

Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level PHYSICS

Paper 3 Section A

Thursday 15 June 2023

Morning

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 70 minutes on this section.

Materials

For this paper you must have:

- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 45.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use

Question	Mark
1	
2	
3	
TOTAL	



J U N 2 3 7 4 0 8 3 A 0 1

Section AAnswer **all** questions in this section.**0 1**

A stroboscope emits bright flashes of white light.
The duration of each flash and the frequency of the flashes can be varied.

Table 1 shows information about the stroboscope.

Table 1

	Minimum	Maximum
Duration of each flash / μs	60	300
Frequency of flashes / Hz	1	150

The duration of each flash is T_1 .

The time from the start of a flash to the start of the next flash is T_2 .

The duty cycle of a stroboscope is defined as $\frac{T_1}{T_2}$.

0 1 . 1

What is the maximum duty cycle of the stroboscope?

Tick (✓) **one** box.

[1 mark]

6.0×10^{-5}

☐

3.0×10^{-4}

☐

9.0×10^{-3}

☐

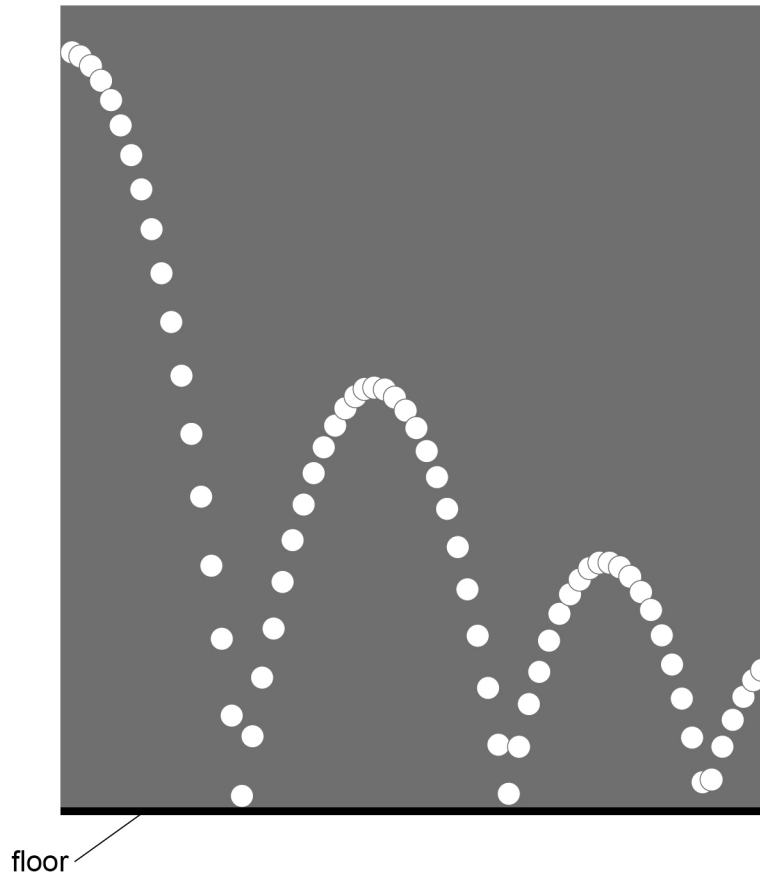
4.5×10^{-2}

☒


0 1 2

Figure 1 shows images produced in an experiment in which a bouncing ball is illuminated by a stroboscope. The stroboscope flashes at a constant frequency.

Figure 1



Suggest why T_1 must be very short for this experiment.

[1 mark]

So that each image of the ball is sharp (not blurred or elongated): the ball moves a negligible distance during each flash, so its position in each image can be determined.

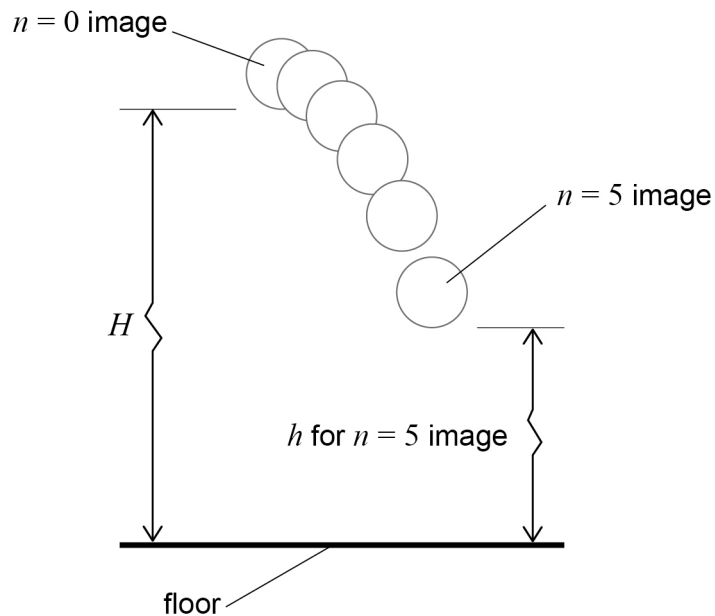
Question 1 continues on the next page

Turn over ►



Figure 2 shows the first six images starting with $n = 0$, where n is the image number.

Figure 2



The images are used to determine:

H , the vertical distance from the bottom of the ball to the floor when $n = 0$

h , the vertical distance from the bottom of the ball to the floor for each non-zero value of n .

