AQA

Please write clearly in block capitals.

| Centre number | 5 | 3 | 6 | 0 | 2 | Candidate number | 8 | 7 | 4 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|

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Forename(s): Lewis

Candidate signature: [signature]

I declare this is my own work.

# A-level PHYSICS

## Paper 3 Section A

ALevelPhysicsOnline.com/aqa-paper-3a

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** | |

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## Section A

Answer **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]**

- $6.0 \times 10^{-5}$ ☐
- $3.0 \times 10^{-4}$ ☐
- $9.0 \times 10^{-3}$ ☐
- $4.5 \times 10^{-2}$ ☑ ✓

$$\frac{T_{1\,max}}{T_{2\,min}} = \frac{300 \times 10^{-6}}{1/150} = 4.5 \times 10^{-2}$$

$$T_{2\,min} = \frac{1}{f_{max}}$$

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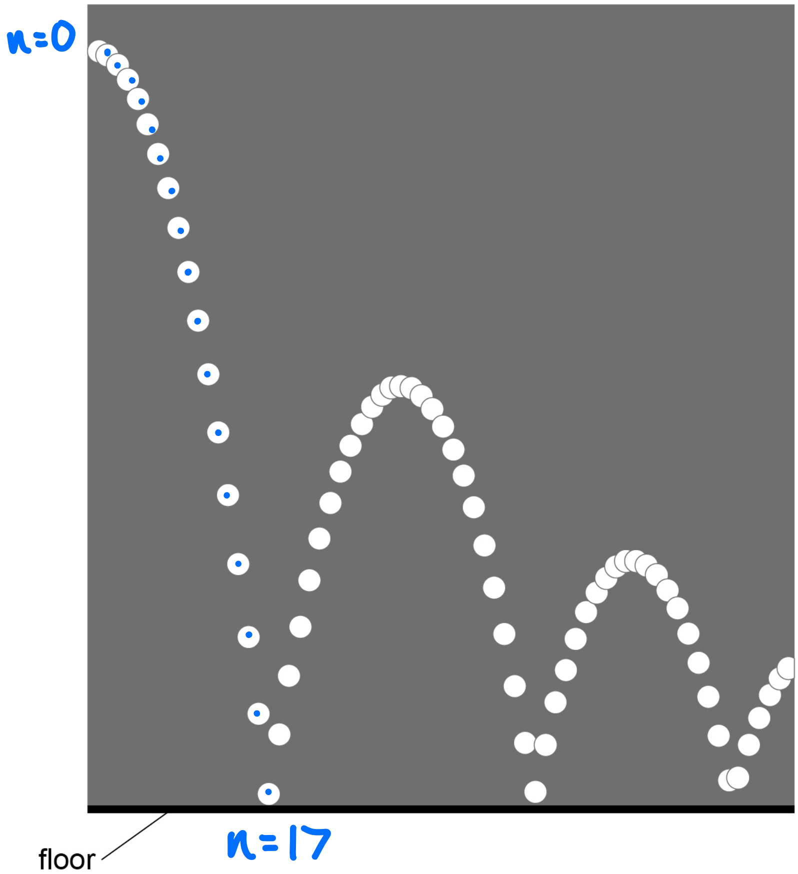
**0 1 . 2** **Figure 1** shows images produced in an experiment in which a bouncing ball is illuminated by a stroboscope.
The stroboscope flashes at a constant frequency.

**Figure 1**




Suggest why $T_1$ must be very short for this experiment.

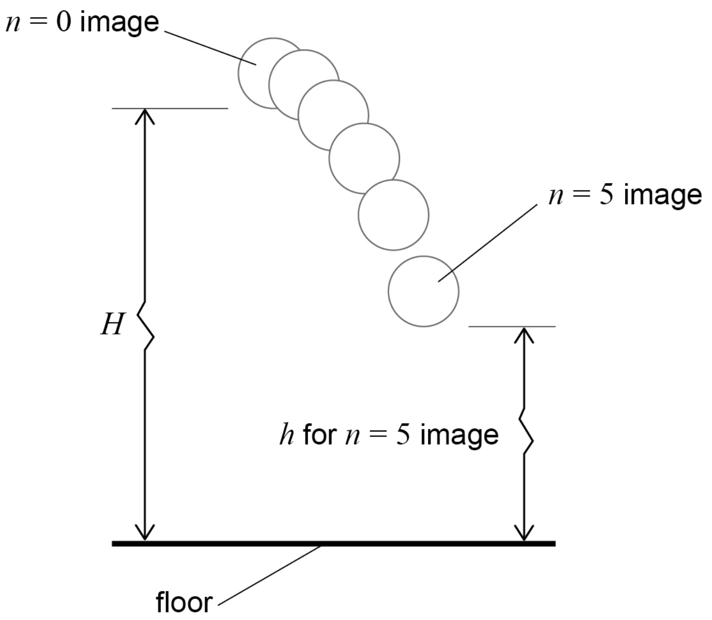
**[1 mark]**

So images of the ball are not blurred. ✓

**Question 1 continues on the next page**

**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.

$$\frac{H-h}{n} = \frac{u_0}{f} + \frac{gn}{2f^2} \checkmark$$

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

$$y = m x + c$$

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**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]**

