You may not need to use all of the materials provided.

1 In this experiment, you will investigate how the lengths of strings affect the period of oscillation of a pendulum bob.

You have been provided with two strings. The longer string is connected to a pendulum bob. The shorter string has a loop at one end.

(a) • Set up the apparatus as shown in Figure 1.1.

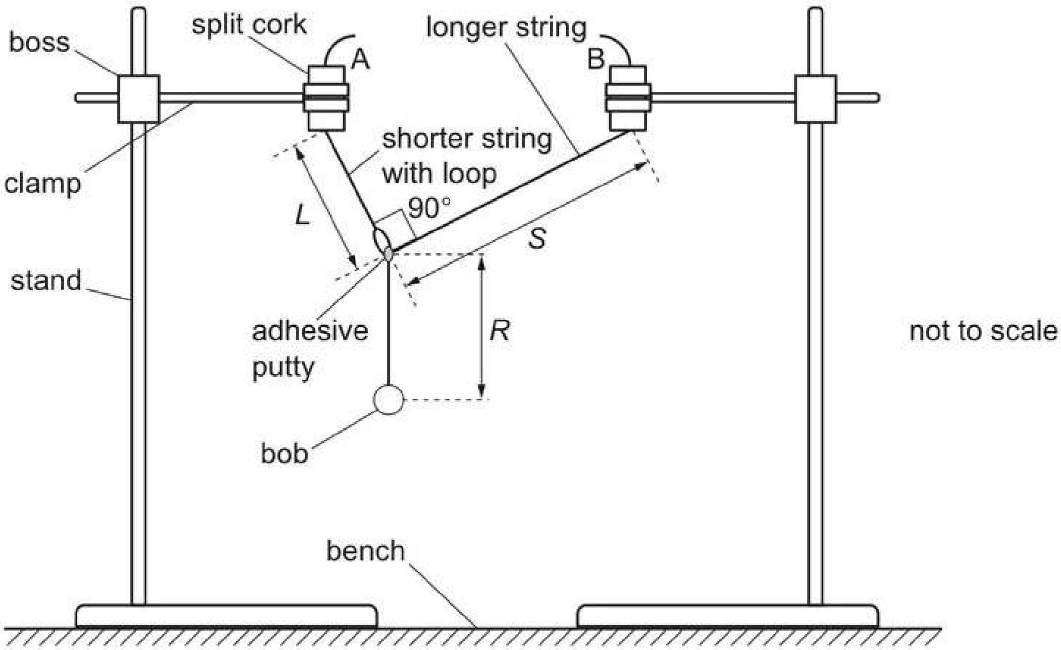

Figure 1.1

- A and B are split corks. Adjust the bosses so that A and B are at the same height above the bench.
- Clamp the shorter string in split cork A.
- The distance between the bottom of split cork A and the end of the loop is L.

  Adjust the position of the shorter string in split cork A so that L is approximately 15 cm.
- Pass the longer string through the loop.
- The distance between the end of the loop and the centre of the bob is R.

  Adjust the position of the loop so that R is equal to L.
- Use the adhesive putty to fix the loop at this position on the longer string.
- Clamp the longer string in split cork B.
- The distance between the end of the loop and the bottom of split cork B is S.

  Adjust the position of the longer string in split cork B so that S is equal to $2L$.
- Move the stands so that the angle between the strings is 90°, as shown in Figure 1.1.

- Measure and record L and S.

L = 15.5 cm

S = 31.0 cm

[2]

(b)
- Pull the bob towards you through a short distance.
- Release the bob. The bob will oscillate.
- Determine the period T of these oscillations.

$$\frac{11.3+11.3+11.2}{3} = 11.3 \text{ s}$$

$$\frac{11.3}{10}$$

T = 1.13 s [2]

(c) Change L. Adjust the apparatus so that R is equal to L, S is equal to $2L$ and the angle between the strings is 90°. Determine T. Repeat until you have five sets of values of L and T.

Record your results in a table. Include values of T^2 in your table.

L/cm	T/s	T^2/s^2
6.0	0.75	0.56
8.0	0.84	0.71
11.0	0.97	0.94
15.5	1.13	1.28
18.0	1.21	1.46
21.0	1.30	1.69

[7]

(d) (i) Plot a graph of T^2 on the y-axis against L on the x-axis. [3]

(ii) Draw the straight line of best fit. [1]

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

$$\frac{1.61 - 0.80}{20.0 - 9.2} = 7.50 \times 10^{-2}$$

$$1.61 = 20.0 \times 7.50 \times 10^{-2} + b$$

$$b = 0.110$$

gradient = 7.50×10^{-2}

y-intercept = 0.110

[2]

