Name: ____

Damping and Resonance

Date:

Time:

Total marks available:

Total marks achieved: ______

Questions

Q1.

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)

Q2.

Whilst a car is being driven over a bridge, it sets the bridge into vibration. Which of the following terms definitely describes the oscillations of the bridge?

The oscillations of the bridge are

☐ **A** free.

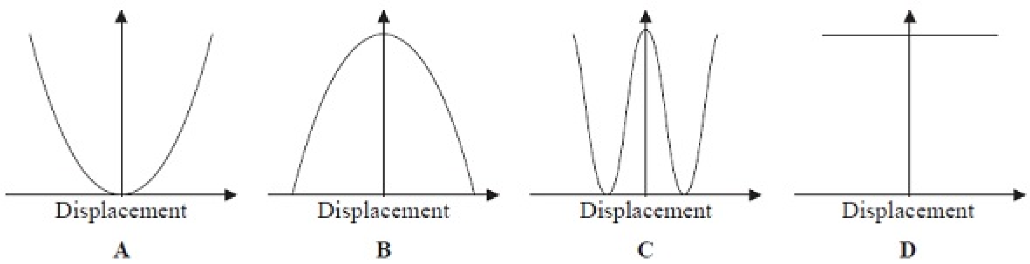
☐ **B** forced.

☐ **C** natural.

☐ **D** resonant.

(Total for question = 1 mark)

Q3.



For an object undergoing simple harmonic motion select the graph that represents the variation of kinetic energy with displacement.

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question = 1 mark)

Q4.

New buildings in earthquake zones are often designed to be earthquake resistant. Such buildings incorporate mechanisms to reduce the tranfer of kinetic energy from the ground to the building.

Which of the following would be the most important property of a material used in such a mechanism?

☒ **A** density

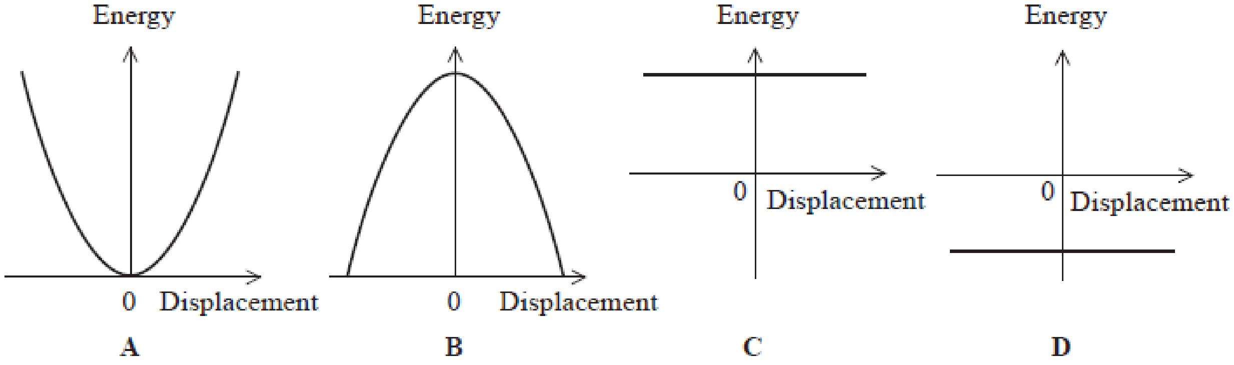
☒ **B** ductility

☒ **C** stiffness

☒ **D** strength

(Total for question = 1 marks)

Q5.



Which graph correctly shows the variation of total energy with displacement for a particle undergoing simple harmonic motion?

