AS Physics Cambridge Survival Guide

This Guide Belongs To:

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Intro to Cambridge Physics

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

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

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

Parts of the Cambridge Physics Test:

1. *Multiple Choice (1 hour 15 minutes)*
   This paper consists of 40 multiple choice questions, all with four options. This paper will test assessment objectives AO1 (48%) & AO2 (52%). This paper will be weighted at 31% of the final total mark.
2. *Structured Questions (Free-Response) (1 hour 15 minutes)*
   This paper consists of a variable number of questions of variable mark value. This paper will test assessment objectives AO1 (48%) & AO2 (52%). This paper will weigh 46% of the total final mark.
3. *Practical (2 hours)*
   This paper requires candidates to carry out practical work in timed conditions. The paper will consist of two experiments drawn from different areas of physics. The experiments may be based on physics not included in the syllabus content, but candidates will be assessed on their practical skills rather than their knowledge of theory. Candidates will answer both questions. This paper will test assessment objectives AO3. This paper will be weighted at 23% of the final total mark.

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

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

Significant Figures:
Cambridge is very particular about using the correct number of significant figures. If a correct number answer is not written with the appropriate number of significant figures, you may not receive a mark (or point) for your answer. You need to be able to take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified.

Except where they are produced by addition or subtraction, calculated quantities should be given to the same number of significant figures (or one more than) the measured quantity of least accuracy. For example, if values of a potential difference and of a current are measured to 2 and 4 significant figures respectively, then the corresponding resistance should be given to 2 or 3 significant figures, but not 1 or 4. The number of significant figures may, if necessary, vary down a column of values for a calculated quantity.

Mathematical Requirements

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

Arithmetic: Candidates should be able to...

- recognise and use expressions in decimal and standard form (scientific) notation
- use an electronic calculator for addition, subtraction, multiplication and division. Find arithmetic means, powers (including reciprocals and square roots), sines, cosines, tangents (and the inverse functions)
- take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified
- make approximate evaluations of numerical expressions (e.g. $\pi^2 \approx 10$) and use such approximations to check the magnitude of calculated results.

Algebra: Candidates should be able to...

- change the subject of an equation. Most relevant equations involve only the simpler operations but may include positive and negative indices and square roots.
- solve simple algebraic equations. Most relevant equations are linear but some may involve inverse and inverse square relationships. Linear simultaneous equations and the use of the formula to obtain the solutions of quadratic equations are required.
- substitute physical quantities into physical equations using consistent units and check the dimensional consistency of such equations
- set up simple algebraic equations as mathematical models of physical situations, and identify inadequacies of such models
- express small changes or uncertainties as percentages and vice versa
- understand and use the symbols $<$, $>$, $<$, $>$, %, &, $\approx$, /, $\propto$, Σ, Δx, $\sqrt{\ }$

Geometry and Trigonometry: Candidates should be able to...

- calculate areas of right-angled and isosceles triangles, circumference and area of circles, areas and volumes of cuboids, cylinders and spheres
- use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle
- use sines, cosines and tangents of angles (especially for 0°, 30°, 45°, 60°, 90°)

Vectors: Candidates should be able to...

- find the resultant of two coplanar vectors, recognising situations where vector addition is appropriate
- obtain expressions for components of a vector in perpendicular directions, recognising situations where vector resolution is appropriate.

Graphs: Candidates should be able to...

- translate information between graphical, numerical, algebraic and verbal forms
- select appropriate variables and scales for graph plotting

- determine the gradient, intercept and intersection of linear graphs
- choose, by inspection, a straight line which will serve as the line of best fit through a set of data points presented graphically
- draw a curved trend line through a set of data points presented graphically, when the arrangement of these data points is clearly indicative of a non-linear relationship
- recall standard linear form y= mx+ c and rearrange relationships into linear form where appropriate
- sketch and recognise the forms of plots of common simple expressions like 1/x, x^2, $1/x^2$, sin(x), cos(x)
- draw a tangent to a curve, and understand and use the gradient of the tangent as a means to obtain the gradient of the curve at a point
- understand and use the area below a curve where the area has physical significance.

Assessment Objectives

AO1: Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

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

The syllabus content defines the factual knowledge that candidates may be required to recall and explain. Questions testing these assessment objectives will often begin with one of the following words: define, state, describe, or explain (see Glossary of Terms section).

AO2: Handling information and problem solving

Candidates should be able (in words or by using symbolic, graphical and numerical forms of presentation) to locate, select, organise and present information from a variety of sources

1. translate information from one form to another
2. manipulate numerical and other data
3. use information to identify patterns, report trends, draw inferences and report conclusions
4. present reasoned explanations for phenomena, patterns and relationships
5. make predictions and put forward hypotheses
6. apply knowledge, including principles, to new situations
7. evaluate information and hypotheses
8. demonstrate an awareness of the limitations of physical theories and models.

