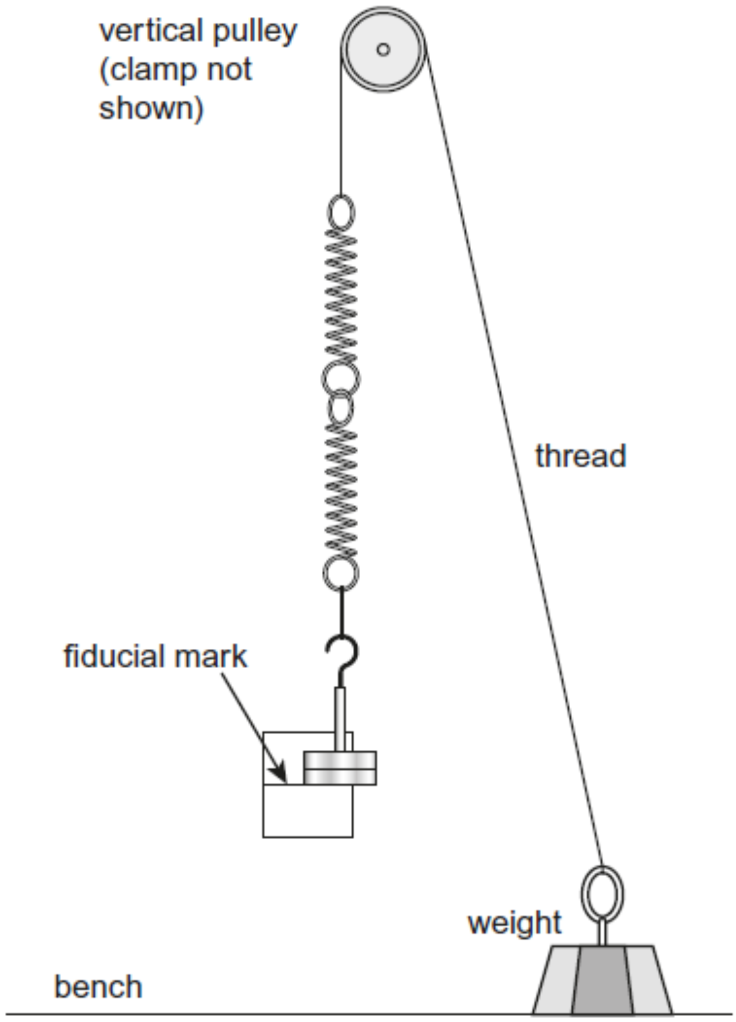
Q1.

A student investigates the vertical oscillations of the mass–spring system shown in **Figure 1**.

Figure 1



The system is suspended from one end of a thread passing over a pulley.

The other end of the thread is tied to a weight.

The system is shown in **Figure 1** with the mass at the equilibrium position.

The spring constant (stiffness) is the same for each spring.

(a) Explain why the position of the fiducial mark shown in **Figure 1** is suitable for this experiment.

___

___

___

___

(1)

The table below shows the measurements recorded by the student.

Time for 20 oscillations of the mass-spring system/s				
22.9	22.3	22.8	22.9	22.6

(b) (i) Determine the percentage uncertainty in these data.

percentage uncertainty = ____

(3)

(ii) Determine the natural frequency of the mass-spring system.

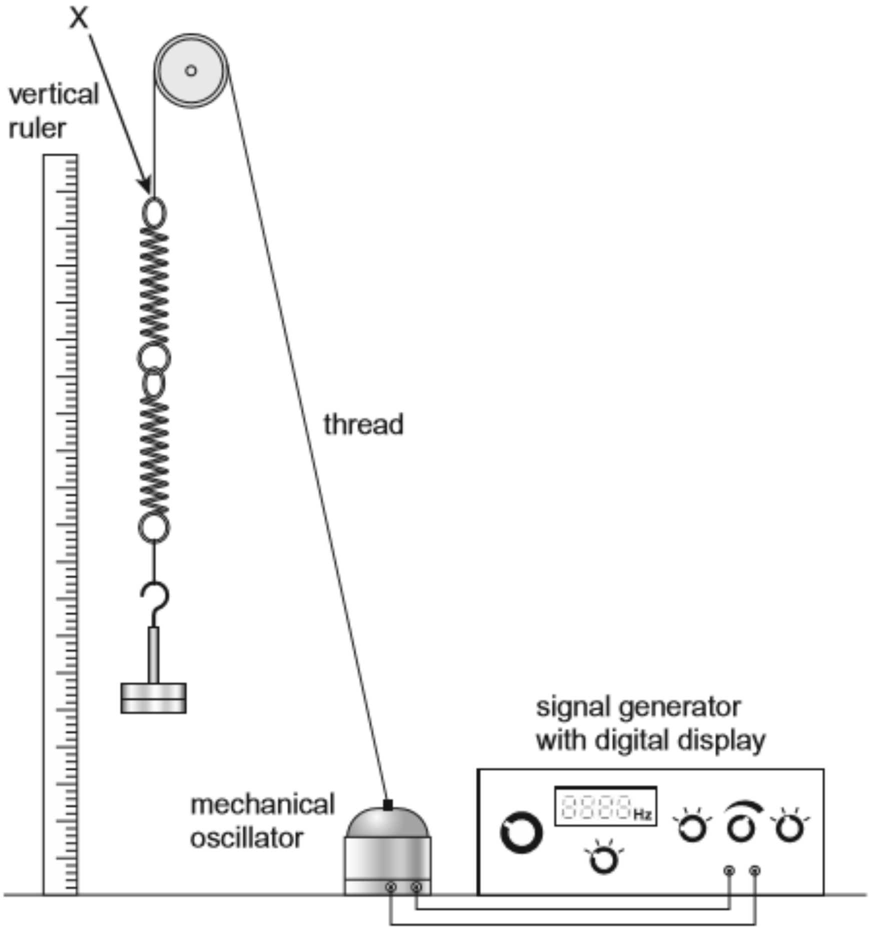
natural frequency = ____

(1)

(c) The student connects the thread to a mechanical oscillator. The oscillator is set in motion using a signal generator and this causes the mass–spring system to undergo forced oscillations.