The $n = N$ image is produced at the instant that the ball hits the floor for the first time. For n between 0 and N it can be shown that

$$H - h = \frac{u_0 n}{f} + \frac{g}{2} \left(\frac{n}{f} \right)^2$$

where

u_0 is the vertical velocity of the ball when $n = 0$

g is the acceleration due to gravity

f is the frequency of the flashes.



0 1 . 3

In order to find g , a graph is plotted with values of $\frac{H-h}{n}$ on the y -axis.

Suggest what is plotted on the x -axis.

Go on to explain how g is determined from this graph.

[3 marks]

*Dividing the equation by n gives $(H - h)/n = u_0/f + (g/2f^2) \times n$,
which has the form $y = c + mx$.*

*So plot n , the image number, on the x -axis. The graph is a straight line
with gradient $g/2f^2$ and y -intercept u_0/f .*

Find the gradient of the line of best fit, then $g = \text{gradient} \times 2f^2$.

The following data are recorded.

$$H = 1550 \text{ mm}$$

$$f = 31.0 \text{ Hz}$$

The graphical analysis of data from **Figure 1** gives g as 9.79 m s^{-2} .

0 1 . 4

Determine u_0 .

[3 marks]

From Figure 1 the ball first hits the floor at image $n = N = 17$, where $h = 0$

$$t = n \div f = 17 \div 31.0 = 0.548 \text{ s}$$

$$H = u_0 t + \frac{1}{2} g t^2 \quad (\text{equation above with } h = 0)$$

$$1.550 = u_0 \times 0.5484 + \frac{1}{2} \times 9.79 \times 0.5484^2$$

$$1.550 = 0.5484 u_0 + 1.472$$

$$u_0 = (1.550 - 1.472) \div 0.5484 = 0.142 \text{ m s}^{-1}$$

$$u_0 = \underline{\quad 0.14 \quad} \text{ m s}^{-1}$$

Question 1 continues on the next page

Turn over ►



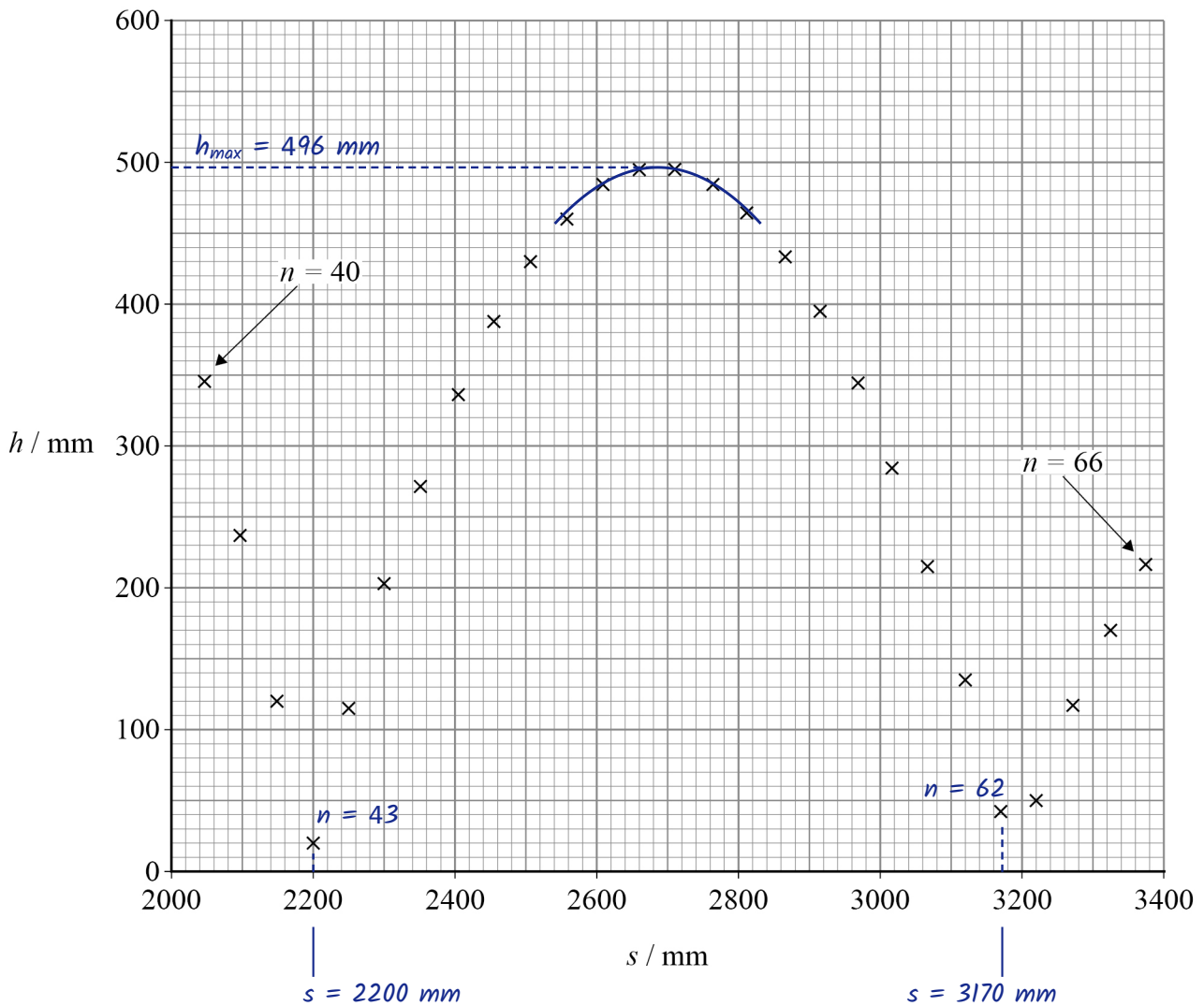
Figure 3 shows positions of the bottom of the ball for $n = 40$ to $n = 66$

In this range of positions, the ball makes contact with the floor for the second and third times.

