Cambridge Assessment International Education

Interactive

Learner Guide

Cambridge International AS & A Level
Physics 9702

For examination from 2022

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Cambridge Pathway

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About this guide

This guide explains what you need to know about your Cambridge International AS & A Level Physics 9702 course and examinations.

This guide will help you to:

- understand what skills you should develop by taking this Cambridge International AS & A Level course
- understand how you will be assessed
- understand what we are looking for in the answers you write
- plan your revision programme
- revise, by providing revision tips and an interactive revision checklist (Section 5).

Following a Cambridge International AS & A Level programme will help you to develop abilities that universities value highly, including a deep understanding of your subject; higher order thinking skills (analysis, critical thinking, problem solving); presenting ordered and coherent arguments; and independent learning and research.

Studying Cambridge International AS & A Level Physics will help you to develop a set of transferable skills, including handling data, practical problem-solving, and applying the scientific method. In addition, it will help you to develop skills such as concern for accuracy and precision, objectivity, integrity, enquiry, initiative and inventiveness.

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Section 1: Syllabus content - what you need to know

This section gives you an outline of the syllabus content for this course.

Content section	Assessment component	Topics included
AS Level Physics	Paper 1 and Paper 2	1. Physical quantities and units 2. Kinematics 3. Dynamics 4. Forces, density and pressure 5. Work, energy and power 6. Deformation of solids 7. Waves 8. Superposition 9. Electricity 10. D.C. circuits 11. Particle physics
AS Level Physics	Paper 3	Practical skills
A Level Physics	Paper 4	In addition to the AS topics 12. Motion in a circle 13. Gravitational fields 14. Temperature 15. Ideal gases 16. Thermodynamics 17. Oscillations 18. Electric fields 19. Capacitance 20. Magnetic fields 21. Alternating currents 22. Quantum physics 23. Nuclear physics 24. Medical physics 25. Astronomy and cosmology
A Level Physics	Paper 5	Practical skills

Make sure you always check the latest syllabus, which is available from our public website.

Prior knowledge

Knowledge of the content of the Cambridge IGCSE™ Physics 0625 (Extended curriculum), or Cambridge International O Level Physics 5054, is assumed.

Key concepts

Key concepts are essential ideas that help you to develop a deep understanding of your subject and make links between different aspects of the course. The key concepts for Cambridge International AS & A Level Physics are:

- **Models of physical systems**

  Physics is the science that seeks to understand the behaviour of the Universe. The development of models of physical systems is central to physics. Models simplify, explain and predict how physical systems behave.

- **Testing predictions against evidence**

  Physical models are usually based on prior observations, and their predictions are tested to check that they are consistent with the behaviour of the real world. This testing requires evidence, often obtained from experiments.

- **Mathematics as a language, and problem-solving tool**

  Mathematics is integral to physics, as it is the language that is used to express physical principles and models. It is also a tool to analyse theoretical models, solve quantitative problems and produce predictions.

- **Matter, energy and waves**

  Everything in the Universe comprises matter and/or energy. Waves are a key mechanism for the transfer of energy and are essential to many modern applications of physics.

- **Forces and fields**

  The way that matter and energy interact is through forces and fields. The behaviour of the Universe is governed by fundamental forces with different magnitudes that interact over different distances. Physics involves study of these interactions across distances ranging from the very small (quantum and particle physics) to the very large (astronomy and cosmology).

Section 2: How you will be assessed

Cambridge International AS Physics makes up the first half of the Cambridge International A Level course in Physics and provides a foundation for the study of Physics at Cambridge International A Level.

About the examinations

There are three papers you take to obtain an AS Level Physics qualification:

- Paper 1 – Multiple Choice
- Paper 2 – AS Level Structured Questions
- Paper 3 – Advanced Practical Skills

There are five papers you take to obtain an A Level Physics qualification:

- Paper 1 – Multiple Choice
- Paper 2 – AS Level Structured Questions
- Paper 3 – Advanced Practical Skills
- Paper 4 – A Level Structured Questions
- Paper 5 – Planning, Analysis and Evaluation

There are two different routes you can take to obtain an A Level Physics qualification:

- Staged over two years
  Year 1: Papers 1, 2 and 3 (in the same examination series e.g. in May/June)
  Year 2: Papers 4 and 5 (in the same examination series e.g. in May/June)
- In the same examination series
  Papers 1, 2, 3, 4 and 5.

About the papers

The table gives you further information about the examination papers:

Component	Time and marks	Questions	Percentage of qualification
Paper 1 Multiple Choice (AS and A Level)	1 hour 15 minutes 40 marks	40 multiple choice questions Questions are based on the AS Level syllabus content. Each question will have four possible responses.	31% of the AS Level 15.5% of the A Level
Paper 2 AS Level Structured Questions (AS and A Level)	1 hour 15 minutes 60 marks	Structured questions Questions are based on the AS Level syllabus content	46% of the AS Level 23% of the A Level
Paper 3 Advanced Practical Skills (AS and A Level)	2 hours 40 marks	Practical work and structured questions Two questions based on the experimental skills in the Practical assessment section of the syllabus. The context of the questions may be outside the syllabus content. Each question is worth 20 marks. The first question will include the collecting data, plotting a graph and drawing conclusions. The second question will include collecting data, drawing a conclusion and evaluating the method and suggesting improvements.	23% of the AS Level 11.5% of the A Level

Component	Time and marks	Questions	Percentage of qualification
Paper 4 A Level Structured Questions (A Level only)	2 hours 100 marks	Structured questions Questions are based on the A Level syllabus content; knowledge of material from the AS Level syllabus content will be required.	38.5% of the A Level
Paper 5 Planning, Analysis and Evaluation (A Level only)	1 hour 15 minutes 30 marks	Two questions based on the experimental skills in the Practical assessment section of the syllabus. The context of the questions may be outside the syllabus content. Each question is worth 15 marks. Question 1 will be a planning question, in which you will be required to design an experimental investigation of a given problem. Your answer will include a diagram with an extended piece of writing. Question 2 will be an analysis, conclusion and evaluation question. You will be given an equation and some experimental data to find the value of a constant with an estimate of the uncertainty in your answer. This question will be structured.	11.5% of the A Level

Section 3: What skills will be assessed?

The examiners take account of the following skills areas (**assessment objectives**) in the examinations:

- AO1 Knowledge and understanding
- AO2 Handling, applying and evaluating information
- AO3 Experimental skills and investigations

Assessment objectives (AO)	What does the AO mean?
AO1 Knowledge and Understanding	You should be able to demonstrate knowledge and understanding of: • scientific phenomena, facts, laws, definitions, concepts and theories • scientific vocabulary, terminology and conventions (including symbols, quantities and units) • scientific instruments and apparatus, including techniques of operation and aspects of safety • scientific quantities and their determination • scientific and technological applications with their social, economic and environmental implications.
AO2 Handling, applying and evaluating information	You should be able to handle, apply and evaluate information in words or using other forms of presentation (e.g. symbols, graphical or numerical) to: • locate, select, organise and present information from a variety of sources • translate information from one form to another • manipulate numerical and other data • use information to identify patterns, report trends and draw conclusions • give reasoned explanations for phenomena, patterns and relationships • make predictions and construct arguments to support hypotheses • make sense of new situations • evaluate hypotheses • demonstrate an awareness of the limitations of physical theories and models • solve problems.
AO3 Experimental skills and investigations	You should be able to: • plan experiments and investigations • collect, record and present observations, measurements and estimates • analyse and interpret experimental data to reach conclusions • evaluate methods and quality of experimental data, and suggest improvements to experiments.

It is important that you know the different weightings (%) of the assessment objectives, as this affects how the examiner will assess your work.

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

Assessment objectives as a percentage of each qualification

Assessment objective	Weighting at AS Level %	Weighting at A Level %
AO1 Knowledge and understanding	40	40
AO2 Handling, applying and evaluating information	40	40
AO3 Experimental skills and investigations	20	20
Total	100	100

Assessment objectives as a percentage of each component or paper

Assessment objective	Weighting in AS Level %				
	Paper 1	**Paper 2**	**Paper 3**	**Paper 4**	**Paper 5**
AO1 Knowledge and understanding	50	50	0	50	0
AO2 Handling, applying and evaluating information	50	50	0	50	0
AO3 Experimental skills and investigations	0	0	100	0	100
Total	100	100	100	100	100

Command Words

Questions in examinations will often have a command word which should help you to answer the question is sufficient detail. The table below includes command words used in the assessment for this syllabus. The use of the command word will relate to the subject context.

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

Section 4: Example candidate response

This section takes you through an example question and candidate response. It will help you to see how to identify the command words within questions and to understand what is required in your response. Understanding the questions will help you to know what you need to do with your knowledge. For example, you might need to state something, calculate something, find something or show something.

All information and advice in this section is specific to the example question and response being demonstrated. It should give you an idea of how your responses might be viewed by an examiner but it is not a list of what to do in all questions. In your own examination, you will need to pay careful attention to what each question is asking you to do.

This section is sructured as follows:

Question

Command words have been highlighted and their meaning explained. This will help you to understand clearly what is required. For more information go to www.cambridgeinternational.org/exam-administration/what-to-expect-on-exams-day/command-words

Example candidate response

This is a sample answer of a high standard. Points have been highlighted to show you how to answer a question.

