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## A LEVEL

## Examiners' report

# PHYSICS B (ADVANCING PHYSICS)

## H557

For first teaching in 2015

## H557/01 Summer 2024 series

Version 1

ocr.org.uk/science

# Contents

# Introduction

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

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

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

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

# Paper 1 series overview

H557/01 'Fundamentals of Physics' component is worth 110 marks and assesses specification content from across all the teaching modules.

Section A consisted of thirty multiple choice questions, each worth 1 mark.

Section B included five structured short answer questions worth a total of 21 marks. Each question typically examined a single context. In addition to performing calculations, to do well in this section candidates needed to be comfortable answering questions that involved problem-solving and practical-based questions that required them to explain concepts of physics.

Section C, consisted of five questions worth 59 marks in total. These longer questions included two opportunities for extended writing (Questions 36(b) and 39 (c) (ii)) worth 6 marks each.

| Candidates who did well on this paper generally: | Candidates who did less well on this paper generally: |
|---|---|
| • attempted all the multiple choice questions in Section A<br>• performed the calculations required in Section B well<br>• were able to give explanations for effects and phenomena such as explaining why a signal could not be reconstructed accurately in Question 32 (b), and a reaction could still take place at a reasonable rate in Question 35 (b), despite the average energy of molecules being below the bond-breaking energy<br>• were able to use physics ideas to construct coherent arguments – for example in comparing the risks of harm from two different sources of radiation in Question 39 (b)<br>• applied their knowledge to experimental situations, using data and information given in graphical form, for example the experiment to determine the wavelength of sound in Question 37 and state assumptions made in their calculations<br>• used sound physics, covering fully the required strands identified in the question, in a logical structure for the extended response questions 36 (b) and 39 (c) (ii). | • omitted some of the multiple choice questions in Section A<br>• used physics terms such as p.d., e.m.f. and voltage in a vague and incorrect manner<br>• lacked precision in their arguments, for example by referring to 'increased' instead of 'double' or 'three times larger' when comparing the frequency and amplitudes of signals in Question 34 (a)<br>• gave incomplete arguments for questions that were allocated more than 1 mark – for example by only referring to the oscillations of metal or rubber not both in Question 36 (a) (iii)<br>• lacked clarity in numerical and algebraic manipulation – for example by not making their working clear in explaining the gradient in Question 37 (b) (iii)<br>• covered just one of the required strands for the extended response Questions 36 (b) and 39 (c) (ii) and lacked structure in their reasoning. |

# Section A overview

This section consisted of thirty multiple choice questions, each worth one mark.

## Question 2

**2** Which statement about ultrasound is correct?

**A** Ultrasound can be diffracted and polarised.

**B** Ultrasound can be diffracted but cannot be polarised.

**C** Ultrasound cannot be diffracted but can be polarised.

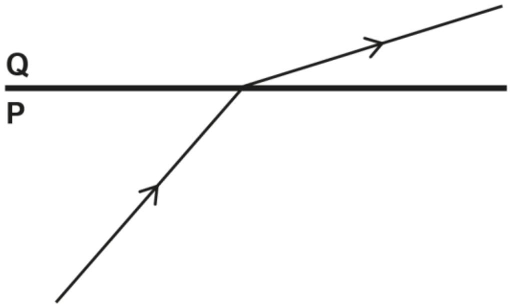
**D** Ultrasound can neither be diffracted nor polarised.

Your answer ☐ **[1]**

Candidates who recognised that ultrasound is a longitudinal wave, rather than a transverse wave, and hence cannot be polarised could quickly eliminate all answers other than the correct response, B.

## Question 5

5 The diagram shows a ray of light passing between two transparent media, **P** and **Q**.




Which row in the table describes what happens to the light as it passes from **P** to **Q**?

| | Frequency | Speed | Wavelength |
|---|---|---|---|
| **A** | decreases | decreases | stays the same |
| **B** | increases | decreases | stays the same |
| **C** | increases | stays the same | decreases |
| **D** | stays the same | increases | increases |

Your answer ☐ **[1]**

This was a relatively straightforward question for candidates who recognised that the frequency of the light remains constant, giving only one possible correct response, D.

## Question 11

**11** A monochromatic beam of light is incident on a clean metal surface, and the frequency of the light is greater than the threshold frequency of the metal.

What happens if the original light source is replaced with one with double the frequency but the same intensity?

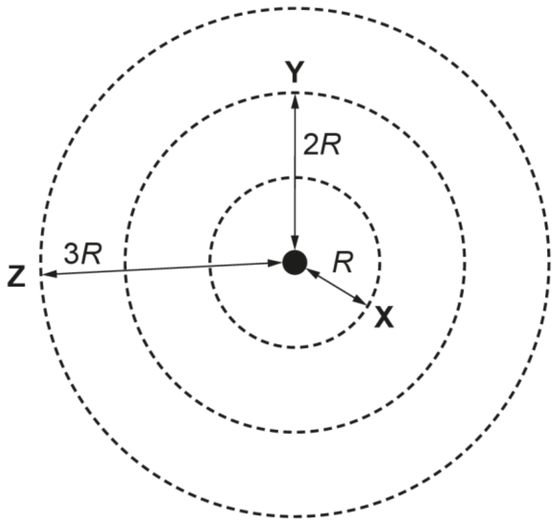
| | **Rate of emission of photoelectrons** | **Maximum kinetic energy of photoelectrons** |
|---|---|---|
| **A** | decreases | decreases |
| **B** | decreases | increases |
| **C** | increases | decreases |
| **D** | increases | increases |

Your answer ☐ **[1]**

Responses to this question suggest that candidates recognised that the maximum kinetic energy would increase, with a significant number of candidates believing that the rate of emission would also increase (response D) rather than decrease – the correct response being B.

## Question 13

**13** The diagram shows three gravitational equipotentials, **X**, **Y** and **Z**, at distances *R*, 2*R* and 3*R* from an isolated point mass.




The gravitational potential of **X** is *V*.

What is the change in gravitational potential between **Y** and **Z**?

**A** *V*/8

**B** *V*/6

**C** *V*/4

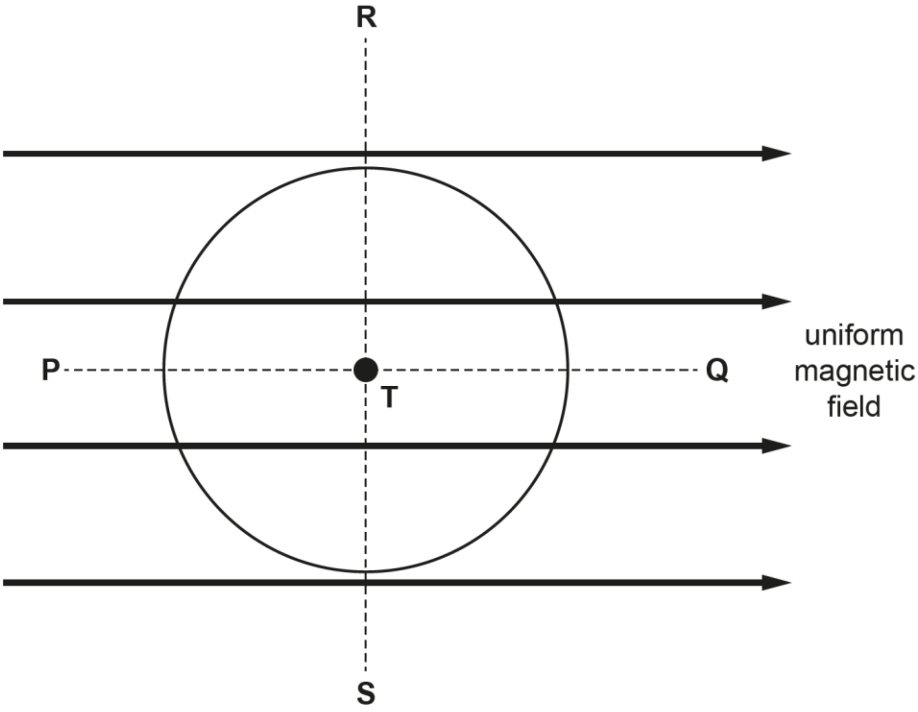
**D** *V*/2

Your answer [1]

Many correct responses showed understanding that potential is inversely proportional to radius via annotations on the diagram to show 'V' at a distance R, then subsequently V/2 and V/3 at 2R and 3R respectively, allowing correct calculation of the change in potential as V/6.

## Question 14

**14** The diagram shows a circular coil with its plane parallel to a uniform magnetic field.




The coil can move in three ways within the magnetic field:

- It can rotate about the axis **PQ**
- It can rotate about the axis **RS**
- It can rotate about the axis through **T** that is perpendicular to the magnetic field.

Which ways of moving will result in an induced e.m.f. in the coil?

