Oxford Cambridge and RSA

# Wednesday 24 May 2023 – Afternoon

## AS Level Physics A

**H156/02** Depth in physics

**Time allowed: 1 hours 30 minutes**

**You must have:**
- the Data, Formulae and Relationships Booklet

**You can use:**
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) ______________________

Last name ______________________

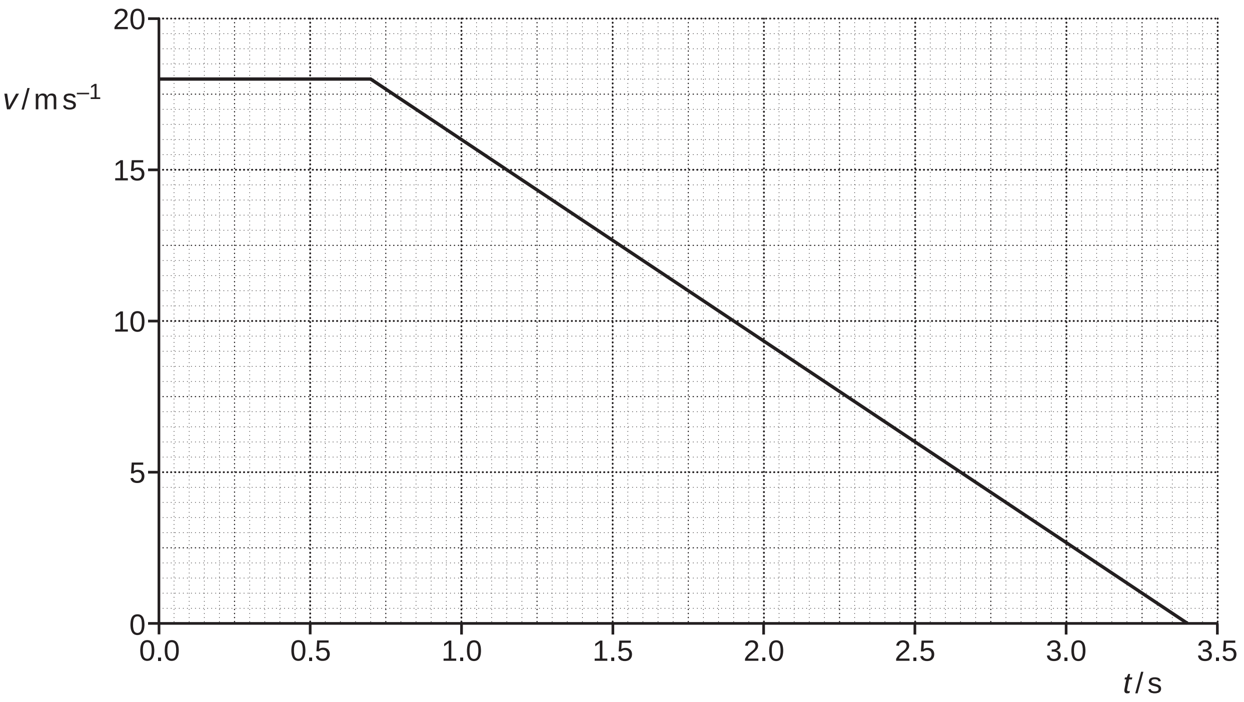
**INSTRUCTIONS**
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

**INFORMATION**
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

**ADVICE**
- Read each question carefully before you start your answer.

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

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




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

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

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

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

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

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

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

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

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

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

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

**(i)** the driver was tired

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

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

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

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

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

where
$\rho$ is the density of the metal
$\sigma$ is the density of the liquid
$g$ is the acceleration of free fall = $9.81\,\text{m}\,\text{s}^{-2}$ and
$K$ is a constant.

Describe, with the aid of a suitable diagram:

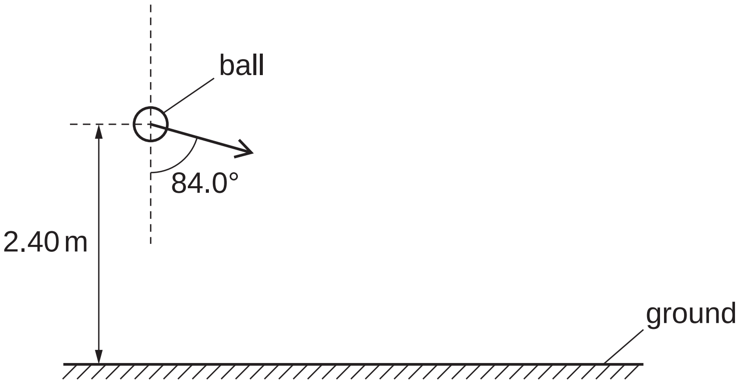
- how an experiment can be safely conducted to test this relationship between *v* and *d*, and
- how the data can be analysed to determine *K*.

