OSCILLATIONS OF A PENDULUM

1 The class is investigating the motion of a pendulum. Fig. 4.1 shows the apparatus.

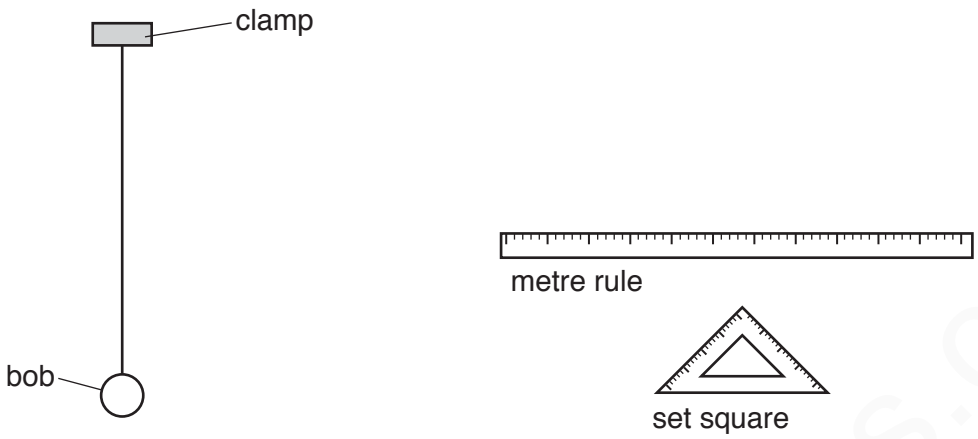

Fig. 4.1

(a) (i) On Fig. 4.1, show clearly the length l of the pendulum. [1]

(ii) Use Fig. 4.2 to explain how you would measure the length l accurately. You may draw on the diagram.

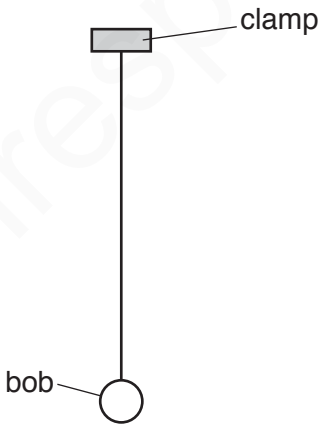

Fig. 4.2

.....

.....

.....

.....

.....[2]

(b) A student determines the period T of the pendulum. The period is the time taken for one complete oscillation. The student measures the time t for 20 oscillations.

Fig. 4.3 shows the time t.

Fig. 4.3

(i) Calculate the period T of the pendulum.

T = ...[1]

(ii) Explain how measuring the time for 20 oscillations rather than one oscillation helps the student to obtain a more reliable value for the period.

.....

.....

.....[2]

(c) The student wants to determine a value for the acceleration of free fall from his results. He needs the value of T^2 to do this.

Calculate T^2.

Give your answer to a suitable number of significant figures and include the unit.

T^2 = ... [2]

[Total: 8]

MARKING SCHEME

(a)(i)	*l* shown clearly from bottom of clamp to centre of bob	1
(a)(ii)	Any 2 from: Metre rule close to pendulum Measurement from bottom of clamp Set-square used as a horizontal reference	2
(b)(i)	1.01(1)	1
(b)(ii)	Any 2 from: Idea of averaging Reaction time / judgement of when to stop / start (owtte) Reduces effect of error / spreads error over 20 swings (owtte)	2
(c)	1.02(212) with 2, 3 or 4 significant figures	1
	unit s^2	1
	Total:	8

2 A student uses a pendulum to determine a value for the acceleration of free fall *g*.

Figs. 1.1 and 1.2 show the apparatus.

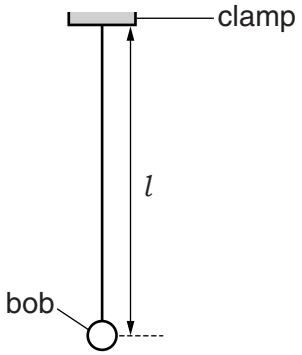

Fig. 1.1

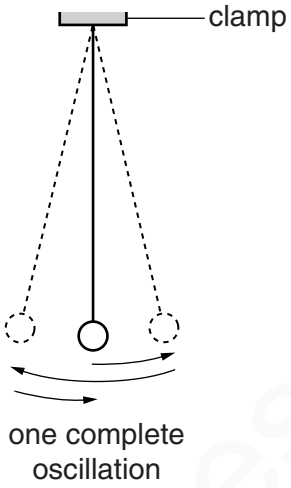

Fig. 1.2

(a) On Fig. 1.1, measure the length l of the pendulum.

l = ... cm [1]

(b) The student adjusts the pendulum until its length l = 50.0 cm. The length l is measured to the centre of the bob.

