Name: _____

Simple Harmonic Motion

Questions

Date:

Time:

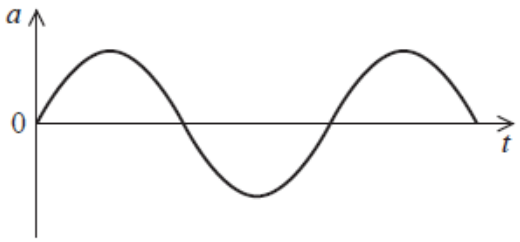
Total marks available:

Total marks achieved: _____

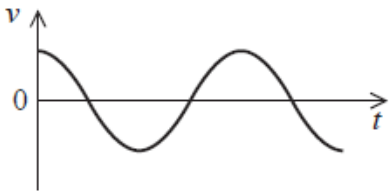
Questions

Q1.

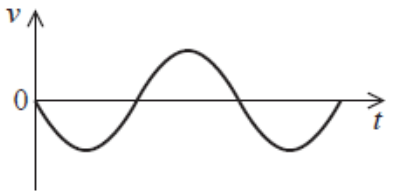
The graph shows how the acceleration varies with time for an object undergoing simple harmonic motion.



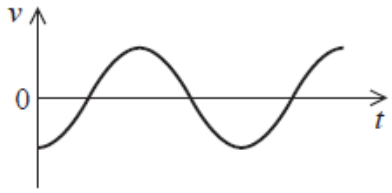
Which of the following graphs, **A**, **B**, **C** or **D**, shows how the velocity of the object varies with time?



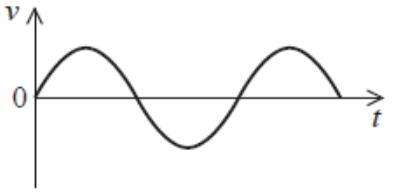
A



B



C



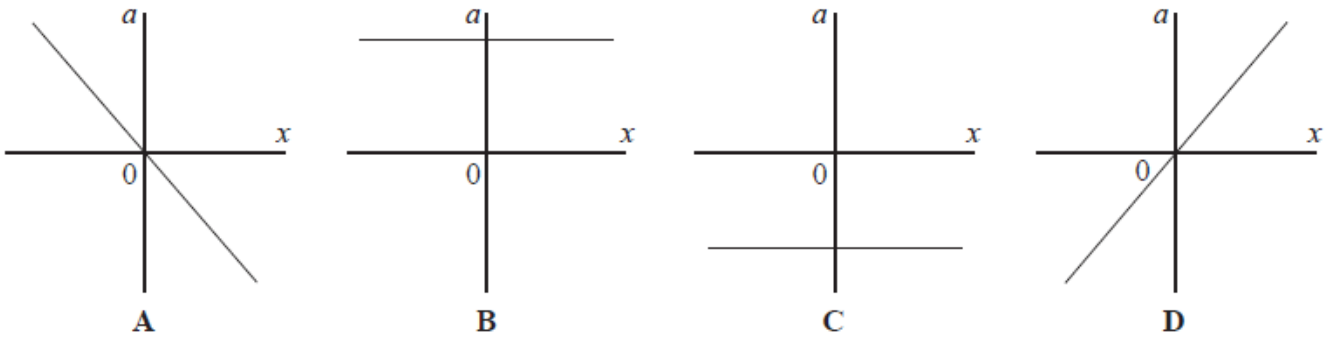
D

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for question = 1 mark)

Q2.

An object is undergoing simple harmonic motion.
Which graph shows how the acceleration *a* varies with displacement *x* from the equilibrium position?



- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for question = 1 mark)

Q3. A mass is bouncing on the end of a vertical spring. Its motion will be simple harmonic if the spring

- ☒ **A** can store energy.
- ☒ **B** has elasticity.
- ☒ **C** is hung vertically.
- ☒ **D** obeys Hooke's law.

(Total for Question = 1 mark)

Q4.