**[6]**

**Diagram**

Additional answer space if required

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




(not to scale)

Assume that air resistance is negligible.

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

**[1]**

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

**[2]**

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

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

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

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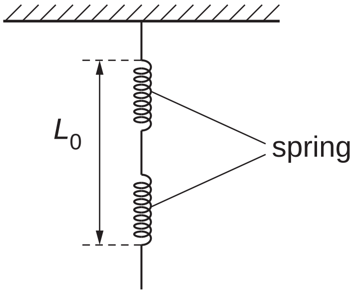
4 **(a)** Two identical springs each have a force constant of 36 N m$^{-1}$. In an experiment, the two springs are suspended from a fixed support as shown in **Fig. 4.1**.

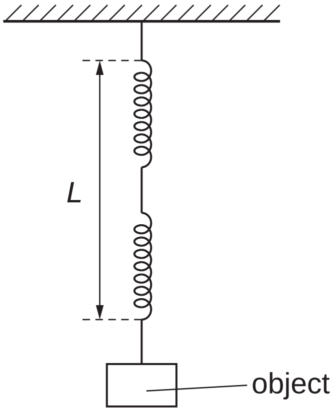
**Fig. 4.1**




The initial length of the spring arrangement is $L_0$.

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

**Fig. 4.2**




The new length of the spring arrangement is $L$.

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

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

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

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

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

$x$ = ........................... ± ........................... mm **[1]**

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

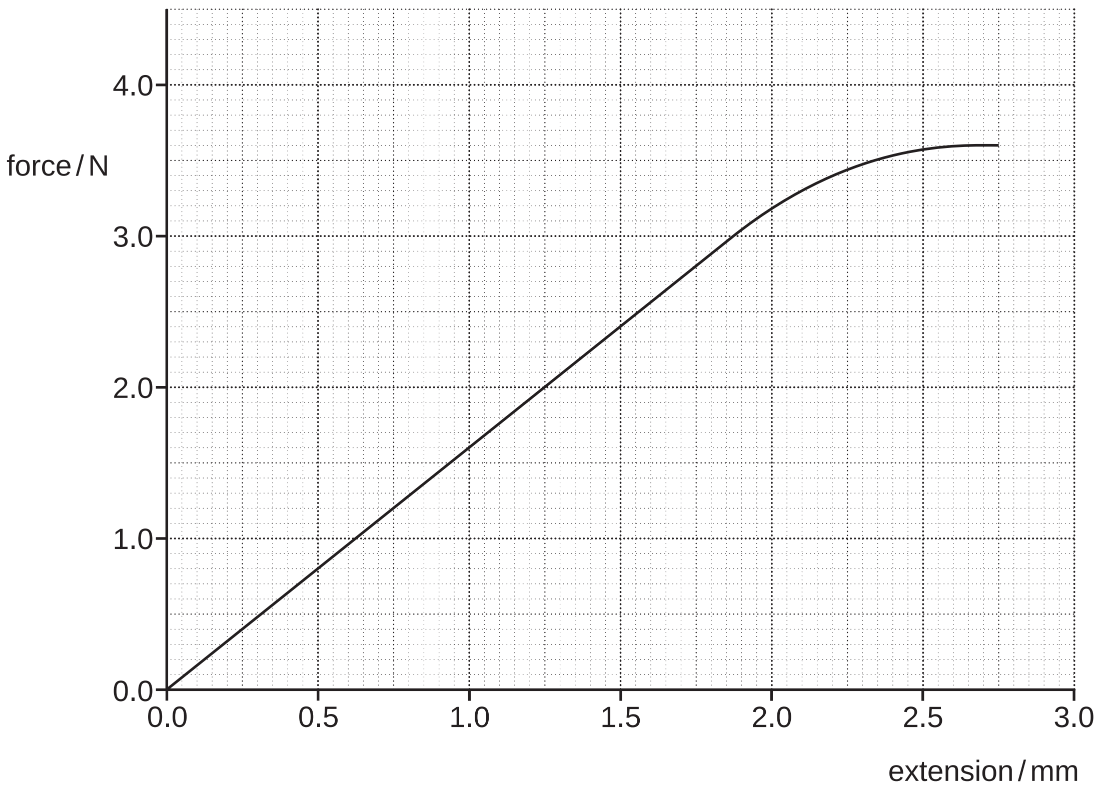
$M$ = ...................................................... kg **[2]**

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

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

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

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




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

Determine the cross-sectional area $A$ of the wire.

