Qualification Accredited

Oxford Cambridge and RSA

AS LEVEL

Examiners' report

PHYSICS A

H156
For first teaching in 2015

H156/02 Summer 2019 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. 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 can be downloaded from OCR.

Paper 2 series overview

A good range of marks were achieved by candidates and it did not appear that candidates were short of time. There are several questions on the paper which test the practical skills that candidates should have experienced in their AS course.

The quality of written work was variable. 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.

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 answer the question set in a logical way with clear explanations.

There were also several "show" questions on the paper. These types of questions prevent candidates who struggle with one part of a question being penalised on the next part. 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 performed well tended to:	*Candidates who did less well tended to:*
• demonstrate clear, detailed reasoning in explanation type questions. • show clear logical working in calculation type questions • use technical terms correctly • demonstrate an understanding of a practical physics course, particularly with regard to the use of graphs and the treatment of uncertainties.	• omit the detail needed in explaining concepts and understanding • not use appropriate units in their quantities and were unsure of conversions • omit steps in their calculations • be unsure of some technical terms and not know definitions in detail • be unsure in the interpretation of graphs and the treatment of uncertainties

Note

From this series students have been provided with a fixed number of answer lines and an additional answer space. The additional answer space will be clearly labelled as additional and is only to be used when required. Teachers are encouraged to keep reminding students about the importance of conciseness in their answers. Please follow this link to our SIU:

https://www.ocr.org.uk/administration/support-and-tools/siu/alevel-science-538595/

Question 1 (a) (i)

1 A student investigates the motion of a tennis ball of mass 57 g which falls vertically from rest, then bounces once on a soft horizontal surface.
Fig. 1 shows the variation with time t of the velocity v of the tennis ball falling from rest until it hits the soft surface.

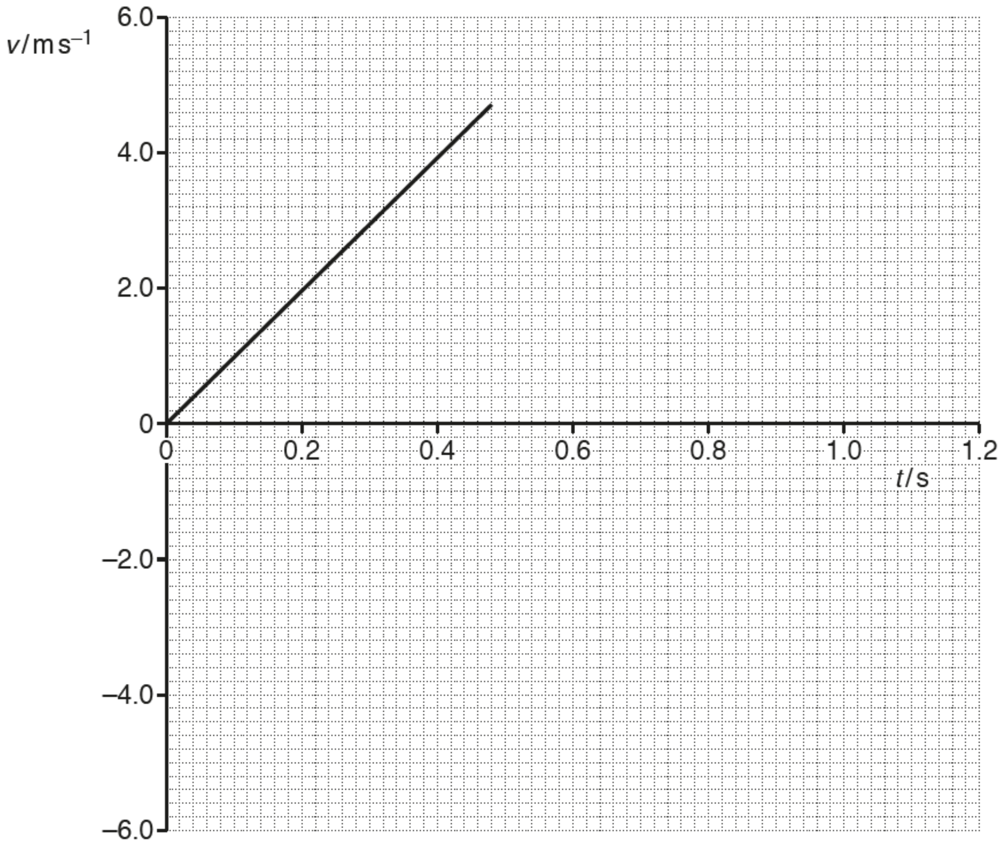


Fig. 1

Air resistance has a negligible effect on the motion of the tennis ball.