Values of h , the vertical distance from the bottom of the ball to the floor, are plotted on the y -axis.

Values of s , the horizontal displacement from a point on the floor below the centre of the $n = 0$ image, are plotted on the x -axis.

Figure 3



0 1 . 5

Determine, in mm s^{-1} , the horizontal velocity of the ball between the second and third contacts of the ball with the floor.

[2 marks]

Images are $1/31.0$ s apart. Between the contacts the ball goes from

$n = 43$ ($s = 2200$ mm) to $n = 62$ ($s = 3170$ mm): 19 intervals

horizontal displacement = $3170 - 2200 = 970$ mm

time = $19 \div 31.0 = 0.613$ s

horizontal velocity = $970 \div 0.613 = 1580$ mm s^{-1}

horizontal velocity = 1580 mm s^{-1}

0 1 . 6

Determine the time between the second and third contacts. Annotate **Figure 3** to show your method.

[3 marks]

Smooth curve through top points on Figure 3: $h_{\text{max}} = 496$ mm = 0.496 m

At the top the vertical velocity is zero, so the fall from h_{max} to the floor uses $s = ut + \frac{1}{2}gt^2$ with $u = 0$:

$t = \sqrt{2h_{\text{max}} \div g} = \sqrt{2 \times 0.496 \div 9.79} = 0.318$ s

Rise time = fall time, so time between contacts = $2 \times 0.318 = 0.637$ s

time = 0.64 s

13

Turn over ►

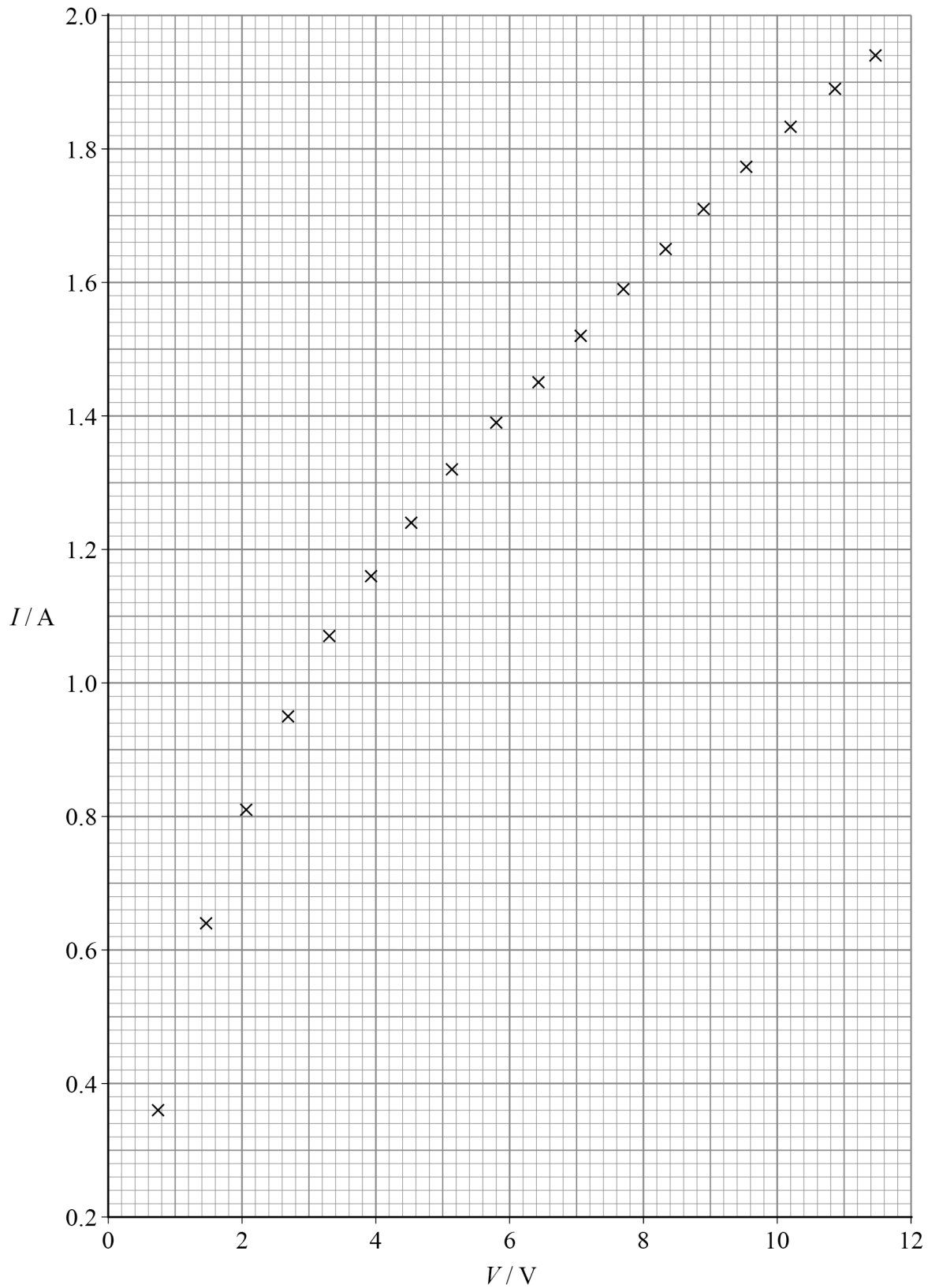


0 2

Figure 4 is a plot of current–voltage data for a filament lamp **L**.