A vertical ruler is set up alongside the mass–spring system as shown in **Figure 2**. The student measures values of *A*, the amplitude of the oscillations of the mass as *f*, the frequency of the forcing oscillations, is varied.

Figure 2



A graph for the student's experiment is shown in **Figure 3**.

(i) Add a suitable scale to the frequency axis.
You should refer to your answer in part **(b)(ii)** and note that the scale starts at 0 Hz.

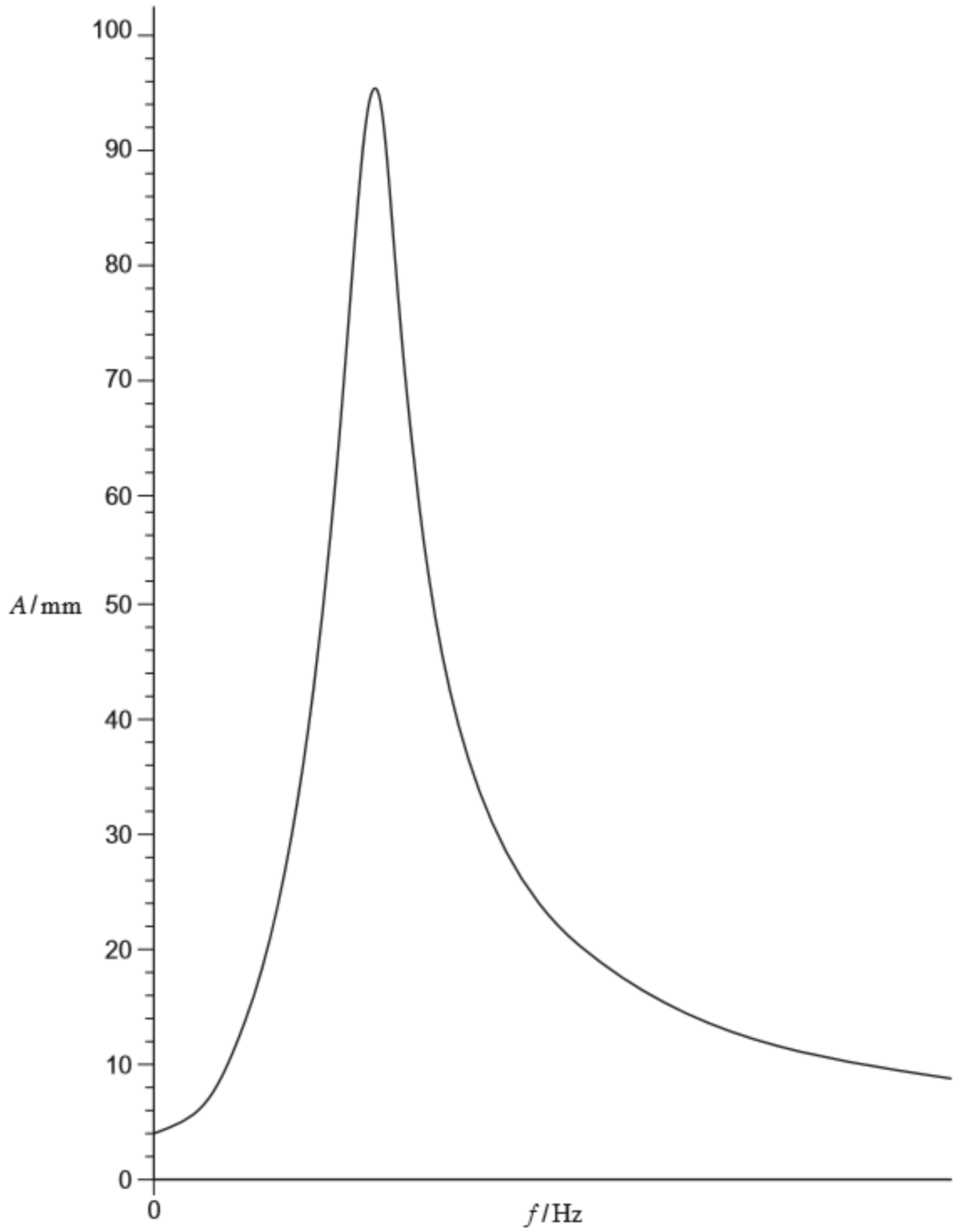
(1)

(ii) Deduce from **Figure 3** the amplitude of the oscillations of X, the point where the mass–spring system is joined to the thread.
You should assume that the length of the thread is constant.

amplitude of X = ___________________________________

(1)

Figure 3



(d) (i) State and explain how the student was able to determine the accurate shape of the graph in the region where *A* is a maximum.

____

____

(2)

(ii) The student removes one of the springs and then repeats the experiment.

Add a new line to **Figure 3** to show the graph the student obtains.

You may wish to use the equation $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

(2)

(Total 11 marks)

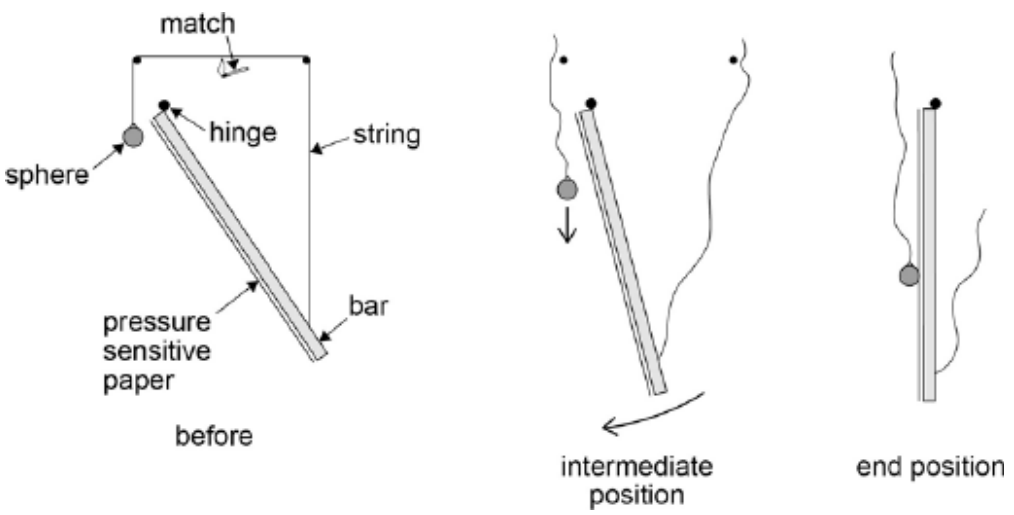
Q2.