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

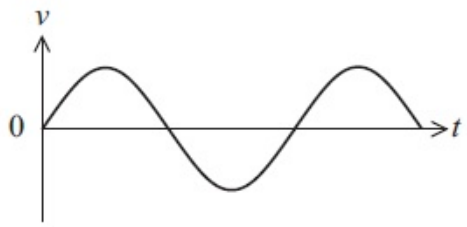
☒ **C** 2.5 Hz

☒ **D** 24 Hz

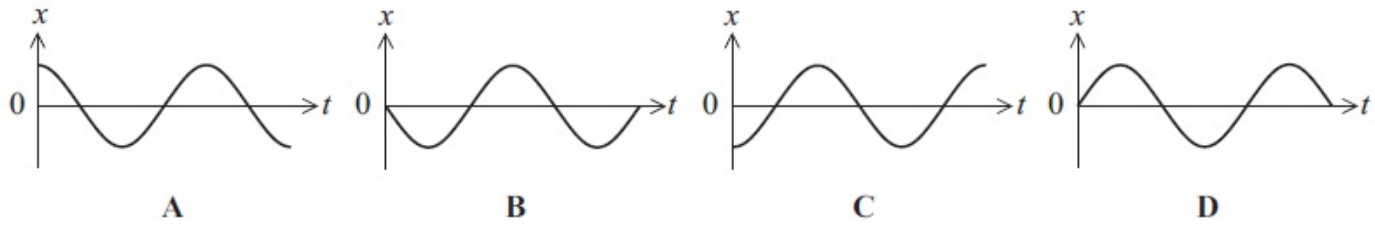
(Total for question = 1 mark)

Q5.

The graph below shows how the velocity varies with time for an object undergoing simple harmonic motion.



Which graph shows the variation of displacement with time?



☒ **A**

☒ **B**

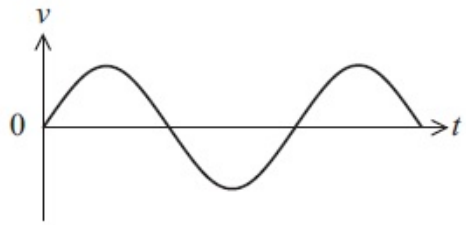
☒ **C**

☒ **D**

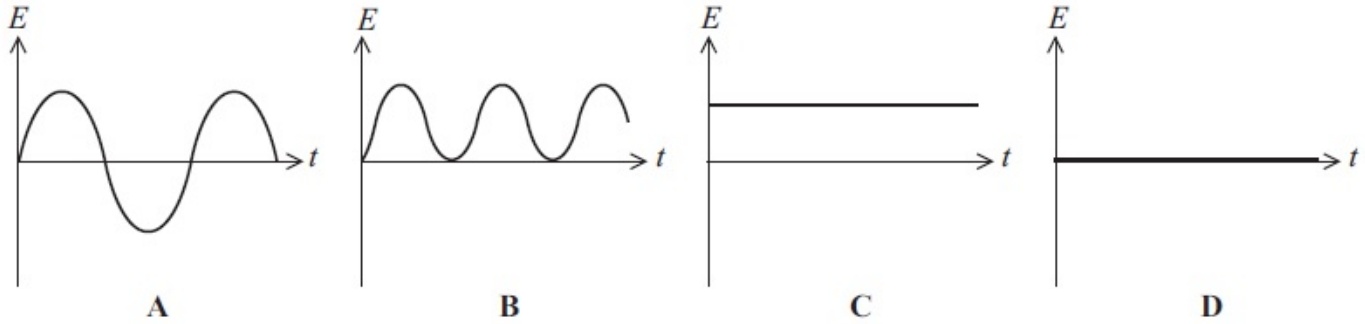
(Total for question = 1 marks)

Q6.

The graph below shows how the velocity varies with time for an object undergoing simple harmonic motion.



Which graph shows the variation of total energy with time?



☒ **A**

☒ **B**

☒ **C**

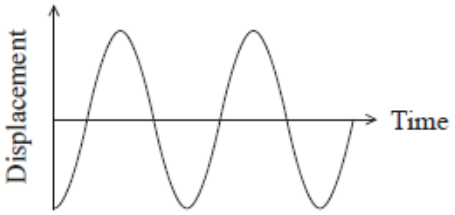
☒ **D**

(Total for question = 1 marks)

Q7.

