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OCR
Oxford Cambridge and RSA

AS LEVEL

Examiners' report

PHYSICS A

H156

For first teaching in 2015

H156/02 Summer 2023 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 2 series overview

This is the second paper of the AS Physics course.

To do well on this paper candidates need to have an in-depth knowledge and understanding of the subject content in Modules 3 and 4 as well as the foundation physics and practical skills in Modules 1 and 2.

A significant number of candidates could have gained more marks by stating definitions correctly and carefully answering the questions set showing all their working. It is important for all candidates to understand key command terms such as state, describe, define, etc.

For numerical questions, candidates should state the equation that is to be used and substitute the data before evaluating an answer.

It is worth reminding candidates that their scripts are scanned and then electronically marked by examiners. It is therefore important that answers are not written outside the space provided for the answers. The legibility of some candidates' work remains a concern.

There were two levels of response (LoR) questions which gave candidates the opportunity of demonstrating their knowledge and understanding of Physics. It is important that candidates' answers are structured and logical with clear explanations.

There were a number of questions that tested candidates' knowledge and understanding of practical skills that candidates have developed throughout their physics course.

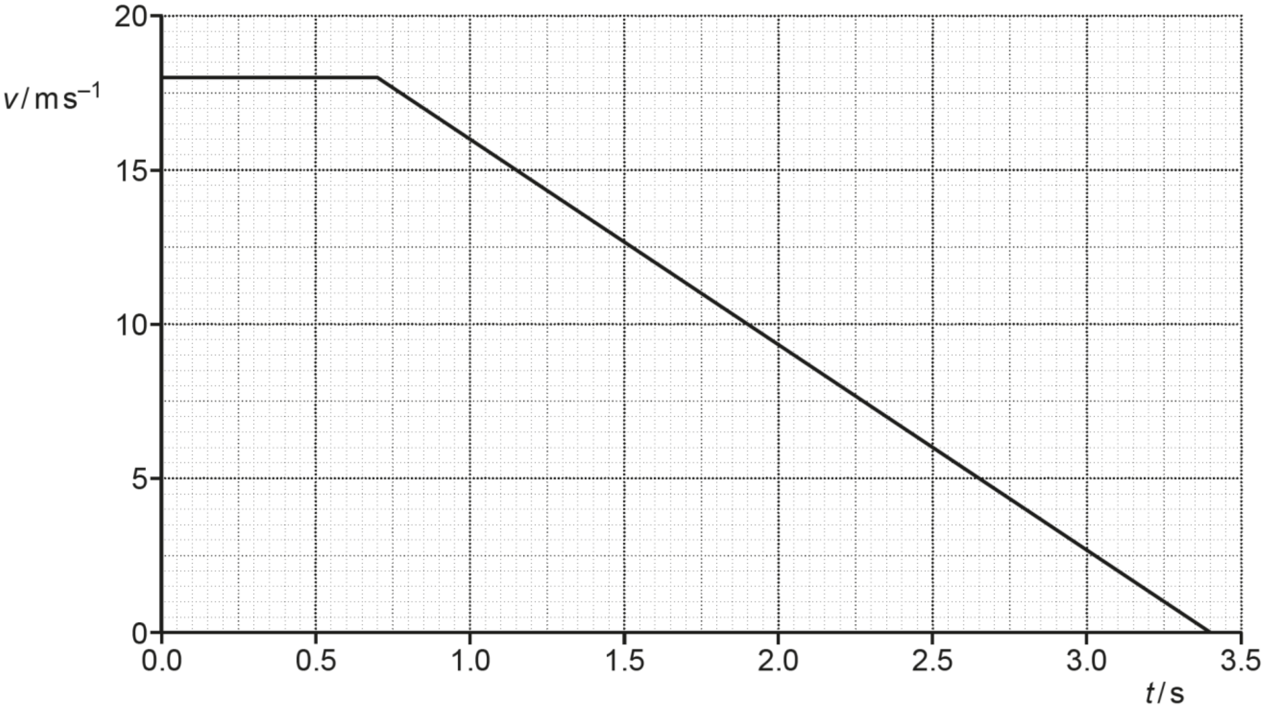
There were also several "show" questions on the paper. These "show" questions do require candidates to clearly indicate their method. The unknown should be the subject of any equation – credit is not given for using the "show" value.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• demonstrated good knowledge of definitions • wrote logical reasoned answers when answering explanation type questions • clearly demonstrated the working to numerical questions substituting in the appropriate numbers into stated equations • used technical terms correctly • demonstrated an understanding of practical skills.	• omitted detail when answering explanation type questions • omitted to show clear substitution of data into equations in calculation questions • were unsure of some technical terms • did not know definitions in sufficient detail • did not clearly explain their reasoning.

Question 1 (a) (i)

1 The brakes of a car of mass 1200 kg are being tested on a track. The driver sees a hazard and applies the brakes.

The graph shows the variation of the velocity *v* of the car with time *t* from when the driver sees the hazard to when the car stops.



(a) (i) Calculate the acceleration *a* of the car while the brakes are applied.

a = ... m s^{-2} **[1]**

This question required candidates to calculate the gradient of the sloping line. More able candidates clearly demonstrated the co-ordinates used and substituted the values into $\frac{y_2 - y_1}{x_2 - x_1}$. Candidates should be encouraged to show working since the read-offs could have helped with gaining credit in Question 1 (a) (iii) and (iv) where the values from the graph were used again.

Some candidates incorrectly gave the answer to one significant figure (as "7"). Other candidates incorrectly wrote 6.6; this should have been rounded to 6.7.

Question 1 (a) (ii)

(ii) Calculate the average braking force *F* while the brakes are applied.

F = ... N **[1]**

This question was answered well with the majority of candidates multiplying 1200 by the answer to Question 1 (a) (i).

Question 1 (a) (iii)

(iii) Calculate the total stopping distance *d* of the car.

d = ... m **[2]**

Candidates who showed working usually gained credit. A common error was to calculate the distance travelled while braking rather than the stopping distance.

Assessment for learning

Understand the meaning of the terms thinking distance, braking distance and stopping distance.

Question 1 (a) (iv)

(iv) Calculate the work *W* done by the brakes to stop the car.

W = ... J **[2]**

Many candidates multiplied force (from Question 1 (a) (ii)) by the braking distance. A common error was to use the stopping distance rather than the braking distance.

Other candidates correctly calculated the kinetic energy.

One error that was occasionally observed was the incorrect use of $P = Fv$.

Question 1 (b)

(b) The same driver in the same car repeats the test at half the initial velocity. The braking force is constant.