This question is about measuring the acceleration of free fall g.

A student undertakes an experiment to measure the acceleration of free fall.

Figure 1 shows a steel sphere attached by a string to a steel bar. The bar is hinged at the top and acts as a pendulum. When the string is burnt through with a match, the sphere falls vertically from rest and the bar swings clockwise. As the bar reaches the vertical position, the sphere hits it and makes a mark on a sheet of pressure-sensitive paper that is attached to the bar.

Figure 1



The student needs to measure the distance d fallen by the sphere in the time t taken for the bar to reach the vertical position.

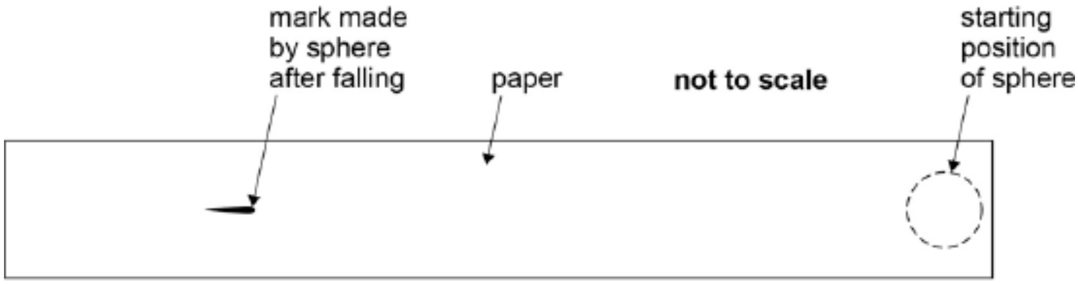
To measure d the student marks the initial position of the sphere on the paper. The student then measures the distance between the initial mark and the mark made by the sphere after falling.

To measure t the student sets the bar swinging without the string attached and determines the time for the bar to swing through 10 small-angle oscillations.

(a) **Figure 2** shows the strip of paper after it has been removed from the bar. The initial position of the sphere and the final mark are shown.

Mark on **Figure 2** the distance that the student should measure in order to determine d.

Figure 2



(1)

(b) The student repeats the procedure several times.

Data for the experiment is shown in the table below.

d / m
0.752
0.758
0.746
0.701
0.772
0.769

Time for bar to swing through 10 oscillations as measured by a stop clock = 15.7 s

Calculate the time for one oscillation and hence the time t for the bar to reach the vertical position.

time____________________s

(1)

(c) Determine the percentage uncertainty in the time t suggested by the precision of the recorded data.

uncertainty =____________________ %

(2)

(d) Use the data from the table to calculate a value for d.

d = ____________________ m

(2)

(e) Calculate the absolute uncertainty in your value of d.

uncertainty = ____________________ m

(1)

(f) Determine a value for g and the absolute uncertainty in g.

g = ____________________ ms^{-2}

uncertainty = ____________________ ms^{-2}

(3)

(g) Discuss **one** change that could be made to reduce the uncertainty in the experiment.

____

____

____

____

(2)

(h) The student modifies the experiment by progressively shortening the bar so that the time for an oscillation becomes shorter. The student collects data of distance fallen s and corresponding times t over a range of times.

Suggest, giving a clear explanation, how these data should be analysed to obtain a value for g.