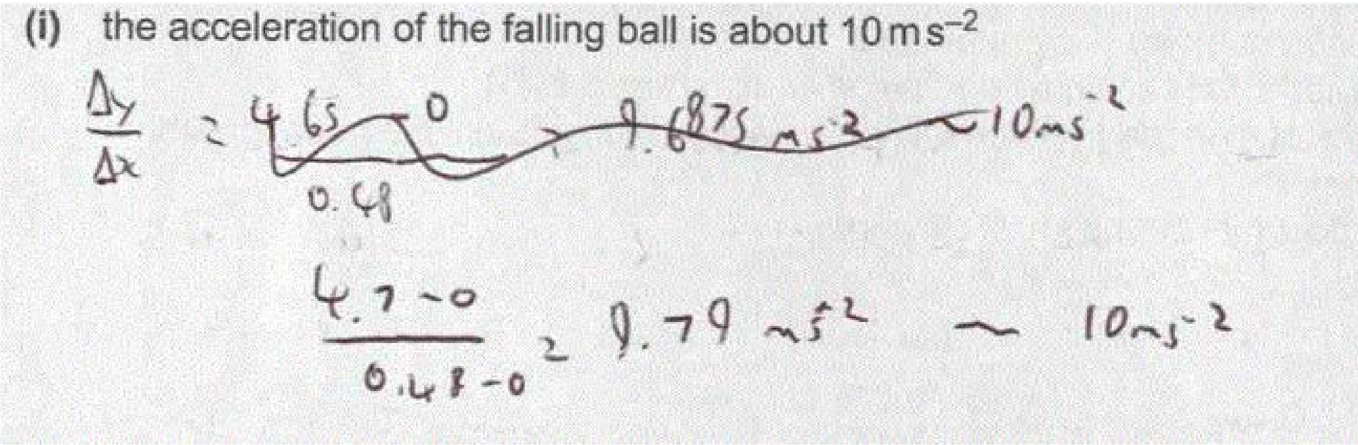
(a) Use Fig. 1 to show that

(i) the acceleration of the falling ball is about $10\,\mathrm{m\,s^{-2}}$

[1]

This question was a "show" type question. Candidates needed to show their working logically. Ideally candidates would state that that the acceleration was equal to the gradient, and then show the substitution of the data values for the gradient calculation. It was expected that candidates would have gained an answer of $9.79\ \mathrm{m\,s^{-2}}$.

Exemplar 1


(i) the acceleration of the falling ball is about $10\,m\,s^{-2}$

$\frac{\Delta y}{\Delta x} = \frac{4.7-0}{0.48-0} = 9.79\ m\,s^{-2} \sim 10\,m\,s^{-2}$

This candidate has clearly demonstrated from Δy / Δx that the gradient is to be determined. Co-ordinates are substituted into the gradient expression and it is clear that the candidate has used more than half the hypotenuse. The candidate then correctly evaluated the expression to give of 9.79 $m\,s^{-2}$. and then states that this is about 10 $m\,s^{-2}$.

	AfL	Determining a gradient. Candidates should clearly demonstrate the co-ordinates that are used to calculate the gradient. The co-ordinates must lie on the line. A common error is when a candidate uses a data point from a table of results. Candidates should be encouraged to read carefully the quantities from the axes and to pay attention to powers of ten and units. The length of the hypotenuse used for the gradient calculation should be at least half the length of the line. Candidates should clearly show the substitution of the co-ordinates and then evaluate the answer using the expression: $\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1}$. The advantage of this method, it that negative gradients are automatically determined.

	AfL	The gradient of a velocity-time graph is acceleration.

Question 1 (a) (ii)

(ii) the kinetic energy of the ball just before impact with the surface is 0.63 J.

[2]

This was also a "show" type of question. Candidates needed to correctly read the maximum velocity (4.79 m s^{-1}) from the graph and change the mass of 57 g into kilograms. To gain the marks, clear substitution into the kinetic energy equation was needed with a correctly evaluated answer.

Exemplar 2

(ii) the kinetic energy of the ball just before impact with the surface is 0.63 J.

$v = 4.7\ ms^{-1}$

$KE = \frac{1}{2}mv^2$

$KE = \frac{1}{2}(57\times10^{-3})(4.7)^2$

$= 0.62957$

$\approx 0.63 J$

[2]

In this two-mark answer, the candidate has clearly demonstrated the value from the graph as well as the equation that is going to be used. The candidate has correctly changed 57 g to kilograms effectively by using standard form.

The candidate has then correctly evaluated the expression as 0.62957 before stating that this is approximately equal to 0.63 J.

Candidates often find it helpful to underline relevant quantities. In this response the candidate has underlined 0.63 J.

Question 1 (b) (i)

(b) The ball leaves the surface with 80% of the kinetic energy just before impact.

(i) Calculate the magnitude of the velocity *v* of the ball as it leaves the surface.

v = ... m s^{-1} **[3]**

In this question, higher ability candidates initially determined the kinetic energy (0.504 J) as the ball leaves the surface, before rearranging the kinetic energy equation. A few candidates did not take the final square root.

Question 1 (b) (ii)

(ii) Complete Fig. 1 to show the variation of the velocity of the ball after it leaves the surface until it is at rest again.

[2]

In this question, a large number of candidates did not understand that velocity is a vector quantity and drew a line with a negative gradient back towards the *x*-axis. The velocity of the ball as it leaves the surface is in the opposite direction and is therefore $-4.2\ \mathrm{m\,s^{-1}}$. Candidates then needed to draw a parallel line to the initial line (since the acceleration is still the same).

	AfL	Vector quantities have both a magnitude and a direction.

Question 1 (b) (iii)

(iii) Determine the maximum height *h* reached by the ball after it bounces.

h = ... m **[2]**

There were many methods in which candidates could gain the marks in this question. It was helpful for clear methods to be demonstrated. The simplest was to determine the area under the velocity-time graph. Candidates also used the equations of uniform motion.

Common errors seen included the incorrect velocity and when using the equations of motion but being confused about negative signs.

Examiners on this occasion allowed an answer of 0.9 m which is one significant figure. Since the data used is to two significant figures, the final answer should also be to two significant figures.

	AfL	The area under a velocity-time graph is displacement.

Question 1 (c)

(c) The student repeats the experiment with a different ball that is affected by air resistance.

Explain how the graph in Fig. 1 now appears from the time the ball is released to the time it hits the surface.

....

....

....

....

.... **[2]**

Candidates found this question challenging. Many candidates answered the question in terms of air resistance and terminal velocity.

The question required candidates to explain how the graph would appear. Several candidates stated that the gradient would be smaller but did not clearly state that the gradient would decrease over time and not indicate that the line would curve. Candidates needed to also indicate that the line would indicate a lower maximum velocity at a longer time.

