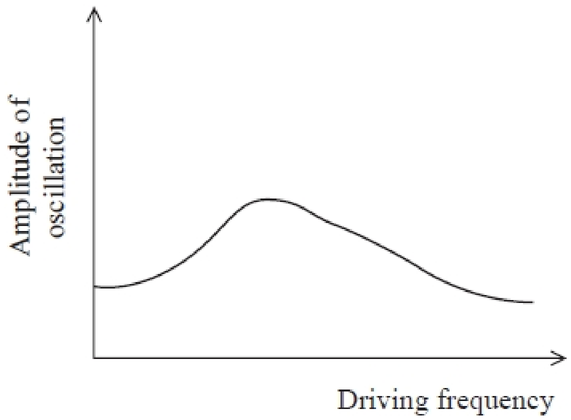
Oscillations

Q1.

A damped mass-spring system is driven into oscillation. The graph shows the amplitude of oscillation as the driving frequency is varied.



The damping is decreased.

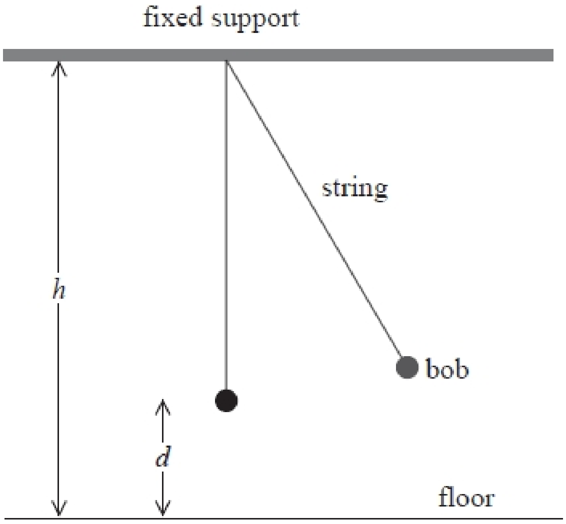
Which row of the table describes what happens to the maximum amplitude of oscillation and the driving frequency at which this occurs?

	Maximum amplitude	Frequency at which maximum amplitude occurs
☒ **A**	decreases	decreases
☒ **B**	decreases	increases
☒ **C**	increases	decreases
☒ **D**	increases	increases

(Total for question = 1 mark)

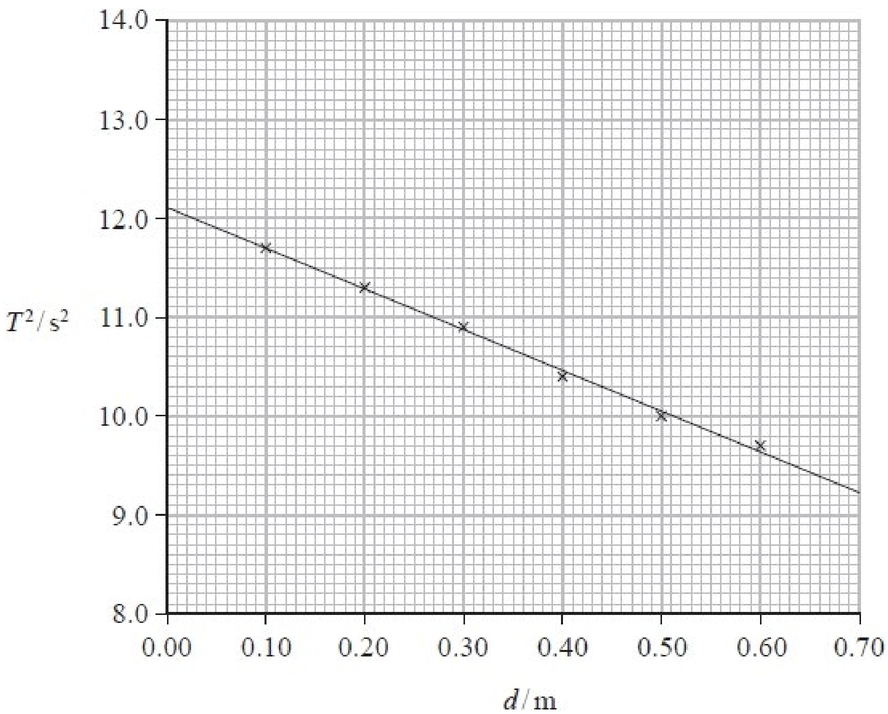
Q2.

A student carried out an experiment with a pendulum hung from a fixed support. The fixed support was a distance *h* above floor level as shown.



As the student was unable to measure the length of the pendulum directly, she measured the distance *d* from the bob to the floor.

The student used her data to plot a graph of T^2 against *d* as shown below.



Determine a value for the acceleration due to gravity *g*.

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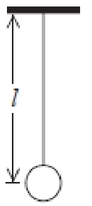
g = ...

(Total for question = 5 marks)

Q3.

A student is using a simple pendulum to determine a value for the acceleration of free fall *g*.



She measures the length *l* of the pendulum four times with a metre rule and records the following values.

l / cm			
l_1	l_2	l_3	l_4
85.5	86.0	87.5	85.5

She calculates the mean length l_m of the pendulum using the following method:

$$l_m = \frac{85.5 + 86.0 + 87.5 + 85.5}{4} = 86.1 \text{ cm}$$

(i) Calculate a more accurate value for l_m.

(2)

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l_m = ...

(ii) Determine the time period of the oscillations of this pendulum, using your calculated value for l_m.

(2)

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Time period of oscillations = ...

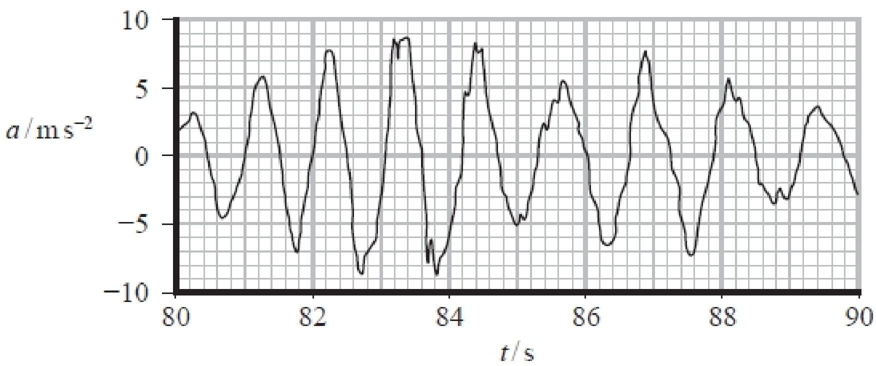
(Total for question = 4 marks)

Q4.

In 2011, a tsunami was caused by a massive earthquake centred some distance off the coast of Japan. The tsunami caused a cooling system failure at the Fukushima Nuclear Power Plant. This resulted in a nuclear meltdown and radioactive materials were released into the surroundings.

Buildings in nearby Tohoku University suffered structural damage during the 2011 earthquake.

The graph shows how the acceleration of one of the buildings, measured on the 9th floor, varied with time during the earthquake.



(Source: https://www.sciencedirect.com/science/article/pii/S0038080612001035)

At the time it was reported that during the earthquake the 9th floor of the building displaced by more than 30 cm from its normal position.

Assess the accuracy of this report.