☒ **A**

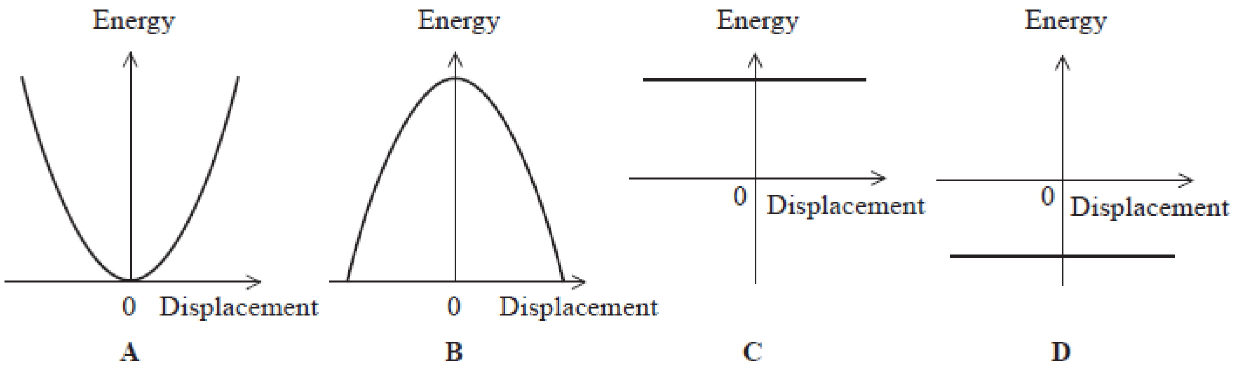
☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q6.



Which graph correctly shows the variation of potential energy with displacement for a particle undergoing simple harmonic motion?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q7.

A very long pendulum set into oscillation continues to swing for several hours. During this time, as a result of the Earth's rotation, the pendulum will appear to change its direction of swing.

The movement of this pendulum is an example of

☒ **A** critical oscillation.

☒ **B** forced oscillation.

☒ **C** free oscillation.

☒ **D** resonant oscillation.

(Total for question = 1 mark)

Q8.

An object is hung from a vertical spring and undergoes undamped simple harmonic motion.

It is correct to say that there are **no** changes in the

☒ **A** elastic potential energy of the oscillating system.

☒ **B** gravitational potential energy of the oscillating system.

☒ **C** kinetic energy of the oscillating system.

☒ **D** total energy of the oscillating system.

(Total for Question = 1 mark)

Q9.

A mass is hanging vertically from a spring. The mass is set into small amplitude vertical oscillations.
The total energy of the undamped oscillating system is

☒ **A** a maximum at an extreme position of the mass.

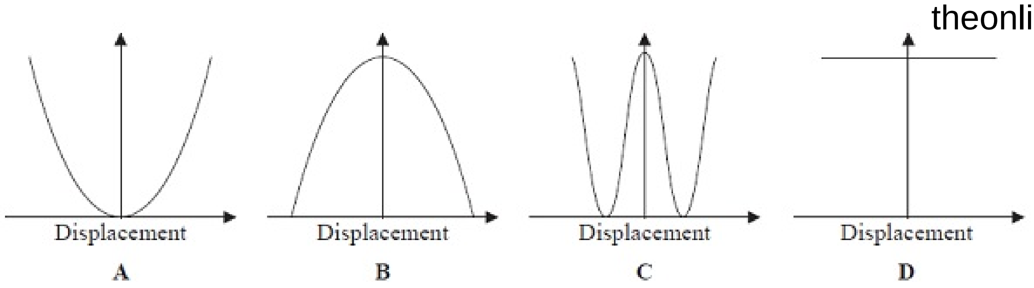
☒ **B** a maximum at the mean position of the mass.

☒ **C** a minimum at the mean position of the mass.

☒ **D** the same at all positions of the mass.

(Total for question = 1 mark)

Q10.



For an object undergoing simple harmonic motion select the graph that represents the variation of the total energy with displacement.

