



Rewarding Learning

ADVANCED
General Certificate of Education
2023

Centre Number

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Candidate Number

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Physics

StemUp Model Solution

Assessment Unit A2 3B

assessing

Practical Techniques
and Data Analysis



[APH32]

APH32

MONDAY 26 JUNE, MORNING

TIME

1 hour.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen.**

Answer **all four** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 50.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

You may use an electronic calculator.

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- 1 The upwards force, or lift L , on the wings of an aircraft is given by **Equation 1.1**.

$$L = \frac{C_L \rho v^2 A}{2} \quad \text{Equation 1.1}$$

where

C_L is a constant called the coefficient of lift,

ρ is the density of the air,

v is the air speed,

A is the area of the wings.

- (a) Show that C_L is a quantity that has no units.

$$C_L = 2L / (\rho v^2 A)$$

$$\text{Units of } L: N = \text{kg m s}^{-2}$$

$$\text{Units of } \rho v^2 A: \text{kg m}^{-3} \times (\text{m s}^{-1})^2 \times \text{m}^2 = \text{kg m}^{-3} \text{ m}^2 \text{ s}^{-2} \text{ m}^2 = \text{kg m s}^{-2}$$

So units of $C_L = \text{kg m s}^{-2} / \text{kg m s}^{-2}$: all units cancel (the 2 has no units),
so C_L has no units.

[3]

- (b) To determine C_L a student placed a model aircraft into a wind tunnel. The model was connected to a spring balance that allowed the lift L to be measured. The student varied the air speed v in the wind tunnel and measured L . The student was told by the teacher that the spring balance used to measure L has a 'zero error'. The results the student obtained are given in the **Table 1.1**.

Table 1.1

$v / \text{m s}^{-1}$	$v^2 / \text{m}^2 \text{s}^{-2}$	L / N			
		Reading 1	Reading 2	Reading 3	Average
10.0	100	1.48	1.50	1.52	1.50
20.0	400	2.38	2.38	2.37	2.38
30.0	900	3.85	8.36	3.87	3.86
40.0	1600	5.94	5.90	5.92	5.92
50.0	2500	8.59	8.58	8.58	8.58



- (i) Explain why the average value of L for an air speed of 30.0 m s^{-1} was correctly recorded as 3.86 N .

Reading 2 at 30.0 m s^{-1} (8.36 N) is an anomaly, so it is

ignored: $(3.85 + 3.87) / 2 = 3.86 \text{ N}$.

[1]

Using the results from **Table 1.1**, the student plotted the points on the grid in **Fig. 1.1**.