Plot $\frac{H-h}{n}$ against $n$, gradient $= \frac{g}{2f^2}$ ✓

$\therefore g =$ gradient $\times 2f^2$ ✓

The following data are recorded.

$H = 1550$ mm
$f = 31.0$ 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]**

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

When $h=0$, $n=17$ ✓ (from Fig 1)

$$1.550-0 = \frac{u_0 \times 17}{31.0} + \frac{9.79}{2}\left(\frac{17}{31}\right)^2 \checkmark$$

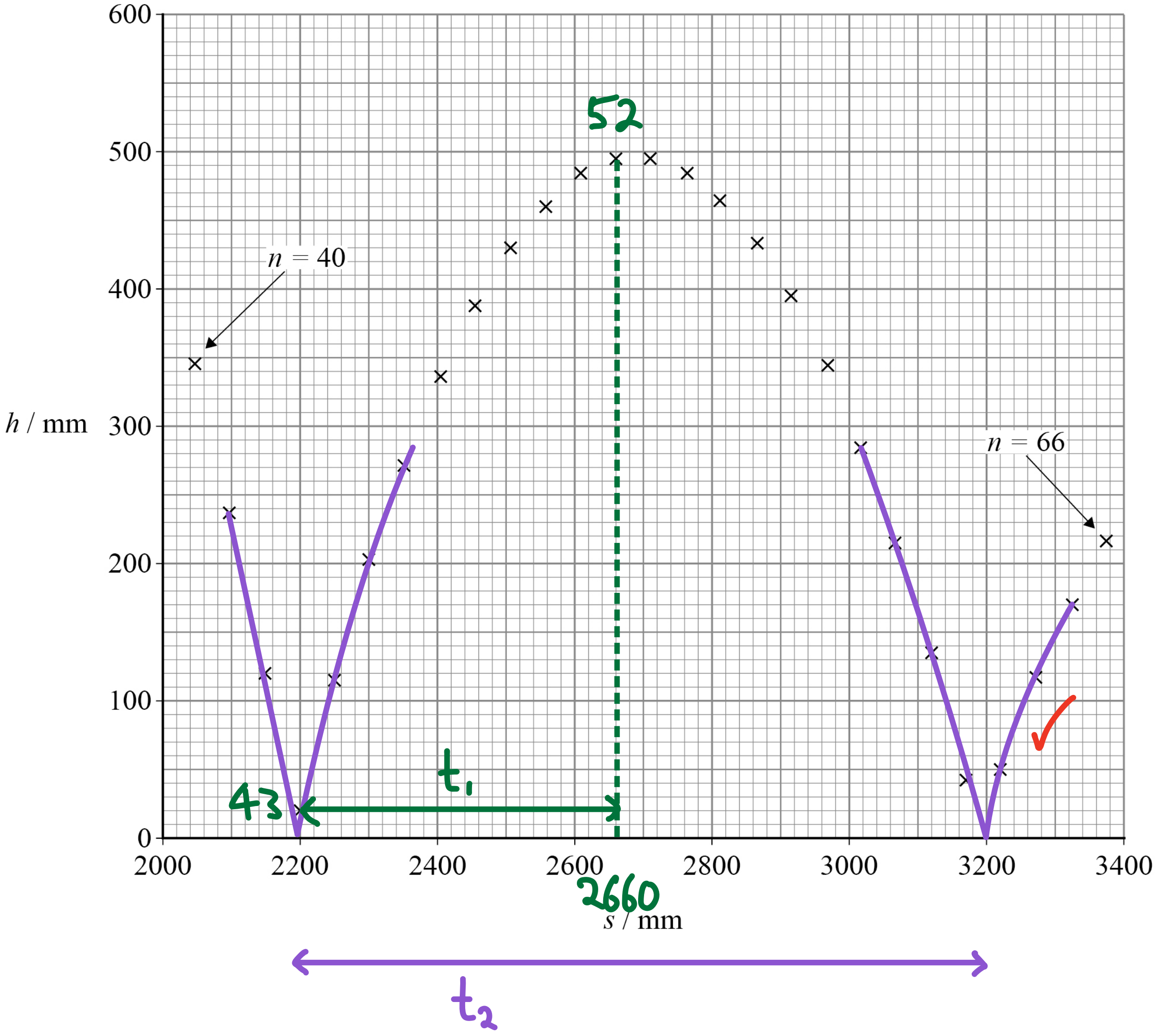
$$u_0 = 0.142$$

$u_0 =$ 0.142 ✓ m s$^{-1}$

Question 1 continues on the next page

**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**



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**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]**