Question 2 (a)

2 (a)* A student is investigating the stretching of materials.
The student applies varying loads to material **J** and determines the stress and the strain until the material breaks.
The experiment is then repeated for a second material **K**.
Fig. 2.1 shows how the stress for each material varies with strain.

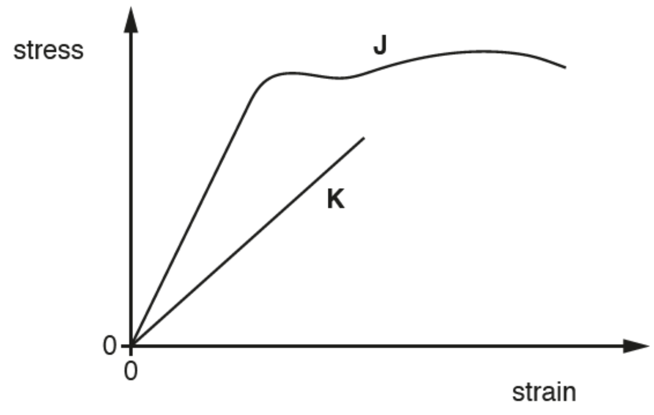


Fig. 2.1

Compare materials **J** and **K** using Fig. 2.1 and the six terms listed below.

brittle **ductile** **elastic** **plastic**

ultimate tensile strength **Young modulus**

Include in your answer an explanation of each term. **[6]**

This was the first level of response question. A good range of marks from zero to six were credited.

This type of question allows candidates to demonstrate structuring an answer logically using appropriate terms correctly. To achieve the highest marks, candidates needed to explain all six terms and compare the two materials using the terms. Some candidates in their answer included a discussion of Hooke's law.

Candidates who did not achieve a Level 3 response, often did not include all the terms or incorrectly described some of terms. Often ultimate tensile strength was not understood. Answers could have been improved by explaining why the gradient was an indication of the Young modulus. Many candidates did not state that an elastic material returned to its original length when a load was removed.

Some candidates who did less well, attempted to describe the material in terms of named materials, often incorrectly, e.g. J was rubber.

Exemplar 3

Material J is ductile. This means the material undergoes a large amount of plastic deformation before breaking and so is used for things like wires. Material K is brittle because it does not ~~undergo~~ undergo plastic deformation at all but it reaches its breaking point after only elastic deformation. Brittle ~~means that~~ ~~material~~ materials like glass and cast iron have this graph because ~~any stress they go under they~~ they obey hookes law. J obeys hookes law (force $\propto$ extension) up until its elastic limit. Elastic deformation means it returns to its original shape once the force is removed. Plastic deformation means it does not. Young modulus is the $\frac{\text{stress}}{\text{strain}}$ and can be calculated from the directly proportional sections of the graph. J has a larger Young Modulus because the line is steeper, and has a larger breaking point. J also has a larger ultimate tensile strength which ~~means~~ is the most stress a material can go under before breaking.

The candidate has explained all the terms and there is a comparison of the two materials. The reference to Hooke's law is acceptable and does not detract from the answer and is not irrelevant.

The candidate's reasoning is clear and logically structured. This is a Level 3, 6-mark answer.

Question 2 (b)

(b) A student is designing a three-legged wooden stool as shown in Fig. 2.2.

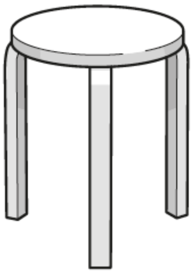


Fig. 2.2

The stool must be able to support the weight of an adult.
The maximum compressive stress of the wood is 2.3 MPa.

Estimate the minimum cross-sectional area *A* of **one** leg.

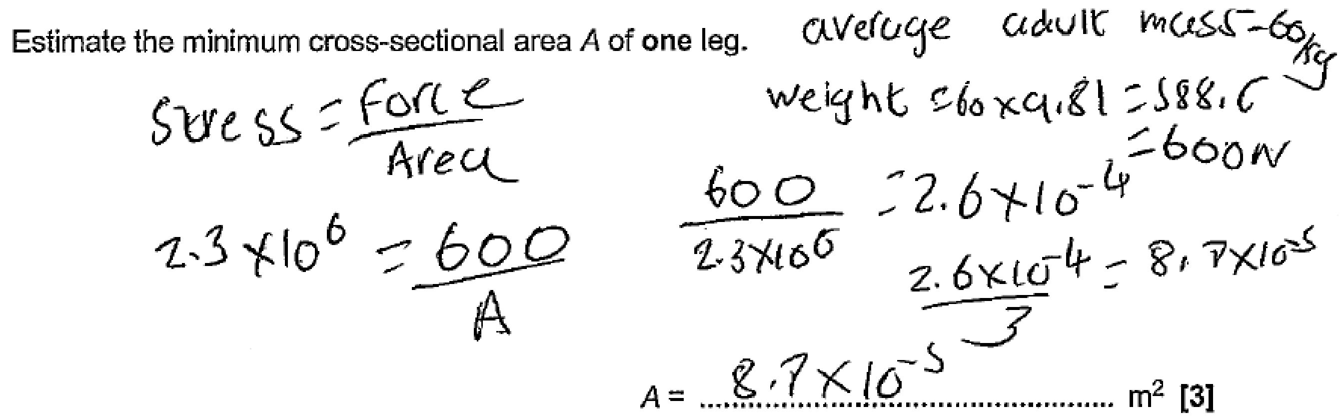
A = ... m^2 **[3]**

A good proportion of the candidates scored full marks on this question. Some candidates found the total area rather than the area of one leg. A few candidates assumed that the stool had four legs.