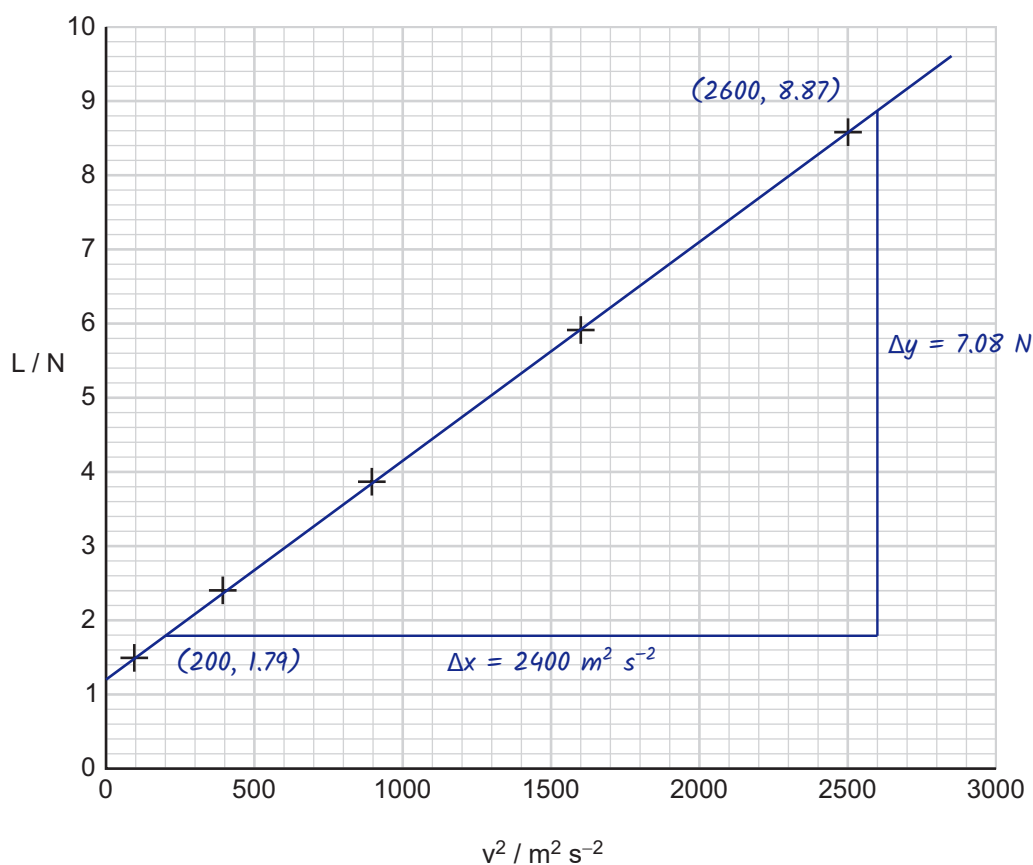


Fig 1.1

- (ii) Draw the best fit line for the points plotted on **Fig. 1.1**.

[1]

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- (iii) Explain how you can tell from your graph that the spring balance has a 'zero error'.

The best fit line does not pass through the origin: it cuts the L axis at 1.2 N, not zero.

[1]

- (iv) Determine the magnitude of the 'zero error' on the spring balance.

Zero error = 1.2 N

[1]

- (c) The density ρ of the air used in the wind tunnel was 1.23 kg m^{-3} and the area A of the wings of the model was $2.40 \times 10^{-2} \text{ m}^2$.

- (i) Determine the gradient of the line of best fit. State the unit of the gradient.

Large triangle drawn on my best fit line in Fig. 1.1:

from (200, 1.79) to (2600, 8.87)

$$\text{gradient} = \Delta y / \Delta x = (8.87 - 1.79) / (2600 - 200)$$

$$= 7.08 / 2400 = 2.95 \times 10^{-3}$$

Gradient = 2.95×10^{-3}

Unit of gradient = $\text{N s}^2 \text{ m}^{-2}$

[3]



(ii) Use the gradient to determine C_L .

$$L = (C_L \rho A / 2) v^2, \text{ so gradient} = C_L \rho A / 2$$

$$C_L = 2 \times \text{gradient} / (\rho A)$$

$$= (2 \times 2.95 \times 10^{-3}) / (1.23 \times 2.40 \times 10^{-2})$$

$$= 5.90 \times 10^{-3} / 2.952 \times 10^{-2} = 0.200$$

$$C_L = \underline{0.200} \quad [3]$$

(iii) Explain why the 'zero error' on the spring balance does not affect the value of C_L determined in (c)(ii).

The zero error adds the same amount to every reading of L , so it shifts the whole line up but does not change its gradient.

C_L is found only from the gradient, so it is unaffected. [1]



- 2 The frequency of the first mode of vibration for a stretched string is dependent on the tension of the string. A student performed an experiment using the apparatus in **Fig. 2.1** to determine the tension on the string.