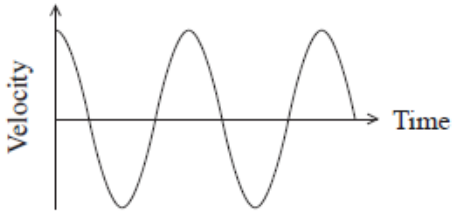
Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

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

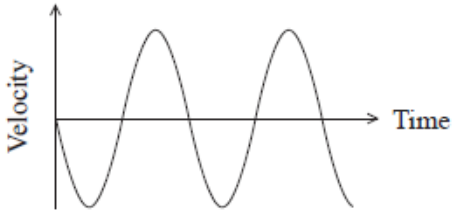


Which of the following graphs shows how velocity varies with time for the same oscillator, over the same time period?

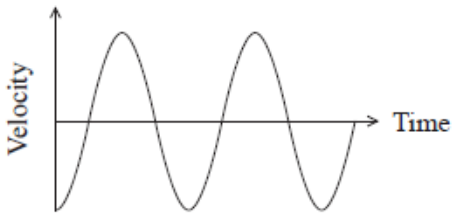
☒ **A**



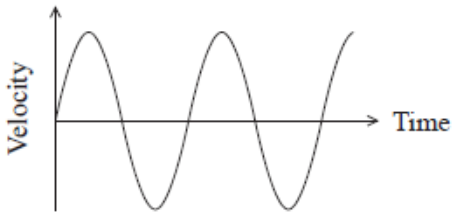
☒ **B**



☒ **C**



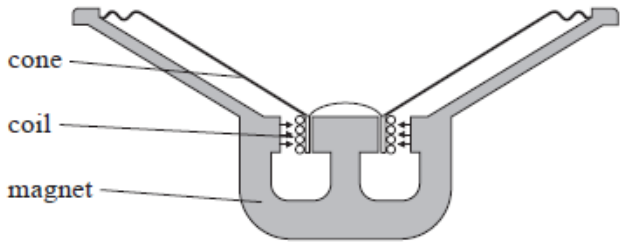
☒ **D**



(Total for question = 1 mark)

Q8.

A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate.



The loudspeaker cone undergoes simple harmonic motion.

(i) State what is meant by simple harmonic motion.

(2)

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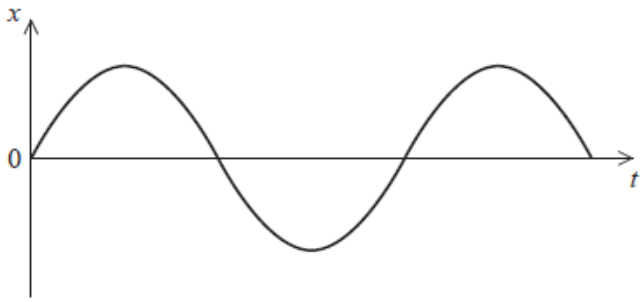
(ii) The graph below shows how the displacement x of the cone varies with time t.

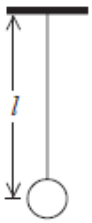
Add another line to the graph to show how the acceleration of the cone varies over the same time interval.

(1)

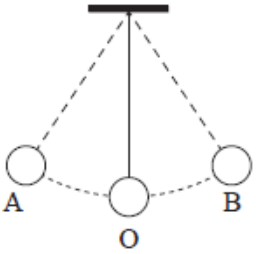


Q9.