General advice

These tips will help you to answer questions in general.

Question

This question is assessing Topic 9 Electricity and Topic 10 D.C. Circuits on the AS Level Physics syllabus. This type of question is likely to occur on Paper 2 – AS Level Structured Questions.

(a) The command word is "explain". In this part the term that needs to be explained is "quantised".

This question part is clearly an example of assessing Assessment Objective (AO1). Candidates should be able to demonstrate knowledge and understanding of the terms. Candidates should learn definitions in precise detail - the omission of a key word may prevent credit from being awarded.

(a) Electric current is a flow of charge carriers. The charge on the carriers is quantised. Explain what is meant by *quantised*.

.....[1]

(b) A battery of electromotive force (e.m.f.) 9.0V and internal resistance 0.25Ω is connected in series with two identical resistors X and a resistor Y, as shown in Fig. 7.1.

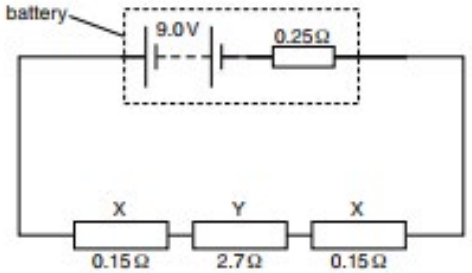

Fig. 7.1

The resistance of each resistor X is 0.15Ω and the resistance of resistor Y is 2.7Ω.

(i) Show that the current in the circuit is 2.8A.

(b)(i) The command word in this part is "show". To gain credit in this type of question all the working should be shown with clear explanations.

In "show" type questions there may be the need to convert the units, e.g. millimetre (mm) to metre (m). These conversions should be demonstrated in the working and not arbitrarily added at the end.

(ii) Calculate the potential difference across the battery.

(b)(ii) The command word in this part is "calculate".

In this question part full marks would be scored for the correct answer although candidates should show all their working.

potential difference = ... V [2]

(c) Each resistor X connected in the circuit in (b) is made from a wire with a cross-sectional area of 2.5 mm^2. The number of free electrons per unit volume in the wire is 8.5×10^{29} m^{-3}.

(i) Calculate the average drift speed of the electrons in X.

(c)(i) The command word in this part is again "calculate".

Candidates should be confident in converting the units of areas and volumes.

Candidates are also being assessed in this question on the correct use of a calculator to multiply and divide numbers in standard form.

drift speed = ... m s^{-1} [2]

(ii) The two resistors X are replaced by two resistors Z made of the same material and length but with half the diameter.

Describe and explain the difference between the average drift speed in Z and that in X.

.....

.....

.....

.....[2]

[Total: 10]

(c)(ii) There are two words in this part – "describe" and "explain". Answers to this question need both a description of how the average drift speed changes and an explanation. Since the question states that the resistors are now half the diameter, it is expected that the answers would be quantitative. Answers that describe the resistance as increasing without describing the actual factor in the change lack the necessary detail.

To answer this type of question, it is useful to identify all the quantities and state whether they remain constant or change.

Example candidate response

(a) Electric current is a flow of charge carriers. The charge on the carriers is quantised. Explain what is meant by *quantised*.

It means that charge is made up of discrete amounts [1]

The candidate has correctly stated that charge exists in discrete amounts. This is basic theory that all candidates should know. The syllabus states that candidates should be able to understand that the charge on charge carriers is quantised.

Common incorrect answers include repeating the question, e.g. charge is quantised, or giving part of an answer e.g. quantised means expressed as a numerical value or charge is divided among the electrons.

(b) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance 0.25 Ω is connected in series with two identical resistors X and a resistor Y, as shown in Fig. 7.1.

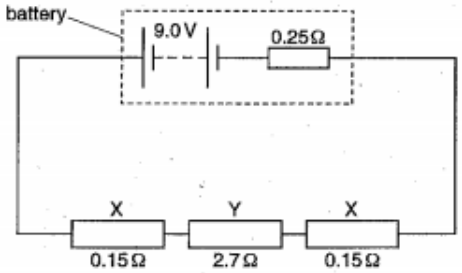

Fig. 7.1

The resistance of each resistor X is 0.15 Ω and the resistance of resistor Y is 2.7 Ω.

(i) Show that the current in the circuit is 2.8 A.

$I = \frac{V_{battery}}{R_{total}}$

$I = \frac{9}{0.25+0.15+2.7+0.15} = \frac{9}{3.25}$

Method to determine the total resistance.

$I = 2.769 \approx 2.8\,A$

Evidence that the calculation is complete.

[3]

The answer shows clearly the method by stating the equation. The explanation is helped by using the words "battery" and "total". It is expected that equations should include a quantity on the left-hand side (in this case *I*). The candidate in this example has scored the second mark by clearly working out the total resistance of the circuit. This could be written as a separate line. The candidate calculates the answer (2.769) and then rounds it to two significant figures – this demonstrates that the calculation has been completed correctly.

A common mistake in this question would be to ignore the internal resistance of the battery. In this case the first mark could still be scored.

(ii) Calculate the potential difference across the battery.

p.d. across battery = p.d. across 3 resistors

$V = IR$

$V = 2.8\,A \times 3.0\,\Omega$

Candidate uses the current given from the previous part.

potential difference = 8.4 V [2]

The candidate has shown an understanding by stating that the p.d. across the battery is equal to the p.d. across the three resistors. It is expected that the current given in the previous part should be used although as the mark scheme indicates it would be acceptable to have used 2.77 A or 2.769 A from the previous part.

The first mark is awarded for the selection of the correct values for the current and resistance in a correct equation. An answer of 8.3 V or 8.4 would score both marks.

The candidate would also have gained credit for using the equation $V = E - Ir$; in this case the first mark would again be for selecting the correct values and substituting them into a correct equation, i.e.

$V = 9.0 - 2.8 \times 0.25 = 9.0 - 0.70 = 8.3$ V.

Common incorrect answers include determining the potential difference across the internal resistance or the 'lost volts' in the battery ($2.8\ A \times 0.25\ \Omega = 0.70$ V) or writing down / calculating the e.m.f. of the power supply (9.0 V).

(c) Each resistor X connected in the circuit in **(b)** is made from a wire with a cross-sectional area of 2.5 mm^2. The number of free electrons per unit volume in the wire is 8.5×10^{29} m^{-3}.

(i) Calculate the average drift speed of the electrons in X.

$I = Anvq$

$v = \frac{I}{Anq} = \frac{2.8}{2.5 \times 10^{-3} \times 8.5 \times 10^{29} \times 1.6 \times 10^{-19}}$

Incorrect conversion of mm^2 to m^2

Should be 2.5×10^{-6} m^2

drift speed = 8.2×10^{-9} ms^{-1} [2]

This candidate has clearly demonstrated the use of the correct equation $I = Anvq$ which is a formula given on page two of the question paper. The candidate then correctly rearranges the equation before substituting in the numbers. It is good practice to substitute the numbers in the same order as the quantities appear in the original equation.

The candidate has made an error in converting mm^2 to m^2 – it should be 2.5×10^{-6}. Since the answer is correct following this error, one mark is awarded. This is a common mistake that candidates make. Candidates should be confident in converting the units of areas and volumes.

(ii) The two resistors X are replaced by two resistors Z made of the same material and length but with half the diameter.

Describe and explain the difference between the average drift speed in Z and that in X.

Since the drift speed is inversely proportional to cross-sectional area the drift speed in Z will be increased by 4 times. It will be four times more than X as the area is four times less than X. [2]

[Total: 10]

Incorrectly assumes that the current is constant

Correctly identifies the change in area

The candidate has correctly identified that the resistance increases by a factor of four but the candidate has incorrectly assumed that the current is constant. Thus, the candidate only scores the first mark. To gain full credit it was important that the candidate referred back to the circuit diagram.

The candidate has written more than the answer lines allow. In this case, it is obvious where the extra answer to this question is written. If the candidate is to write anywhere else in the question paper, the candidate should indicate where the answer is continued e.g. "cont. on page 12".

General advice

It is always a good idea to read the question carefully, noticing the command words and key instructions.

You may want to underline them to help you think what they mean.

Read the question first and pause to think about what you need to do to answer the question set – this will help you to choose an efficient method so you don't waste time in the examination. Don't forget that your working is part of your solution and you can gain marks even if you don't get as far as a correct answer. If you go on to use *your* values correctly, even if they are wrong, you can often still get subsequent marks in later questions.

Using correct acceptable symbols and notation in your working will help you to think clearly as well as making it easier for the examiner to understand what you have done.

If you have had a good attempt at a question and still not managed to finish it, it is best to move on to another question and come back to it later. This will help you to make good use of the time you have available.

Allow a few minutes at the end of the examination to check your work. This will help you to spot errors in your working that could lose you marks. This is another good reason for showing your working – it makes it easier for you to check your answers.

Section 5: Revision

This advice will help you revise and prepare for the examinations. It is divided into general advice and specific advice for each of the papers.

Use the tick boxes to keep a record of what you have done, what you plan to do or what you understand.

General advice

Before the examination

Start early – do not leave it until just a couple of weeks before the examinations.