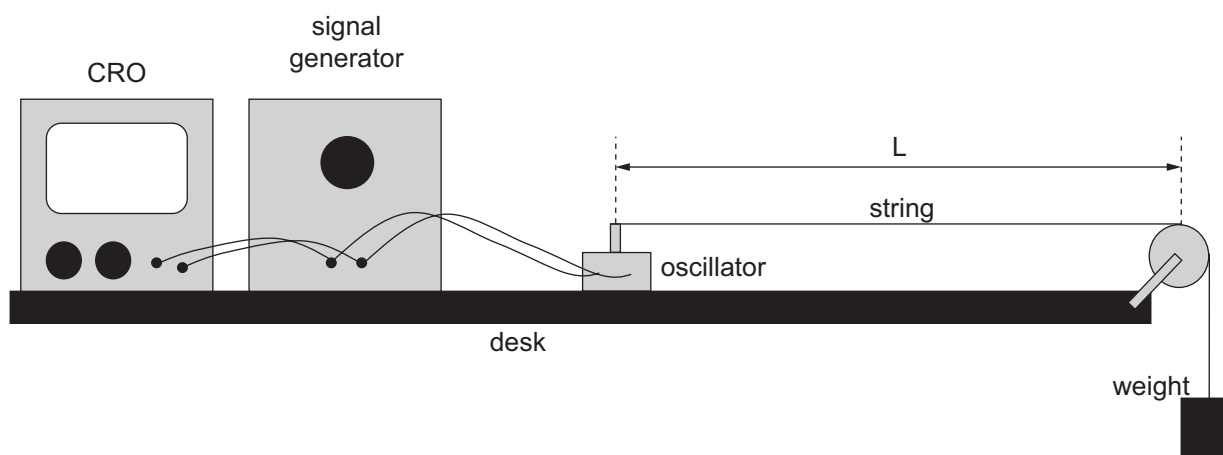


Fig. 2.1

The student increased the frequency on the signal generator until the string vibrated in the first mode of vibration. To determine an accurate value for the frequency the student attached the output from the signal generator to a CRO. The time-base setting on the oscilloscope was set to 5 ms cm^{-1} . The display on the oscilloscope screen obtained is shown in **Fig. 2.2**.

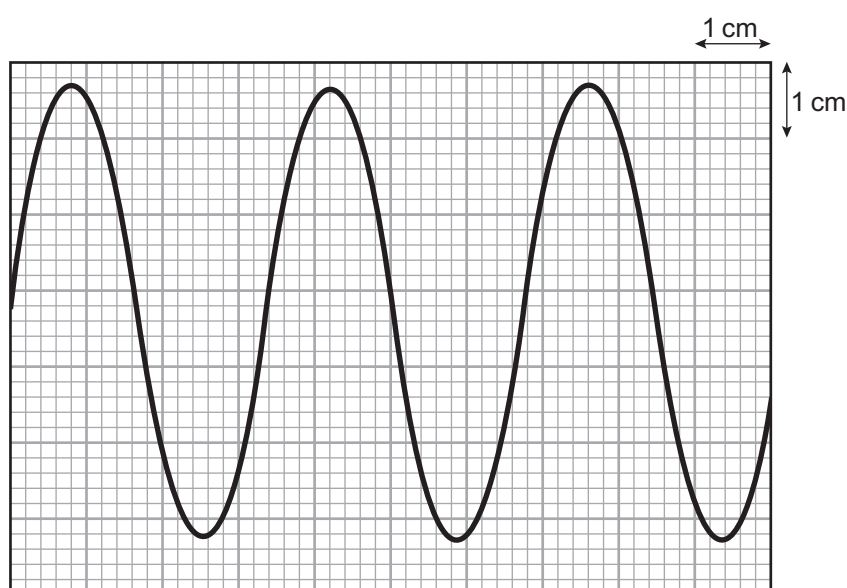


Fig. 2.2



- (a) Use Fig. 2.2 to calculate a value for the frequency of the signal that has the smallest possible percentage uncertainty. State the value of this frequency and the percentage uncertainty.