$$v = \frac{s}{t} = \frac{2660-2200}{0.290} = 1586\ mm\ s^{-1}$$

$$T = \frac{1}{f} = \frac{1}{31.0}$$

$$t_1 = 9 \times \frac{1}{31.0} = 0.290\ s$$

52-43

horizontal velocity = 1590 $mm\ s^{-1}$

**0 1 . 6** Determine the time between the second and third contacts.
Annotate **Figure 3** to show your method.

**[3 marks]**

$$t_2 = \frac{s}{v} = \frac{3200-2190}{1586} = 0.6368$$

time = 0.64 s s

13

**0 2** **Figure 4** is a plot of current–voltage data for a filament lamp **L**.

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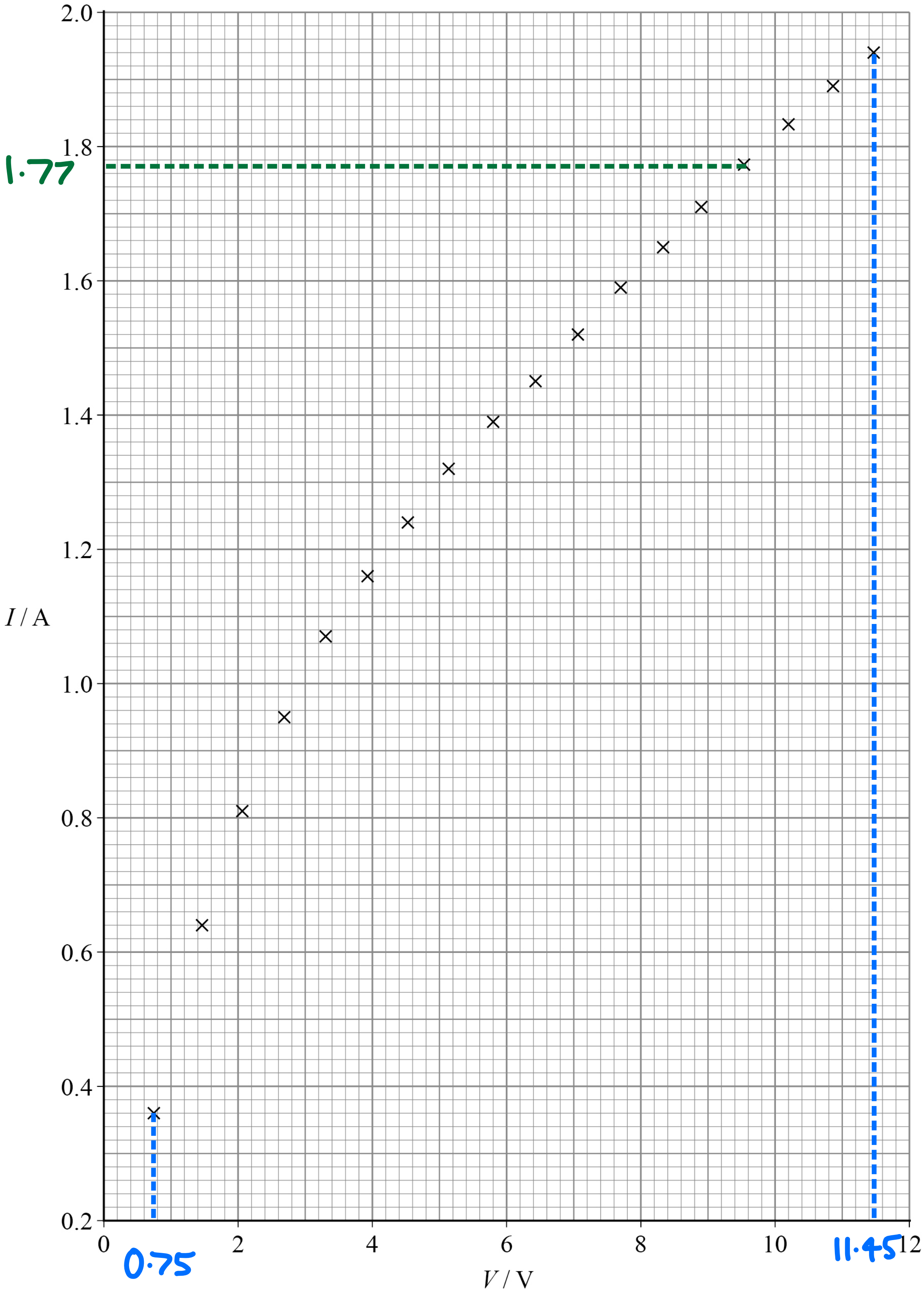
**Figure 4**



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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 $\text{V s}^{-1}$, the rate of increase of $V$.