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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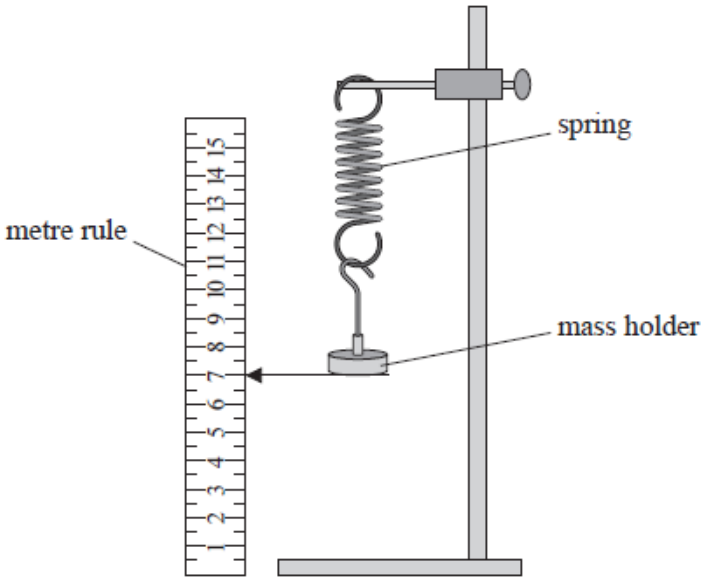
(Total for question = 4 marks)

Q10.

A student investigated the behaviour of a spring under tension. The spring was hung vertically with a mass holder attached.



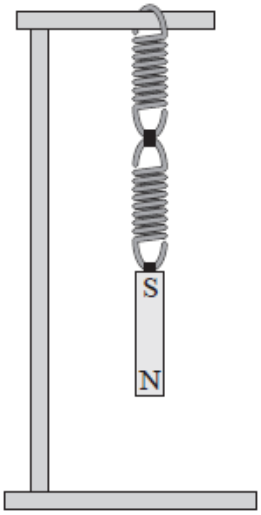
The position of the bottom of the mass holder was recorded. The spring was stretched by adding

masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

The student produced the following table.

Mass added / g	Extension / cm	Stretching force / N
50	1.9	0.49
70	3	0.69
90	3.5	0.9
110	4.5	1.08
130	5.3	1.28
150	5.8	1.47

Two identical springs are joined in series and a bar magnet is hung from one end as shown.



The bar magnet is displaced a small distance vertically from its equilibrium position and released.

Calculate the frequency at which the system oscillates.

mass of magnet = 120 g
spring constant of each spring = 22 N m^{-1}

(4)

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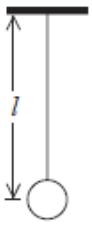
Frequency = ...

(Total for question = 4 marks)

Q11.

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 I_m.

(2)

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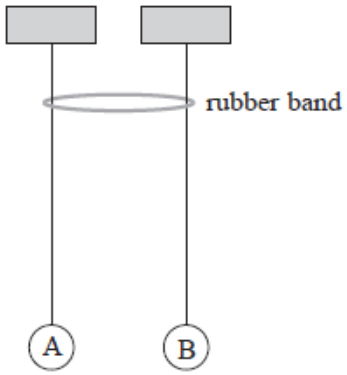
Time period of oscillations = ...

(Total for question = 4 marks)

Q12.

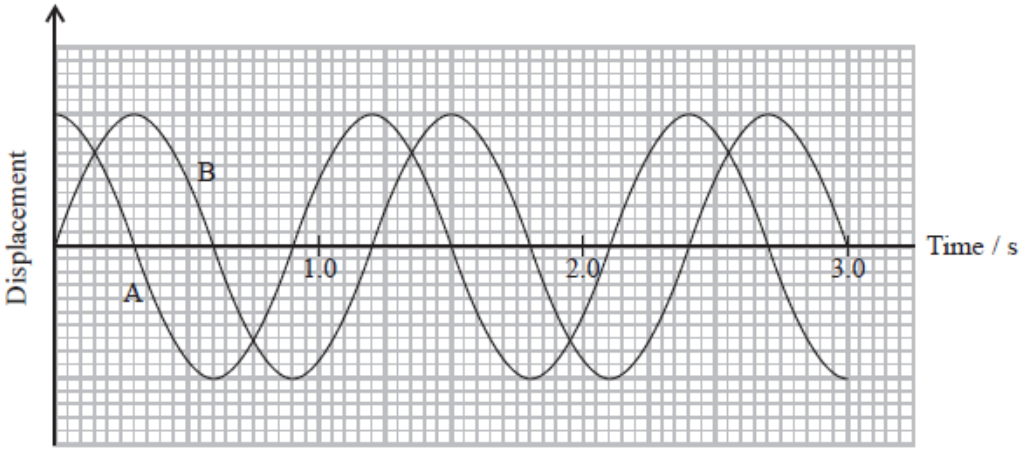
The diagram shows two identical pendulums, A and B, side by side with a rubber band placed over both strings.