On the graph, draw the variation of velocity of the car from the time the driver sees the hazard to the time the car stops. **[2]**

Most candidates correctly realised that the horizontal section of the line would now start at $9.0\,\text{m}\,\text{s}^{-1}$. Many candidates also realised that the thinking time remained constant and that the acceleration (deceleration) remained constant.

Errors usually occurred when drawing the sloping line either so that it ended on the *x*-axis at 3.4 s or it was a much shorter time (implying a larger acceleration).

Question 1 (c) (i)

(c) Explain how your graph in **(b)** would change if:

(i) the driver was tired

....

.... **[1]**

Many candidates stated the change in thinking time rather than explaining how the horizontal line on the graph would change. More successful candidates explained that the horizontal line would be longer.

Question 1 (c) (ii)

(ii) the surface of the track was more resistive.

....

.... **[1]**

Many candidates stated the change in the braking time rather explaining how the sloping line on the graph would change. More successful candidates explained that the sloping line would be steeper.

Question 2*

2* A student is investigating the motion of small metal balls falling from rest vertically through a liquid.

The student drops a ball of diameter *d* from rest at the surface of the liquid. The student determines the terminal velocity *v* of the ball in the liquid.

It is suggested that the relationship between the terminal velocity *v* and the diameter *d* is

$$v = \frac{(\rho - \sigma)gd^2}{18K}$$

where
ρ is the density of the metal
σ is the density of the liquid
g is the acceleration of free fall = 9.81 m s^{-2} and
K is a constant.

Describe, with the aid of a suitable diagram:

- how an experiment can be safely conducted to test this relationship between *v* and *d*, and
- how the data can be analysed to determine *K*.

[6]

This question enabled candidates to plan an experiment. In candidates' descriptions it was important to include how the independent and dependent variables were measured. Candidates could also explain how the density of the ball and liquid could be determined.

Many candidates did not explain how the terminal velocity could be determined. Often descriptions was just timing the ball leaving the surface to the bottom. Some high scoring candidates discussed the need to check between successive distances that the velocity was constant.

To determine the value of constant *K* it was expected that the axes of an appropriate graph would be suggested with an equation with *K* as the subject to indicate how the gradient could be used.

Exemplar 1

A student is investigating the motion of small metal balls falling from rest vertically through a liquid.

The student drops a ball of diameter d from rest at the surface of the liquid. The student determines the terminal velocity v of the ball in the liquid.

It is suggested that the relationship between the terminal velocity v and the diameter d is

$$v = \frac{(\rho - \sigma)gd^2}{18K}$$

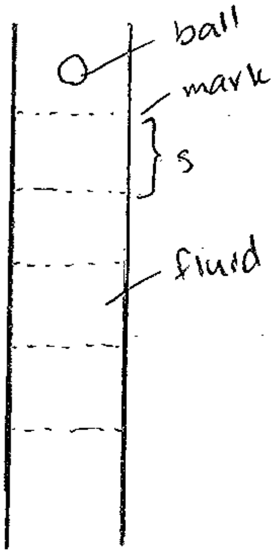
where
ρ is the density of the metal
σ is the density of the liquid
g is the acceleration of free fall = 9.81 m s^{-2} and
K is a constant.

Describe, with the aid of a suitable diagram:

- how an experiment can be safely conducted to test this relationship between v and d, and
- how the data can be analysed to determine K.

[6]

Diagram



The ~~do~~ diameter of the ball can be measured using a vernier calliper. ~~The~~ This ~~do~~ measurement should be repeated about several points on the ball and averaged for accuracy.

The ball should be dropped into a transparent viscous liquid of known density eg. oil, in a tube, ~~the~~ The tube should be marked with several fixed distances, 's'. The time taken, 't', for the ball to travel through each ~~mark~~ interval should be recorded using a stopwatch. The velocity of the ball at each interval can be ~~m~~ calculated using the formula $\frac{s}{t}$. ~~When ... the velocity~~ This velocity will ~~decrease~~ increase as the ball falls. when the ~~vel~~ velocity is constant, this is the terminal velocity of the ball.

~~This experiment should be repeated and the 'v' should be averaged.~~

The ball can be removed by tilting the tube sideways.

The experiment should be repeated for balls of different 'd' and each 'v' should be recorded. The balls should be made of the same metal of known density, σ.

The experiment should be ~~repead~~ repeated for each 'd' and 'v' should be averaged.

A graph of v against d^2 could be drawn. ~~on~~ If the graph is a straight line that passes through the origin, the relationship is confirmed.

The gradient of the line of best fit is $\frac{(\rho - \sigma)g}{18K}$.

$K = \frac{(\rho - \sigma)g}{18 \times \text{gradient}}$. ~~ρ/1000 kg m^{-3}~~

This candidate starts their response by drawing a sketch diagram with markings on the side of the tube experiment. This diagram could be improved – it would have been helpful to have seen the bench for example. However, it does indicate that the candidate is thinking about terminal velocity.

The description of the experiment is logically structured and contains appropriate detail, for example a viscous liquid oil. This candidate has included a method to measure the diameter of the balls.

Importantly the candidate explains how terminal velocity is determined using the marks on the side of the tube.

There is then a clear section of how the results could be analysed including an appropriate graph and then how *K* could be determined from the gradient.

Overall, this candidate has provided a good description of the method including how terminal velocity is determined and how the data can be analysed. The information is clearly and logically structured and is relevant.

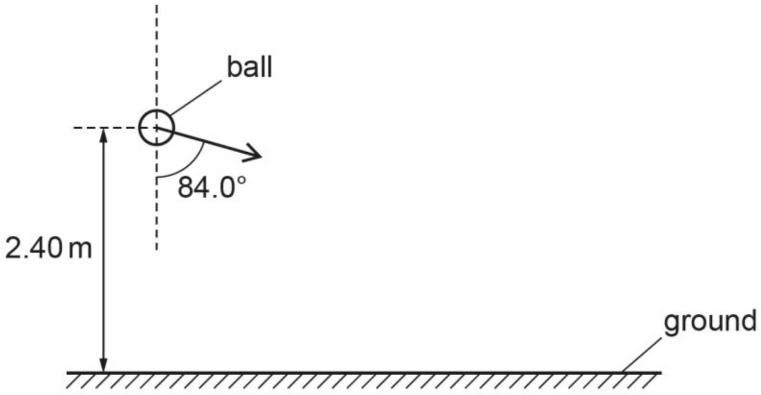
Assessment for learning

Practical techniques

Candidates should have experience of describing methods as well as analysing data.

Question 3 (a)

3 A student throws a ball of mass 0.210 kg. The hand of the student is a vertical distance of 2.40 m above the ground. The ball leaves the student's hand with a velocity of 22.3 m s^{-1} at an angle of 84.0° to the vertical as shown in the diagram.