**[2 marks]**

$T = \frac{1}{f} = \frac{1}{2.5} = 0.40\text{ s}$

17 time intervals from first to last

$\Delta t = 17 \times T = 17 \times 0.40 = 6.8\text{ s}$

$\frac{\Delta V}{\Delta t} = \frac{11.45 - 0.75}{6.8} = 1.574$

rate of increase of $V$ = 1.6 ✓✓ $\text{V s}^{-1}$

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

**[2 marks]**

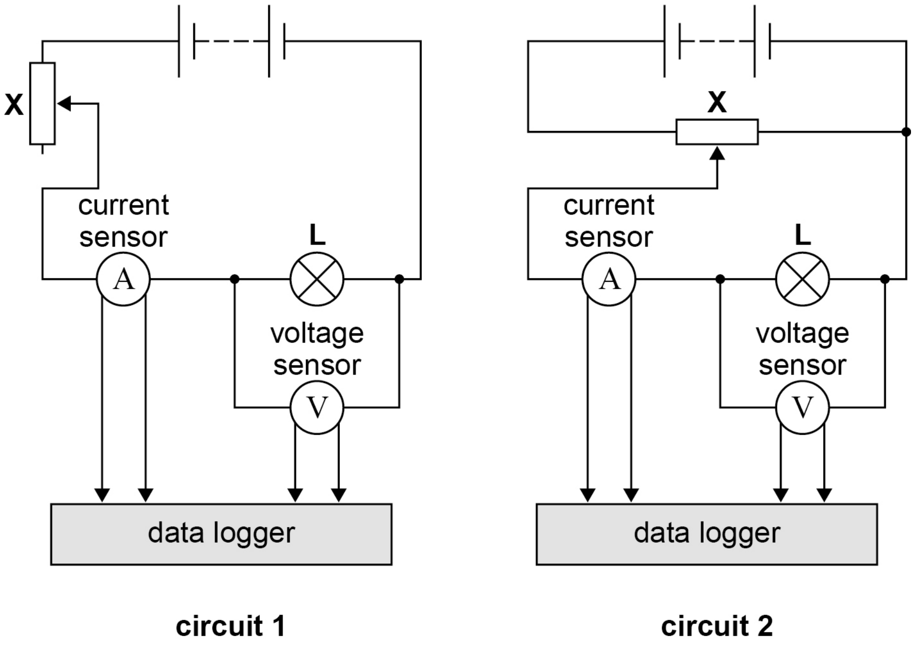
1 Data can be collected at a high rate. ✓

2 Reduces the impact of statistical ✓ error involved in manually reading data.

**Question 2 continues on the next page**

**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 $12\ \text{V}$ 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.

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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 $R_{X(max)} = 14.9\ \Omega$
$R_L = 2.3\ \Omega$

$R_{T(max)} = R_X + R_L = 14.9 + 2.3 = 17.2\ \Omega$

$\therefore I_{min} = \frac{V}{R_{T(max)}} = \frac{12}{17.2} = 0.70\ A$ ✓

On Fig 4, $I_{min} = 0.36 < I_{min}$ in circuit 1
∴ Circuit 1 cannot produce all this data ✓

Circuit 2: p.d across lamp L can be varied between 0V and 12V ✓ ∴ it can produce the data in Fig 4. ✓

**Question 2 continues on the next page**

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**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 |

