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Examiners' report

A LEVEL

PHYSICS B (ADVANCING PHYSICS)

OCR Level 3 Advanced GCE in Physics B (Advancing Physics)

H557

For first teaching in 2015

H557/03 Summer 2025 series

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 responses 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 Teach Cambridge.

Paper 3 series overview

This paper is the third paper for the students following the Advancing Physics A Level course. It aims to test candidates understanding of practical skills and techniques. The questions use the context of practical activities listed in the specification and there is an emphasis on graphical work and uncertainties.

This year's paper had questions covering the following practical activities:

- investigation of terminal velocity of falling cupcake cases,
- measurement of magnetic field strength using a simple current balance,
- investigation of diffraction gratings,
- investigation of the oscillations of a mass on a spring.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• showed good understanding of uncertainties in measurements • demonstrated familiarity with the practical contexts for the questions • explained their method for checking the relationship between average velocity and number of cupcake cases (Question 1 (d)) • were able to apply knowledge of Fleming's left-hand rule in a novel situation (Question 2 (d)).	• over-complicated the preliminary steps relating to the way the practicals were set-up • omitted to show all the steps clearly in calculation and algebra • did not make use of good scientific vocabulary in their responses.

Section A overview

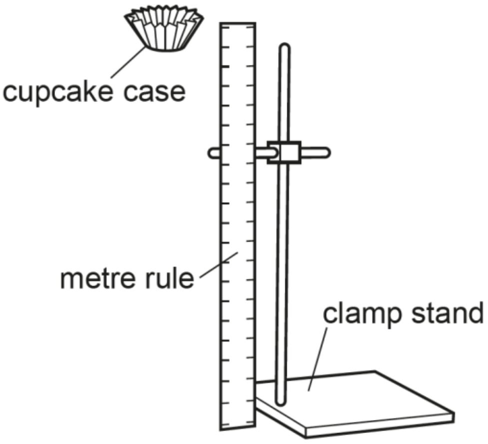
Section A consists of mainly short-answer questions on three different practical activities as well as one extended response question about determining whether the use of average velocity of a falling cupcake case is a close approximation of its terminal velocity. The questions tended to focus on the practicalities of the investigations, uncertainties and some straightforward calculations.

Question 1 (a) (i)

1 This question is about terminal velocity and drag for falling cupcake cases.

(a) A student times how long a cupcake case takes to fall though a height of 2.000 ± 0.005 m using the equipment as shown in **Fig. 1.1**.

Fig. 1.1



A light-gate timer (not shown) is used, and the measurement repeated five times. The times are shown in **Table 1.1**.

Table 1.1

Time/s
1.68
1.69
1.71
1.70
1.73

(i) Determine the absolute uncertainty in the measurement of time.

Absolute uncertainty = ± .... s **[1]**

Most candidates used the accepted method for finding the absolute uncertainty by halving the range between the minimum and maximum values of time given in the table. Some candidates continue to use the resolution of the measuring instrument.

Question 1 (a) (ii)

(ii) Calculate the average velocity of the cupcake case.
Include the uncertainty in your answer.
Give your answer to an appropriate number of significant figures.

Average velocity = ... ± .... $m\,s^{-1}$ **[3]**

Most candidates were able to correctly calculate the average velocity using the length of the drop (2.000 m) and the mean value of time from the data in Table 1.1. Many candidates then added the percentage uncertainty for both quantities to find the percentage uncertainty in the calculated velocity to find the absolute uncertainty. Other methods such as finding the upper and lower bounds were also commonly seen. Some candidates then gave their absolute uncertainty to more than one significant figure. In many cases the steps in the calculation were not clearly laid out in a logical manner.

Assessment for learning

The value for average velocity should then be quoted to the same resolution as the absolute uncertainty at one significant figure.

Average velocity = 1.18 ± 0.02 ms^{-1}.

Here the uncertainty is given to the nearest 0.01 ms^{-1}, so the average velocity should be quoted to the nearest 0.01 ms^{-1}.

Question 1 (b)

(b) The cupcake case will accelerate from rest to reach terminal velocity at some point during its fall. The student is calculating the average velocity.

Comment on how the average velocity relates to the terminal velocity.

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.... **[3]**

Most candidates correctly stated that the average velocity would always be slightly smaller than the terminal velocity but that they would be close as long as the drop was long enough for the cupcake case to take a very short time to accelerate to terminal velocity. Some candidates described terminal velocity and average velocity but did not answer the question.