Look after yourself. Do ensure you have plenty of sleep, eat well and take some exercise.

Find out when the examinations are and plan your revision so you have enough time for each topic. A revision timetable will help you.

Make sure you are organised so that you do not waste time looking for books or notes.

Find out how long each Paper is and how many questions you have to answer – see Section 2 of this guide.

Make revision notes; try different styles of notes. Discover what works best for you.

Work for short periods then have a break. Revise small sections of the syllabus at a time.

Build your confidence by practising questions on each of the topics.

Make sure you practise lots of past examination questions so that you are familiar with the format of the examination papers. You could time yourself when doing a paper so that you know how quickly you need to work in the real examination.

Make sure you understand the meanings of the command words used in the syllabus.

Look at mark schemes to help you to understand how the marks are awarded for each question.

Make sure you are familiar with the mathematical notation that you need for this syllabus. Your teacher will be able to advise you on what is expected.

When your teacher returns marked work, make a note of what was not correct and revise these topics.

Check which data and formulae are provided in the examination papers, and which ones you need to learn.

Check which definitions and formulae you need to learn.

During the examination

Read the instructions carefully and answer **all** the questions.

Check the number of marks for each question or part question. This helps you to judge how long you should be spending on the response. You don't want to spend too long on some questions and then run out of time at the end.

Do not leave out questions or parts of questions. Remember, no answer means no mark.

You do not have to answer the questions in the order they are printed in the answer booklet. You may be able to do a later question more easily then come back to an earlier one for another try.

Read each question very carefully. Misreading a question can cost you marks:

- Identify the command words – you could underline or highlight them.
- Identify the other key words and perhaps underline them too.
- Identify data and perhaps underline them too.
- Try to put the question into your own words to understand what it is really asking.

Read all parts of a question before starting your answer. Think carefully about what is needed for each part.

Look very carefully at the information you are given.

- For diagrams, look at the labels and data.
- For graphs, read the axes to find out both the quantity and the unit.
- Try using coloured pencils or pens to pick out anything that the question asks you about.

Answer the question set. This is very important!

- Use your knowledge and understanding.
- Do not just try all the methods you know. Only use the ones you need to answer the question.

Make sure that you have answered everything that a question asks. Sometimes one sentence asks two things, e.g. 'State and explain'. It is easy to concentrate on the first "stating" and omitting to "explain".

Always show your working. Marks are usually awarded for using correct steps in the method even if you make a mistake somewhere.

Don't cross out any working until you have replaced it by trying again. Even if you know it's not correct you may still be able to get method marks. If you have made two or more attempts, make sure you cross out all except the one you want marked.

Annotated diagrams and graphs can help you, and can be used to support your answer. Use them whenever possible but do not repeat the information in words.

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.

Make sure all your numbers are clear, for example make sure your '1' doesn't look like a '7' and a 's' does not look like a '5'

If you need to change a word or a number, or even a sign (+ to – for example), it is better to cross out your work and rewrite it. Don't try to write over the top of your previous work as it will be difficult to read and you may not get the marks.

Advice for all Papers

Remember that you are demonstrating your knowledge and understanding when you answer examination questions.

Ensure that you are fully aware of what data and formulae are given at the front of the question paper.

Learn the definitions and formulae that need to be recalled.

Learn the standard circuit symbols.

Look for details of the depth of answer required. For example, a question worth one mark ([1]) is likely to need a simple phrase or a simple number whereas a question worth three marks ([3]) is likely to need three separate points or for a calculation question two lines of working before an answer.

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.

Do not 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.

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.

Do practice using your calculator so that you know how to use it for fractions, powers, square roots and standard form

Check that you know how to use your calculator in degrees if you need to find a sine (sin), cosine (cos) or tangent (tan).

All answers should have their correct unit with the appropriate power of ten. 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.

You should not give more than one answer to a question. If multiple answers are provided that are contradictory, then you cannot be awarded credit for a correct answer.

Advice for all Paper 1 Multiple Choice

Do practise answering multiple choice questions before your examinations.

Attempt all of the questions – a mark is not deducted for a wrong answer.

There are 40 questions to answer in 75 minutes, i.e. you need to read, understand and answer each question in less than two minutes. Some questions will be quicker to answer than others.

Read each question thoroughly before reviewing answer options.

Questions usually use the command words "which" or "what".

Underline the key data or terms, as you read each question.

Pay particular attention to the words such as "not", "sometimes", "always" and "never".

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.

If you see the response that you anticipated, circle it and then check to be sure that none of the other responses is better.

Eliminate answer options which you are sure are incorrect before selecting the answer you believe is correct.

It is generally better to answer all the questions in order so that you do not make an error completing the answer sheet. However, each question needs to be answered in less than two minutes so if you do have difficulty answering a question, do move on and come back to answer it later. Perhaps star the question number on the paper to remind you to look at it.

If you are coming to the end of the examination, make an educated guess at any question you have not yet answered.

Do not choose your answer based on the number of times each letter appears or any (apparent) pattern in the answers.

Advice for Paper 2

The paper will have a number of questions with sub-parts which will total 60 marks. The time allowed is 75 minutes; you should aim to complete almost mark a minute. This will allow you time to review your work.

Read each question thoroughly before reviewing answer options.

Underline the key data or terms, as you read each question.

Ensure you are aware of the key quantities, symbols and units that are used in the question papers.

Ensure you can recognise and understand the unit prefixes.

Ensure you know the standard circuit symbols.

Learn all the laws and definitions – you will need to be as precise as possible when quoting them in the examination. Quantities are defined in terms of other quantities and should not include units (for example, speed is defined as distance / time, not as distance per second). 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").

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. Avoid giving answers to one significant figure e.g. 4.0 is better than 4.

In general, a final answer to a numerical calculation should be expressed as a decimal number and not left as a fraction.

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 final 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.

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.

In 'show that' questions, you should methodically present every step of your calculation as well as the final answer

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".

If you are asked to explain what happens when a quantity is half a previous value, then your answer should also be quantitative.

When substituting in the value of g use 9.81 m s–2 (not 10 m s–2) as this is the value from the data given to you.

When interpreting graphs, think what the gradient and the area under the line could represent.

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 appropriate data.

Advice for Paper 3

Each question should take one hour. You only have the use of the apparatus for one hour for each question.

Read the whole question carefully so that you know what you are aiming to do.

Identify the apparatus that you need to use.

The question paper will guide you as to exactly what you have to do. Do not panic if the context of the practical experiment appears unfamiliar.

If you find yourself in real difficulty setting up your practical equipment you may ask your supervisor for help. The Examiner will not award full credit for the collection of data but you will not lose access to a large number of marks. By asking for help you will be able to take measurements and access marks later for the recording of data, and analysis of your results.

Think carefully how you will take the measurements using the apparatus provided.

Repeat readings where appropriate.

Take the number of readings indicated by the question paper. Do not waste time by exceeding this number.

Ensure you know how to use common laboratory apparatus such as millimetre scales, protractors, top-pan balances, newton meters, analogue or digital electrical meters, measuring cylinders, calipers, micrometer screw gauges, stop-watches and thermometers.

Remember to measure all your data to the precision of the measuring instrument, e.g. if you are measuring a length using a millimetre scale then 10.0 cm is a length measured to the nearest millimetre (not 10 cm).

Think about the maximum and minimum values you could take so that you have a large range of values.

Draw a single table for your results in advance of taking any readings and enter your readings in the table as you take them. You should not waste time recording results in rough and then copying them up later.

Each column heading in your table must contain both a quantity and its unit. For example, 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.

Record all your raw readings in the results table. Include repeat readings where appropriate.

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 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, label each axis with the appropriate quantity and unit, using the same format for column headings in a table.

Choose a scale so that the plotted points occupy at least half the graph grid in both the x and y directions. The x-axis scale and the y-axis scale do not need to start from zero.

The x-axis scale should increase positively to the right and the y-axis scale should increase positively upwards. Use a sensible 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.

You should mark scale values on each axis at least every 2 cm square.

All your data from your table should be plotted on the on the grid; points in the white margin area will be ignored.

All the data from your table should be plotted to better than 1 mm (i.e. less than 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. The line should be drawn from at least the furthest left data point. It is best to use a 30 cm ruler so that there are no joins or kinks in the line.

When you draw a curve, it should be smooth with no sudden changes.

Remember if you are required to draw a tangent, it is a straight line which touches the curve at one point only.

If you have an anomalous point, circle it and label it. The anomalous should be ignored when you draw your line of best fit.

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 less than half a small square). The length of the hypotenuse of the triangle should be greater than half the length of the graph line.
Do not use data points from the table.

$$\text{Gradient} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

If you are required to give a value for the y-intercept, it may be possible to directly read it off from your graph when the x-axis has an origin, i.e. x = 0.

If it is not possible to read the y-intercept from the graph, use the gradient value and substitute a point from the line of best-fit into the equation of a straight line ($y = mx + c$). You can save time by using one of the pairs of data points used to determine the gradient.

Rearrange the given relationship into the form of the equation of a straight line ($y = mx + c$) to determine constants. Again, show your working.

Ensure that your unit are compatible, e.g. if you are asked to determine a value for the acceleration of free fall g and you have measured distances in centimetres (cm) and time in seconds (s), then g will be measured in cm s^{-2}.