These assessment objectives cannot be precisely specified in the syllabus content because questions testing such skills may be based on information that is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, reasoned or deductive manner to a new situation. Questions testing these objectives will often begin with one of the following words: predict, suggest, deduce, calculate or determine (see Glossary of Terms section).

AO3: Experimental skills and investigations

Candidates should be able to:

1. plan experiments and investigations
2. collect, record and present observations, measurements and estimates
3. analyse and interpret data to reach conclusions
4. evaluate methods and quality of data, and suggest improvements

This Assessment objective will only be tested in Paper 3.

Glossary of Terms

This glossary should prove helpful to candidates as a guide, although it is not exhaustive and it has deliberately been kept brief. Candidates should understand that the meaning of a term must depend in part on its context. The number of marks allocated for any part of a question is a guide to the depth required for the answer.

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

Practical Test

Candidates' experimental skills will be assessed in Paper 3. In each of these papers, the questions may be based on physics not included in the syllabus content, but candidates will be assessed on their practical skills rather than their knowledge of theory. Where appropriate, candidates will be told exactly what to do and how to do it.

Paper 3 will be a timetabled, laboratory-based practical paper, focusing on the following experimental skills:

- manipulation, measurement and observation
- presentation of data and observations
- analysis, conclusions and evaluation.

Each paper will consist of two questions, each of 1 hour and each of 20 marks.

The first question will be an experiment requiring candidates to collect data, to plot a graph and to draw conclusions.

The second question will be an experiment requiring candidates to collect data and to draw conclusions, but may or may not include the plotting of a graph. In the second question, the experimental method to be followed will be inaccurate, and candidates will be required to evaluate the method and suggest improvements.

The two questions will be set in different areas of physics. No prior knowledge of the theory will be required.

McKeon Message: The first question is usually about building and measuring a circuit.

Mark Scheme for Paper 3

Paper 3 will be marked using the generic mark scheme below. The expectations for each mark category are listed in the sections that follow.

Question 1			
Skill	**Minimum mark allocation***	**Breakdown of skills**	**Minimum mark allocation***
Manipulation, measurement and observation	7 marks	Successful collection of data	5 marks
		Range and distribution of values	1 mark
		Quality of data	1 mark
Presentation of data and observations	6 marks	Table of results	1 mark
		Recording of data, observations and calculations	2 marks
		Graph	3 marks
Analysis, conclusions and evaluation	4 marks	Interpretation of graph	2 marks
		Drawing conclusions	2 marks

*The remaining 3 marks will be allocated across the skills in this grid and their allocation may vary from paper to paper.

Question 2			
Skill	**Minimum mark allocation***	**Breakdown of skills**	**Minimum mark allocation***
Manipulation, measurement and observation	5 marks	Successful collection of data	4 marks
		Quality of data	1 mark
Presentation of data and observations	2 marks	Recording of data, observations and calculations	2 marks
Analysis, conclusions and evaluation	10 marks	Drawing conclusions	1 mark
		Estimating uncertainties	1 mark
		Identifying limitations	4 marks
		Suggesting improvements	4 marks

*The remaining 3 marks will be allocated across the skills in this grid and their allocation may vary from paper to paper.

Expectations for Each Mark Category

Manipulation, measurement and observation

Successful collection of data
Candidates should be able to:

- set up apparatus correctly without assistance from the Supervisor
- follow instructions given in the form of written instructions, diagrams or circuit diagrams
- use their apparatus to collect an appropriate quantity of data
- repeat readings where appropriate
- make measurements using common laboratory apparatus, such as millimetre scales, protractors, toppan balances, newton-meters, analogue or digital electrical meters, measuring cylinders, calipers*, micrometer screw gauges and thermometers
- use a stopwatch 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.

Range and distribution of values
Candidates should be able to:

- make measurements that span the largest possible range of values within the limits either of the equipment provided or of the instructions given
- make measurements whose values are appropriately distributed within this range.

In most experiments, including those involving straight-line graphs, a regularly-spaced set of measurements will be appropriate. For other experiments, such as those requiring the peak value of a curved graph to be determined, it may be appropriate for the measurements to be concentrated in one part of the range investigated. Candidates will be expected to be able to identify the most appropriate distribution of values.

Quality of data
Candidates should be able to:

- make and record accurate measurements.

Marks will be awarded for measured data in which the values obtained are reasonable. In some cases, the award of the mark will be based on the scatter of points on a graph; in other cases, the candidate's data may be compared with information supplied by the Supervisor or known to the Examiners.

Presentation of data and observations

Table of results
Candidates should be able to:

- 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.