Use as many cycles as possible: peak 1 to peak 3 = 2 waves = 6.8 cm

1 wave = 6.8 / 2 = 3.4 cm

$T = 3.4 \text{ cm} \times 5 \text{ ms cm}^{-1} = 17 \text{ ms} = 0.017 \text{ s}$

$f = 1/T = 1 / 0.017 = 58.8 \text{ Hz} = 59 \text{ Hz}$

Uncertainty in reading = $\pm 0.1 \text{ cm}$, so % uncertainty = $(0.1 / 6.8) \times 100 = 1.5 \%$

Frequency = 59 Hz

Percentage uncertainty = 1.5 %

[6]

- (b) The frequency of the first mode of vibration and the tension of the string are linked by Equation 2.1.

$$T = 4 L m f^2 \quad \text{Equation 2.1}$$

where

T is the tension of the string in N,

f is the frequency of the first mode of vibration in Hz,

L is the length of the string in m,

m is the mass of the string in kg.

The student measured the mass of the string to be 0.82 g and the length to be 0.723 m.

The percentage uncertainty in the reading of the mass was 1.22% and the percentage uncertainty in the reading of the length was 0.138%.

Calculate the tension T and the percentage uncertainty of T.

$m = 0.82 \text{ g} = 8.2 \times 10^{-4} \text{ kg}$

$T = 4 L m f^2 = 4 \times 0.723 \times 8.2 \times 10^{-4} \times 59^2 = 8.25 \text{ N} = 8.3 \text{ N}$

% unc in T = % unc in L + % unc in m + 2 × % unc in f

$= 0.138 + 1.22 + (2 \times 1.5) = 4.36 \% = 4.4 \%$

T = 8.3 N

Percentage uncertainty = 4.4 %

[4]

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- 3 Atmospheric air pressure decreases with height above sea-level. The pressure P at a height h can be approximated by **Equation 3.1**.

$$P = P_0 e^{-h/k} \quad \text{Equation 3.1}$$

where P_0 and k are constants.

A set of data for pressure at various heights is given in **Table 3.1**.

Table 3.1

h / m	P / kPa	$\ln (P / \text{kPa})$
1000	92.4	4.53
2000	78.9	4.37
3000	71.2	4.27
4000	65.2	4.18
5000	56.4	4.03
6000	49.3	3.90

- (a) (i) State the physical meaning of the constant P_0 .

P_0 is the atmospheric pressure at sea level, where $h = 0$.

[1]

- (ii) Show that a graph of $\ln P$ against h will produce a straight-line graph from which the values of k and P_0 can be determined.

$P = P_0 e^{-h/k}$. Take natural logs of both sides:

$\ln P = \ln (P_0 e^{-h/k}) = \ln P_0 + \ln (e^{-h/k}) = \ln P_0 - h/k$

so $\ln P = (-1/k) h + \ln P_0$. Compare with $y = mx + c$:

$y = \ln P$, $x = h$, gradient $m = -1/k$ (constant), intercept $c = \ln P_0$

A straight line: $k = -1/\text{gradient}$ and $P_0 = e^{\text{intercept}}$.

[3]

- (iii) Complete the last column in **Table 3.1** by calculating $\ln P$ to **2 decimal places**. Include a suitable heading and unit.

[3]



- (b) (i) Draw a graph of $\ln P$ (y-axis) against h (x-axis) on the grid in **Fig. 3.1**. Choose a suitable scale for the axes, plot the points and draw the best fit line for the points. [5]

