forces, density and pressure | **5.3 Equilibrium of forces** | a) state and apply the principle of moments<br>b) understand that, when there is no resultant force and no resultant torque, a system is in equilibrium<br>c) use a vector triangle to represent coplanar forces in equilibrium | |
| 5 Forces, density and pressure | **5.4 Density and pressure** | a) define and use density<br>b) define and use pressure<br>c) derive, from the definitions of pressure and density, the equation $\Delta p = \rho g \Delta h$<br>d) use the equation $\Delta p = \rho g \Delta h$ | |
| 6 Work, energy and power | **6.1 Energy conversion and conservation** | a) give examples of energy in different forms, its conversion and conservation, and apply the principle of conservation of energy to simple examples | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 6 Work, energy and power | 6.2 Work and efficiency | a) understand the concept of work in terms of the product of a force and displacement in the direction of the force<br>b) calculate the work done in a number of situations including the work done by a gas that is expanding against a constant external pressure: $W = p\Delta V$<br>c) recall and understand that the efficiency of a system is the ratio of useful energy output from the system to the total energy input<br>d) show an appreciation for the implications of energy losses in practical devices and use the concept of efficiency to solve problems | |
| 6 Work, energy and power | 6.3 Potential energy and kinetic energy | a) derive, from the equations of motion, the formula for kinetic energy $E_k = \frac{1}{2}mv^2$<br>b) recall and apply the formula $E_k = \frac{1}{2}mv^2$<br>c) distinguish between gravitational potential energy and elastic potential energy<br>d) understand and use the relationship between force and potential energy in a uniform field to solve problems<br>e) derive, from the defining equation $W = Fs$, the formula $\Delta E_p = mg\Delta h$ for potential energy changes near the Earth's surface<br>f) recall and use the formula $\Delta E_p = mg\Delta h$ for potential energy changes near the Earth's surface | |
| 6 Work, energy and power | 6.4 Power | a) define power as work done per unit time and derive power as the product of force and velocity<br>b) solve problems using the relationships $P = \frac{W}{t}$ and $P = Fv$ | |
| 7 Motion in a circle | **7.1 Kinematics of uniform circular motion** | **a) define the radian and express angular displacement in radians**<br>**b) understand and use the concept of angular speed to solve problems**<br>**c) recall and use $v = r\omega$ to solve problems** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 7 Motion in a circle | **7.2 Centripetal acceleration and centripetal force** | **a) describe qualitatively motion in a curved path due to a perpendicular force, and understand the centripetal acceleration in the case of uniform motion in a circle**<br>**b) recall and use centripetal acceleration equations** $a = r\omega^2$ **and** $a = \frac{v^2}{r}$<br>**c) recall and use centripetal force equations** $F = mr\omega^2$ **and** $F = \frac{mv^2}{r}$ | |
| 8 Gravitational fields | **8.1 Gravitational field** | **a) understand the concept of a gravitational field as an example of a field of force and define gravitational field strength as force per unit mass** | |
| 8 Gravitational fields | **8.2 Gravitational force between point masses** | **a) understand that, for a point outside a uniform sphere, the mass of the sphere may be considered to be a point mass at its centre**<br>**b) recall and use Newton's law of gravitation in the form** $F = \frac{Gm_1m_2}{r^2}$<br>**c) analyse circular orbits in inverse square law fields, including geostationary orbits, by relating the gravitational force to the centripetal acceleration it causes** | |
| 8 Gravitational fields | **8.3 Gravitational field of a point mass** | **a) derive, from Newton's law of gravitation and the definition of gravitational field strength, the equation** $g = \frac{GM}{r^2}$ **for the gravitational field strength of a point mass**<br>**b) recall and solve problems using the equation** $g = \frac{GM}{r^2}$ **for the gravitational field strength of a point mass**<br>**c) show an appreciation that on the surface of the Earth** $g$ **is approximately constant** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 8 Gravitational fields | **8.4 Gravitational potential** | **a) define potential at a point as the work done per unit mass in bringing a small test mass from infinity to the point**<br>**b) solve problems using the equation $\phi = -\frac{GM}{r}$ for the potential in the field of a point mass** | |
