OXFORD
INTERNATIONAL
AQA EXAMINATIONS

# INTERNATIONAL A-LEVEL PHYSICS

## (PH05)

## Unit 5: Physics in practice

## Example responses with commentary

For teaching from September 2016 onwards
For A-level exams in May/June 2018 onwards

This guide includes some examples of student responses to a selection of questions from the summer 2018 PH05 unit.

The question parts are reproduced, along with the final mark scheme, student responses and a commentary from the Lead Examiner on each of the students' answers.

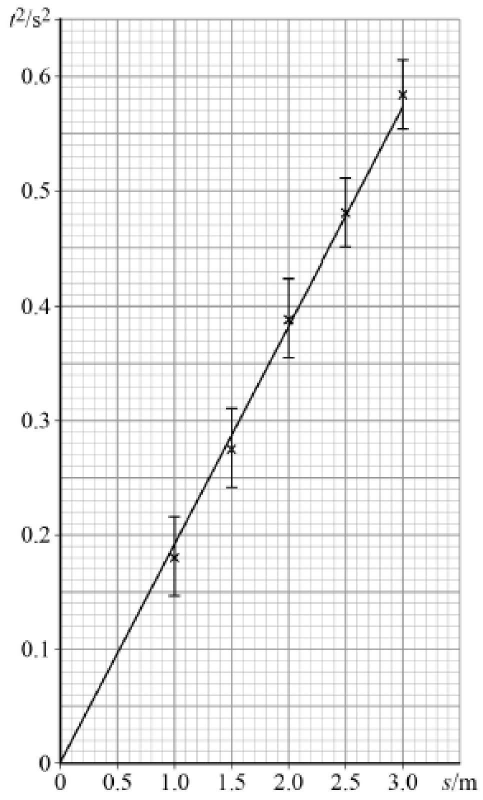
## QUESTION

## 01

**0 1** A class measures the time $t$ for a ball to fall from rest through a distance $s$ for a range of values of $s$.

**Figure 1** shows the variation of $t^2$ with $s$.

**Figure 1**




**0 1 . 1** Determine the gradient of the graph.

**[2 marks]**

gradient = ______________________ $s^2\ m^{-1}$

## MARK SCHEME

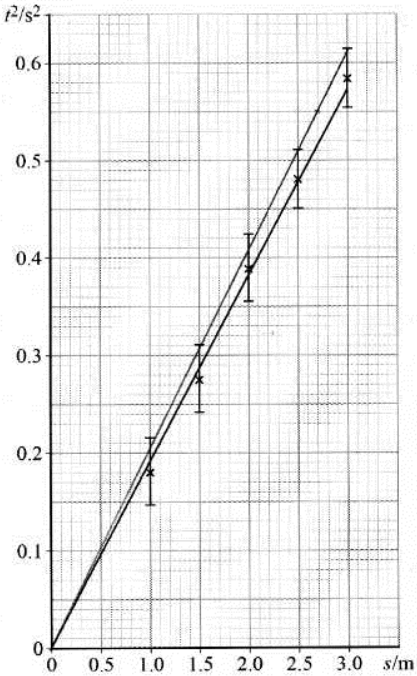
| Question | Marking guidance | Mark | Comments |
|---|---|---|---|
| 01.1 | Answer in the range 0.185 to 0.200 ✓<br><br>Large triangle plus some evidence of correct data extraction ✓ | 2 | |

## STUDENT A

**0 1** A class measures the time $t$ for a ball to fall from rest through a distance $s$ for a range of values of $s$.

**Figure 1** shows the variation of $t^2$ with $s$.

**Figure 1**




**0 1 . 1** Determine the gradient of the graph.

**[2 marks]**

(0,0) (1.2, 0.23)

$\frac{0.23 - 0}{1.2 - 0}$

= 0.19167

gradient = 0.19 $s^2\,m^{-1}$

## EXAMINER COMMENTARY

Although the student obtains an estimate for the gradient within the allowed range and gains one mark for this, the student does not show the triangle used to obtain the gradient on the graph. In fact, the triangle used is implicit as the student has provided the coordinates of the points that define it. No further credit is possible, however, because the triangle used is less than half the length of the drawn line. This is a standing rule in this assessment.

It is crucial that students use a large triangle and that the examiner can determine what it was. Further, students should **not** use plotted data points that do not lie on the line – this is a common error.

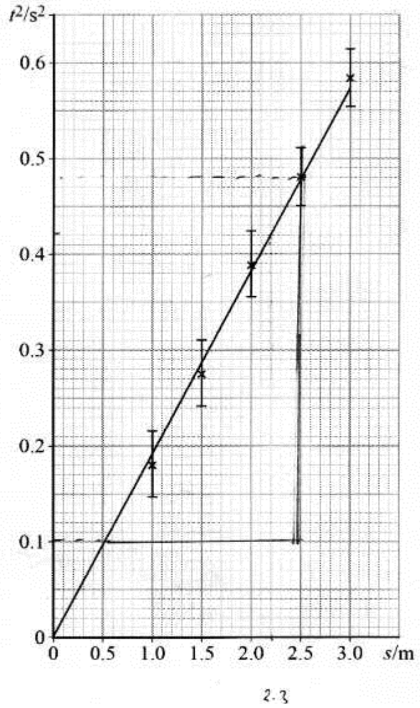
1 mark awarded.

## STUDENT B

of values of *s*.

**Figure 1** shows the variation of $t^2$ with *s*.

**Figure 1**




**0 1 . 1** Determine the gradient of the graph.

**[2 marks]**

$$\text{gradient} = \frac{0.48 - 0.1}{2.5 - 0.5} = \frac{0.38}{2}$$

gradient = 0.19 $s^2\ m^{-1}$

## EXAMINER COMMENTARY

In this script the triangle used for the gradient is shown on the graph – this is the ideal situation. The hypotenuse of this triangle is greater than half the drawn line and so can score both marks. The answer is within range.

2 marks awarded.

## QUESTION

## 01

**01.2** Calculate $g$ using your answer to question **01.1**.

**[2 marks]**

$g$ = ______________________ $m\,s^{-2}$

**01.3** Estimate, using **Figure 1**, the uncertainty in your value for $g$.

**[3 marks]**

uncertainty in $g$ = ± ______________________ $m\,s^{-2}$

## MARK SCHEME

| Question | Marking guidance | Mark | Comments |
|---|---|---|---|
| 01.2 | $g = \frac{2}{\text{gradient}}$ ✓<br><br>Answer in range 10.0 to 10.8 ✓ | 2 | Ecf from 01.1<br><br>Max 1 dp |
| 01.3 | Draws another line that has max possible or min possible gradient and finds a new value for $g$ ✓<br><br>Draws 2 lines: max gradient and min gradient ✓<br><br>Uncertainty is half of the range of values of $g$ given by their 2 extreme gradients expect to see approx $\pm 1.6$<br><br>**or** uncertainty is the difference between their new $g$ and their value for 01.2 ✓ | 3 | Condone max or min gradient through the origin<br><br>Not through the origin for this mark |

## STUDENT A

**0 1 . 2** Calculate $g$ using your answer to question **01.1**.

**[2 marks]**

$s = ut + \frac{1}{2}at^2$

$s = \frac{1}{2}at^2$

$at^2 = 2s$

$t^2 = \frac{2}{a}s$

gradient $= \frac{2}{a}$

$0.19 = \frac{2}{a}$ $\therefore a = \frac{2}{0.19}$

$= 10.43$

$g =$ 10.4 $\text{m s}^{-2}$

**0 1 . 3** Estimate, using **Figure 1**, the uncertainty in your value for $g$.

**[3 marks]**

(0,0) (2.7, 0.55)

$\frac{0.55}{2.7} = 0.2037$

$\frac{0.2037 - 0.19167}{0.19167} \times 100$

$= 6.117\%$

$\frac{6.12}{100} \times 10.43$

$= 0.638$

uncertainty in $g = \pm$ 0.64 $\text{m s}^{-2}$

### EXAMINER COMMENTARY

In Question 1.2 the student states that $a = \frac{g}{2}$ and thus gains the first mark even though this is not in the exact form given in the mark scheme. The answer is in the middle of the required range and scores the second mark.

Question 1.3 (refer to the graph for student A in 1.1) shows only one line drawn, in this case for the maximum gradient. However, even had two lines been shown, the second marking point would not have been given as the maximum is forced through the origin. One further mark is given because the student quotes the uncertainty that arises from the value and does not divide by 2 (which would have been appropriate had maximum and minimum lines been shown).

4 marks awarded.