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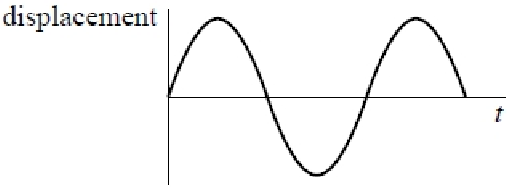
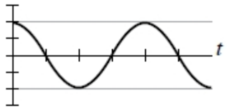
(Total for question = 5 marks)

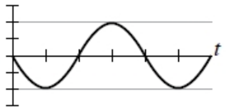
Q5.

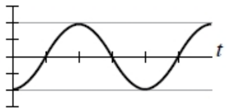
The graph shows the variation of displacement with time for a particle undergoing simple harmonic motion.

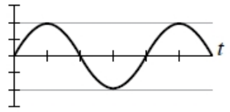


Select the graph that correctly shows the variation of velocity with time for the particle.

☐ **A** 

☐ **B** 

☐ **C** 

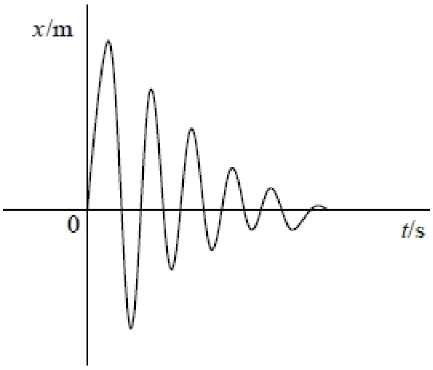
☐ **D** 

(Total for question = 1 mark)

Q6.

A tennis player uses a racket to hit a ball over a net. When the racket strikes the ball the racket frame is set into oscillation.

The graph shows how the displacement *x* of the centre of the frame varies with time *t* immediately following the strike.



Hollow spaces are built into the racket frame and small lead spheres are packed into these spaces.

Explain how this results in the graph shown.

(3)

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(Total for question = 3 marks)

Q7.

A pendulum of length *l* with a bob of mass *m* oscillates with frequency *f*.

What is the frequency of a pendulum of length 4*l* with a bob of mass 2*m*?

☒ **A** $4f$

☒ **B** $2f$

☒ **C** f

☒ **D** $\frac{f}{2}$

(Total for question = 1 mark)

Q8.

A playground swing completes 24 oscillations in 1 minute.

Which of the following is the frequency of the oscillations?

(1)

☒ **A** 0.042 Hz

☒ **B** 0.40 Hz

☒ **C** 2.5 Hz

☒ **D** 24 Hz

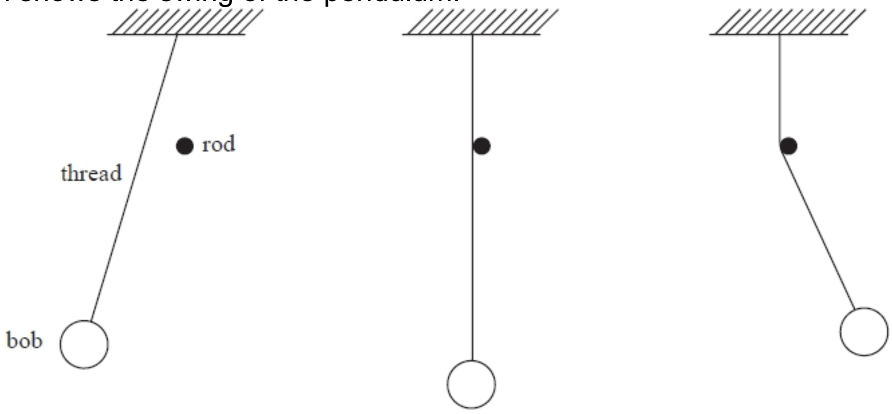
(Total for question = 1 mark)

Q9.

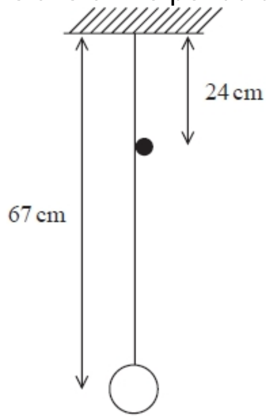
A simple pendulum consisting of a thread and a bob is set up next to a horizontal rod.

The bob is displaced to the left and released. When the bob reaches the equilibrium position the thread strikes the horizontal rod. For half of the cycle, only the lower part of the pendulum moves.

The diagram shows the swing of the pendulum.



The diagram below shows the dimensions of the pendulum.



Determine the frequency of the oscillations of the pendulum.

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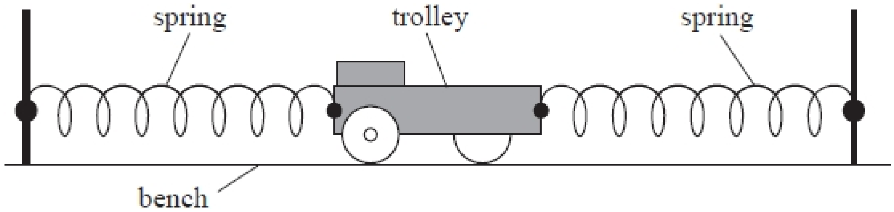
Frequency = ...

(Total for question = 4 marks)

Q10.

A trolley is attached to the ends of two springs as shown. When displaced from its equilibrium position, the trolley moves with simple harmonic motion.



The student displaces the trolley a greater distance from the equilibrium position, so the amplitude of oscillation is doubled. The trolley still moves with simple harmonic motion.

Explain how the maximum kinetic energy of the trolley will change.

(3)

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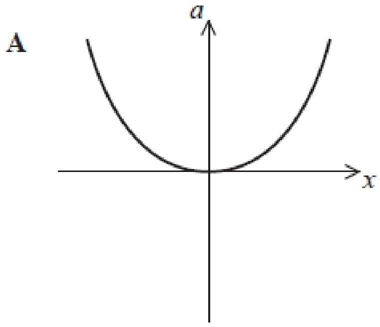
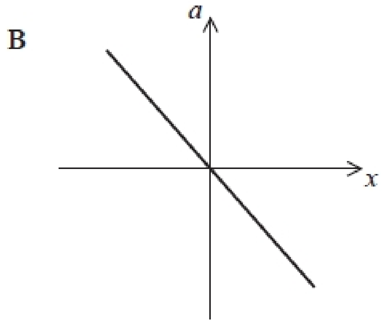
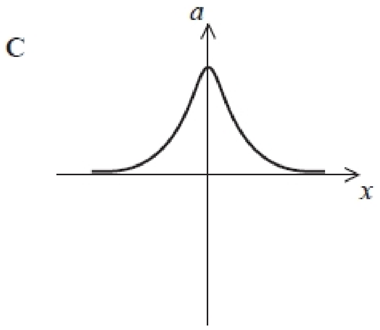
(Total for question = 3 marks)

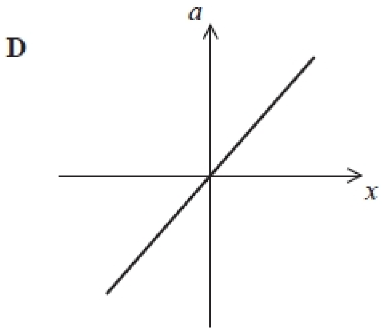
Q11.

Which of the following graphs correctly shows the relationship between acceleration *a* and displacement *x* for a simple harmonic oscillator?









☐ **A**

☐ **B**

☐ **C**

☐ **D**

Q12.

A pendulum of length *l* oscillates with a frequency *f*. The length of the pendulum is doubled.