As an example of accepted practice in column headings, if the quantity being measured is current in milliamperes, then 'I/ mA' would be the usual way to write the column heading, but 'Iin mA' or 'I(mA)' or 'current / mA' would be allowed. Headings such as 'ImA' or just 'mA' are not acceptable. The quantity or the unit or both may be written in words rather than symbols. Conventional symbols or abbreviations (such as p.d.) may be used without explanation.

Recording of data, observations and calculations
Candidates should be able to:

- record raw readings of a quantity to the same degree of precision
- 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.

For example, if one measurement of length in a column of raw data is given to the nearest millimetre, then all the lengths in that column should be given to the nearest millimetre. The degree of precision used should be compatible with the measuring instrument used: it would be inappropriate to record a distance measured on a millimetre scale as either '2 cm' or '2.00 cm'.
Except where they are produced by addition or subtraction, calculated quantities should be given to the same number of significant figures (or one more than) the measured quantity of least accuracy. For example, if values of a potential difference and of a current are measured to 2 and 4 significant figures respectively, then the corresponding resistance should be given to 2 or 3 significant figures, but not 1 or 4. The number of significant figures may, if necessary, vary down a column of values for a calculated quantity.

Graphing data

Layout
Candidates should be able to:

- plot the independent variable on the x-axis and the dependent variable on the y-axis, except where the variables are conventionally plotted the other way around
- clearly label graph axes with both the quantity and the unit, following accepted scientific conventions

- 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.

The accepted scientific conventions for labelling the axes of a graph are the same as for the column headings in a table of results.

Plotting of points

Candidates should be able to:

- plot all their data points on their graph grid to an accuracy of better than 1 mm.

Points should be finely drawn with a sharp pencil, but must still be visible. A fine cross or an encircled dot is suitable; a thick pencil blob is not.

Trend line

Candidates should be able to:

- identify when the trend of a graph is linear or curved
- draw straight lines of best fit or curves to show the trend of a graph
- draw tangents to curved trend lines.

The trend line should show an even distribution of points on either side of the line along its whole length. Lines should be finely drawn and should not contain kinks or breaks.

Analysis, conclusions and evaluation

Interpretation of graph

Candidates should be able to:

- 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 co-ordinates of points on the trend line of a graph
- determine the gradient of a straight-line graph or of a tangent to a curve
- 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.

When a gradient is to be determined, the points on the line chosen for the calculation should be separated by at least half of the length of the line drawn.
In cases where the y-intercept cannot be read directly from the y-axis, it is expected that the co-ordinates of a point on the line and the gradient will be substituted into $y= mx+ c$.

Drawing conclusions

Candidates should be able to:

- draw conclusions from an experiment, including determining the values of constants, considering whether experimental data supports a given hypothesis, and making predictions.

Estimating uncertainties

Candidates should be able to:

- estimate, quantitatively, the uncertainty in their measurements

- determine the uncertainty in a final result
- express the uncertainty in a measurement as an absolute, fractional or percentage uncertainty, and translate between these forms
- express the uncertainty in a repeated measurement as half the range of the repeated readings.

Identifying limitations

Candidates should be able to:

- identify and describe the limitations in an experimental procedure
- identify the most significant sources of uncertainty in an experiment
- show an understanding of the distinction between systematic errors (including zero errors) and random errors.

Suggesting improvements

Candidates should be able to:

- 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.

Candidates' suggestions should be realistic, so that in principle they are achievable in practice in a school laboratory. The suggestions may relate either to the apparatus used or to the experimental procedure followed. Candidates may include improvements that they have actually made while carrying out the experiment. The suggested modifications may relate to sources of uncertainty identified by the candidate. Improvements that could have been made with the apparatus provided while following the instructions in the question will not normally gain credit.

Apparatus That is Used Regularly

Below is a list of the items that are regularly used in Paper 3. The list is not exhaustive: other items are usually required, to allow for variety in the questions set.