P=VI

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

**[3 marks]**

From Fig 4

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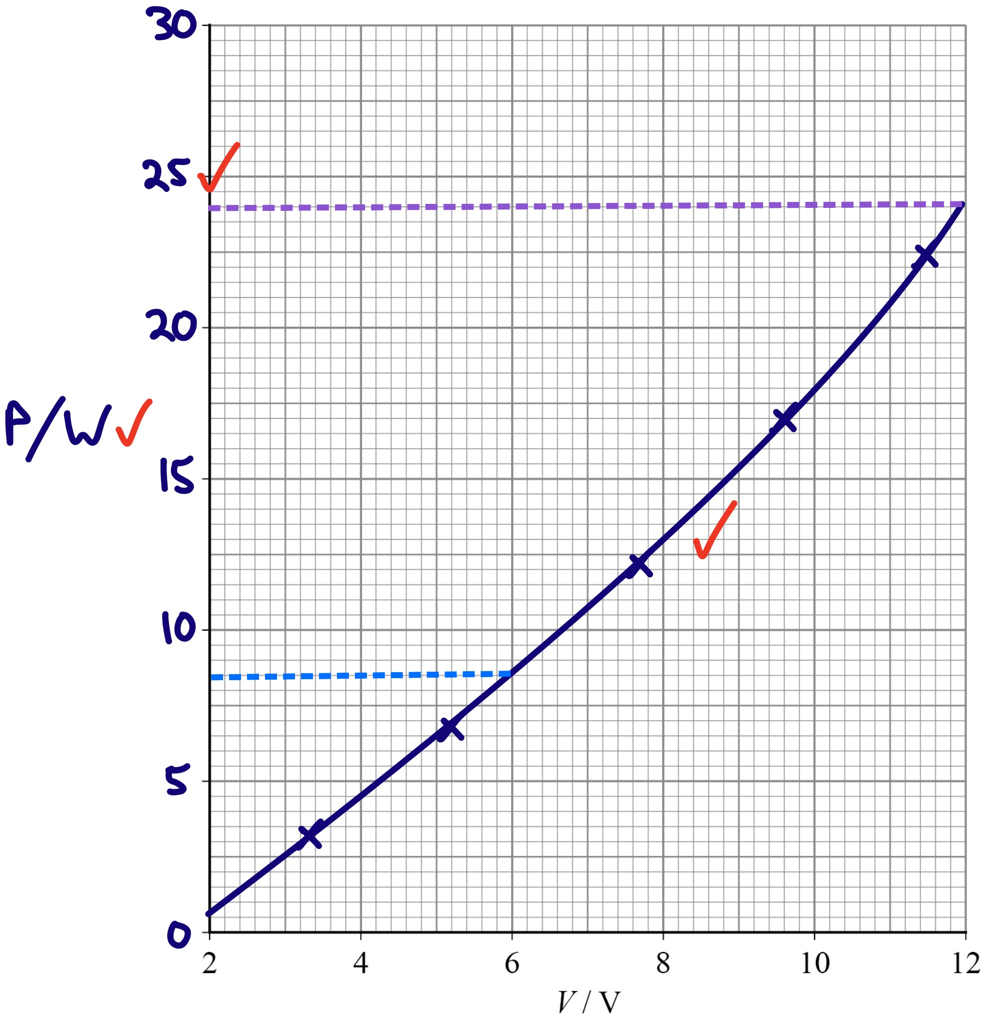
0 2 . 5 Plot on **Figure 6** a graph of $P$ against $V$.
You should use only the data in your completed **Table 2**.

**[3 marks]**

**Figure 6**

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**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]**

$P_r = 24$ W (from Fig 6 at 12 V)

In series, V of second lamp = 6.0 V
∴ read off P at 6.0 V = 8.5 W ✓

percentage = 71 ✓ %

$\% = \frac{P + P}{P_r} \times 100$

$= \frac{2 \times 8.5}{24} \times 100 = 70.8\ \%$

16

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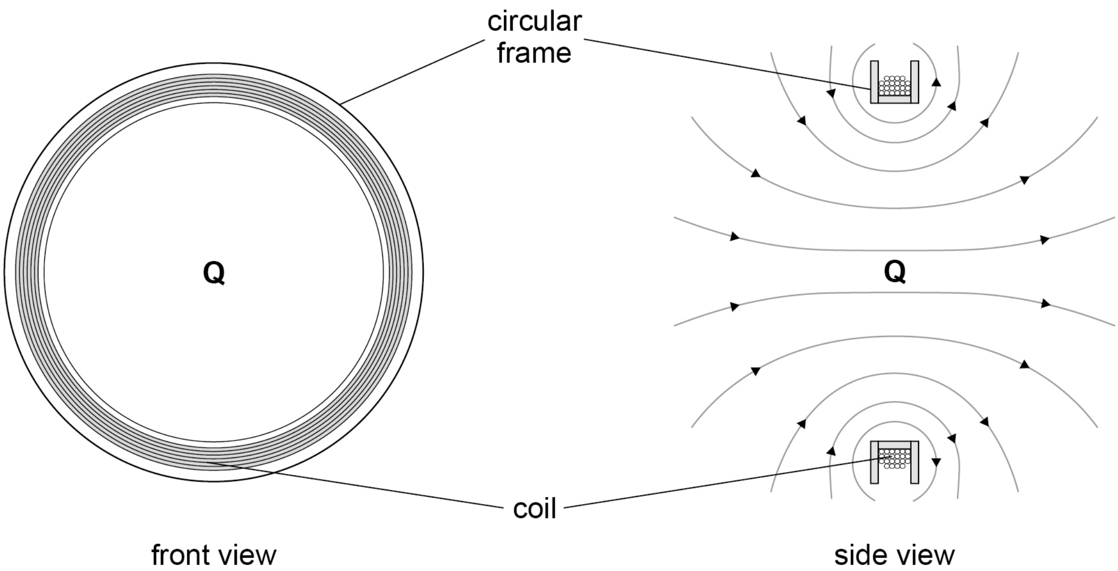
**0 3** **Figure 7a** shows the front view of a vertical coil mounted on a circular frame.