Explain briefly how the student avoids a parallax (line of sight) error when measuring length l.

.....

.....

.....[1]

(c) The student displaces the pendulum bob slightly and releases it so that it swings.

He measures the time t for 20 complete oscillations of the pendulum.

$t =$ 27.8 s

(i) Calculate the period T of the pendulum. The period is the time for one complete oscillation.

$T =$ .....[1]

(ii) Measuring the time for a large number of oscillations, rather than for one oscillation, gives a more accurate value for T.

Suggest one practical reason why measuring the time for 200 oscillations, rather than 20 oscillations, may **not** be suitable.

.....

.....[1]

(iii) Calculate T^2.

$T^2 =$ .....[1]

(iv) Calculate the acceleration of free fall g using the equation $g = \frac{4\pi^2 l}{T^2}$. Give your answer to a suitable number of significant figures for this experiment.

$g =$ ..... m/s^2 [2]

(d) The student checks the value of the acceleration of free fall g in a text book. The value in the book is $9.8\,m/s^2$.

(i) Suggest a practical reason why the result obtained from the experiment may be different.

.....

.....

.....[1]

(ii) Suggest **two** improvements to the experiment.

1. .....

.....

2. .....

.....

[2]

[Total: 10]

MARKING SCHEME

1(a)	l = 4.1 – 4.2 (cm)	**1**
1(b)	Either suitable use of a horizontal straight edge, explained briefly Or holding rule close to pendulum Or line of sight perpendicular (to rule)	**1**
1(c)(i)	T = 1.39 (s) OR 1.4	**1**
1(c)(ii)	Pendulum may stop OR student may lose count	**1**
1(c)(iii)	1.93 s^2 (ecf allowed)	**1**
1(c)(iv)	10.2(2) 2 or 3 significant figures	**1** **1**
1(d)(i)	Explanation of cause of inaccuracy in measurement of t or l. e.g. student did not react quickly enough when starting/stopping stopwatch OR difficulty in measuring accurately to centre of bob	**1**
1(d)(ii)	Any two from: Use different length(s) Repeat timing Use of a fiducial mark Increased number of oscillations Plot a graph using length and time or time^2	**2**
	Total:	**10**

3 **(a)** A student hangs a mass on a spring and observes it as it oscillates up and down.

The student wants to find the factors that affect the time taken for one complete oscillation. She finds that increasing the mass increases the time.

Suggest two other variables that the student could investigate.

1. .....

2. .....
[2]

(b) Another student is investigating the oscillations of the pendulum shown in Fig. 3.1.

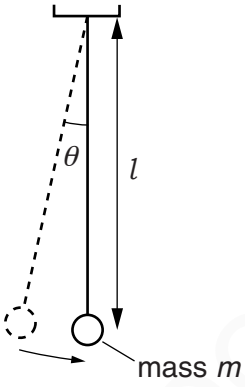

Fig. 3.1

The variables are

- the length l of the pendulum
- the mass m of the pendulum bob
- the amplitude θ of the swing.

The time taken for one complete oscillation is called the period T.

She carries out three experiments. Each experiment investigates the effect on the period T of changing one variable.

Her results are shown in Tables 3.1, 3.2 and 3.3.

Table 3.1

l/m	T/s
0.200	0.89
0.400	1.25
0.600	1.54
0.800	1.78
1.000	1.99

Table 3.2

m/g	T/s
50	1.40
60	1.42
70	1.39
80	1.41
90	1.38

Table 3.3

θ/°	T/s
4	2.00
6	1.98
8	2.06
10	2.02
12	1.97

(i) Study the results tables and use words from this list to complete the sentences.

increases

decreases

has no effect on

is proportional to

- An increase in length l ..... the period T.
- An increase in mass m ..... the period T.
- An increase in amplitude θ ..... the period T.

[3]

(ii) Suggest a precaution you would take in this pendulum experiment to obtain T values that are as reliable as possible.

.....

.....