Do not write
outside the
box

Figure 4



The current I was measured as the voltage V across L was increased at a steady rate.
These data were obtained using a current sensor and a voltage sensor connected to a data logger.
The logger recorded data at a rate of 2.5 Hz.

0 2 . 1 Determine, in V s^{-1} , the rate of increase of V .

[2 marks]

Figure 4 has 18 points from $V = 0.76 \text{ V}$ to $V = 11.47 \text{ V}$, so 17 intervals

time between readings = $1 \div 2.5 = 0.40 \text{ s}$

total time = $17 \times 0.40 = 6.8 \text{ s}$

rate = $(11.47 - 0.76) \div 6.8 = 1.58 \text{ V s}^{-1}$

rate of increase of $V = \underline{\hspace{2cm} 1.58 \hspace{2cm}} \text{ V s}^{-1}$

0 2 . 2 State **two** advantages of using data logging for this experiment.

[2 marks]

1 *Data can be collected at a high rate (2.5 readings every second),
many more readings in a short time than could be taken by hand.*

2 *The I and V readings are taken simultaneously and stored digitally, so
they can easily be processed and graphed on a computer or
spreadsheet.*

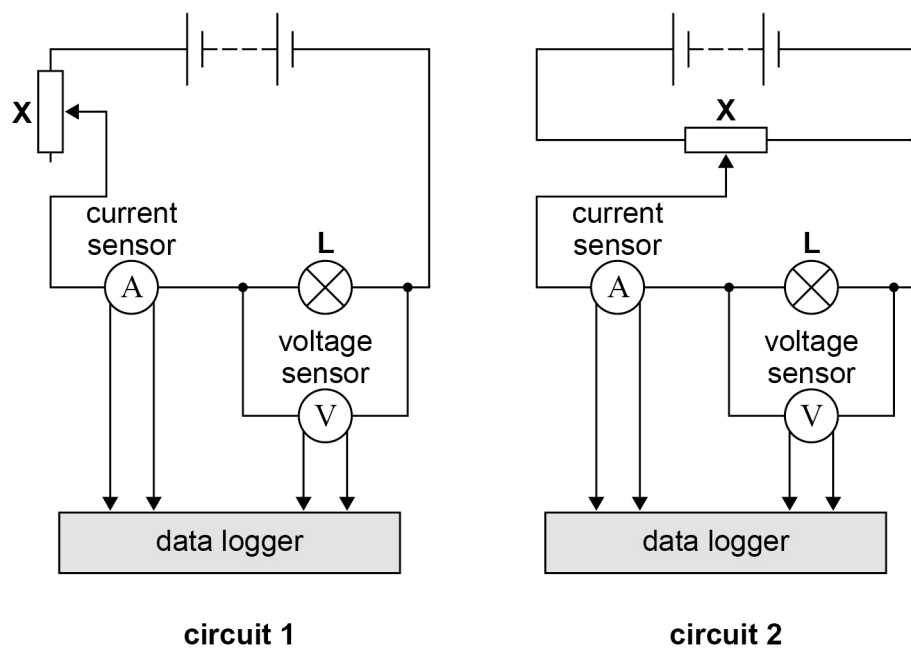
Question 2 continues on the next page

Turn over ►



0 2 . 3 Figure 5 shows two circuits that can be used to collect current–voltage data.

Figure 5



The dc supply has an emf of 12 V and negligible internal resistance.
The current sensor and the voltage sensor behave as ideal meters.

In circuit 1:

- **X** is used as a variable resistor with a maximum resistance of $14.9\ \Omega$
- when **X** is set to maximum resistance, the resistance of **L** is $2.3\ \Omega$.

In circuit 2, **X** is used as a potential divider.



Discuss, with reference to circuit **1** and circuit **2**, whether either circuit can produce all the data shown in **Figure 4**.

Support your answer with a calculation.

[4 marks]

Circuit 1 with X at maximum resistance (smallest current):

$$\text{total resistance} = 14.9 + 2.3 = 17.2 \, \Omega$$

$$\text{minimum } I = \varepsilon \div R = 12 \div 17.2 = 0.70 \, \text{A}$$

$$\text{minimum } V \text{ across } L = IR = 0.698 \times 2.3 = 1.6 \, \text{V}$$

Figure 4 has data points with $I = 0.36 \, \text{A}$ ($V = 0.76 \, \text{V}$) and $I = 0.64 \, \text{A}$ ($V = 1.45 \, \text{V}$), which are below this minimum of $0.70 \, \text{A}$ ($1.6 \, \text{V}$).

Circuit 1 cannot produce all of the data in Figure 4: its minimum current is $0.70 \, \text{A}$, but the first two points in Figure 4 have currents less than $0.70 \, \text{A}$ ($0.36 \, \text{A}$ and $0.64 \, \text{A}$).

Circuit 2 can produce all of the data: as a potential divider X allows the pd across L to be varied continuously from $0 \, \text{V}$ up to the full $12 \, \text{V}$, covering the whole range $0.76 \, \text{V}$ to $11.47 \, \text{V}$ in Figure 4.

Question 2 continues on the next page

Turn over ►



Table 2 shows some values of V that are plotted on **Figure 4** and corresponding results for I and for the power P dissipated in **L**.

