18 Appendix 2: Preparing for the IB Diploma Physics examination

Revision techniques

There are many different ways of revising for examinations, but some general words of advice apply to everyone:

- Use the IB syllabus and the summaries of knowledge for each chapter to identify your strengths and weaknesses at an early stage of your revision. Effective revision will concentrate on the parts of the syllabus with which you are less confident, rather than repeating topics you already know well. Monitor your progress, and you will be motivated by the fact that the list of topics left to revise becomes shorter and shorter.
- Revision should usually be *active* rather than passive. Discussing physics or answering questions is generally much more useful than reading or watching a physics video. However, it is sensible to *start* your revision of a topic by re-reading the appropriate section of this book.
- Answering questions from past examination papers is very important and many students and teachers believe that it is the best way to revise. You should do as many questions as you can, and check your answers, or have them checked by someone else. Completing 'mock exams', in which you answer all the required questions on complete examination papers in the regulation times, will also help you to judge whether you are working too quickly or slowly. You may also have taken a series of tests and examinations during your course; these are valuable resources for revision – we should all learn from our mistakes.
- Very few students enjoy revision so it is a good idea to use a variety of different revision techniques to stimulate interest. Some students also find that working in different surroundings can be a way to freshen up their revision. It is not a good idea to force yourself to revise when you are tired, nor to work for too long at one time. (Between 40 and 60 minutes may be the ideal length of time for revision without a break.)
- Most students find that planning a revision schedule helps to organize and structure their work. But it can be a waste of time if you don't stick to your schedule, so you need to keep re-writing it!
- You must be familiar with the structure of the examination papers and the styles of different exam questions (see below).

Examination paper details

The Physics data book is provided in all examinations. There is no choice of questions in any paper.

Make sure you take into the examination room all the equipment you may need: 30 cm ruler, protractor, compass, pens and pencils and a calculator of an approved type (not allowed in Paper 1).

	Standard Level	Higher Level
Paper 1	45 minutes	1 hour
	30 multiple-choice questions	45 multiple-choice questions
	Questions will be set on the Standard Level Core (Chapters 1–8)	Questions will be set on the Standard Level Core (Chapters 1–8) + the Additional Higher Level (AHL) content from Chapters 9–12
	Calculators are *not* allowed	Calculators are *not* allowed
	20% of total examination mark	20% of total examination mark
Paper 2	1 hour 15 minutes	2 hours 15 minutes
	Questions will be set on the Standard Level Core (Chapters 1–8)	Questions will be set on the Standard Level Core (Chapters 1–8) + AHL content from Chapters 9–12
	Short-answer and extended-response type questions	Short-answer and extended-response type questions
	Calculators are allowed	Calculators are allowed
	40% of total examination mark	36% of total examination mark
Paper 3	1 hour	1 hour 15 minutes
	Section A has one data-based type question and several short-answer questions on experimental work (Knowledge of Core material will be assumed (Chapters 1–8))	Section A has one data-based type question and several short-answer questions on experimental work. (Knowledge of Core and AHL material will be assumed (Chapters 1–12))
	Section B has short-answer and extended-response type questions on the Options (you select the questions for one Option)	Section B has short-answer and extended-response type questions on the Options (you select the questions for one Option)
	Calculators are allowed	Calculators are allowed
	20% of total examination mark	24% of total examination mark
Internal assessment	20% of total examination mark	

Taking the examination

There are very few students who (with the same knowledge of physics) could not improve their marks simply by improving their examination technique. Here are some tips.

Paper 1

- The questions are generally arranged in approximate syllabus order.
- Although multiple-choice questions are often considered to be easier than many of the questions in the other two papers, it is common for students to make careless mistakes. If you have time, double-check your answers.
- Never select any answer until you have read *all* the alternative possibilities.
- If you are unsure of an answer, do not spend too much time on it. Write comments next to the question, cross out any answers that seem obviously wrong (there are usually one or two!) and move on to the next question. If you work quickly enough you should have time to return to unfinished questions later – the question may seem easier second time around.
- Be aware that sometimes a possible answer is a correct statement in itself, but not the correct answer to the question.
- Look out for the inclusion of two answers that contradict each other. It is likely that one of them is correct (and the other wrong).
- Remember that there is no penalty for wrong answers. Never leave a question without an answer, even if it is only a guess.

Papers 2 and 3

- Read through the *whole* question before you begin to answer any part.
- Judge the amount of detail you need to supply in your answers from the amount of space allowed and the number of marks allocated to the question. In general you need to make a separate point for each mark.
- Read the questions very carefully and note or underline key words and phrases. If a question asks you to 'use' certain information, graphs or laws make sure that your answer does exactly that. If you answer the question in some other way, even correctly, you will not get the marks. If the question refers to a law or definition, begin your answer by quoting it.
- The presentation of your answers is important. Although neatness and correct spelling are not directly assessed, they create a favourable impression. Use a ruler to draw straight lines.
- Always show all your working in calculations.
- Give your answers in decimals not fractions. Use scientific notation wherever appropriate.
- Use appropriate significant figures in your answers and do not forget units.
- In general, it is better to express physical quantities in words, rather than symbols, although standard symbols can be used in the working of calculations.
- If you need to change one of yours answers, neatly cross out the work you want to delete. If there is not enough space for your new work, use extra pages and attach them to your answer booklet at the end of the examination.