(not to scale)

Assume that air resistance is negligible.

(a) Show that the vertical component u_v of the velocity of the ball as it leaves the student's hand is about 2.33 m s^{-1}.

[1]

Most candidates clearly showed how the initial velocity of the ball could be resolved into its horizontal component. Most candidates used cos 84° although there was a significant minority who correctly used sin 6°.

Question 3 (b)

(b) Show that the vertical component v_v of the velocity of the ball as it hits the ground is about 7.25 m s^{-1}.

[2]

For this part of the question it was necessary for candidates to clearly show the substitution of the data into the equation. This includes the value of g (as 9.81 m s^{-2}) from the data sheet. It was also necessary for candidates to show that having determined v^2, this value needed to have the square root taken. Higher performing candidates wrote the final answer as 7.247 or 7.24685 ≈ 7.25 (m s^{-1}).

Question 3 (c)

(c) Calculate the kinetic energy E_k of the ball as it hits the ground.

E_k = ... J **[3]**

This question proved challenging to candidates. The common error was to calculate the kinetic energy using a value of 7.25 m s^{-1}.

There were two main methods of answering this question:

Either:

determining the horizontal component of the velocity of the ball, (which remains constant)

then working out the resultant velocity of the ball as it hits the ground

and then calculate the kinetic energy.

Or:

Calculate the change in gravitational potential energy

Calculate the initial kinetic energy of the ball

And then add the two values together.

Misconception

Omitting the kinetic energy in the horizontal direction when calculating the kinetic energy of the ball.

Candidates should be able to compare the motion of a projectile in two perpendicular directions and also confirm that similar results are obtained by considering energy transfers.

Question 3 (d)

(d) Explain why the momentum of the ball changes as the ball travels from the hand to the ground.

....

....

....

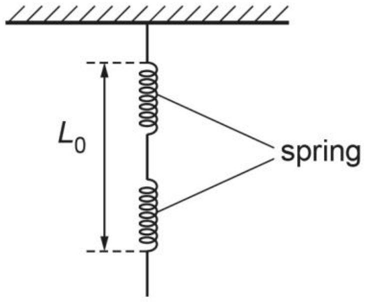
.... **[2]**

There are many possible explanations as to why the momentum of the ball changes. To score full marks candidates needed to state a property of momentum, e.g. momentum = mass × velocity before then explaining why the momentum would change, e.g. as the ball falls, velocity increases so for constant mass the momentum increases.

Question 4 (a) (i)

4 **(a)** Two identical springs each have a force constant of $36\,N\,m^{-1}$. In an experiment, the two springs are suspended from a fixed support as shown in **Fig. 4.1**.

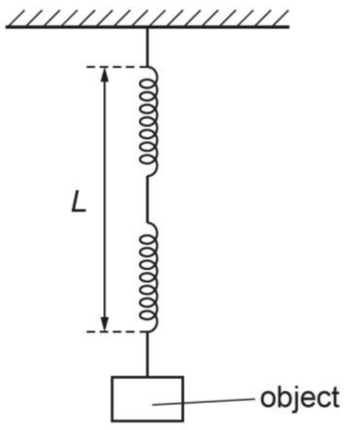
Fig. 4.1



The initial length of the spring arrangement is L_0.

An object of mass M is added to the spring arrangement as shown in **Fig. 4.2**.

Fig. 4.2



The new length of the spring arrangement is L.

A student measures L_0 and L and records the results in a table.

Quantity	Measurement / mm
L_0	(22.2 ± 0.1)
L	(54.9 ± 0.1)

(i) State the name of the instrument the student used to measure L_0 and L.

.... **[1]**

Many candidates stated a ruler or metre rule without realising that these measuring instruments had a resolution of 1 mm not 0.1 mm. Other candidates incorrectly stated micrometer – a micrometer is not usually used for distances greater than two or three centimetres and normally a micrometer has a resolution of 0.01 mm or better.

Assessment for learning

Candidates should experience a wide range of measuring instruments in a science laboratory.

Question 4 (a) (ii)

(ii) Determine the extension *x* of the spring arrangement. Include the absolute uncertainty in your answer.

x = ... ± ....mm **[1]**

Most candidates correctly determined *x* but a significant minority of candidates did not realise that the uncertainty in the measurements needed to be added.

Assessment for learning

Candidates should understand that when quantities are added or subtracted the absolute uncertainties are added.

OCR support

In the Practical Skills Handbook there is a section on uncertainties.

Question 4 (a) (iii)

(iii) Calculate the mass *M* of the object. Write your answer to **2** significant figures.

M = ... kg **[2]**

The common error was to use 36 $N m^{-1}$ as the force constant and 0.0327 m as the extension. Other errors included either rounding the answer to one significant figure (0.06) or not changing the millimetre to metre.

Clear working was needed to allow error carried forward marks into the next section.

Misconception

A number of candidates did not understand significant figures.

Candidates should understand the implication of trailing zeros both before and after the decimal place. For example, 0.06 is one significant figure, 0.060 is two significant figures, etc.

Question 4 (a) (iv)

(iv) Calculate the total energy W stored by the springs when the object is suspended.