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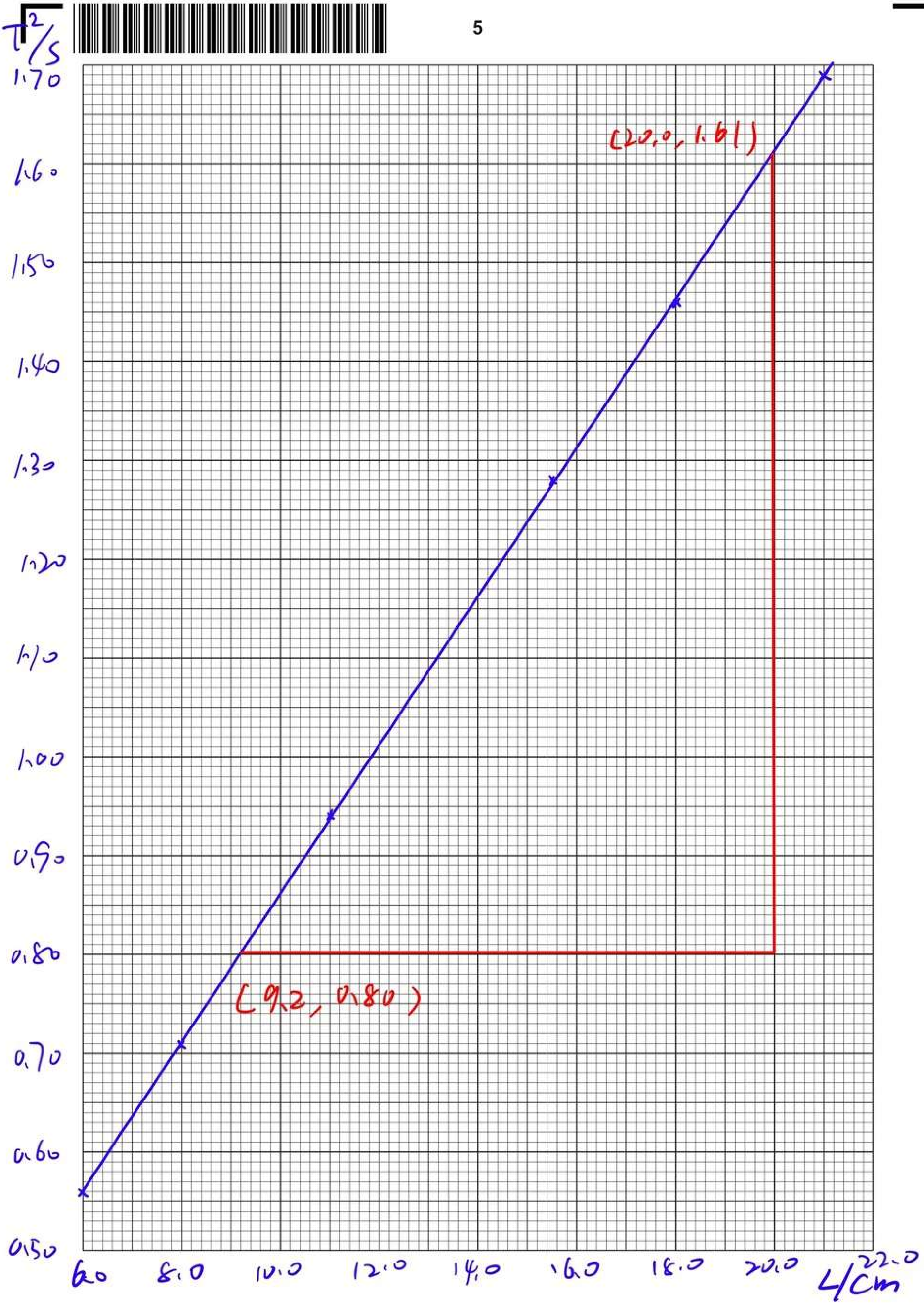

(e) It is suggested that the quantities T and L are related by the equation

$$T^2 = PL + Q$$

where P and Q are constants.

Using your answers in **1(d)(iii)**, determine the values of P and Q.
Give appropriate units.

$P =$ 7.50×10^{-2} $s^2 \cdot cm^{-1}$

$Q =$ 0.110 s^2

[2]

(f) Theory suggests that

$$g = \frac{4\pi^2\left(1 + \frac{2}{\sqrt{5}}\right)}{P}$$

where g is the acceleration of free fall.

Use your answer in **1(e)** to determine a value for g.
Give an appropriate unit.

$$g = \frac{4\pi^2 (1 + \frac{2}{\sqrt{5}})}{7.50 \times 10^{-2} \times 10^2}$$

$g =$ 9.97 m/s^2 [1]

[Total: 20]

You may not need to use all of the materials provided.

2 In this experiment, you will investigate the stability of a wooden block.

You have been provided with two wooden blocks labelled E and F. Each block has a square cross-section.

(a) The thickness of block E is t as shown in Figure 2.1.

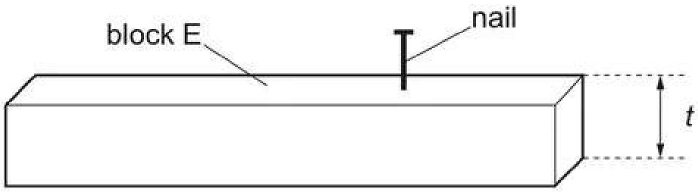

Figure 2.1

Measure and record t.

t = 2.3 cm [1]

(b) • Place E on the bench as shown in Figure 2.2.