**A** Axis **PQ** and **RS**

**B** Axis **PQ** only

**C** Axis **RS** and axis **T**

**D** Axis **RS** only

Your answer [ ] **[1]**

Many candidates appeared to have struggled to visualise this problem in three dimensions, incorrectly believing that there would be an induced e.m.f. through axis PQ as well as axis RS, selecting A as their response rather than D.

## Question 15

UVA is a part of the electromagnetic spectrum with wavelengths in the range 315 – 400 nm.
For a typical human, human skin and the tissue immediately below it has a mass of about 4.5 kg per $m^2$.
On a particular day UVA is absorbed by a person's skin at a rate of 2 mW per $m^2$.

**15** What is the best estimate of the number of UVA photons incident on 1 $cm^2$ of human skin each second?

**A** $4 \times 10^8$

**B** $4 \times 10^{11}$

**C** $4 \times 10^{12}$

**D** $4 \times 10^{15}$

Your answer **[1]**

## Question 16

**16** What is the best estimate of the absorbed dose of UVA per second for a typical human?

**A** 0.4 mGy

**B** 0.9 mGy

**C** 4 mGy

**D** 9 mGy

Your answer **[1]**

Candidates found this pair of questions the most challenging in Section A. In Question 15, candidates' workings showed they struggled to identify the powers of ten conversions from $m^2$ to $cm^2$ and mW to W. Question 16 should have represented a relatively easy substitution of values into the formula 'absorbed dose = energy deposited per unit mass' given in the formulae booklet but candidates did not see this as a standalone question and it therefore had the highest rate of 'no response' of all the multiple choice questions as candidates sought to use their answer from Question 15.

**Assessment for learning**

On occasion, candidates showed working for questions but did not select from one of the options given. Centres could make sure that candidates know that they do not lose marks by selecting an incorrect response.

## Question 17

**17** The density of a stone is determined by measuring its mass and volume, and using the equation **density = mass ÷ volume**. The mass of the stone measures 25.6 ± 0.2 g and its volume measures 5.2 ± 0.4 $cm^3$.

What is the calculated value of density of the stone?

**A** 4.9 ± 0.4 g $cm^{-3}$

**B** 4.92 ± 0.34 g $cm^{-3}$

**C** 4.923 ± 0.340 g $cm^{-3}$

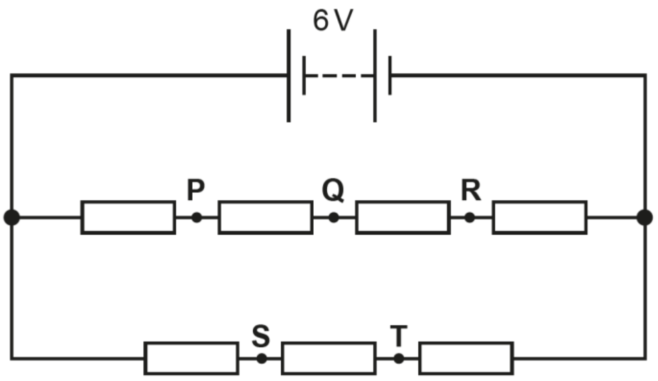
**D** 5 ± 0.4 g $cm^{-3}$

Your answer ☐ **[1]**

Candidates needed to approach this question in two parts - firstly they needed to calculate the density of the stone, before adding the percentage errors for each measurement. Some candidates relied solely on the first calculation which gives 4.92g$cm^{-3}$ and incorrectly selected B as their answer.

## Question 27

**27** The diagram shows seven identical resistors connected in a circuit with a 6 V battery.




Which pair of points has a potential difference of 0.5 V between them?

**A** **P** and **S**

**B** **P** and **T**

**C** **Q** and **S**

**D** **R** and **S**

Your answer **[1]**

Successful candidates often annotated their diagrams or showed working. In this case, it was a useful strategy to systematically identify and note the potential at each point before determining the potential difference between the points given, allowing successful identification of A (points P and S) having a p.d. of 0.5V between them.

**Assessment for learning**

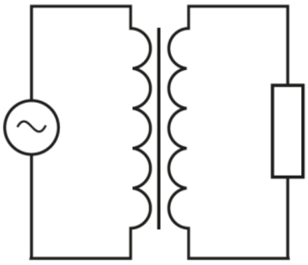
Candidates are encouraged to write on the question paper to help with their calculations or evaluations, rather than trying to hold information in their head or in their calculator.

# Section B overview

This section included five structured short answer questions worth a total of 21 marks

## Question 31 (a) and (b)

**31** The diagram shows the circuit for a 100% efficient transformer. It has an alternating potential difference connected across the primary coil and a resistor connected across the secondary coil.



**(a)** Explain how an alternating current in the primary coil causes an alternating current in the secondary coil.

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**(b)** The table shows the values of the resistor and of the potential differences in the coils.

| Primary potential difference / V | Primary current / A | Secondary potential difference / V | Secondary current / A | Resistance / Ω |
|---|---|---|---|---|
| 20 | | 50 | | 800 |

Complete the table to show the currents in the coils. **[2]**

Most candidates were able to identify in part (a) that a changing magnetic field is produced before going on to explain that an alternating current is induced in the secondary coil. Some candidates' responses lacked sufficient detail – for example, referring to 'field' rather than magnetic field, whereas others made incorrect statements such as 'there is a current induced through the core'.

In part (b) most candidates were able to calculate the secondary current, however for the primary current many incorrectly divided the primary p.d. by the given resistance leading to an incorrect answer of 0.025A.

**Misconception**

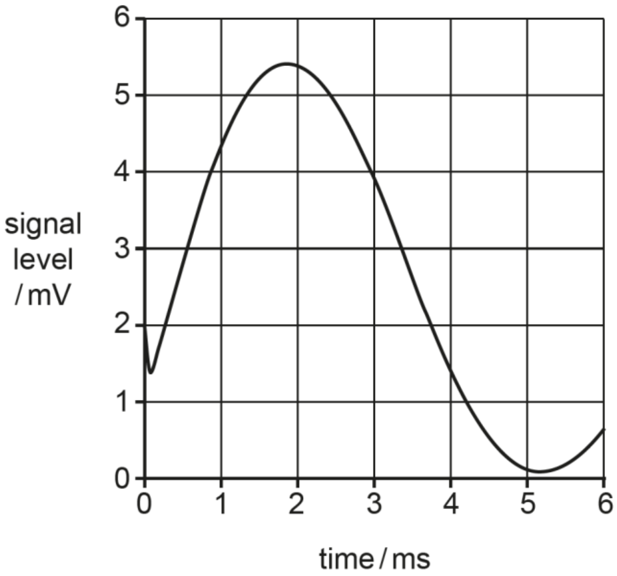
Candidates should be aware that the terms ‘emf’, ‘p.d.’ and ‘voltage’ have precise meanings and should not be used interchangeably.

## Question 32 (a) and (b)

**32** This question is about an exercise carried out by some students to show the digitisation and reconstruction of an analogue signal.

**(a)** **Fig. 32.1** shows the signal given to the students.

**Fig. 32.1**



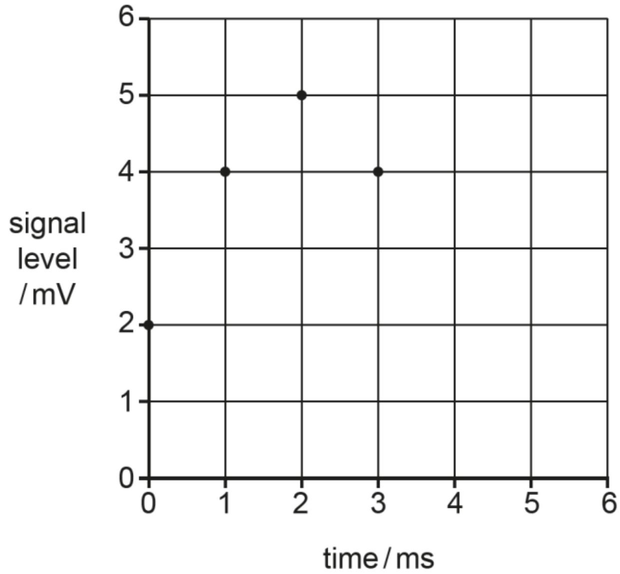

The students:

- sample the signal every millisecond
- round the value to the nearest millivolt
- and then convert the value to a binary number.