The uncertainty in a measurement depends on both the precision of the instrument and the way the measurement is carried out. For example, a stop-watch may measure to the nearest 0.01 s, but the uncertainty in measuring a time is likely to be greater than ± 0.1 s, given the uncertainty introduced by reaction time.

$$\text{Percentage uncertainty} = \frac{\text{absolute uncertainty in the measurement}}{\text{(mean) measurement}} \times 100$$

When measurements are repeated the absolute uncertainty in the repeated measurement is half the range of the repeated readings, i.e.

$$\text{Absolute uncertainty in repeated measurement} = \frac{\text{maximum reading} - \text{minimum reading}}{2}$$

When determining whether experimental data supports a give hypothesis with only two sets of data, calculate the values of a constant in each case. Show your working when rearranging the equation and substituting in your experimental results.

When determining whether a relationship containing a constant is supported, determine the percentage difference between the two values and compare it with a the given criterion, e.g. if you have determined two values of a constant k_1 and k_2

$$\text{Percentage difference} = \frac{k_2 - k_1}{k_1} \times 100 \text{ or } \frac{k_2 - k_1}{k_2} \times 100 \text{ or } \frac{k_2 - k_1}{\text{average } k} \times 100$$

When identifying and describing limitations in an experimental procedure, it is helpful to consider each of the measurements you have taken, e.g. if you have measured a small distance with a ruler reading to the nearest millimetre, the percentage uncertainty in this measurement is likely to be large.

When suggesting improvements, consider an improvement for each of the limitations that you have described.

Advice for Paper 4

The paper will have a number of questions with sub-parts which will total 100 marks. The time allowed is 120 minutes (2 hours); you should aim to complete almost mark a minute (a mark every 70 seconds). This will allow you time to review your work.

Read each question thoroughly; underline the key data or terms, as you read each question.

Ensure you are aware of the key quantities, symbols and units that are used in the question papers.

Ensure you can recognise and understand the unit prefixes.

Ensure you know the standard circuit symbols.

Learn all definitions – you will need to be as precise as possible when quoting them in the examination. Quantities are defined in terms of other quantities and should not include units (for example, speed is defined as distance / time, not as distance per second). In defining quantities, ensure that the definition you give is dimensionally correct. This often requires use of the phrase 'per unit' where the quantity being defined is the ratio between two other quantities, or 'product' where the quantity being defined is two other quantities being multiplied together.

Use technical language accurately. Examples of words that are often confused are atom and molecule, nuclide and nucleus, and force and field.

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. Avoid giving answers to one significant figure e.g. 4.0 is better than 4.

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.

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.

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".

Similarly if you are asked to explain what happens when a quantity is half a previous value, then your answer should also be quantitative.

When substituting in the value of g use 9.81 m s^{-2} (not 10 m s^{-2}) as this is the value from the data given to you.

When interpreting graphs, think what the gradient and the area under the line could represent.

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 appropriate data.

Ensure you are confident on the use of logarithms.

You should also be confident on the use of natural logarithms. You will need to use them for the decay of a capacitor, nuclear decay and the attenuation of ultrasound and X-rays.

Advice for Paper 5

The total time to answer both questions is one hour fifteen minutes.

Read both questions carefully before you start. This gives you "sub conscious" thinking time.

Question 1 - Planning question

Read the question very carefully – it may give you guidance on those aspects of your plan to which you need to pay particular attention.

Identify the independent variable and the dependent variable from the given relationship – perhaps highlight these variables on the question paper.

Identify the quantities that need to be kept constant so that the experiment will be a fair test. Use the word 'constant' when identifying these quantities; saying you will 'control' them is insufficient.

Choose apparatus that will enable a workable experiment to be performed in a laboratory.

Draw a labelled detailed diagram. All the apparatus should be labelled. For example, if you are using protractor, mark the position of the protractor clearly on the diagram.

Add appropriate measurements to the diagram so that you can refer to them when describing the experiment to be performed. For example, make clear the exact points between which measurements, such as distance, are to be made.

Describe the procedure to be followed. Include how the independent and dependent variables will be measured.

Describe how other constant quantities may be measured.

Describe how to use laboratory apparatus that you have seen and used during your AS and A Level practical course safely.

If measurements need to be repeated, describe in detail what is being repeated.

Explain how any quantities may be calculated from measured values

Consider the safety precautions. The safety precaution relevant to the experiment is required, including a reason why the safety precaution is selected. General laboratory safety rules such as "tie hair back" are unlikely to score marks.

To test the relationship, you should determine what graph should be plotted. Rearrange the given relationship into the equation of a straight line. Identify the quantities that the gradient and y-intercept represent.

You should understand how to test relationships of the forms y = mx + c, y = axn and y = aekx.

You should state the quantities to be plotted explicitly. Perhaps sketch graph axes.

Remember to explain how your graph will demonstrate that the relationship is valid, e,g, if you are testing a directly proportional relationship, "if the relationship is valid the graph should be a straight line passing through the origin" or if you testing a power law relationship and suggest plotting a graph of lg P against lg Q, "if the relationship is valid the graph should be a straight line with gradient 2".

The quantity that you are required to determine from your results should be stated as the subject of the formula and related to the gradient or y-intercept of your graph.

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 of 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.

Question 2 Analysis and Evaluation question

To determine the expressions for gradient and/or intercept, rearrange the given equation into the form of the equation of a straight line. You may need to take logarithms to base 10 (log or lg) or natural logarithms (ln).

The advice for Paper 3 for completing a table of results, graph plotting and determining the gradient and y-intercept also applies to this paper.

Do show units in the quantity whose logarithm is taken e.g. lg (d / cm). The logarithm does not have a unit itself.

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.

For logarithmic quantities the number before the decimal point is not counted, so the number of decimal places (or one more) in the logarithm should correspond to the number of significant figures in the raw quantity.

You should understand how to determine absolute uncertainties in calculated quantities when adding, subtracting, multiplying, dividing and taking logarithms. This requires plenty of practice.

You should understand how to transfer between an absolute uncertainty and a percentage uncertainty.

You should be able to translate the calculated uncertainties into error bars on the graph. Each error bar should be accurate to less than 1 mm.

When drawing your line of best fit, ensure you have an even balance of points about the line along its whole length; the line may not necessarily pass through the first and/or last data point. Use a clear plastic ruler so that you can see points on both sides of the line as it is being drawn. The line should be drawn from at least the furthest left data point. It is best to use a 30 cm ruler so that there are no joins or kinks in the line.

The worst acceptable line should be the steepest or shallowest straight line that passes through all the error bars. Remember to label your line or use a dashed line. If you use a dashed line, make sure that the dashed parts of the line pass through each error bar.

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 less than half a small square). The length of the hypotenuse of the triangle should be greater than half the length of the graph line. Do not use data points from the table.

To determine the uncertainty in the gradient, find the gradient of the worst acceptable line and find the difference. To determine the gradient of the worst acceptable line use a similar method as you used to determine the gradient of the line of best fit. Take care to read the points from the correct 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 when the x-axis has an origin, i.e. $x = 0$. If it is not possible to read the y-intercept from the graph, use the gradient value and substitute a point from the line of best-fit into the equation of a straight line ($y = mx + c$). You can save time by using one of the pairs of data points used to determine the gradient.

To determine the uncertainty in the y-intercept, find the y-intercept of the worst acceptable line and find the difference. To determine the y-intercept of the worst acceptable line use a similar method as you used to determine the y-intercept of the line of best fit. Take care to read the points from the correct line.

Use your expressions for the gradient and y-intercept to determine the values of the constants you are asked to determine. Do show your clearly your working with clear substitution of the gradient and y-intercept.

Do remember to work out appropriate units and give your answers to an appropriate number of significant figures.

Revision checklists

The tables below can be used as a revision checklist: **It doesn't contain all the detailed knowledge you need to know, just an overview.** For more detail see the syllabus and talk to your teacher.

The table headings are explained below:

Topic	You should be able to	R	A	G	Comments
		You can use the tick boxes to show when you have revised an item and how confident you feel about it. R = RED means you are really unsure and lack confidence; you might want to focus your revision here and possibly talk to your teacher for help A = AMBER means you are reasonably confident but need some extra practice G = GREEN means you are very confident. As your revision progresses, you can concentrate on the RED and AMBER items in order to turn them into GREEN items. You might find it helpful to highlight each topic in red, orange or green to help you prioritise.			You can use the 'Comments' column to: • • add more information about the details for each point • • add formulae or notes • • include a reference to a useful resource • • highlight areas of difficulty or things that you need to talk to your teacher about or look up in a textbook.