Question 1 (c)

(c) The experiment is repeated with an increasing number of stacked cupcake cases, as shown in **Fig. 1.2**.

Fig. 1.2

The average times are recorded in **Table 1.2**.

Table 1.2

Number of cup cases	Average time t/s
1	
2	1.27
3	0.97
4	0.81
5	0.70

Explain the trend in the relative percentage uncertainty in the calculated values of average velocity as the number of cupcake cases increases.

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....

.... **[2]**

Most candidates stated that the percentage uncertainty would increase with increasing number of cupcake cases, but only a few candidates gave the full explanation involving the percentage uncertainty in the time values increasing as the time to fall decreased for increasing number of cupcake cases.

Question 1 (d) (i)

(d) Drag force = $\frac{1}{2}\rho A v_t^2$ where v_t is the terminal velocity. A is the cross-sectional area of the falling object.

(i) Show that v_t^2 is proportional to the number of cupcake cases.

[2]

Although most candidates were able to rearrange the algebraic relationship, a common error was to stop at v^2 α m, without bringing N into it. Some candidates missed the first step of equating weight and drag force at terminal velocity. A few candidates had difficulty trying to use ρ as the density of the cupcake case.

Question 1 (d) (ii)*

(ii)* Calculate the values of average velocity squared in **Table 1.3**.

Determine whether the average velocity calculated in this experiment is close enough to the terminal velocity to be used in the relationship: Drag force = $\frac{1}{2}\rho A v_t^2$.

Describe how the experiment can be improved so that the average velocity is as close as possible to the terminal velocity.

Table 1.3

Number of cupcake cases	Average time t / s	Average velocity v_{ave} / m s^{-1}	Average velocity squared v_{ave}^2 / m^2 s^{-2}
1			
2	1.27		
3	0.97		
4	0.81		
5	0.70		

While nearly all the candidates calculated values of v_{ave} and v_{ave}^2 to complete the table, many made no attempt at any quantitative analysis to determine whether the value of v_{ave} showed a similar relationship with number of cupcake cases as v_{term}.

Many candidates suggested increasing the length of the drop in order to reduce percentage uncertainty of measuring height obtained as well as including the advantage of reaching terminal velocity at an earlier stage in the motion.

A few suggested making the cases either more streamlined or heavier, so that they "reach terminal velocity faster", obviously not considering that the proportion of the fall at terminal velocity would be reduced and so worsening the results.

Common misconceptions included performing the experiment in a vacuum to remove the effects of air resistance or in a more viscous fluid. Some suggested using light gates as an improvement, despite these being part of the original experiment.

Exemplar 1

Number of cupcake cases	Average time t/s	Average velocity v_{ave}/m s^{-1}	Average velocity squared v_{ave}^2/m^2 s^{-2}
1	1.70	1.18	1.39 ~~[illegible]~~
2	1.27	1.57	2.48
3	0.97	2.06	4.25
4	0.81	2.47	6.10
5	0.70	2.86	8.16

$\frac{1}{1.39} = 0.719 = K$

$\frac{2}{2.48} = 0.806 = K$

$\frac{3}{4.25} = 0.706 = K$

$\frac{4}{6.10} = 6.56 = K$

$\frac{5}{8.16} = 0.61 = K$

K not same so

N is not proportional to V_{ave}^2

So not suitable to use in ~~[illegible]~~ relationship

This candidate has calculated all the values of v_{ave} and v_{ave}^2, including the first row. They have then calculated the ratio of number of cupcake cases to v_{ave}^2 and then stated that the ratio is not constant so v_{ave} is not close enough to v_{term}. There are two suggested improvements. If the candidate had commented on or explained this anomalous calculated value of k (6.56), this would have been a Level 3 response.