## QUESTION

## 02

**0 2 . 1** An experiment was performed to measure the resistivity of a sample of the alloy nichrome. A student used a metre ruler to measure the length $L$ of a wire made from nichrome. Her value for $L$ was $521 \pm 2$ mm.

Calculate the percentage uncertainty in the measurement of $L$.

**[1 mark]**

percentage uncertainty in $L$ = ± ____________________

**0 2 . 2** The student then measured the diameter $d$ of the wire using a micrometer. Her readings are recorded in **Table 1**.

**Table 1**

| $d$ / mm | 0.19 | 0.21 | 0.20 | 0.19 | 0.20 |
|---|---|---|---|---|---|

The student took five measurements at different points along the wire.

Explain why.

**[1 mark]**

____________________

____________________

____________________

**0 2 . 3** Calculate the mean value of $d$ and the absolute uncertainty in the measurement of $d$.

**[2 marks]**

mean value = ____________________ mm

absolute uncertainty = ± ____________________ mm

**0 2 . 4** Calculate the cross-sectional area $A$ of the wire and its percentage uncertainty.

**[3 marks]**

$A$ = ____________ $m^2$

percentage uncertainty in $A$ = ± ____________

**0 2 . 5** The student used a resistance meter to determine the resistance of the wire and found it to be 18.8 Ω with an uncertainty of 1.5%

Calculate the resistivity of nichrome and the absolute uncertainty in your value of resistivity.

**[3 marks]**

resistivity of nichrome = ____________ Ω m

absolute uncertainty in resistivity = ± ____________ Ω m

0 2 . 6 A second student does a similar experiment with a nichrome wire of the same length but with twice the diameter.

Explain how this affects the uncertainty in the value of the resistivity of nichrome.

Assume the absolute uncertainty in the diameter and the absolute uncertainty in the resistance do not change.

**[3 marks]**

## MARK SCHEME

| Question | Marking guidance | Mark | Comments |
|---|---|---|---|
| 02.1 | 0.4 ✓ | 1 | Accept 0.38 |
| 02.2 | Reduce the effect of random errors **or** identify anomalous results to reject these **or** confirm the uniformity of the wire ✓ | 1 | Not just to ensure accuracy or to get a mean |
| 02.3 | 0.20 cao ✓<br><br>(±) 0.01 ✓ | 2 | |
| 02.4 | $A = 3.1 \times 10^{-8}$ ✓ ecf from 02.3<br><br>% uncertainty in $d$ is 5% **or** doubles candidate's % uncertainty in $d$ to find % uncertainty in $A$ ✓<br><br>10% cao ✓ | 3 | 2 or 3 sf only |
| 02.5 | $1.1 \times 10^{-6}$ ✓<br><br>adds the percentage uncertainty in L, A and R ✓ ecf<br><br>uncertainty in $\rho = 0.1 \times 10^{-6}$ **to** $0.15 \times 10^{-6}$ **ecf** ✓ | 3 | 1 or 2 sf |

| | | | |
|---|---|---|---|
| 02.6 | (If the wire were to be twice as thick then)<br>The percentage uncertainty in area would reduce **or** the percentage uncertainty in resistance would increase ✓<br><br>correct numerical comment about the change in percentage uncertainty eg: percentage uncertainty in area becomes ¼ of previous value **or** the percentage uncertainty in R would increase by a factor of 4 ✓<br><br>Correct comment about the combined effect of the changes in uncertainties eg this would have a smaller effect on uncertainty in ρ since (%) uncertainty in R < (%) uncertainty in A ✓ | 3 | Can get this mark for calculating a new uncertainty (look for 8.9%) |

## STUDENT A

**0 2 . 2** The student then measured the diameter $d$ of the wire using a micrometer. Her readings are recorded in **Table 1**.

**Table 1**

| $d$ / mm | 0.19 | 0.21 | 0.20 | 0.19 | 0.20 |
|---|---|---|---|---|---|

The student took five measurements at different points along the wire.

Explain why.

**[1 mark]**

This is to make the mecsurement more accurate by finding the mean of these values. The ~~mean~~ diameter may be different at different points on the wire.

**0 2 . 3** Calculate the mean value of $d$ and the absolute uncertainty in the measurement of $d$.

**[2 marks]**

mean = $\frac{0.19+0.21+0.20+0.19+0.20}{5}$

= 0.198

= 0.20

uncertainty = $\frac{0.21-0.19}{2}$ = 0.01

mean value = 0.20 mm

absolute uncertainty = ± 0.01 mm

**0 2 . 4** Calculate the cross-sectional area $A$ of the wire and its percentage uncertainty.

**[3 marks]**

$A = \frac{\pi d^2}{4}$

~~$A = \frac{\pi \times (0.2)^2}{4} = 0.0314$~~

$A = \frac{\pi \times (0.2 \times 10^{-3})^2}{4} = 3.14 \times 10^{-8}$

~~uncertainty = $\frac{(0.01 \times 10^{-3} \times 2)}{3.14 \times 10^{-8}} \times 100$ =~~

uncertainty = $\frac{0.01}{0.2} \times 100 \times 2$

= 10%

$A$ = $3.14 \times 10^{-8}$ m²

percentage uncertainty in $A$ = ± 10%

**0 2 . 5** The student used a resistance meter to determine the resistance of the wire and found it to be 18.8 Ω with an uncertainty of 1.5%

Calculate the resistivity of nichrome and the absolute uncertainty in your value of resistivity.

**[3 marks]**

$\rho = \frac{RA}{L}$ $\rho = \frac{18.8 \times 3.14 \times 10^{-8}}{52 \times 10^{-3}}$

$= 1.13 \times 10^{-6}$

uncertainty = 1.5% + 10% + 0.384%

percentage = 11.8%

Absolute = $\frac{11.8}{100} \times 1.13 \times 10^{-6}$

$= 1.34 \times 10^{-7}$

resistivity of nichrome = $1.13 \times 10^{-6}$ Ω m

absolute uncertainty in resistivity = ± $1.34 \times 10^{-7}$ Ω m

**0 2 . 6** A second student does a similar experiment with a nichrome wire of the same length but with twice the diameter.

Explain how this affects the uncertainty in the value of the resistivity of nichrome.

Assume the absolute uncertainty in the diameter and the absolute uncertainty in the resistance do not change.

**[3 marks]**

The uncertainty in the value of resistivity will be less than in the original experiment. When twice the diameter is used, the absolute uncertainty remains the same, but the percentage uncertainty is halved. This means that overall percentage uncertainty will be less than in the first experiment, and the new value for resistivity will be more accurate.

$\rho = \frac{RA}{L}$

**EXAMINER COMMENTARY**

Question 2.1. is not included.

The student answering Question 2.2 makes a common error in focusing (in the first sentence) on the information already provided in the question. There are three possible answers here: variation in wire uniformity (as here), the reduction of the impact of random errors, and the identification of anomalous results. No credit is given.

The evaluations in 2.3 are entirely correct. The abbreviation "cao" in the mark scheme indicates that only a correct answer is accepted irrespective of any possible errors carried forward. 2 marks are awarded.

Question 2.4 involves the use of earlier derived data to evaluate the cross-sectional area of the wire together with its percentage uncertainty. Note also that students should take particular care with significant figures in questions in this section of PH03. The expectation of examiners is that answers will show the same care for significant figures that students would show with data that they have collected in the laboratory. Thus only 2 or 3 sf were acceptable. Student A gains full credit here.

In Question 2.5 the appropriate level for the significance is 1 or 2 figures – and this is what must be provided. Student A has given the uncertainty of the resistivity to 3 sf and this is too great a precision even though the answer is in range. 2 marks are awarded.

Question 2.6 demanded a clear understanding of the impact of change on the uncertainty of the resistivity. The student fails to give this (first marking point) and there is no correct numerical comment about the changes (second point). Finally, the combined effect is not considered. No credit is gained.

7 marks awarded.

## STUDENT B

**0 2 . 2** The student then measured the diameter $d$ of the wire using a micrometer. Her readings are recorded in **Table 1**.

**Table 1**

| $d$ / mm | 0.19 | 0.21 | 0.20 | 0.19 | 0.20 |
|---|---|---|---|---|---|

The student took five measurements at different points along the wire.

Explain why.

**[1 mark]**

To get an accurate results as much as can.
To minimise error, the student took five measurements.