This question required candidates to estimate the mass or weight of an adult. In general, in this type of question a more generous mass is sensible.

Candidates who did well on this question started by stating the mass (or weight) of an adult. Examiners allowed a mass between 50 kg and 150 kg. Candidates then often worked out the total area before working out the area of one of the legs. Some candidates did not correctly understand that 2.3 MPa was equal to 2.3×10^6 Pa. Some candidates incorrectly divided the stress by three.

Exemplar 4


Estimate the minimum cross-sectional area *A* of **one** leg.

average adult mass ~ 60 kg

weight = 60 × 9.81 = 588.6 = 600 N

Stress = Force / Area

$2.3 \times 10^6 = \frac{600}{A}$

$\frac{600}{2.3 \times 10^6} = 2.6 \times 10^{-4}$

$\frac{2.6 \times 10^{-4}}{3} = 8.7 \times 10^{-5}$

A = 8.7×10^{-5} m² **[3]**

This candidate has clearly identified the average weight of an adult and then indicated how the weight of the adult is determined. The candidate has then clearly stated the equation for stress and shown their working for full marks.

	AfL	Candidates should be encouraged to practise making estimates of physical quantities.

Question 3 (a) (i)

3 **(a)** A student measures the diameter of a ball in different directions.
The student's results are:

2.43 cm 2.54 cm 2.59 cm

(i) State the name of a suitable measuring instrument to measure the diameter of the ball.

.... **[1]**

This question was well answered with most candidates stating either Vernier calliper or a micrometer screw gauge.

Question 3 (a) (ii)

(ii) Calculate the mean diameter *d* of the ball.
Include the absolute uncertainty in *d*.

d = ... ± .... cm **[2]**

Most candidates correctly calculated the mean diameter of the ball. A much smaller proportion of the candidates determined the absolute uncertainty in the diameter correctly. In this case, the range was 0.16 cm, so the absolute uncertainty was 0.08 cm. Examiners allowed the maximum value minus average value or average value minus minimum value.

	AfL	When measurements are repeated the absolute uncertainty is given by: Absolute uncertainty = ½ × range = ½ × (maximum value – minimum value)

Question 3 (a) (iii)

(iii) Show that the volume of the ball is about $8.4 \times 10^{-6}\,m^3$.

[1]

This was another "show" question. Many candidates find dealing with standard form terms in their calculator difficult.

Candidates needed to show clearly the conversion of the diameter in cm to radius in m. There was some evidence of candidate just adding a 10^{-6} power to their answer.

Question 3 (a) (iv)

(iv) The mass of the ball is 23 ± 1 g.
Determine the density ρ of the ball.
Give your answer to an appropriate number of significant figures.

ρ = ... kg m^{-3} **[2]**

In this question, most candidates were able to determine the density correctly although, a few candidates did not change the mass in gram to kilogram.

A large number of candidates did not give their answer to an appropriate number of significant figures; the common answer being 2738 kg m^{-3}. In this case, the mass was given to two significant figures and the volume was calculated from data give to three significant figures, thus the final answer should be given to the same number of significant figures as the least significant data, i.e. to two significant figures.

Question 3 (a) (v)

(v) Determine the percentage uncertainty in ρ.

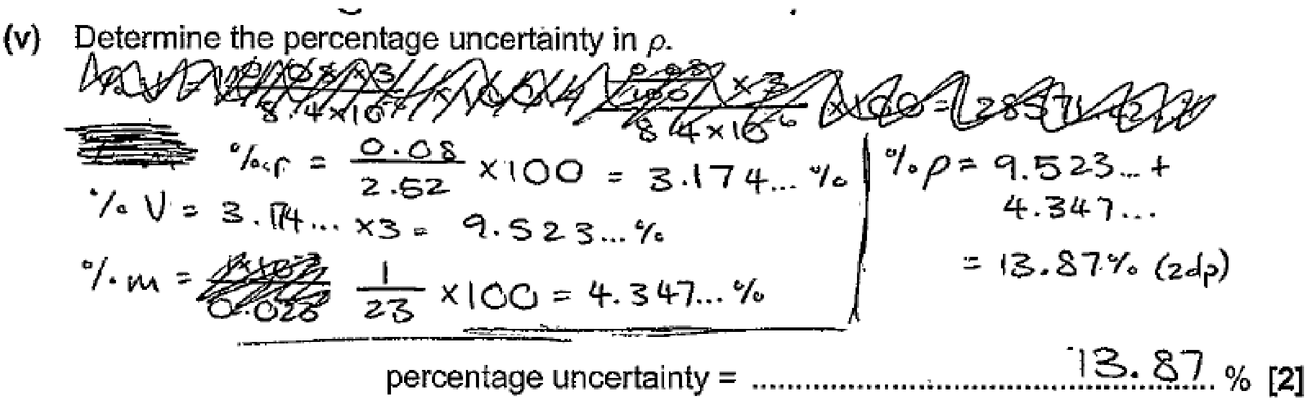
percentage uncertainty = ... % **[2]**

The majority of candidates were able to determine the percentage uncertainty in the mass correctly. Fewer candidates realised that the percentage uncertainty in the volume was three times the percentage uncertainty in the diameter. Candidates who did well, clearly showed their working.

Some candidates tried to use a maximum/minimum method. This was a more complex method and more difficult for candidates to gain the correct answer. In this case, the maximum mass needed to be divided by the minimum volume or the minimum mass needed to be divided by the maximum volume

	AfL	How to use percentage uncertainties.

Exemplar 5


(v) Determine the percentage uncertainty in ρ.