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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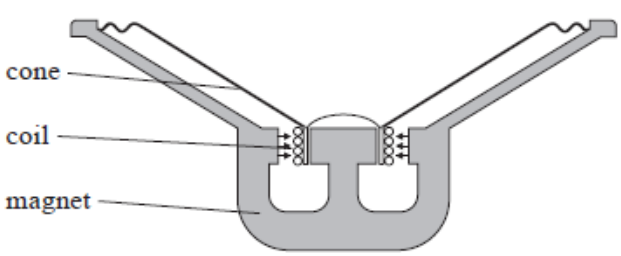
Length = ...

(Total for question = 4 marks)

Q13.

A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate.



Some sand is sprinkled onto the cone. The sand oscillates vertically with the frequency of the cone. Keeping the frequency constant, the current is increased. This increases the amplitude of oscillation of the cone.

At a particular amplitude of oscillation the sand begins to lose contact with the cone.

(i) By considering the forces acting on a grain of sand, explain why this happens.

(3)

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(ii) At a particular frequency, when the amplitude of the cone is 0.25 mm, a grain of sand loses contact with the cone.

Calculate this frequency.

(3)

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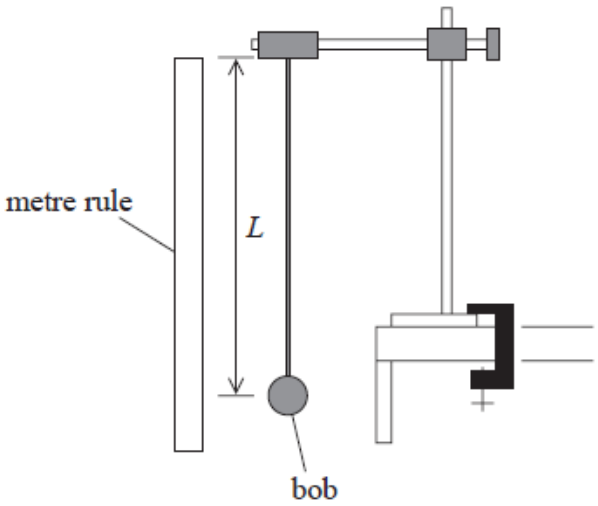
Frequency = ...

Q14.

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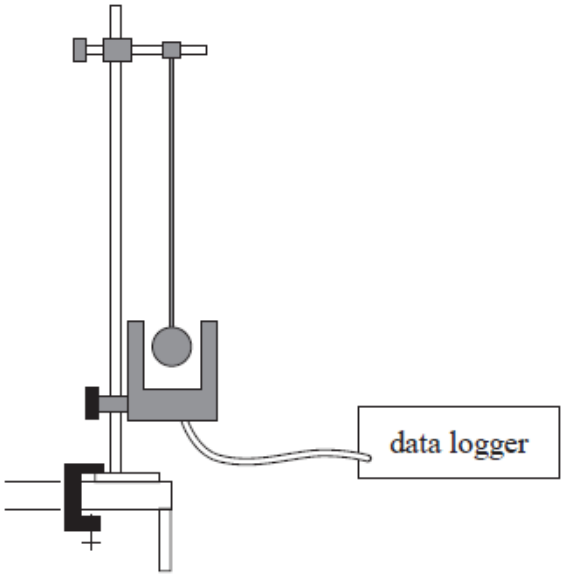
(c) Another student suggested that the uncertainty in the measurement of the time period of the pendulum could be reduced by using a light gate and a data logger. The data logger would record the time between successive interruptions of the light beam. Both the data logger and the stopwatch have a resolution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



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

(4)