- Cells: 1.5 V
- Connecting leads and crocodile clips
- Digital ammeter, minimum ranges 0–1 A reading to 0.01 A or better, 0–200 mA reading to 0.1 mA or better, 0–20 mA reading to 0.01 mA or better (digital multimeters are suitable)
- Digital voltmeter, minimum ranges 0–2 V reading to 0.001 V or better, 0–20 V reading to 0.01 V or better (digital multimeters are suitable)
- Lamp and holder: 6 V 60 mA; 2.5 V 0.3 A
- Power supply: variable up to 12 V d.c. (low resistance)
- Rheostat (with a maximum resistance of at least 8 Ω, capable of carrying a current of at least 4 A)
- Switch
- Wire: constantan 26, 28, 30, 32, 34, 36, 38 s.w.g. or similar metric sizes
- Long stem thermometer: –10 °C to 110 °C ×1 °C
- Means to heat water safely to boiling (e.g. an electric kettle)
- Plastic or polystyrene cup 200 cm^3
- Stirrer
- Adhesive putty (e.g. Blu-Tack)
- Adhesive tape (e.g. Sellotape)
- Balance to 0.1 g (this item may often be shared between sets of apparatus)
- Bar magnet
- Bare copper wire: 18, 20, 26 s.w.g. or similar metric sizes
- Beaker: 100 cm^3, 200 cm^3, or 250 cm^3
- Card
- Expendable steel spring (spring constant approx. 25 N m^{-1}; unstretched length approx. 2 cm)
- G-clamp
- Magnadur ceramic magnets
- Mass hanger
- Micrometer screw gauge (this item may often be shared between sets of apparatus)
- Modelling clay (e.g. Plasticine)
- Newton-meter (1 N, 10 N)
- Pendulum bob
- Protractor
- Pulley
- Rule with a millimetre scale (1 m, 0.5 m, 300 mm)
- Scissors
- Slotted masses (100 g, 50 g, 20 g, 10 g) or alternative
- Stand, boss and clamp
- Stopwatch (candidates may use their wristwatches), reading to 0.1 s or better
- Stout pin or round nail
- String/thread/twine
- Vernier or digital calipers (this item may often be shared between sets of apparatus)
- Wire cutters

Checklist for Practical

The Experiment

1) Taking readings
   - Repeat all readings and average. Show all readings. If timing, measure the period of at least five oscillations each time. Try for ten if time allows. Remember, timing uncertainty is 0.1 s with a hand-held stopclock.
   - When taking a set of readings make sure that they cover the whole range of the readings fairly evenly.
2) The table of results
   - Try to arrange for a single table that shows all readings, even the first, and their averages;
   - Use the correct units and quantities for each column.
   - Use the same precision (i.e. number of significant figures) for every reading in a particular column.
   - Choose a sensible number of significant figures for your readings (usually 2 or 3).
3) The graph
   - Label each axis of the graph with both quantity and unit.
   - Make sure your graph occupies at least 5 × 7 squares (i.e. half the paper) with yourplotted points.
   - Ask yourself whether the origin should be plotted.
   - Do not use an awkward scale, i.e. 1 square = 3, 7, 9 units.
   - Plot points neatly, with no large blobs, or crosses.
   - Circle your points if you plot them as dots.
   - The line you draw should be clear, thin and even.
4) Measuring the slope
   - Use at least half of the drawn straight line.
   - Show the coordinates that you use for the slope or the values of the sides of the triangle that you use.
   - Give your answer to 1 or 2 significant figures as appropriate. Don't forget units.
5) The straignt-line formula for a graph, y=mx+b
   - If $y^2 = ax^3$ then plot y^2 against x^3 and the slope is a.
   - If $y = ax^n$ then $\ln(y) = n\ln(x) + \ln(a)$. Plot $\log_{10}(y)$ or $\ln(y)$ against $\log_{10}(x)$ or $\ln(x)$ and the slope is n.
   - If $y = ae^{kx}$ then $\ln(y) = kx + \ln(a)$. Plot $\ln(y)$ against x and the slope is k.
   - On tables and graphs the label is ln (y/m) or $\log_{10}$(y/m) to show the unit of y as metres,
   - Check that you know how to use logs.
6) Checking relationships

   When checking, state what should be constant, perform the calculation and then state whether the constant was found and whether the relationship is verified. You may want to refer to the uncertainty.

• *y* proportional to *x*	$\frac{y}{x}$ should be constant.
• *y* proportional to $\frac{1}{x}$	$y \times x$ should be constant.
• *y* proportional to e^x	*y* decreases by same factor if *x* increases by equal amounts.

Uncertainties

Graphs can be plotted with each point having error bars on the x-axis and the y-axis to show the expected absolute uncertainties. Th e worst acceptable line should be drawn as a dotted line or labelled as worst acceptable line; it should be the steepest or shallowest line that goes through the error bars of all the points. If this is not possible because of one point that point may be anomalous. Check it – it may be wrong.

1) Causes of uncertainty in simple measurements
   - Lengths – rulers may have battered ends, or the zero may not actually be at the end. To avoid parallax uncertainty, you must view any reading from directly above. The likely uncertainty is ±1 mm or perhaps ± 0.3 mm.
   - Times – stopwatches measure to ± 0.01 s but you can't press them that accurately. The likely uncertainty is ± 0.1 s.

- Meters (e.g. ammeter) – uncertainty is the smallest scale reading, or any fluctuation.
- Graphs – uncertainty in gradient is diff erence between gradient of best fit line and worst acceptable line. Use similar idea to find uncertainty in y-intercept.

2) Combining uncertainties
- There are absolute uncertainties and percentage uncertainties – know the difference.
- When adding or subtracting quantities, add absolute uncertainties.
- When multiplying or dividing quantities, add percentage uncertainties to get the percentage uncertainty in the answer.