The students start to use the table to record their results and the graph in **Fig. 32.2** to show the reconstructed signal.

| time / ms | signal level / mV | digitised signal level |
|---|---|---|
| 0 | 2 | 010 |
| 1 | 4 | 100 |
| 2 | 5 | 101 |
| 3 | 4 | 100 |
| 4 | | |
| 5 | | |
| 6 | | |

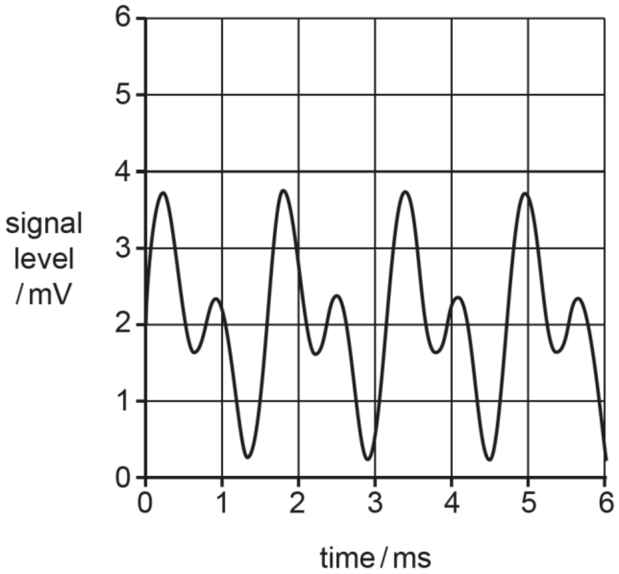
**Fig. 32.2**




Use information from **Fig. 32.1** to complete the table and the reconstructed signal in **Fig. 32.2**. **[2]**

**(b)** **Fig. 32.3** shows another signal given to the student.

**Fig. 32.3**




Explain why, when this signal is digitised with the same sampling rate and number of levels, it cannot be accurately reconstructed. You do not need to plot the reconstructed signal.

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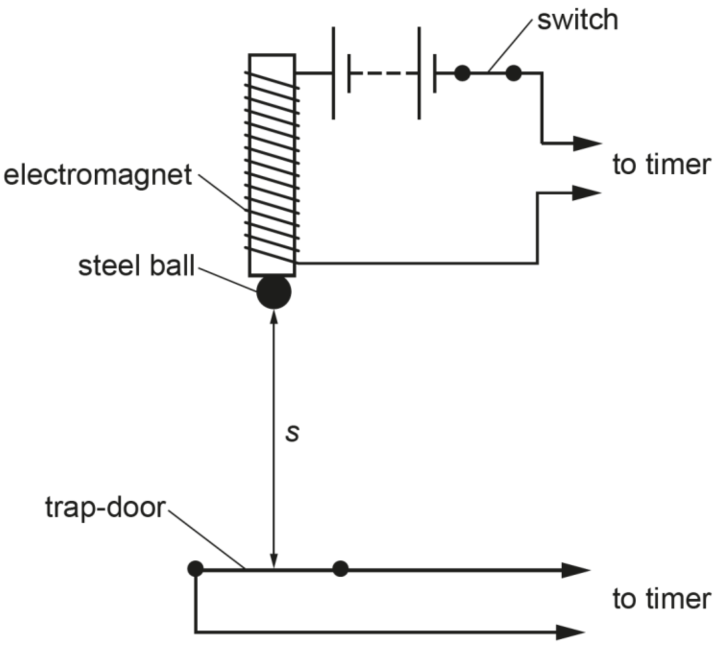
Almost all candidates successfully completed the table as required in part (a).

In part (b) many candidates were able to articulate why the sampling rate is not high enough - often quoting Nyquist Theorem as part of their argument. To gain full marks, candidates needed to comment on the number of quantisation levels being insufficient. Candidates were not awarded marks for discussion of the effects of the inaccurate reconstruction – for example, aliasing - since the question asks why the sample cannot be accurately reconstructed, not the effect on the reconstructed signal.

## Question 33 (a)

**33** **Fig. 33.1** shows an experiment that can be carried out to measure the time taken for a steel ball to fall through a known distance *s*.

**Fig. 33.1**




When the switch is opened the steel ball is released. At the same time an electronic timer is started. When the steel ball hits the trap-door it opens and the timer is stopped.

**(a)** In one experiment the ball falls through a height of 0.75 m in 0.41 s.

Calculate the acceleration due to gravity based on this result.

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

Almost all candidates were able to successfully manipulate and use $s = ½ at^2$ to calculate the acceleration as 8.9 $ms^{-2}$. The most common mistake was to omit the ½, leading to an incorrect answer of 4.46 $ms^{-2}$ .

## Question 33 (b)

**(b)** In another experiment the time *t* taken for the steel ball to fall from the electromagnet to the trap-door is measured for several values of *s*. A graph of $t^2$ against *s* is drawn.

Explain how the graph can be used to determine the acceleration due to gravity.

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Most responses incorrectly stated that the gradient would give a/2 and went on to say 'you would need to double the gradient' or stated that the gradient itself would be the acceleration.

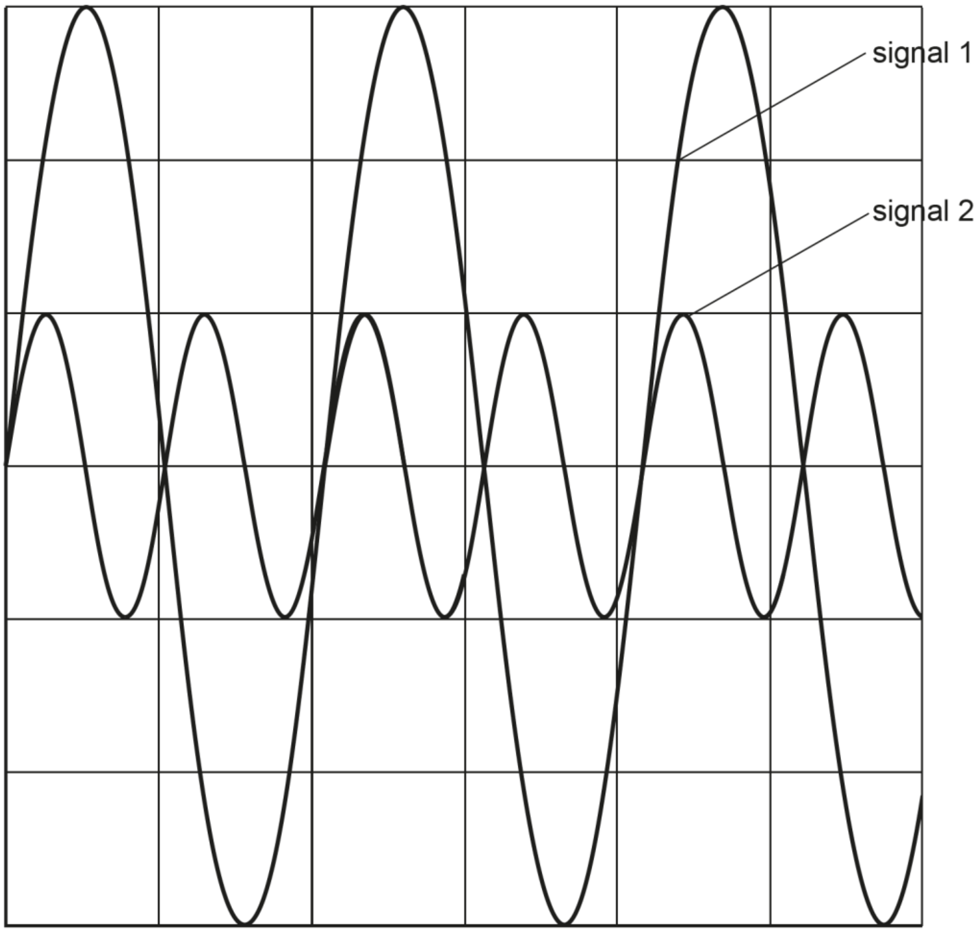
Candidates who gave the correct response recognised that the question was asking about a graph of $t^2$ against s. They went on to correctly explain that the gradient of that graph is 2/a and therefore acceleration could be found by multiplying the inverse of the gradient by 2.

## Question 34 (a)

**34**

**(a)** **Fig. 34.1** shows a dual-trace oscilloscope being used to display two electrical signals.
The horizontal time-base of the oscilloscope is set at 50 ms per division and the vertical gain is set at 0.2 V per division.

**Fig. 34.1**




Compare the frequencies and amplitudes of signal 1 and signal 2.

Frequencies ..............................................................................................................................

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Amplitudes ..............................................................................................................................

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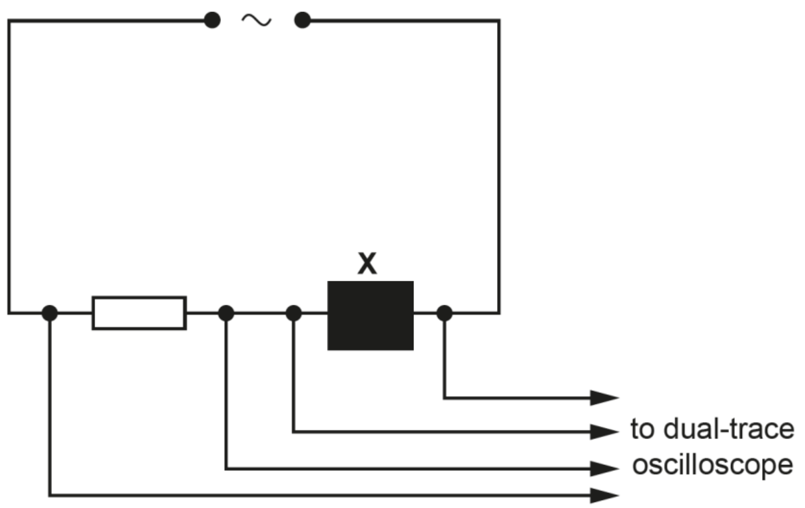
**[2]**

This question was well answered with candidates often using information from the graph to calculate and then compare frequencies and amplitudes. A small minority of candidates gave answers such as 'the frequency of signal one is smaller than signal 2' which lacked the detail required for credit.