**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.

**Figure 7a** **Figure 7b**




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 needs to be cut by a changing flux. ✓ In this case the flux is constant ∴ no induced emf. ✓ So it's not suitable.

**Question 3 continues on the next page**

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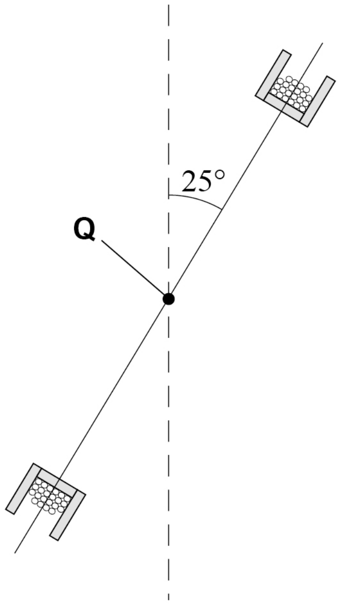
$B_H$ is measured at **Q** with the coil vertical.

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]**

$$\% B_H = \frac{B_H - B_H \cos 25°}{B_H} \times 100 = (1 - \cos 25) \times 100$$

$$= 9.37$$

percentage change = 9.4 %

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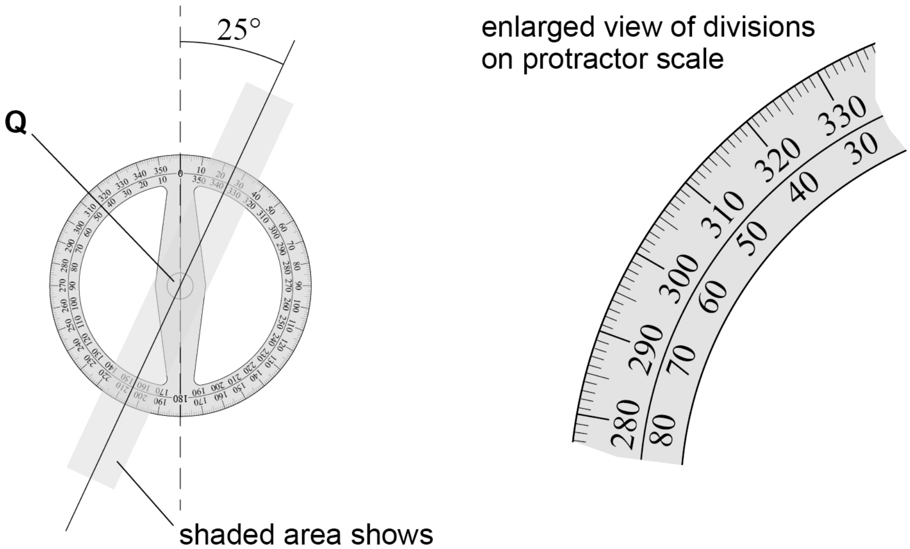
**0 3 . 3** **Figure 9** shows a protractor being used to measure the angle through which the coil is rotated.

**Figure 9**




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

**[3 marks]**

% uncertainty = $\frac{1}{25} \times 100$ = 4.0%

Absolute uncertainty in $\theta$ = 1°, due to 0.5° ✓ in each of the two readings ✓ (at 0° and 25°).