Table 2

V / V	I / A	P / W
3.30	1.07	3.53
5.17	1.32	6.82
7.69	1.59	12.2
9.58	1.77	17.0
11.47	1.94	22.3

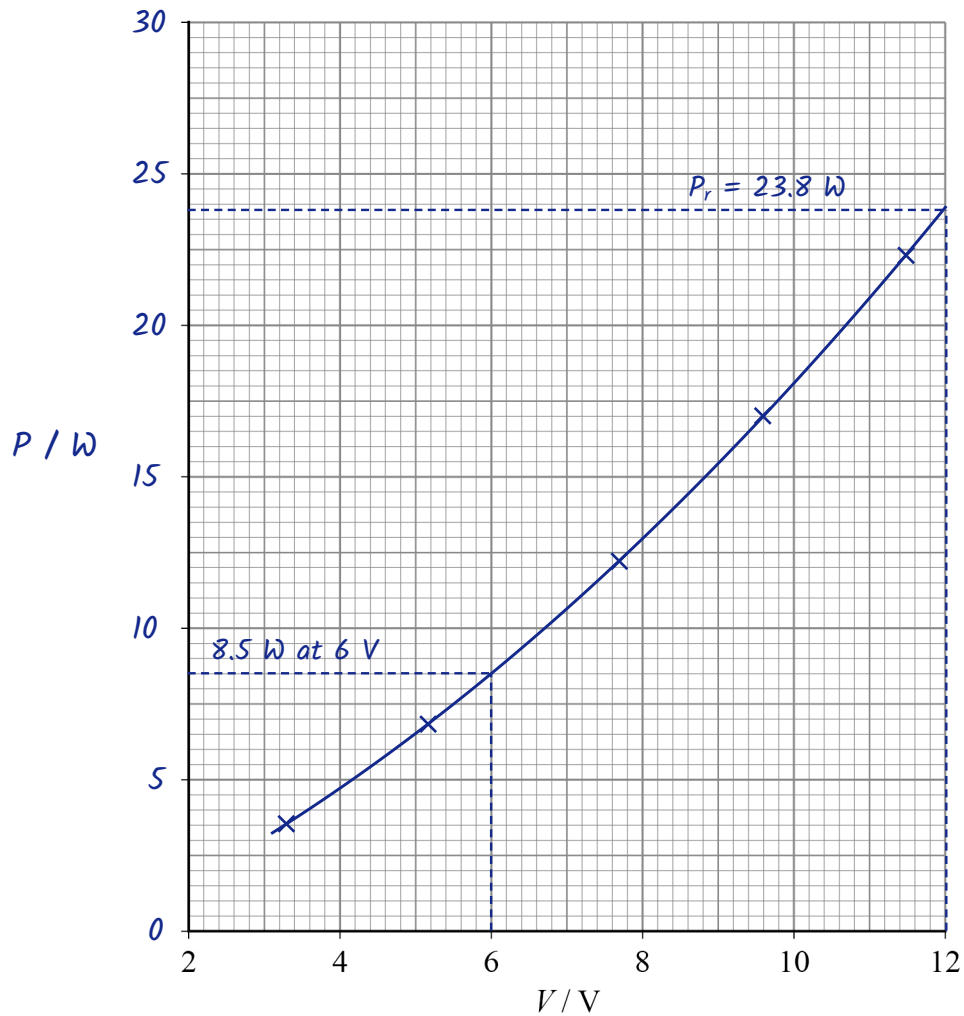
0 2 . 4 Complete **Table 2**.

[3 marks]



0 2 . 5

Plot on **Figure 6** a graph of P against V .
You should use only the data in your completed **Table 2**.

[3 marks]**Figure 6**

Question 2 continues on the next page

Turn over ►



0 2 . 6

L is connected to a 12 V power supply of negligible internal resistance.
L then dissipates its rated power P_r .

A second lamp, identical to **L**, is now connected in series with **L**.

Determine the percentage of P_r that is dissipated in this circuit.

[2 marks]