## Question 34 (b)

**(b)** **Fig. 34.2** shows a circuit containing a source of alternating emf, a resistor and a component, **X**. A dual-trace oscilloscope is used to observe the potential differences across the resistor and the component **X**.

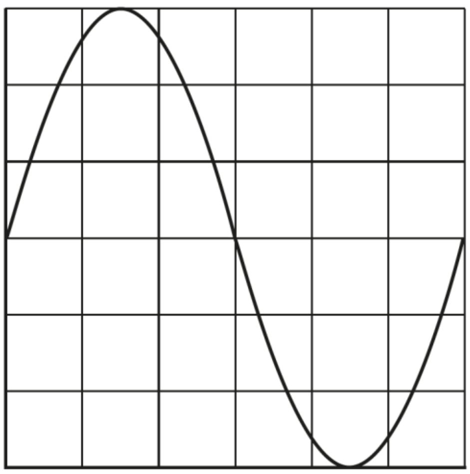
**Fig. 34.2**




The peak value of the potential difference across the resistor is 6 V.
The peak value of the potential difference across the component **X** is 4 V and the potential difference across the component **X** has the same frequency, and a phase difference of $\pi/2$ with the potential difference across the resistor.

**Fig. 34.3** shows the trace of the potential difference across the resistor.

**Fig. 34.3**



Draw the trace for the potential difference across the component **X** on **Fig. 34.3**.

**[2]**

Candidates found identifying and plotting key points – for example where the new trace reaches a peak, a trough, and where it has zero amplitude – a useful technique for sketching the trace with the correct amplitude and phase difference from the original trace.

## Question 35 (a) and (b)

**35** When hydrogen reacts chemically, the hydrogen molecules must have enough energy to break the H-H bonds between the atoms.
The Boltzmann factor for the H-H bonds in hydrogen at a temperature of 1000 K is $1.64 \times 10^{-23}$.

**(a)** Calculate the energy required to break all the H-H bonds in one mole of hydrogen.

energy = ............................................................ J **[3]**

**(b)** The average energy of hydrogen molecules at 300 K is below the energy needed to break the H-H bonds.

Explain why hydrogen still reacts at a reasonable rate at 300 K.

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Exemplar 1 shows a response that is typical for part (a) – the candidate has successfully calculated the energy required to break one bond, $7.24 \times 10^{-19}$ J, but not gone on to multiply by the Avogadro Constant to work out the energy required to break the bonds in one molecule.

In part (b) the response gains both marks – the candidate has stated that there are many collisions, and that a molecule can gain enough energy through successive collisions to break the H-H bonds. Responses often lacked that clarity of reasoning.

**Assessment for learning**

Candidates should make sure they explain the relevance of key terms – stating 'because of the Maxwell-Boltzmann distribution' as an answer to this question needs further explanation as, even though the concept is relevant, the question asks candidates to 'explain why…'.

## Exemplar 1

$$f = e^{-\frac{E}{kT}}$$

$$-\ln f = \frac{E}{kT}$$

so $E = kt(-\ln f)$

$= 1.38 \times 10^{-23} \times 1000 \times (-\ln(1.64 \times 10^{-23}))$

$= 7.24 \times 10^{-19}$

energy = $7.24 \times 10^{-19}$ J **[3]**

There are a large number of hydrogen molecules and many collisions per second. On collision, molecules exchange energy, so a molecule may get 'lucky' after multiple successive collisions **[2]** and gain enough energy to break the H-H bonds.

# Section C overview

This section consisted of five questions worth 59 marks in total.

## Question 36 (a) (i) and (ii)

**36** **Fig. 36.1** shows how the extension of a metal alloy wire varies with increasing load.
**Fig. 36.2** shows the same information for a rubber strip.
The metal alloy wire fractures when its extension exceeds $16 \times 10^{-4}$ m.

**Fig. 36.1**

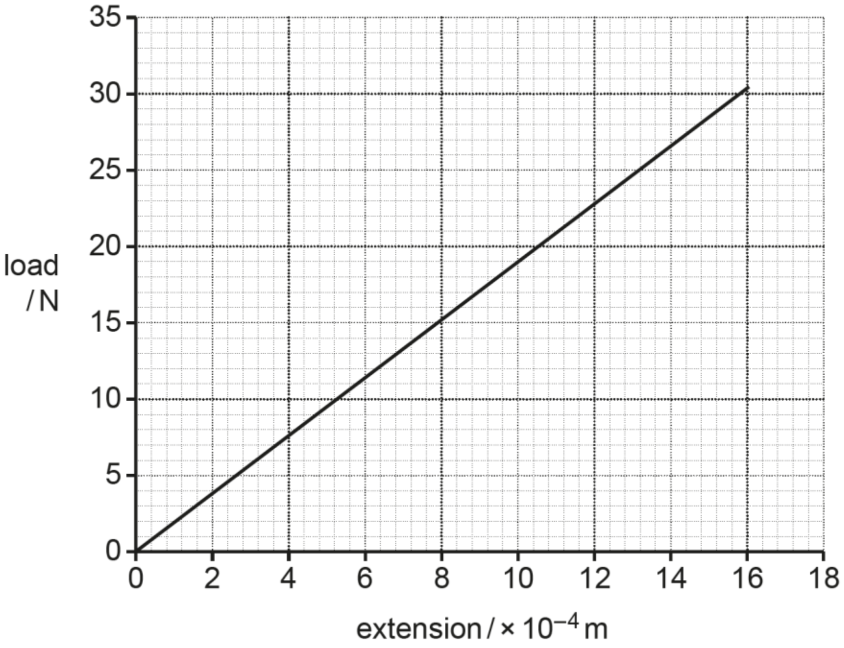
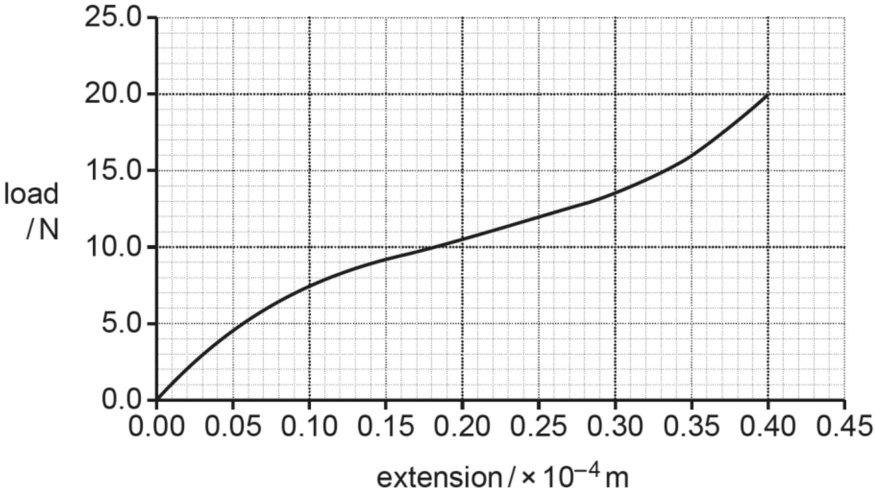



**Fig. 36.2**



**(a)** When the wire and the rubber strip are first loaded with 10 N the loads oscillates vertically with microscopic amplitudes for a short time.

**(i)** Use information from **Fig. 36.1** to calculate the stiffness **k** of the wire.

stiffness = .................................................. $N m^{-1}$ **[2]**

**(ii)** The mass suspended from the wire oscillates vertically with simple harmonic motion.

Calculate the period of oscillation for the wire when it carries a 10 N load.

period = .......................................................... s **[2]**

Most candidates successfully calculated the stiffness in (a) (i). A common mistake in part (a) (ii) was to incorrectly multiply the 10N load by 9.81 instead of dividing by it to find the mass, or to omit the conversion entirely.

## Question 36 (a) (iii)

**(iii)** Explain why the oscillations of the wire are simple harmonic but those of the rubber strip are not.

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Most responses to this question gained the second marking point for identifying that the stiffness of the rubber strip is not constant. Fewer responses gained the first marking point as candidates often stated that the 'force is proportional to the displacement' without including reference to the direction.

### Assessment for learning

Candidates should take care to check what the question requires. In this question an explanation as to why the oscillations of the wire and rubber are/are not simple harmonic is required; the question does not ask for a description of simple harmonic motion in terms of its period or amplitude - explaining that $x(t)=A\cos(\omega t)$ for example, does not provide the explanation sought.