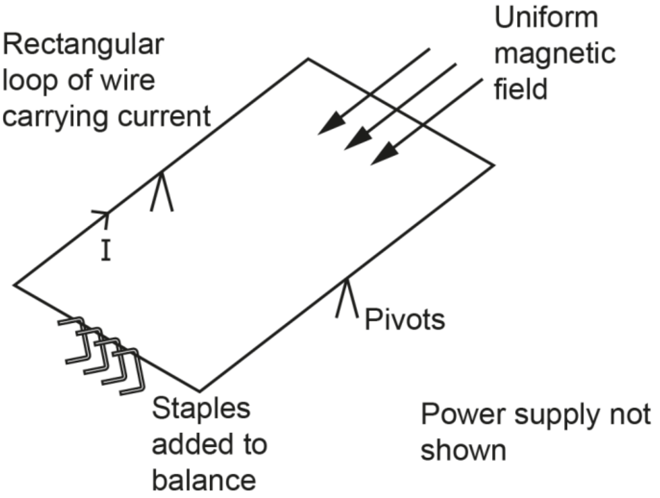
Question 2 (a) (i)

2 A simple current balance can be used to find the magnetic field strength of a magnetic field.

The current balance shown in **Fig. 2.1** is made from a single rectangular loop of stiff wire connected to a power supply.

The length of wire within the magnetic field is 5.0 cm. The pivots are in the centre of the long edges of the rectangle.

Fig. 2.1



The current is varied, and staples are added to restore the rectangular loop to a horizontal balanced position.

(a) The mean mass of a staple is found to be 0.0325 g.

(i) Describe how the mass of one staple could be found using a standard laboratory balance with a precision of 0.1 g and a maximum of 2000.0 g.

....

....

....

.... **[2]**

Nearly all candidates suggested weighing a number of staples and then dividing by the number of staples, but very few justified a suitable number of staples to use in order to obtain the mean mass to three significant figures. Many candidates simply worked out the maximum number of staples to give a value close to 2000 g but made no comment that it would be difficult to count over 61000 staples.

Exemplar 2

Place 1000 staples on the balance, measure its mass and divide by 1000 (total mass ≈ 32.5g << 2000g) as this value will be correct to 3sf as required.

This candidate suggests using 1000 staples which should give a total mass of 32.5 g which would give the mean mass for one staple to three significant figures.

Question 2 (a) (ii)

(ii) Estimate the absolute uncertainty in the value of mass of one staple obtained by your method in part **(a)(i)**.

Uncertainty = ± .... g **[2]**

Many candidates calculated the percentage uncertainty for the total mass of a number of staples and then worked out the absolute uncertainty by multiplying by 0.0325 g to give a correct value rather than simply dividing the ± 0.1 g by the number of staples being weighed. Many candidates misinterpreted the precision of ± 0.1 g to give an uncertainty of ± 0.05 g.

Question 2 (b)

(b) The experiment is repeated several times for each value of current.

With a current of 1.5A, the number of staples needed to balance the wire horizontally was found four times. The results are shown in **Table 2.1**.

Table 2.1

Number of staples needed to balance when current = 1.5A
4
5
4
5

Calculate the mean magnetic force exerted on the wire when the current is 1.5A.

