1 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.

(1)

(ii) Explain why this effect occurs.

(2)

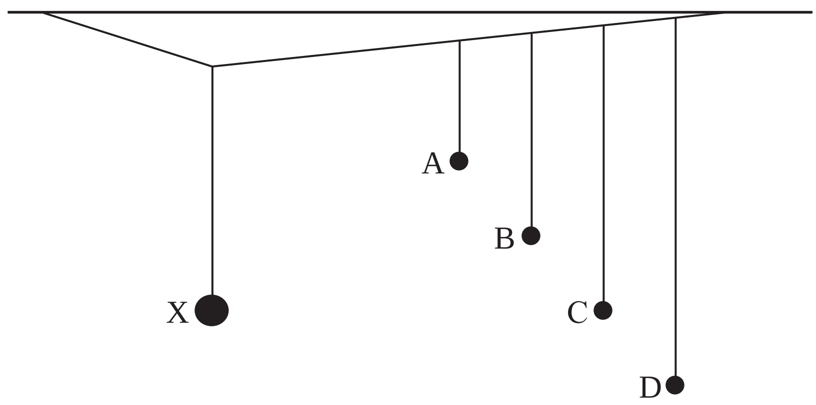
(b) A rubber band may be placed around the glass to provide some damping. This would reduce the amplitude of vibration and prevent the glass from shattering.

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

(2)

(Total for Question = 5 marks)

2 The diagram shows a number of pendulums hanging from a single thread. Pendulum X has a heavy lead sphere as the bob and the others have low mass bobs. When X is set into motion energy is transferred to the others which all begin to oscillate.

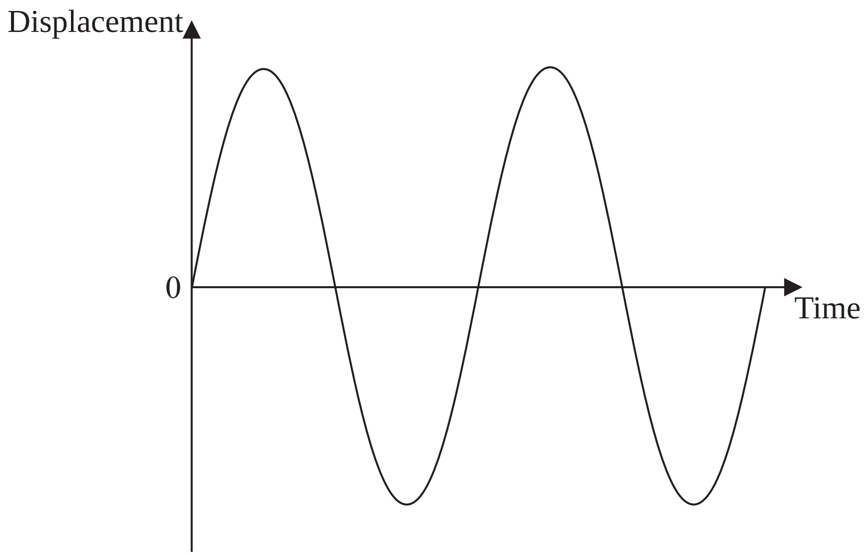


After a short time C is observed to have the largest amplitude of oscillation.

(a) Explain why pendulum C has the largest amplitude of oscillation.

(3)

(b) For an efficient energy transfer pendulum C must be at rest when pendulum X has its maximum kinetic energy. The graph below shows how the displacement of pendulum X varies with time.



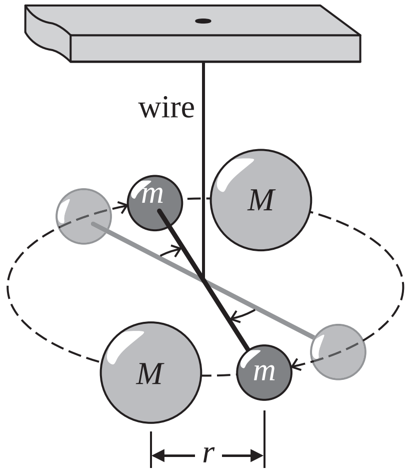
Mark a point P on this graph showing an instant when pendulum X has a maximum kinetic energy, and add a curve to show how the displacement of pendulum C varies over the same time interval.