Extrapolating the curve on Figure 6 to $V = 12$ V: $P_r = 23.8$ W

In series, the identical lamps share the 12 V, so each has 6.0 V across it

From Figure 6, P at 6.0 V = 8.5 W per lamp

total power = $2 \times 8.5 = 17.0$ W

percentage = $17.0 \div 23.8 \times 100 = 71$ %

percentage = 71 %

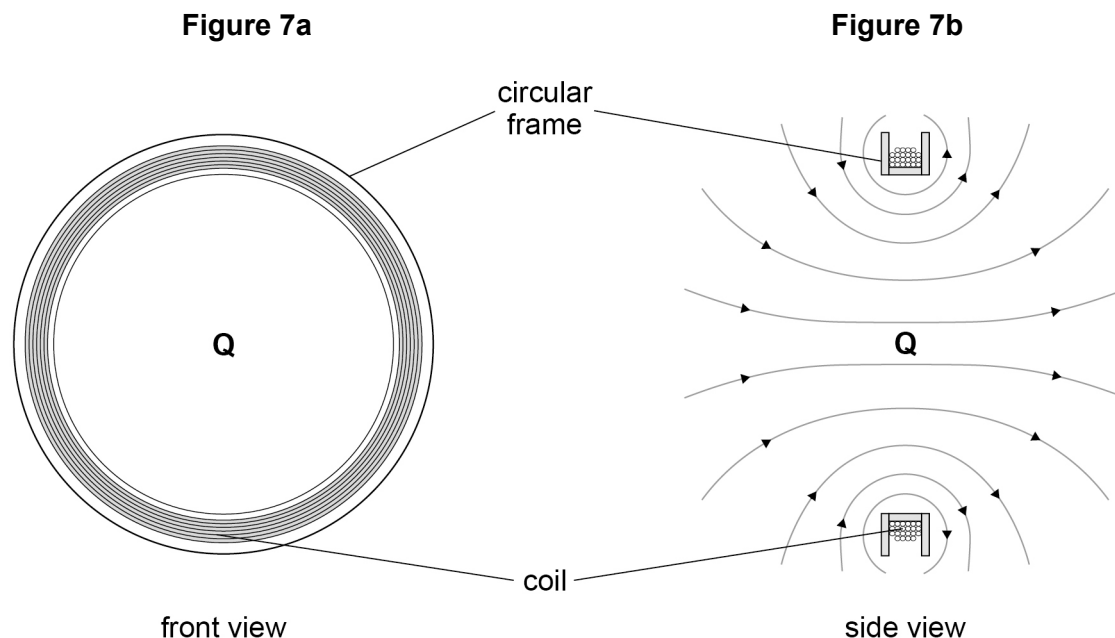
16



0 3

Figure 7a shows the front view of a vertical coil mounted on a circular frame.

Figure 7b is a side view showing a section through the frame and coil. A constant direct current in the coil produces magnetic flux represented by the magnetic field lines on this diagram.



Point **Q** is at the centre of the coil.

A sensor placed at **Q** detects B_H , the horizontal component of the magnetic flux density.

The effect of the Earth's magnetic field at **Q** is negligible.

0 3 . 1

Discuss whether a search coil is a suitable sensor to detect B_H .

[2 marks]

A search coil is not suitable. An emf is only induced in a search coil when the flux through it (flux linkage) changes.

The current in the coil is constant (dc), so the flux through a stationary search coil at Q is constant and no emf would be induced, so it cannot measure B_H .

Question 3 continues on the next page

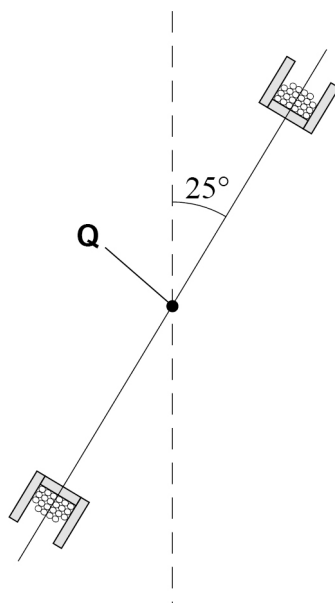
Turn over ►



B_H is measured at **Q** with the coil vertical.

The coil is now rotated about **Q** through 25° as shown in **Figure 8**.
The current in the coil does not change.

Figure 8



A new measurement of B_H is made with the coil fixed in this new position.

0 3 . 2

Determine the percentage change in B_H produced by this rotation of the coil.
Show your working.

[2 marks]

Only the horizontal component of B is detected: $B_H = B \cos \theta$

after rotation $B_H = B \cos 25^\circ = 0.906 B$

percentage change = $(0.906 - 1) \times 100 = -9.4 \%$ (a decrease)

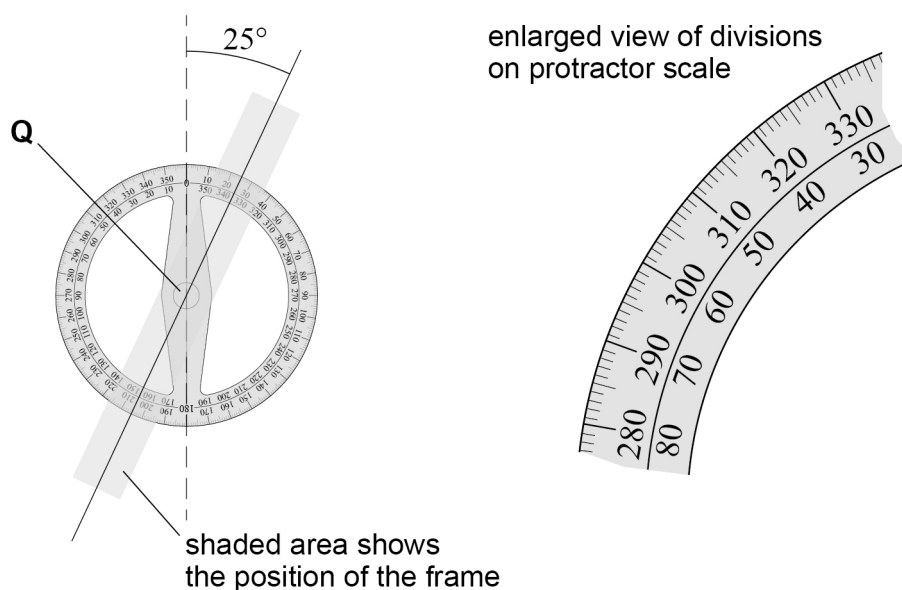
percentage change = -9.4 %



0 3 . 3

Figure 9 shows a protractor being used to measure the angle through which the coil is rotated.

Figure 9



Estimate the percentage uncertainty in this result.
Justify your answer.

[3 marks]

The protractor scale is marked in 1° divisions, so the uncertainty in each reading (judgement) is $\pm 0.5^\circ$.

The angle is found from two readings (start and final position of the frame), so the uncertainty in θ is $2 \times 0.5^\circ = 1^\circ$.