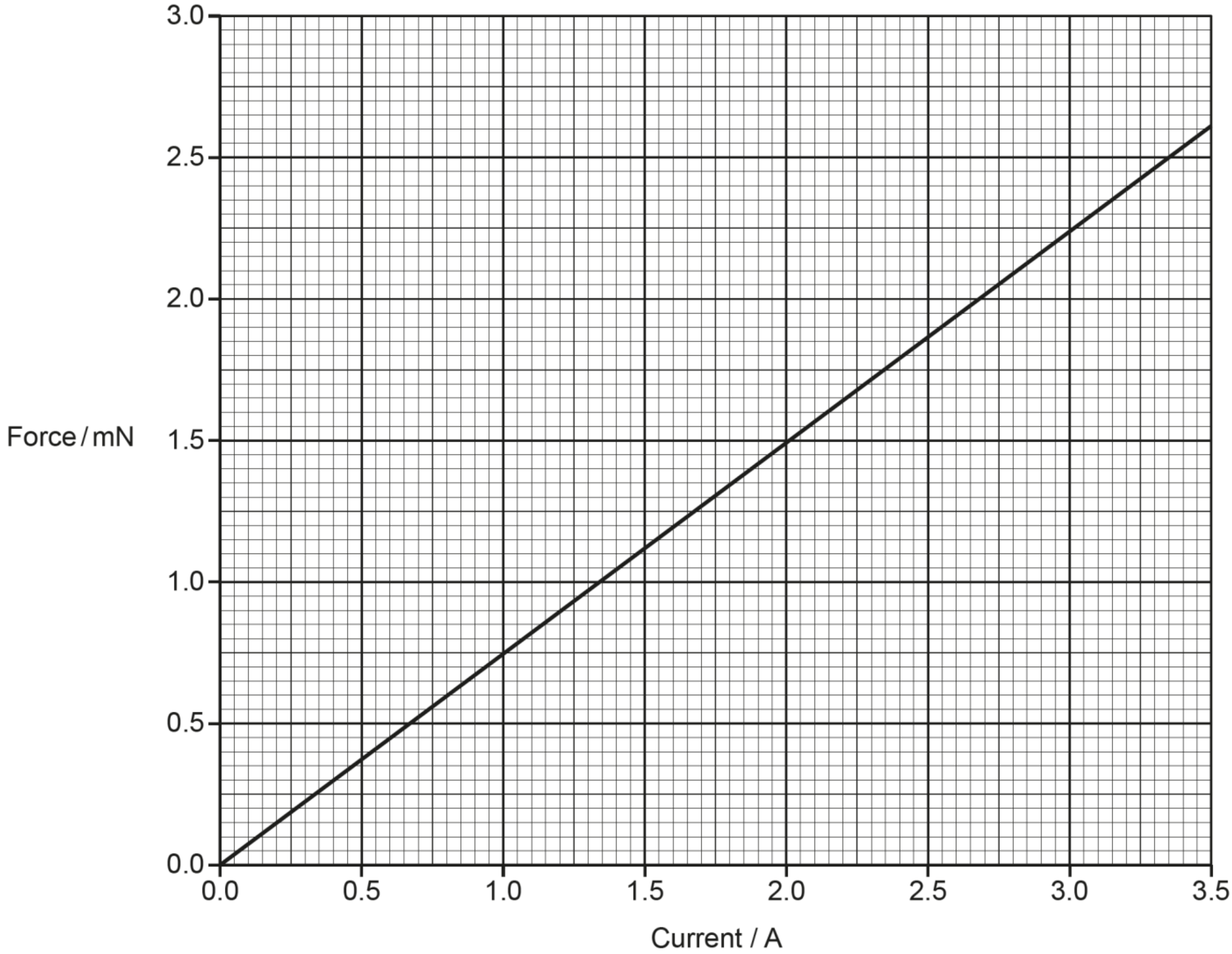
Force = ... N **[2]**

Most candidates realised that all they needed to do was to find the mean number of staples (4.5) and multiply by the weight of one staple. Common errors included forgetting to convert the mass in g to kg and forgetting to multiply the mass by *g*.

Question 2 (c) (i) and (ii)

(c) Further data were collected for other values of current. **Fig. 2.2** shows the graph of the data.

Fig. 2.2



(i) Calculate the gradient of the line.

Gradient = ... **[2]**

(ii) Use the value of gradient to calculate the value of magnetic field strength.

Magnetic field strength = ... T **[3]**

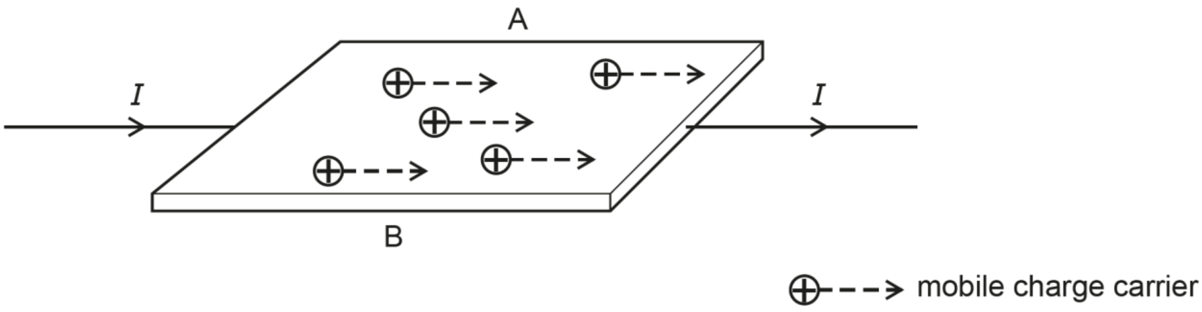
Both parts of this question were answered well. Nearly all candidates used appropriate coordinates from the line to calculate gradient and then used the gradient value to find the magnetic field strength to the correct power of ten.