W = ... J **[2]**

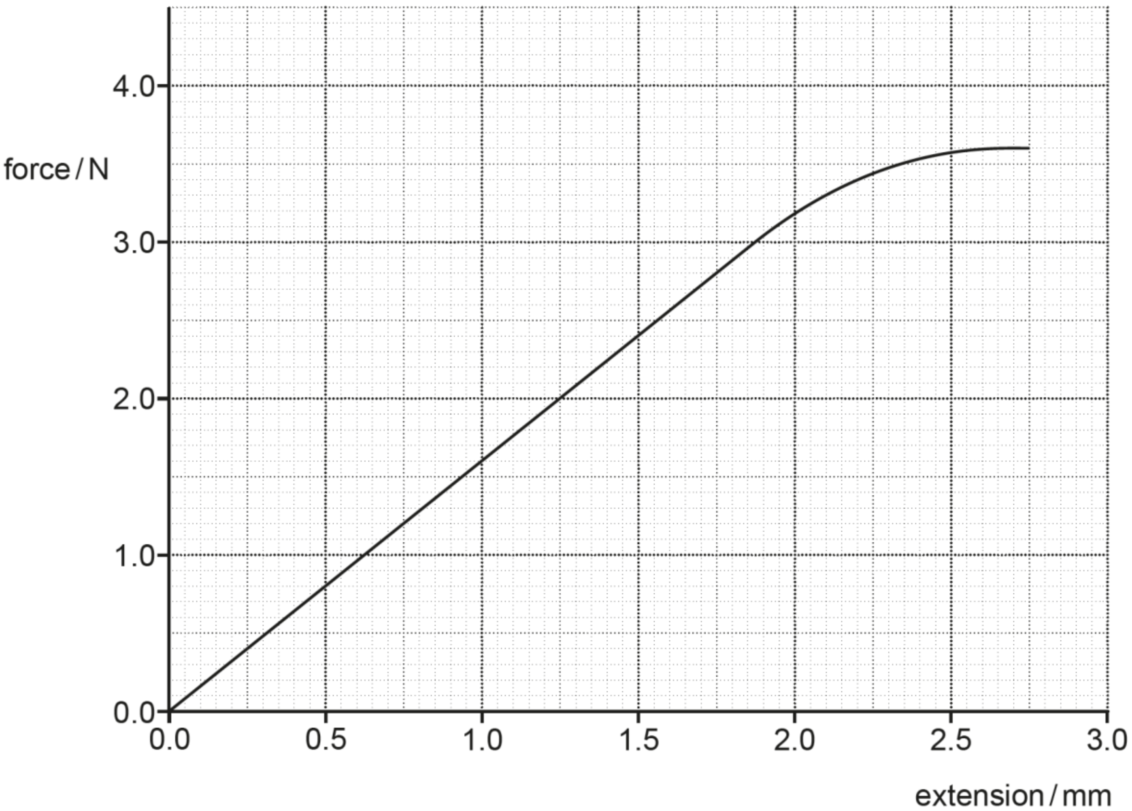
Most candidates gained credit in this question. Many correctly used $W = 0.5kx^2$. Other candidates correctly used $W = 0.5Fx$ using their value for F from the previous part.

Some lower scoring candidates incorrectly determined the change in gravitational potential energy.

Question 4 (b) (i)

(b) A metal wire has a length of 4.4 m. The Young modulus of the metal is 120 GPa.

In an experiment force is applied to the wire and the extension is measured.
The graph shows the variation of the extension of the wire with the force applied.



(i) The gradient of the linear section of the graph is 1.6 N mm^{-1}.

Determine the cross-sectional area A of the wire.

A = ... m^2 **[3]**

Many candidates did not understand the significance of the gradient. More able candidates derived an equation into a $y = mx$ format and then successful calculated an answer. A number of candidates did not use an appropriate power of ten for the Young modulus or convert the gradient to be consistent with the length of the wire.

Candidates who read a value of force and extension directly from the graph could still gain full credit – often the read-offs were from the non-linear section of the graph.

Assessment for learning

Candidates should make sure that they are using consistent units when calculating quantities and should know the common prefixes for units.

Question 4 (a) (ii)

(ii) Use the graph to determine an estimate of the work done E_w in stretching the wire when a 3.5 N force is applied.

E_w = ... J **[3]**

For this question it was essential that candidates showed their working.

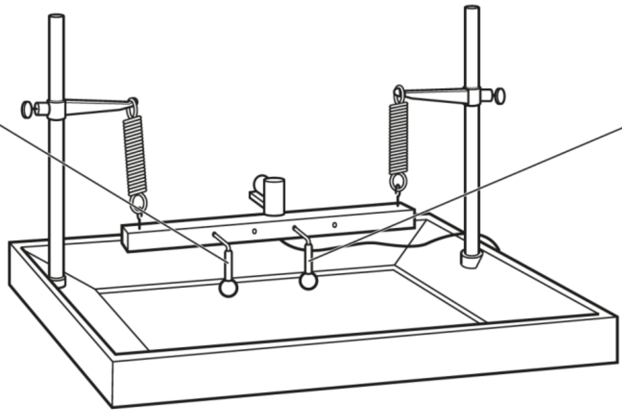
Many candidates incorrectly used the extension for a force of 3.5 N and substituted it into an equation.

More able candidates stated that the area under the line would be equal to the work done and then clearly showed the method used to work out the area under the line.

Question 5 (a) (i)

5 Two spherical dippers, **D1** and **D2** oscillate on a ripple tank as shown in **Fig. 5.1**.

Fig. 5.1



Waves on the surface of the water are produced from each dipper. These waves are in phase with each other.

The water waves have a speed of $8.0\,\text{cm}\,\text{s}^{-1}$ and a wavelength of 3.2 cm.

(a) (i) State and explain whether these waves are transverse or longitudinal waves.

....

....

.... **[1]**

Many candidates incorrectly stated that water waves were longitudinal waves. High scoring candidates referred to oscillations or vibrations of the water particles and the direction of travel of the wave or energy transfer.

Question 5 (a) (ii)

(ii) State and explain whether these waves are plane polarised.

....

....

.... **[1]**

Few candidates were able to explain why the waves were plane polarised. High scoring candidates stated that the oscillations were in the vertical plane only.

Question 5 (b)

(b) Calculate the frequency *f* of the dippers.

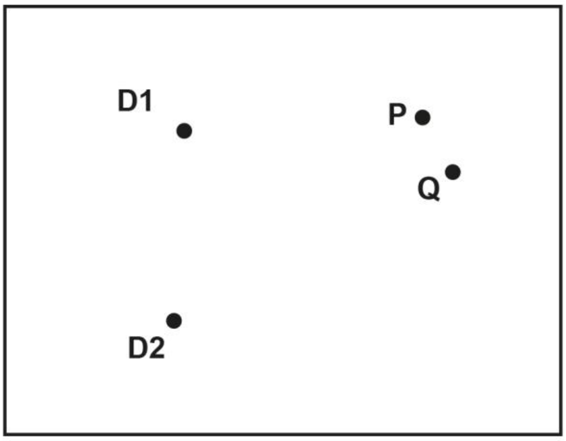
f = ... Hz **[1]**

This question was very well answered.

Question 5 (c) (i)

(c) **Fig. 5.2** shows the positions **D1** and **D2** of the two dippers in the ripple tank.

Fig. 5.2



P and **Q** are two points on the water.

(i) The distance between **P** and **D1** is 12.2 cm.
The distance between **P** and **D2** is 20.2 cm.

Explain whether constructive or destructive interference occurs at **P**.

....

....

.... **[3]**

High scoring candidates showed their method clearly. It was expected that candidates would determine the path difference and then determine the path difference in terms of the number of wavelengths (2.5). There were some excellent explanations in terms of destructive interference occurring when there was an odd number (5) of half wavelengths.

Question 5 (c) (ii)

(ii) The distance between **Q** and **D1** is 12.5 cm.
The distance between **Q** and **D2** is 19.7 cm.

Calculate the phase difference ϕ, in rad, between the waves arriving at point **Q** from **D1** and the waves arriving at **Q** from **D2**.

ϕ = ... rad **[3]**

Candidates who scored well on this question showed their working clearly. Many clearly stated the path difference and determined that this path difference corresponded to 2.25 wavelengths. Some candidates struggled changing this to radians.