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____

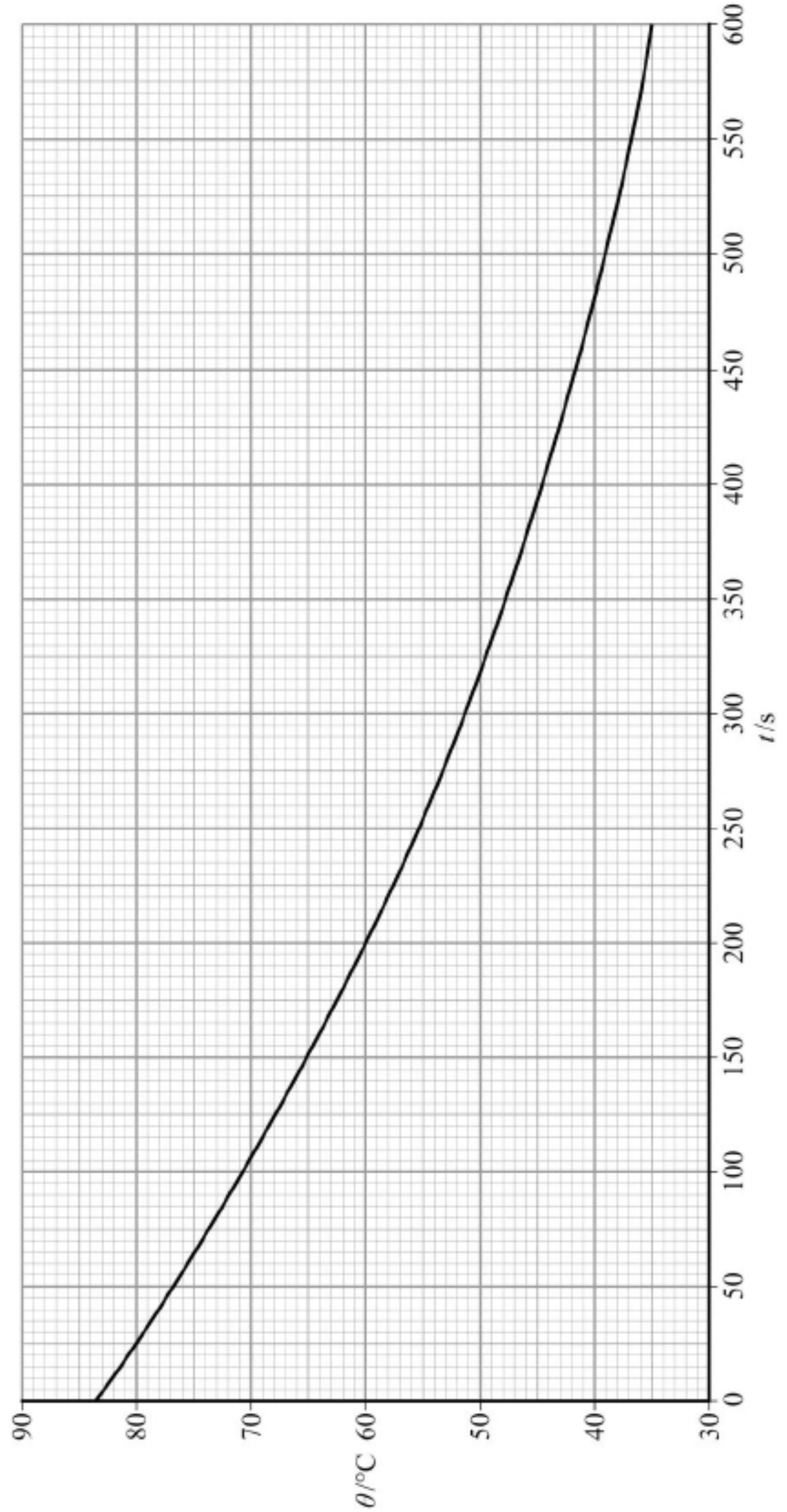
____

____

____

(3)

(Total 15 marks)



(a) Determine the temperature θ_1 of the water when t is 190 s.

3 A student is investigating simple harmonic motion using an electric vibrator. A plate is attached to the top of the electric vibrator. A small mass is placed on the metal plate as shown in Fig. 1.1.

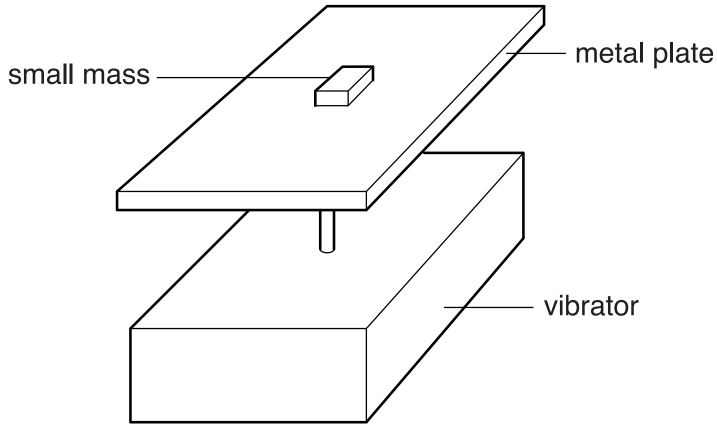


Fig. 1.1

An alternating potential difference (p.d.) is applied to the vibrator. For a given peak p.d. V, there is a maximum frequency f at which the small mass remains in contact with the plate. The contact between the small mass and plate is lost when the frequency is greater than f.

It is suggested that the relationship between f and V is

$$k = \pi^2 f^2 V$$

where k is a constant.

Design a laboratory experiment to test the relationship between f and V. Explain how your results could be used to determine a value for k. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken.

[15]

Defining the problem	Methods of data collection	Method of analysis	Safety considerations	Additional detail

4A student is investigating the oscillations of a mass attached to an arrangement of springs. Fig. 2. 1 shows a mass attached to two springs connected in series.

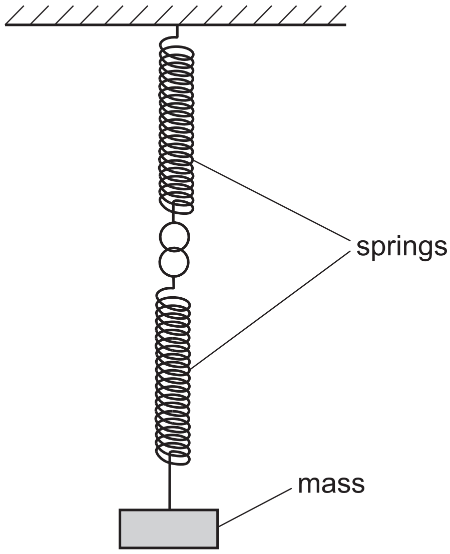


Fig. 2.1

The student determines the spring constant k for the arrangement of the springs. A stopwatch is used to measure the time t for 20 oscillations. The measurement of t is repeated and the average period T is determined.

The experiment is repeated for different arrangements and different numbers of springs.

It is suggested that T and k are related by the equation

$$T = 2\pi\sqrt{\frac{M}{k}}$$

where M is the mass.

(a) A graph is plotted of T^2 on the y-axis against $\frac{1}{k}$ on the x-axis.