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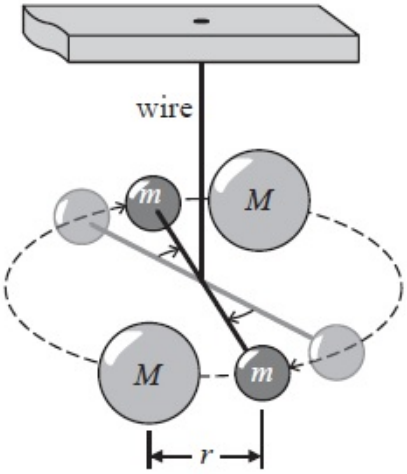
(Total for question = 8 marks)

Q15. In the 18th century Henry Cavendish devised an experiment to determine the average density of the Earth. This involved the first laboratory determination of the universal gravitational constant *G*.

A light horizontal rod with a small metal sphere at each end was hung from a fixed point by a

very thin wire. Two large lead spheres were then brought close to the small spheres causing the rod to oscillate and then settle into a new position of equilibrium.



(a) In a modern version of the experiment the following data was obtained:

mass of large lead sphere M = 160 kg

mass of small sphere m = 0.75 kg

distance r = 0.23 m

gravitational force between adjacent large and small spheres $F = 1.5 \times 10^{-7}$ N.

Use this data to calculate a value for G.

(2)

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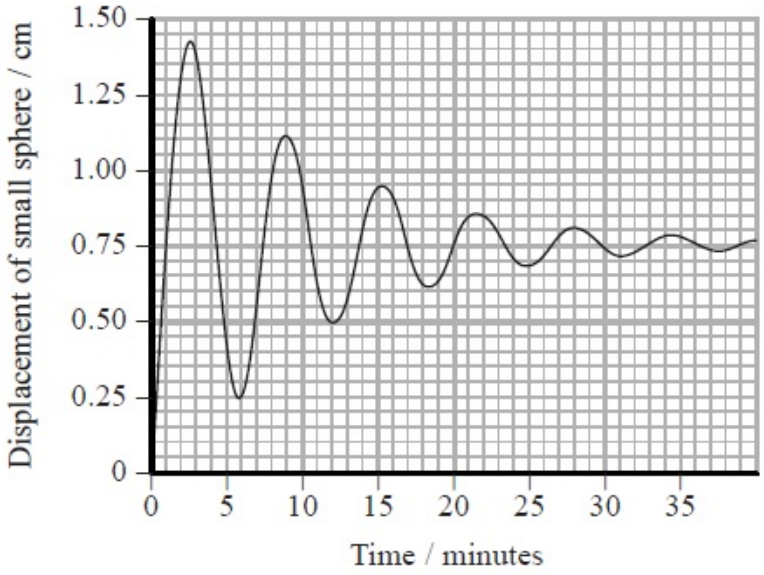
G = ...$Nm^2\ kg^{-2}$

(b) The graph shows how the displacement of one of the small spheres varies with time.



(i) Use the graph to determine the period of oscillation of the sphere.

(2)

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Period = ...

(ii) The amplitude of the oscillation decreases with each cycle.

Explain why this effect is observed.

(2)

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(iii) It is suggested that the decrease in amplitude is exponential. Use the graph to determine if this is approximately true.

(3)

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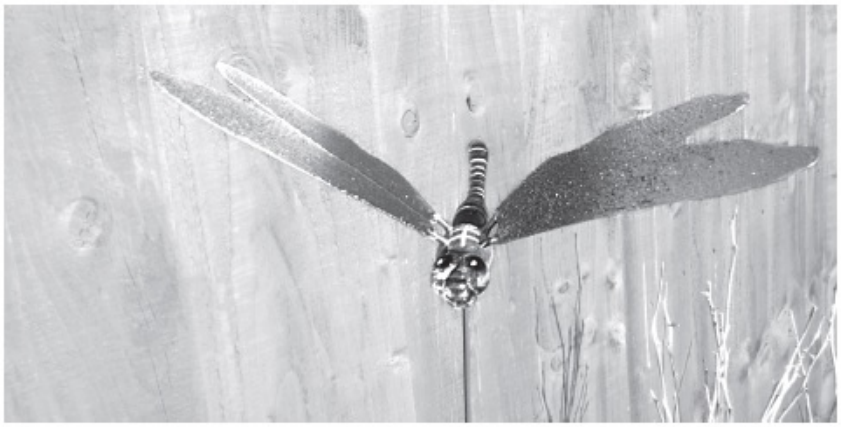
(Total for Question = 9 marks)

Q16.