.....[1]

[Total: 6]

MARKING SCHEME

3(a)	any two from: length of spring / number of coils diameter / thickness of spring material / type / stiffness / elasticity / spring constant of spring how far spring is displaced / amplitude (of oscillations)	**2**
3(b)(i)	increases has no effect on has no effect on	**1** **1** **1**
3(b)(ii)	one from: repeats large number of oscillations and divide timing sensor / light gate use a fiducial mark (however expressed) counting down to zero (before starting the timer)	**1**
	Total:	**6**

4 A student is investigating whether the diameter of a pendulum bob affects the period of a pendulum. The period is the time taken for one complete oscillation of the pendulum. Fig. 3.1 shows a pendulum.

Fig. 3.2 shows one complete oscillation.

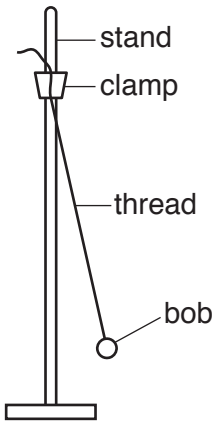

Fig. 3.1

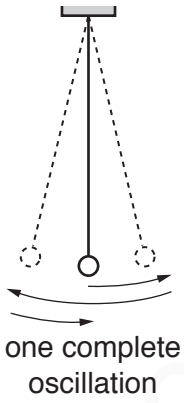

Fig. 3.2

The student has the following apparatus:

pendulum bobs made of polystyrene with diameters 1 cm, 2 cm, 3 cm, 4 cm and 5 cm
a supply of thread and a pair of scissors
clamp and stand.

Plan an experiment to investigate whether the diameter of a pendulum bob affects the period of a pendulum.

You should:

- list additional apparatus that you would require
- explain briefly how you would carry out the investigation
- state the key variables that you would control
- draw a table with column headings, to show how you would display your readings (You are **not** required to enter any readings in the table.)
- explain briefly how you would use your readings to reach a conclusion.

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.....[7]

[Total: 7]

3	**MP1**	Stopwatch (or equivalent) AND (metre) rule / ruler	1
	MP2	Measure time for 5 (+) oscillations	1
	MP3	Divide by number of oscillations to find period (T)	1
	MP4	Repeat for each bob	1
	MP5	Variable; one from: Initial amplitude / starting position Length of pendulum / thread Number of oscillations	1
	MP6	Table with column headings for t, or period (T), or both AND d, with correct units	1
	MP7	Conclusion: Plot graph(s) of d against period (T) or t (or vice versa) OR compare period (T) or t values for different diameters	1

5 A student is comparing the oscillations of two pendulums. Fig. 1.1 shows the first pendulum.

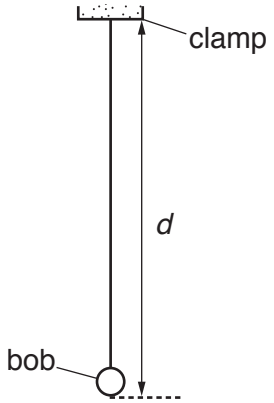


Fig. 1.1

(a) (i) On Fig. 1.1, measure the distance *d*, from the bottom of the clamp to the bottom of the bob.

d = ...cm [1]

(ii) Fig. 1.1 is drawn 1/10th actual size. Calculate the actual distance *D* from the bottom of the clamp to the bottom of the bob.

D = ...cm [1]

(iii) Explain briefly how to use a set-square to avoid a parallax (line-of-sight) error when measuring the length of this pendulum. You may draw a diagram.

.....

.....[1]

(b) The student displaces the bob slightly and releases it so that it swings. She measures the time t for 20 complete oscillations. The time t is shown on the stopwatch in Fig. 1.2.

Fig. 1.2

(i) Write down the time t shown in Fig. 1.2.

t = ...[1]

(ii) Calculate the period T_1 of the pendulum. The period is the time for one complete oscillation.

T_1 = ...[2]

(c) The student repeats the procedure using another pendulum as shown in Fig. 1.3. This has a long, thin pendulum bob. The distance *D* from the bottom of the clamp to the bottom of the pendulum bob is the same as for the first pendulum.