Question 2 (d)

(d) Another method to measure magnetic field strength is to use a Hall probe.

A small current passes through a slice of semiconductor material as represented in **Fig. 2.3**.

Fig. 2.3



The probe is placed in a magnetic field. The large face of the semiconductor is at right angles to the field.

Explain why a small potential difference is detected across sides A and B of the semiconductor.

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.... **[3]**

This question was intended to challenge candidates as the Hall probe is likely to be unfamiliar. Some candidates interpreted the question correctly and used first principles to explain that the moving charges would experience a force while passing through the magnetic field. Common errors included attempting to use Faraday's law, electromagnetic induction and eddy currents.

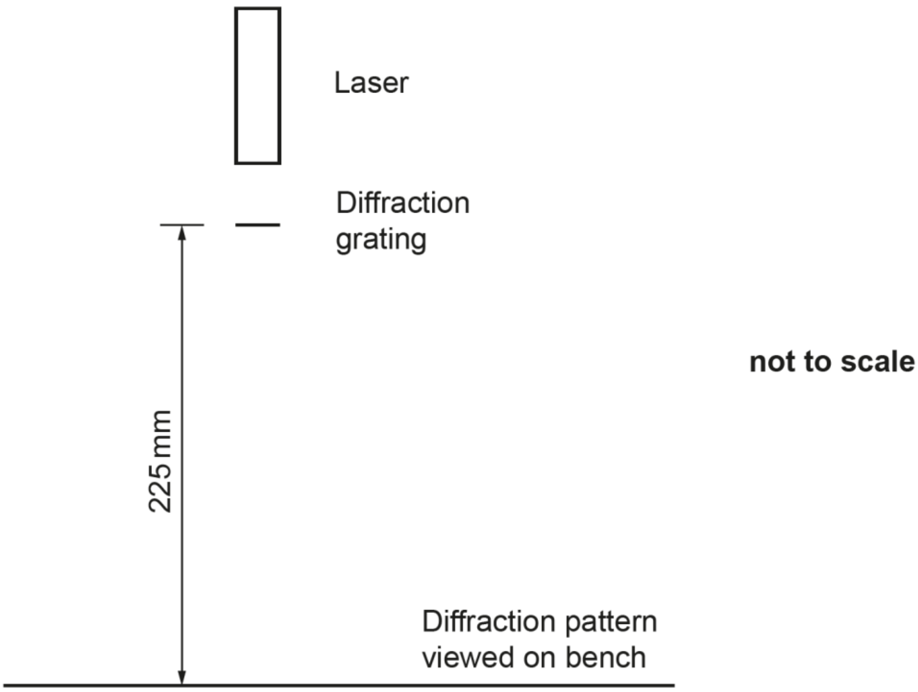
Question 3 (a) (i)

3 This question is about diffraction gratings.

A teacher has a box of 20 unlabelled diffraction gratings. The students are asked to find the number of lines per mm for each grating in the box.

A laser beam is directed downwards at one diffraction grating, as shown in **Fig. 3.1**.
The laser light is red, wavelength 650 nm.
The distance between the grating and the bench is 225 mm.
The diffraction pattern is visible on the surface of the bench.

Fig. 3.1



(a) The distance between the two first order maxima is measured as 191 mm.

(i) Calculate the angle between the straight-through direction and the first order maximum.

Angle = ... ° **[2]**

Many candidates started by using $n\lambda = d\sin\theta$, instead of using simple trigonometry to find the angle from the dimensions given in the question. Some candidates who used the correct method did not halve the distance between the two first-order maxima to find the distance from the centre to the first-order maximum.

Question 3 (a) (ii)

(ii) Calculate the number of lines per mm on the diffraction grating.

Number of lines per mm = ... mm^{-1} **[2]**

This question was challenged many candidates trying to use the Young's slits equation, despite having written down the diffraction grating equation in the previous part. A few candidates correctly found the distance between the lines but then did not convert this to the number of lines per mm.

Question 3 (b)

(b) Describe how you could determine a more accurate value for the number of lines per mm on the diffraction grating.

....

....

.... **[2]**

While some candidates correctly suggested to either increase the distance from the grating to the bench or to measure the distance between several maxima, many seemed more focused on taking repeat readings to reduce percentage uncertainty rather than improving accuracy. Some candidates suggested looking at the grating under a microscope and counting lines.

