INSTRUCTIONS

- Answer all questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do not use an erasable pen or correction fluid.
- Do not write on any bar codes.
- You will be allowed to work with the apparatus for a maximum of 1 hour for each question.
- You should record all your observations in the spaces provided in the question paper as soon as these observations are made.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [ ].
You may not need to use all of the materials provided.

1. In this experiment, you will investigate the oscillations of a chain.

   (a) (i) Assemble the apparatus as shown in Fig. 1.1 with each nail held securely in a boss and at the same height above the bench. Position the stands so that the distance between the nails is approximately 60 cm.

   ![Fig. 1.1]

   - Rest one of the metre rules on the nails, as shown in Fig. 1.2.

   ![Fig. 1.2]

   - The vertical distance between the horizontal metre rule and the lowest part of the chain is $C$.

   Using the other metre rule, measure and record $C$.

   \[ C = \ldots \text{cm} \]
(ii)  
- Push the bottom of the chain a short distance away from you. Release it so that it swings towards and away from you.
- Take measurements to determine the period $T$ of these oscillations.

$$T = \text{.................................................................} \quad [2]$$
(b) Repeat (a) with different distances between the stands until you have six sets of values of $C$ and $T$.
All values of $C$ must be greater than 15 cm.

Record your results in a table. Include values of $\frac{1}{T}$ and $\frac{1}{\sqrt{C}}$ in your table.

(c) (i) Plot a graph of $\frac{1}{T}$ on the $y$-axis against $\frac{1}{\sqrt{C}}$ on the $x$-axis.

(ii) Draw the straight line of best fit.

(iii) Determine the gradient and $y$-intercept of this line.

\[ \text{gradient} = \ldots \]
\[ \text{y-intercept} = \ldots \]
(d) It is suggested that the quantities $T$ and $C$ are related by the equation

$$\frac{1}{T} = \frac{a}{\sqrt{C}} + b$$

where $a$ and $b$ are constants.

Use your answers in (c)(iii) to determine the values of $a$ and $b$. Give appropriate units.

$$a = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$b = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

[2]

[Total: 20]
In this experiment, you will investigate the deformation of a foam ring.

(a) (i) • Assemble the apparatus as shown in Fig. 2.1. The wooden rod should pivot freely on the nail.

• Take the larger of the two foam rings.

• Using the metre rule, measure and record the inner diameter $D_1$ and the outer diameter $D_2$, as shown in Fig. 2.2.

![Fig. 2.1](image-url)

![Fig. 2.2](image-url)

\[ D_1 = \text{mm} \]

\[ D_2 = \text{mm} \]
(ii) Estimate the percentage uncertainty in your value of $D_2$. Show your working.

$$\text{percentage uncertainty} = \text{.........................................................}$$  [1]

(b) Position the ring under the line on the rod and centrally on the wooden block, as shown in Fig. 2.3.

* Adjust the height of the boss so that the rod is horizontal.
* The vertical distance, next to the ring, of the top of the rod above the block is $h_1$, as shown in Fig. 2.3.

Using the calipers, measure and record $h_1$.

$$h_1 = \text{.........................................................} \text{ mm}$$

* Place the slotted mass at the end of the rod, as shown in Fig. 2.4.
• The vertical distance, next to the ring, of the top of the rod above the block is now \( h_2 \), as shown in Fig. 2.4.

Measure and record \( h_2 \).

\[ h_2 = \ldots \text{mm} \]

• Calculate \( y \) where \( y = h_1 - h_2 \).

\[ y = \ldots \text{mm} \]

\[ \text{(c) (i)} \]

The distance between the nail and the line is \( A \) and the distance between the nail and the centre of the slotted mass is \( B \), as shown in Fig. 2.5.

![Fig. 2.5](image_url)

Measure and record \( A \) and \( B \).

\[ A = \ldots \text{cm} \]

\[ B = \ldots \text{cm} \]

\[ \text{(ii)} \]

Calculate the additional force \( F \) on the ring using

\[ F = \frac{mgB}{A} \]

where \( g = 9.81 \text{ N kg}^{-1} \) and \( m = 0.100 \text{ kg} \).

\[ F = \ldots \text{N} \]

\[ \text{(iii)} \]

Justify the number of significant figures you have given for your value of \( F \).
(d) ● Take the **smaller** of the two foam rings.

● Using the metre rule, measure and record the inner diameter $D_1$ and the outer diameter $D_2$.

\[ D_1 = \text{........................................................ mm} \]

\[ D_2 = \text{........................................................ mm} \]

● Repeat (b) using the smaller ring.

\[ h_1 = \text{........................................................ mm} \]

\[ h_2 = \text{........................................................ mm} \]

\[ y = \text{........................................................ mm} \] [2]
(e) It is suggested that the relationship between \( D_1, D_2, F \) and \( y \) is

\[
\frac{(D_2^2 - D_1^2)}{D_2^3} = \frac{kF}{y}
\]

where \( k \) is a constant.

(i) Using your data, calculate two values of \( k \).

first value of \( k = \) .................................................................

second value of \( k = \) ................................................................. [1]

(ii) Explain whether your results support the suggested relationship.

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(f) (i) Describe four sources of uncertainty or limitations of the procedure for this experiment.

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2. ...........................................................................................................................................
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3. ...........................................................................................................................................
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4. ...........................................................................................................................................
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[4]

(ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

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[4]

[Total: 20]