The frequency of oscillation will be

☐ **A** $\frac{f}{\sqrt{2}}$

☐ **B** $\frac{f}{2}$

☐ **C** $\sqrt{2}f$

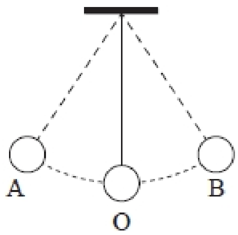
☐ **D** $2f$

(Total for question = 1 mark)

Q13.

A student is using a simple pendulum to determine a value for the acceleration of free fall *g*.

She sets the pendulum into oscillations with small amplitude and uses a stopwatch to determine the time period.



The student releases the pendulum at A and simultaneously starts the stopwatch. She measures the time taken for 5 oscillations and divides the value by 5. She repeats the procedure twice and calculates a mean time period.

Explain **two** modifications to the student's method that would improve the value obtained for the time period.

(4)

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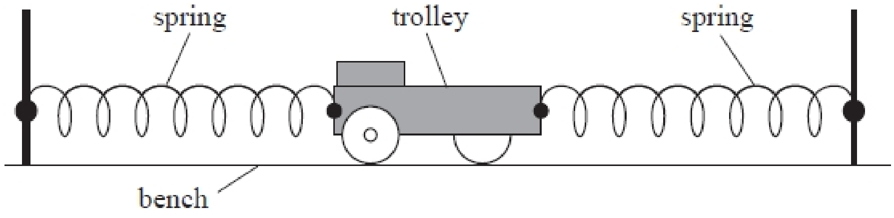
(Total for question = 4 marks)

Q14.

A trolley is attached to the ends of two springs as shown. When displaced from its equilibrium position, the trolley moves with simple harmonic motion.



A student has a stopwatch and metre rule available.

(i) Explain the procedure that the student should follow to make an accurate determination of the time period *T* of the trolley.

(6)

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(ii) Describe how the student should use her value of *T* to determine the maximum speed of the trolley.

(3)

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(Total for question = 9 marks)

Q15.

The photograph shows an example of a Foucault pendulum.

This is a pendulum that consists of a massive sphere, suspended by a long wire from a high ceiling. Over time the vertical plane through which the pendulum swings appears to rotate because of the rotation of the Earth.

mass of sphere = 28.0 kg

The pendulum makes 8 complete oscillations in 52.2 s.

Show that the length of the wire supporting the sphere is about 10 m.

diameter of sphere = 60.0 cm

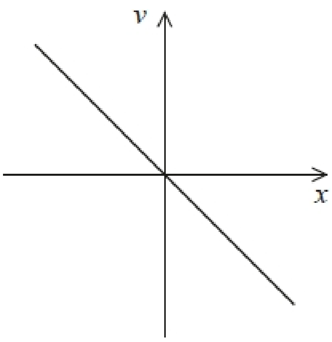
(4)

(Total for question = 4 marks)

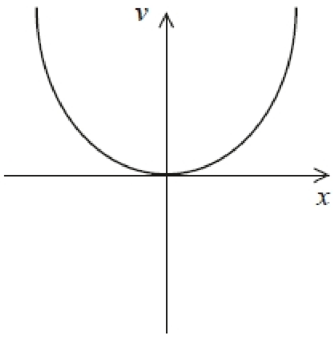
Q16.

A mass at the end of a spring is set into small amplitude simple harmonic motion.

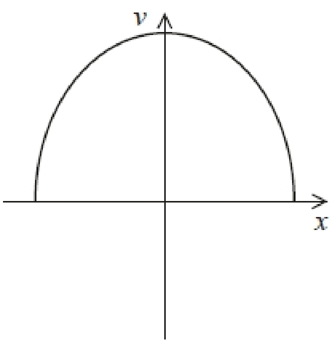
☐ **A**



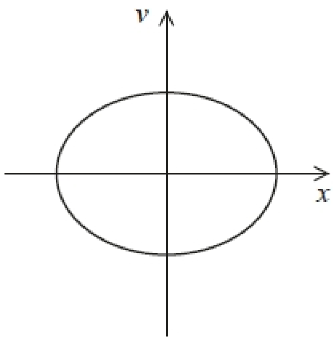
☐ **B**



☐ **C**



☐ **D**

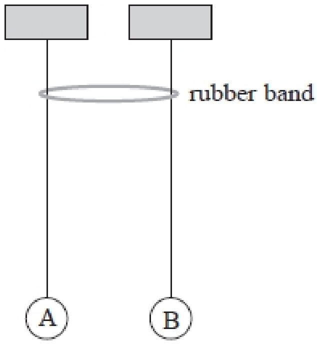


Which of the following graphs correctly shows the variation of velocity *v* of the mass with displacement *x* for one complete oscillation?

(Total for question = 1 mark)

Q17.

The diagram shows two identical pendulums, A and B, side by side with a rubber band placed over both strings.



Pendulum A is displaced and starts to oscillate. As pendulum A oscillates, pendulum B starts to oscillate with the same time period, its amplitude increasing as the amplitude of pendulum A decreases. At one stage pendulum A is no longer oscillating and pendulum B has its maximum amplitude. Then pendulum A starts to oscillate again with increasing amplitude, as the amplitude of pendulum B decreases.

The apparatus is adjusted so that the pendulums do not have the same length as each other. When the first pendulum is set into oscillation, the second pendulum starts to oscillate, but with very small amplitude; the first pendulum does not stop oscillating.

* Explain this behaviour.

(6)

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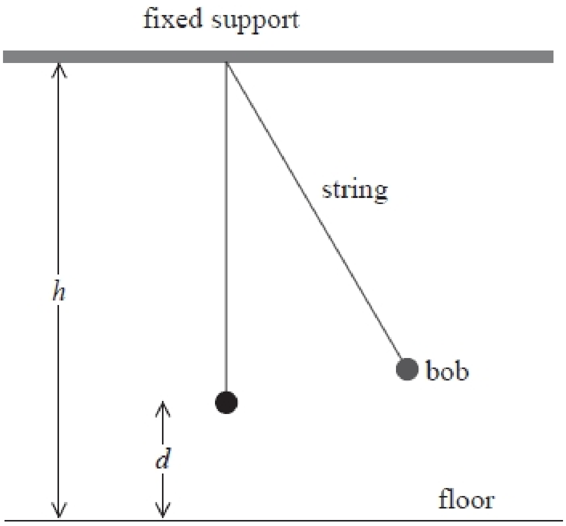
(Total for question = 6 marks)

Q18.

A student carried out an experiment with a pendulum hung from a fixed support. The fixed support was a distance *h* above floor level as shown.



As the student was unable to measure the length of the pendulum directly, she measured the distance *d* from the bob to the floor.

To determine the period *T* of the pendulum, the student used the following method:

- release the bob from its highest position and start a stopwatch
- stop the stopwatch when the bob reaches the same position again.

Criticise the student's method for measuring the period.

(2)

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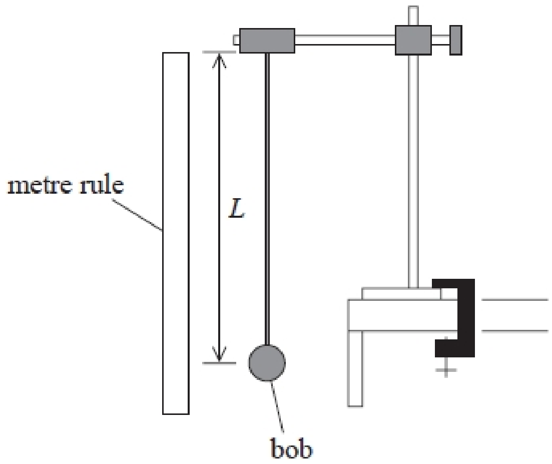
(Total for question = 2 marks)

Q19.