| 9 Deformation of solids | 9.1 Stress and strain | a) appreciate that deformation is caused by a force and that, in one dimension, the deformation can be tensile or compressive<br>b) describe the behaviour of springs in terms of load, extension, elastic limit, Hooke's law and the spring constant (i.e. force per unit extension)<br>c) define and use the terms stress, strain and the Young modulus<br>d) describe an experiment to determine the Young modulus of a metal in the form of a wire | |
| 9 Deformation of solids | 9.2 Elastic and plastic behaviour | a) distinguish between elastic and plastic deformation of a material<br>b) understand that the area under the force-extension graph represents the work done<br>c) deduce the strain energy in a deformed material from the area under the force-extension graph | |
| 10 Ideal gases | **10.1 Equation of state** | **a) recall and solve problems using the equation of state for an ideal gas expressed as $pV = nRT$, where $n$ = amount of substance (number of moles)** | |
| 10 Ideal gases | **10.2 Kinetic theory of gases** | **a) infer from a Brownian motion experiment the evidence for the movement of molecules**<br>**b) state the basic assumptions of the kinetic theory of gases**<br>**c) explain how molecular movement causes the pressure exerted by a gas and hence deduce the relationship $pV = \frac{1}{3}Nm$â$c^2$ä, where $N$ = number of molecules**<br>**[A simple model considering one-dimensional collisions and then extending to three dimensions using $\frac{1}{3}$â$c^2$ä = â$c_x^{\,2}$ä is sufficient.]** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 10 Ideal gases | **10.3 Kinetic energy of a molecule** | **a) recall that the Boltzmann constant *k* is given by the expression $k = \frac{R}{N_A}$**<br>**b) compare $pV = \frac{1}{3}Nm\langle c^2\rangle$ with $pV = NkT$ and hence deduce that the average translational kinetic energy of a molecule is proportional to *T*** | |
| 11 Temperature | **11.1 Thermal equilibrium** | **a) appreciate that (thermal) energy is transferred from a region of higher temperature to a region of lower temperature**<br>**b) understand that regions of equal temperature are in thermal equilibrium** | |
| 11 Temperature | **11.2 Temperature scales** | **a) understand that a physical property that varies with temperature may be used for the measurement of temperature and state examples of such properties**<br>**b) understand that there is an absolute scale of temperature that does not depend on the property of any particular substance (i.e. the thermodynamic scale and the concept of absolute zero)**<br>**c) convert temperatures measured in kelvin to degrees Celsius and recall that $T$ / K = $T$ / °C + 273.15** | |
| 11 Temperature | **11.3 Practical thermometers** | **a) compare the relative advantages and disadvantages of thermistor and thermocouple thermometers as previously calibrated instruments** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 12 Thermal properties of materials | **12.1 Specific heat capacity and specific latent heat** | **a) explain using a simple kinetic model for matter:**<br>**• the structure of solids, liquids and gases**<br>**• why melting and boiling take place without a change in temperature**<br>**• why the specific latent heat of vaporisation is higher than specific latent heat of fusion for the same substance**<br>**• why a cooling effect accompanies evaporation**<br>**b) define and use the concept of specific heat capacity, and identify the main principles of its determination by electrical methods**<br>**c) define and use the concept of specific latent heat, and identify the main principles of its determination by electrical methods** | |
| 12 Thermal properties of materials | **12.2 Internal energy and the first law of thermodynamics** | **a) understand that internal energy is determined by the state of the system and that it can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of a system**<br>**b) relate a rise in temperature of a body to an increase in its internal energy**<br>**c) recall and use the first law of thermodynamics $\Delta U = q + w$ expressed in terms of the increase in internal energy, the heating of the system (energy transferred <u>to</u> the system by heating) and the work done <u>on</u> the system** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 13 Oscillations | **13.1 Simple harmonic oscillations** | **a) describe simple examples of free oscillations**<br>**b) investigate the motion of an oscillator using experimental and graphical methods**<br>**c) understand and use the terms amplitude, period, frequency, angular frequency and phase difference and express the period in terms of both frequency and angular frequency**<br>**d) recognise and use the equation $a = -\omega^2 x$ as the defining equation of simple harmonic motion**<br>**e) recall and use $x = x_0 \sin \omega t$ as a solution to the equation $a = -\omega^2 x$**<br>**f) recognise and use the equations $v = v_0 \cos \omega t$ and $v = \pm \omega \sqrt{x_0^2 - x^2}$**<br>**g) describe, with graphical illustrations, the changes in displacement, velocity and acceleration during simple harmonic motion** | |