## Question 36 (b)*

**(b)*** Use ideas about the microscopic structures of metal alloys and polymers, such as rubber, to explain the different shapes of the graphs in **Fig. 36.1** and **Fig. 36.2**.

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This extended response question expected candidates to explain the shape of load-extension graphs for metal alloys and rubber by using ideas about their microscopic structure. To gain full marks candidates needed to give a clear explanation of both microscopic structures and link them to the shape of each graph. Responses that described the structure of pure metals rather than alloys, and those that described the structure of the materials without reference to the shape of the graphs were limited to Level 2 (maximum 4 marks).

Most candidates found it easier to explain the structure of rubber than that of the metal alloy. Annotated diagrams helped support responses. **Exemplar 2** shows how a basic diagram of the pinning in metal alloys can help with the candidate's explanation of the structure, while the annotation of the graph sections adds clarity to the points made regarding the structure of rubber and how it relates to the different sections of the graph. This quality of communication enabled the response to be awarded maximum marks within Level 3 (6 marks).

## Exemplar 2

Fig. 36.1: In a metal alloy we have a giant lattice of +ve metal ions (of each alloy metal) and -ve electrons (see below). When this lattice is stretched, each metallic bond produces a directly proportional force (to the extension) to oppose it, resulting in the entire structure to behave similarly, having a load directly proportional to extension.

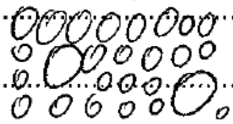
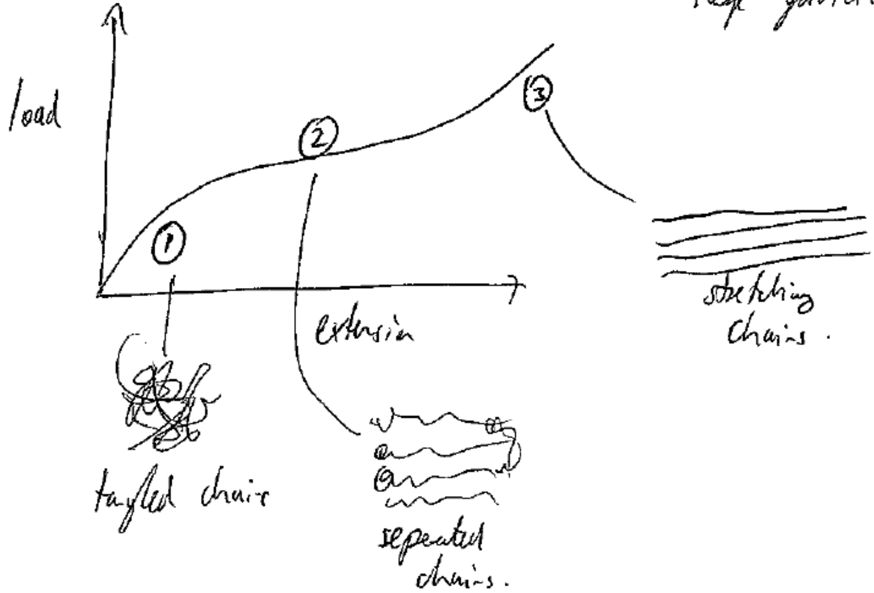


Fig 36.2: In a polymer like rubber, when unstretched the long polymer chains are disorganised and "tangled", so to produce unit extension a large force is required (to untangle the chains), resulting in a large gradient of Fig 36.2, (① on below diagram). After the chains have been untangled, a smaller force is required per unit extension since the chains need only to be individually straightened, resulting in a smaller gradient (②). After the chains have been straightened, a large force is required per unit extension since each individual chain must be stretched, requiring bonds to be broken/stretched and hence a large gradient (③) **[6]**



## Question 37 (a)

**37** **Fig. 37.1** shows a violin. When a note is played, a stationary wave is formed on a string between the bridge and the fingerboard with a frequency determined by the position of the finger on the fingerboard.

**Fig. 37.1**

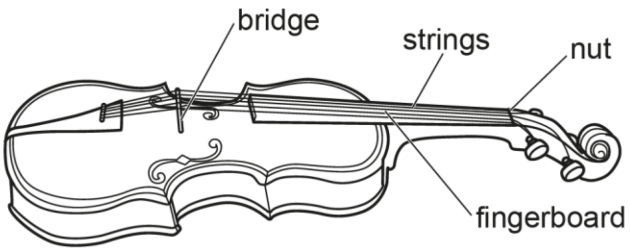
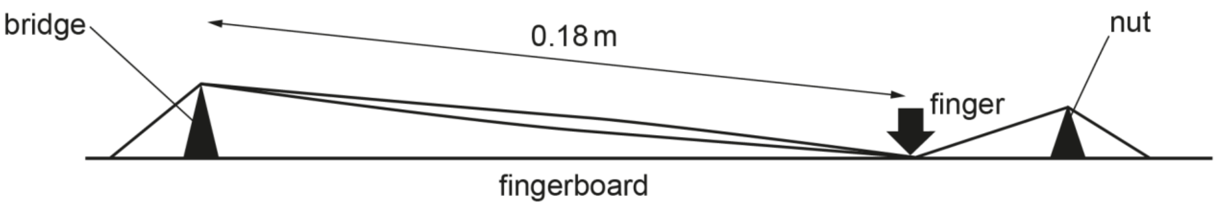



**Fig. 37.2** shows a standing wave formed on a violin string when it is freely oscillating at a natural frequency of 370 Hz.

The length of the vibrating section of the string is 0.18 m.

**Fig. 37.2**




NOT to scale

The speed $v$ of a transverse wave on a stretched string is given by the equation

$v = \sqrt{(T/\mu)}$

where $T$ is the tension of the string and $\mu$ is the mass per unit length of the string.

All the strings on the violin have the same tension and are made from the same material. One of the strings has a diameter 1.4 times greater than the string shown in **Fig. 37.2**.

**(a)** Calculate the length of this string when it oscillates with a natural frequency of 370 Hz.

length = ........................................................ m **[3]**

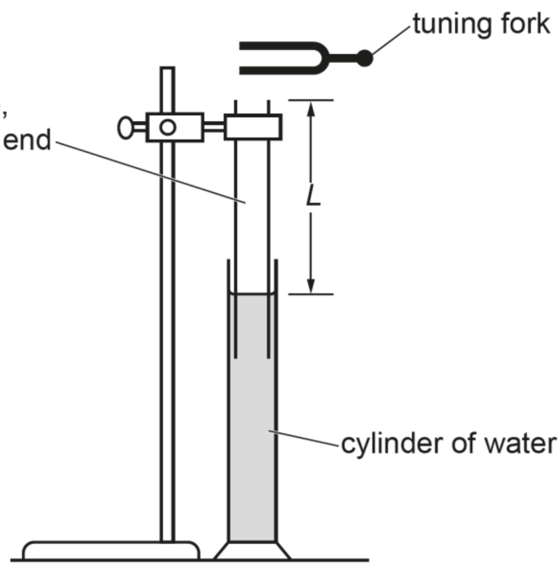
Candidates found this question challenging – a small number managed to evaluate the length as being 0.31m, gaining all 3 marks, but usually responses gained no credit as the algebra shown lacked clarity as candidates tried lots of different manipulations or approaches.

## Question 37 (b) (i), (ii) and (iii)

**(b)**

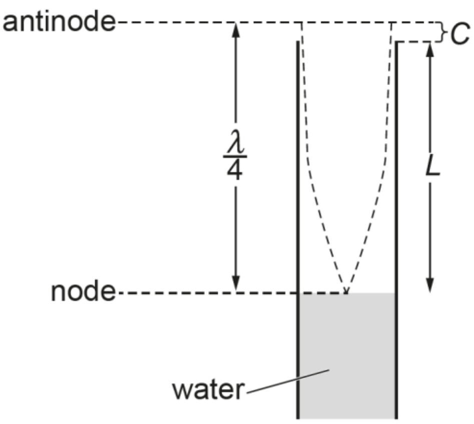
**(i)** **Fig. 37.3** shows apparatus used to determine the speed of sound in air.
The wavelength of the sound = $\lambda$.

**Fig. 37.3**




The tuning fork is struck and vibrates at a note of frequency 440 Hz. The clamped tube is raised so the length $L$ increases from a very small value. The amplitude of the note reaches a maximum value when length $L$ is 17.0 cm. At this length the air in the tube resonates with a node at the water surface and an antinode at a short distance $C$ above the end of the tube as shown in **Fig. 37.4**.

**Fig. 37.4**



Show that the **minimum** value of the speed of sound in air is about 300 m s$^{-1}$ and state any assumptions made. Include a calculation in your answer.