**0 2 . 3** Calculate the mean value of $d$ and the absolute uncertainty in the measurement of $d$.

**[2 marks]**

Mean value of $d = \frac{0.19 + 0.21 + 0.20 + 0.19 + 0.20}{5}$

$= 0.198$

$\frac{0.21 - 0.19}{2}$

mean value = 0.198 mm

absolute uncertainty = ± 0.01 mm

**0 2 . 4** Calculate the cross-sectional area $A$ of the wire and its percentage uncertainty.

**[3 marks]**

% Uncertainty = $\frac{\text{Uncertainty}}{\text{measured value}} \times 100 = \frac{0.01}{0.198} \times 100$

$= 5.05\ \%$

$A = \frac{\pi d^2}{4} = \frac{\pi \times 0.198^2}{4} = 0.0308$

$A$ = 0.0308 m²

percentage uncertainty in $A$ = ± 5.05%

**0 2 . 5** The student used a resistance meter to determine the resistance of the wire and found it to be 18.8 Ω with an uncertainty of 1.5%

Calculate the resistivity of nichrome and the absolute uncertainty in your value of resistivity.

**[3 marks]**

$R = \frac{\rho L}{A} \Rightarrow \rho = \frac{RA}{L} = \frac{18.8 \times 0.0308}{0.521}$

$= 1.11$

Absolute uncertainty = $1.11 \pm 0.015$

resistivity of nichrome = 1.11 Ω m

absolute uncertainty in resistivity = ± 1.1 ± 0.015 Ω m

**0 2 . 6** A second student does a similar experiment with a nichrome wire of the same length but with twice the diameter.

Explain how this affects the uncertainty in the value of the resistivity of nichrome.

Assume the absolute uncertainty in the diameter and the absolute uncertainty in the resistance do not change.

**[3 marks]**

When the diameter of the wire becomes double, the resistance of the wire becomes half. When resistance decrease, the resistivity will also decrease and so the uncertainty in the value of the resistivity of nichrome will decrease.

## EXAMINER COMMENTARY

In Question 2.2 the comment is too weak for credit. Students need to give definite explanations rather than vague generalities about improving accuracy.

In Question 2.3 the mean is quoted to too many significant figures which means that the full marks cannot be awarded. The number of figures should never exceed that quoted for the data without legitimate comment. The absolute uncertainty is correct.

The examiner exercises some judgement in awarding 2 out of the 3 marks in Question 2.4. The evaluation has been carried through using data in millimetres but the answer line has a printed $m^2$ unit; Student B has failed to spot this. Normally this would mean that the response cannot gain the mark as the student has not deleted the printed symbol to replace it with the correct one. Instead the only mark not awarded is for the percentage uncertainty, which is incorrect.

The response to Question 2.5 scores 1 of the 3 marks. The resistivity value is a factor of $10^6$ too large because the power of ten mistake in 2.4 has not been corrected. This is not an error carried forward as the student should have realised that the unit used in 2.4 was wrong. The calculation of absolute uncertainty is incorrect.

In Question 2.6 the chain of argument does not include numerical estimates of the uncertainty and the comments with respect to it are too vague. No credit for this approach.

4 marks awarded in total.

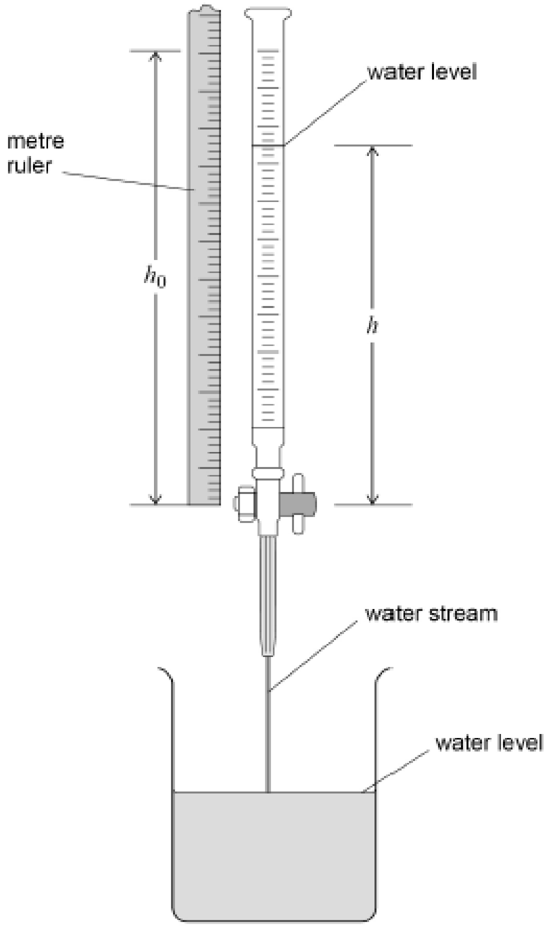
 

## QUESTION

**0 3** A burette is used to measure the volume of liquids.
A student investigated how the height $h$ of water flowing out of a burette varied with time $t$.

**Figure 2** shows the apparatus the student used.

**Figure 2**



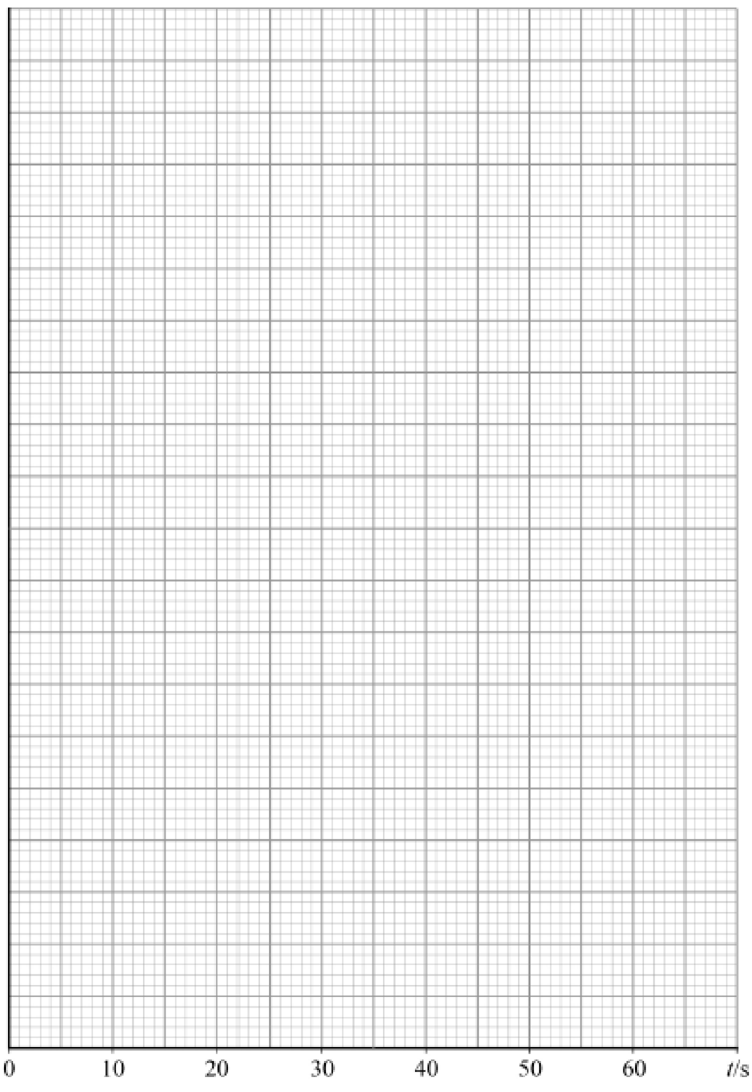
0 3 . 2 Plot on **Figure 3** a graph of $\ln(h/\mathrm{mm})$ against $t$/s.

**[4 marks]**

0 3 . 3 Determine the gradient of your line.