Paper 1 Multiple Choice and Paper 2 AS Level Structured Questions

1 Physical quantities and units

Topic	You should be able to	R	A	G	Comments
1.1 Physical quantities	• understand that all physical quantities consist of a numerical magnitude and a unit • make reasonable estimates of physical quantities included within the syllabus				
1.2 SI units	• recall the following SI base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K) • express derived units as products or quotients of the SI base units and use the derived units for quantities listed in this syllabus as appropriate • use SI base units to check the homogeneity of physical equations • recall and 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)				
1.3 Errors and uncertainties	• understand and explain the effects of systematic errors (including zero errors) and random errors in measurements • understand the distinction between precision and accuracy • assess the uncertainty in a derived quantity by simple addition of absolute or percentage uncertainties				
1.4 Scalars and vectors	• understand the difference between scalar and vector quantities and give examples of scalar and vector • quantities included in the syllabus • add and subtract coplanar vectors • represent a vector as two perpendicular components				

2 Kinematics

Topic	You should be able to	R	A	G	Comments
2.1 Equations of motion	• define and use distance, displacement, speed, velocity and acceleration • use graphical methods to represent distance, displacement, speed, velocity and acceleration • determine displacement from the area under a velocity–time graph • determine velocity using the gradient of a displacement–time graph • determine acceleration using the gradient of a velocity–time graph • derive, from the definitions of velocity and acceleration, equations that represent uniformly accelerated • motion in a straight line • 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 • describe an experiment to determine the acceleration of free fall using a falling object • describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction				

3 Dynamics

Topic	You should be able to	R	A	G	Comments
3.1 Momentum and Newton's laws of motion	• understand that mass is the property of an object that resists change in motion • recall F = ma and solve problems using it, understanding that acceleration and resultant force are always in the same direction • define and use linear momentum as the product of mass and velocity • define and use force as rate of change of momentum				

Topic	You should be able to	R	A	G	Comments
	• state and apply each of Newton's laws of motion • 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				
3.2 Non-uniform motion	• show a qualitative understanding of frictional forces and viscous/drag forces including air resistance (no treatment of the coefficients of friction and viscosity is required, and a simple model of drag force increasing as speed increases is sufficient) • describe and explain qualitatively the motion of objects in a uniform gravitational field with air resistance • understand that objects moving against a resistive force may reach a terminal (constant) velocity				
3.3 Linear momentum and its conservation	• state the principle of conservation of momentum • apply the principle of conservation of momentum to solve simple problems, including elastic and inelastic interactions between objects in both one and two dimensions (knowledge of the concept of coefficient of restitution is not required) • recall that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation • understand that, while momentum of a system is always conserved in interactions between objects, some change in kinetic energy may take place				

4 Forces, density and pressure

Topic	You should be able to	R	A	G	Comments
4.1 Turning effects of forces	• understand that the weight of a body may be taken as acting at a single point known as its centre of gravity • define and apply the moment of a force • understand that a couple is a pair of forces that acts to produce rotation only • define and apply the torque of a couple				

Topic	You should be able to	R	A	G	Comments
4.2 Equilibrium of forces	• state and apply the principle of moments • understand that, when there is no resultant force and no resultant torque, a system is in equilibrium • use a vector triangle to represent coplanar forces in equilibrium				
4.3 Density and pressure	• define and use density • define and use pressure • derive, from the definitions of pressure and density, the equation for hydrostatic pressure $\Delta p = \rho g \Delta h$ • use the equation $\Delta p = \rho g \Delta h$ • understand that the upthrust acting on an object in a fluid is due to a difference in hydrostatic pressure • calculate the upthrust acting on an object in a fluid using the equation $F = \rho g V$ (Archimedes' principle)				

5 Work, energy and power

Topic	You should be able to	R	A	G	Comments
5.1 Energy conservation	• understand the concept of work, and recall and use *work done* = *force* × *displacement* in the direction of the force • recall and apply the principle of conservation of energy • recall and understand that the efficiency of a system is the ratio of useful energy output from the system to the total energy input • use the concept of efficiency to solve problems • define power as work done per unit time • solve problems using $P = W / t$ • derive $P = Fv$ and use it to solve problems				

You should be able to	Ways to practise skills	R	A	G	Comments
5.2 Gravitational potential energy and kinetic energy	• derive, using $W = Fs$, the formula $\Delta E_p = mg\Delta h$ for gravitational potential energy changes in a uniform gravitational field • recall and use the formula $\Delta E_p = mg\Delta h$ for gravitational potential energy changes in a uniform gravitational field • derive, using the equations of motion, the formula for kinetic energy $EK = ½mv^2$ • recall and use $EK = ½mv^2$				

6 Deformation of solids

You should be able to	Ways to practise skills	R	A	G	Comments
6.1 Stress and strain	• understand that deformation is caused by tensile or compressive forces (forces and deformations will be assumed to be in one dimension only) • understand and use the terms load, extension, compression and limit of proportionality • recall and use Hooke's law • recall and use the formula for the spring constant $k = F / x$ • define and use the terms stress, strain and the Young modulus • describe an experiment to determine the Young modulus of a metal in the form of a wire				
6.2 Elastic and plastic behaviour	• understand and use the terms elastic deformation, plastic deformation and elastic limit • understand that the area under the force–extension graph represents the work done • determine the elastic potential energy of a material deformed within its limit of proportionality from the area under the force–extension graph • recall and use $EP = ½ F x = ½ k x^2$ for a material deformed within its limit of proportionality				

7 Waves

Topic	You should be able to	R	A	G	Comments
7.1 Progressive waves	• describe what is meant by wave motion as illustrated by vibration in ropes, springs and ripple tanks • understand and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed • understand the use of the time-base and y-gain of a cathode-ray oscilloscope (CRO) to determine frequency and amplitude • derive, using the definitions of speed, frequency and wavelength, the wave equation $v = f\lambda$ • recall and use $v = f\lambda$ • understand that energy is transferred by a progressive wave • recall and use *intensity* = *power* / *area* and *intensity* α (*amplitude*)^2 for a progressive wave				
7.2 Transverse and longitudinal waves	• compare transverse and longitudinal waves • analyse and interpret graphical representations of transverse and longitudinal waves				
7.3 Doppler effect for sound waves	• understand that when a source of sound waves moves relative to a stationary observer, the observed frequency is different from the source frequency (understanding of the Doppler effect for a stationary source and a moving observer is not required) • use the expression $f_o = f_s v / (v \pm v_s)$ for the observed frequency when a source of sound waves moves relative to a stationary observer				
7.4 Electromagnetic spectrum	• state that all electromagnetic waves are transverse waves that travel with the same speed c in free space • recall the approximate range of wavelengths in free space of the principal regions of the electromagnetic spectrum from radio waves to γ-rays • recall that wavelengths in the range 400–700 nm in free space are visible to the human eye				
7.5 Polarisation	• understand that polarisation is a phenomenon associated with transverse waves				

You should be able to	Ways to practise skills	R	A	G	Comments
	• recall and use Malus's law ($I = I_0 \cos^2\theta$) to calculate the intensity of a plane polarised electromagnetic wave after transmission through a polarising filter or a series of polarising filters				

8 Superposition

You should be able to	Ways to practise skills	R	A	G	Comments
8.1 Stationary waves	• explain and use the principle of superposition • show an understanding of experiments that demonstrate stationary waves using microwaves, stretched strings and air columns (it will be assumed that end corrections are negligible; knowledge of the concept of end corrections is not required) • explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes • understand how wavelength may be determined from the positions of nodes or antinodes of a stationary wave				
8.2 Diffraction	• explain the meaning of the term diffraction • show an understanding of experiments that demonstrate diffraction including the qualitative effect of the gap width relative to the wavelength of the wave; for example diffraction of water waves in a ripple tank • understand the terms interference and coherence • show an understanding of experiments that demonstrate two-source interference using water waves in a ripple tank, sound, light and microwaves				
8.3 Interference	• understand the conditions required if two-source interference fringes are to be observed • recall and use λ = ax / D for double-slit interference using light • explain and use the principle of superposition				

7 Waves

Topic	You should be able to	R	A	G	Comments
	• show an understanding of experiments that demonstrate stationary waves using microwaves, stretched strings and air columns (it will be assumed that end corrections are negligible; knowledge of the concept of end corrections is not required)				
8.4 The diffraction grating	• recall and use $d \sin \theta = n \lambda$ • describe the use of a diffraction grating to determine the wavelength of light (the structure and use of the spectrometer are not included)				

9 Electricity

Topic	You should be able to	R	A	G	Comments
9.1 Electric current	• understand that an electric current is a flow of charge carriers • understand that the charge on charge carriers is quantised • recall and use $Q = I t$ • use, for a current-carrying conductor, the expression $I = Anvq$, where n is the number density of charge carriers				
9.2 Potential difference and power	• define the potential difference across a component as the energy transferred per unit charge • recall and use $V = W / Q$ • recall and use $P = VI$, $P = I^2 R$ and $P = V^2 / R$				
9.3 Resistance and resistivity	• define resistance • recall and use $V = IR$ • sketch the I–V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp • explain that the resistance of a filament lamp increases as current increases because its temperature increases				

You should be able to	Ways to practise skills	R	A	G	Comments
	• state Ohm's law • recall and use R = ρL / A • understand that the resistance of a light-dependent resistor (LDR) decreases as the light intensity increases • understand that the resistance of a thermistor decreases as the temperature increases (it will be assumed that thermistors have a negative temperature coefficient)				