Examples of different styles of exam question (Papers 2 and 3)

Command terms

All Paper 2 and 3 questions in IB Diploma Physics examinations contain one of a limited number of clear instructions, such as *define*, *outline* and *calculate*. These one-word instructions are known as *command terms* and they indicate the way in which you should answer the question. The command terms can be divided into three groups:

- demonstrate understanding (AO1)
- apply and use (AO2)
- construct, analyse and evaluate (AO3).

Demonstrate understanding

These command terms will be used to test your memory of factual knowledge of the syllabus.

Define

You are required to give the *exact* meaning of a word, phrase or quantity. You are strongly advised to make sure that you know all these definitions before the examination.
A surprisingly high proportion of students fail to achieve these 'easy' marks.

A definition should usually be written in words, rather than as an equation, although an equation is acceptable if the meanings of all the symbols are explained.

Worked example

Question: *Define* resistance.

Answer: Resistance is the ratio of the potential difference across a conductor to the current passing through it. ($R = \frac{V}{I}$ is only acceptable if the symbols are explained.)

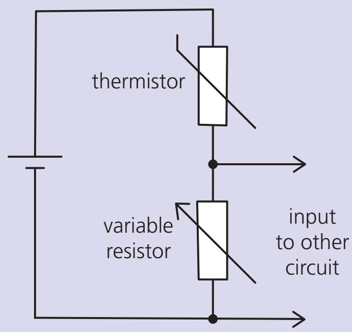
Draw

This widely used command term usually requires you to add something to an existing diagram or graph, but sometimes you may be asked to draw a completely new diagram. Use a sharp pencil and a ruler for drawing. Drawing a line of best fit on a graph is a common question (see Chapter 17).

Worked example

Question: *Draw* a circuit to show how a cell, a thermistor and a variable resistor can be connected to provide a potential dividing input to another circuit.

Answer:



Note that, in this example, it is not essential to label the components if standard electrical circuit symbols are used (see the *Physics data booklet*). The question is partly aimed at testing whether or not you know these symbols. If you are unsure of the correct symbol, draw a box and write beside it what it is meant to represent.

Label

This common instruction is often combined with an instruction to draw something. It may refer to an existing diagram, or an addition to a diagram that you are asked to make, or occasionally to a new drawing. The labels should normally be words rather than symbols. It is important to do this neatly and clearly, so the examiner can be sure exactly what you are labelling.

Worked example

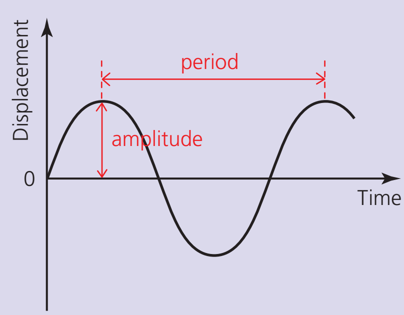
Question: Draw an arrow on the diagram to show the direction of the current and *label* it with the letter *I*.

This could be testing if you know that current flows conventionally from positive to negative around a circuit. The letter *I* should be placed close to the arrow. Without the labelling you may not be awarded the mark, even if the direction is correct.

Worked example

Question: Label the drawing to show the meaning of amplitude and period.

Answer:



Worked example

Question: The diagram shows a car moving at constant velocity. Draw fully *labelled* vectors to indicate the forces acting on the car.

Answer: At least four force vectors should be labelled as: weight, normal contact force, air resistance and push of road on tyres. The pairs of vectors should have equal lengths.

List

This means that you should provide a series of items *without* explanation. It should be clear from the question if the terms need to be in any order.

Worked example

Question: *List* the main energy sources used around the world to generate electrical power.

Answer: coal, nuclear, oil, natural gas, hydroelectric. (In this answer the order of the list is not important, nor is the list complete. A complete list would not be required by the examiner because the question is not intended to be definitive.)

Measure

This command term requires that you measure the value of a physical quantity from a diagram or graph on the examination paper. It could be a length, an area, an angle, or may require interpretation from a scale. Clearly you should be prepared by taking a 30 cm ruler and a protractor into the examination room. Obviously, measurement has to be accurate in order to get the marks available.

Worked example

Question: The diagram shows a ray of light being refracted as it enters some glass. Take *measurements* in order to calculate the refractive index of the medium. (This combines measurements with a calculation.)

Answer: It will be necessary to measure the angles of incidence and refraction.

State

State is similar to *define* in that a short, precise answer is required, without the need for any further explanation. This is one of the most widely used command terms in IB Diploma physics examinations. The syllabus contains some important laws and terms that may need to be 'stated' in an examination, and these should be memorized in the same way as definitions.

Worked example

Question: *State* what is meant by damping.

Answer: Damping is the dissipation of the energy of an oscillation when it is acted on by a resistive force.

Write down

This requires only a short, straightforward answer without explanation. The information is often readily available from within the question.

Worked example

Question: *Write down* the name of the source of most radiant energy arriving at the Earth.

Answer: The Sun.

Apply and use

These command terms will test your ability to *use* the concepts and principles of physics that you have learned during the course.