Worked example:

Suppose two measurements have values $A = 2.34 \pm 0.02$ and $B = 6.0 \pm 0.1$

(Notice that the values are quoted to the number of decimal places justified by the uncertainty. Uncertainties are only themselves usually accurate to no better than 1 significant fig so giving more than 2 significant figures is meaningless.)

What are the uncertainties in $A + B$, $B - A$, $\frac{B}{A}$ and $B \times A$?

Adding and subtracting:

$$A + B = 8.34 \pm 0.12 = 8.3 \pm 0.1$$

$$B - A = 3.64 \pm 0.12 = 3.6 \pm 0.1$$

Dividing:

$$\frac{B}{A} = 2.56$$

$$\%\text{ uncertainty in } \frac{B}{A} = \%\text{ uncertainty in } A + \%\text{ uncertainty in } B$$

$$= 1 + 1.5$$

$$= 2.5\%$$

$$\text{actual uncertainty in } \frac{B}{A} = \frac{2.56 \times 2.5}{100} = 0.06$$

so

$$\frac{B}{A} = 2.56 \pm 0.06$$

Multiplying:

$$B \times A = 14.04$$

As when dividing, the percentage uncertainty in $B \times A$ is again 2.5%. This gives:

$$\text{actual uncertainty in } B \times A = \frac{14.04 \times 2.5}{100} = 0.4$$

$$B \times A = 14.0 \pm 0.4$$

Describing and improving an experiment
- State every reading you will take. Do not say, 'Take the readings as before.'
- Make clear what is kept constant and what is changed.
- Give sensible values for quantities, particularly those that are changed. Use your common sense.
- Have at least five sets of readings as a variable changes.
- Say that you will repeat and average each reading.
- Say what the axes will be for a straight-line graph. Never just say, 'plot a graph'.
- Set out your account clearly and logically; use any suggested format if you think it helps.
- Plan your account briefly before you start writing.

Syllabus Objectives

Physical quantities and units

The measurement and recording of quantities is central to the whole of physics. The skills of estimating a physical quantity and having a feeling for which quantities are reasonable and which are unreasonable are very useful for any physicist.

This topic introduces the SI system of units, which provides a universal framework of measurement that is common to all scientists internationally.

Candidates should be aware of the nature of a physical measurement, in terms of a magnitude and a unit. They should have experience of making and recording measurements in the laboratory.

1) Physical Quantities
    a) understand that all physical quantities consist of a numerical magnitude and a unit
    b) make reasonable estimates of physical quantities included within the syllabus
2) SI Units
    a) recall the following SIbase quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K)
    b) express derived units as products or quotients of the SIbase units and use the named units listed in this syllabus as appropriate
    c) use SIbase units to check the homogeneity of physical equations
    d) use the following prefixes and their symbols to indicate decimal submultiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega(M), giga(G), tera(T)
    e) understand and use the conventions for labelling graph axes and table columns
3) Scalars and vectors
    a) distinguish between scalar and vector quantities and give examples of each
    b) add and subtract coplanar vectors
    c) represent a vector as two perpendicular components

Measurement techniques

Measurement is essential to the study of physics. Physicists need to be familiar with a wide range of measuring instruments.

Measurements themselves may be misleading and result in inappropriate conclusions as a result of errors and uncertainties. This topic develops an understanding of errors and uncertainties in measured and derived physical quantities.

1) Measurements
    a) use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the ranges of magnitude implied by the relevant parts of the syllabus. In particular, candidates should be able to:
        i) measure lengths using rulers, calipers and micrometers
        ii) measure weight and hence mass using balances
        iii) measure an angle using a protractor
        iv) measure time intervals using clocks, stopwatches and the calibrated
        v) time-base of a cathode-ray oscilloscope (c.r.o.)
        vi) measure temperature using a thermometer
        vii) use ammeters and voltmeters with appropriate scales
        viii) use a galvanometer in null methods
        ix) use a cathode-ray oscilloscope (c.r.o.)
    b) use both analogue scales and digital displays
    c) use calibration curves
2) Errors and Uncertainties
    a) understand and explain the effects of systematic errors (including zero errors) and random errors in measurements
    b) understand the distinction between precision and accuracy

c) assess the uncertainty in a derived quantity by simple addition of absolute, fractional or percentage uncertainties (a rigorous statistical treatment is not required)

Kinematics

Kinematics is the study of motion. Movement is part of everyday experience, so it is important to be able to analyse and predict the way in which objects move.

The behaviour of moving objects is studied both graphically and through equations of motion.