| 13 Oscillations | **13.2 Energy in simple harmonic motion** | **a) describe the interchange between kinetic and potential energy during simple harmonic motion** | |
| 13 Oscillations | **13.3 Damped and forced oscillations, resonance** | **a) describe practical examples of damped oscillations with particular reference to the effects of the degree of damping and the importance of critical damping**<br>**b) describe practical examples of forced oscillations and resonance**<br>**c) describe graphically how the amplitude of a forced oscillation changes with frequency near to the natural frequency of the system, and understand qualitatively the factors that determine the frequency response and sharpness of the resonance**<br>**d) appreciate that there are some circumstances in which resonance is useful and other circumstances in which resonance should be avoided** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 14 Waves | **14.1 Progressive waves** | a) describe what is meant by wave motion as illustrated by vibration in ropes, springs and ripple tanks<br>b) understand and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed<br>c) deduce, from the definitions of speed, frequency and wavelength, the wave equation $v = f\lambda$<br>d) recall and use the equation $v = f\lambda$<br>e) understand that energy is transferred by a progressive wave<br>f) recall and use the relationship $intensity \propto (amplitude)^2$ | |
| 14 Waves | **14.2 Transverse and longitudinal waves** | a) compare transverse and longitudinal waves<br>b) analyse and interpret graphical representations of transverse and longitudinal waves | |
| 14 Waves | **14.3 Determination of frequency and wavelength of sound waves** | a) determine the frequency of sound using a calibrated cathode-ray oscilloscope (c.r.o.)<br>b) determine the wavelength of sound using stationary waves | |
| 14 Waves | **14.4 Doppler effect** | a) understand that when a source of waves moves relative to a stationary observer, there is a change in observed frequency<br>b) use the expression $f_o = \frac{f_s v}{(v \pm v_s)}$ for the observed frequency when a source of sound waves moves relative to a stationary observer<br>c) appreciate that Doppler shift is observed with all waves, including sound and light | |
| 14 Waves | **14.5 Electromagnetic spectrum** | a) state that all electromagnetic waves travel with the same speed in free space and recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 14 Waves | **14.6 Production and use of ultrasound in diagnosis** | **a) explain the principles of the generation and detection of ultrasonic waves using piezo-electric transducers**<br>**b) explain the main principles behind the use of ultrasound to obtain diagnostic information about internal structures**<br>**c) understand the meaning of specific acoustic impedance and its importance to the intensity reflection coefficient at a boundary**<br>**d) recall and solve problems by using the equation $I = I_0 e^{-\mu x}$ for the attenuation of ultrasound in matter** | |
| 15 Superposition | 15.1 Stationary waves | a) explain and use the principle of superposition in simple applications<br>b) show an understanding of experiments that demonstrate stationary waves using microwaves, stretched strings and air columns<br>c) explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes | |
| 15 Superposition | 15.2 Diffraction | a) explain the meaning of the term diffraction<br>b) show an understanding of experiments that demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap | |
| 15 Superposition | 15.3 Interference, two-source interference | a) understand the terms interference and coherence<br>b) show an understanding of experiments that demonstrate two-source interference using water ripples, light and microwaves<br>c) understand the conditions required if two-source interference fringes are to be observed<br>d) recall and solve problems using the equation $\lambda = \frac{ax}{D}$ for double-slit interference using light | |
| 15 Superposition | 15.4 Diffraction gratings | a) recall and solve problems using the formula $d \sin\theta = n\lambda$<br>b) describe the use of a diffraction grating to determine the wavelength of light (the structure and use of the spectrometer are not included) | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 16 Communication | **16.1 Communication channels** | **a) appreciate that information may be carried by a number of different channels, including wire-pairs, coaxial cables, radio and microwave links, optic fibres** | |