Misconception

Candidates often confuse the following terms:

- Accuracy: a measured value is accurate if it close to the true value.
- Precision: measurements are precise if several repeated values are close together.
- Uncertainty: there will always be some uncertainty related to a measured value and it tends to be given as the interval in which the value is expected to lie.

Question 3 (c)

(c) **Table 3.1** shows the values obtained from all 20 diffraction gratings.

Table 3.1

Number of lines per mm				
144	320	590	594	603
156	567	591	599	605
299	588	592	600	605
310	590	593	602	610

Standard values for school diffraction gratings are usually 80 lines / mm, 150 lines / mm, 300 lines / mm and 600 lines / mm.

Explain which set the majority of these gratings are from.
Suggest a value for the **absolute** uncertainty in the published value for the number of lines per mm.

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....

.... **[3]**

Nearly all candidates correctly suggested that most of the gratings were from the 600 lines mm^{-1} set. Few identified that 567 was an outlier so when they calculated the uncertainty it was usually ± 21.5.

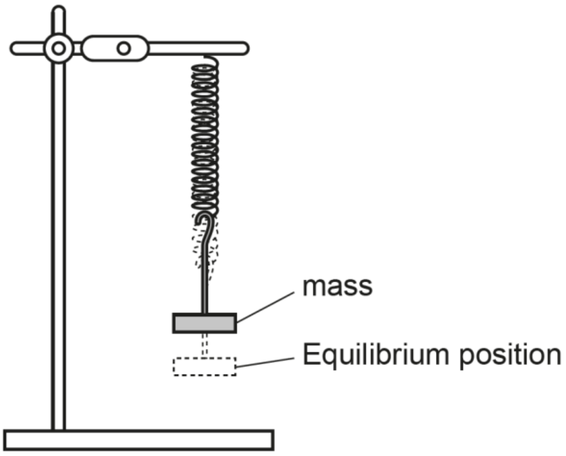
Section B overview

Section B takes the form of one longer structured question which includes a second extended response question. The early parts of the question relate to the natural oscillations of a mass on a spring and included some graphical work. The extended response question related to forced oscillation.

Question 4 (a)

4 A student carries out an experiment investigating how the period of oscillation of a mass on a spring varies as the mass is increased. The experimental setup is shown in **Fig. 4.1**.

Fig. 4.1



The teacher tells the student that measuring the time for ten oscillations rather than the time for one oscillation will provide more reliable data.

(a) State why measuring ten oscillations provides a more reliable measurement of the time period.

....

.... **[1]**

Most candidates correctly stated that measuring the time for 10 oscillations decreases the percentage uncertainty of the period.

Question 4 (b)

(b) One pair of data points is shown below.

Time for ten oscillations = 10.4 s ± 0.5 s
Mass = 0.50 kg ± 0.01 kg

The student decides to ignore the uncertainty in the mass and the teacher agrees.

Explain whether this is a reasonable decision. Use calculations in your answer.

....

....

....

.... **[2]**

Several candidates correctly evaluated the two uncertainties but many did not then compare the two values or did not consider whether the decision to ignore the uncertainly in the mass to be reasonable or not. Very few considered the fact that relationship between period and mass involves a power of 2.

Question 4 (c) (i), (ii), (iii) and (iv)

The student gathers the data in **Table 4.1**.

Table 4.1

Mass / kg	Time for ten oscillations (±0.5) / s	Time for one oscillation, T / s	T^2 / s^2
0.10	4.9	0.49	0.240
0.20	5.9	0.59	0.348
0.30	7.9	0.79	0.624
0.40	9.2	0.92	0.846
0.50	10.4	1.04	1.082
0.60	10.9	1.09	1.188
0.70	12.0		

(c) The student plots the data as a graph as shown in **Fig. 4.2** and includes uncertainty bars for T^2 values based on the uncertainty value given in part **(b)**.