**[2 marks]**

gradient = ______________________

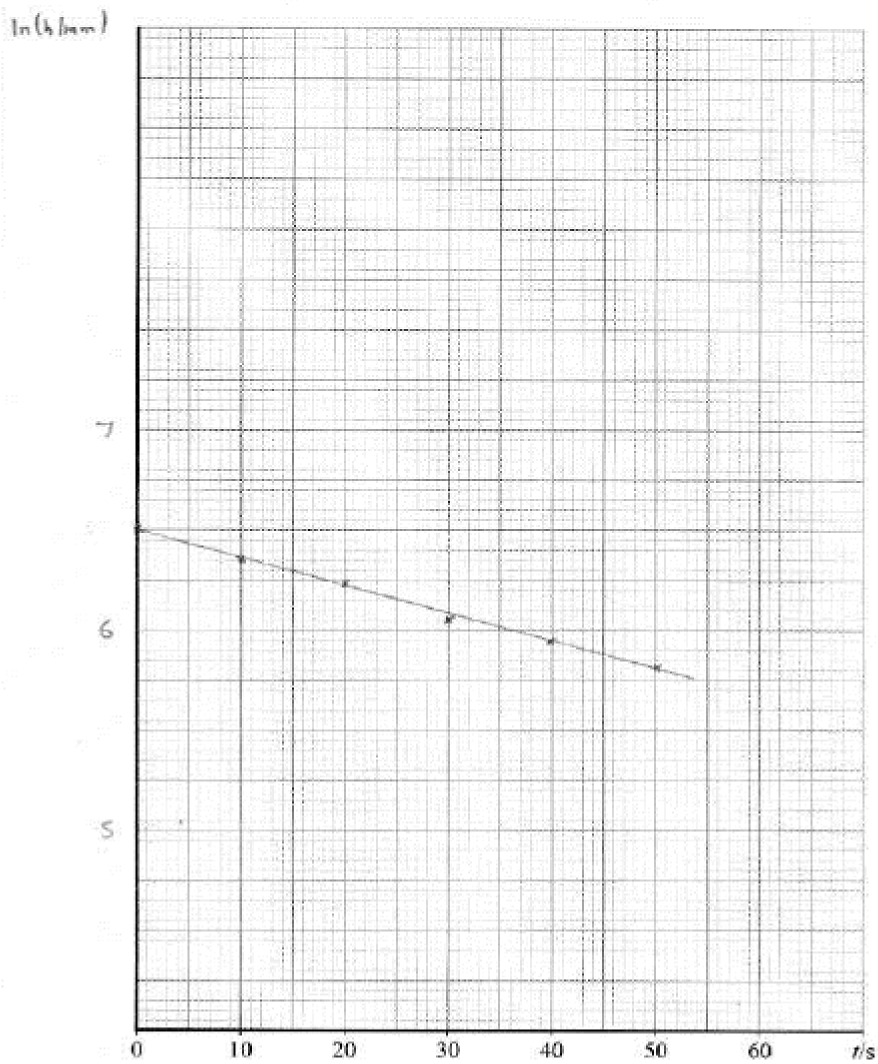


## MARK SCHEME

| Question | Marking guidance | Mark | Comments |
|---|---|---|---|
| 03.2 | Sensible scale (with appropriate label/unit) marked on the y-axis ✓<br>five points accurately plotted ✓<br>Six points accurately plotted ✓<br>Well drawn straight line of best fit ✓ | 4 | The line of best fit should follow the trend of the points with an even scatter of points on either side of the line.<br>Must have acceptable scales to get the plotting marks<br>Can get the final mark even with a poor scale |
| 03.3 | Gradient value quoted with a minus sign ✓<br>Value in the range 0.0136 to 0.0140 (with or without minus sign) ✓ | 2 | 2 or 3 sf only<br>Ignore any unit given |

## STUDENT A




**0 3 . 3** Determine the gradient of your line.

**[2 marks]**

$$\frac{6.5 - 5.82}{50}$$

gradient = 0.614

## EXAMINER COMMENTARY

The marking in Question 3.2 illustrates the need for students to be practised in the construction of accurate and well-presented graphs. There are several faults in the graph work that have led to the award of only 1 mark:

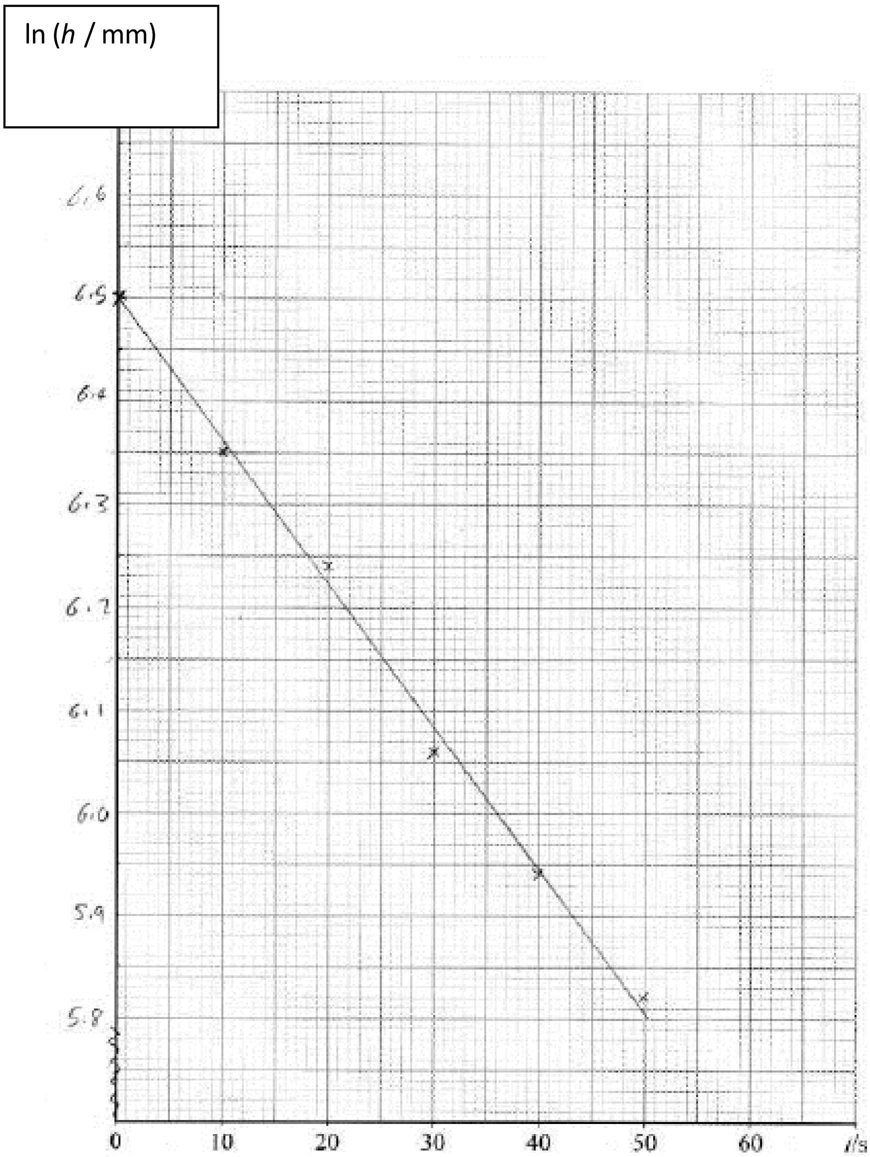
- The *y*-scale is poor and far too compressed. The range of the graph should extend over at least half the grid in both axis directions.
- This unacceptable scale means that the plotting marks cannot be awarded.
- The line is just about acceptable as one point is relatively far from the line compared to all others. There should be an attempt to balance points on each side.

Although there is a gradient calculation in Question 3.3, it is negligent in a number of ways:

- The student has used data points from the table rather than points lying on the line. Close examination of the graph will show that the line and the data points are not quite coincident.
- The sign of the gradient (negative) has been omitted in the solution.

2 marks awarded in total.

**STUDENT B**




0 3 . 3 Determine the gradient of your line.

**[2 marks]**

$\frac{6.5 - 5.82}{0 - 50} = \frac{0.68}{-50} = -0.014$

gradient = −0.014

## EXAMINER COMMENTARY

Student B has produced a well-crafted graph that extends well over half the grid and that has a line drawn with due regard to giving equal weight to each point. The lines are thin and the plotting is accurate (to within half a square of the correct point). This question gains all 4 marks.

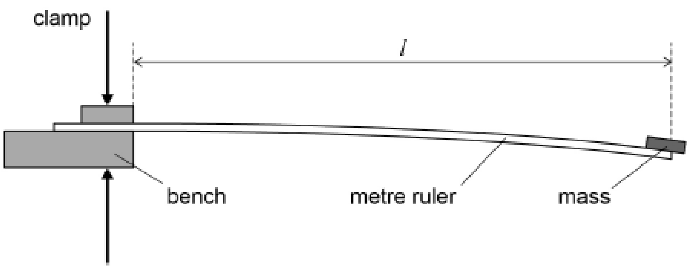
In Question 3.3 the answer is marred by the use of data points for the gradient calculation rather than points on the line (as with Student A). This is an error that students should avoid, tempting as it is. Only 1 mark is awarded here.

5 marks awarded.

## QUESTION

**0 4** A metre ruler with a mass attached to the free end is clamped to the edge of a bench as shown in **Figure 4**. The ruler oscillates when the mass is displaced vertically through a small distance and released.

**Figure 4**




Theory predicts that the period of oscillation $T$ of the system varies with length $l$ according to the equation

$$T^2 = kl^3$$

where $k$ is a constant.

Describe the procedure you would use to verify the equation. You may suggest the use of the apparatus in **Figure 4** together with other standard laboratory equipment.