| 16 Communication | **16.2 Modulation** | **a) understand the term modulation and be able to distinguish between amplitude modulation (AM) and frequency modulation (FM)**<br>**b) recall that a carrier wave, amplitude modulated by a single audio frequency, is equivalent to the carrier wave frequency together with two sideband frequencies**<br>**c) understand the term bandwidth**<br>**d) recall the frequencies and wavelengths used in different channels of communication**<br>**e) demonstrate an awareness of the relative advantages of AM and FM transmissions** | |
| 16 Communication | **16.3 Digital communication** | **a) recall the advantages of the transmission of data in digital form, compared with the transmission of data in analogue form**<br>**b) understand that the digital transmission of speech or music involves analogue-to-digital conversion (ADC) before transmission and digital-to-analogue conversion (DAC) after reception**<br>**c) understand the effect of the sampling rate and the number of bits in each sample on the reproduction of an input signal** | |
| 16 Communication | **16.4 Relative merits of channels of communication** | **a) discuss the relative advantages and disadvantages of channels of communication in terms of available bandwidth, noise, crosslinking, security, signal attenuation, repeaters and regeneration**<br>**b) recall the relative merits of both geostationary and polar orbiting satellites for communicating information** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 16 Communication | **16.5 Attenuation** | **a) understand and use signal attenuation expressed in dB and dB per unit length**<br>**b) recall and use the expression *number of dB* = 10 lg $\left(\frac{P_1}{P_2}\right)$ for the ratio of two powers** | |
| 17 Electric Fields | 17.1 Concept of an electric field | a) understand the concept of an electric field as an example of a field of force and define electric field strength as force per unit positive charge acting on a stationary point charge<br>b) represent an electric field by means of field lines | |
| 17 Electric Fields | 17.2 Uniform electric fields | a) recall and use $E = \frac{\Delta V}{\Delta d}$ to calculate the field strength of the uniform field<br>between charged parallel plates in terms of potential difference and separation<br>b) calculate the forces on charges in uniform electric fields<br>c) describe the effect of a uniform electric field on the motion of charged particles | |
| 17 Electric Fields | **17.3 Electric forces between point charges** | **a) understand that, for any point outside a spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre**<br>**b) recall and use Coulomb's law in the form $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ for the force**<br>**between two point charges in free space or air** | |
| 17 Electric Fields | **17.4 Electric field of a point charge** | **a) recall and use $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ for the field strength of a point**<br>**charge in free space or air** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 17 Electric Fields | **17.5 Electric potential** | **a) define potential at a point as the work done per unit positive charge in bringing a small test charge from infinity to the point**<br>**b) state that the field strength of the field at a point is equal to the negative of potential gradient at that point**<br>**c) use the equation $V = \frac{Q}{4\pi\varepsilon_0 r}$ for the potential in the field of a point charge**<br>**d) recognise the analogy between certain qualitative and quantitative aspects of electric fields and gravitational fields** | |
| 18 Capacitance | **18.1 Capacitors and capacitance** | **a) define capacitance and the farad, as applied to both isolated conductors and to parallel plate capacitors**<br>**b) recall and use $C = \frac{Q}{V}$**<br>**c) derive, using the formula $C = \frac{Q}{V}$, conservation of charge and the**<br>**addition of potential differences, formulae for combined capacitance for capacitors in series and in parallel**<br>**d) solve problems using the capacitance formulae for capacitors in series and in parallel** | |
| 18 Capacitance | **18.2 Energy stored in a capacitor** | **a) deduce, from the area under a potential-charge graph, the equation $W = \frac{1}{2}QV$ and hence $W = \frac{1}{2}CV^2$**<br>**b) show an understanding of the functions of capacitors in simple circuits** | |
| 19 Current of electricity | 19.1 Electric current | a) understand that electric current is a flow of charge carriers<br>b) understand that the charge on charge carriers is quantised<br>c) define the coulomb<br>d) recall and use $Q = It$<br>e) derive and use, for a current-carrying conductor, the expression $I = Anvq$, where $n$ is the number density of charge carriers | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 19 Current of electricity | **19.2 Potential difference and power** | a) define potential difference and the volt<br>b) recall and use $V = \frac{W}{Q}$<br>c) recall and use $P = VI$ and $P = I^2R$ | |