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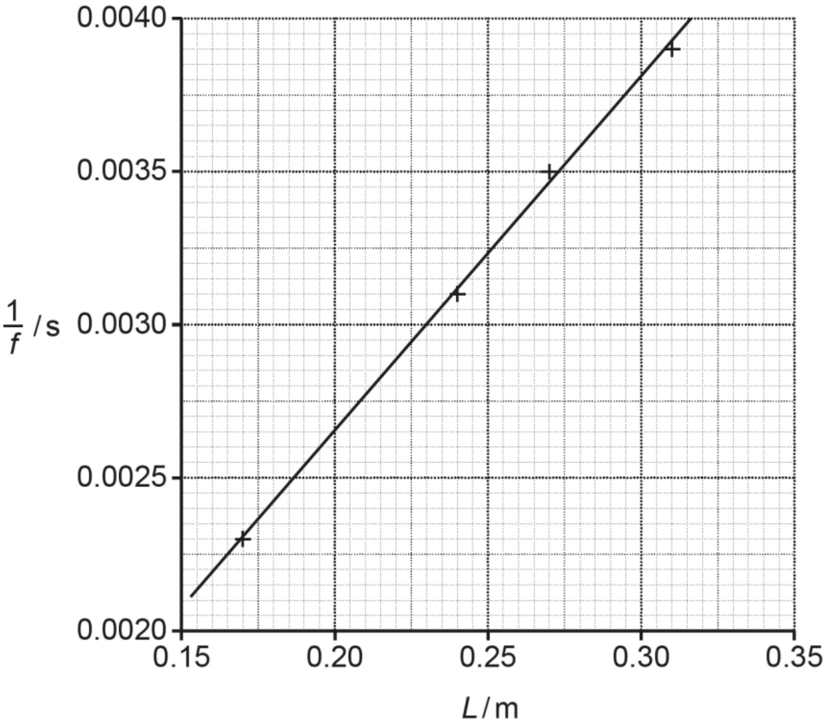
The measurement is repeated with a number of tuning forks of different frequencies *f*. A graph of 1/*f* against length of air column *L* is plotted as shown in **Fig. 37.5**.

**Fig. 37.5**




**(ii)** The gradient of the line = $\frac{4}{v}$ where *v* is the speed of sound in air. Use the graph to determine the speed of sound in air.

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

**(iii)** Explain why the gradient of the line = $\frac{4}{v}$.

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In (b) (i) most candidates were able to calculate the speed of sound and give the assumption that the distance C is insignificant. Some candidates incorrectly stated that 'the speed of sound is constant', or 'there is no energy lost' while others did not give an assumption.

Parts (b) (ii) and (iii) were well answered, with candidates making clear the gradient they had used either in dy/dx form or by drawing a large triangle on the graph in part (ii) and scoring at least 2 marks in part (iii) by re-arranging the equation to identify the gradient. Some candidates did not gain the final mark as their comparison with y=mx+c was not made clear.

## Question 37 (b) (iv)

**(iv)** Discuss the suggestion that using a loudspeaker above the tube connected to a signal generator will give a more reliable determination of the speed of sound than using tuning forks.

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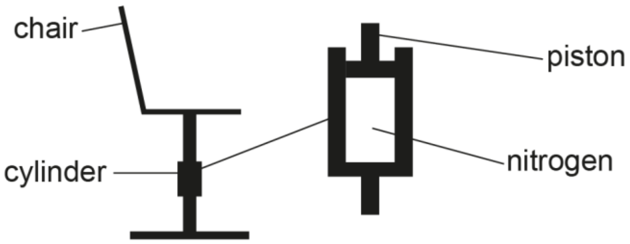
Candidates found (b) (iv) more challenging as they were expected to give two distinct reasons and link them to an experimental advantage/disadvantage. A common error was to suggest that a signal generator would give a constant frequency when it was clear from the rest of the response that the candidate meant constant amplitude. An equally common error was to state that the signal generator would give a more accurate frequency than the tuning fork.

## Question 38 (a) (i)

**38**

**(a)** **Fig. 38.1** shows an office chair fitted with a gas strut.
The gas strut consists of a cylinder containing nitrogen and a lubricated gas-tight piston. This cushions the downward movement of the seat when someone sits on it.

**Fig. 38.1**




The gas strut on the chair has a piston with a cross-sectional area of 15.0 $cm^2$.
When the chair is empty the length $l$ of the cylinder is 10.0 cm and the pressure inside it is 170 kPa.

A person sits on the chair when the room temperature is 18 °C, and the length of the cylinder decreases to 3.0 cm.

**(i)** Show that the mass of the person is about 61 kg.

**[2]**

## Question 38 (a) (i) and (ii)

**(ii)** At the end of the day the temperature is 30 °C and the same person sits on the chair.

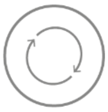
Calculate the length $l$ of the cylinder at the end of the day, when a person of mass 61 kg sits on the chair.

length of cylinder = ...................................................... m **[2]**

In a(i) candidates found it relatively straightforward to find the new pressure as 567kPa, but many were not able to show correct substitution and then evaluation of the new mass as 60.7kg.

Candidates found part a(ii) trickier with many omitting this question. Some, however, successfully used PV=nRT to calculate the new length as 0.031m

**Assessment for learning**

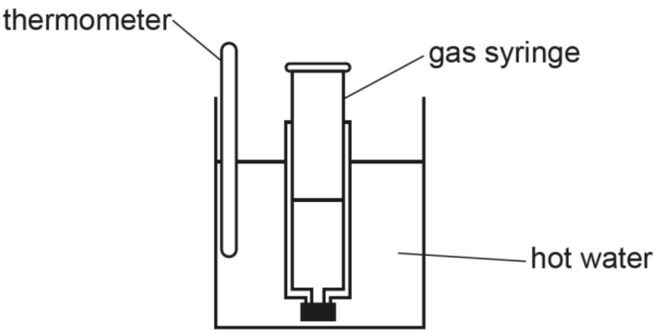


'Show that' questions require candidates to show their working and evaluation of their own answer. In Question 37 a(i), for example, they should have evaluated to a mass of 60.7kg – the use of the 'almost equal to' symbol with mass ≈ 61kg was insufficient for the second mark.

## Question 38 (b) (i) and (ii)

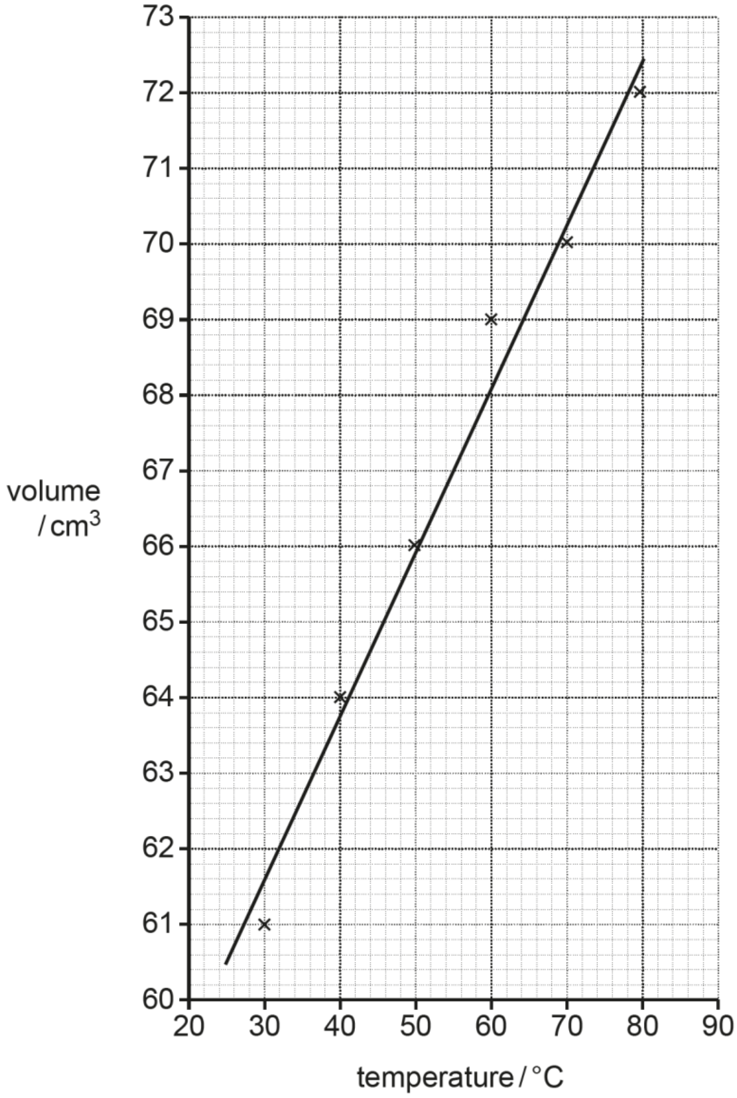
**(b)** **Fig. 38.2** shows the equipment used in an experiment to investigate the relationship between the volume of a fixed mass of air and its temperature, at constant pressure.

**Fig. 38.2**




The end of the gas syringe is sealed. It has an initial volume of air trapped inside it. The syringe is put into a beaker of hot water with a thermometer.
The volume of air in the syringe is measured at different water temperatures as the water cools from 80 °C to 30 °C.