A student set up a "seconds pendulum". This is a simple pendulum for which the time taken to move from the bob's highest position on one side to its highest position on the opposite side is 1.00 s.



(a) Calculate the length *L* required for the pendulum to be a "seconds pendulum".

(2)

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L = ...

(b) The student set the pendulum into oscillation. She used a stopwatch to check the accuracy of the pendulum's period *T*.

Describe the procedure the student should have used to obtain an accurate value for *T*.

(2)

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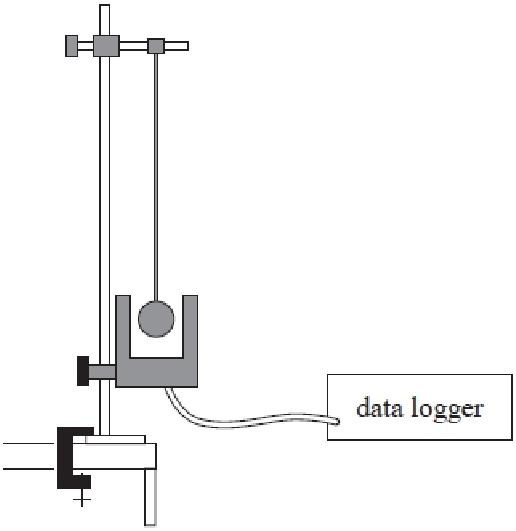
(c) Another student suggested that the uncertainty in the measurement of the time period of the pendulum could be reduced by using a light gate and a data logger. The data logger would record the time between successive interruptions of the light beam. Both the data logger and the stopwatch have a resolution of 0.01 s.



Comment on the student's suggestion of using a data logger rather than a stopwatch.

(4)

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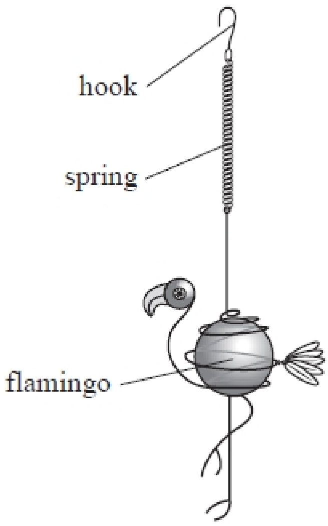
(Total for question = 8 marks)

Q20.

A garden ornament consists of a metal flamingo suspended from a spring as shown. The spring is hung from a support using the hook.



In a slight breeze the flamingo swings from side to side and behaves as a simple pendulum.

(i) Show that the period of oscillation of the flamingo pendulum is about 2.2 s.

pendulum length = 1.25 m

(2)

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(ii) The amplitude of oscillation of the flamingo pendulum is 7.5 cm.

Calculate the maximum velocity of the flamingo pendulum.

(3)

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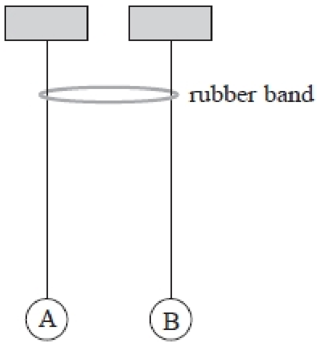
Maximum velocity = ...

(Total for question = 5 marks)

Q21.

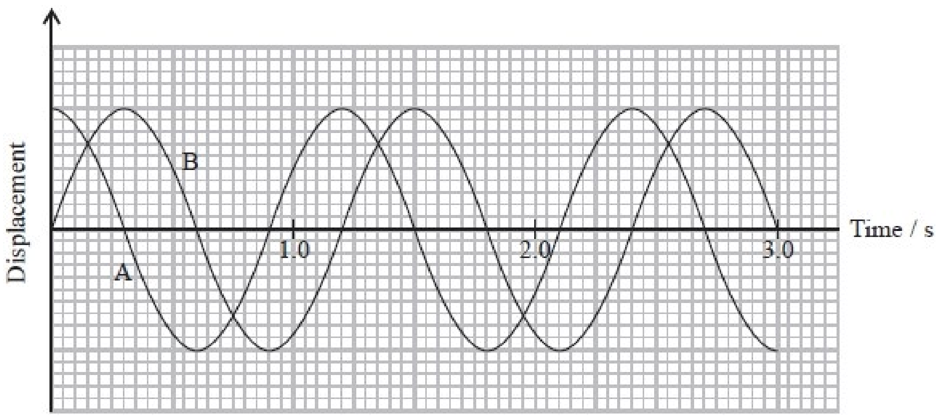
The diagram shows two identical pendulums, A and B, side by side with a rubber band placed over both strings.



Pendulum A is displaced and starts to oscillate. As pendulum A oscillates, pendulum B starts to oscillate with the same time period, its amplitude increasing as the amplitude of pendulum A decreases. At one stage pendulum A is no longer oscillating and pendulum B has its maximum amplitude. Then pendulum A starts to oscillate again with increasing amplitude, as the amplitude of pendulum B decreases.

The apparatus is adjusted so that the pendulums do not have the same length as each other. When the first pendulum is set into oscillation, the second pendulum starts to oscillate, but with very small amplitude; the first pendulum does not stop oscillating.

The graph shows how the displacement of each pendulum varies with time at one stage in the motion.



(i) State the phase relationship between the two pendulums.

(1)

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(ii) Determine the length of pendulums A and B.

(3)

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Length = ...

(Total for question = 4 marks)

Q22.

The photograph shows a 'singing bowl'.

When the handles are rubbed with both hands the bowl 'sings', producing a loud note with a frequency of 720 Hz.

A vibration generator is attached to the bowl and connected to a signal generator. The signal generator is adjusted to produce frequencies from 600 Hz to 800 Hz.

At all frequencies in this range the bowl produces a sound at the applied frequency. The sound is quiet for all frequencies except 720 Hz, when it is much louder.

Explain these observations.

(6)

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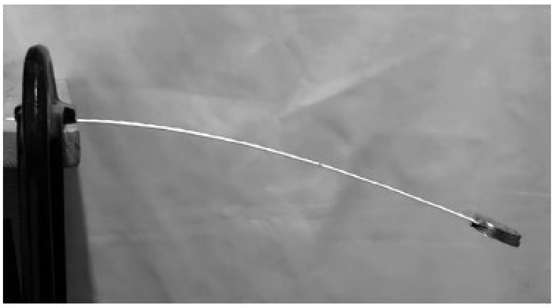
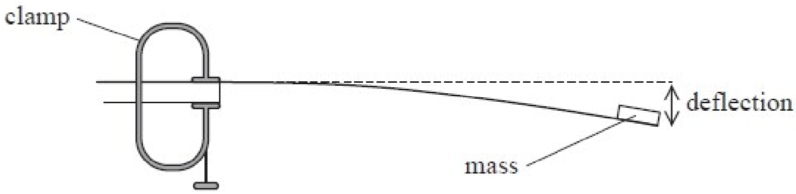
(Total for question = 6 marks)

Q23.

A student measured the deflection of a mass attached to the end of a thin strip of metal.

The strip was clamped to a bench at one end as shown.