Determine an expression for the gradient.

gradient = ... [1]

(b) Values of k, $\frac{1}{k}$ and the measurements of t are given in Fig. 2.2.

k / N m^{-1}	$\frac{1}{k}$ / m N^{-1}	t / s	t / s	T / s	T^2 / s^2
7.9	0.13	22.2	22.6		
11	0.091	19.2	18.8		
15	0.067	16.6	16.0		
24	0.042	12.8	13.4		
32	0.031	11.0	11.8		
49	0.020	9.8	9.0		

Fig. 2.2

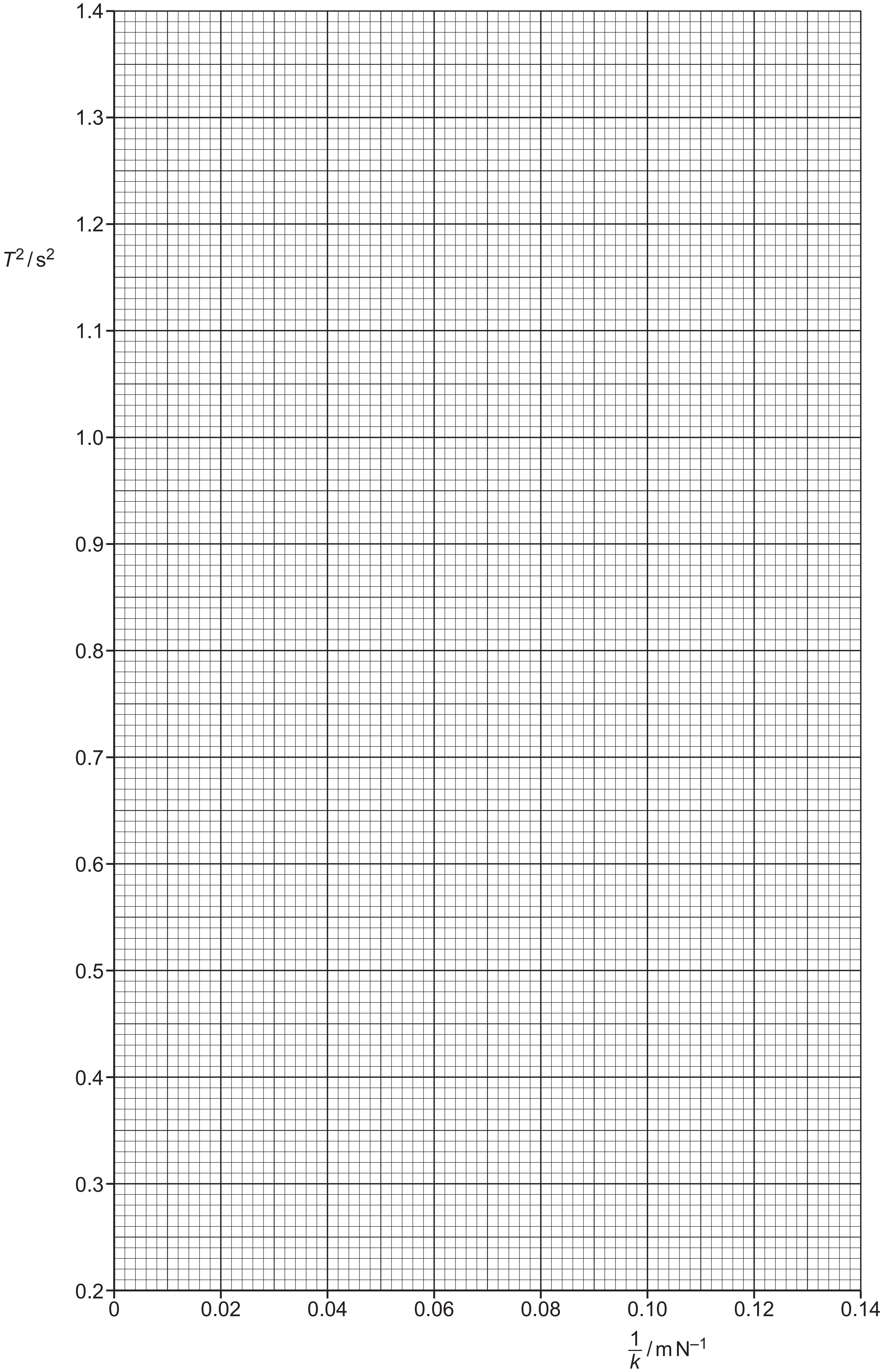
Calculate and record values of T / s and T^2 / s^2 in Fig. 2.2.
Include the absolute uncertainties in T and T^2. [4]

(c) **(i)** Plot a graph of T^2 / s^2 against $\frac{1}{k}$ / m N^{-1}.
Include error bars for T^2. [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

gradient = ... [2]


T^2 / s^2
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
$\frac{1}{k}$ / m N^{-1}

(d) **(i)** Using your answers to **(a)** and **(c)(iii)**, determine the value of *M*. Include an appropriate unit.

M = ... [1]

(ii) Determine the percentage uncertainty in *M*.

percentage uncertainty = ... % [1]

(e) Determine the spring constant *k* for an arrangement of springs using the same mass that would have a period of 2.50 ± 0.01 s. Include the absolute uncertainty in your answer.

k = ... $N\,m^{-1}$ [2]

[Total: 15]

5 student investigates the oscillations of a simple pendulum attached to a pole on the side of a building, as shown in Fig. 2.1.

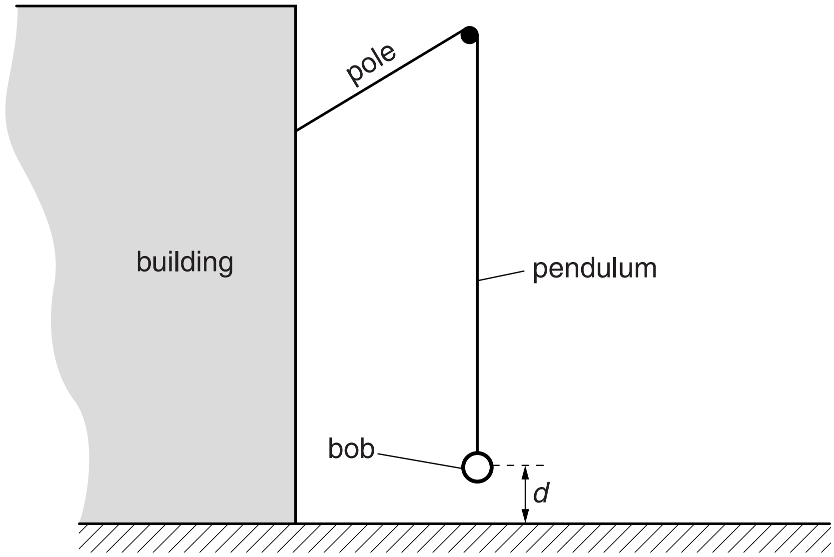


Fig. 2.1

The student records the distance d from the ground to the centre of the pendulum bob and the time t for the pendulum to complete 10 oscillations.