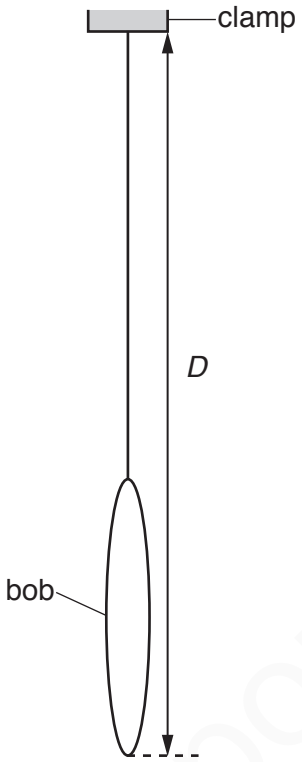


Fig. 1.3

She determines the period T_2 of this pendulum.

T_2 = 1.37 s

In this experiment, both pendulum bobs have the same mass. A student suggests that since both pendulums have the same overall length *D* and mass, the periods T_1 and T_2 should be equal. State whether the results support this suggestion. Justify your answer by reference to the results.

statement .....

justification .....

.....

.....[2]

(d) The period T of a pendulum can be determined by measuring the time t for 20 complete oscillations and then calculating the period. Some students are asked to explain the reason for this method being more accurate than measuring the time taken for a single oscillation.

Tick the box next to the sentence that gives the best explanation.

- ☐ The method eliminates errors from the measurements.
- ☐ The method is more accurate because the experiment is repeated.
- ☐ The method includes more readings so there is less chance for errors.
- ☐ The method reduces the effect of errors when starting and stopping the stopwatch.

[1]

(e) A student plans to carry out more pendulum experiments. He considers possible variables and precautions to improve accuracy.

In the following list, mark the possible variables with the letter **V** and the precautions with the letter **P**.

- ☐ amplitude of swing
- ☐ length of pendulum
- ☐ mass of pendulum bob
- ☐ shape of pendulum bob
- ☐ use of a reference point to aid counting
- ☐ viewing the rule at right-angles when measuring the length

[2]

[Total: 11]

MARKING SCHEME

1(a)(i)	d = 5.0 (cm)	**1**
1(a)(ii)	D = 50 cm	**1**
1(a)(iii)	clear correct use of set-square AND vertical ruler	**1**
1(b)(i)	28.12	**1**
1(b)(ii)	1.406 / 1.41 / 1.4	**1**
	unit s / secs / seconds seen in **1(b)(i)** or **1(b)(ii)** at least once	**1**
1(c)	statement to match readings justification to include the idea of within (or beyond e.c.f.)	**1**
	the limits of experimental accuracy e.g. (very) close / almost equal	**1**
1(d)	final box ticked	**1**
1(e)	V, V, V, V, P, P all correct = 2 marks 4 or 5 correct = 1 mark Fewer than 4 correct = 0 marks	**2**

6 A student investigates a pendulum. Fig. 1.1 and Fig. 1.2 show some of the apparatus used.

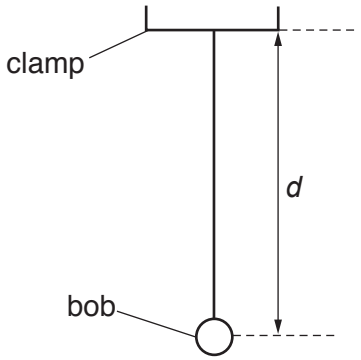


Fig. 1.1

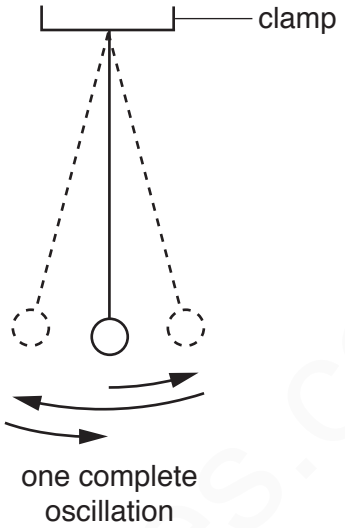


Fig. 1.2

(a) The student adjusts the length of the pendulum until the distance *d*, measured to the centre of the bob, is 50.0 cm. State one precaution that you would take to obtain the length of 50.0 cm as accurately as possible.

.....

..... [1]

(b) The student displaces the bob slightly and releases it so that it swings. Fig. 1.2 shows one complete oscillation of the pendulum.

(i) He measures the time *t* for 20 complete oscillations. The time *t* is shown on the stopwatch in Fig. 1.3.