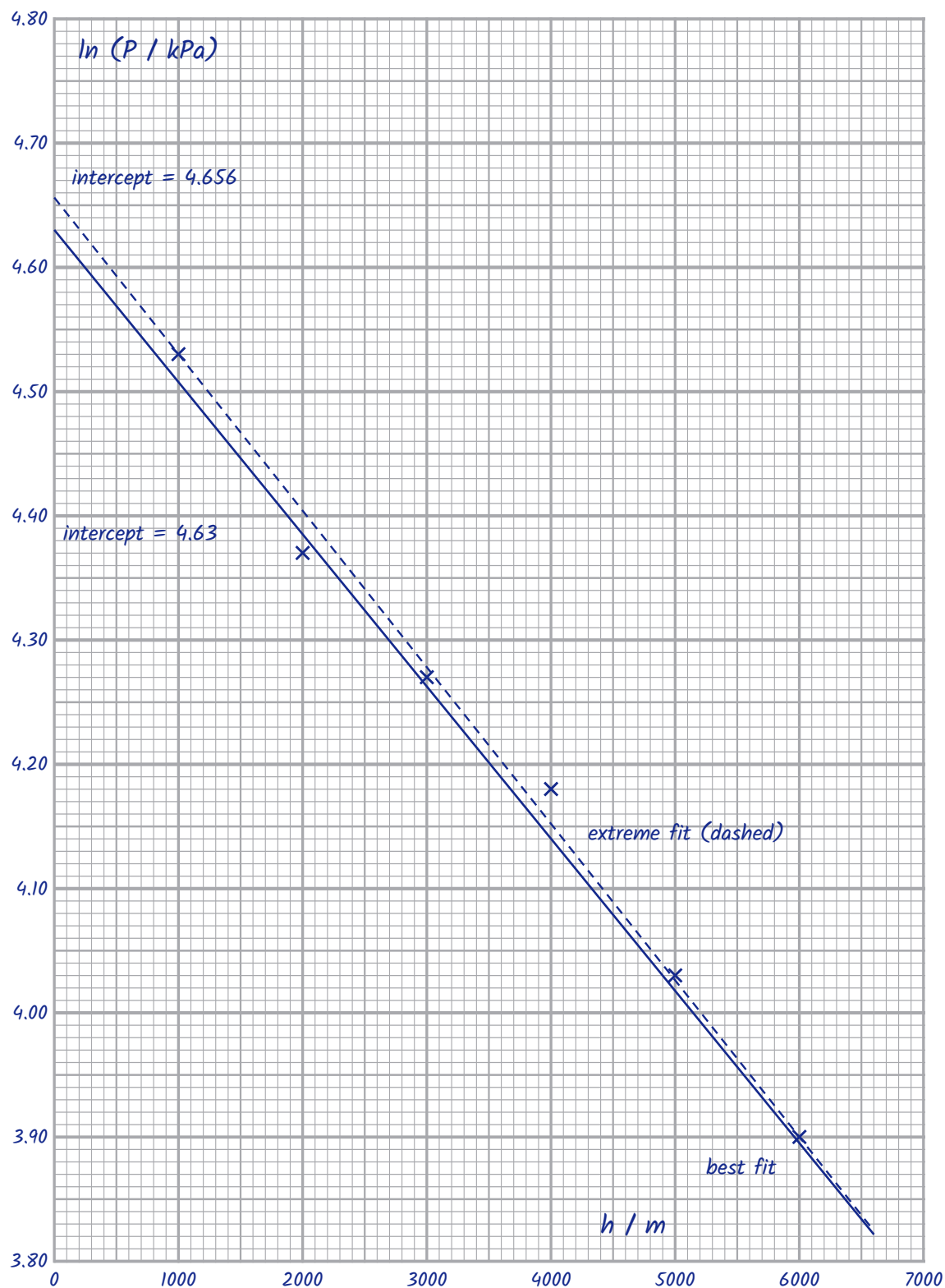


Fig. 3.1

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(ii) Use your graph to determine a value for P_0 .

At $h = 0$, the intercept of my best fit line is $\ln P = 4.63$

intercept = $\ln P_0$, so $\ln (P_0 / \text{kPa}) = 4.63$

$$P_0 = e^{4.63} = 102.5 \text{ kPa} \approx 103 \text{ kPa}$$

$$P_0 = \underline{103} \text{ kPa}$$

[3]

(iii) By drawing an extreme fit line determine the absolute uncertainty in P_0 .

Extreme fit line (dashed) through (1000, 4.53) and (6000, 3.90):

$$\text{gradient} = (3.90 - 4.53) / 5000 = -1.26 \times 10^{-4} \text{ m}^{-1}$$

$$\text{new intercept} = 4.53 + (1000 \times 1.26 \times 10^{-4}) = 4.656$$

$$\text{new } P_0 = e^{4.656} = 105.2 \text{ kPa}$$

$$\text{uncertainty} = 105.2 - 102.5 = 2.7 \text{ kPa} \approx 3 \text{ kPa}$$

$$\text{Uncertainty} = \pm \underline{3} \text{ kPa}$$

[3]





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- 4 A student performs an experiment using a simple pendulum in order to determine the relationship between the time period of oscillation T and its length L .