(2)

(Total for Question = 5 marks)

3 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

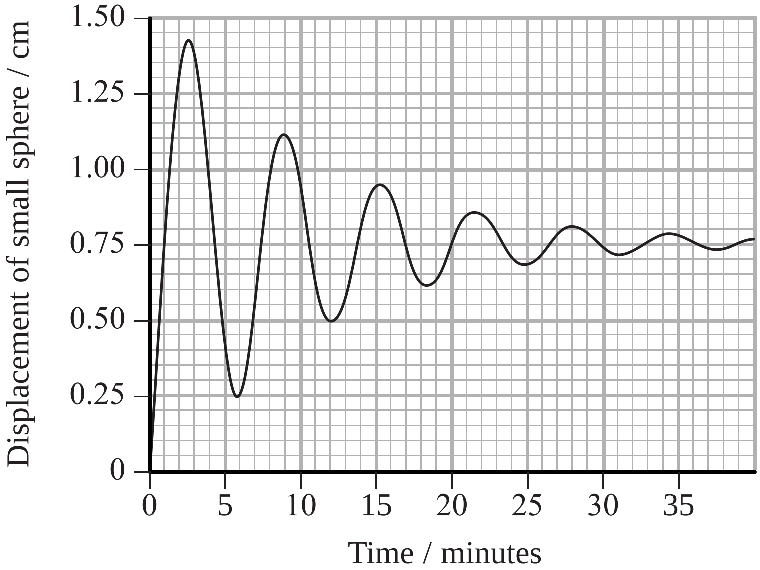
gravitational force between adjacent large and small spheres $F = 1.5 \times 10^{-7}$ N.

Use this data to calculate a value for *G*.

(2)

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)

Period =

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

Explain why this effect is observed.

(2)

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

(3)

(Total for Question = 9 marks)

4 The photograph shows a nodding tiger toy. The tiger is placed on a car's dashboard and its head nods up and down as the car is driven along a rough road surface.

It is noticed that at a particular speed the tiger's head vibrates with maximum amplitude.

(a) (i) What is the name of this phenomenon?

(1)

....

(ii) Describe the conditions necessary for this phenomenon to occur.

(2)

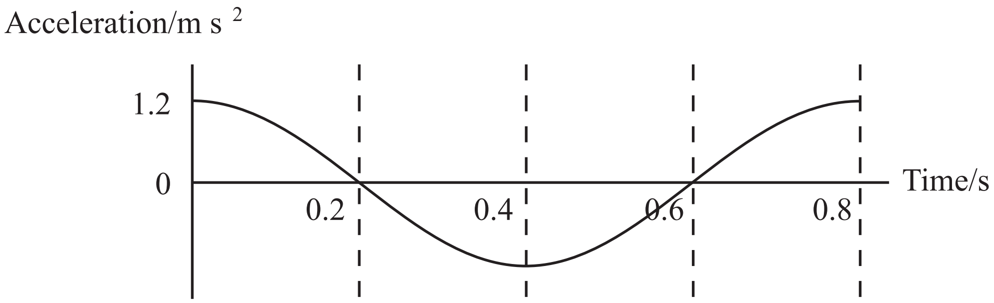
....

....

....

(b) (i) The graph shows the variation of acceleration with time for the tiger's head. Using values from the graph calculate the amplitude of oscillation of the tiger's head.

(3)



....

....

....

Amplitude of oscillation ....