Fig. 1.3

In the first row of Table 1.1, record the time *t* shown in Fig. 1.3. [1]

(ii) Calculate, and record in Table 1.1, the period *T* of the pendulum. The period is the time for one complete oscillation. [1]

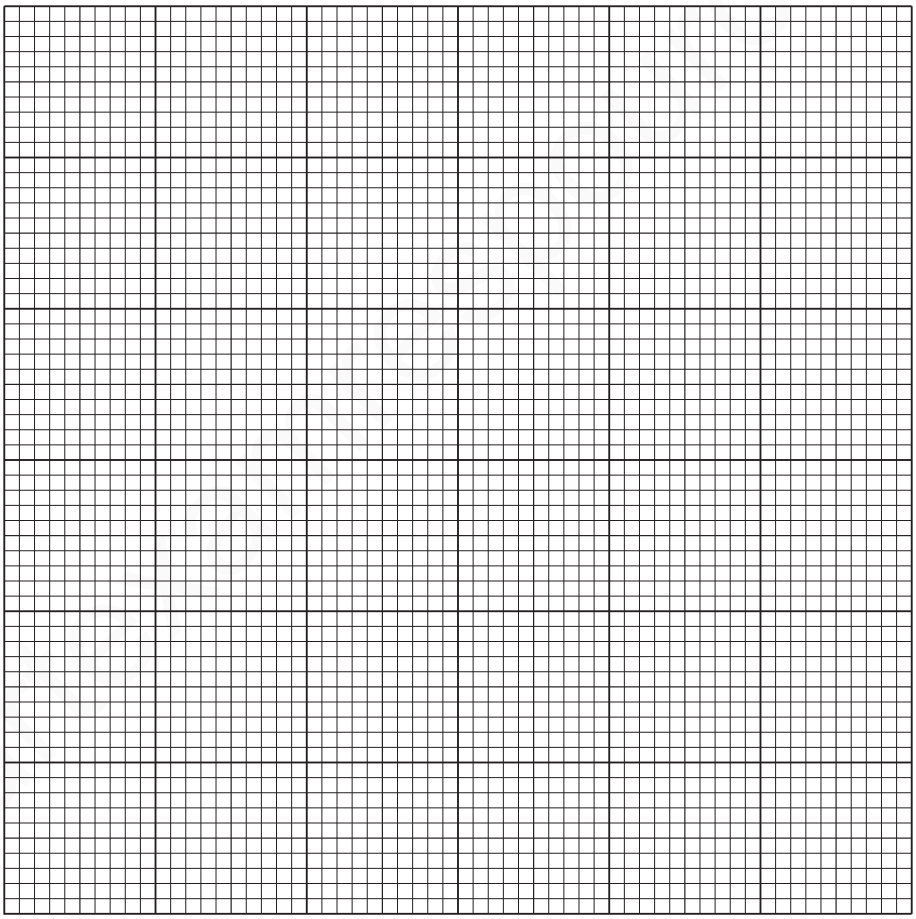
(iii) Calculate T^2. Record its value in Table 1.1. [1]

(c) The student repeats the procedure in **(b)** using $d = 60.0\,\text{cm}$, $70.0\,\text{cm}$, $80.0\,\text{cm}$ and $100.0\,\text{cm}$. The readings are shown in Table 1.1.

Table 1.1

d/cm	t/s	T/s	T^2/s^2
50.0			
60.0	30.00	1.50	2.25
70.0	33.20	1.66	2.76
80.0	35.80	1.79	3.20
100.0	39.80	1.99	3.96

Plot a graph of T^2/s^2 (y-axis) against d/cm (x-axis). You do **not** need to start your axes at the origin (0,0).



[4]

(d) Determine the gradient G of the line. Show clearly on the graph how you obtained the necessary information.

$G =$ ..... [2]

(e) Calculate the acceleration of free fall g in m/s^2 using the equation $g = \frac{0.395}{G}$, where G is your gradient from **(d)**.

Write down the value of g to a suitable number of significant figures for this experiment.

g = ...m/s^2 [2]

[Total: 12]

MARKING SCHEME

1(a)	perpendicular viewing of scale / use of horizontal aid, e.g. set-square / clamp rule / rule close to pendulum	**1**
1(b)(i)	27.6(0)	**1**
1(b)(ii)	1.38	**1**
1(b)(iii)	1.90	**1**
1(c)	graph: axes correctly labelled and right way round	**1**
	suitable scales	**1**
	all plots correct to ½ small square	**1**
	good line judgement, thin, continuous line	**1**
1(d)	triangle method indicated on graph	**1**
	with triangle at least half of candidate's line between the extreme plotted points	**1**
1(e)	correct calculation of *g*	**1**
	to 2 or 3 significant figures	**1**

7

1A student investigates the period of a pendulum. Fig. 1.1 and Fig. 1.2 show the apparatus she uses.