Annotate and apply

These are unusual command terms in IB Diploma Physics examinations.

- To *annotate* is similar to *label*, but requires *brief notes* to be added to a diagram or graph.
- To *apply* means to use knowledge in a new situation. For example, you could be asked to *apply* your understanding of Newton's laws of motion to a fairground ride.

Calculate

In this very common type of question you are required to use data given in the question and/or in the *Physics data booklet* in order to determine a numerical answer.

- You must show clearly *how* you obtained your answer. Marks are usually awarded for correct working, even if your final answer is wrong.
- Your answer must have a suitable number of significant figures (see Chapter 1).
- Your answer must have a unit (unless it is a ratio).

Worked example

Question: A stone is thrown vertically upwards with a speed of $8.10\,\text{m}\,\text{s}^{-1}$. Ignoring air resistance, *calculate* the maximum height reached by the stone.

Answer:

$v^2 = u^2 + 2as$ (Quote the equation you are using.)

$0 = 8.10^2 + (2 \times -9.81 \times s)$ (Substitute the data. The value for *a* was taken from the *Physics data booklet*.)

$s = 3.34\,\text{m}$

Answers of 3.3 m or 3.344 m will also be accepted.

Describe

Use knowledge from the course and/or information given in the question to give a straightforward account. The amount of detail needed will vary from question to question, and is best judged from the number of marks available for the answer.

The command term *describe* appears frequently in the IB examinations.

Worked example

Question: *Describe* what is meant by the term resonance. (3 marks)

Answer: Resonance is the increase in the amplitude of an oscillation when it is disturbed by an external force that has the same frequency as the natural frequency of the oscillator.

Note that there are three separate ideas included in this answer – in response to the 3 marks allocated to the question.

Distinguish

This command term means you should explain the essential difference(s) between two (or more) things. You may also briefly indicate what they have in common.

Worked example

Question: *Distinguish* between speed and velocity.

Answer: Speed is calculated from distance/time. Velocity has the same magnitude as speed, but a direction of motion must also be given. (Examples might help, but are not essential, unless asked for in the question.)

Estimate

This is similar to *calculate*, but an accurate answer will not be possible. For example, the question may involve you making a calculation based on *your* reasonable estimates of unknown quantities. Estimated answers should be given with an appropriate number of significant figures (which may be only one), or just an order of magnitude.

Making estimates is demanding for many students, but marks will be awarded for *any* reasonable estimates, rather than an expected answer. Your assumptions should be stated clearly.

Worked example

Question: *Estimate* the amount of coal that would be burned in a 100 MW power station in one hour.

Answer:

$$\text{mass of coal needed every second} = \frac{\text{output power}}{\text{efficiency} \times \text{energy density}}$$

Assuming that the power station has an efficiency of 35% and the energy density of the coal used is 30 MJ kg^{-1}:

$$\text{mass of coal needed per second} = \frac{10^8}{0.35 \times 3 \times 10^7} = 9.5\,\text{kg}$$

$$\text{mass of coal needed per hour} = 9.5 \times 3600 \approx 3 \times 10^4\,\text{kg}$$

Formulate

Use existing knowledge to construct a precise and methodical answer to a non-mathematical problem.

Worked example

Question: Use the kinetic theory of gases to *formulate* an explanation of why the density of the Earth's atmosphere decreases with increasing distance from the Sun.

Answer: Gas molecules move at high speeds in random directions. Molecules further away from a planet's surface will have transferred kinetic energy to gravitational potential energy and slowed down. Fewer molecules have sufficient energy to reach greater heights.

Identify

This requires that you give a name for something, or select a correct answer from a number of different possibilities (which *may* be provided in the question). Only a brief answer is required.

Worked example

Question: The following equation represents the production of carbon-14 in the Earth's atmosphere by neutron bombardment of nitrogen:

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + X$$

Identify the particle denoted by X.

Answer: A proton ($^{1}_{1}p$ is an acceptable answer).

Outline

This is similar to *describe*, except that full details are *not* needed. The command signifies to the student to give only a *brief* answer, and there will usually only be 1 or 2 marks for such a question.

Worked example

Question: *Outline* how the energy carried by a water wave can be converted to electrical energy in an ocean-wave energy converter.

Answer: As the crests and troughs of the water pass through the converter, air is forced backwards and forwards past a turbine. The turbine causes coils of wire to rotate in a magnetic field and generate a voltage.

Plot

Mark the positions of points on a graph or diagram.

Construct, analyse and evaluate

This group of command terms may involve less familiar situations or a deeper understanding. They can test more complex skills, such as critical thinking and imagination.

Comment

This command term requires your judgment or opinion of a calculated numerical answer or a statement provided in a question. Usually only one comment is required.

Worked example

Question: The value for the specific latent heat of fusion of ice determined by experiment using an immersion heater was lower than the accepted value. *Comment* on this difference.

Answer: This was probably because thermal energy was transferred to the ice from the hotter surroundings, so less energy was needed from the heater to melt it.

Worked example

Question: There is an enormous amount of energy in the waves on the world's oceans. *Comment* on the fact that very little of this energy is transferred to forms that are useful to us.

Answer: The construction and maintenance costs of ocean-wave energy converters are currently much more expensive than for most other energy sources.