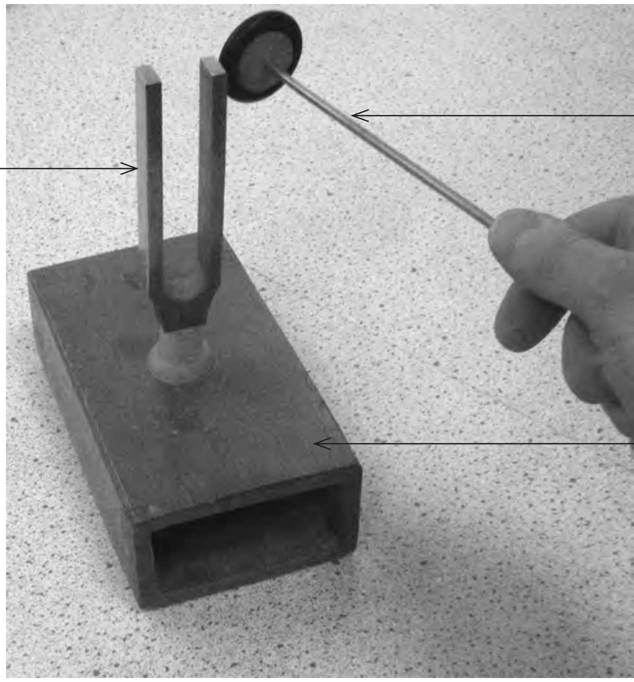
(ii) Sketch a graph of the head's displacement against time over the same time interval on the axes below.

(2)

(Total for Question 8 marks)

***5** When a tuning fork is struck with a rubber hammer, a pure sound of fixed frequency is produced. The photograph shows a tuning fork connected to a wooden sounding box.

Tuning fork



Hammer

Sound box

- The sounding box amplifies the sound produced when the tuning fork is struck.
- The sound lasts for a shorter time than if the tuning fork were to be struck identically but without the sounding box.

Explain these observations.

(5)

....

....

....

....

....

....

....

....

....

....

(Total for Question 5 marks)

6 A pan attached to a spring balance is used to determine the mass of fruit and vegetables in a supermarket.

A bunch of bananas is dropped into the pan. The pan oscillates with an initial amplitude of 10 cm. The total mass of bananas and pan is 0.55 kg.

The spring constant of the system is 120 N m ^{1}.

(a) Calculate the period of oscillation of the pan.

(2)

Period ....

(b) The oscillations of the pan are damped.

(i) Explain what is meant by this statement.

(2)

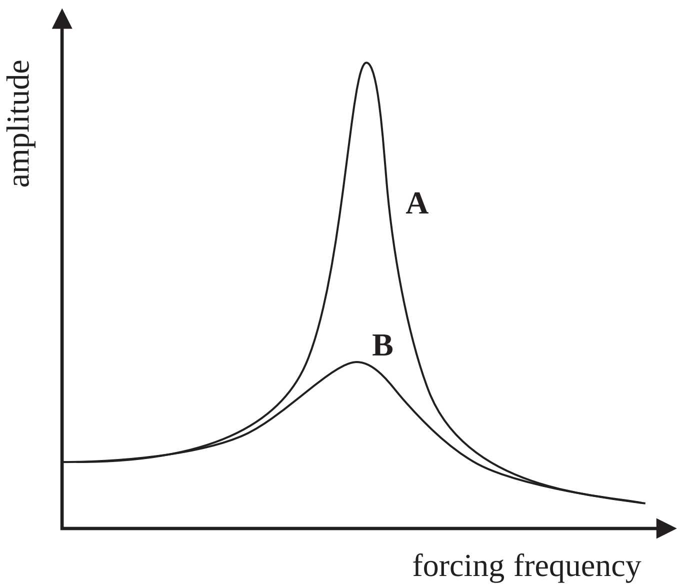
(ii) Sketch a graph to show how the displacement of the damped pan varies with time.

(3)

(Total for Question 7 marks)

***7** 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.

(4)

(Total for Question = 4 marks)

8 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)

....