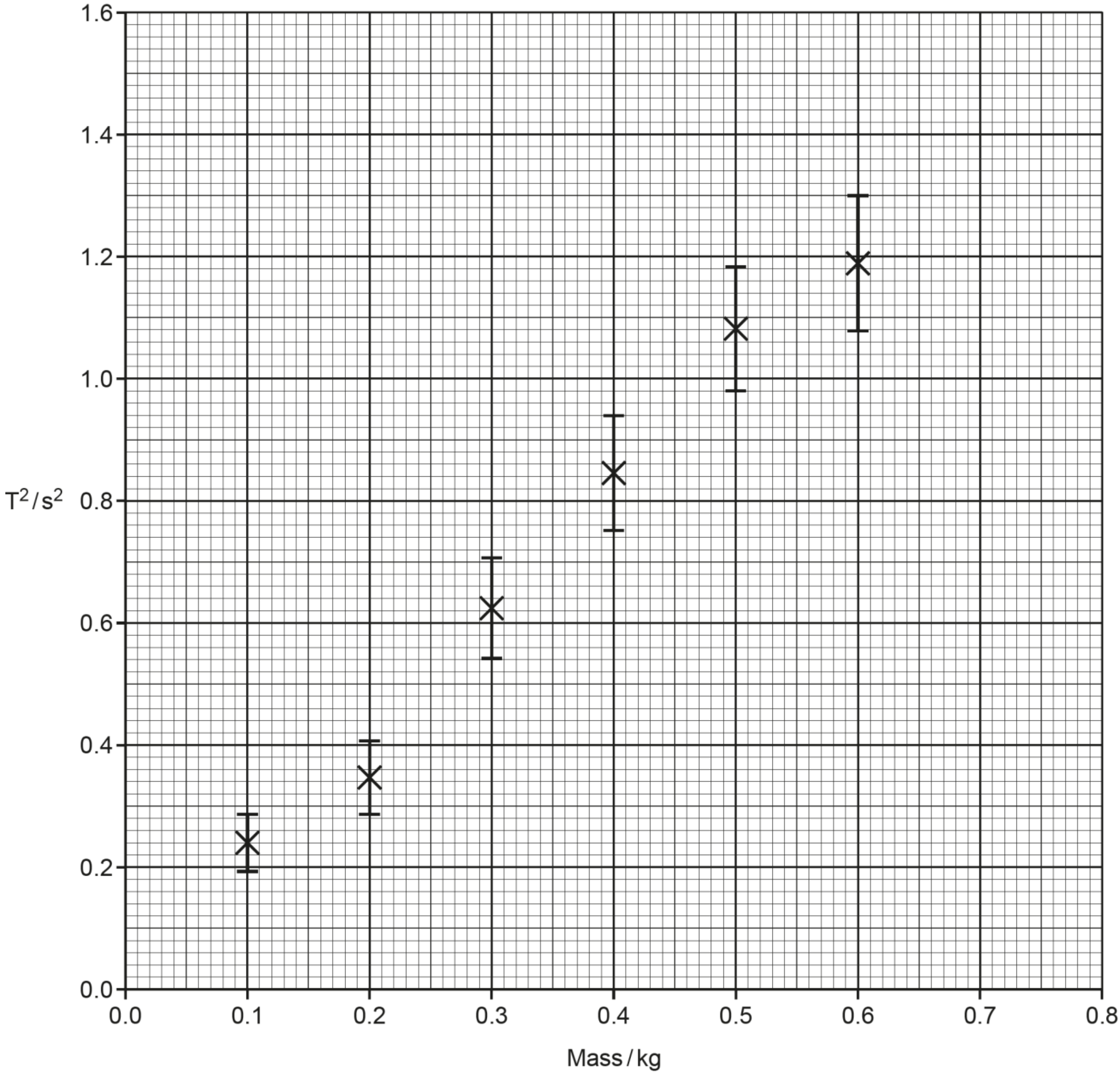
(i) Complete **Table 4.1** and plot the remaining point on **Fig. 4.2**. **[2]**

(ii) Calculate the uncertainty in the value of T^2 for the final data point and add these uncertainty bars to the graph.

[3]

(iii) Draw a line of best fit on **Fig. 4.2**. **[1]**

Fig. 4.2



(iv) A different student calculates their gradient to be 2.05 s^2kg^{-1}.

Show that the spring constant of the oscillating system is approximately 19 Nm^{-1}.