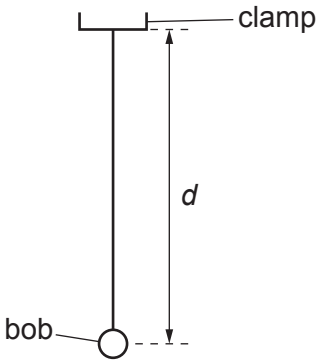


Fig. 1.1

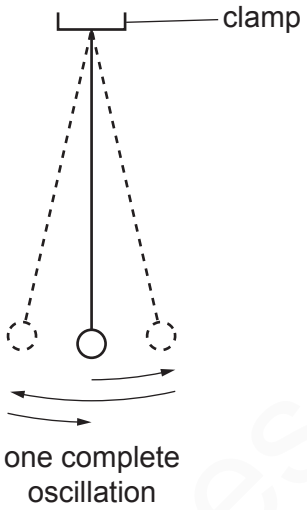


Fig. 1.2

(a) Explain briefly, with the help of a diagram, how you would use a metre rule and set square to measure the length *d* of a pendulum as accurately as possible.

Diagram:

.....

.....

..... [3]

(b) The student adjusts the pendulum so that d = 50.0 cm. She displaces the bob slightly and releases it so that it swings. Fig. 1.2 shows one complete oscillation of the pendulum.
She measures the time t_1 for 20 complete oscillations.

(i) Record the time t_1 shown in Fig. 1.3.

Fig. 1.3

t_1 = ... [1]

(ii) Calculate the period T_1 of the pendulum. The period is the time for one complete oscillation.

T_1 = ... [1]

(c) The student adjusts the pendulum until the distance d is 100.0 cm.

She repeats the procedure and records the time t_2 for 20 oscillations and the period T_2.

t_2 = 39.80 s

T_2 = 1.99 s

She measures the mass m_A of the pendulum bob. The reading on the balance is shown in Fig. 1.4.

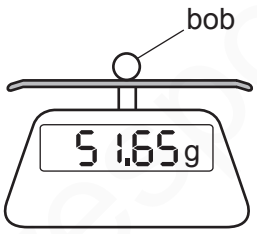


Fig. 1.4

Record mass m_A of the pendulum bob to the nearest gram.

m_A = ... g [1]

The student repeats the procedure using a pendulum bob of mass m_B.

m_B = 109 g

She obtains these results:

distance d = 50.0 cm

period T_3 = 1.39 s

distance d = 100.0 cm

period T_4 = 2.02 s

(d) **(i)** Using the results T_1, T_2, T_3 and T_4, for the period of each of the pendulums, tick (✓) the response that matches your results within the limits of experimental accuracy.

☐ the period T is affected by d only

☐ the period T is affected by both d and m

☐ the period T is affected by m only

☐ the period T is not affected by d or m

[1]

(ii) Justify your answer to **(d)(i)** by reference to the results.

.....

..... [1]

(e) The student now investigates the effect of the size of the oscillations on the period of the pendulum.

(i) Suggest briefly how you would measure the size of an oscillation. You may draw a diagram.

.....

..... [2]

(ii) State **one** variable that you would keep constant during this part of the investigation.

..... [1]

[Total: 11]

MARKING SCHEME

1(a)	clear diagram showing use of set square and rule with horizontal line of set square across to vertical rule from approximate centre of bob	**1**
	rule positioned to enable measurement of *d* from bottom of clamp	**1**
	wording to include perpendicular viewing of the rule	**1**
1(b)(i)	$t_1 = 28.12$ (s)	**1**
1(b)(ii)	$T_1 = 1.406$ (s)	**1**
1(c)	$m_A = 52$	**1**
1(d)(i)	first box only ticked (error carried forward possible)	**1**
1(d)(ii)	justified by correct reference to results	**1**
1(e)(i)	rule or protractor used	**1**
	method explained / diagram drawn	**1**
1(e)(ii)	length	**1**