$\%_r = \frac{0.08}{2.52} \times 100 = 3.174...\%$

$\%V = 3.174... \times 3 = 9.523...\%$

$\%m = \frac{1}{23} \times 100 = 4.347...\%$

$\%\rho = 9.523... + 4.347... = 13.87\%$ (2dp)

percentage uncertainty = 13.87 % [2]

The candidate’s answer is logically structured showing the percentage uncertainty in the mass and volume and then adding them together so gaining both marks.

An answer of 14% would have been acceptable.

Question 3 (b)

(b) The 23 g mass ball from **(a)** is used in an experiment with a spring.

The student measures the unstretched length L_0 of a spring as shown in Fig. 3.1.

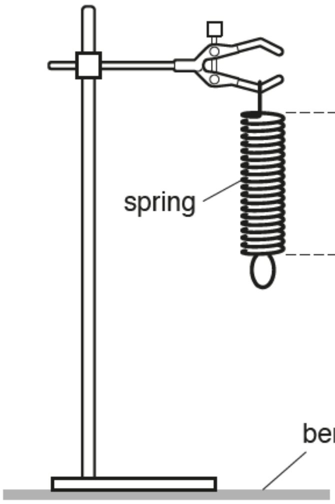


Fig. 3.1

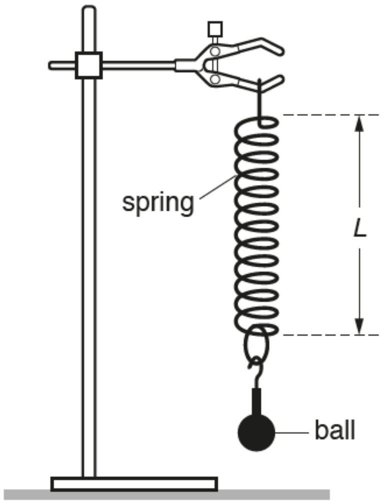


Fig. 3.2

The student then attaches the ball to the spring and measures the length L of the spring as shown in Fig. 3.2.

The student's results are:

$L_0 = 0.078\,\text{m}$ and $L = 0.096\,\text{m}$

Calculate the force constant k of the spring.

k = ... N m^{-1} **[3]**

The majority of the candidates clearly showed their working and calculated the force constant correctly. Some incorrectly used the energy stored equation.

Question 3 (c) (i)

(c) The 23 g mass ball from **(a)** and the spring from **(b)** are now used in an experiment to investigate upthrust.

The ball attached to the spring is lowered into a beaker containing a liquid so that it is totally submerged. The student measures the new length L_N of the spring, as shown in Fig. 3.3.

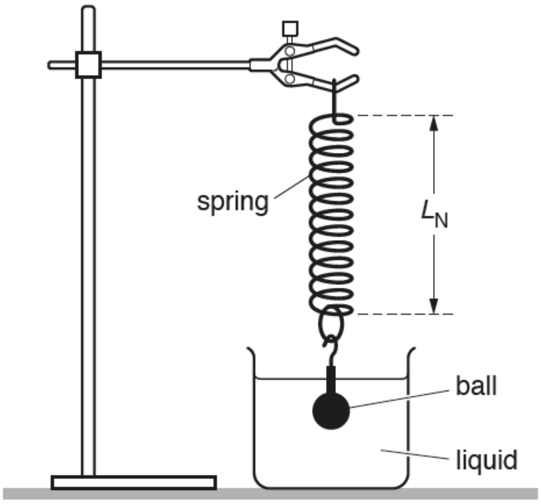


Fig. 3.3

The length L_N of the spring is now 0.088 m.

(i) Calculate the upthrust on the submerged ball.

upthrust = ... N **[2]**

In this question, many candidates calculated the apparent weight and then incorrectly assumed that this was the upthrust. Other errors included using the incorrect values for length to determine the extension. Some candidates correctly determined the upthrust by determining the change in extension.

Question 3 (c) (ii)

(ii) Calculate the density of the liquid.

density of liquid = ... $kg\,m^{-3}$ **[2]**

Candidates generally found this last question challenging. Some candidates who did less well, attempted to use the equation for liquid pressure. Candidates who did well again clearly showed their reasoning.

Question 4 (a) (i)

4 **(a)** Fig. 4 shows a circuit with five identical 60 Ω resistors. The battery has electromotive force (e.m.f.) 9.0 V and negligible internal resistance.

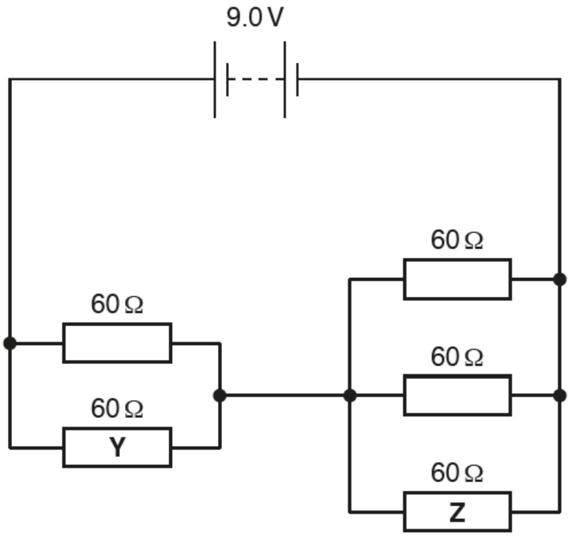


Fig. 4

(i) Show that the total resistance in the circuit is 50 Ω.
Make your reasoning clear.

[2]

This question was generally answered well although, a number of candidates did not take due care when writing the mathematical expressions.

Exemplar 6

4 **(a)** Fig. 4 shows a circuit with five identical 60 Ω resistors. The battery has electromotive force (e.m.f.) 9.0 V and negligible internal resistance.