Deduce

This is a widely used command term. To *deduce* means to reach a conclusion (stated in the question) from the information provided. Most commonly, this will require you to show all the steps in a calculation and, in this respect, *deduce* has a similar meaning to *show*. However, *deducing* is not quite as straightforward and may involve more steps (and marks). As with *show*, it is important to show every step of the calculation.

Worked example

Question: A laser has an output power of 4.0 mW and forms a parallel beam of width 0.46 cm, which strikes a surface perpendicularly. If the wavelength of the light is 630 nm, *deduce* that photons are striking the surface at a rate of about $3.0 \times 10^{14}\,\text{cm}^{-2}\,\text{s}^{-1}$. (3 marks)

Answer:

number of photons per second in the beam $= \dfrac{\text{power}}{\text{energy of each photon}} = \dfrac{hc}{\lambda}$

$= \dfrac{4.0 \times 10^{-3}}{6.63 \times 10^{-34} \times 3.00 \times 10^{8}/6.30 \times 10^{-9}}$

$= 1.3 \times 10^{14}\,\text{s}^{-1}$

rate per $\text{cm}^2 = 1.3 \times 10^{14}/0.46 = 2.8 \times 10^{14}\,\text{cm}^{-2}\,\text{s}^{-1}$

Note that you should show the answer that is produced from the data provided, *not* just the approximate answer provided in the question.

Demonstrate

Use an example, or reasoning, to show that a proposition is correct.

Worked example

Question: Use an everyday example to demonstrate that water has a high specific heat capacity.

Answer: A glass of hot water will take a longer time to cool to room temperature, compared with similar amounts of other materials under the same circumstances.

Derive

To *derive* means to show all the physics principles and mathematical reasoning that leads to a particular equation.

Worked example

Question: *Derive* an expression for the gravitational field strength on the surface of a planet in terms of its mass M, its radius R and the universal gravitational constant G. (2 marks)

Answer: Gravitational field strength, g, is defined as $\dfrac{\text{gravitational force}}{\text{mass}}$:

$$g = \frac{F}{m}$$

From Newton's universal law of gravitation we know that:

$$F = G\frac{Mm}{R^2}$$

(In this case there is no need to explain the symbols, because they are explained in the question.)

Combining these two equation gives:

$$g = \frac{GMm/R^2}{m}$$

Determine

This command term usually relates to questions requiring numerical answers. It has a meaning very similar to *calculate*, although the term itself relates to finding a definite answer. The context of the questions may be more difficult than straightforward calculations.

Discuss

This command term requires that you present (and compare) alternative explanations and opinions, or the advantages and disadvantages of various choices.

Worked example

Question: *Discuss*, in terms of efficiency and transportability the use of natural gas rather than coal in the production of electrical energy. (3 marks)

Answer: Natural gas is preferred because (i) the conversion of the chemical potential energy in natural gas to electrical energy is more efficient than with coal, and (ii) gas can be continuously transferred along pipelines from its source to power stations, while coal has to be transferred in mobile containers of various kinds.

Answers to this kind of open-ended question can easily become too lengthy. Three marks are allocated to the answer, but the mark scheme will probably award marks to *any* three relevant comments. Note that the question requires answers *only* related to *efficiency and transportability*, so if you discuss other features (such as pollution), those comments will be ignored.

Explain

This command term is very widely used in examination papers, usually requiring you to make something understandable by giving details, or the reasons why something may, or may not, happen. The detail required in an answer can be assessed from the number of marks allocated.

Worked example

Question: A constant forward force is used to accelerate a car. *Explain* why the magnitude of the acceleration produced by a constant forward force decreases as the car moves faster. (4 marks)

Answer: Acceleration is proportional to the resultant force acting on the car. The resultant force equals the forward force less the resistive forces opposing motion. As the car moves faster, the resistive forces (mainly air resistance) increase. So the resultant force and acceleration decrease. (Four marks require that four different points of explanation are made.)

Show

This is similar to *calculate* and *determine*, but the main intention here is for you to *show in detail* how an answer (given in the question) was obtained, rather than just to perform the calculation. This kind of question may be asked in the first part of a series of calculations, so that you then have the correct data for further calculations.

Worked example

Question: An electron moved between charged parallel plates with a p.d. of 250 V across them. Show that the electric potential energy of the electron changed by 4.0×10^{-17} J.

Answer:

$$\text{potential difference} = \frac{\text{energy transferred}}{\text{charge flowing}}$$

$$V = \frac{E}{q}$$

This can be rearranged to give $E = Vq$

(Include details of *every step* of the calculation.)

So:

$$E = 250 \times 1.6 \times 10^{-19} = 4.0 \times 10^{-17}\ \text{J}$$

Sketch

This command term requires that you draw a graph, but without any numerical data. The word *sketch* does not imply 'untidy'. Your drawing *does* need to be neat, so draw using a ruler! The axes should be labelled with the quantities that they represent, as should any important features of the graph (for example gradients or intercepts). You may need to take information from another part of the question and add it to the graph.

Worked example

Question: *Sketch* a graph to show how the force between two point charges varies with their separation.