Your answer should include details of:

- the measurements to be made
- the measuring instruments that you would use
- how you would make the measurements accurately
- how you would analyse and interpret the results.

**[5 marks]**

## MARK SCHEME

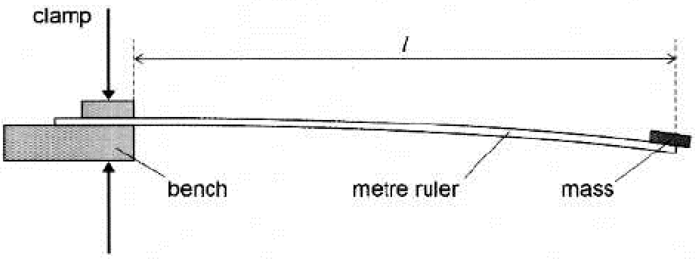
| Question | Marking guidance | Mark | Comments |
|---|---|---|---|
| 04 | • Take measurements of $T$ for six (or more) different values of $l$ ✓<br>• Use the metre ruler to measure $l$ ✓<br>• Time ten (or more) oscillations and repeat and average this measurement ✓<br>• Calculate the mean value of $T$ ✓<br>• Plot a graph of $T^2$ against $l^3$ ✓<br><br>The formula would be verified if<br>• The best-fit line is straight through the origin ✓ | 5 | Award any four of the first four marking points plus last marking point |

## STUDENT A

**0 4** A metre ruler with a mass attached to the free end is clamped to the edge of a bench as shown in **Figure 4**. The ruler oscillates when the mass is displaced vertically through a small distance and released.

**Figure 4**




Theory predicts that the period of oscillation $T$ of the system varies with length $l$ according to the equation

$$T^2 = kl^3$$

where $k$ is a constant.

Describe the procedure you would use to verify the equation. You may suggest the use of the apparatus in **Figure 4** together with other standard laboratory equipment.

Your answer should include details of:

- the measurements to be made
- the measuring instruments that you would use
- how you would make the measurements accurately
- how you would analyse and interpret the results.

**[5 marks]**

You would start the experiment by making L 0.90m. You would need to place a fiducial marker horizontally on a clamp stand. Adjust the height, so as to make it the same height as the end of the ruler (rest position). You should displace the ruler by a ~~[struck out]~~ known constant vertical displacement each time. Using a stopwatch, time how long it takes for 15 oscillations to occur. Repeat the experiment at least 3 times, keeping L the same each time. Find the average time of the 15 oscillations and divide this by 15 to get time for one oscillation. Then square this time, in order to get $T^2$. For each length, you need to record what $L^3$ would be. On a table, write down the value of $T^2$ for each value of $L^3$. Do this experiment again and again, shortening length by 0.05m each time until the final length is 0.50m. Record results in the table. Finally, plot $T^2/s^2$ on the y axis against $L^3/m^3$ on the x-axis. The gradient should be a constant value (k) if the equation is correct. A straight line through the origin should be seen.

## EXAMINER COMMENTARY

The mark scheme is clear about the points needed for the answer. These can generally be condensed to:

- What is measured?
- How is it measured?
- What precautions are taken to improve the measurements or to check validity?
- How the data are analysed including both the algorithm and the graphing if needed?
- What the graph is expected to show or how it would be used to derive further data?

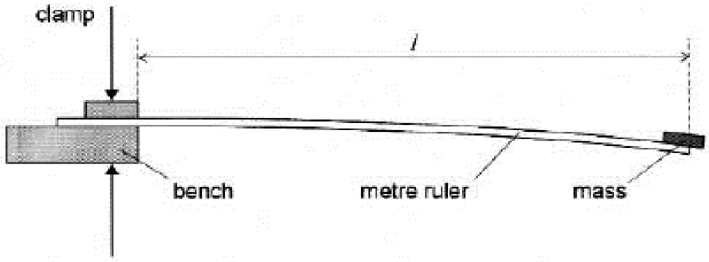
Student A gains a maximum score for a largely careful and sustained piece of writing.

5 marks awarded.

## STUDENT B

**0 4** A metre ruler with a mass attached to the free end is clamped to the edge of a bench as shown in **Figure 4**. The ruler oscillates when the mass is displaced vertically through a small distance and released.

**Figure 4**




Theory predicts that the period of oscillation $T$ of the system varies with length $l$ according to the equation

$$T^2 = kl^3$$

where $k$ is a constant.

Describe the procedure you would use to verify the equation. You may suggest the use of the apparatus in **Figure 4** together with other standard laboratory equipment.

Your answer should include details of:

- the measurements to be made
- the measuring instruments that you would use
- how you would make the measurements accurately
- how you would analyse and interpret the results.

**[5 marks]**

The meter ruler would be used to calculate the distance ~~from~~ of the mass from the clamp.
A stop watch should be used to calculate the time take for a certain number of oscillations (e.g 10 oscillations)
Once the mass is release the timer begins and stopped once 10 oscill ations are completed and this time is recorded

at that particular height.
Record at different heights to get a range of data.
Repeat procedure at least 3 times for each height and calculate mean to reduce uncertainity and get more accurate readings.

**EXAMINER COMMENTARY**

Although there are 6 points available on the mark scheme for a maximum of 5 marks, Student B scores only 2 of them. There is the use of a metre ruler for the measurement and the idea that the timing period should be for a reasonably large number of oscillations. Questions often, as here, contain a set of bullet points to prompt students for the discussion points that the answer should contain. Students would do well to:

- Read the bullet points carefully and anticipate what is required
- Draft rough notes, or plan mentally, before beginning the answer.

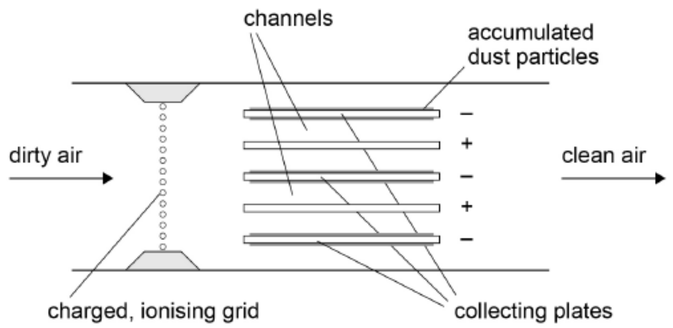
This question has 5 marks and therefore roughly 8 minutes for its completion. Many students spend far less time on the answer than it merits.

2 marks awarded.

## QUESTION

**0 5** **Figure 5** shows an electrostatic precipitator that is designed to remove small dust particles from the dirty air in a factory.
The dirty air passes through a charged, ionising grid where the dust particles acquire a charge.
The dust particles, which are electrical conductors, are attracted to collecting plates, removing them from the air. The clean air passes back to the factory. The electrostatic precipitator is cleaned regularly to remove the dust particles that have accumulated on the collecting plates. The dust particles move horizontally as they enter a channel between the plates.

**Figure 5**

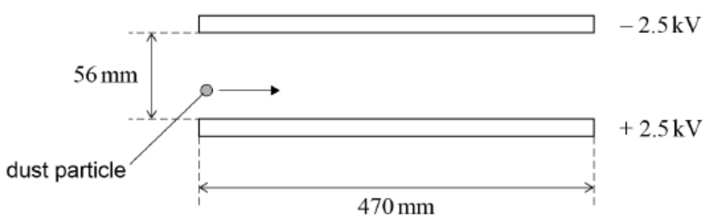



**0 5 . 1** Explain how the dust particles gain a positive charge as they pass through the charged, ionising grid.

**[1 mark]**

**0 5 . 2** **Figure 6** shows one of the channels between a pair of adjacent clean plates.
A dust particle of mass $5.6 \times 10^{-15}$ kg enters the region between the collecting plates travelling horizontally with an initial velocity of $10 \text{ m s}^{-1}$. The particle carries a charge of $2.4 \times 10^{-18}$ C.

**Figure 6**




Show that the electrostatic force acting on the particle is approximately $2 \times 10^{-13}$ N.

**[2 marks]**

**0 5 . 3** Some particles pass through the channel without hitting a collecting plate.

Show that these particles spend approximately 0.05 s between the plates.

**[1 mark]**

**0 5 . 4** Deduce whether all $5.6 \times 10^{-15}$ kg particles with a charge of $2.4 \times 10^{-18}$ C and an initial velocity of $10 \text{ m s}^{-1}$ are likely to reach a negatively charged plate as they pass through a channel.

Assume that the particles are unaffected by gravity and that such dust particles have not yet accumulated on the collecting plates. All adjacent plates have the same potential difference between them.