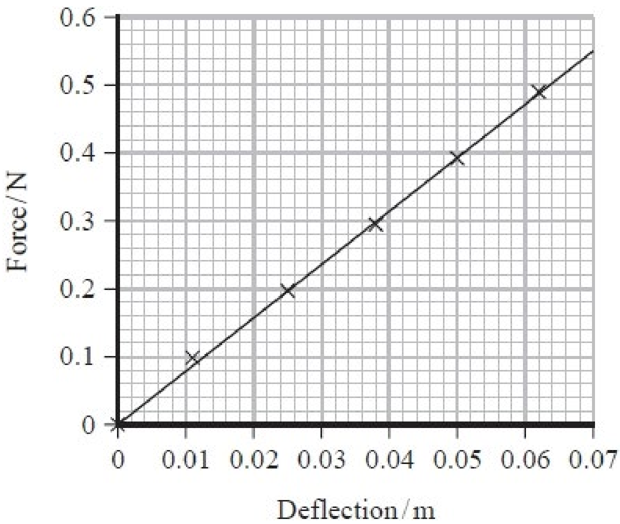




The student varied the force on the end of the strip by changing the mass attached.

The deflection was measured each time when the mass was in its equilibrium position.

The student obtained the following graph of deflection against force.



State why the mass will oscillate with simple harmonic motion when it is displaced slightly from its equilibrium position and released.

(2)

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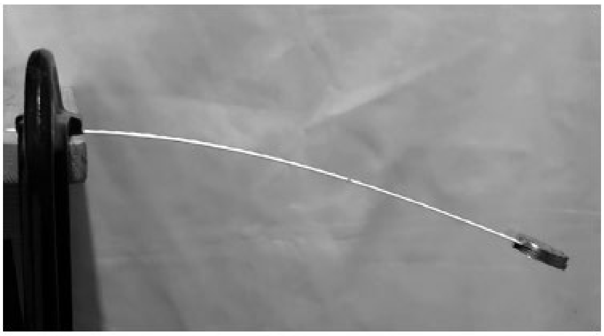
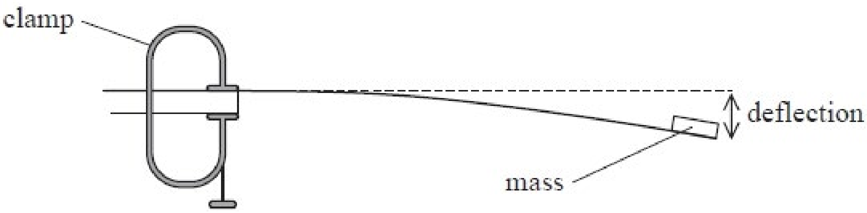
(Total for question = 2 marks)

Q24.

A student measured the deflection of a mass attached to the end of a thin strip of metal.

The strip was clamped to a bench at one end as shown.

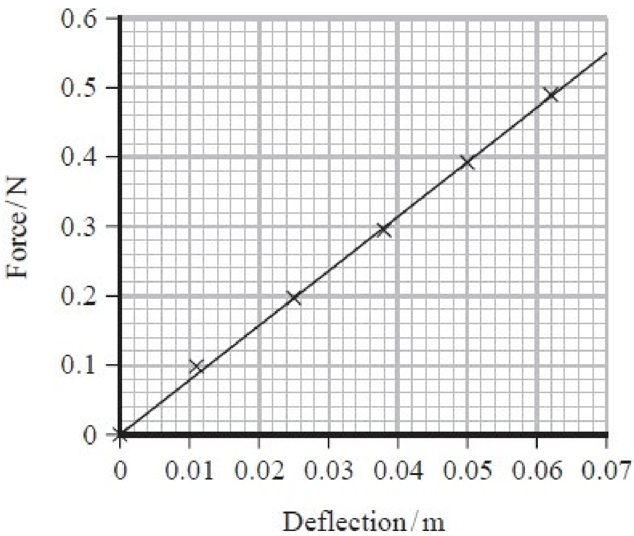




The student varied the force on the end of the strip by changing the mass attached.

The deflection was measured each time when the mass was in its equilibrium position.

The student obtained the following graph of deflection against force.



The student then investigated the oscillations of the mass on the metal strip. The student fixed different numbers of 10 g masses to the end of the metal strip.

The student noticed that the smaller the mass the higher the frequency of the oscillations. He estimated that the maximum number of oscillations he could count was two per second. He decided that the smallest mass he should use was 50 g.

Determine whether 50 g is the smallest mass he should use.

You may assume that the system acts in the same way as a mass on a spring.

(5)

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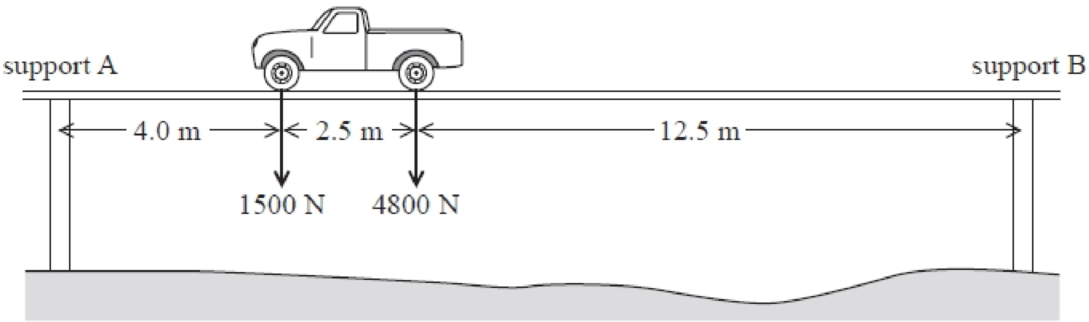
(Total for question = 5 marks)

Q25.

A beam bridge is a rigid structure that consists of one horizontal beam supported at each end.

The diagram shows a bridge with a uniform beam of mass 8 500 kg.

A small truck is crossing the beam bridge. The position of the truck and the forces of the truck on the bridge are shown, but are not drawn to scale.



(a) (i) State the conditions necessary for the bridge to be in equilibrium.

(2)

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(ii) Calculate the vertical forces at each of the bridge supports.

(5)

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Force at A = ...

Force at B = ...

The Volgograd Bridge is a concrete beam bridge across the River Volga in Russia.

In 2010 the bridge was closed to traffic due to windy conditions leading to resonance of the structure.

(i) Explain what is meant by resonance in this context.

(2)

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(ii) To suppress the oscillations of the bridge, dampers were installed.

Explain how damping resulted in the suppression of the oscillations of the bridge.

(3)

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(iii) Each damper contains an enclosure filled with a fluid. When this fluid is subjected to a magnetic field, the viscosity of the fluid greatly increases.

Describe how the behaviour of the fluid would change in a magnetic field and how this would be useful for the operation of the dampers.

(2)

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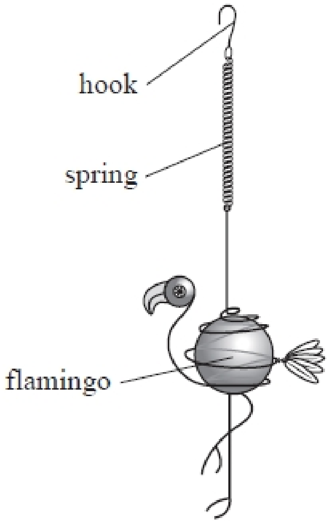
(Total for question = 14 marks)

Q26.

A garden ornament consists of a metal flamingo suspended from a spring as shown.
The spring is hung from a support using the hook.



The mass of the flamingo is 65 g. When the flamingo is suspended vertically the spring extends by 8.5 cm.

The flamingo is pulled downwards by a small extra displacement and then released.
The flamingo undergoes simple harmonic motion vertically.

The instructions state that the flamingo will oscillate with a frequency of 2.5 Hz.

Deduce whether this statement is correct.

(5)

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(Total for question = 5 marks)

Q27.

The Millennium Bridge is a pedestrian suspension bridge across the River Thames in London. The bridge had to be closed soon after its opening because of a large swaying motion created by people walking across it. A damping mechanism was installed to fix the problem.