1) Equations of Motion
   a) define and use distance, displacement, speed, velocity and acceleration
   b) use graphical methods to represent distance, displacement, speed, velocity and acceleration
   c) determine displacement from the area under a velocity-time graph
   d) determine velocity using the gradient of a displacement-time graph
   e) determine acceleration using the gradient of a velocity-time graph
   f) derive, from the definitions of velocity and acceleration, equations that represent uniformly accelerated motion in a straight line
   g) solve problems using equations that represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitational field without air resistance
   h) describe an experiment to determine the acceleration of free fall using a falling body
   i) describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction

Dynamics

The motion of any object is governed by forces that act on the object.

This topic introduces Newton's laws of motion, which are fundamental to understanding the connection between forces and motion. The concept of momentum and the use of momentum conservation to analyse interactions are also studied.

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

Forces, density and pressure

In this topic, the natures of some different types of force are studied, including how forces give rise to both translational and rotational equilibrium.

The concept of pressure is introduced. This acts as a starting point for later work on pressure in gases.

1) Types of forces

a) describe the force on a mass in a uniform gravitational field and on a charge in a uniform electric field
b) understand the origin of the upthrust acting on a body in a fluid
c) show a qualitative understanding of frictional forces and viscous forces including air resistance (no treatment of the coefficients of friction and viscosity is required)
d) understand that the weight of a body may be taken as acting at a single point known as its centre of gravity

2) Turning effects of forces
a) define and apply the moment of a force
b) understand that a couple is a pair of forces that tends to produce rotation only
c) define and apply the torque of a couple

3) Equilibrium of forces
a) state and apply the principle of moments
b) understand that, when there is no resultant force and no resultant torque, a system is in equilibrium
c) use a vector triangle to represent coplanar forces in equilibrium

4) Density and pressure
a) define and use density
b) define and use pressure
c) derive, from the definitions of pressure and density, the equation $\Delta p = \rho g \Delta h$
d) use the equation $\Delta p = \rho g \Delta h$

Work, energy and power

This topic introduces different forms of energy in both qualitative and quantitative terms. The concept of energy and its conservation provide useful accounting tools that help to understand the behaviour of physical systems.

The concepts of power and efficiency are also studied.

1) Energy conversion and conservation
a) give examples of energy in different forms, its conversion and conservation, and apply the principle of conservation of energy to simple examples

2) Work and efficiency
a) understand the concept of work in terms of the product of a force and displacement in the direction of the force
b) calculate the work done in a number of situations including the work done by a gas that is expanding against a constant external pressure: $W = p\Delta V$
c) recall and understand that the efficiency of a system is the ratio of useful energy output from the system to the total energy input
d) show an appreciation for the implications of energy losses in practical devices and use the concept of efficiency to solve problems

3) Potential energy and kinetic energy
a) derive, from the equations of motion, the formula for kinetic energy $E_k = 1/2\ mv^2$
b) recall and apply the formula $E_k = 1/2\ mv^2$
c) distinguish between gravitational potential energy and elastic potential energy
d) understand and use the relationship between force and potential energy in a uniform field to solve problems
e) derive, from the defining equation $W = Fs$, the formula $\Delta E_p = mg\Delta h$ for potential energy changes near the Earth's surface
f) recall and use the formula $\Delta E_p = mg\Delta h$ for potential energy changes near the Earth's surface

4) Power
a) define power as work done per unit time and derive power as the product of force and velocity
b) solve problems using the relationships $P = W/t$ and $P = Fv$

Deformation of solids

Solids change their shape under the action of forces. This change may be large in the case of springs or hardly noticeable in some structures such as buildings.

The study of the deformation of solids is an important aspect of engineering. This topic provides an introduction to both elastic and plastic deformation of materials.

1) Stress and strain

   a) appreciate that deformation is caused by a force and that, in one dimension, the deformation can be tensile or compressive
   b) describe the behaviour of springs in terms of load, extension, elastic limit, Hooke's law and the spring constant (i.e. force per unit extension)
   c) define and use the terms stress, strain and the Young modulus
   d) describe an experiment to determine the Young modulus of a metal in the form of a wire
2) Elastic and plastic behavior
   a) distinguish between elastic and plastic deformation of a material
   b) understand that the area under the force-extension graph represents the work done
   c) deduce the strain energy in a deformed material from the area under the force-extension graph

Waves

This topic introduces the basic properties of transverse and longitudinal progressive waves, including the determination of the frequency and speed of sound waves. The electromagnetic spectrum is also introduced.

These basic properties of waves are developed further into a study of the Doppler effect and of ultrasound for diagnostic purposes.

The ideas of simple wave behaviour, such as reflection and refraction of light, would be useful prior knowledge.