Assessment for learning

Candidates need to understand the radian and how to covert between degrees and proportion of a wavelength.

Question 6 (a)

6 A switch, resistor of resistance *R* and a component **Z** are connected to a battery of electromotive force (e.m.f.) *E* and internal resistance *r*. An ammeter and voltmeter are also connected to the circuit as shown in **Fig. 6.1**.

Fig. 6.1

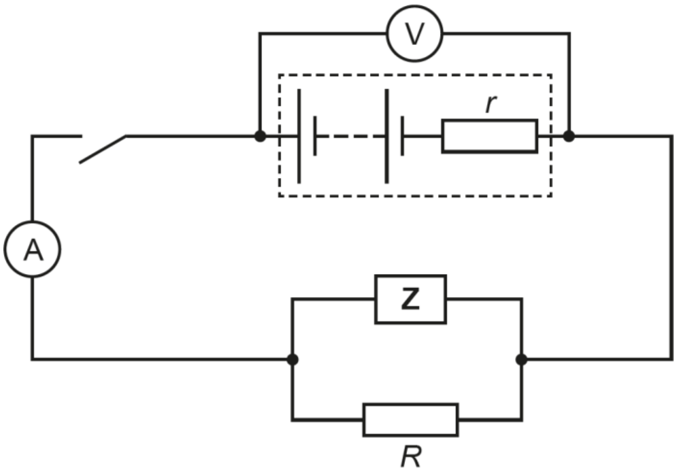
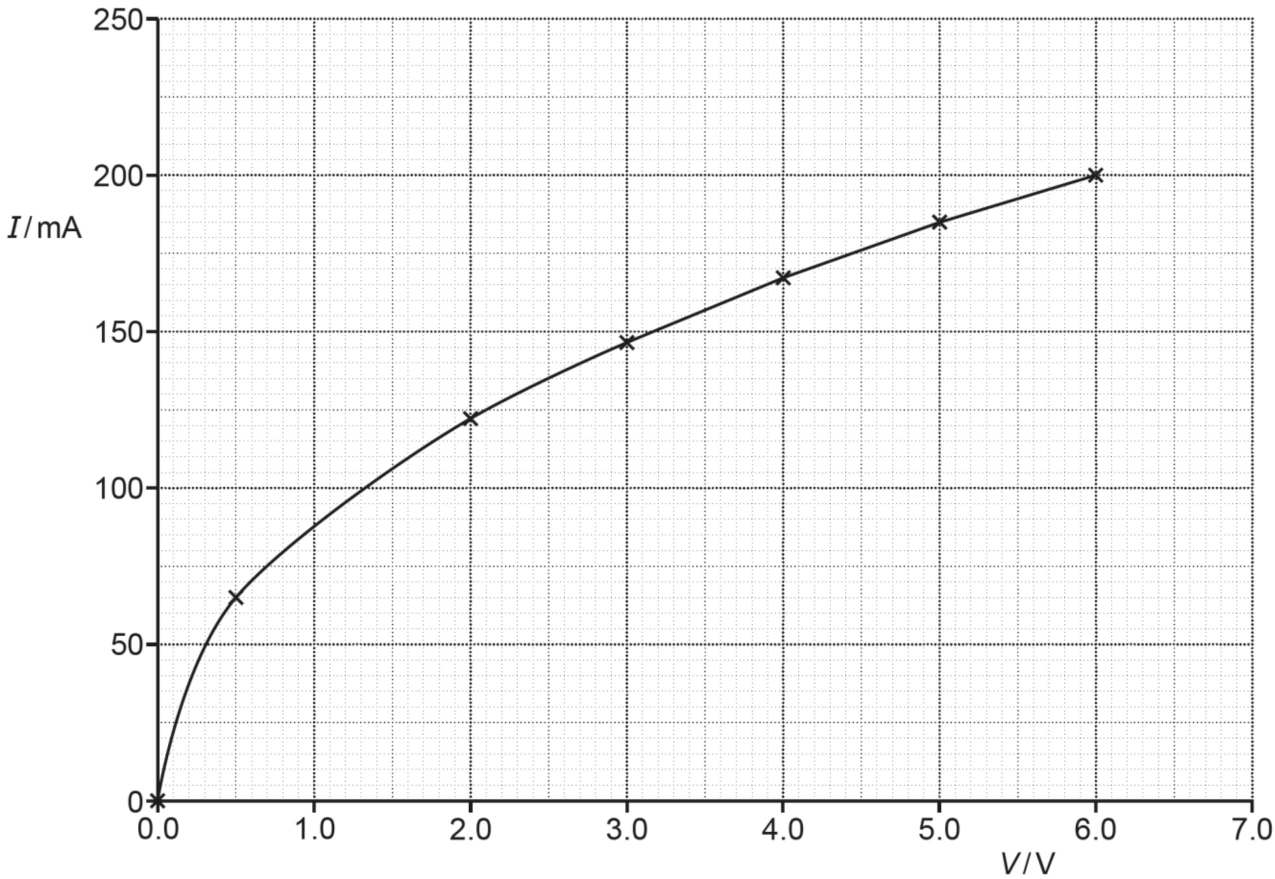


Fig. 6.2 shows the current *I* and potential difference *V* characteristic for the electrical component **Z**.

Fig. 6.2



(a) State the name of component **Z**.

.... **[1]**

A significant minority of candidates did not score this mark. An array of answers were given. The specification is specific about the *I*-*V* characteristics that are expected to be understood by candidates.

Question 6 (b)

(b) The switch is initially open.

The voltmeter reading is 5.72 V

The following voltmeters are available:

A: 0–2 V, ± 0.001 V **B:** 0–2 V, ± 0.01 V **C:** 0–2 V, ± 0.1 V

D: 0–20 V, ± 0.001 V **E:** 0–20 V, ± 0.01 V **F:** 0–20 V, ± 0.1 V

State the voltmeter, **A** to **F**, that has been used in this experiment.

Voltmeter .... **[1]**

The majority of candidates correctly identified E as the correct voltmeter. The common mistake was either choosing B for the correct number of decimal places or D or F for the correct range but not considering the number of decimal places.

Question 6 (c) (i)

(c) The switch is now closed.

The ammeter and voltmeter readings are:

Ammeter reading = 220 mA

Voltmeter reading = 4.80 V

(i) Show that the resistance of *R* is 120 Ω.