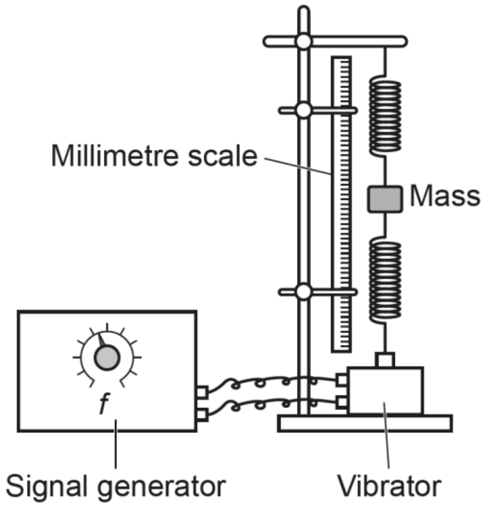
[2]

This graphical work was generally well answered. In part (i) all candidates correctly calculated T^2, but some did not use consistent resolution in the tabulated values. Nearly all candidates plotted the point correctly. Most were able to calculate the uncertainty in the value in part (ii) and plot error bars. A common mistake was to use the value of percentage uncertainty they had calculated for T = 10.4 s in part (b). Nearly all candidates drew an acceptable line of best fit through the error bars. Incorrectly drawn lines tended to miss the error bar at m = 0.2 kg.

Question 4 (d) (i)*

(d) The student develops their experiment to investigate resonance. In the modified experiment, the oscillations are driven by a signal generator and vibrator as shown in **Fig. 4.3**.

Fig. 4.3



(i)* Suggest how the student could use this apparatus to investigate how the resonant frequency of the system varies with mass. You should describe the experimental process including:

- How the student could obtain precise determinations of the resonant frequencies.
- Describe and explain the relationship between resonant frequency and mass you would expect the student to obtain.
- Include in your explanations how the amplitude would vary with frequency for a given mass.

You may use diagrams in your response.

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.... **[6]**

Most candidates were able to suggest increasing the frequency from the signal generator and then observe the oscillations of the mass in order to find the resonant frequency. Few, if any candidates, appreciated that if they found the exact resonant frequency, this would damage the vibrator. Some candidates also suggested finding the natural frequency of the system by displacing the mass when it is not connected to the vibrator, and then just varying *f* within ± 10 Hz of this value, appreciating that natural and resonant frequency will be the same. Some candidates seemed more concerned about obtaining accurate values for maximum amplitude rather than resonant frequency. A few candidates suggested connecting an oscilloscope to the signal generator, and using it find a value for the frequency, instead of just reading it from the signal generator. Several candidates connected increasing the mass with the degree of damping, some including sketch graphs of amplitude against frequency for light, moderate and heavy damping but labelling this as the effect of increasing mass. The relationship between amplitude and frequency for a single mass was usually described with the inclusion of a sketch graph, but the relationship between resonant frequency and mass was usually just shown algebraically.

Exemplar 3

21

They should vary the frequency using the signal generator and record the amplitude, using small intervals of frequency either side of the resonance peak, ~~This is~~ to get a more ~~acc~~ precise estimate for the resonant frequency. They could also use a fiducial marker attached to the mass to reduce parallax error when reading the amplitude off the scale, and always read from the same point on the mass. As the mass increases, the natural frequency and hence resonant frequency should decrease, since $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$. This is also because the mass would have more inertia so will have less freedom to react to higher frequencies, meaning the resonance peak shifts ~~down~~ to lower frequencies. Another more precise way of recording amplitude is to use a video camera and analyse frame by frame, since the mass may be moving very fast. For low frequencies, amplitude is equal to that of driving force. When the driving force matches the natural frequency, resonance occurs and maximum amplitude oscillations are produced. **[6]**

This response begins with a good description of experimental method including a suitable method for the improving accuracy of the measured value for resonant frequency. It briefly states the relationship between *f* and *m* and described resonant frequency. There are no sketch graphs or description of how amplitude varies with frequency for a given mass so this is a Level 2 response.

Question 4 (d) (ii)

(ii) Measurements of mass in space can be challenging.
Suggest briefly how to adapt the method shown in **Fig. 4.3** to measure mass in zero g environments.

Estimate a reasonable spring constant for the system, if it were to be used to measure an astronaut's mass.
Assume that the time period of the system is designed to be about 2 s for a typical mass.

....

.... **[3]**

Most candidates were able to give an appropriate estimate for the mass of an astronaut and use that to calculate the required stiffness to give a frequency of about 2 s. Most did not suggest suitable adaption for use in zero *g* environment. Few mentioned any calibration on Earth and some even suggested using it in a vacuum.

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