| 19 Current of electricity | **19.3 Resistance and resistivity** | a) define resistance and the ohm<br>b) recall and use $V = IR$<br>c) sketch and discuss the $I$–$V$ characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp<br>d) state Ohm's law<br>e) recall and use $R = \frac{\rho L}{A}$ | |
| 19 Current of electricity | **19.4 Sensing devices** | **a) show an understanding of the change in resistance with light intensity of a light-dependent resistor (LDR)**<br>**b) sketch the temperature characteristic of a negative temperature coefficient thermistor**<br>**c) show an understanding of the action of a piezo-electric transducer and its application in a simple microphone**<br>**d) describe the structure of a metal-wire strain gauge**<br>**e) relate extension of a strain gauge to change in resistance of the gauge** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 20 D.C. circuits | **20.1 Practical circuits** | a) recall and use appropriate circuit symbols as set out in the ASE publication *Signs, Symbols and Systematics* (example circuit symbols are given in Section 5.5.)<br>b) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus<br>c) define electromotive force (e.m.f.) in terms of the energy transferred by a source in driving unit charge round a complete circuit<br>d) distinguish between e.m.f. and potential difference (p.d.) in terms of energy considerations<br>e) understand the effects of the internal resistance of a source of e.m.f. on the terminal potential difference | |
| 20 D.C. circuits | **20.2 Kirchhoff's laws** | a) recall Kirchhoff's first law and appreciate the link to conservation of charge<br>b) recall Kirchhoff's second law and appreciate the link to conservation of energy<br>c) derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series<br>d) solve problems using the formula for the combined resistance of two or more resistors in series<br>e) derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel<br>f) solve problems using the formula for the combined resistance of two or more resistors in parallel<br>g) apply Kirchhoff's laws to solve simple circuit problems | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 20 D.C. circuits | **20.3 Potential dividers** | a) understand the principle of a potential divider circuit as a source of variable p.d.<br>b) recall and solve problems using the principle of the potentiometer as a means of comparing potential differences<br>**c) understand that an electronic sensor consists of a sensing device and a circuit that provides an output that can be registered as a voltage**<br>**d) explain the use of thermistors, light-dependent resistors and strain gauges in potential dividers to provide a potential difference that is dependent on temperature, illumination and strain respectively** | |
| 21 Electronics | **21.1 The ideal operational amplifier** | **a) recall the main properties of the ideal operational amplifier (op-amp)** | |
| 21 Electronics | **21.2 Operational amplifier circuits** | **a) deduce, from the properties of an ideal operational amplifier, the use of an operational amplifier as a comparator**<br>**b) understand the effects of negative feedback on the gain of an operational amplifier**<br>**c) recall the circuit diagrams for both the inverting and the non-inverting amplifier for single signal input**<br>**d) understand the virtual earth approximation and derive an expression for the gain of inverting amplifiers**<br>**e) recall and use expressions for the voltage gain of inverting and of non-inverting amplifiers** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 21 Electronics | **21.3 Output devices** | **a) understand that an output device may be required to monitor the output of an op-amp circuit**<br>**b) understand the use of relays in electronic circuits**<br>**c) understand the use of light-emitting diodes (LEDs) as devices to indicate the state of the output of electronic circuits**<br>**d) understand the need for calibration where digital or analogue meters are used as output devices** | |
| 22 Magnetic fields | **22.1 Concept of magnetic field** | **a) understand that a magnetic field is an example of a field of force produced either by current-carrying conductors or by permanent magnets**<br>**b) represent a magnetic field by field lines** | |
| 22 Magnetic fields | **22.2 Force on a current-carrying conductor** | **a) appreciate that a force might act on a current-carrying conductor placed in a magnetic field**<br>**b) recall and solve problems using the equation $F = BIL \sin\theta$, with directions as interpreted by Fleming's left-hand rule**<br>**c) define magnetic flux density and the tesla**<br>**d) understand how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field using a current balance** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 22 Magnetic fields | **22.3 Force on a moving charge** | **a) predict the direction of the force on a charge moving in a magnetic field**<br>**b) recall and solve problems using $F = BQv \sin\theta$**<br>**c) derive the expression $V_H = \frac{BI}{ntq}$ for the Hall voltage, where $t$ = thickness**<br>**d) describe and analyse qualitatively the deflection of beams of charged particles by uniform electric and uniform magnetic fields**<br>**e) explain how electric and magnetic fields can be used in velocity selection**<br>**f) explain the main principles of one method for the determination of $v$ and $\frac{e}{m_e}$ for electrons** | |