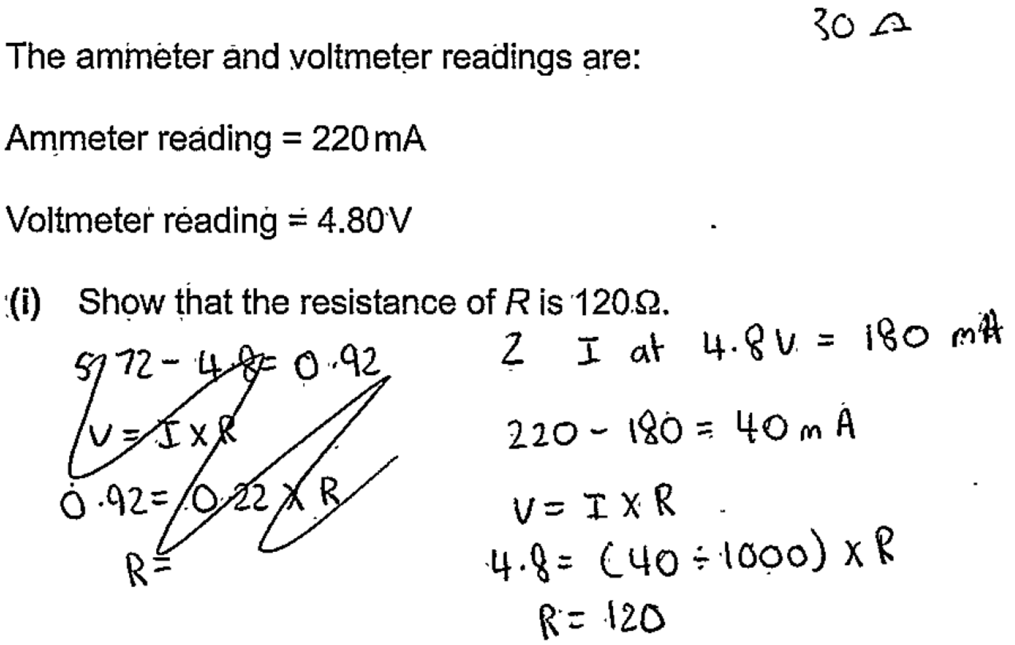
[2]

For this 'show question' it was expected that candidates would begin by stating that the current in component Z was 180 mA for the given potential difference. More able candidates then stated that the current in *R* was 220 mA – 180 mA = 0.040 A before stating the final division.

A common alternative method which also gained full marks was again to identify 180 mA as the current in Z which gave the resistance of Z as 26.7 Ω. The resistance of the parallel network was then calculated to be 21.8 Ω. Candidates then needed to show correct working for the use of the parallel network of resistances formula.

Many candidates did not know the current of 180 mA and so did not score marks. Some candidates attempted to working backwards by stating the current in *R* was 0.040 A – without explanation this did not score marks.

Exemplar 2


30 Ω

The ammeter and voltmeter readings are:

Ammeter reading = 220 mA

Voltmeter reading = 4.80 V

(i) Show that the resistance of *R* is 120 Ω.

5.72 − 4.8 = 0.92
V = I x R
0.92 = 0.22 x R
R =

Z I at 4.8V = 180 mA
220 − 180 = 40 mA
V = I x R
4.8 = (40 ÷ 1000) x R
R = 120

In this exemplar, the candidate clearly stated the current in Z for a p.d. of 4.8 V which gains the first mark.

The subtraction of 220 mA – 180 mA is then shown and the then the final line demonstrates the equation used by the substitution of correct numbers, including the conversion of 40 mA to 0.04 A, and the response of 120 Ω.

Question 6 (c) (ii)

(ii) Determine values for *E* and *r*.

E = ... V

r = ... Ω

[3]

Candidates struggled with this question. Few candidates realised that when the switch was open, the voltmeter reading of 5.72 V was the terminal p.d. and equal to the e.m.f. of the battery.

Some candidates did manage to determine the internal resistance without specifically stating the e.m.f.

Question 6 (d)

(d) The resistor *R* is changed to a lower value.

State and explain the change, if any, in the ammeter and voltmeter readings when the switch is closed.

....

....

....

....

....

.... **[4]**

This question allowed candidates the opportunity of structuring their answer. The majority of candidates stated that the current in the circuit and thus the ammeter reading would increase. Fewer candidates were able to state that the <u>total</u> resistance of the circuit decreased – many just referred to *R*.

Fewer candidates were able to explain the change in the voltmeter. Many stated it would stay the same since it was a parallel circuit. Other candidates stated that the p.d. would increase since p.d. is proportional to current. Ideally candidates would explain their answer by relating the increase in current to a greater p.d. across the internal resistance ('lost volts') and then stating that the p.d. across the parallel network decreases so the voltmeter reading decreases.

Some candidates gave a good explanation by applying potential divider arguments.

Misconception

Since current increases, the p.d. increases in a circuit containing a battery with internal resistance.

Assessment for learning

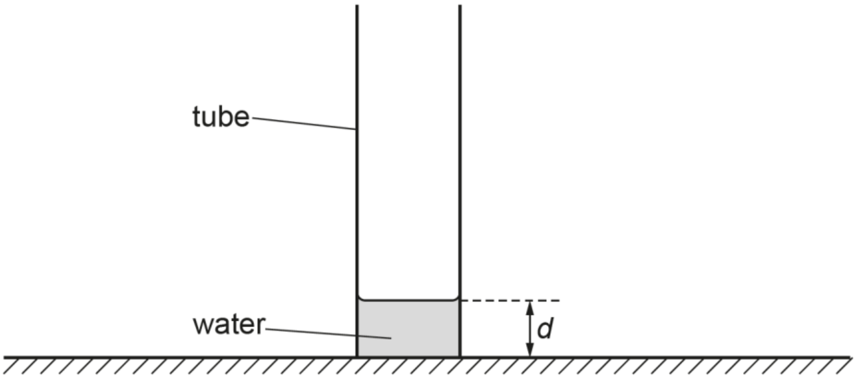
The variation of current and potential difference in a circuit containing a battery with internal resistance when the value of the external resistance changes.

It would be useful for candidates to see the effect on the ammeter and voltmeter practically and to practise writing explanations.

Question 7*

7* A student carries out an experiment to determine the speed v of sound in air. The student forms stationary sound waves in a resonance tube with water at the bottom as shown in **Fig. 7.1**.

Fig. 7.1



The depth of the water is d.

Sound is produced by a signal generator connected to a loudspeaker. The sound is detected by a microphone connected to an oscilloscope.

The signal generator is adjusted. The frequency f of the fundamental mode of vibration of the sound in air is determined.

The experiment is repeated for different values of d.

The table shows the results. Values of $\frac{1}{f}$ have been included.