- (a) Describe how the student should obtain a reliable value for the time period of oscillation.

Use a stopwatch to time 20 complete oscillations, timed from a fiducial marker at the centre of the swing.

Repeat and find the average time, then divide by 20 to get T .

[2]

A plot of the results obtained by the student is shown in **Fig. 4.1**.

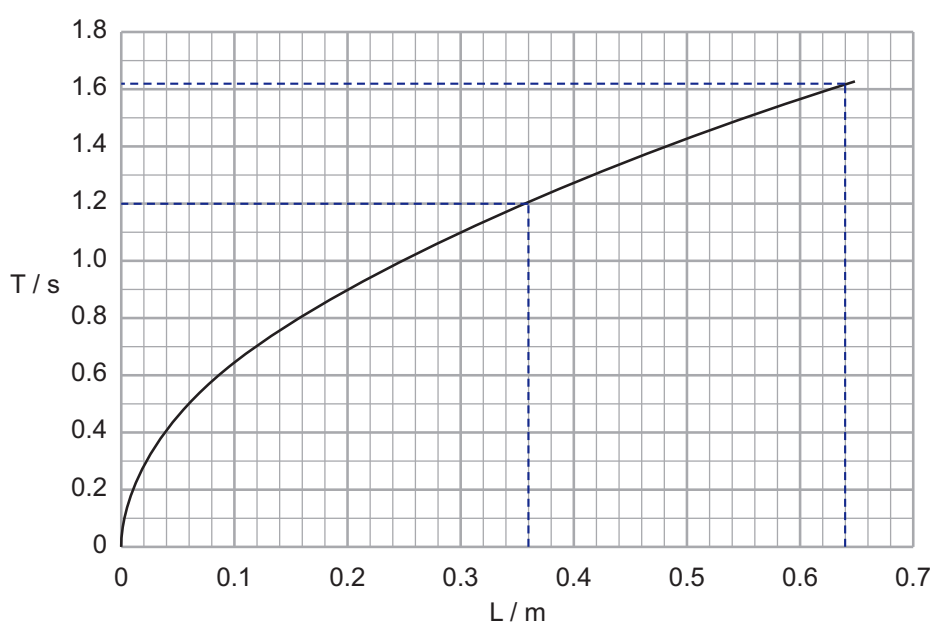


Fig. 4.1



(b) **Without calculation**, explain what feature of the graph in **Fig. 4.1** confirms that the following relationships are incorrect:

(i) $T \propto L$

The graph is a curve, not a straight line through the origin, so T is

not proportional to L .

[1]

(ii) $T \propto L^{-1}$

The gradient is positive (T increases as L increases), but for $T \propto L^{-1}$

T would decrease as L increases.

[1]

(iii) $T \propto L^2$

The graph gets less steep as L increases, but for $T \propto L^2$ it would get

steeper.

[1]

(c) The correct relationship between T and L is given by **Equation 4.1**.

$$T = k L^{1/2} \quad \text{Equation 4.1}$$

Use the graph in **Fig. 4.1** to determine a reliable value for the constant k .

$$k = T / L^{1/2}$$

From the graph: $L = 0.36 \text{ m}$, $T = 1.20 \text{ s}$: $k = 1.20 / \sqrt{0.36} = 1.20 / 0.60 = 2.00$

From the graph: $L = 0.64 \text{ m}$, $T = 1.62 \text{ s}$: $k = 1.62 / \sqrt{0.64} = 1.62 / 0.80 = 2.03$

Average $k = (2.00 + 2.03) / 2 = 2.0 \text{ s m}^{-1/2}$

$$k = 2.0 \text{ s m}^{-1/2}$$

[3]

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Question Number	Marks
1	
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Examiner Number

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