Answer: The *y*-axis should be labelled as *force*, and the *x*-axis labelled as *separation*. The origin should be labeled (0,0). An appropriate, neatly drawn and labelled curve should indicate an inverse square relationship. The graph does not need to be plotted accurately, but it should be clear that the curved line will not touch the axes.

Suggest

This command term is usually used when a single correct answer is not expected, perhaps because not enough information is available or there are many possible answers. Or a definite answer may require knowledge beyond that covered in the syllabus. Generally, there are several acceptable answers to this kind of question.

Worked example

Question: *Suggest* a reason why the melting point of ice was measured to be –1.5°C and not 0.0°C (referring to an experiment in which the temperature of some ice and water was measured over a period of time).

Answer: The thermometer used was wrongly calibrated. (Only *one* suggestion is required here. There is no way of knowing if this suggestion is actually correct. For example, an alternative answer could be that 'the ice was not pure'.)

Other terms

The following command terms are listed in the IB Diploma Physics syllabus, but they are less commonly used in examinations.

- **Analyse** – use data or information provided in a question in order to reach some kind of conclusion.
- **Compare** – describe the similarities between two or more situations or objects.
- **Construct** – describe the similarities and *differences* between two or more situations or objects.
- **Design** – this command term usually means that you are required to write some kind of plan.
- **Evaluate** – consider the advantages and disadvantages of a process.
- **Hence** – answer a part of a question by only using information from earlier in the same question.
- **Hence or otherwise** – answer a part of a question by only using information from earlier in the same question is suggested, but any other correct method will also be acceptable.
- **Justify** – give reasons to support your answer.
- **Predict** – give the expected result of a course of action or calculation.
- **Solve** – determine an answer by using algebraic methods.

Understanding mark schemes

How marks are allocated

After you have taken your IB Diploma Physics examination, your answers will be sent to the IB office in the UK. The papers are then scanned and made available on a secure IB website for examiners (based all around the world), together with an agreed *mark scheme*. Examiners must use this detailed mark scheme when carefully assessing students' work. The marking of all examiners is checked automatically by the IB's marking software to ensure that the work of all students is treated fairly and equally. Examiners know nothing about the students – except their examination number.

As already mentioned, past examination questions and their mark schemes should be an important part of your revision. You should be aware of the following points when using a mark scheme.

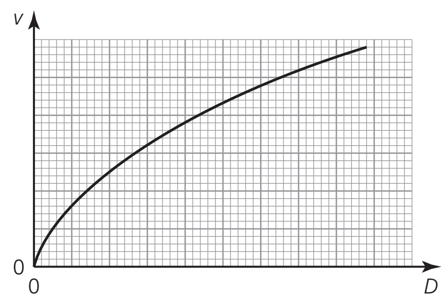
- Marking is meant to be *positive*. Answers are given credit for the understanding that they demonstrate. The examiner will *not* usually look for the exact words shown in the mark scheme, but will award marks if the same ideas are shown clearly in some other way. (Anticipated alternative answers or wording are indicated in the mark scheme by a '/'.)
- **OWTTE** means 'or words to that effect'. This is used on the mark scheme when it is expected that different students will write different acceptable answers to a certain question.
- Each marking point starts on a new line and ends with a semicolon (;).
- Occasionally for some answers, a certain word is considered to be *essential*, indicated by underlining that word in the mark scheme.
- Words in brackets (…) are used to clarify an issue for the examiners. They are not required to gain the mark.
- The separate points in a mark scheme do not need to be in any particular order.
- You will *not* be penalized for poor grammar or spelling, as long as your meaning is clear.
- Sometimes there are more relevant points (which can be made in response to a certain question) than there are marks allocated to that question. For example there may be six or more marking points for a question that only has 4 marks. In this case, *any four* of those points will result in the maximum mark of 4 being awarded.
- **ECF** means 'error carried forward'. This is used by examiners to explain why they have given marks to an incorrect answer – for example, in a calculation, the student has only got the wrong answer because they used their incorrect answer to a previous part of the same question.
- In your answers to calculations, don't forget to give a *unit* (unless it is a ratio) and use the correct number of *significant figures*. If you do not do this, you will lose a maximum of 2 marks (one for each type of mistake) for the *whole* paper.
- If you have to take a measurement from a graph on the examination paper, there will be a range of acceptable answers, but accurate measurement is required, so be careful.

Paper 3, Section A exemplar questions

Data-based questions

Note that the following past IB Physics data analysis questions are longer than those that will be included in the new examinations.

1 As part of a road-safety campaign, the braking distances of a car were measured. A driver in a particular car was instructed to travel along a straight road at a constant speed, v. A signal was given to the driver to stop and she applied the brakes to bring the car to rest in as short a distance as possible. The total distance, D, travelled by the car after the signal was given was measured for corresponding values of v. A sketch graph of the results is shown here.



a State why the sketch graph suggests that D and v are not related by an expression of the form:

$$D = mv + c$$

where m and c are constants. (1)

b It is suggested that D and v may be related by an expression of the form:

$$D = av + bv^2$$

where a and b are constants.