....

....

....

....

....

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)

....

....

....

....

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

Explain why this happens.

(2)

....

....

....

....

....

(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)

....

....

....

....

....

(Total for Question 9 marks)

***9** Read this passage and answer the questions that follow.

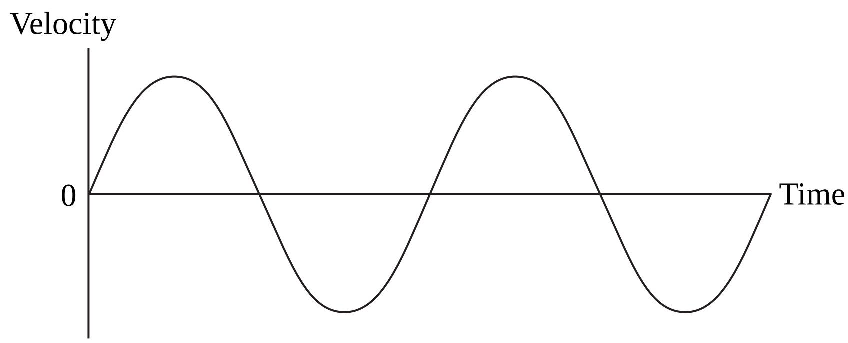
The Millennium Bridge opened on 10 June 2000 as London's first new Thames crossing in more than 100 years. The bridge uses "lateral suspension" – an engineering innovation that allows suspension bridges to be built without tall supporting columns. Tens of thousands of people crossed the bridge on its opening day. The structure was designed to take the weight, but suddenly the bridge began to sway and twist in regular oscillations. The worst of the movement occurred on the central span where the edge of the bridge oscillated through a total distance of 70 mm.

To solve the problem the engineers decided to use damping mechanisms – giant shock absorbers to limit the bridge's response to external forces. They decided to use two systems: viscous dampers, similar to car shock absorbers, and tuned mass dampers. A tuned mass damper is a large mass stiffened by springs.

(a) Name the effect that results in a system being driven into large amplitude oscillations, and state the condition necessary for this to happen.

(2)

(b) The graph shows the variation of velocity with time at the edge of the central span of the bridge.



Mark on this graph:

(i) An instant X at which the displacement was a maximum.

(1)

(ii) An instant Y at which the acceleration was zero.

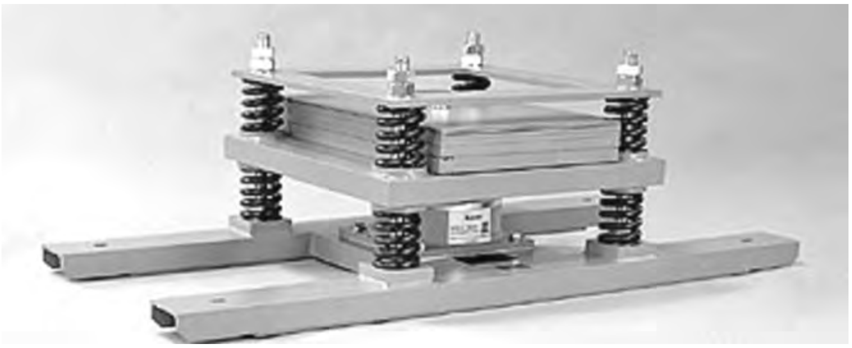
(1)

(c) Before modification the edge of the central span of the bridge oscillated with simple harmonic motion, and had a maximum acceleration of 0.89 m s^{-2}. Calculate the maximum velocity of the edge of the central span of the bridge.

(4)

Maximum velocity =

(d) The photograph shows the tuned mass dampers which were fitted to the bridge.
They are tuned to the natural frequency of oscillation of the bridge.



Discuss how the tuned mass dampers reduce the amplitude of the oscillations of the bridge and explain why they must be very heavily damped.

(3)

(Total for Question = 11 marks)