% uncertainty = $1^\circ \div 25^\circ \times 100 = 4\%$

percentage uncertainty = 4 %

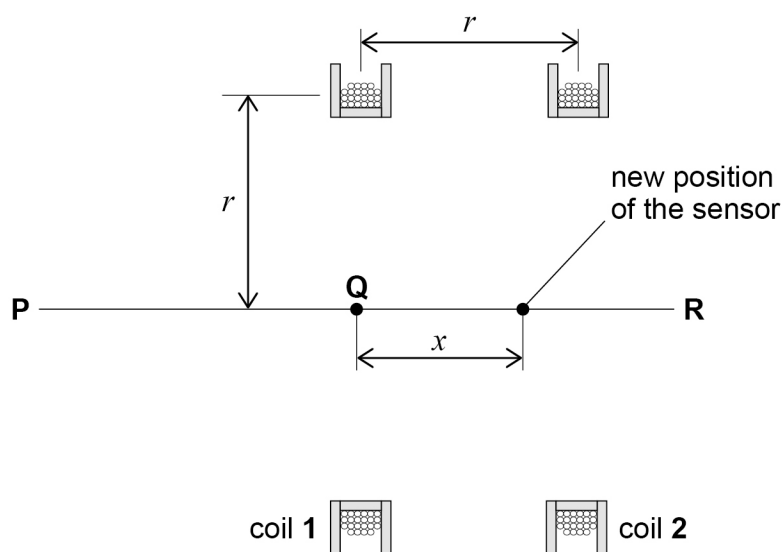
Question 3 continues on the next page

Turn over ►



Figure 10 shows an arrangement of two vertical coils.
Four experiments are done using this arrangement.

Figure 10



Coil **1** and coil **2** are identical and have a radius r .
The coils are separated by a distance r and have a common axis **PR**.
Q is at the centre of coil **1**.

The four different experiments investigate how B_H varies with x , the displacement of the sensor from **Q** along **PR**.

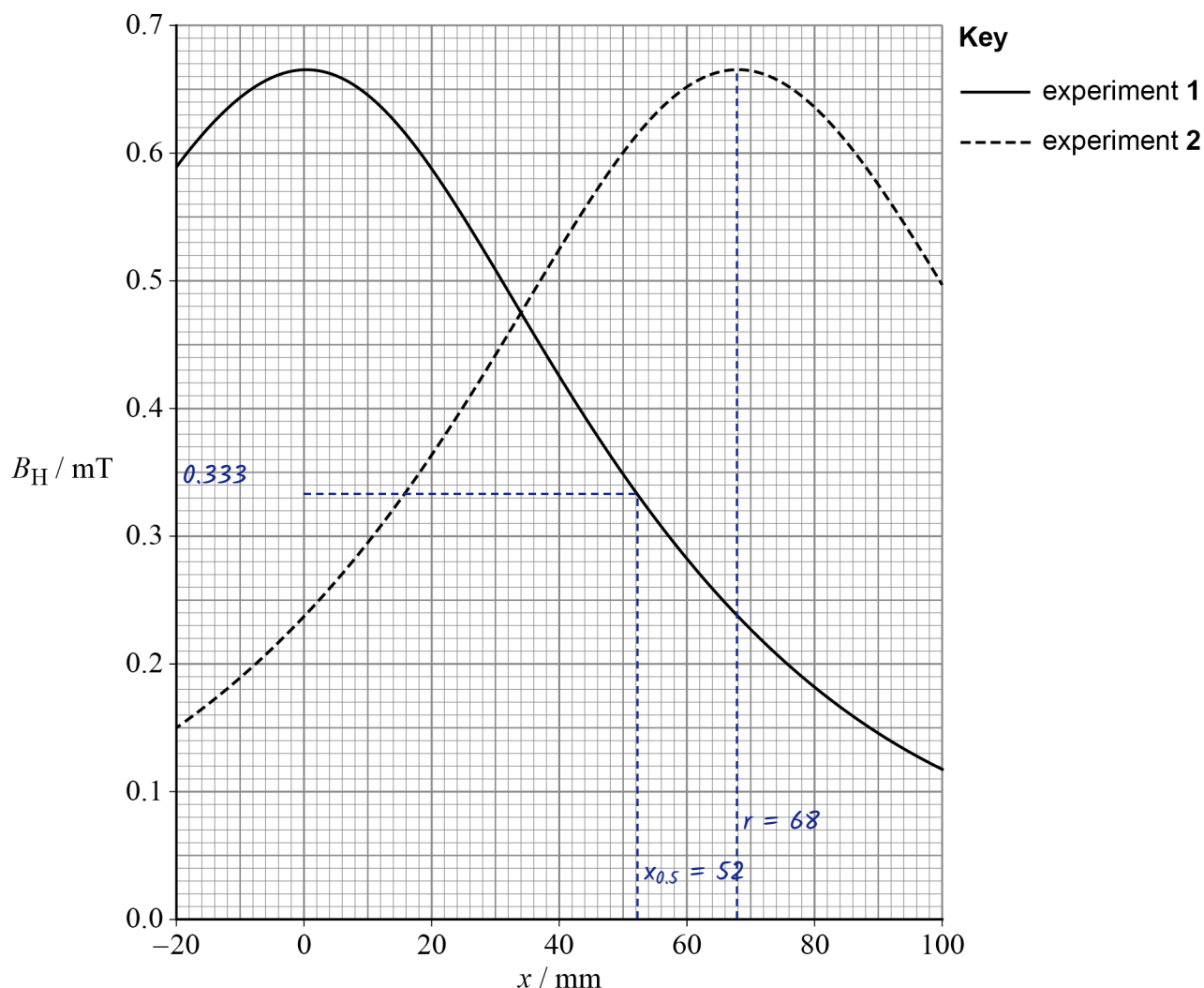
In experiment **1**, the current in coil **1** is 225 mA and the current in coil **2** is zero.