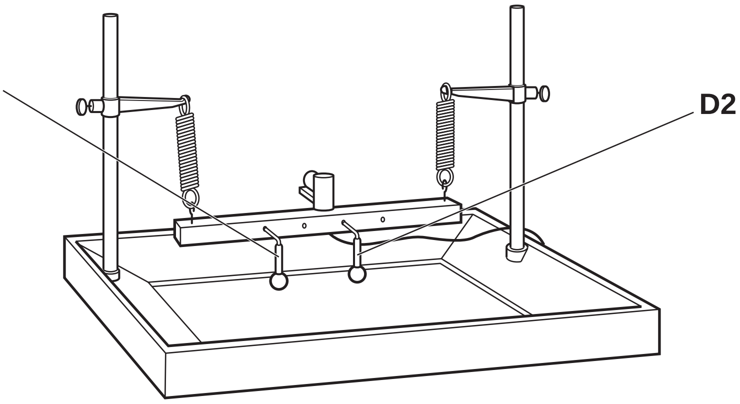
$A$ = ...................................................... m$^2$ **[3]**

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

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

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

**Fig. 5.1**




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

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

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

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

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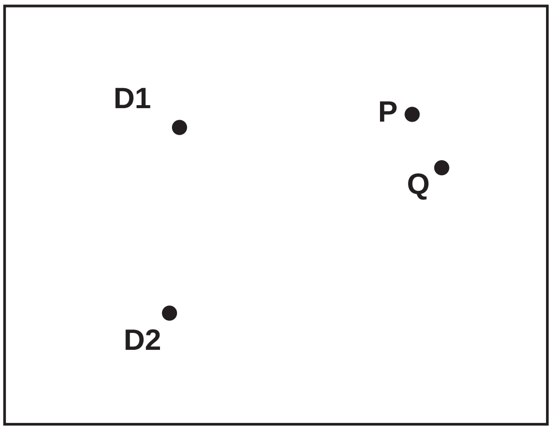
**(b)** Calculate the frequency *f* of the dippers.

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

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

**Fig. 5.2**




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

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

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

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...................................................................................................................... **[3]**