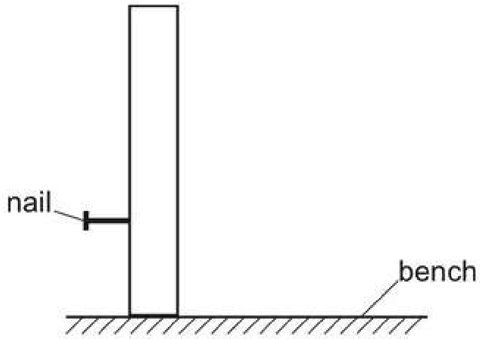

Figure 2.2

• Gently push the block until it overbalances as shown in Figure 2.3.

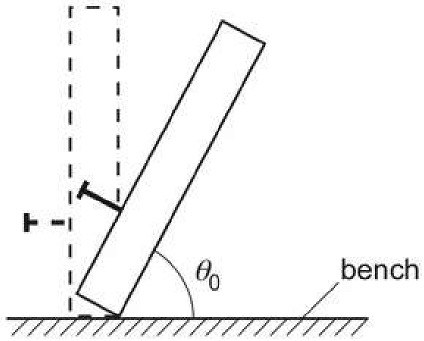

Figure 2.3

• The angle between the edge of the block and the bench at the point the block just overbalances is θ_0.

Measure and record θ_0.

θ_0 = 81 ° [2]

(c) (i) • Place E on the bench. Hang a mass m of 50 g on the nail as shown in Figure 2.4.

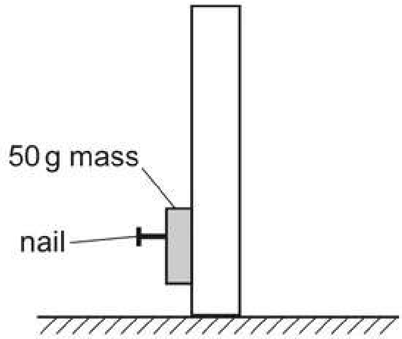

Figure 2.4

• Record m.

m = 50 g

• Gently push the block until it overbalances as shown in Figure 2.5.

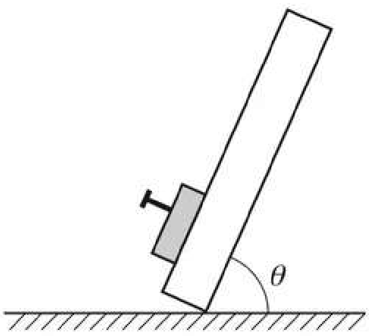

Figure 2.5

• The angle between the edge of the block and the bench at the point the block just overbalances is θ.

Measure and record θ.

θ = 76 °

[1]

(ii) Estimate the percentage uncertainty in this value of θ. Show your working.

$\frac{5^\circ}{76^\circ} \times 100\% = 6.5\%$

percentage uncertainty = 6.5 % [1]

(iii) Calculate $\dfrac{\tan\theta}{\tan\theta_0}$.

$\dfrac{\tan 76^\circ}{\tan 81^\circ} = 0.64$

$\dfrac{\tan\theta}{\tan\theta_0}$ = 0.64 [1]

(iv) Justify the number of significant figures that you have given for your value of $\dfrac{\tan\theta}{\tan\theta_0}$.

θ and θ_0 has 2 s.f.

$\dfrac{\tan\theta}{\tan\theta_0}$ has 2 s.f., which is equal to least no. of s.f of θ and θ_0 [1]

(d) Using block F and a mass m of 100 g, repeat **2(a)**, **2(b)**, **2(c)(i)** and **2(c)(iii)**.

t = 5.2 cm

θ_0 = 72 °

m = 100 g

θ = 66 °

$\dfrac{\tan\theta}{\tan\theta_0}$ = 0.73 [3]

(e) It is suggested that the relationship between θ, θ_0, t and m is

$$\frac{\tan\theta}{\tan\theta_0} = \frac{kt}{\sqrt{m}}$$

where k is a constant.

Using your data, calculate **two** values of k.

$$K_1 = \frac{0.64 \times \sqrt{50}}{2.3} = 1.97$$

$$K_2 = \frac{0.73 \times \sqrt{100}}{5.2} = 1.40$$

first value of k = 1.97

second value of k = 1.40

[1]

(f) It is suggested that the percentage uncertainty in the values of k is 15%.

Using this uncertainty, explain whether your results support the relationship in **2(e)**.

$$\frac{1.97 - 1.40}{(1.97 + 1.40) \div 2} \times 100\% = 34\% > 15\%$$

not support

[1]

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

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

1 Two readings are not enough to draw a conclusion

2 difficult to push the block steady and slow

3 The block slides when it is pushed

4 difficult to measure θ_0 and θ because the block falls too fast

[4]

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

1 Take more readings and plot a graph

2 use a electric motor to push the block

3 insert a paper between block and bench to increase friction

4 take a video, play frame by frame, measure the angle in the video

[4]

[Total: 20]