It is suggested that the period T of the oscillations and the distance d are related by the equation

$$T^2 = \frac{4\pi^2}{g}(k - d)$$

where g is the acceleration of free fall and k is a constant.

(a) A graph is plotted of T^2 on the y-axis against d on the x-axis. Determine expressions for the gradient and the y-intercept in terms of g and k.

gradient = ...

y-intercept = ...

[1]

(b) For each value of *d* the measurement of *t* is repeated. Values of *d* and *t* are given in Fig. 2.2.

d / m	*t* / s	*t* / s			
0.45 ± 0.05	56.4	56.4			
0.70 ± 0.05	55.4	55.6			
1.00 ± 0.05	54.6	54.2			
1.20 ± 0.05	53.4	53.8			
1.45 ± 0.05	52.9	52.5			
1.65 ± 0.05	51.6	52.0			

Fig. 2.2

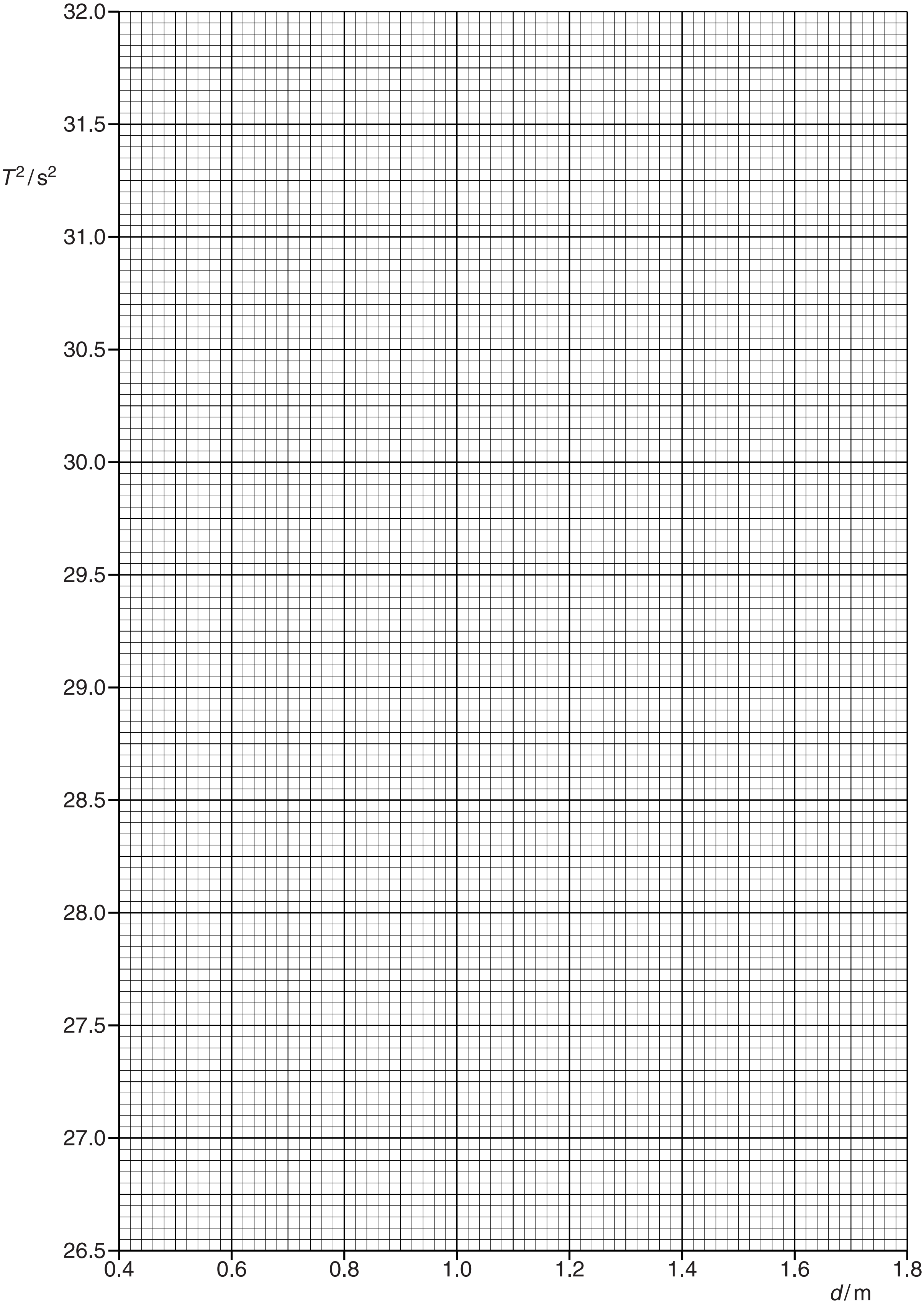
Calculate and record values of mean *t* / s, *T* / s and T^2 / s^2 in Fig. 2.2. [2]

(c) **(i)** Plot a graph of T^2 / s^2 against *d* / m. Include error bars for *d*. [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the line of best fit. Include the uncertainty in your answer.

gradient = ... [2]


32.0
31.5
T^2 / s^2
31.0
30.5
30.0
29.5
29.0
28.5
28.0
27.5
27.0
26.5
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
d / m

(iv) Determine the *y*-intercept of the line of best fit. Include the uncertainty in your answer.

y-intercept = ... [2]

(d) **(i)** Using your answers to **(c)(iii)** and **(c)(iv)**, determine values for *g* and *k*. Include appropriate units.