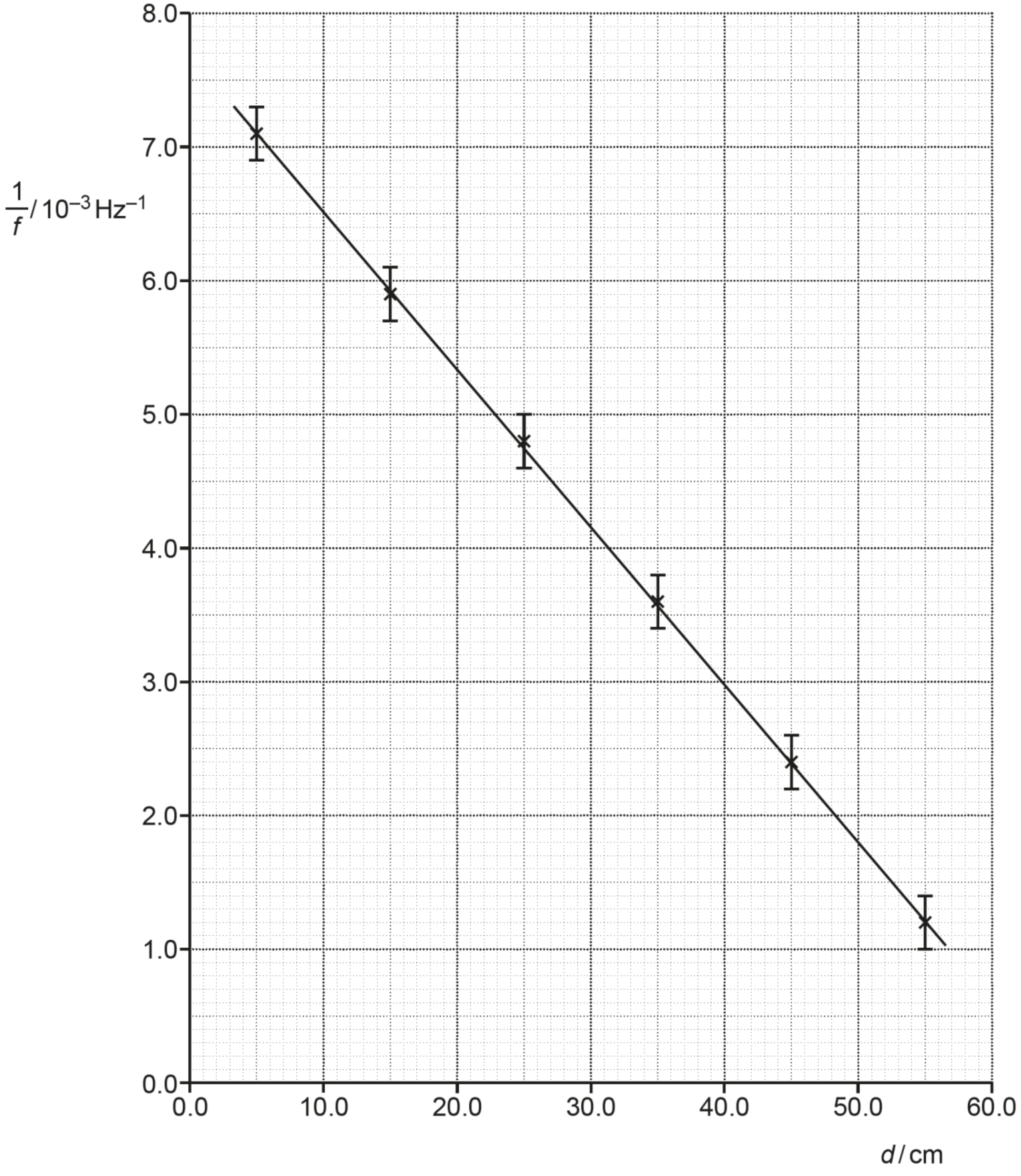
d / cm	f / Hz	$\frac{1}{f}$ / 10^{-3} Hz^{-1}
5.0	140	7.1 ± 0.2
15.0	170	5.9 ± 0.2
25.0	210	4.8 ± 0.2
35.0	280	3.6 ± 0.2
45.0	420	2.4 ± 0.2
55.0	840	1.2 ± 0.2

It is suggested that the relationship between f and d is

$$\frac{1}{f} = -\frac{4d}{v} + c$$

where v is the speed of sound in air and c is a constant.

A graph of $\frac{1}{f}$ / 10^{-3} Hz^{-1} on the *y*-axis against *d* / cm on the *x*-axis is plotted as shown below.



Explain how the apparatus is used to determine *f* **and** use the graph to determine *v*. Include the percentage uncertainty in your value of *v*. **[6]**

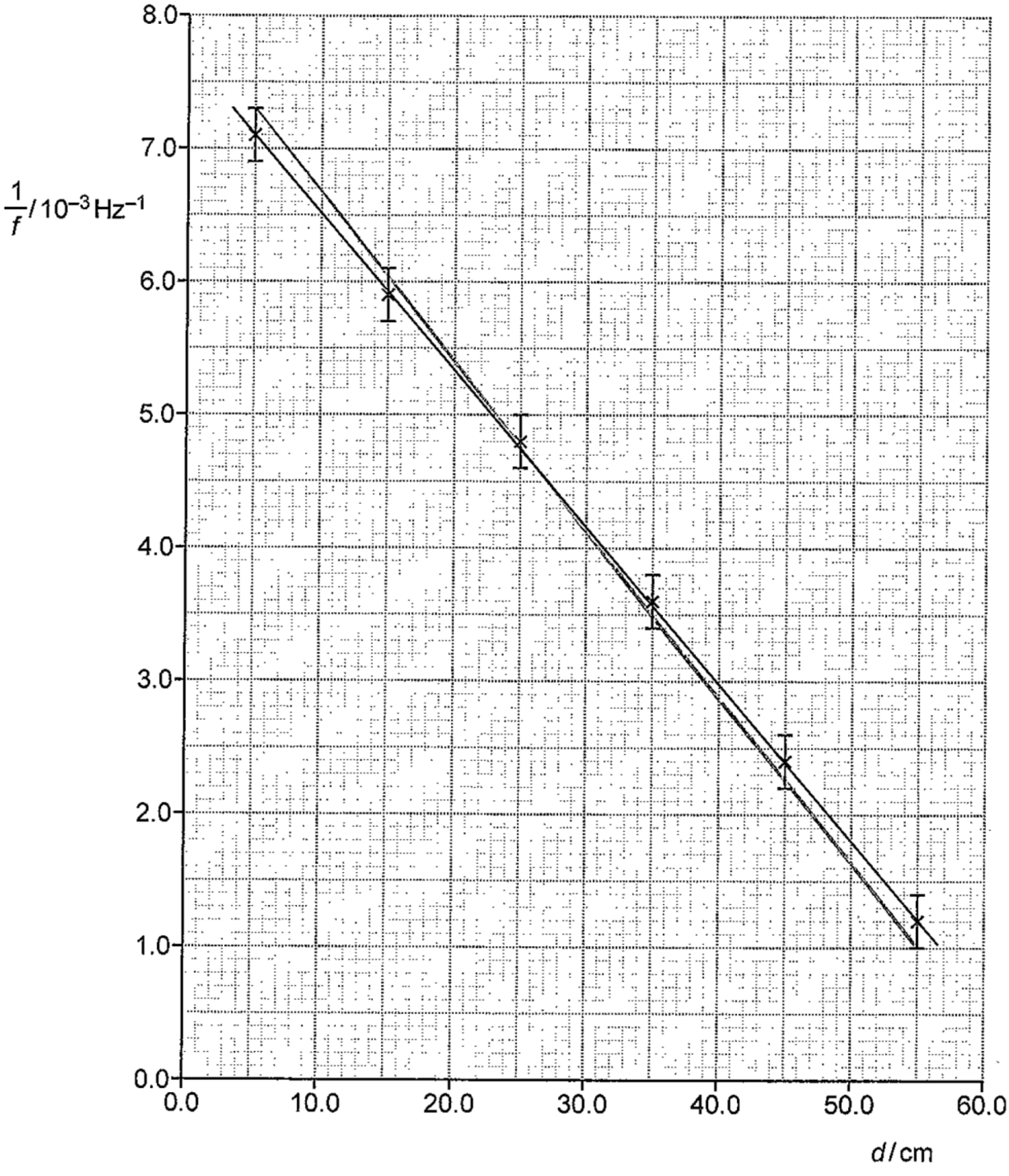
The second level of response question gave candidates the opportunity of drawing conclusions from an experiment as well as explaining how the fundamental frequency *f* may be determined experimentally.