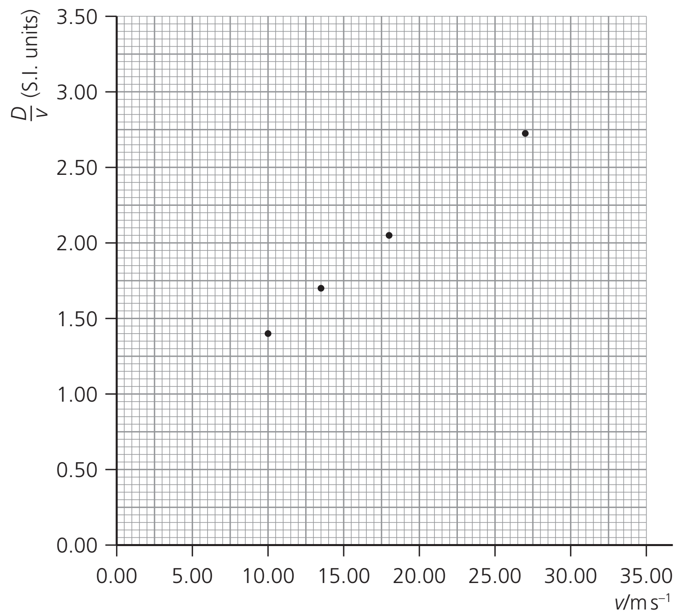
In order to test this suggestion, the data shown below are used. The uncertainties in the measurements of D and v are not shown.

v/m s^{-1}	D/m	$\frac{D}{v}$
10.0	14.0	1.40
13.5	22.7	1.68
18.0	36.9	2.05
22.5	52.9	
27.0	74.0	2.74
31.5	97.7	3.10

i State the unit of $\frac{D}{v}$. (1)

ii Calculate the magnitude of $\frac{D}{v}$, to an appropriate number of significant digits, for $v = 22.5\,\text{m s}^{-1}$. (1)

c Data from the table are used to plot a graph for $\frac{D}{v}$ (y-axis) against v (x-axis). Some of the data points are plotted on a graph as shown.



- **i** On a copy of the graph, plot the data points for speeds corresponding to 22.5 m s^{-1} and to 31.5 m s^{-1}. (2)
- **ii** Draw the best-fit line for all the data points. (1)

d Use your graph from (c) to determine:
- **i** the total stopping distance D for a speed of 35 m s^{-1} (2)
- **ii** the intercept on the $\frac{D}{v}$ axis (1)
- **iii** the gradient of the best-fit line. (2)

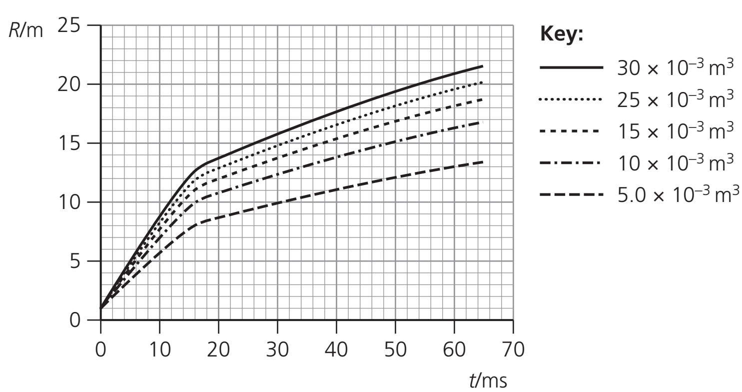
e Using your answers to (dii) and (diii), deduce the equation for D in terms of v. (1)

f The uncertainty in the measurement of the distance D is ±0.3 m and the uncertainty in the measurement of the speed v is ±0.5 m s^{-1}.
- **i** For the data point corresponding to v = 27.0 m s^{-1}, calculate the absolute uncertainty in the value of $\frac{D}{v}$. (2)
- **ii** Each of the data points in (b) was obtained by taking the average of several values of D for each value of v. Suggest what effect, if any, the taking of averages will have on the uncertainties in the data points. (2)

2 The question is about investigating a fireball caused by an explosion.

When a fire burns in a confined space, the fire can sometimes spread very rapidly in the form of a circular fireball. Knowing the speed with which these fireballs can spread is of great importance to fire-fighters. In order to be able to predict this speed, a series of controlled experiments was carried out in which a known amount of petroleum (petrol) stored in a can was ignited.

The radius, R, of the resulting fireball produced by the explosion of some petrol in a can was measured as a function of time, t. The results of the experiment for five different volumes of petroleum are shown on the graph. (Uncertainties in the data are not shown.)



a The original hypothesis was that, for a given volume of petrol, the radius, R, of the fireball would be directly proportional to the time, t, after the explosion. State two reasons why the plotted data do not support this hypothesis. (2)