percentage uncertainty = 4.0 ✓ %

**Question 3 continues on the next page**

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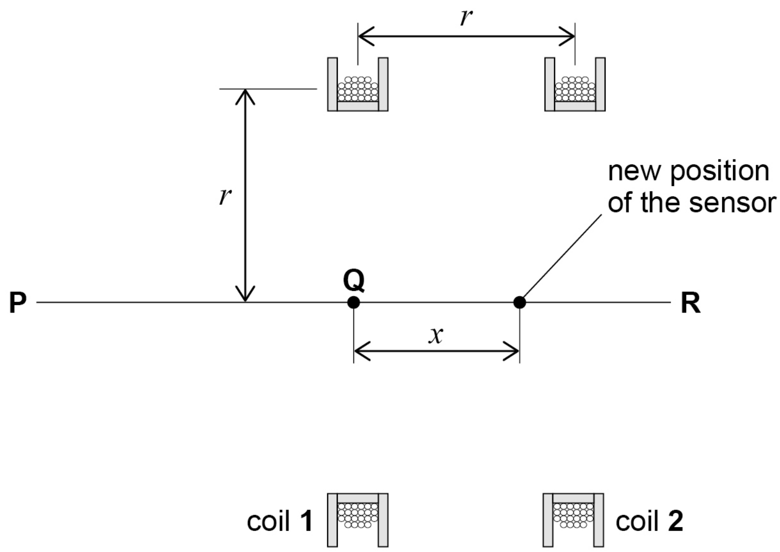
**Figure 10** shows an arrangement of two vertical coils.
Four experiments are done using this arrangement.

**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 $225\ mA$.

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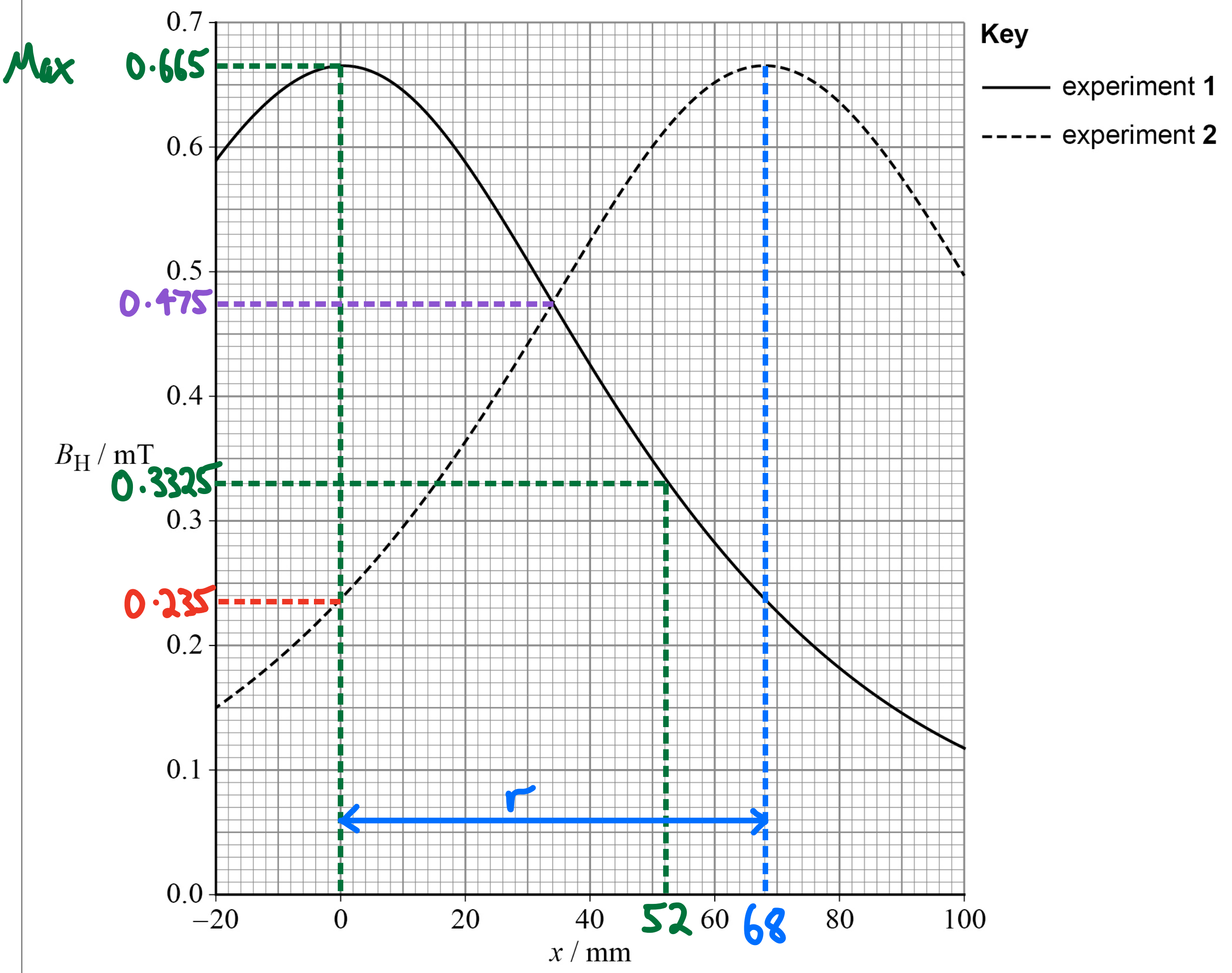
**Figure 11** shows the results of experiment **1** and experiment **2**.