1) Progressive waves
   a) describe what is meant by wave motion as illustrated by vibration in ropes, springs and ripple tanks
   b) understand and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed
   c) deduce, from the definitions of speed, frequency and wavelength, the wave equation $v = f\lambda$
   d) recall and use the equation $v = f\lambda$
   e) understand that energy is transferred by a progressive wave
   f) recall and use the relationship intensity $\propto$ (amplitude)
2) Transverse and longitudinal waves
   a) compare transverse and longitudinal waves
   b) analyse and interpret graphical representations of transverse and longitudinal waves
3) Determination of frequency and wavelength in sound waves
   a) determine the frequency of sound using a calibrated cathode-ray oscilloscope (c.r.o.)
   b) determine the wavelength of sound using stationary waves
4) Doppler Effect
   a) understand that when a source of waves moves relative to a stationary observer, there is a change in observed frequency
   b) use the expression $f_0 = \frac{f_s v}{(v \pm v_s)}$ for the observed frequency when a source of sound waves moves relative to a stationary observer
   c) appreciate that Doppler shift is observed with all waves, including sound and light
5) Electromagnetic Spectrum
   a) state that all electromagnetic waves travel with the same speed in free space and recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays

Superposition

Superposition is used to develop the concept of stationary waves.

Diffraction and interference are then studied, including two-source interference and the diffraction grating.

1) Stationary waves
   a) explain and use the principle of superposition in simple applications
   b) show an understanding of experiments that demonstrate stationary waves using microwaves, stretched strings and air columns
   c) explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes
2) Diffraction
   a) explain the meaning of the term diffraction

   - b) show an understanding of experiments that demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap
3) Interference, two-source interference
   - a) understand the terms interference and coherence
   - b) show an understanding of experiments that demonstrate two-source interference using water ripples, light and microwaves
   - c) understand the conditions required if two-source interference fringes are to be observed
   - d) recall and solve problems using the equation $\lambda = ax/D$ for double-slit interference using light
4) Diffraction gratings
   - a) recall and solve problems using the formula $d\sin\theta = n\lambda$
   - b) describe the use of a diffraction grating to determine the wavelength of light

Electric Fields

In this topic, the concept of an electric field is introduced. This is further developed to study the field and potential energy of point charges.

Awareness of the two types of charge and the processes of charging by friction and by induction are useful prior knowledge.

1) Concept of an electric field
   - a) understand the concept of an electric field as an example of a field of force and define electric field strength as force per unit positive charge acting on a stationary point charge
   - b) represent an electric field by means of field lines
2) Uniform electric fields
   - a) recall and use $E = \Delta V/\Delta d$ to calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation
   - b) calculate the forces on charges in uniform electric fields
   - c) describe the effect of a uniform electric field on the motion of charged particles

Current of electricity

Electric current, potential difference, resistance and power in electrical circuits are introduced. The concept of resistivity is included. Some electrical components may be used to sense environmental changes.

1) Electric current
   - a) understand that electric current is a flow of charge carriers
   - b) understand that the charge on charge carriers is quantised
   - c) define the coulomb
   - d) recall and use $Q = It$
   - e) derive and use, for a current-carrying conductor, the expression $I = Anvq$, where nis the number density of charge carriers
2) Potential difference and power
   - a) define potential difference and the volt
   - b) recall and use $V = W/Q$
   - c) recall and use $P = VI$ and $P = I^2R$
3) Resistance and resistivity
   - a) define resistance and the ohm
   - b) recall and use $V = IR$
   - c) sketch and discuss the I–V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp
   - d) state Ohm's law
   - e) recall and use $R = \rho L/A$

D.C. circuits

In this topic, practical circuits are considered. Circuit diagrams are studied with particular reference to Kirchhoff's laws and the consequences of internal resistance.

The use of potential divider circuits for monitoring environmental conditions is studied

1) Practical circuits
   a) recall and use appropriate circuit symbols (see Electrical Symbols section)
   b) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus
   c) define electromotive force (e.m.f.) in terms of the energy transferred by a source in driving unit charge round a complete circuit
   d) distinguish between e.m.f. and potential difference (p.d.) in terms of energy considerations
   e) understand the effects of the internal resistance of a source of e.m.f. on the terminal potential difference
2) Kirchhoff's laws
   a) recall Kirchhoff's first law and appreciate the link to conservation of charge
   b) recall Kirchhoff's second law and appreciate the link to conservation of energy
   c) derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series
   d) solve problems using the formula for the combined resistance of two or more resistors in series
   e) derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel
   f) solve problems using the formula for the combined resistance of two or more resistors in parallel
   g) apply Kirchhoff's laws to solve simple circuit problems
3) Potential dividers
   a) understand the principle of a potential divider circuit as a source of variable p.d.
   b) recall and solve problems using the principle of the potentiometer as a means of comparing potential differences

Particle and nuclear physics

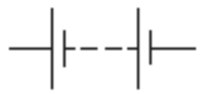
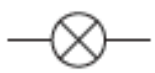
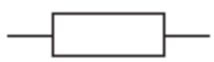
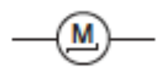
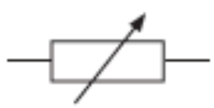
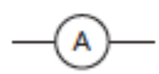
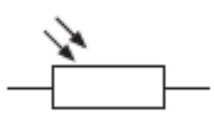
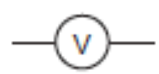
Alpha-particle scattering is studied as evidence for the structure of the atom.