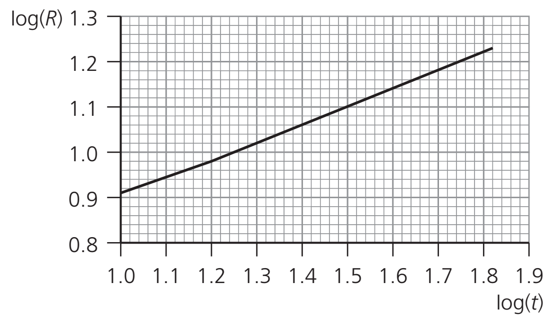
b The uncertainty in the radius is ±0.5 m. The addition of error bars to the data points would show that there is in fact a systematic error in the plotted data. Suggest one reason for this systematic error. (2)

c (HL only) Because the data do not support direct proportionality between the radius R of the fireball and time t, a relation of the form:

$$R = kt^n$$

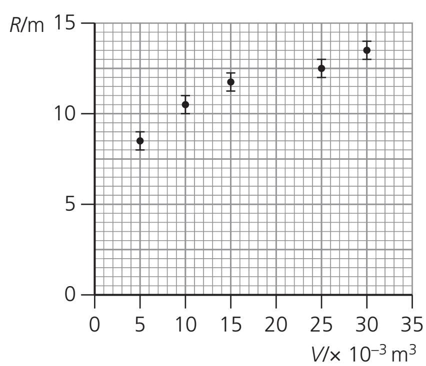
is proposed, where k and n are constants.

In order to find the value of k and n, log(R) is plotted against log(t). The resulting graph, for a particular volume of petrol, is shown. (Uncertainties in the data are not shown.)



Use this graph to deduce that the radius R is proportional to $t^{0.4}$. Explain your reasoning. (4)

d It is known that the energy released in the explosion is proportional to the initial volume of petrol. A hypothesis made by the experimenters is that, at a given time, the radius of the fireball is proportional to the energy, E, released by the explosion. In order to test this hypothesis, the radius, R, of the fireball 20 ms after the explosion was plotted against the initial volume, V, of petrol causing the fireball. The resulting graph is shown.



The uncertainties in R have been included. The uncertainty in the volume of petrol is negligible.

i Describe how the data for the above graph are obtained from the graph in (a). (1)

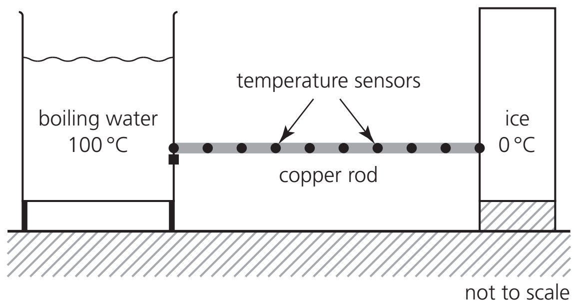
ii Make a copy of the graph and draw the line of best fit for the data points. (2)

iii Explain whether the plotted data together with the error bars support the hypothesis that R is proportional to V. (2)

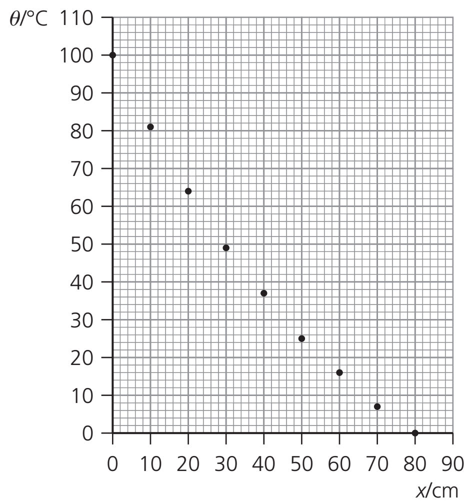
e Analysis shows that the relation between the radius R, energy E released and time t is in fact given by $R^5 = Et^2$.

Use data from the graph in (d) to deduce that the energy liberated by the combustion of $1.0 \times 10^{-3}\,m^3$ of petrol is about 30 MJ. (4)

3 This question is about thermal energy transfer through a rod.
A student designed an experiment to investigate the variation of temperature along a copper rod when each end is kept at a different temperature. In the experiment, one end of the rod is placed in a container of boiling water at 100°C and the other end is placed in contact with a block of ice at 0.0°C, as shown in the diagram.



Temperature sensors are placed at 10 cm intervals along the rod. The final steady state temperature, θ, of each sensor is recorded, together with the corresponding distance, x, of each sensor from the hot end of the rod. The data points are shown plotted on the axes below.



The uncertainty in the measurement of θ is ±2°C. The uncertainty in the measurement of x is negligible.

a Make a copy of the graph and draw the uncertainty in the data points for x = 10 cm, x = 40 cm and x = 70 cm. (2)

b Draw the line of best fit for the data. (1)

c Explain, by reference to the uncertainties you have indicated, the shape of the line you have drawn. (2)

d **i** Use your graph to estimate the temperature of the rod at x = 55 cm. (1)

ii Determine the magnitude of the gradient of the line (the temperature gradient) at x = 50 cm. (3)

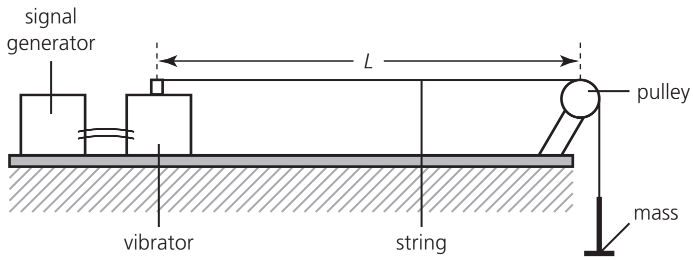
e The rate of transfer of thermal energy, R, through the cross-sectional area of the rod is proportional to the temperature gradient $\Delta\theta/\Delta x$ along the rod. At x =10 cm, R = 43 W and the magnitude of the temperature gradient is $\Delta\theta/\Delta x$ = 1.81°C cm^{-1}. At x = 50 cm the value of R is 25 W.