10 D.C. circuits

You should be able to	Ways to practise skills	R	A	G	Comments
10.1 Practical circuits	• recall and use the circuit symbols shown in section 6 of this syllabus • draw and interpret circuit diagrams containing the circuit symbols shown in section 6 of this syllabus • define and use the electromotive force (e.m.f.) of a source as energy transferred per unit charge in driving charge around a complete circuit • distinguish between e.m.f. and potential difference (p.d.) in terms of energy considerations • understand the effects of the internal resistance of a source of e.m.f. on the terminal potential difference				
10.2 Kirchhoff's laws	• recall Kirchhoff's first law and understand that it is a consequence of conservation of charge • recall Kirchhoff's second law and understand that it is a consequence of conservation of energy • derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series • use the formula for the combined resistance of two or more resistors in series • derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel				

Topic	You should be able to	R	A	G	Comments
	• use the formula for the combined resistance of two or more resistors in parallel • use Kirchhoff's laws to solve simple circuit problems				
10.3 Potential dividers	• understand the principle of a potential divider circuit • recall and use the principle of the potentiometer as a means of comparing potential differences • understand the use of a galvanometer in null methods • explain the use of thermistors and light-dependent resistors in potential dividers to provide a potential difference that is dependent on temperature and light intensity				

11 Particle physics

Topic	You should be able to	R	A	G	Comments
11.1 Atoms, nuclei and radiation	• infer from the results of the α-particle scattering experiment the existence and small size of the nucleus • describe a simple model for the nuclear atom to include protons, neutrons and orbital electrons • distinguish between nucleon number and proton number • understand that isotopes are forms of the same element with different numbers of neutrons in their nuclei • understand and use the notation ${}^{A}_{Z}X$ for the representation of nuclides • understand that nucleon number and charge are conserved in nuclear processes • describe the composition, mass and charge of α-, β- and γ-radiations (both β– (electrons) and β+ (positrons) are included) • understand that an antiparticle has the same mass but opposite charge to the corresponding particle, and that a positron is the antiparticle of an electron				

Topic	You should be able to	R	A	G	Comments
	• state that (electron) antineutrinos are produced during β– decay and (electron) neutrinos are produced during β+ decay • understand that α-particles have discrete energies but that β-particles have a continuous range of energies because (anti)neutrinos are emitted in β-decay • represent α- and β-decay by a radioactive decay equation of the form $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$ • use the unified atomic mass unit (u) as a unit of mass				
11.2 Fundamental particles	• understand that a quark is a fundamental particle and that there are six flavours (types) of quark: up, down, strange, charm, top and bottom • recall and use the charge of each flavour of quark and understand that its respective antiquark has the opposite charge (no knowledge of any other properties of quarks is required) • recall that protons and neutrons are not fundamental particles and describe protons and neutrons in terms of their quark composition • understand that a hadron may be either a baryon (consisting of three quarks) or a meson (consisting of one quark and one antiquark) • describe the changes to quark composition that take place during β^- and β^+ decay • recall that electrons and neutrinos are fundamental particles called leptons				

Paper 3 Advanced Practical Skills

Manipulation, measurement and observation

Topic	You should be able to	R	A	G	Comments
Successful collection of data	• set up apparatus correctly without assistance • follow instructions given in the form of written instructions and diagrams (including circuit diagrams) • use the apparatus to collect an appropriate quantity of data				

Topic	You should be able to	R	A	G	Comments
	• repeat readings where appropriate • make measurements using common laboratory apparatus, such as – millimetre scales, – protractors, – top-pan balances, – newton meters, – analogue or digital electrical meters, – measuring cylinders, – calipers, – micrometer screw gauges and – thermometers • use a stop-watch to measure intervals of time, including the period of an oscillating system by timing an appropriate number of consecutive oscillations • use both analogue scales and digital displays				
Quality of data	• make and record accurate measurements • make measurements that span the largest possible range of values within the limits either of the equipment provided or of the instructions given				

Presentation of data and observations

Topic	You should be able to	R	A	G	Comments
Table of results	• present numerical data and values in a single table of results • record all data in the table • draw up the table in advance of taking readings so that they do not have to copy up their results • include in the table of results columns for raw data and for values calculated from them • use column headings that include both the quantity and the unit and that conform to accepted scientific conventions, e.g. *I* / mA or *I* (mA)				

Topic	You should be able to	R	A	G	Comments
Recording of data, observations and calculations	• record raw readings of a quantity to the same degree of precision, e.g. if a length measurement using a ruler with a millimetre scale is used then all the measurements should be given to the nearest millimetre • calculate other quantities from their raw data • show their working in calculations, and the key steps in their reasoning • use and justify the correct number of significant figures in calculated quantities				
Graph	• clearly label graph axes with both the quantity and the unit, following accepted scientific conventions, e.g. *I* / mA or *I* (mA) • choose scales for graph axes such that the data points occupy at least half of the graph grid in both *x*- and *y*-directions • use a false origin where appropriate • choose scales for the graph axes that allow the graph to be read easily, such as 1, 2 or 5 units to a 2 cm square • place regularly-spaced numerical labels along the whole of each axis at least every 2 cm • plot all your data points on the graph grid to an accuracy of better than 1 mm • draw straight lines of best fit or curves to show the trend of a graph • draw tangents to curved trend lines				

Analysis, conclusions and evaluation

Topic	You should be able to	R	A	G	Comments
Interpretation of graph	• relate straight-line graphs to equations of the form $y = mx + c$, and derive expressions that equate to the gradient and/or the *y*-intercept of their graphs • read the coordinates of points on the trend line of a graph • determine the gradient of a straight-line graph or of a tangent to a curve				

Topic	You should be able to	R	A	G	Comments
	• determine the *y*-intercept of a straight-line graph or of a tangent to a curve, including where these are on graphs with a false origin.				
Estimating uncertainties	• estimate the absolute uncertainty in measurements • express the uncertainty in a measurement as an absolute or percentage uncertainty, and translate between these forms • express the absolute uncertainty in a repeated measurement as half the range of the repeated readings, where this is appropriate				
Drawing conclusions	• draw conclusions from an experiment, including determining the values of constants • explain whether experimental data supports a given hypothesis • make predictions • determine whether a relationship containing a constant is supported by experimental data by calculating the percentage difference between values of the constant, comparing this percentage difference with a given percentage uncertainty and give a conclusion based on this comparison				
Identifying limitations	• identify and describe the limitations in an experimental procedure • identify the most significant sources of uncertainty in an experiment • for uncertainties in measured quantities, state the quantity being measured and a reason for the uncertainty				
Suggesting improvements	• suggest modifications to an experimental arrangement that will improve the accuracy of the experiment or to extend the investigation to answer a new question • describe these modifications clearly in words or diagrams				

Paper 4 A Level Structured Questions

12 Motion in a circle

You should be able to	Ways to practise skills	R	A	G	Comments
12.1 Kinematics of uniform circular motion	• define the radian and express angular displacement in radians • understand and use the concept of angular speed • recall and use $\omega = 2\pi / T$ and $v = r\omega$				
12.2 Centripetal acceleration	• understand that a force of constant magnitude that is always perpendicular to the direction of motion causes centripetal acceleration • understand that centripetal acceleration causes circular motion with a constant angular speed • recall and use $a = r\omega^2$ and $a = v^2 / r$ • recall and use $F = mr\omega^2$ and $F = mv^2 / r$				

13 Gravitational fields

You should be able to	Ways to practise skills	R	A	G	Comments
13.1 Gravitational field	• understand that a gravitational field is an example of a field of force and define gravitational field as force per unit mass • represent a gravitational field by means of field lines				
13.2 Gravitational force between point masses	• 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 • recall and use Newton's law of gravitation $F = Gm_1m_2 / r^2$ for the force between two point masses • analyse circular orbits in gravitational fields by relating the gravitational force to the centripetal acceleration it causes • understand that a satellite in a geostationary orbit remains at the same point above the Earth's surface, with an orbital period of 24 hours, orbiting from west to east, directly above the Equator				

Topic	You should be able to	R	A	G	Comments
13.3 Gravitational field of a point mass	• derive, from Newton's law of gravitation and the definition of gravitational field, the equation $g = GM / r^2$ for the gravitational field strength due to a point mass • recall and use $g = GM / r^2$ • understand why g is approximately constant for small changes in height near the Earth's surface				
13.4 Gravitational potential	• define gravitational potential at a point as the work done per unit mass in bringing a small test mass from infinity to the point • use $\phi = -GM / r$ for the gravitational potential in the field due to a point mass • understand how the concept of gravitational potential leads to the gravitational potential energy of two point masses and use $E_p = -GMm / r$				

14 Temperature

Topic	You should be able to	R	A	G	Comments
14.1 Thermal equilibrium	• understand that (thermal) energy is transferred from a region of higher temperature to a region of lower temperature • understand that regions of equal temperature are in thermal equilibrium				
14.2 Temperature scales	• understand that a physical property that varies with temperature may be used for the measurement of temperature and state examples of such properties, including the density of a liquid, volume of a gas at constant pressure, resistance of a metal, e.m.f. of a thermocouple • understand that the scale of thermodynamic temperature does not depend on the property of any particular substance • convert temperatures between kelvin and degrees Celsius and recall that $T / \text{K} = \theta / °\text{C} + 273.15$ • understand that the lowest possible temperature is zero kelvin on the thermodynamic temperature scale and that this is known as absolute zero				