☒ **A**

☒ **B**

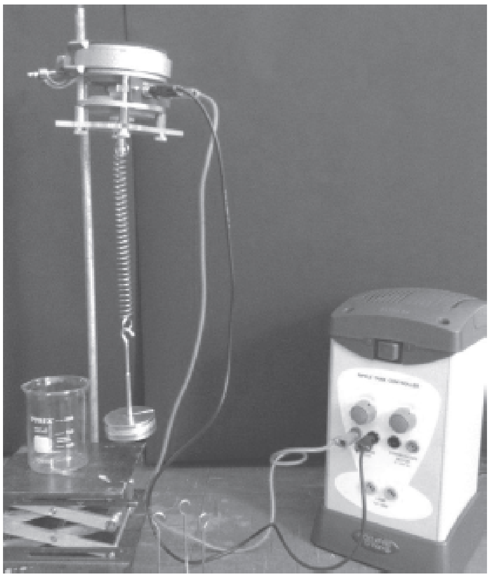
☒ **C**

☒ **D**

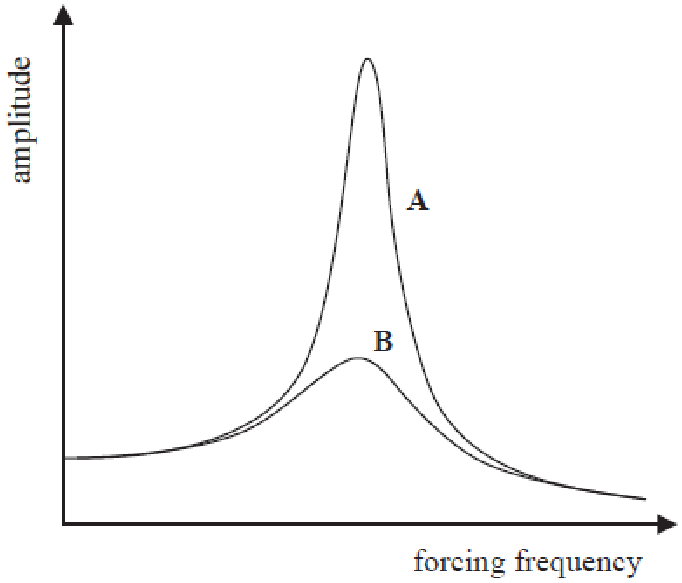
(Total for Question = 1 mark)

Q11.

* A student uses the apparatus shown below to investigate the behaviour of a mass-spring system when it is forced into oscillation.



The graph shows how the amplitude of the oscillating mass varies over a range of forcing frequencies.



Curve A shows the results of the investigation using the apparatus as shown.

The student repeats the investigation with the oscillating mass in a beaker of water.
Curve B shows these results.

Making reference to important features in the graph, describe and explain the two sets of results.

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(Total for question = 4 marks)

Q12.

Figure 1 shows a wine glass being driven into oscillation at its natural frequency by a high-power loudspeaker. The loudspeaker is close to, but not touching, the glass. The loudspeaker is driven by a sine-wave generator.

Figure 1

Figure 2

In Figure 2, the amplitude of vibration of the glass has become so large that the glass shatters.

(a) (i) Name the effect being demonstrated.

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(ii) Explain why this effect occurs.

(2)

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(b) A rubber band may be placed around the glass to provide some damping. This would reduce the amplitude of vibration and prevent the glass from shattering.

Explain how a rubber band around the glass would provide damping.

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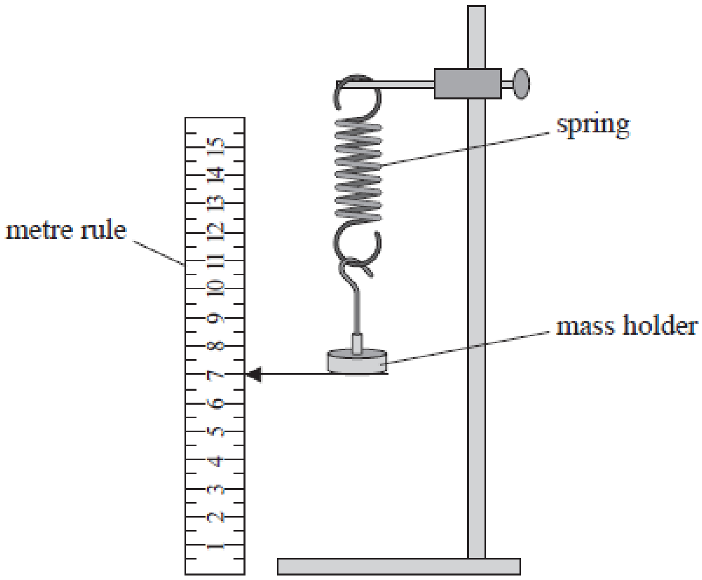
(Total for question = 5 marks)