Use these data and your answer to (dii) to suggest whether or not the rate R of thermal energy transfer is in fact proportional to the temperature gradient. (3)

f (HL only) It is suggested that the variation of x with the temperature θ is of the form $\theta = \theta_0 e^{-kx}$ where θ_0 and k are constants.

State how the value of k may be determined from a suitable graph. (2)

4 This is a data analysis question. The frequency, f, of the fundamental vibration of a standing wave of fixed length is measured for different values of the tension, T, in the string, using the apparatus shown.

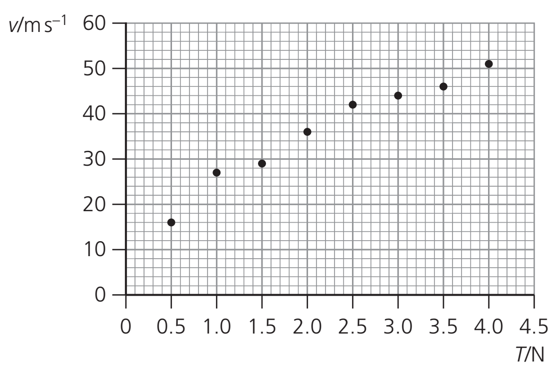


In order to find the relationship between the speed, v, of the wave and the tension, T, in the string, the speed, v, is calculated from the relationship:

$v = 2fL$

where L is the length of the string.

The data points are shown plotted on the axes below. The uncertainty in v is $\pm 5\,\mathrm{m\,s^{-1}}$ and the uncertainty in T is negligible.



a Make a copy of the graph and draw error bars on the first and final data points to show the uncertainty in speed v. (1)

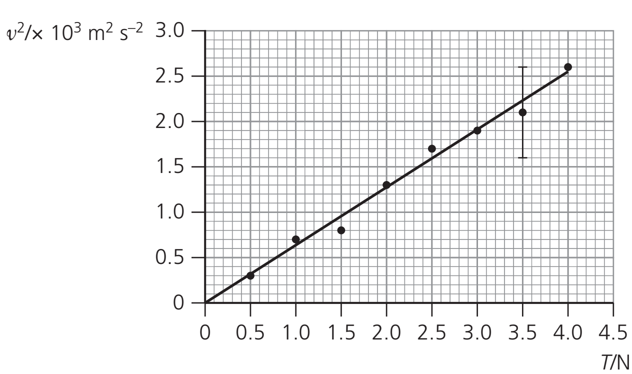
b The original hypothesis is that the speed is directly proportional to the tension T. Explain why the data do **not** support this hypothesis. (2)

c It is suggested that the relationship between speed and tension is of the form:

$v = k\sqrt{T}$

where k is a constant.

To test if the data support this relationship, a graph of v^2 against T is plotted as shown below.



The best-fit line shown takes into account the uncertainties for each data point. The uncertainty in v^2 for $T = 3.5$ N is shown as an error bar on the graph.

i State the value of the uncertainty in v^2 for $T = 3.5$ N. (1)

ii At $T = 1.0$ N the speed $v = 27 \pm 5$ m s^{-1}. Calculate the uncertainty in v^2. (3)

d Use the graph in (c) to determine k without its uncertainty. (4)

Questions on experimental work

Questions about experimental work may concentrate on ten key experiments:

- Determining the acceleration of free-fall.
- Applying the calorimetric techniques of specific heat capacity or specific latent heat.
- Investigating at least one gas law.
- Investigating the speed of sound.
- Determining refractive index.
- Investigating one or more of the factors that affect resistance.
- Determining internal resistance.
- Investigating half-life experimentally or by simulation.
- Investigating Young's double-slit.
- Investigating a diode bridge rectification circuit.

1 A student uses observations of a double-slit interference pattern in a darkened room to determine the wavelength of the light used in the experiment.

a Explain why light from a laser is a good choice for this experiment.

b Discuss if it is a good idea to move the screen as far as possible from the slits.

c Explain what effect the diffraction pattern of light through the individual slits has on the observations.

2 **a** A student is investigating the resistances of wires of different cross-sectional areas of the same metal alloy (of the same length). She measured the radius of one wire to be 0.48 ± 0.01 mm and the length of the same wire to be 86.4 ± 0.5 mm. The resistance of this wire was found to be 1.1 ± 0.1 Ω. She can calculate the resistivity of the wire from the equation $\rho = RA/L$. Use the data to determine the resistivity of the material of the wire and the uncertainty in the result.

b Suggest how the uncertainty in this experiment could be reduced.

3 The half-life of a radioisotope was measured in a school laboratory. Before the experiment was carried out the background count was recorded on three occasions to be 36 min^{-1}, 37 min^{-1} and 29 min^{-1}.

a Explain why these readings are different from each other.

b List two safety precautions that should be taken when doing this investigation.

c The experiment had to be completed within 10 minutes. Suggest a suitable half-life for the chosen radioisotope.