g = ...

k = ...
[2]

(ii) Determine the percentage uncertainties in *g* and *k*.

percentage uncertainty in *g* = ...%

percentage uncertainty in *k* = ...%
[2]

6 A student is investigating how the period T of a simple pendulum depends on its length l, as shown in Fig. 2.1.

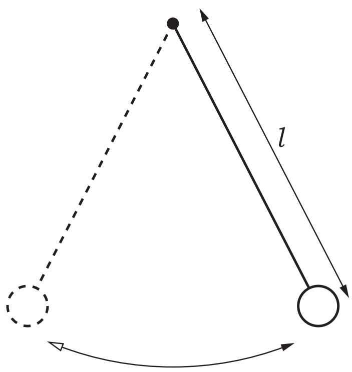


Fig. 2.1

The time t for 10 oscillations is recorded for a pendulum of length l. The period T of the pendulum is determined. The procedure is then repeated for different lengths.

Question 7 continues on the next page.

It is suggested that T and l are related by the equation

$$T = al^b$$

where a and b are constants.

(a) A graph is plotted of lg T on the y-axis and lg l on the x-axis. Determine expressions for the gradient and y-intercept in terms of a and b.

gradient = ...

y-intercept = ...
[1]

(b) Values of l and t are given in Fig. 2.2.

l / cm	t / s	T / s	lg (l / cm)	lg (T / s)
95.0	19.6 ± 0.2			
85.0	18.4 ± 0.2			
75.0	17.4 ± 0.2			
65.0	16.2 ± 0.2			
55.0	14.8 ± 0.2			
45.0	13.4 ± 0.2			

Fig. 2.2

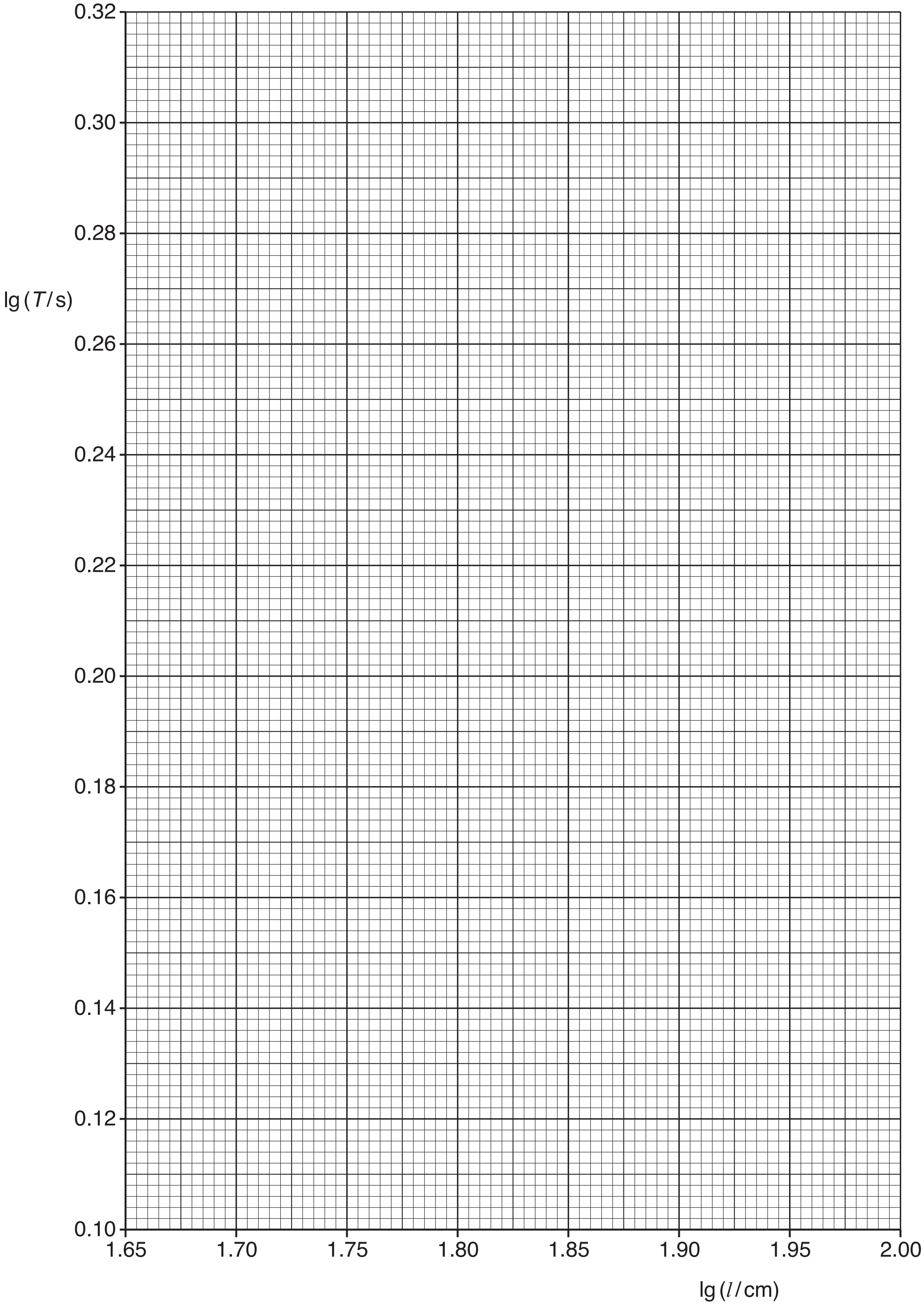
Calculate and record values of T / s, lg (l / cm) and lg (T / s) in Fig. 2.2. Include the absolute uncertainties in lg (T / s). [3]

(c) (i) Plot a graph of lg (T / s) against lg (l / cm). Include error bars for lg (T / s). [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the line of best fit. Include the uncertainty in your answer.

gradient = ... [2]


0.32
0.30
0.28
lg (T / s)
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
1.65
1.70
1.75
1.80
1.85
1.90
1.95
2.00
lg (l / cm)

(iv) Determine the *y*-intercept of the line of best fit. Include the uncertainty in your answer.

y-intercept = ... [2]

(d) Using your answers to **(c)(iii)** and **(c)(iv)**, determine values for *a* and *b*. Include the uncertainties in your answers. You need not be concerned with the units of *a* and *b*.

a = ...