The damping mechanism

☐ **A** increased the stiffness of the bridge.

☐ **B** increased the natural frequency of the bridge.

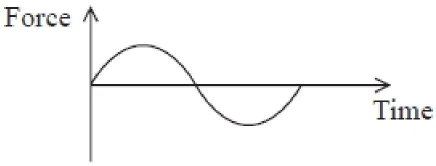
☐ **C** dissipated energy from the bridge.

☐ **D** decreased the forcing frequency on the bridge.

(Total for question = 1 mark)

Q28.

A mass is suspended from a spring and allowed to come to equilibrium.
The mass is displaced vertically and moves with simple harmonic motion.
The graph shows how the resultant force on the mass varies with time.



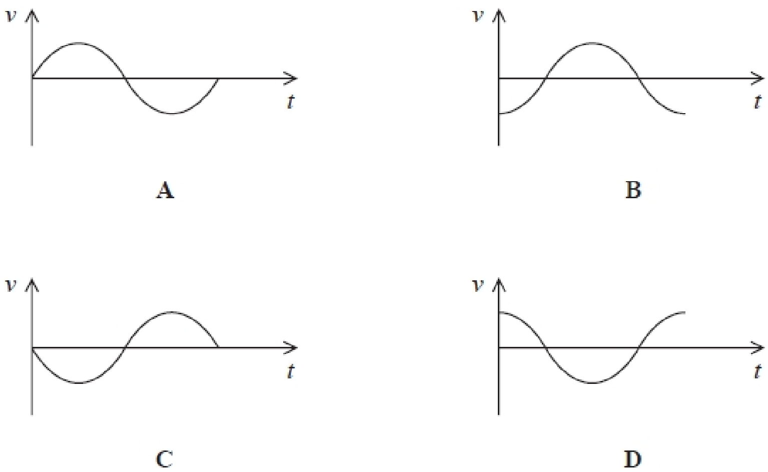
Which of the following graphs shows how the velocity v of the mass varies with time t over the same time interval?

☐ **A**

☐ **B**

☐ **C**

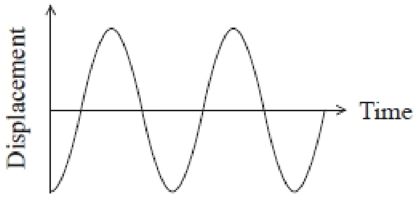
☐ **D**



(Total for question = 1 mark)

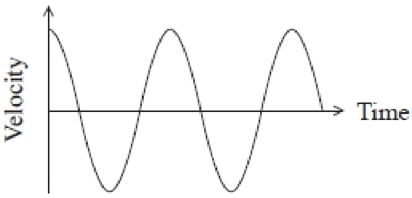
Q29.

The graph shows how the displacement of a simple harmonic oscillator varies with time.

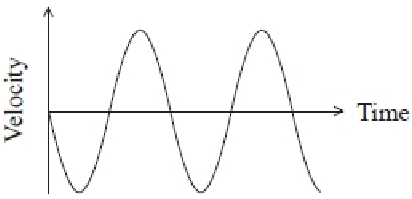


Which of the following graphs shows how velocity varies with time for the same oscillator, over the same time period?

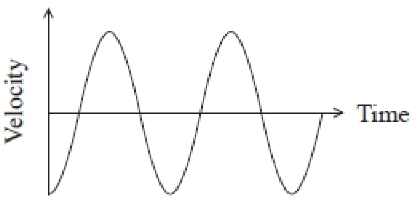
☐ **A**



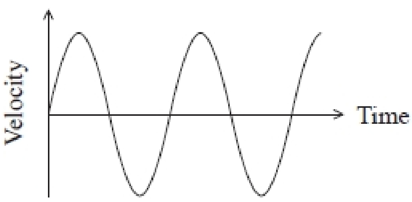
☐ **B**



☐ **C**



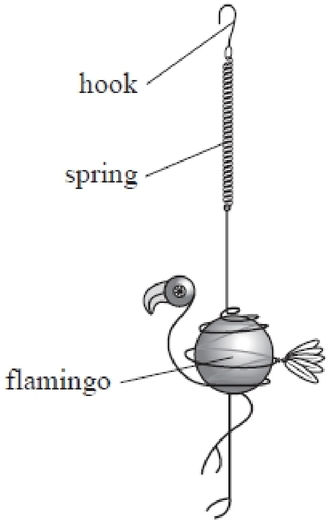
☐ **D**



(Total for question = 1 mark)

Q30.

A garden ornament consists of a metal flamingo suspended from a spring as shown. The spring is hung from a support using the hook.



After being set into vertical oscillation, the flamingo comes to rest after a short time.

Explain why the flamingo comes to rest.

(2)

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....

....

....

(Total for question = 2 marks)

Q31.

The International Space Station (ISS) is in a low Earth orbit. Astronauts in ISS have an apparent weight of zero. In order to determine their mass, the astronauts must secure themselves to a platform which is set into oscillation and moves with simple harmonic motion.

Explain why the astronauts in the ISS have an apparent weight of zero.

(2)

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....

(Total for question = 2 marks)

Q32.

The photograph shows an example of a Foucault pendulum.

This is a pendulum that consists of a massive sphere, suspended by a long wire from a high ceiling. Over time the vertical plane through which the pendulum swings appears to rotate because of the rotation of the Earth.

mass of sphere = 28.0 kg

To show the rotation of the Earth, the pendulum needs to oscillate for several hours.

Explain how using a heavy sphere is better than using a light sphere of the same diameter.

(3)

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(Total for question = 3 marks)

Mark Scheme

Q1.

Question Number	Acceptable answer	Additional guidance	Mark
	D	The only correct answer is **D** because when damping is decreased maximum amplitude increases and the frequency at which it occurs increases A is not correct because it states that they both decrease B is not correct because it states that the maximum amplitude decreases C is not correct because it states that the frequency decreases	1

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Determination of gradient (1) • Re-arrangement of $T = 2\pi\sqrt{\frac{l}{g}}$ (1) • Algebra to show $T^2 = -\frac{4\pi^2}{g}d + \frac{4\pi^2}{g}h$ (1) • Gradient = $(-)\frac{4\pi^2}{g}$ (1) • g = 9.6 m s^{-2} [accept 9.5 → 9.7 m s^{-2}] (1)	$T^2 = \frac{4\pi^2}{g}l$ $T^2 = \frac{4\pi^2}{g}(h-d)$ $T^2 = -\frac{4\pi^2}{g}d + \frac{4\pi^2}{g}h$ Example of calculation gradient = $\frac{(12.1-9.2)\ s^2}{(0.00-0.70)\ m}$ $= -4.1\ s^2m^{-1}$ $\therefore g = \frac{4\pi^2}{4.1\ s^2m^{-1}} = 9.6\ m\ s^{-2}$	5

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• discards value for l_3 (1) • l_m=85.7 (cm) (1)	MP2: answer to 1 d.p. only Example of calculation $l_m = \frac{85.5+86.0+85.5}{3}$ =85.7 cm	2
(ii)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ (1) • T=1.86 s (1)	ECF from (i) MP2: accept T = 1.9 s Example of calculation $T = 2\pi\sqrt{\frac{\ell}{g}}$ $= 2\pi \times \sqrt{\frac{0.857\ m}{9.81\ m\ s^{-2}}}$ =1.86 s	2

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Maximum value of a read from graph [8 m s^{-2} → 9 m s^{-2}] **(1)** • Value for period determined from time for at least 3 cycles **(1)** • Use of $\omega = \frac{2\pi}{T}$ **(1)** • Use of $a = (-)A\omega^2 \cos \omega t$ **(1)** • A = 0.33 m, so report is correct **(1)** [Accept value for A in range 0.25 m → 0.40 m with appropriate conclusion]	Example of calculation $T = \frac{(89.2 - 81.0)\text{ s}}{7} = 1.2\text{ s}$ $\omega = \frac{2\pi}{1.2\text{ s}} = 5.2\text{ rad s}^{-1}$ $x = \frac{a}{\omega^2} = \frac{9\text{ m s}^{-2}}{(5.2\text{ rad s}^{-1})^2} = 0.33\text{ m}$	5

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	A		1

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to: **Either** • The oscillating frame causes the lead spheres to deform plastically **(1)** • And this removes energy from the oscillating frame **(1)** • So the amplitude of oscillations decrease with time as shown by the graph **(1)** **OR** • Spheres collide/vibrate **(1)** • Hence energy dissipated **(1)** • So the amplitude of oscillations decrease with time as shown by the graph **(1)**		3

Q7.