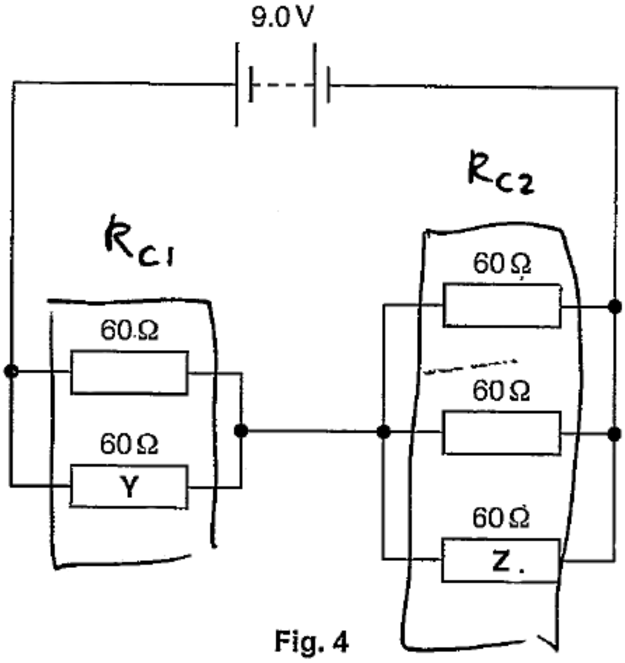


Fig. 4

R_{C1} is combination of resistors with Y

R_{C2} is combination of resistors with Z

R_T is total resistance of circuit

(i) Show that the total resistance in the circuit is 50 Ω. Make your reasoning clear.

$R_{C1} = 1 \div \left(\frac{1}{60} + \frac{1}{60}\right) = 30\,\Omega$

$R_{C2} = 1 \div \left(3\left(\frac{1}{60}\right)\right) = 20\,\Omega$

$R_T = R_{C1} + R_{C2} = 30 + 20 = 50\,\Omega$ **[2]**

The candidate's response is logically structured showing the effective resistance of the two combinations of resistors and then clearly showing the adding of the two effective resistances together. This answer gained both marks.

Question 4 (a) (ii)

(ii) Calculate the potential difference *V* across resistor **Y**.

V = ... V **[2]**

For this question, many candidates incorrectly stated that the potential difference was 4.5 V. Other candidates tried determining the current but did not make clear their working.

The simplest solution was to use the potential divider relationship.

Question 4 (a) (iii)

(iii) Calculate the charge *Q* passing through resistor **Y** in two minutes (include an appropriate unit).

Q = ... unit: .... **[3]**

The majority of the candidates gained a mark for the unit of charge on this question.

A common incorrect answer was 21.6 C where candidates had used the total current in the circuit rather than the current of 0.09 A in resistor Y. Some candidates did not change the time in minutes to a time in seconds.

Question 4 (a) (iv)

(iv) Calculate the energy *W* dissipated in resistor **Y** in two minutes.

W = ... J **[1]**

Candidates who multiplied the charge by the potential difference easily gained the mark in this question. Other candidates who used different methods often made mistakes.

Question 4 (b)

(b) Explain how the mean drift velocity of electrons in resistor **Y** compares with the mean drift velocity of electrons in resistor **Z**.

....

....

....

....

....

.... **[3]**

In this question, many candidates correctly quoted the equation and stated that the mean drift velocity was directly proportional to the current. The majority of the candidates realised that there was a larger current in resistor Y than resistor Z; however, few candidates realised that the current was 1.5 times larger and therefore the mean drift velocity was 1.5 times larger.

Question 4 (c)

(c) Copper is a metal, carbon is a semiconductor and ceramic is an insulator.

Describe the difference between these three materials in terms of the number density *n* of free electrons. Include an explanation of the term **number density**.

....

....

....

....

....

....

....

.... **[3]**

In this question, many candidates did not score the mark for explaining that the number density was the number of free charge carriers per unit volume. Some candidates incorrectly defined it as the number of electrons as opposed to free electrons, while other candidates stated that it was per unit area.

The majority of the candidates gained two marks on this question. They explained that copper was a conductor or the larger the value of the number density the better the conduction and then related the three materials correctly. A number of candidates correctly stated example number densities.

Some candidates' explanations were too vague.

Question 5 (a) (i)

5 **(a)** Fig. 5 shows the variation with distance of the displacement for two progressive waves **P** and **Q**.