Q13.

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

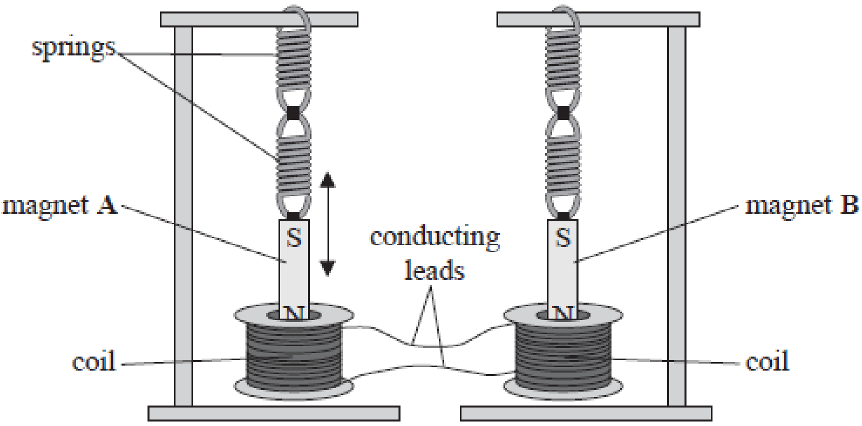


The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

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

* Identical bar magnets are suspended from identical springs, with the North pole of each magnet inside a coil of wire as shown. The two coils are connected together with conducting leads.



Magnet A is displaced so that it oscillates vertically. The North pole of magnet A moves into and out of the coil of wire with simple harmonic motion. As this motion continues, magnet B starts to oscillate. The amplitude of oscillation of magnet B increases over time.

Explain why magnet B starts to oscillate with an increasing amplitude.

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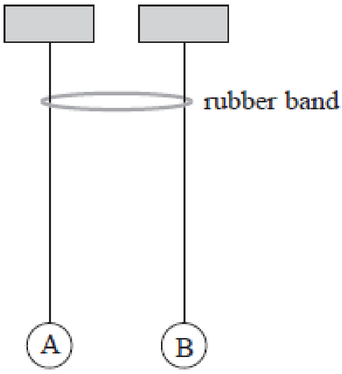
(Total for question = 6 marks)

Q14.

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.

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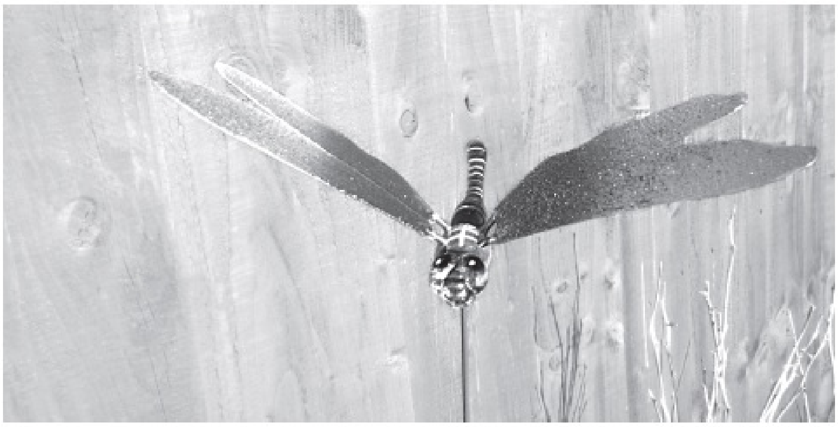
(Total for question = 6 marks)

Q15.