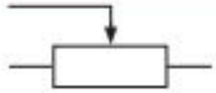
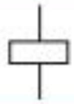
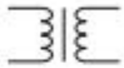
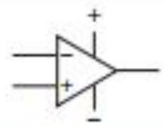
Nuclear composition, in terms of nucleons, leads to an appreciation of mass defect and binding energy. Nuclear processes including radioactive decay, fission and fusion are studied.

An introduction to fundamental particles is included.

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

Electrical Symbols

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

potentiometer		oscilloscope	
relay coil		antenna	
transformer		capacitor	
diode		operational amplifier	
light-emitting diode			

Symbols and Units

The list below is intended as a guide to the more important quantities which might be encountered in teaching and used in question papers. This list is for use in both AS Level and full A Level qualifications.

Quantity	Usual symbols	Usual unit
Base quantities		
mass	m	kg
length	l	m
time	t	s
electric current	I	A
thermodynamic temperature	T	K
amount of substance	n	mol
Other quantities		
acceleration	a	$\mathrm{m\,s^{-2}}$
acceleration of free fall	g	$\mathrm{m\,s^{-2}}$
activity of radioactive source	A	Bq
amplitude	x_0	m
angle	θ	°, rad
angular displacement	θ	°, rad
angular frequency	ω	$\mathrm{rad\,s^{-1}}$
angular speed	ω	$\mathrm{rad\,s^{-1}}$
angular velocity	ω	$\mathrm{rad\,s^{-1}}$
area	A	$\mathrm{m^2}$
atomic mass	m_a	kg, u
attenuation/absorption coefficient	μ	$\mathrm{m^{-1}}$
Avogadro constant	N_A	$\mathrm{mol^{-1}}$
Boltzmann constant	k	$\mathrm{J\,K^{-1}}$
capacitance	C	F
Celsius temperature	θ	°C
decay constant	λ	$\mathrm{s^{-1}}$
density	ρ	$\mathrm{kg\,m^{-3}}$
displacement	s, x	m
distance	d	m
efficiency	η	
electric charge	q, Q	C

Quantity	Usual symbols	Usual unit
electric field strength	E	$N C^{-1}$, $V m^{-1}$
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
electron mass	m_e	kg, u
elementary charge	e	C
energy	E, U, W	J
force	F	N
frequency	f	Hz
gravitational constant	G	$N m^2 kg^{-2}$
gravitational field strength	g	$N kg^{-1}$
gravitational potential	ϕ	$J kg^{-1}$
half-life	$t_{\frac{1}{2}}$	s
Hall voltage	V_H	V
heating	q, Q	J
intensity	I	$W m^{-2}$
internal energy change	ΔU	J
kinetic energy	E_k	J
magnetic flux	Φ	Wb
magnetic flux density	B	T
mean-square speed	$\langle c^2 \rangle$	$m^2 s^{-2}$
molar gas constant	R	$J mol^{-1} K^{-1}$
molar mass	M	$kg mol^{-1}$
moment of force	T	N m
momentum	p	N s
neutron mass	m_n	kg, u
neutron number	N	
nucleon number	A	
number	N, n, m	
number density (number per unit volume)	n	m^{-3}
period	T	s
permeability of free space	μ_0	$H m^{-1}$
permittivity of free space	ε_0	$F m^{-1}$
phase difference	ϕ	°, rad
Planck constant	h	J s
potential energy	E_p	J

Quantity	Usual symbols	Usual unit
power	P	W
pressure	p	Pa
proton mass	m_p	kg, u
proton number	Z	
ratio of powers		dB
relative atomic mass	A_r	
relative molecular mass	M_r	
resistance	R	Ω
resistivity	ρ	Ω m
specific acoustic impedance	Z	$\text{kg m}^{-2}\text{s}^{-1}$
specific heat capacity	c	$\text{J kg}^{-1}\text{K}^{-1}$
specific latent heat	L	J kg^{-1}
speed	u, v, w, c	m s^{-1}
speed of electromagnetic waves	c	m s^{-1}
spring constant	k	N m^{-1}
strain	ε	
stress	σ	Pa
torque	T	N m
velocity	u, v, w, c	m s^{-1}
volume	V, v	m^3
wavelength	λ	m
weight	W	N
work	w, W	J
work function energy	Φ	J
Young modulus	E	Pa

Data and Formulae

The following data and formulae will appear as pages 2 and 3 in Papers 1, 2 (AS Test) and 4 (A Test). Some of the data and formulae will not be needed for the AS Papers.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0{}^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$