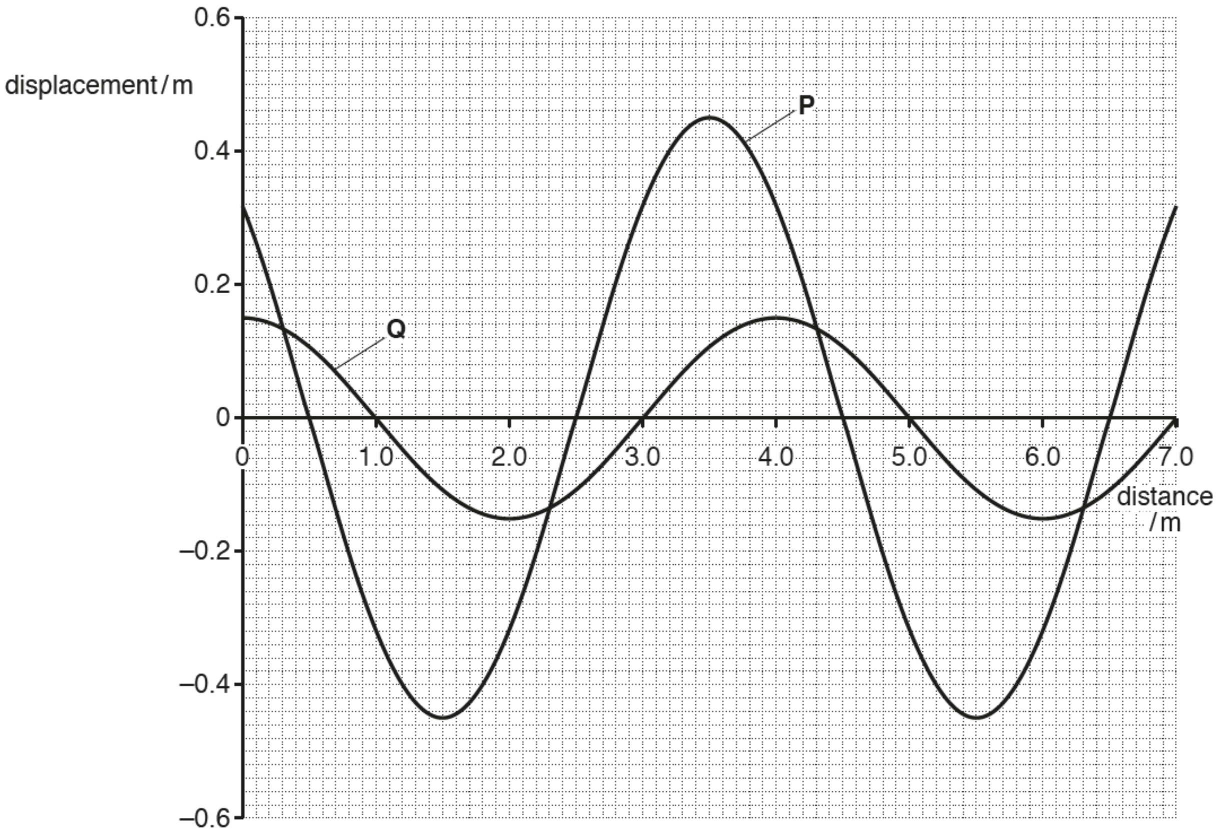


Fig. 5

(i) State the amplitude of wave **P**.

amplitude = ... m **[1]**

This question was generally answered very well. Most candidates understood the definition of amplitude although, a number of candidates incorrectly stated 0.9 m

Question 5 (a) (ii)

(ii) State the wavelength of wave **P**.

wavelength = ... m **[1]**

This question was generally answered very well with most candidates understanding the definition of wavelength.

Question 5 (a) (iii)

(iii) Determine the phase difference, in radians, between wave **P** and wave **Q**.

phase difference = ... rad **[2]**

The majority of candidates did not gain credit on this question.

Successful candidates clearly showed their working. Some candidates were not sure how to change a fraction of a wavelength into a phase difference in radians.

Question 5 (a) (iv)

(iv) Determine the ratio $\frac{\text{intensity of wave } \mathbf{P}}{\text{intensity of wave } \mathbf{Q}}$.

ratio = ... **[2]**

Candidates found this question challenging. They often did not realise that the intensity is proportional to the amplitude squared. It was helpful where candidates showed their working.

Question 5 (b)

(b)* A student wishes to investigate how the fringe spacing x of an interference pattern produced by sound waves varies with the frequency f of the sound waves.

It is suggested that $\frac{v}{f} = \frac{ax}{D}$ where

a is the separation of the sources of sound
D is the distance from the sources of sound to the interference maxima and minima
v is the speed of sound in air.

Describe with the aid of a suitable diagram how an experiment can be safely conducted in the laboratory, and how the data can be analysed to determine v. **[6]**

This question is assessing candidates’ abilities to plan an investigation.

Some candidates assumed that this was two-source light interference and discussed the use of lasers, etc. It is important that candidates answer the question set.

The stem of the question indicates that a suitable diagram should be drawn. Many candidates did not label their diagrams, or the diagrams were not workable. Higher ability candidates indicated two loudspeakers connected to a signal generator and a microphone connected to an oscilloscope to detect the resultant signal.

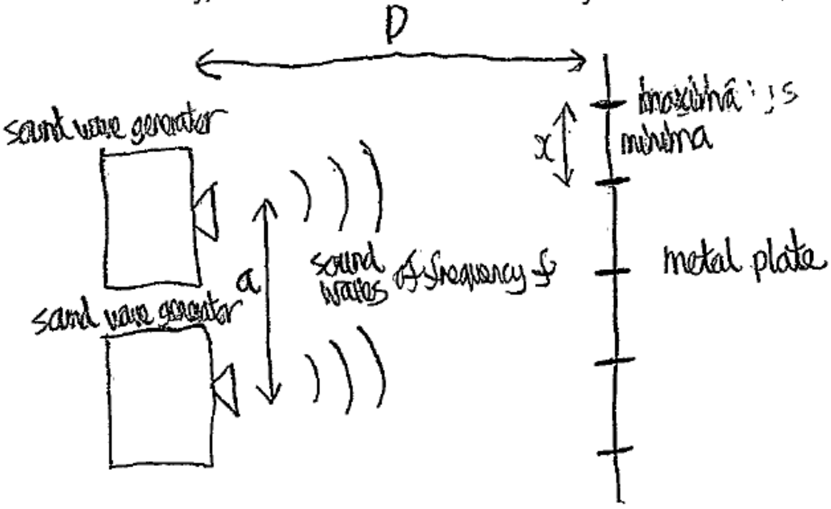
When answering planning questions, candidates should identify the measurements that need to be taken and indicate appropriate measuring instruments. In this experiment, candidates were able to explain how the frequency of the sound could be determined using an oscilloscope as well as how distances could be measured.