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

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

$\phi$ = ...................................................... rad **[3]**

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

**Fig. 6.1**

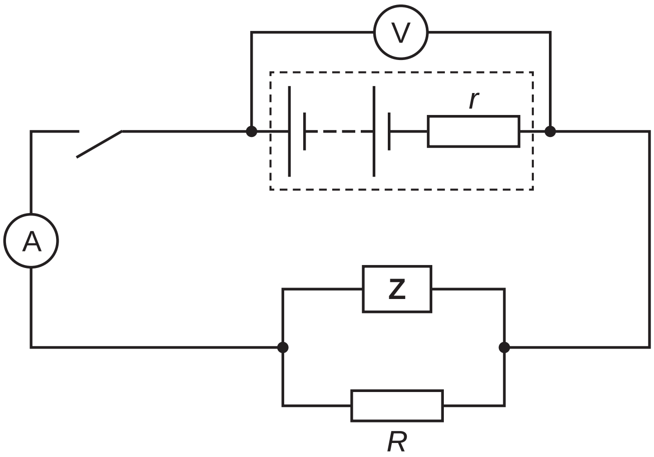
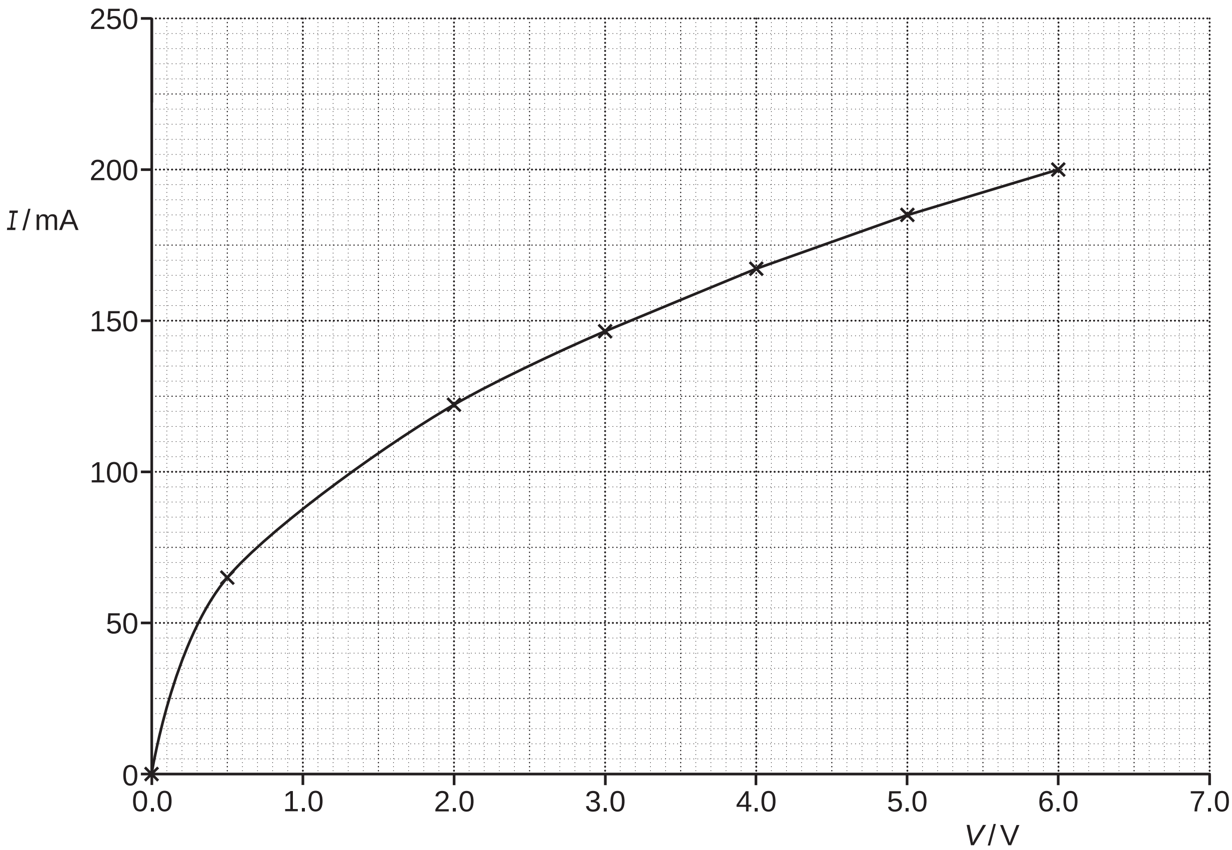



**Fig. 6.2** shows the current *I* and potential difference *V* characteristic for the electrical component **Z**.

**Fig. 6.2**



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

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**(b)** The switch is initially open.

The voltmeter reading is 5.72 V

The following voltmeters are available:

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

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

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

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

**(c)** The switch is now closed.

The ammeter and voltmeter readings are:

Ammeter reading = 220 mA

Voltmeter reading = 4.80 V

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

**[2]**

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

*E* = ........................................................... V

*r* = ........................................................... Ω

**[3]**

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

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

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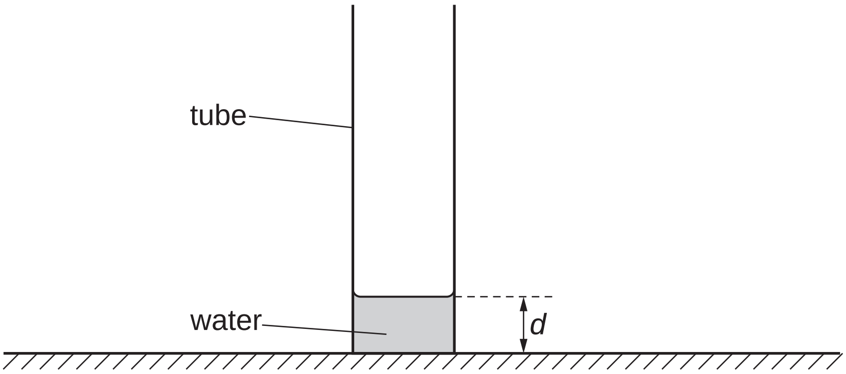
**7*** A student carries out an experiment to determine the speed $v$ of sound in air. The student forms stationary sound waves in a resonance tube with water at the bottom as shown in **Fig. 7.1**.

**Fig. 7.1**




The depth of the water is $d$.

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

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

The experiment is repeated for different values of $d$.