**[4 marks]**

Are all such dust particles likely to reach a collecting plate? ____________________

**0 5 . 5** The particles gradually accumulate on the collecting plates as shown in **Figure 5**. This causes the channel to become narrower by up to 5 mm before the precipitator is cleaned.

Discuss whether the narrowing of the channels will make the precipitator more or less effective at removing dust particles.

**[3 marks]**

## MARK SCHEME

| Question | Marking guidance | Mark | Comments |
|---|---|---|---|
| 05.1 | The dust particle loses electron(s) leaving them with surplus positive charge wtte ✓ | 1 | |
| 05.2 | Use of $E = \frac{V}{d}$ ✓ **or** use of $F = Eq$ ✓<br>Both seen and leading to $2.14 \times 10^{-13}$ (N) ✓ | 2 | To at least 2 sf |
| 05.3 | $s = vt$ in some form as a symbol equation leading to 0.047 (s) ✓ | 1 | |
| 05.4 | Use of $a = \frac{F}{m}$ ✓<br>Use of $s = \frac{1}{2}gt^2$ ✓<br>Leading to 48 mm ✓<br>Conclusion that particles (between 48 mm and 56 mm from the negative plate) will fail to reach the plate wtte ✓ | 4 | 39 mm, 42 mm, 45 mm or 48 mm according to which data is used from 05.2 and 05.3. |
| 05.5 | Any plausible conclusion with reasoning eg<br>Gap narrower so field strength or force greater so more particles reach the plate ✓<br>**or** gap narrower so air flow obstructed so more time in which to reach the plate ✓<br>**or** gap narrower so less vertical distance to travel so more particles reach the plate ✓<br>Charged particles will be pushed closer together and be affected by stronger electrostatic forces ✓<br>ANY 3 | 3 | |

## STUDENT A

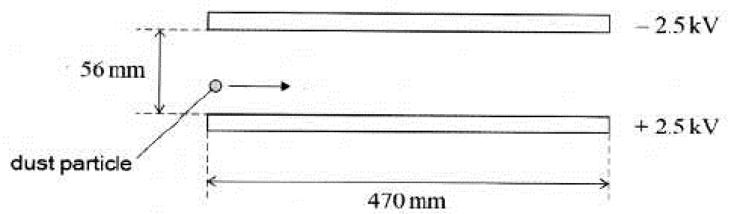
**0 5 . 1** Explain how the dust particles gain a positive charge as they pass through the charged, ionising grid.

**[1 mark]**

They are bombarded with high energy electrons. This knocks off electrons from the particles, giving them a positive charge.

**0 5 . 2** **Figure 6** shows one of the channels between a pair of adjacent clean plates. A dust particle of mass $5.6 \times 10^{-15}$ kg enters the region between the collecting plates travelling horizontally with an initial velocity of $10\ \text{m s}^{-1}$. The particle carries a charge of $2.4 \times 10^{-18}$ C.

**Figure 6**




Show that the electrostatic force acting on the particle is approximately $2 \times 10^{-13}$ N.

**[2 marks]**

$F = \frac{QV}{d} = \frac{2.4 \times 10^{-18}\,\text{C} \times 5000\,\text{V}}{56 \times 10^{-3}\,\text{m}}$

$= 2.14 \times 10^{-13}\,\text{N}$

$\therefore \simeq 2 \times 10^{-13}\,\text{N}$

**0 5 . 3** Some particles pass through the channel without hitting a collecting plate.

Show that these particles spend approximately 0.05 s between the plates.

**[1 mark]**

$s = vt$

$t = \frac{s}{v} = \frac{470 \times 10^{-3}}{10}$

$= 0.0475$

$\therefore \simeq 0.05\,\text{s}$

**0 5 . 4** Deduce whether all $5.6 \times 10^{-15}$ kg particles with a charge of $2.4 \times 10^{-18}$ C and an initial velocity of $10 \text{ m s}^{-1}$ are likely to reach a negatively charged plate as they pass through a channel.

Assume that the particles are unaffected by gravity and that such dust particles have not yet accumulated on the collecting plates. All adjacent plates have the same potential difference between them.

**[4 marks]**

$s = \frac{1}{2}at^2$

$F = (2.14 \times 10^{-13})$ $a = \frac{F}{m}$

$= \frac{2.14 \times 10^{-13}}{5.6 \times 10^{-15}} = 38.2 \text{ms}^{-2}$

$s = \frac{1}{2} \times 38.2 \times (0.047)^2$
$= 0.0422 \text{m}$
$= 42.2 \text{mm}$

$42.2 < 56$
$\therefore$ Not all likely

Are all such dust particles likely to reach a collecting plate? No

**0 5 . 5** The particles gradually accumulate on the collecting plates as shown in **Figure 5**. This causes the channel to become narrower by up to 5 mm before the precipitator is cleaned.

Discuss whether the narrowing of the channels will make the precipitator more or less effective at removing dust particles.

**[3 marks]**

It makes it ~~more~~ less effective. Even though distance between plates decreases, the electric field strength felt by dust particles also decreases when dust accumulates on the negative plate. The force experienced by the passing dust particles is less and it's upwards acceleration and displacement is now less than before

**EXAMINER COMMENTARY**

Question 5.1 contains a misunderstanding in that the student thinks that the electric field produces a high-energy electron beam. Although there is a suggestion that the effects of ionisation are understood, the false reason for this ionisation denies any credit.

Question 5.2 receives full credit with a clear equation together with a correct substitution and an explanation of how the final answer relates to the value in the question.

Similarly, 5.3 shows the correct use of the definition of speed and a rounding process to arrive at the 'show that' value.

Question 5.4 is one of the multi-stage questions that trip up many students in modules PH03, 04 and 05. Not so here as the steps can be clearly seen and a numerical answer is provided for each stage. Again, full credit is awarded.

The final part needs clear thought and deduction by the student. A narrower channel increases the field strength, restricts the air flow, and reduces the distance to be moved vertically. All of these act to increase the number of particles adhering to the plates. In this answer the student (perhaps unwisely) reaches a conclusion first and then describes the physics in these terms. It may be better to think the problem through as thoroughly as possible before writing and then describe the effects making an overall conclusion at the end.

7 marks awarded.

## STUDENT B

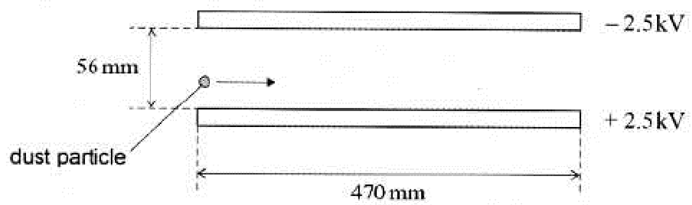
**0 5 . 1** Explain how the dust particles gain a positive charge as they pass through the charged, ionising grid.

**[1 mark]**

they lose electrons which leaves a positive charge

**0 5 . 2** **Figure 6** shows one of the channels between a pair of adjacent clean plates. A dust particle of mass $5.6 \times 10^{-15}$ kg enters the region between the collecting plates travelling horizontally with an initial velocity of $10\ \mathrm{m\,s^{-1}}$. The particle carries a charge of $2.4 \times 10^{-18}$ C.

**Figure 6**




Show that the electrostatic force acting on the particle is approximately $2 \times 10^{-13}$ N.

**[2 marks]**

$$\frac{2.4 \times 10^{-18} \times 5000}{[illegible]\ 0.056} = 2.14 \times 10^{-13} \sim 2 \times 10^{-13}$$

**0 5 . 3** Some particles pass through the channel without hitting a collecting plate.

Show that these particles spend approximately 0.05 s between the plates.

**[1 mark]**

$W = F \times d$

$mgh = F \times V \times t$

$t = \frac{mgh}{FV}$

Question 5 continues on the next page

$$t = \frac{5.6 \times 10^{-15} \times 9.81 \times 0.47}{2 \times 10^{-13} \times 10} = 0.05\ \mathrm{s}$$

**0 5 . 4** Deduce whether all $5.6 \times 10^{-15}$ kg particles with a charge of $2.4 \times 10^{-18}$ C and an initial velocity of $10 \text{ m s}^{-1}$ are likely to reach a negatively charged plate as they pass through a channel.

Assume that the particles are unaffected by gravity and that such dust particles have not yet accumulated on the collecting plates. All adjacent plates have the same potential difference between them.

**[4 marks]**

Because particle is moving in uniform electric field, particle will not loose its energy as gravity not effected on particle. The force on the particle is the same at all points between the plates.