Topic	You should be able to	R	A	G	Comments
14.3 Specify heat capacity and specific latent heat	• define and use specific heat capacity • define and use specific latent heat and distinguish between specific latent heat of fusion and specific latent heat of vaporisation				

15 Ideal gases

Topic	You should be able to	R	A	G	Comments
15.1 The mole	• understand that amount of substance is an SI base quantity with the base unit mol • use molar quantities where one mole of any substance is the amount containing a number of particles of that substance equal to the Avogadro constant N_A				
15.2 Equation of state	• understand that a gas obeying $pV \propto T$, where T is the thermodynamic temperature, is known as an ideal gas • recall and use the equation of state for an ideal gas expressed as $pV = nRT$, where n = amount of substance (number of moles) and as $pV = NkT$, where N = number of molecules • recall that the Boltzmann constant k is given by $k = R / N_A$				
15.3 Kinetic theory of gases	• state the basic assumptions of the kinetic theory of gases • explain how molecular movement causes the pressure exerted by a gas and derive and use the relationship $pV = 1/3Nm\langle c^2 \rangle$, where $\langle c^2 \rangle$ is the mean-square speed (a simple model considering one dimensional collisions and then extending to three dimensions using $1/3\langle c^2 \rangle = \langle cx^2 \rangle$ is sufficient) • understand that the root-mean-square speed $_{c.m.s.}$ is given by $\sqrt{\langle c^2 \rangle}$ • compare $pV = 1/3Nm\langle c^2 \rangle$ with $pV = NkT$ to deduce that the average translational kinetic energy of a molecule is $3/2\ kT$				

16 Thermodynamics

Topic	You should be able to	R	A	G	Comments
16.1 Internal energy	• 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 • relate a rise in temperature of an object to an increase in its internal energy				
16.2 The first law of thermodynamics	• recall and use $W = p\Delta V$ for the work done when the volume of a gas changes at constant pressure and understand the difference between the work done by the gas and the work done on the gas • 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 to the system by heating) and the work done on the system				

17 Oscillations

Topic	You should be able to	R	A	G	Comments
17.1 Simple harmonic oscillations	• understand and use the terms displacement, amplitude, period, frequency, angular frequency and phase difference in the context of oscillations, and express the period in terms of both frequency and angular frequency • understand that simple harmonic motion occurs when acceleration is proportional to displacement from a fixed point and in the opposite direction • use $a = -\omega^2 x$ and recall and use, as a solution to this equation, $x = x_0 \sin \omega t$ • use the equations $v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{(x_o^2 - x^2)}$ • analyse and interpret graphical representations of the variations of displacement, velocity and acceleration for simple harmonic motion				
17.2 Energy in simple harmonic motion	• describe the interchange between kinetic and potential energy during simple harmonic motion • recall and use $E = \frac{1}{2}m\omega^2 x_0^2$ for the total energy of a system undergoing simple harmonic motion				

Topic	You should be able to	R	A	G	Comments
17.3 Damped and forced oscillations, resonance	• understand that a resistive force acting on an oscillating system causes damping • understand and use the terms light, critical and heavy damping and sketch displacement–time graphs illustrating these types of damping • understand that resonance involves a maximum amplitude of oscillations and that this occurs when an oscillating system is forced to oscillate at its natural frequency				

18 Electric fields

Topic	You should be able to	R	A	G	Comments
18.1 Electric fields and field lines	• understand that an electric field is an example of a field of force and define electric field as force per unit positive charge • recall and use $F = qE$ for the force on a charge in an electric field • represent an electric field by means of field lines				
18.2 Uniform electric fields	• recall and use $E = \Delta V / \Delta d$ to calculate the field strength of the uniform field between charged parallel plates • describe the effect of a uniform electric field on the motion of charged particles				
18.3 Electric force between point charges	• understand that, for a point outside a spherical conductor, the charge on the sphere may be considered to be a point charge at its centre • recall and use Coulomb's law $F = Q_1Q_2 / (4\pi\varepsilon_0 r^2)$ for the force between two point charges in free space				
18.4 Electric field of a point charge	• recall and use $E = Q / (4\pi\varepsilon_0 r^2)$ for the electric field strength due to a point charge in free space				
18.5 Electric potential	• define electric potential at a point as the work done per unit positive charge in bringing a small test charge from infinity to the point • recall and use the fact that the electric field at a point is equal to the negative of potential gradient at that point • use $V = Q / (4\pi\varepsilon_0 r^2)$ for the electric potential in the field due to a point charge				

Topic	You should be able to	R	A	G	Comments
	• understand how the concept of electric potential leads to the electric potential energy of two point charges and use $EP = Qq / (4\pi\varepsilon_0 r^2)$				

19 Capacitance

Topic	You should be able to	R	A	G	Comments
19.1 Capacitors and capacitance	• define capacitance, as applied to both isolated spherical conductors and to parallel plate capacitors • recall and use $C = Q / V$ • derive, using $C = Q / V$, formulae for the combined capacitance of capacitors in series and in parallel • use the capacitance formulae for capacitors in series and in parallel				
19.2 Energy stored in a capacitor	• determine the electric potential energy stored in a capacitor from the area under the potential–charge graph • recall and use $W = ½QV = ½CV^2$				
19.3 Discharging a capacitor	• analyse graphs of the variation with time of potential difference, charge and current for a capacitor discharging through a resistor • recall and use $\tau = RC$ for the time constant for a capacitor discharging through a resistor • use equations of the form $x = x_0 e^{-(t / RC)}$ where x could represent current, charge or potential difference for a capacitor discharging through a resistor				

20 Magnetic fields

Topic	You should be able to	R	A	G	Comments
20.1 Concept of a magnetic field	• understand that a magnetic field is an example of a field of force produced either by moving charges or by permanent magnets • represent a magnetic field by field lines				

Topic	You should be able to	R	A	G	Comments
20.2 Force on a current-carrying conductor	• understand that a force might act on a current-carrying conductor placed in a magnetic field • recall and use the equation $F = BIL \sin\theta$, with directions as interpreted by Fleming's left-hand rule • define magnetic flux density as the force acting per unit current per unit length on a wire placed at right angles to the magnetic field				
20.3 Force on a moving charge	• determine the direction of the force on a charge moving in a magnetic field • recall and use $F = BQv \sin\theta$ • understand the origin of the Hall voltage and derive and use the expression $VH = BI / (ntq)$, where t = thickness • understand the use of a Hall probe to measure magnetic flux density • describe the motion of a charged particle moving in a uniform magnetic field perpendicular to the direction of motion of the particle • explain how electric and magnetic fields can be used in velocity selection				
20.4 Magnetic fields due to currents	• sketch magnetic field patterns due to the currents in a long straight wire, a flat circular coil and a long solenoid • understand that the magnetic field due to the current in a solenoid is increased by a ferrous core • explain the origin of the forces between current-carrying conductors and determine the direction of the forces				
20.5 Electromagnetic induction	• define magnetic flux as the product of the magnetic flux density and the cross-sectional area perpendicular to the direction of the magnetic flux density • recall and use $\Phi = BA$ • understand and use the concept of magnetic flux linkage				

Topic	You should be able to	R	A	G	Comments
	• understand and explain experiments that demonstrate: – that a changing magnetic flux can induce an e.m.f. in a circuit – that the induced e.m.f. is in such a direction as to oppose the change producing it – the factors affecting the magnitude of the induced e.m.f. • recall and use Faraday's and Lenz's laws of electromagnetic induction				

21 Alternating currents

Topic	You should be able to	R	A	G	Comments
21.1 Characteristics of alternating currents	• understand and use the terms period, frequency and peak value as applied to an alternating current or voltage • use equations of the form $x = x_0 \sin \omega t$ representing a sinusoidally alternating current or voltage • recall and use the fact that the mean power in a resistive load is half the maximum power for a sinusoidal alternating current • distinguish between root-mean-square (r.m.s.) and peak values and recall and use $I_{r.m.s.} = I_0 / \sqrt{2}$ and $V_{r.m.s.} = V_0 / \sqrt{2}$ for a sinusoidal alternating current				
21.2 Rectification and smoothing	• distinguish graphically between half-wave and full-wave rectification • explain the use of a single diode for the half-wave rectification of an alternating current • explain the use of four diodes (bridge rectifier) for the full-wave rectification of an alternating current • analyse the effect of a single capacitor in smoothing, including the effect of the values of capacitance and the load resistance				

22 Quantum physics

Topic	You should be able to	R	A	G	Comments
22.1 Energy and momentum of a photon	• understand that electromagnetic radiation has a particulate nature • understand that a photon is a quantum of electromagnetic energy				

Topic	You should be able to	R	A	G	Comments
	• recall and use $E = hf$ • use the electronvolt (eV) as a unit of energy • understand that a photon has momentum and that the momentum is given by $p = E / c$				
22.2 Photoelectric effect	• understand that photoelectrons may be emitted from a metal surface when it is illuminated by electromagnetic radiation • understand and use the terms threshold frequency and threshold wavelength • explain photoelectric emission in terms of photon energy and work function energy • recall and use $hf = \Phi + \frac{1}{2} m v_{max}^2$ • explain why the maximum kinetic energy of photoelectrons is independent of intensity, whereas the photoelectric current is proportional to intensity				
22.3 Wave-particle duality	• 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 • describe and interpret qualitatively the evidence provided by electron diffraction for the wave nature of particles • understand the de Broglie wavelength as the wavelength associated with a moving particle • recall and use $\lambda = h / p$				
22.4 Energy levels in atoms and line spectra	• understand that there are discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) • understand the appearance and formation of emission and absorption line spectra • recall and use $hf = E_1 - E_2$				