Candidates also needed to explain how the data would be analysed. Higher ability candidates suggested the plotting of an appropriate graph and explained how the speed of sound could be determined from the gradient.

	AfL	Practical skills guidance can be found in the Practical Skills Handbook available on the OCR website: https://www.ocr.org.uk/Images/295483-practical-skills-handbook.pdf

Exemplar 7

Describe with the aid of a suitable diagram how an experiment can be safely conducted in the laboratory, and how the data can be analysed to determine *v*. **[6]**



(keep a and D constant)

Measure a, x and D with a metre rule with mm markers (to reduce % uncertainty). Take v to be 330 m s⁻¹. Vary the frequency of the sound waves and record the values of x for each frequency.

$x = \frac{Dv}{af}$ $x = \left(\frac{Dv}{a}\right)\frac{1}{f}$

$y = m\,x$

The candidate's is answering the question as shown by the diagram containing two speakers. There is an indication of how the distances may be measured and that the frequency is going to be varied. The candidate also indicated how the results would be analysed graphically and how the speed of sound could be determined from the gradient of the plotted graph. This is a Level 2 response worth four marks since there is a line of reasoning and the information provided is relevant.

To improve this response, the candidate could have included a signal generator and also a means of detecting the sound at the distance indicated. There should also have been detail on how the frequency was determined.

Question 6 (a) (i)

6 **(a)** In an experiment to demonstrate the photoelectric effect, electromagnetic waves are incident on a silver surface.
Fig. 6 shows the variation with frequency f of the maximum kinetic energy KE_{max} of the photoelectrons.

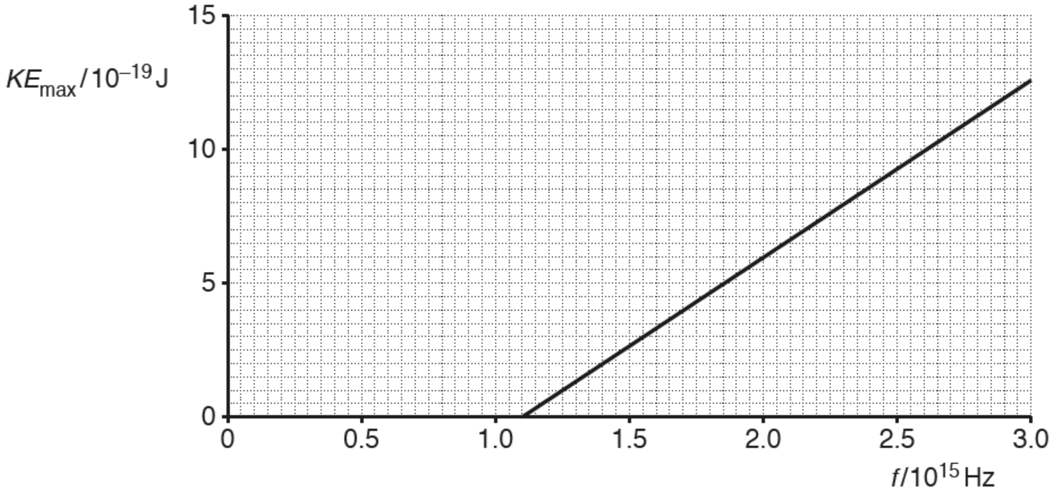


Fig. 6

(i) Define the term **threshold frequency**.

....

....

.... **[1]**

The majority of the candidates gained a mark for this question. When the mark was not scored, it was often due to candidates not realising it was the "minimum" frequency or answering the question in terms of energy.

Question 6 (a) (ii)

(ii) Use Fig. 6 to state the threshold frequency f_0 for silver.

f_0 .... Hz **[1]**

Most candidates were able to read the threshold frequency from the graph. Where errors were made it was for either mis-reading the scale as 1.2 or omitting the 10^{15} Hz.

	AfL	When reading data from a graph, read the scale and the units from each axis.

Question 6 (a) (iii)

(iii) Use your answer in **(ii)** to calculate the work function ϕ of silver.

Give your answer in electron volt (eV).

ϕ = ... eV **[2]**

The majority of the candidates scored two marks on this question. Again, clear working assists candidates with appropriate units being included in intermediate stages of the calculation. Most candidates calculated the work function from the threshold frequency, their answer to the previous part. Some candidates correctly took a data point from the graph and substituted it into Einstein's photoelectric equation which also gained credit.

Exemplar 8

(iii) Use your answer in **(ii)** to calculate the work function ϕ of silver.

Give your answer in electron volt (eV).

at the threshold frequency, KEmax = 0

$h f_0 = \emptyset$

$\emptyset = 6.63 \times 10^{-34} \times 1.1 \times 10^{15} = 7.293 \times 10^{-19}$ J

$\frac{7.293 \times 10^{-19}}{1.60 \times 10^{-19}} = 4.6$ eV

ϕ = ...4.6........ eV **[2]**

The candidate states the condition for the threshold frequency, indicates clearly the calculation of the work function in joule, before clearly demonstrating the conversion to electron volt so gained both marks.

Question 6 (b)

(b) Electrons can behave as a wave.

Describe the behaviour of electrons which demonstrates that they have wave properties.

....

....

....

....

....

.... **[4]**

The final question gave candidates the opportunity to describe the electron diffraction experiment. Answers were often vague, lacking necessary detail. Most candidates were able to describe electrons being diffracted by a graphite crystal lattice. Additional marks could have been gained by discussing the observations, the idea that electrons have a de Broglie wavelength and how the wavelength may be changed and the effect on the observations of a change in wavelength. Some candidates described why a circular pattern may be produced.

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