Question Number	Acceptable answer	Additional guidance	Mark
	D	The only correct answer is **D** because the frequency is inversely proportional to the square root of length and independent of the mass, so if length is quadrupled, frequency is halved to $f/2$ A is not the correct answer because it is $4f$ B is not the correct answer because it is $2f$ C is not the correct answer because it is f	1

Q8.

Question Number	Answer	Mark
	B – 0.40 Hz	**1**
	Incorrect Answers: Correct method: $f = 24 \div 60\text{ s} = 0.40\text{ Hz}$ A – uses 1 minute ÷ 24 C – uses 60 s ÷ 24 D – uses 24 ÷ 1 minute	

Q9.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $T = 2\pi\sqrt{(l/g)}$ • Apply factor of 2 correctly for 2 half cycles • Use of $f = 1/T$ • $f = 0.68$ Hz	(1) (1) (1) (1)	Example of calculation $T = 2\pi\sqrt{(l/g)}$ $T = 2\pi\sqrt{(0.43 / 9.81)}$ $= 1.32$ s $T = 2\pi\sqrt{(0.67 / 9.81)}$ $= 1.64$ s $T = (1.32\text{ s} + 1.64\text{ s}) / 2 = 1.48$ s $f = 1 / 1.48\text{ s} = 0.68$ Hz	4

Q10.

Question Number	Acceptable Answer		Additional Guidance	Mark
	An explanation that makes reference to the following points:			
	• $v_{max} = \omega A$ and ω constant	(1)		
	• If A doubles, then v_{max} doubles	(1)		
	• Hence max E_k will quadruple, since $E_k = \frac{1}{2}mv^2$[dependent upon MP2]	(1)		
	OR			
	• $\Delta E_{el} = \frac{1}{2}F\Delta x$ and $\Delta F = k\Delta x$	(1)		
	• $\Delta E_{el} \propto (\Delta x)^2$ since k is constant	(1)		
	• Hence max E_k will quadruple, since max E_k = max ΔE_{el} (dependent upon MP2)	(1)		3

Q11.

Question Number	Answer	Additional guidance	Mark
	B		**(1)**

Q12.

Question Number	Answer	Additional guidance	Mark
	A	$(\frac{f}{\sqrt{2}})$	**(1)**

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Max 4 from 2 out of 3 pairs • The student should let the pendulum swing back and to before starting the stopwatch. (1) • The first swing may be affected by the student pushing the bob as they release it (1) • The student should use a (fiducial) marker at O (1) • Easier to determine when it passes O (1) • Time more oscillations (1) • A longer time reduces (%) uncertainty (in T) (1)	For each pair, the second marking point is dependent on the first marking point MP4: Accept the pendulum travelling fastest when it passes O	4

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • Time n oscillations and divide by n, where n is a large number (1) • Increasing the time (measured) reduces the uncertainty (in T) (1) • Repeat timing and calculate a mean (1) • Use a (fiducial) marker to indicate the reference position (1) • Use equilibrium position as reference position (1) • The trolley is moving fastest at this point so the uncertainty in starting/stopping the stopwatch is least (1)	Where $n \geq 5$ For equilibrium allow centre/undisplaced	6
(ii)	• Use $\omega = 2\pi/T$ (to calculate a value for ω) (1) **Or** use $\omega = 2\pi f$ with $f = 1/T$ • Measure the maximum displacement of the trolley from the equilibrium position (with the metre rule) (1) • Use $v_{max} = \omega A$ (to calculate a value for the maximum velocity of the trolley) (1)	For equilibrium allow centre/undisplaced [accept initial displacement for maximum displacement]	3

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	• Determine period, T (1) • Use of $T = 2\pi\sqrt{(l/g)}$ (1) • Subtracts radius of mass (1) • Length of wire = 10.3 (m) (1)	Example of calculation T = 52.2 s / 8 = 6.53 s 6.53 s = $2\pi\sqrt{(l/9.81 \text{ N kg}^{-1})}$ Length of pendulum to centre of mass = 10.6 m Length of wire = 10.6 m − 0.3 m = 10.3 m	4

Q16.

Question Number	Acceptable answer	Additional guidance	Mark
	D	The only correct answer is **D**: velocity is maximum when displacement is zero, and vice versa, and has positive and negative values since the direction reverses A is not correct because this shows maximum velocity when it should be minimum and vice versa B is not correct because this shows maximum velocity when it should be minimum and vice versa C is not correct because this does not show the change in direction of velocity during an oscillation	**1**

Q17.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th><th>Max linkage mark available</th></tr>
<tr><td>6</td><td>4</td><td>2</td></tr>
<tr><td>5</td><td>3</td><td>2</td></tr>
<tr><td>4</td><td>3</td><td>1</td></tr>
<tr><td>3</td><td>2</td><td>1</td></tr>
<tr><td>2</td><td>2</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>3</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Indicative content

- The pendulums have the same length, so they have the same time period/frequency
- The first pendulum causes forced oscillations of the second pendulum
- The driving frequency equals the natural frequency
- Resonance occurs, so there is maximum transfer of energy so the amplitude increases until all energy is transferred
- The second pendulum then acts as a driver for the first pendulum
  Or the process repeats with energy transfer from B to A
- When the lengths differ the driving frequency is not the natural frequency of the second pendulum so little energy transfer occurs

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Any **TWO** from: • Should have used (a fiducial mark as) a reference point **(1)** • Should have timed from the equilibrium position of the bob **Or** Shouldn't time from the maximum displaced position of the bob **(1)** • Only timed one oscillation **Or** should have times more than one oscillation **(1)** • Should have allowed the pendulum to swing to and fro a few times before starting to time (as the first swing may be different from the others) **(1)**	Accept centre/vertical/undisplaced position for equilibrium position	2

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Use of $T = 2\pi\sqrt{\frac{L}{g}}$ **(1)** • $L = 0.994$ m **(1)**	Example of calculation: $L = \frac{(2.00\,\text{s})^2 \times 9.81\,\text{m}\,\text{s}^{-2}}{4\pi^2} = 0.994\,\text{m}$	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	A description that makes reference to the following points: • Record nT (where n is at least 5) and divide by n (to find T) **(1)** • Time oscillations from equilibrium position of bob using a (fiducial) marker **Or** repeats timings for multiple oscillations and calculate mean **(1)**		2

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• Using the stopwatch there would be reaction time (1) • The uncertainty in the measurement of the time is larger with the stopwatch than with the data logger. (1) • Timing multiple swings (with stopwatch) reduces %U (1) • Light gates are difficult to use with a pendulum bob. (1)	MP2 dependent on MP1	4