For good answers to these type of questions, candidates need to structure their answers logically so that all parts of the question are answered.

An explanation to determine *f* should include the adjustment of the frequency and how to determine the fundamental frequency with the idea of the loudest sound. More successful candidates discussed the peak on the oscilloscope and starting from a low frequency. It was also expected that candidates could describe how to determine the frequency from an oscilloscope. Ideally reference would be made to the time-base.

To determine the value of *v* with the percentage uncertainty, candidates needed to show their working clearly, taking into account the powers of ten and units from the graph.

Exemplar 3


$\frac{1}{f}$ / 10^{-3} Hz^{-1}
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
d / cm

Explain how the apparatus is used to determine *f* **and** use the graph to determine *v*. Include the percentage uncertainty in your value of *v*. **[6]**

The gradient of the graph is $-\frac{4}{v}$. gradient = $\frac{7.1 - 1.8}{5 - 50} \times \frac{10^{-3}}{10^{-2}}$

$-\frac{4}{v} = -0.01178$

$-v = -339.6$

$v \approx 340\ ms^{-1}$

The gradient of the line of worst fit = $\frac{7.3 - 1.0}{5 - 55} \times \frac{10^{-3}}{10^{-2}}$

$-\frac{4}{v} = -0.0126$

worst $v = 317\ ms^{-1}$

percentage uncertainty = $\frac{340 - 317}{340} \times 100\%$

$= 6.5\%$

Sound produced by the loudspeaker is directed into the tube. The signal generator is adjusted from 0Hz and increased until a loud sound is heard. The stationary wave in the tube is at the fundamental mode of vibration. The frequency can be obtained by the reading on the signal generator. The oscilloscope can also be used to determine frequency. $f = \frac{1}{T}$, where T is the time taken for one complete wave to travel. T can be determined by counting squares on the oscilloscope. The loud sound is a point of maximum amplitude. This can be seen on the oscilloscope. The frequency at maximum amplitude is f.

This candidate's response is structured and detailed.

Firstly, this candidate has added the steepest worst acceptable line to the graph which passes through all the error bars.

The candidate then identifies how the gradient is related to the frequency of the wave before calculating the gradient. The calculation of the gradient is demonstrated and the candidate has also clearly taken into account the powers of ten on each axis of the graph before determining *v* with a correct unit. This process is repeated for the worst acceptable line with each of the steps shown before percentage uncertainty is calculated. Throughout this section, it is easy to follow the candidate's method. It is clear that the candidate has used a large triangle to calculate the gradient.

The candidate then explains how *f* is determined by adjusting the signal generator until a loud sound is heard and then explaining how the frequency is determined by the oscilloscope.

Question 8 (a) (i)

8 Electromagnetic radiation is incident on a metal plate. Photoelectrons are emitted.

(a) **(i)** State why electrons are emitted.

....

....

.... **[1]**

Many candidates did not mention photons in their answers. High performing candidates' answers were detailed and included the one-to-one interaction between one photon and one electron and the transfer of energy.

Question 8 (a) (ii)

(ii) The metal plate has a threshold frequency of 990 THz.

State what is meant by the term **threshold frequency**.

....

....

.... **[1]**

The majority of candidates gained a mark in this question. Candidates who did not gain the mark often referred to the minimum energy as opposed to the minimum frequency.

Question 8 (b) (i)

(b) The maximum kinetic energy of the emitted photoelectrons is 1.9 eV.

(i) Show that the maximum kinetic energy of the emitted photoelectrons, is about 3.0×10^{-19} J.

[1]

This question was well answered with the majority of candidates clearly writing $1.9 \times 1.60 \times 10^{-19} = 3.04 \times 10^{-19}$ (J). This is exactly how a show type question should be answered.

Question 8 (b) (ii)

(ii) Determine the wavelength λ of the incident electromagnetic radiation.

λ = ... m **[3]**

Candidates found this question challenging. The common error was to omit the work function of the metal. Other candidates determined the energy but omitted the energy of the electrons.

A significant minority of candidates attempted to answer this question by determining the momentum of the electrons.

Assessment for learning

Understand the differences between the photelectric effect and electron diffraction.

Question 8 (c) (i)

(c) The intensity of the incident radiation is doubled.

State the change, if any, on

(i) the maximum kinetic energy of the photoelectrons emitted from the surface of the metal plate

.... **[1]**

The majority of the candidates correctly stated that there would be no change. Some candidates then added good reasons to explain their answer.

Question 8 (c) (ii)

(ii) the rate of emission of the photoelectrons.

.... **[1]**

Most candidates correctly realised that the rate of emission would increase but many did not give a quantitative answer (double) to match the stem of the question.

Assessment for learning

Where quantitative data is used in questions, answers should also be quantitative wherever possible.

Practice explaining the effect on one quantity due to another quantity is doubled/halved/quartered, etc.

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