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

$B_H$ at Q = 0.665 mT

**[2 marks]**

$x_{0.5}$ at $B_H/2 = 0.665/2 = 0.3325 \therefore x_{0.5} = 52$ mm ✓

$r = 68$ mm $\quad \frac{x_{0.5}}{r} = \frac{52}{68} = 0.7647$

$\frac{x_{0.5}}{r} =$ 0.76 ✓

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In experiment **3**, the current in both coils is $225\ \text{mA}$ 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]**

Add up two values of $B_H$ when it is the same for coil 1 and 2 = 2×0.475
= 0.95 mT

$B_H$ = 0.95 ✓✓ mT

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

**[2 marks]**

1 Field lines are parallel. ✓

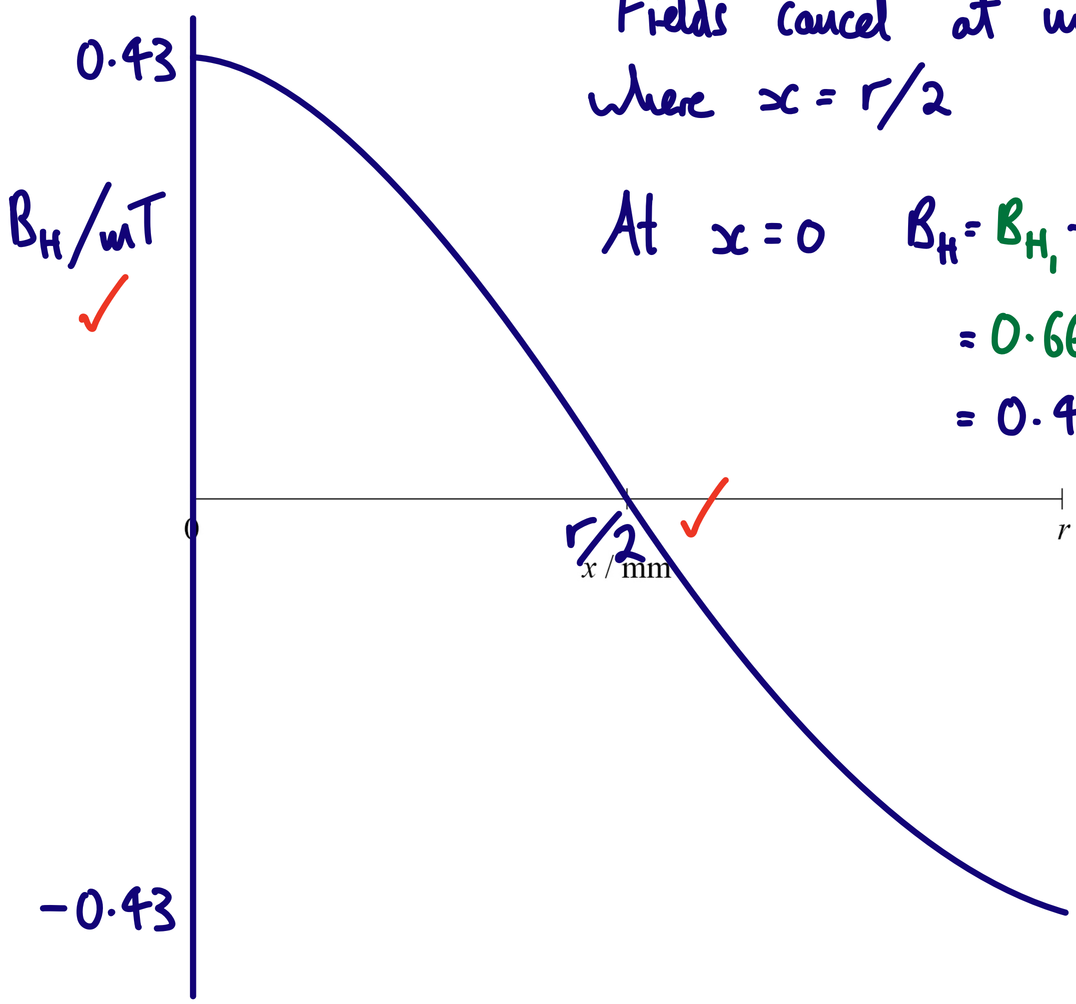
2 They are evenly spaced. ✓

**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]**




Fields cancel at midpoint where $x = r/2$

At $x = 0$ $B_H = B_{H_1} - B_{H_2}$

$= 0.665 - 0.235$

$= 0.43$ mT

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**END OF QUESTIONS**

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