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

Are all such dust particles likely to reach a collecting plate? Yes

**0 5 . 5** The particles gradually accumulate on the collecting plates as shown in **Figure 5**. This causes the channel to become narrower by up to 5 mm before the precipitator is cleaned.

Discuss whether the narrowing of the channels will make the precipitator more or less effective at removing dust particles.

**[3 marks]**

It will take the precipitator less effective as more particles deposit on plate so less amount of air will pass through the plate as the gap between the plates becomes narrower

## EXAMINER COMMENTARY

Although not well expressed with an unclear mechanism, this answer to Question 5.1 satisfies the mark scheme and the 1 available mark is awarded.

Question 5.2 shows a negligent response. Only 1 mark is awarded. The command term is 'show that…' and this instruction means just that. Here there is no equation quoted so that the examiner is completely in the dark about the method in use. The one-line answer ends with the correct value, a squiggle and the value in the question. This is not adequate; students should be encouraged to write a link between their value and the question value and to express their answer (as here) to more significant figures than in the question.

The physics underlying the method in Question 5.3 is spurious – a kinematic equation of motion is required in the solution. The answer to the substituted equation is 0.0129 and the dimensions are not time.

A calculation followed by a conclusion is required in Question 5.4; this is the usual meaning of the command term 'deduce'. The presence of numerical data in the question also implies the need for a calculation. In the event the conclusion is incorrect following from a false argument. No credit was given.

The answer to Question 5.5 does not address any of the three points available in the mark scheme and leads to an incorrect conclusion. No credit is given.

2 marks awarded.

## QUESTION

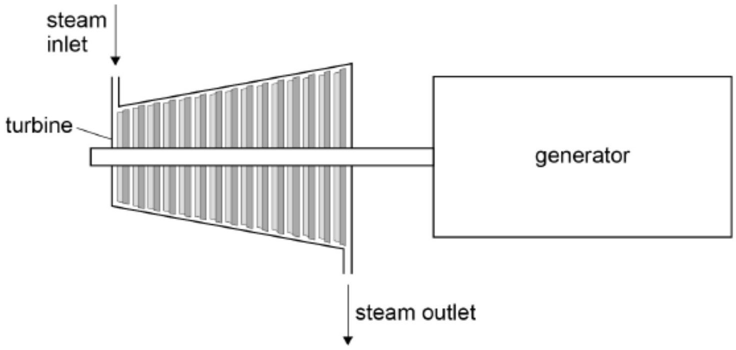
## 06

**0 6** **Figure 7** shows a steam turbine being used to drive a generator. Steam at high temperature and pressure enters the turbine causing fan blades to rotate. The steam expands and cools in the turbine so that 90% of it condenses. The remaining steam is at a lower temperature and pressure.

The data for the turbine and generator are:

| | | |
|---|---|---|
| steam inlet temperature | = | 500 °C |
| steam inlet pressure | = | 100 MPa |
| rate of supply of steam | = | 16 kg $s^{-1}$ |
| output power of the turbine | = | 16 MW |
| frequency of rotation of generator | = | 3000 revolutions per minute |

**Figure 7**




**0 6 . 5** Calculate the torque exerted by the turbine on the generator.

**[3 marks]**

torque = ______________________ N m

**0 6 . 6** The input power to the generator is 16 MW and the generator is 90% efficient.
The generator has three coils, each producing an equal power output.
The rms voltage across each coil is 8500 V.

Calculate the rms current in one of the coils.

**[3 marks]**

rms current = ______________________ A

**0 6 . 7** Explain, in terms of electromagnetic induction, why a torque is required to turn the generator at a constant angular velocity.

**[4 marks]**

## MARK SCHEME

| Question | Marking guidance | Mark | Comments |
|---|---|---|---|
| 06.5 | Uses $P = T\omega$ ✓<br>Uses $\omega = 2\pi f$ ✓<br>$5.09 \times 10^4$ Nm ✓ | 3 | |
| 06.6 | 14.4 MW seen ✓<br>Uses power = V × I ✓<br>565 A ✓ | 3 | |
| 06.7 | Emf induced in coil ✓<br>Causes current in coil ✓<br>Current carrying conductor in magnetic field experiences a force ✓<br>Torque = force distance or mention of Lenz's law ✓ | 4 | |

## STUDENT A

**0 6 . 5** Calculate the torque exerted by the turbine on the generator.

**[3 marks]**

$P = T\omega$ $\omega$ : 3000 revs → 60s

$T = \frac{P}{\omega} = \frac{16 \times 10^6}{(3000 \times \frac{2\pi}{60})} = 50929$

torque = $5.1 \times 10^4$ N m

**0 6 . 6** The input power to the generator is 16 MW and the generator is 90% efficient.
The generator has three coils, each producing an equal power output.
The rms voltage across each coil is 8500 V.

Calculate the rms current in one of the coils.

**[3 marks]**

$16 \times 10^6 \times \frac{90}{100} = 14.4 \times 10^6 W$

$\frac{14.4 \times 10^{-6}}{3} = 4.8 \times 10^{-6} W$

In one s : $P = VI$

$I = \frac{P}{V} = \frac{4.8 \times 10^{-6}}{8500}$

$= 564.7$

rms current = 560 A

**0 6 . 7** Explain, in terms of electromagnetic induction, why a torque is required to turn the generator at a constant angular velocity.

**[4 marks]**

According to Lenz's law, current is induced in the opposite direction to the change that causes it. Faraday's : $\varepsilon = \frac{\Delta \Phi}{\Delta t}$. Since current is induced in the coil, a magnetic field is created which opposes the motion of the turbines, reducing it's angular velocity. Therefore in order to keep angular velocity constant, a torque must be applied.

**EXAMINER COMMENTARY**

Questions 6.5 and 6.6 merit full marks here. In both cases the equations that underpin the solution are clear and the substitutions are both correct and obvious. The answers are expressed to an appropriate number of significant figures.

Question 6.7 can command up to 4 marks; this student gains 3 of them. The omission is a common one; the student provides no mention of the induced EMF. Many students go straight to the presence of an induced current in the coil forgetting that the prime effect in any electromagnetic induction is the production of the EMF. Indeed, if the circuit is not complete there will be an induced EMF but no current.

9 marks awarded.

## STUDENT B

**0 6 . 5** Calculate the torque exerted by the turbine on the generator.

**[3 marks]**

Power = torque × frequency

Torque = $\frac{\text{power}}{\text{frequency}} = \frac{16 \times 10^6 \text{ W}}{3000} =$

torque = 5333 N m

**0 6 . 6** The input power to the generator is 16 MW and the generator is 90% efficient.
The generator has three coils, each producing an equal power output.
The rms voltage across each coil is 8500 V.

Calculate the rms current in one of the coils.

**[3 marks]**

efficiency = $\frac{\text{out power}}{\text{Input power}}$

$0.9 = \frac{\text{output power}}{16 \text{ MW}}$

power output = 0.9 × 16 MW = 14.4 MW

P = VI

$I = \frac{P}{V} = \frac{14.4 \times 10^6}{8500}$

= 1694 A

rms current = 1694 A

**0 6 . 7** Explain, in terms of electromagnetic induction, why a torque is required to turn the generator at a constant angular velocity.

**[4 marks]**

The generator has three coils rotating in a uniform magnetic field. So a torque is required to turn the generator at constant angular velocity because it moves through a magnetic field.
The current flows around the coils which rise a torque on the coil.

**EXAMINER COMMENTARY**

Question 6.5 begins with an error, the *power* = *torque* $\times \omega$ ie, the angular frequency rather than the frequency in Hz. Consequently, the student goes straight to the substitution (so two errors already) and is awarded zero marks here.

In Question 6.6 there is a correct use of efficiency and the output power is seen as 14.4 MW. The manipulation of the $P=VI$ is seen but then the student forgets that there are three coils and therefore only one-third of the current in each one. The answer is therefore three times too large and the third marking point cannot be awarded. 2 marks.

In order to gain marks in Question 6.7, a student must begin from a description of the induced EMF leading to a current that is in the direction to oppose the motion of the coil. There is no identifiable feature from this sequence in the answer of Student B and no marks are gained here. The last sentence does not merit a mark as it is not clear that this current arises from the induction effect. 0 marks.

2 marks awarded.

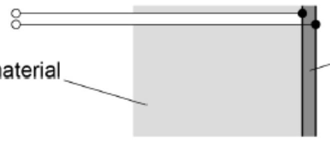
## QUESTION

## 07

**0 7** The transducer shown in **Figure 8** produces pulses of ultrasound. When an alternating current is passed through it, the piezoelectric crystal oscillates with the same frequency as the alternating current. This crystal resonates at a frequency of 2.0 MHz.