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

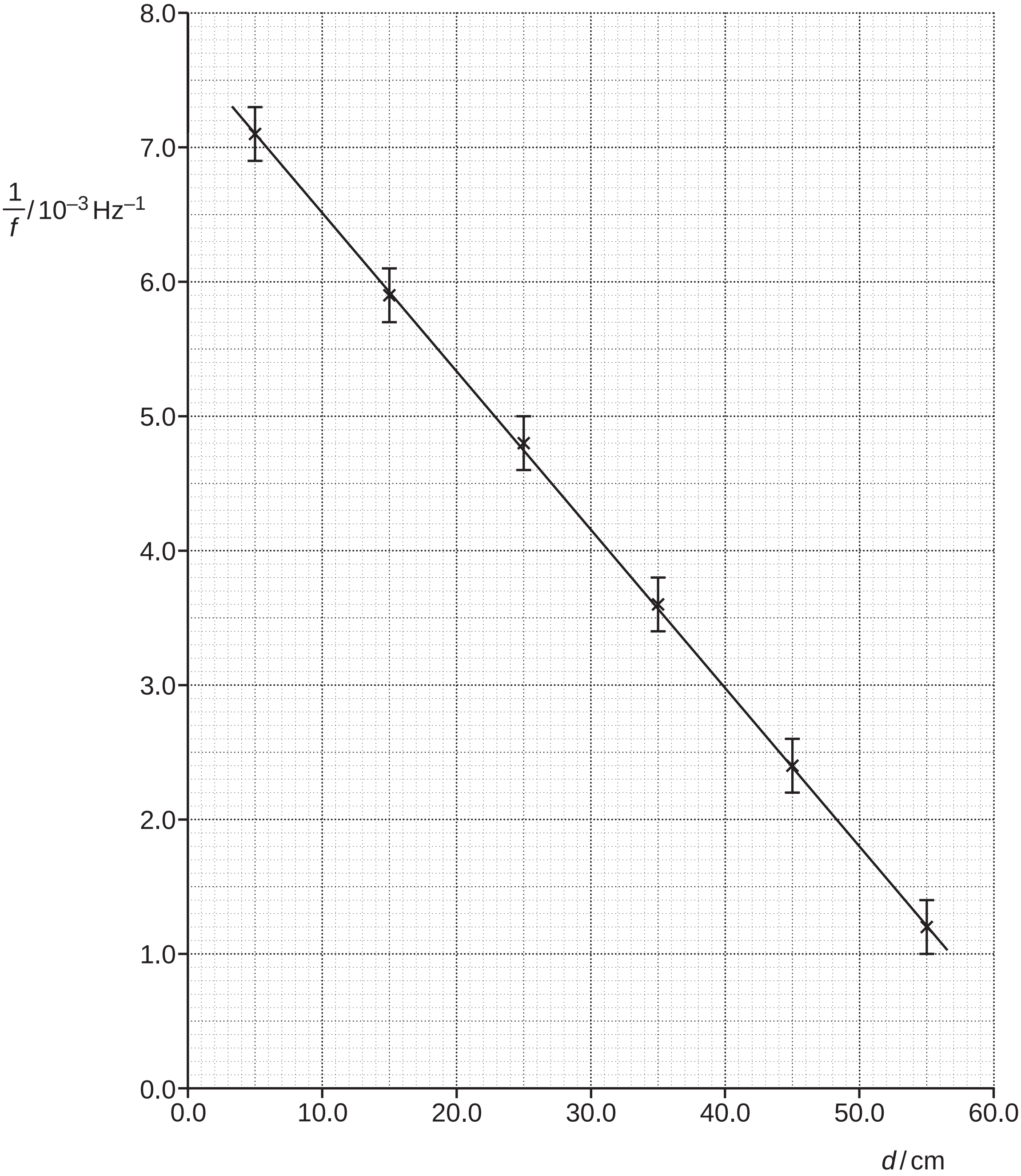
| $d$ / cm | $f$ / Hz | $\frac{1}{f}$ / $10^{-3}$ $Hz^{-1}$ |
|---|---|---|
| 5.0 | 140 | 7.1 ± 0.2 |
| 15.0 | 170 | 5.9 ± 0.2 |
| 25.0 | 210 | 4.8 ± 0.2 |
| 35.0 | 280 | 3.6 ± 0.2 |
| 45.0 | 420 | 2.4 ± 0.2 |
| 55.0 | 840 | 1.2 ± 0.2 |

It is suggested that the relationship between $f$ and $d$ is

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

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

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



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

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

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

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

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

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

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

**[1]**

**(ii)** Determine the wavelength $\lambda$ of the incident electromagnetic radiation.

$\lambda$ = ...................................................... m **[3]**

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

State the change, if any, on

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

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**(ii)** the rate of emission of the photoelectrons.

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**END OF QUESTION PAPER**

## ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).