| 22 Magnetic fields | **22.4 Magnetic fields due to currents** | **a) sketch flux patterns due to a long straight wire, a flat circular coil and a long solenoid**<br>**b) understand that the field due to a solenoid is influenced by the presence of a ferrous core**<br>**c) explain the forces between current-carrying conductors and predict the direction of the forces**<br>**d) describe and compare the forces on mass, charge and current in gravitational, electric and magnetic fields, as appropriate** | |
| 22 Magnetic fields | **22.5 Nuclear magnetic resonance imaging** | **a) explain the main principles behind the use of nuclear magnetic resonance imaging (NMRI) to obtain diagnostic information about internal structures**<br>**b) understand the function of the non-uniform magnetic field, superimposed on the large constant magnetic field, in diagnosis using NMRI** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 23 Electromagnetic induction | **23.1 Laws of electromagnetic induction** | **a) define magnetic flux and the weber**<br>**b) recall and use $\Phi = BA$**<br>**c) define magnetic flux linkage**<br>**d) infer from appropriate experiments on electromagnetic induction:**<br>**• that a changing magnetic flux can induce an e.m.f. in a circuit**<br>**• that the direction of the induced e.m.f. opposes the change producing it**<br>**• the factors affecting the magnitude of the induced e.m.f.**<br>**e) recall and solve problems using Faraday's law of electromagnetic induction and Lenz's law**<br>**f) explain simple applications of electromagnetic induction** | |
| 24 Alternating currents | **24.1 Characteristics of alternating currents** | **a) understand and use the terms period, frequency, peak value and root-mean-square value as applied to an alternating current or voltage**<br>**b) deduce that the mean power in a resistive load is half the maximum power for a sinusoidal alternating current**<br>**c) represent a sinusoidally alternating current or voltage by an equation of the form $x = x_0 \sin\omega t$**<br>**d) distinguish between r.m.s. and peak values and recall and solve**<br>**problems using the relationship $I = \frac{I_0}{\sqrt{2}}$ for the sinusoidal case** | |
| 24 Alternating currents | **24.2 The transformer** | **a) understand the principle of operation of a simple laminated iron-cored transformer and recall and solve problems using $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$ for an ideal transformer**<br>**b) understand the sources of energy loss in a practical transformer** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 24 Alternating currents | **24.3 Transmission of electrical energy** | **a) appreciate the practical and economic advantages of alternating current and of high voltages for the transmission of electrical energy** | |
| 24 Alternating currents | **24.4 Rectification** | **a) distinguish graphically between half-wave and full-wave rectification**<br>**b) explain the use of a single diode for the half-wave rectification of an alternating current**<br>**c) explain the use of four diodes (bridge rectifier) for the full-wave rectification of an alternating current**<br>**d) analyse the effect of a single capacitor in smoothing, including the effect of the value of capacitance in relation to the load resistance** | |
| 25 Quantum physics | **25.1 Energy of a photon** | **a) appreciate the particulate nature of electromagnetic radiation**<br>**b) recall and use $E = hf$** | |
| 25 Quantum physics | **25.2 Photoelectric emission of electrons** | **a) understand that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provide evidence for a wave nature**<br>**b) recall the significance of threshold frequency**<br>**c) explain photoelectric phenomena in terms of photon energy and work function energy**<br>**d) explain why the maximum photoelectric energy is independent of intensity, whereas the photoelectric current is proportional to intensity**<br>**e) recall, use and explain the significance of $hf = \Phi + \frac{1}{2}mv_{max}^2$** | |