The graph shows the results of the experiment.




**(i)** The gas syringe used in this experiment measures volume to the nearest 1 $cm^3$ and the thermometer measures temperature to the nearest 1 °C.

Use this information to calculate the percentage uncertainties in the measured volume and temperature at 30 °C.

% uncertainty in volume = ...............................................................

% uncertainty in temperature = ...............................................................

**[2]**

**(ii)** Use the graph to calculate a value of absolute zero of temperature.

absolute zero of temperature = ...................................................... °C **[3]**

Candidates showed a good understanding of uncertainty in (b) (i) with many scoring both marks – some, though, took the uncertainty as half the resolution and did not gain either mark.

Most candidates went on to evaluate the gradient in (b) (ii), showing either the gradient 'triangle' on the graph or the data drawn from it. An error made by a small number of candidates was to calculate the y-intercept at around 55°C as their final answer, rather than substituting y=0 to find the x intercept.

## Question 39 (a) and (b)

**39**

**(a)** Radioactive decay happens when an unstable nucleus emits a particle or electromagnetic radiation to become more stable. This is a random process.

Explain the meanings of the terms '**unstable nucleus**' and '**random process**' in relation to radioactive decay.

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**(b)** Thorium-232 is a radioactive metal that can be added to welding rods to improve their performance. These welding rods are said to be thoriated.

Thorium-232 decays through the emission of alpha particles and it has a half-life of $1.4 \times 10^{10}$ years.

Through a series of decays, thorium-232 produces radon-220, which is a radioactive gas.

Radon-220 decays through the emission of alpha particles, and it has a half-life of 55 seconds.

Compare the risks of harm to someone handling a thoriated welding rod from the thorium itself with the risk of harm from the radon gas it produces.

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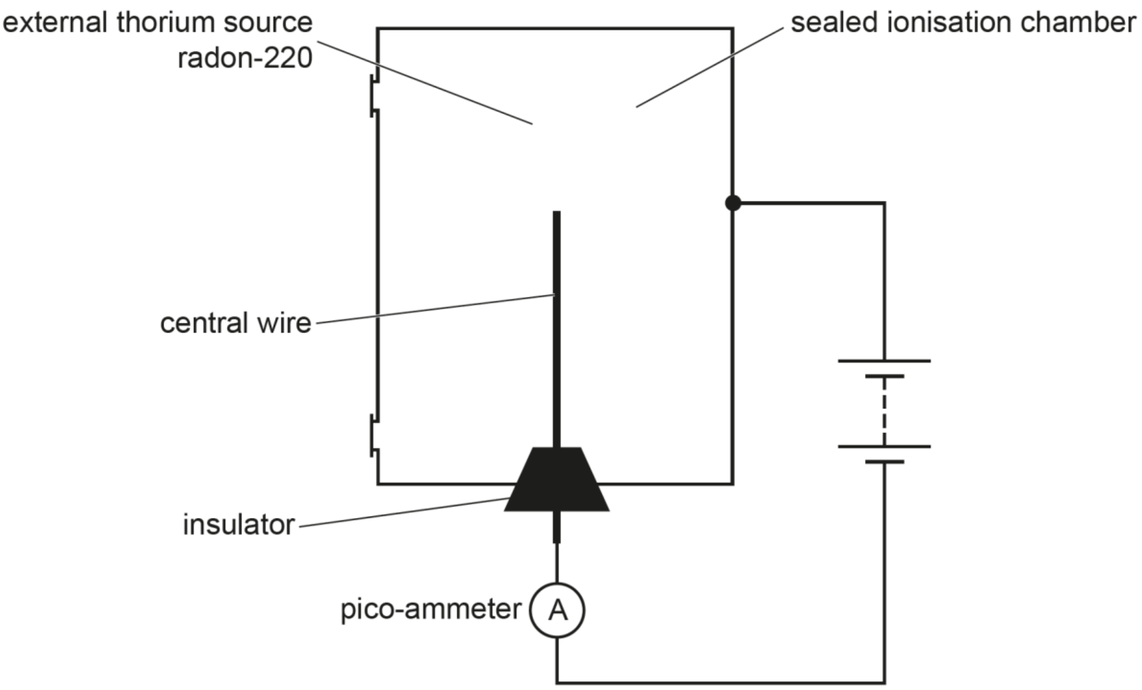
In response to 39(a), most successful candidates gave arguments about unstable nuclei decaying to other nuclei, with descriptions of random process based on the unpredictability of an individual decay.

Most candidates recognised in part (b) that alpha particles are highly ionising and compared their inability to penetrate the skin with the danger of radon gas being inhaled. A very small number of candidates recognised that the relative half-lives is not a factor in this situation as thorium activity limits radon activity. The vast majority, though, inappropriately compared the half-lives of the two isotopes, with a significant proportion calculating the decay constant for each alpha source.

## Question 39 (c) (i)

**(c)** In an experiment, radon-220 gas is used to determine its half-life. The diagram shows the equipment used.




A battery and a pico-ammeter are connected between the metal case of the ionisation chamber and the central wire.
Radon-220 in the ionisation chamber emits alpha particles, which cause ionisation of the air in the chamber and a small ionisation current flows in the circuit. This ionisation current is proportional to the rate of emission of alpha particles from the radon-220.

**(i)** Explain why the ionisation current is proportional to the number of radon-220 atoms remaining in the chamber.

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In this part question many candidates gave vague response that were re-statements of the question 'ionisation current is proportional to the number of radon-220 atoms remaining…' without explaining why this is the case. To do so, responses needed to make clear that the rate of alpha-emission is proportional to the number of nuclei present.

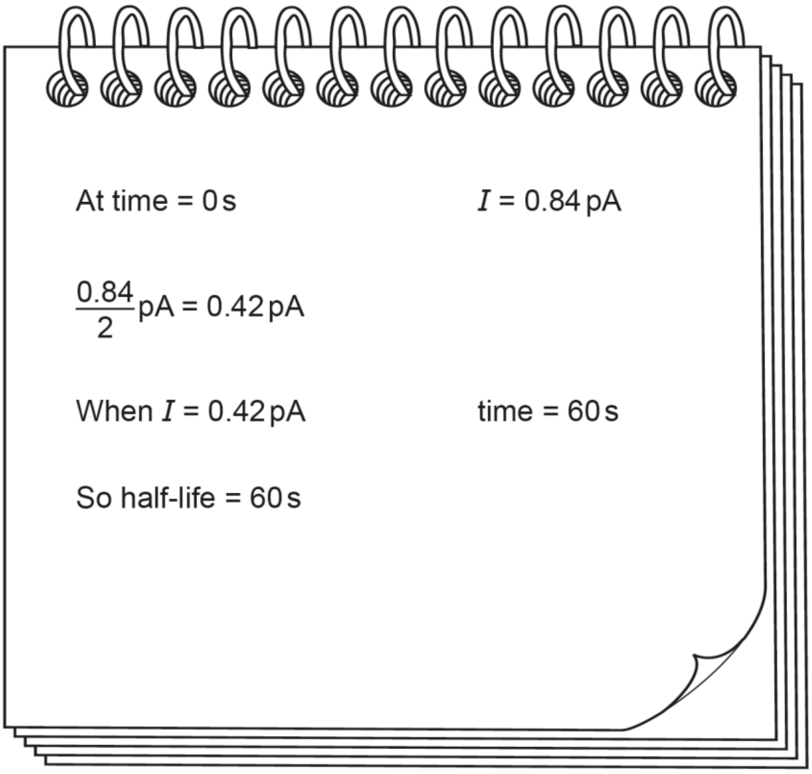
## Question 39 (c) (ii)*

The reading on the pico-ammeter is noted every 20 seconds.