A garden ornament consists of a plastic dragonfly mounted on a stick. The dragonfly's wings are attached to the body with springs, and they flutter up and down in a gentle breeze.



(a) When the air is not moving and the wings are displaced through a small vertical distance, they oscillate. The time for 10 oscillations is recorded. This is repeated twice more.

Time / s		
t_1	t_2	t_3
6.2	6.6	6.9

(i) Calculate the frequency of oscillation of the wings

(3)

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Frequency = ...

(ii) The oscillation of the wings is thought to be simple harmonic motion.

State the conditions required for the oscillations to be simple harmonic.

(2)

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(b) The amplitude of the wings' oscillation dies down after only a small number of oscillations.

Explain why this happens

(2)

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(c) In certain breezy conditions the wings are seen to oscillate with a very large amplitude.

Name this effect and state the condition for it to occur.

(2)

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(Total for question = 9 marks)

Q17.

A baby-bouncer is a light harness, into which a baby can be placed, suspended by a vertical spring.

The height of the baby-bouncer is adjusted so that the baby's feet are a few centimetres above the floor when the baby is in equilibrium in the harness. If the baby is then displaced downwards and released, the system oscillates vertically with simple harmonic motion.

It is stated in a textbook that "a mass-spring system that obeys Hooke's law will lead to simple harmonic motion when the mass is displaced."

*(a) Explain why a system consisting of a mass and a spring that obeys Hooke's law may be set into simple harmonic motion.

(3)

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(b) The acceleration experienced by a baby of mass 8.2 kg is 0.49 m s^{-2} when the displacement from the equilibrium position is 3.0 cm.

Show that the period of vertical oscillations for this baby is about 1.6 s.

(3)

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(c) The amplitude of the oscillations quickly decreases, so the baby has to keep kicking on the floor to maintain them.

(i) State the name given to oscillations that die away quickly.

(1)

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(ii) State the name that is given to oscillations such as those that are kept going by the baby kicking on the floor.

(1)

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(iii) If the baby kicks on the floor at a certain frequency, the amplitude of the bounces can be made to increase to a maximum.

Name this effect and calculate the frequency at which it occurs.

(2)

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Frequency = ...

(d) The baby is replaced by a baby of less mass. This baby also kicks to produce maximum amplitude of oscillation. Without further calculation, explain how the frequency at which the baby must kick compares to that for the larger mass baby.

(2)

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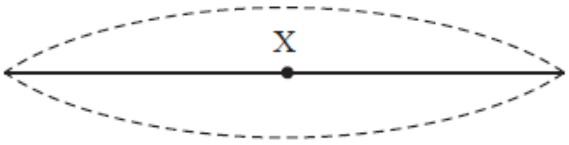
(Total for Question = 12 marks)

Q18.

Guitar strings can oscillate with simple harmonic motion.

Shortly after the string is plucked, a standing wave exists on the string. The simplified diagram below shows a string in three positions of the standing wave.



(a) State what is meant by simple harmonic motion.

(2)

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(b) (i) Describe the acceleration of point X on the string as it moves between the extreme positions of its motion.

(2)

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(ii) Comment on the energy changes in the string as it moves between the extreme positions of its motion.