A damping material behind the crystal stops the oscillations at the end of a pulse.

**Figure 8**




**0 7 . 1** Describe what is meant by resonance.

**[2 marks]**

**0 7 . 3** State what is meant by damping.

**[1 mark]**

**0 7 . 5** The intensity of a pulse decreases as it travels through tissue.

$$I_x = I_0 e^{-\alpha x}$$

Where $I_0$ = initial intensity of pulse
$I_x$ = intensity of pulse after travelling through $x$ cm of tissue
$\alpha$ = absorption coefficient for this tissue = $1.2\ \text{cm}^{-1}$

In this case, only 34% of the pulse intensity is reflected at the tissue boundary 3.5 cm below the skin.

Determine $\frac{I_x}{I_0}$ for the ultrasound received by the transducer.

**[4 marks]**

$\frac{I_x}{I_0}$ = ____________________

**0 7 . 6** The absorption coefficient for a tissue is approximately proportional to the frequency of the ultrasound in the tissue. It is common to use ultrasound of frequency 2 MHz with adult patients but a frequency of 7 MHz with young children.

Suggest why.

**[3 marks]**

## MARK SCHEME

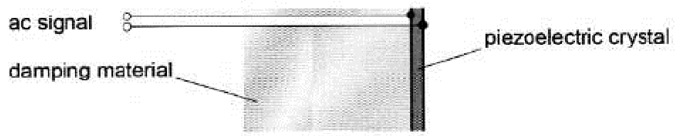
| Question | Marking guidance | Mark | Comments |
|---|---|---|---|
| 07.1 | Large amplitude oscillations …✓<br>Driving frequency matches natural frequency (of oscillating system) ✓ | 2 | |
| 07.3 | Removal of energy from an oscillating system ✓ | 1 | Allow reduction in amplitude of an oscillating system |
| 07.5 | Substitution into equation $I_x = I_0 e^{-1.2 x 7}$ ✓<br>$2.24 \times 10^{-4}$ ✓<br>Uses 66% or 34% ✓<br>$7.6 \times 10^{-5}$ ✓ | 4 | Accept $1.2 \times 3.5$ **or** $1.2 \times 0.035$ **or** $1.2 \times 0.070$ as the exponent for the 1st mark |
| 07.6 | Smaller distances involved for babies **or** larger distances for adults ✓<br>Too much attenuation at higher frequencies for large distances / adults ✓<br>Larger frequency used for babies since resolution or detail is better with high frequency ✓ | 3 | Accept adults having thicker skin, hence need to use lower frequency to limit attenuation in skin |

## STUDENT A

**0 7** The transducer shown in **Figure 8** produces pulses of ultrasound. When an alternating current is passed through it, the piezoelectric crystal oscillates with the same frequency as the alternating current. This crystal resonates at a frequency of 2.0 MHz.

A damping material behind the crystal stops the oscillations at the end of a pulse.

**Figure 8**




**0 7 . 1** Describe what is meant by resonance.

**[2 marks]**

The maximum amplitude formed during an ~~oscillation~~ oscillation. When amplitude of ~~A signal~~ ~~is in phase with~~ crystal is in phase with natural amplitude of the ac signal the amplitudes double.

**0 7 . 3** State what is meant by damping.

**[1 mark]**

Bringing oscillation to a stop or slowing it down

**0 7 . 5** The intensity of a pulse decreases as it travels through tissue.

$$I_x = I_0 e^{-\alpha x}$$

Where $I_0$ = initial intensity of pulse
$I_x$ = intensity of pulse after travelling through $x$ cm of tissue
$\alpha$ = absorption coefficient for this tissue = $1.2\ \text{cm}^{-1}$

In this case, only 34% of the pulse intensity is reflected at the tissue boundary 3.5 cm below the skin.

Determine $\frac{I_x}{I_0}$ for the ultrasound received by the transducer.

**[4 marks]**

$\frac{I_x}{I_0} = e^{-1.2 \times 0.035} = 0.958$

0.958 ✕ 100
x 34

x = 0.326

$\frac{I_x}{I_0}$ = 0.326

**0 7 . 6** The absorption coefficient for a tissue is approximately proportional to the frequency of the ultrasound in the tissue. It is common to use ultrasound of frequency 2 MHz with adult patients but a frequency of 7 MHz with young children.

Suggest why.

**[3 marks]**

2MH ~~has a very~~ is the maximum amplitude and could cause cancer in ~~childre~~ children since they have fast growing cells ~~Adults as~~ Therefore 7MHz is used as the frequency is much lower. Adults on the other hand do not have as much as cells undergoing division so chances of getting cancer in adults is less. Therefore 2MHz is used

## EXAMINER COMMENTARY

In Question 7.1, a description of resonance involves a consideration of the amplitude of the oscillation and the connection between the driven and the driving frequencies. Student A refers only to the amplitude issue. The frequency reference is incorrect and only 1 mark is awarded.

It is important in this topic to use language of an appropriate technical nature and at a correct level. Student A does not do so in Question 7.3 and writes neither about the energy changes in the system or the reduction in amplitude. 'Slowing it down' is a physics error as this has no meaning in the context of an oscillating system. No marks are awarded.

In Question 7.5, 1 mark is awarded for the first line where the student correctly substitutes into the exponential expression. The working then becomes obscure as the exponent is not evaluated correctly and the next line is implausible.

The suggestion in Question 7.6 that ultrasound causes cancer is incorrect. The answer should focus on the balance between attenuation and wavelength. Less attenuation can be tolerated in adult diagnosis. No credit is given here.

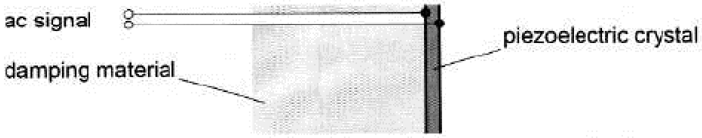
2 marks awarded.

## STUDENT B

**0 7** The transducer shown in **Figure 8** produces pulses of ultrasound. When an alternating current is passed through it, the piezoelectric crystal oscillates with the same frequency as the alternating current. This crystal resonates at a frequency of 2.0 MHz.

A damping material behind the crystal stops the oscillations at the end of a pulse.

**Figure 8**




**0 7 . 1** Describe what is meant by resonance.

**[2 marks]**

Resonance is when something ~~[illegible]~~ experiences a periodic force of the same frequency as its natural ~~frequency~~ frequency resulting in ~~super~~ ~~constructive~~ superposition of the waves leading to higher amplitude oscillations.

**0 7 . 3** State what is meant by damping.

**[1 mark]**

The reduction in the amplitude of a wave.

**0 7 . 5** The intensity of a pulse decreases as it travels through tissue.

$$I_x = I_0 e^{-\alpha x}$$

Where $I_0$ = initial intensity of pulse
$I_x$ = intensity of pulse after travelling through $x$ cm of tissue
$\alpha$ = absorption coefficient for this tissue = 1.2 $cm^{-1}$

In this case, only 34% of the pulse intensity is reflected at the tissue boundary 3.5 cm below the skin.

Determine $\frac{I_x}{I_0}$ for the ultrasound received by the transducer.

**[4 marks]**

~~[illegible]~~ $\frac{I_x}{I_0} = e^{-\alpha x}$

$e^{-1.2 \times 3.5} =$

$\frac{I_x}{I_0}$ = 0.015

**0 7 . 6** The absorption coefficient for a tissue is approximately proportional to the frequency of the ultrasound in the tissue. It is common to use ultrasound of frequency 2 MHz with adult patients but a frequency of 7 MHz with young children.

Suggest why.

**[3 marks]**

The crystal resonates at a frequency of 2MHz creating higher amplitude waves with more energy and less at 7MHz. Less is needed for kids as adults have thicker skin and greater intensity is likely to be lost from waves travelling through their skin compared to kids.

## EXAMINER COMMENTARY

The two aspects, large amplitude and matching frequency, are discussed well in the answer to Question 7.1 and gain both marks.

Although the examiners prefer the answer to Question 7.3 to be couched in terms of energy removal, reduction in amplitude is also possible as an approach. That is the case here and this response receives 1 mark.

As with student A, only the first mark is given in Question 7.5 as the substitution is correct. Students are, in general, poor at carrying through calculations involving powers of e. This is an area in which they appear to require more practice.

Question 7.6 only gains 1 of the 3 available marks. This occurs in the last two lines where the student writes that a greater amplitude may be lost in adults, although the underlying reason for this is not clear.

5 marks awarded.

## FURTHER GUIDANCE AND CONTACTS

You can contact the subject team directly at **science@oxfordaqaexams.org.uk**

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