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ (1) • $T = 2.24$ (s) (at least 3 sf) (1)	Example of calculation: $T = 2\pi\sqrt{\frac{1.25\text{ m}}{9.81\text{ m s}^{-2}}} = 2.24\text{ s}$	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $\omega = \frac{2\pi}{T}$ (1) • Use of $v = -A\omega \sin \omega t$ (1) • $v = 0.21\text{ m s}^{-1}$ (ecf from (i)) (1)	Example of calculation: $\omega = \frac{2\pi}{2.24\text{ s}} = 2.80\text{ rad s}^{-1}$ $v = -7.5 \times 10^{-2}\text{m} \times 2.80\text{ s}^{-1} \times 1$ $= 0.210\text{ m s}^{-1}$	3

Q21.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• Pendulum A is $\pi/2$ ahead of pendulum B (1)		1
(ii)	• $T = 1.2$ s from graph (1) • Use of $T = 2\pi\sqrt{(l/g)}$ (1) • $l = 0.36$ m (1)	$T = 3.0$ s / 2.5 oscillations $1.2\text{ s} = 2\pi\sqrt{(l/9.81\text{ N kg}^{-1})}$ $l = 0.36$ m	3

Q22.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>
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<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
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</table>

Indicative content

720 Hz is the natural frequency of the bowl
The generator/hand causes forced/driven oscillations
When they don't match the natural frequency they are quiet because little/less energy is transferred
The loudness (at 720 Hz) is because of resonance

</td><td></td><td>6</td></tr>
</table>

	• (Resonance occurs when) the driving frequency is equal/similar to the natural frequency • (When resonance occurs) there is maximum transfer of energy so the amplitude is maximum **Or** (When resonance occurs) there is maximum transfer of energy so the amplitude increases	Do not accept 'resonant frequency' for 'natural frequency'	

Q23.

Question Number	Acceptable answers	Additional guidance	Mark
	□ because the (resultant) force is (directly) proportional to displacement from equilibrium position (1) □ force is in the opposite direction to displacement **or** force is (always) acting towards the equilibrium position (1)		2

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of graph to find gradient = k (= F/x) (1) • use of $T = 1/f$ (1) • use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) • m = 0.05 (kg) **or** k using 50 g and 2 Hz = 7.9 (N m^{-1}) **or** f using 50 g and k from graph = 2.0 (Hz) **or** T using 50 g and k from graph = 0.50 (s) (1) • Comparison and correct conclusion (dependent on MP4) (1)	Example of calculation k = 0.55 N / 0.07 m = 7.86 N m^{-1} T = ½ = 0.5 s $0.5\text{ s} = 2\pi\sqrt{\frac{m}{7.86\text{ N m}^{-1}}}$ m = 0.050 kg (0.0498 kg) A smaller mass means a shorter period, so smaller than 0.05 kg would be a higher frequency than 2 Hz, so 50 g is smallest mass.	5

Q25.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)(i)	• no net force on bridge • no net moment of force about any point	(1) (1)	Alternative wording that implies these 2 points will be accepted	**(2)**
(a)(ii)	• use of $W = mg$ to find the weight of the bridge • use of moment = $F\,x$ • applies principle of moments • F_A = 43610 N • applies equilibrium of forces or applies principle of moments about a different point to obtain F_B = 45990 N	(1) (1) (1) (1) (1)	<u>Example of calculation:</u> W = mg = 8500 kg × 9.8 N kg^{-1}= 83300 N Taking moments about A, Clockwise moments = (1500 N × 4 m) + (4800 N × 6.5 m) + (83300 N × 9.5 m) Anticlockwise moments = F_A × 19 m 19 N × F_A = 828550 Nm F_A = 828550 Nm/19 m = 43610 N F_A + F_B = 1500 N + 4800 N + 83300 N F_B = 89600 N − 43610 N = 45990 N	**(5)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(b)(i)	• resonance occurs when the bridge is forced into oscillation at its natural frequency • this results in an increasing amplitude of oscillation of the bridge, which may damage the bridge	(1) (1)		**(2)**
(b)(ii)	• energy was transferred from the oscillating bridge to the dampers • this energy was dissipated in the dampers (and not returned to the bridge) • hence the amplitude of oscillation was kept small	(1) (1) (1)		**(3)**
(b)(iii)	• as the viscosity of the fluid increased the fluid would offer greater resistance to movement [accept reverse argument] • a greater resistance to movement would result in a greater energy dissipation	(1) (1)		**(2)**

Q26.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $W = mg$ (1) • Use of $\Delta F = k\Delta x$ (1) • Use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) • Use of $f = \frac{1}{T}$ (1) • f = 1.7 (Hz), so claim is incorrect. (1)	Example of calculation: $k = \frac{65 \times 10^{-3}\text{kg} \times 9.81\text{ N kg}^{-1}}{0.085\text{ m}} = 7.50\text{ N m}^{-1}$ $T = 2\pi\sqrt{\frac{65 \times 10^{-3}\text{ kg}}{7.50\text{ N m}^{-1}}} = 0.585\text{ s}$ $f = \frac{1}{T} = \frac{1}{0.585\text{ s}} = 1.71\text{ Hz}$	5

Q27.

Question Number	Answer	Mark
	C	1

Q28.

Question Number	Answer	Mark
	The only correct answer is B because acceleration is proportional to force, so the acceleration graph would have the shape of the force graph. The acceleration at the start is zero, so the velocity graph must have an initial gradient of zero. For the acceleration to be positive in the first quarter cycle the velocity must be increasing. This graph has an initial gradient of zero and increasing velocity. A the initial gradient is not zero C the initial gradient is not zero D the velocity in the first quarter cycle is decreasing	1

Q29.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is **D** because velocity is equal to the gradient of the displacement-time graph A is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as proportional to −1 times the displacement B is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as −1 times the gradient C is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as proportional to the displacement		1

Q30.

Question Number	Acceptable answers	Additional guidance	Mark
	• There is damping **Or** resistive forces act on the flamingo (1) • Energy is removed from the oscillating system (and the amplitude decreases) (1)		2

Q31.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • The astronauts are in free fall in the space craft **Or** The acceleration of the astronauts and the space station are the same (1) • So there is no contact/reaction force acting on them (1)	For MP2, accept a statement that the gravitational force (weight) is the only force acting upon them **Or** all of their weight is used to provide the centripetal force /acceleration	2

Q32.

Question Number	Acceptable answers	Additional guidance	Mark
	• There is (damping due to) air resistance and this (damping) force is the same for both (since they have the same shape, area and speed initially) (1) • For large mass the force due to air resistance produces a smaller negative acceleration since $a = F/m$ (1) • The speed will decrease less for each swing, so there is less effect on the amplitude **Or** It will take longer for the (maximum) speed to decrease (to zero) so the pendulum will oscillate for a longer time (1) **OR** • There is air resistance and the force is the same for both (1) • The work done by air resistance per swing is the same for both masses (1) • Initially the larger mass has greater quantity of energy shared between its kinetic and potential energy stores, so the proportion of KE transferred to the thermal energy store of the sphere and the surroundings is less per swing, so there is less effect on the amplitude **Or** Larger mass has greater total energy so fraction dissipated per swing is smaller so the pendulum will oscillate for a longer time (1)		3
	OR There is air resistance and this force is the same for both (1) • For both masses the change in momentum per swing is the same (1)		
	• The larger mass has greater initial momentum so it will take longer for the (maximum) momentum to decrease (to zero) so the pendulum will oscillate for a longer time (1)		