(3)

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(c) The oscillating string has a length of 0.53 m. Calculate the frequency of the sound emitted when the string oscillates as shown previously.

speed of the wave on the string = 270 m s^{-1}

(3)

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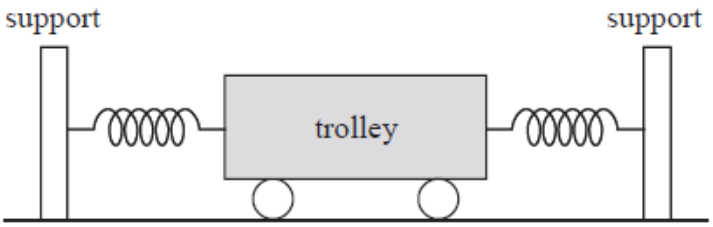
Frequency = ...

(Total for question = 10 marks)

Q19.

The diagram shows a mass-spring system that consists of a trolley held in equilibrium by springs attached to two fixed supports.



The trolley has a mass *m* and the spring arrangement has a force constant *k*.

(a) (i) The trolley is displaced towards one of the supports through a distance *x* and then released. Show that the initial acceleration of the trolley when it is released is given by $a = -\frac{kx}{m}$

and explain the significance of the minus sign.

(2)

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(ii) Use the expression in (i) to show that the trolley will oscillate with a time period T given by

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

(3)

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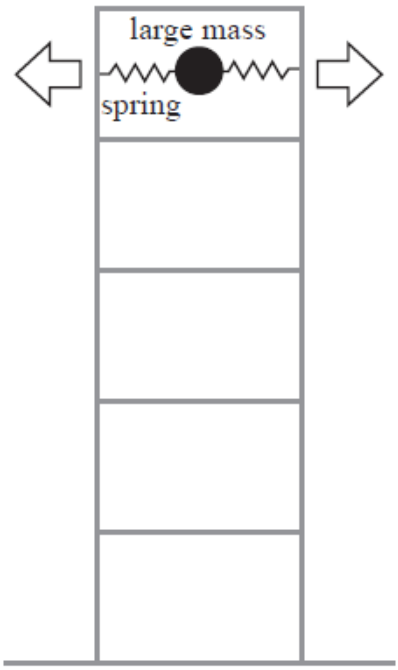
(b) Mass-spring systems are sometimes used in tall buildings to reduce the oscillation of the building due to strong winds.



As the top of the building moves the mass is set into oscillation. The mass-spring system is designed to have a natural frequency equal to that of the building.

(i) In one building a mass-spring system has a mass of 3.5×10^5 kg and the spring arrangement has a force constant of 4.8×10^6 N m^{-1}.

Show that the natural frequency of the mass-spring system is about 0.6 Hz.

(3)

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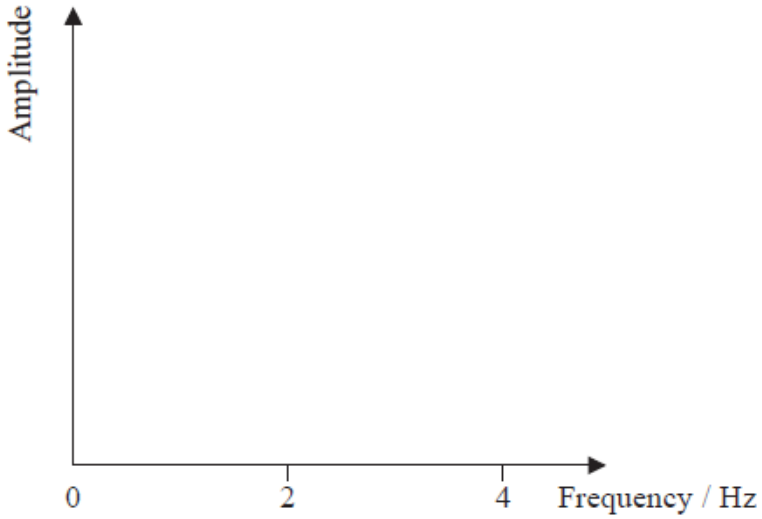
(ii) Sketch a graph to show how the amplitude of oscillation of the mass would vary with the frequency of movement of the building. Ignore the effects of damping.

(3)



(iii) In order to be effective the mass-spring system needs to be damped.

Explain what is meant by damping in this context and suggest why damping is a desirable feature of the mass-spring system in a tall building.

(3)

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(Total for question = 14 marks)