23 Nuclear Physics

Topic	You should be able to	R	A	G	Comments
23.1 Mass defect and nuclear binding energy	• understand the equivalence between energy and mass as represented by $E = mc^2$ and recall and use this equation • represent simple nuclear reactions by nuclear equations of the form ${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8} + {}^{1}_{1}\mathrm{H}$ • define and use the terms mass defect and binding energy • sketch the variation of binding energy per nucleon with nucleon number • explain what is meant by nuclear fusion and nuclear fission • explain the relevance of binding energy per nucleon to nuclear reactions, including nuclear fusion and nuclear fission • calculate the energy released in nuclear reactions using $E = c^2 \Delta m$				
23.2 Radioactive decay	• understand that fluctuations in count rate provide evidence for the random nature of radioactive decay • understand that radioactive decay is both spontaneous and random • define activity and decay constant, and recall and use $A = \lambda N$ • define half-life • use $\lambda = 0.693 / t_{½}$ • understand the exponential nature of radioactive decay, and sketch and use the relationship $x = x0\, e^{-\lambda t}$, where x could represent activity, number of undecayed nuclei or received count rate				

23 Medical Physics

Topic	You should be able to	R	A	G	Comments
24.1 Production and use of ultrasound	• understand that a piezo-electric crystal changes shape when a p.d. is applied across it and that the crystal generates an e.m.f. when its shape changes • understand how ultrasound waves are generated and detected by a piezo-electric transducer • understand how the reflection of pulses of ultrasound at boundaries between tissues can be used to obtain diagnostic information about internal structures • define the specific acoustic impedance of a medium as $Z = \rho c$, where c is the speed of sound in the medium • use $I_R / I_0 = (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ for the intensity reflection coefficient of a boundary between two media • recall and use $I = I_0 e^{-\mu x}$ for the attenuation of ultrasound in matter				
24.2 Production and use of X-rays	• explain that X-rays are produced by electron bombardment of a metal target and calculate the minimum wavelength of X-rays produced from the accelerating p.d. • understand the use of X-rays in imaging internal body structures, including an understanding of the term contrast in X-ray imaging • recall and use $I = I_0 e^{-\mu x}$ for the attenuation of X-rays in matter • understand that computed tomography (CT) scanning produces a 3D image of an internal structure by first combining multiple X-ray images taken in the same section from different angles to obtain a 2D image of the section, then repeating this process along an axis and combining 2D images of multiple sections				
24.3 PET scanning	• understand that a tracer is a substance containing radioactive nuclei that can be introduced into the body and is then absorbed by the tissue being studied • recall that a tracer that decays by β+ decay is used in positron emission tomography (PET scanning) • understand that annihilation occurs when a particle interacts with its antiparticle and that mass-energy and momentum are conserved in the process				

Topic	You should be able to	R	A	G	Comments
	• explain that, in PET scanning, positrons emitted by the decay of the tracer annihilate when they interact with electrons in the tissue, producing a pair of gamma-ray photons travelling in opposite directions • calculate the energy of the gamma-ray photons emitted during the annihilation of an electron-positron pair • understand that the gamma-ray photons from an annihilation event travel outside the body and can be detected, and an image of the tracer concentration in the tissue can be created by processing the arrival times of the gamma-ray photons				

25 Astronomy and cosmology

Topic	You should be able to	R	A	G	Comments
25.1 Standard candles	• understand the term luminosity as the total power of radiation emitted by a star • recall and use the inverse square law for radiant flux intensity F in terms of the luminosity L of the source $F = L / (4\pi d^2)$ • understand that an object of known luminosity is called a standard candle • understand the use of standard candles to determine distances to galaxies				
25.2 Stellar radii	• recall and use Wien's displacement law $\lambda_{max} \propto 1 / T$ to estimate the peak surface temperature of a star • use the Stefan–Boltzmann law $L = 4\pi\sigma r^2 T^4$ • use Wien's displacement law and the Stefan–Boltzmann law to estimate the radius of a star				
25.3 Hubble's law and the Big Bang theory	• understand that the lines in the emission spectra from distant objects show an increase in wavelength from their known values • use $\Delta\lambda / \lambda \approx \Delta f / f \approx v / c$ for the redshift of electromagnetic radiation from a source moving relative to an observer • explain why redshift leads to the idea that the Universe is expanding				

Topic	You should be able to	R	A	G	Comments
	• recall and use Hubble's law $v \approx H_0 d$ and explain how this leads to the Big Bang theory (candidates will only be required to use SI units)				

Paper 5 Planning, Analysis and Evaluation

Planning

Topic	You should be able to	R	A	G	Comments
Defining the problem	• identify the independent variable in the experiment • identify the dependent variable in the experiment • identify the variables that are to be kept constant				
Methods of data collection	• describe the method to be used to vary the independent variable • describe how the independent and dependent variables are to be measured • describe how other variables are to be kept constant • describe, with the aid of a clear labelled diagram, the arrangement of apparatus for the experiment and the procedures to be followed • Describe how an oscilloscope can measure voltage and time. Understand how an oscilloscope should be connected to a circuit • Describe how to use an oscilloscope to determine current and frequency • Describe and understand how light gates connected to a datalogger may be used to determine time, velocity and acceleration • Describe how other sensors such as a motion sensor may be used with a datalogger				
Method of analysis	• describe how the data should be used in order to reach a conclusion, including details of derived quantities to be calculated from graphs				
Safety	• assess the risks of their experiment				

Topic	You should be able to	R	A	G	Comments
	• describe precautions that should be taken to keep risks to a minimum				
Additional detail	• describe the use of an oscilloscope (or storage oscilloscope) to measure voltage, current, time and frequency • describe how to use light gates connected to a data logger to determine time, velocity and acceleration • describe how other sensors can be used with a data logger, e.g. motion sensor				

Analysis, conclusions and evaluation

Topic	You should be able to	R	A	G	Comments
Data analysis	• rearrange expressions into the forms $y = mx + c$, $y = ax^n$ and $y = ae^{kx}$ • understand how a graph of y against x is used to find the constants m and c in an equation of the form $y = mx + c$ • understand how a graph of log y against log x is used to find the constants a and n in an equation of the form $y = ax^n$ • understand how a graph of ln y against x is used to find the constants a and k in an equation of the form $y = ae^{kx}$ • decide what derived quantities to calculate from raw data in order to enable an appropriate graph to be plotted				
Table of results	• complete a table of results following the conventions required for Paper 3 • understand that where logarithms are required, units should be shown with the quantity whose logarithm is being taken, e.g. ln (d / cm). The logarithm itself does not have a unit • calculate other quantities from raw data and record them in a table • use the correct number of significant figures for calculated quantities following the conventions required for Paper 3 • understand for logarithmic quantities, the number of decimal places should correspond to the number of significant figures				

Topic	You should be able to	R	A	G	Comments
Graph	• plot a graph following the conventions required for Paper 3 • show error bars, in both directions where appropriate, for each point on the graph • draw a straight line of best fit and a worst acceptable straight line through the points on the graph • understand that the worst acceptable line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points • distinguish the worst acceptable line from the line of best fit either by being drawn as a broken line or by being clearly labelled				
Conclusion	• determine the gradient and y-intercept of a straight-line graph • derive expressions that equate to the gradient or the y-intercept of their straight lines of best fit • draw the required conclusions, with correct units and appropriate number of significant figures, from these expressions				
Treatment of uncertainties	• convert absolute uncertainty estimates into fractional or percentage uncertainty estimates and vice versa • show uncertainty estimates, in absolute terms, beside every value in a table of results • calculate uncertainty estimates in derived quantities • estimate the absolute uncertainty in the gradient of a graph by recalling that • absolute uncertainty = gradient of line of best fit – gradient of worst acceptable line • estimate the absolute uncertainty in the y-intercept of a graph by recalling that absolute uncertainty = y-intercept of line of best fit – y-intercept of worst acceptable line				

Section 6: Useful websites

The resources listed below will help you to revise and study for your Cambridge International AS & A Level Physics course.

These resources have not been through the Cambridge quality assurance process but have been found suitable for use with various parts of the syllabus. This list includes website links providing direct access to internet resources. Cambridge is not responsible for the accuracy or content of information contained in these resources. The inclusion of a link to an external website should not be understood to be an endorsement of that website or the site's owners (or their products/services).

http://www.iop.org/education/student/index.html
The Institute of Physics website for students. Various resources.

http://www.physics.org/
An Institute of Physics guide to Physics on the web (although material is not currently updated)

You can find a resource list, including endorsed resources to support Cambridge AS & A Level Physics on our public website here.

Endorsed resources have been written to be closely aligned to the syllabus they support, and have been through a detailed quality assurance process. All textbooks endorsed by Cambridge International for this syllabus are the ideal resource to be used alongside this Learner Guide.

In addition to reading the syllabus, you should refer to the past and specimen papers.

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