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

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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.

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

Explain why this happens

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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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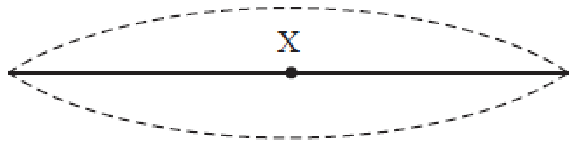
(Total for question = 9 marks)

Q16.

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)

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

(2)

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

(3)

(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)

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.

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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.

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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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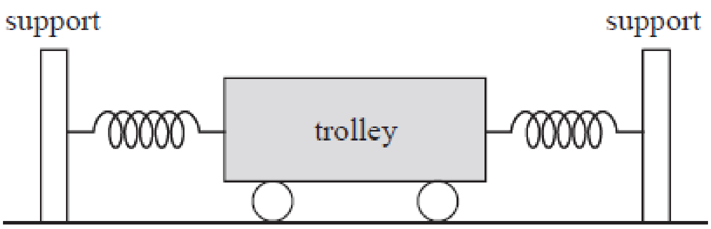
(Total for Question = 12 marks)

Q18.

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

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

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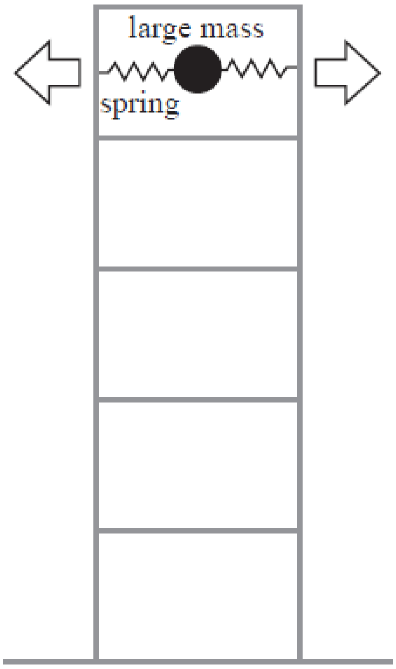
(b) Mass-spring systems are sometimes used in tall buildings to reduce the oscillation of the building due to strong winds.



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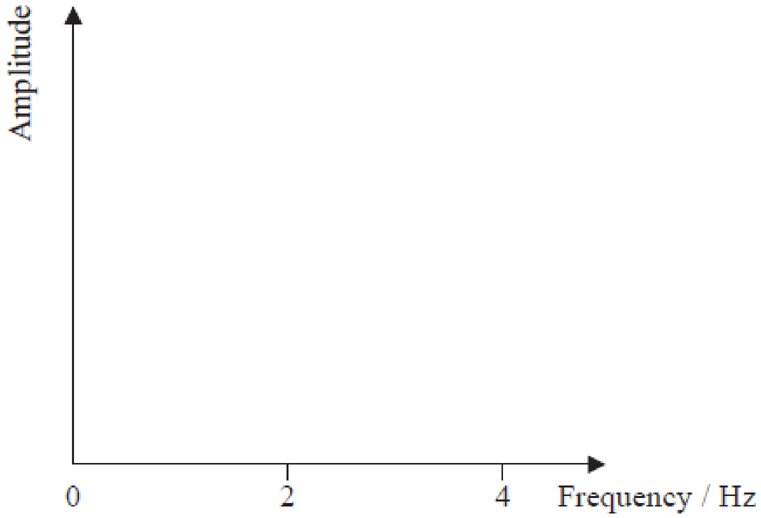
(ii) Sketch a graph to show how the amplitude of oscillation of the mass would vary with the frequency of movement of the building. Ignore the effects of damping.

(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)