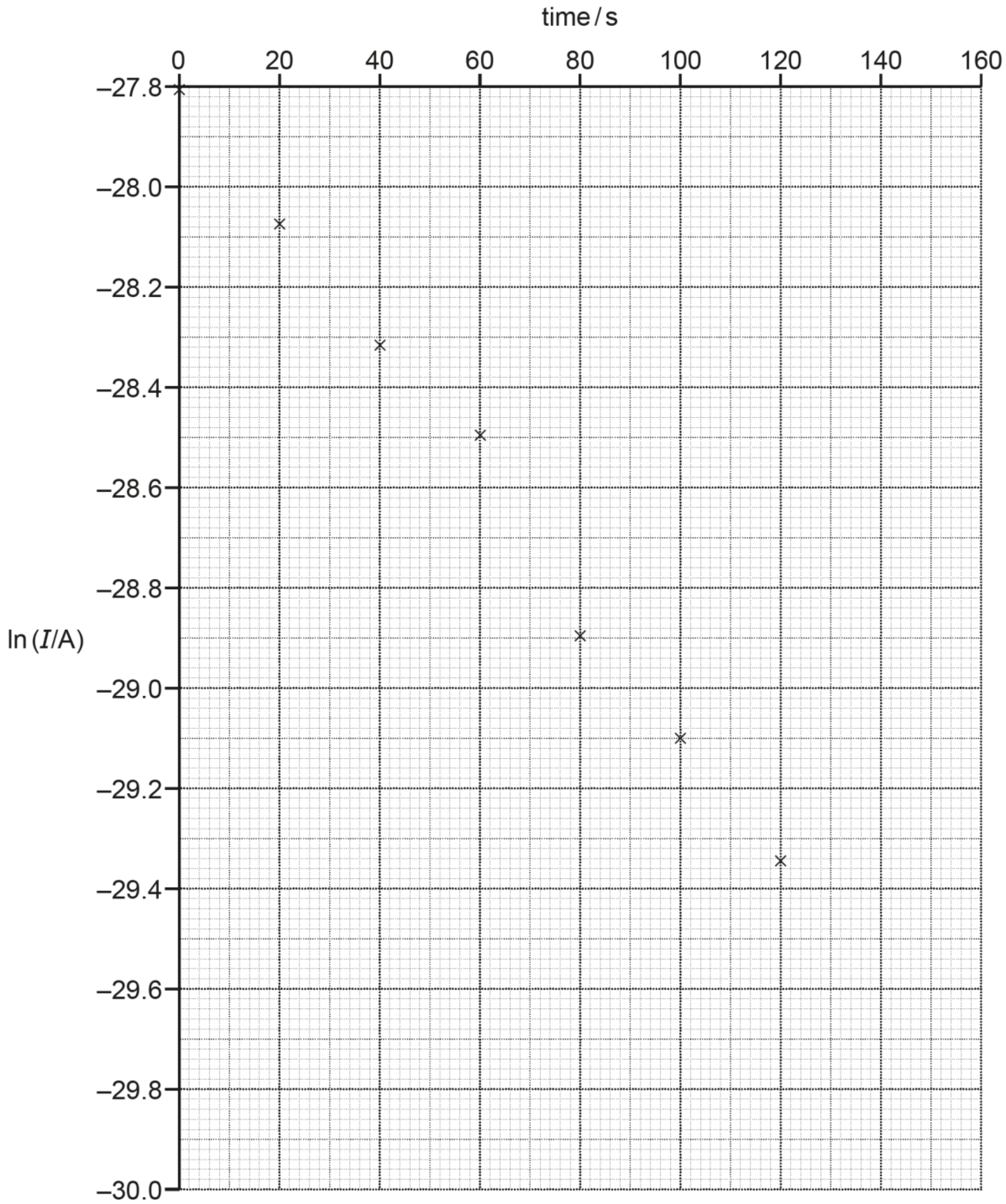
The table shows a typical set of results for this experiment.

| **Time /s** | **Ionisation current *I* / pA** | **ln (*I* / A)** |
|---|---|---|
| 0 | 0.84 | –27.81 |
| 20 | 0.64 | –28.08 |
| 40 | 0.50 | –28.32 |
| 60 | 0.42 | –28.50 |
| 80 | 0.28 | –28.90 |
| 100 | 0.23 | –29.10 |
| 120 | 0.18 | –29.35 |
| 140 | 0.13 | |
| 160 | 0.10 | |

A student calculates the half-life using values from the table:



**(ii)*** Another student starts to plot a graph of ln ($I$) against time.




Use the table to complete the graph and use it to determine a value for the half-life of the radon-220.

Explain why the graph gives a half-life closer to the accepted value.

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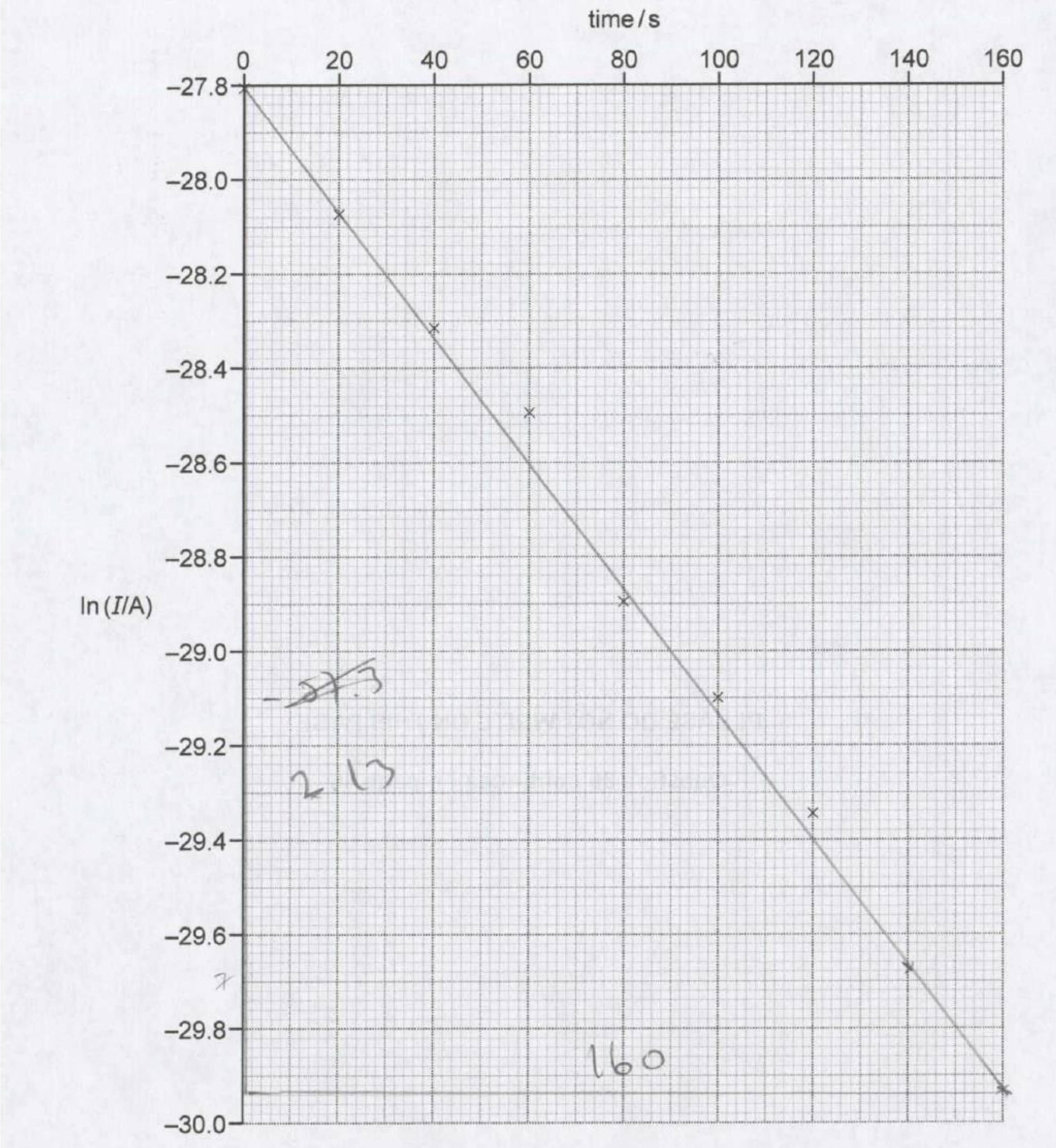
To gain full marks for this extended response question, candidates needed to give a clear explanation of two strands in their answer – the calculation of half-life from the graph, and explanation of why the graph gives a more accurate value of half-life.

**Exemplar 3** is typical of many responses where the candidate has shown clearly their use of the graph by plotting points, taking the gradient (-λ) and, hence calculating half-life. However the description of why the graph is more accurate is limited, restricting the overall mark to Level 2 (4 marks) - a little more detail, for example by explaining how the graph reduces the effect of anomalies or by stating that the value derived from the table depends on which points are chosen could have lifted the response to Level 3.

## Exemplar 3

| Time /s | Ionisation current $I$/pA | ln ($I$/A) |
|---|---|---|
| 0 | 0.84 | –27.81 |
| 20 | 0.64 | –28.08 |
| 40 | 0.50 | –28.32 |
| 60 | 0.42 | –28.50 |
| 80 | 0.28 | –28.90 |
| 100 | 0.23 | –29.10 |
| 120 | 0.18 | –29.35 |
| 140 | 0.13 | -29.67 |
| 160 | 0.10 | -29.93 |




Explain why the graph gives a half-life closer to the accepted value.

~~$-\lambda = -\frac{27.3}{160} = 0.361$~~

$I = I_0 e^{-\lambda t}$

$\ln I = -\lambda t + \ln I_0 \qquad -\lambda = \frac{-2.13}{160} = 0.0133$

$y = mx + c$

Gradient of the graph is ~~half life~~ decay constant

$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \cdot \frac{\ln 2}{0.0137} = 52.1$ s

More accurate due to gradient of graph reducing uncertainty and can reduce anomalies.

Graph is average over time closer to expected value.

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