In experiment **2**, the current in coil **1** is zero and the current in coil **2** is 225 mA.



Figure 11 shows the results of experiment 1 and experiment 2.

Figure 11



0 3 4 During experiment 1, B_H is measured with the sensor at **Q**.

The sensor is then moved along **PR** until the value of B_H is halved.

The distance from **Q** to the sensor is $x_{0.5}$

Determine $\frac{x_{0.5}}{r}$

[2 marks]

At **Q** ($x = 0$): $B_H = 0.665 \text{ mT}$; half of this = 0.333 mT at $x_{0.5} = 52 \text{ mm}$

r = separation of the coils = x at the peak for coil 2 = 68 mm

$x_{0.5}/r = 52 \div 68 = 0.76$

$$\frac{x_{0.5}}{r} = 0.76$$

Turn over ►



In experiment **3**, the current in both coils is 225 mA so that the magnetic fields produced by coil **1** and coil **2** are combined.

The resultant B_H has a constant maximum value in the region between $x = \frac{r}{4}$ and

$$x = \frac{3r}{4}$$

0 3 . 5 Deduce, in mT, the value of B_H in this region.

[2 marks]

$r = 68 \text{ mm}$, so the region is $x = 17 \text{ mm}$ to 51 mm . Add the two fields:

at $x = 34 \text{ mm}$: $B_H = 0.475 + 0.475 = 0.95 \text{ mT}$

(check at $x = 17 \text{ mm}$: $B_H = 0.61 + 0.34 = 0.95 \text{ mT}$)

$B_H =$ 0.95 mT

0 3 . 6 State **two** characteristics of the magnetic field lines in this region.

[2 marks]

1 The field lines are parallel to each other (all in the same direction, along PR).

2 The field lines are evenly (equally) spaced.



0 3 . 7

In experiment 4, the current in coil 2 is reversed so that the direction of the magnetic field produced by coil 2 is also reversed.

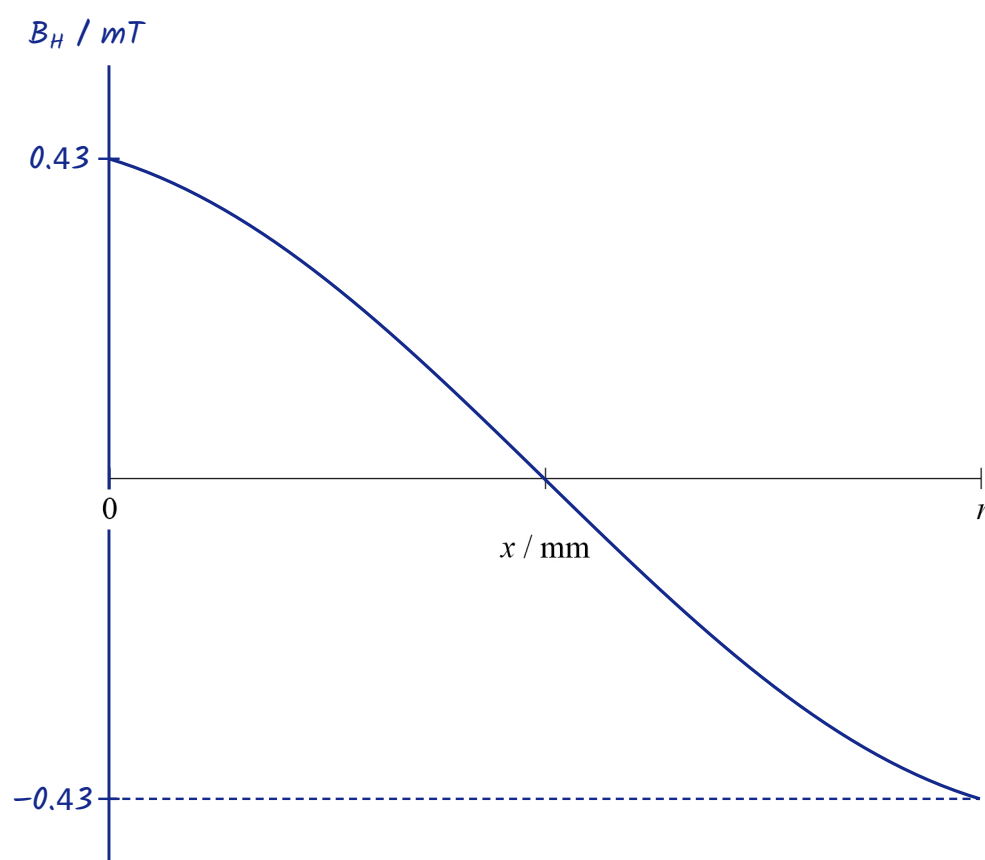
The magnitudes of the currents in coil 1 and coil 2 are still 225 mA.

Sketch a graph to show how B_H varies between $x = 0$ and $x = r$.

The x -axis has been provided for you.

Your graph should include numerical values on your B_H axis that correspond to $x = 0$ and $x = r$.

[3 marks]



END OF QUESTIONS



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



[illegible]

[illegible]