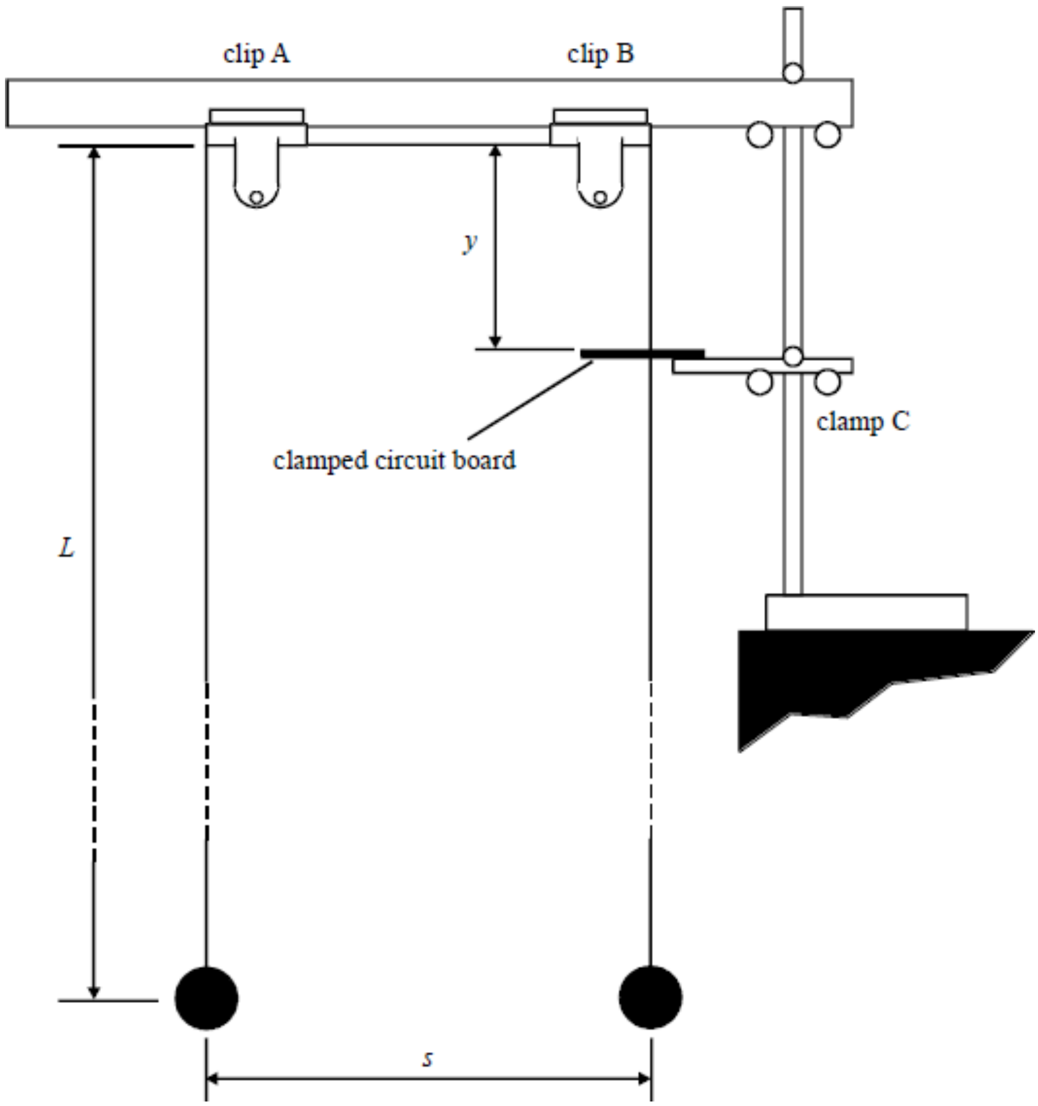
b = ...
[3]

Q7 This question reqires a practical.

In this experiment you will investigate how the time between two pendulums moving in phase depends on their relative lengths.

No description of the experiment is required. You should devote your time to making and recording observations, and giving only the specific information requested.

You are provided with the apparatus shown in the diagram.



(a) (i) Adjust the horizontal separation of the strings, s, by moving clip A so that, **with each pendulum bob at the same height above the floor**, the longer pendulum has a length, L, of about 1.00 m.

(ii) Adjust the height of clamp C until the distance, y, defined in the diagram, is about 0.20 m. Ensure that the part of the string between clip B and the clamped circuit board is vertical.

(iii) Measure and record the distances, s, y and L.

(b) (i) Displace and release one of the pendulums so that it performs small-amplitude oscillations in a plane which is parallel to the edge of the bench. Set the other pendulum in motion so that it performs oscillations in a plane that is parallel to the edge of the bench.

(ii) Start the stopwatch at the instant when the two pendulum motions are seen to be exactly in phase.

(iii) Measure and record, T, which is the time until the pendulums are next seen to move exactly in phase.

(iv) By adjusting clamp C and ensuring that the values of s and L remain unchanged, measure and record further values of T, which correspond to four **larger** values of y.

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

(ii) Measure and record the gradient, G, of your graph.

(iii) Evaluate $\frac{G}{\sqrt{L}}$.

(16)

(d) (i) Describe the measures that you took to ensure that the part of the string between clip B and the clamped circuit board was vertical.

(ii) Describe and explain the factors you considered when choosing your additional values for y.

(iii) A student suggests that in order to extend the enquiry, additional measurements of T should be made using values of y that were **much smaller** than 20.0 cm. Discuss briefly whether you think that such additional readings would improve the quality of the evidence obtained from the experiment.

(6)
(Total 22 marks)