| 25 Quantum physics | **25.3 Wave-particle duality** | **a) describe and interpret qualitatively the evidence provided by electron diffraction for the wave nature of particles**<br>**b) recall and use the relation for the de Broglie wavelength $\lambda = \frac{h}{p}$** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 25 Quantum physics | **25.4 Energy levels in atoms and line spectra** | **a) show an understanding of the existence of discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) and deduce how this leads to spectral lines**<br>**b) distinguish between emission and absorption line spectra**<br>**c) recall and solve problems using the relation $hf = E_1 - E_2$** | |
| 25 Quantum physics | **25.5 Band theory** | **a) appreciate that, in a simple model of band theory, there are energy bands in solids**<br>**b) understand the terms valence band, conduction band and forbidden band (band gap)**<br>**c) use simple band theory to explain the temperature dependence of the resistance of metals and of intrinsic semiconductors**<br>**d) use simple band theory to explain the dependence on light intensity of the resistance of an LDR** | |
| 25 Quantum physics | **25.6 Production and use of X-rays** | **a) explain the principles of the production of X-rays by electron bombardment of a metal target**<br>**b) describe the main features of a modern X-ray tube, including control of the intensity and hardness of the X-ray beam**<br>**c) understand the use of X-rays in imaging internal body structures, including a simple analysis of the causes of sharpness and contrast in X-ray imaging**<br>**d) recall and solve problems by using the equation $I = I_0 e^{-\mu x}$ for the attenuation of X-rays in matter**<br>**e) understand the purpose of computed tomography or CT scanning**<br>**f) understand the principles of CT scanning**<br>**g) understand how the image of an 8-voxel cube can be developed using CT scanning** | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 26 Particle and nuclear physics | **26.1 Atoms, nuclei and radiation** | a) infer from the results of the α-particle scattering experiment the existence and small size of the nucleus<br>b) describe a simple model for the nuclear atom to include protons, neutrons and orbital electrons<br>c) distinguish between nucleon number and proton number<br>d) understand that an element can exist in various isotopic forms, each with a different number of neutrons<br>e) use the usual notation for the representation of nuclides<br>f) appreciate that nucleon number, proton number, and mass-energy are all conserved in nuclear processes<br>g) show an understanding of the nature and properties of α-, β- and γ-radiations (both $\beta^-$ and $\beta^+$ are included)<br>h) state that (electron) antineutrinos and (electron) neutrinos are produced during $\beta^-$ and $\beta^+$ decay | |
| 26 Particle and nuclear physics | **26.2 Fundamental particles** | a) appreciate that protons and neutrons are not fundamental particles since they consist of quarks<br>b) describe a simple quark model of hadrons in terms of up, down and strange quarks and their respective antiquarks<br>c) describe protons and neutrons in terms of a simple quark model<br>d) appreciate that there is a weak interaction between quarks, giving rise to β decay<br>e) describe $\beta^-$ and $\beta^+$ decay in terms of a simple quark model<br>f) appreciate that electrons and neutrinos are leptons | |

| Topic | Sub-topic | You should be able to: | Comments |
|---|---|---|---|
| 26 Particle and nuclear physics | **26.3 Mass defect and nuclear binding energy** | **a) show an appreciation of the association between energy and mass as represented by $E = mc^2$ and recall and use this relationship**<br>**b) understand the significance of the terms mass defect and mass excess in nuclear reactions**<br>**c) represent simple nuclear reactions by nuclear equations of the form $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$**<br>**d) define and understand the terms mass defect and binding energy**<br>**e) sketch the variation of binding energy per nucleon with nucleon number**<br>**f) explain what is meant by nuclear fusion and nuclear fission**<br>**g) explain the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission** | |
| 26 Particle and nuclear physics | **26.4 Radioactive decay** | **a) infer the random nature of radioactive decay from the fluctuations in count rate**<br>**b) show an appreciation of the spontaneous and random nature of nuclear decay**<br>**c) define the terms activity and decay constant and recall and solve problems using $A = \lambda N$**<br>**d) infer and sketch the exponential nature of radioactive decay and solve problems using the relationship $x = x_0 e^{-\lambda t}$, where $x$ could represent activity, number of undecayed nuclei or received count rate**<br>**e) define half-life**<br>**f) solve problems using the relation $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$** | |

Cambridge International Examinations
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
tel: +44 1223 553554    fax: +44 1223 553558
email: info@cie.org.uk    www.cie.org.uk

A DIVISION OF
CAMBRIDGE ASSESSMENT