1)

Fig. 4.1 shows a mass suspended from a spring.

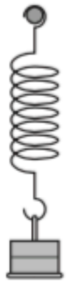

Fig. 4.1

(a) The mass is in equilibrium. By referring to the forces acting on the mass, explain what is meant by *equilibrium*.

....

....

.... **[2]**

(b) The mass in **(a)** is pulled down a vertical distance of 12 mm from its equilibrium position. It is then released and oscillates with simple harmonic motion.

(i) Explain what is meant by *simple harmonic motion*.

....

....

....

.... **[2]**

(ii) The displacement x, in mm, at a time t seconds after release is given by

$$x = 12\cos(7.85\,t).$$

Use this equation to show that the frequency of oscillation is 1.25 Hz.

[2]

(iii) Calculate the maximum speed V_{max} of the mass.

V_{max} = ... $\mathrm{m\,s^{-1}}$ **[2]**

(c) Fig. 4.2 shows how the displacement x of the mass varies with time t.

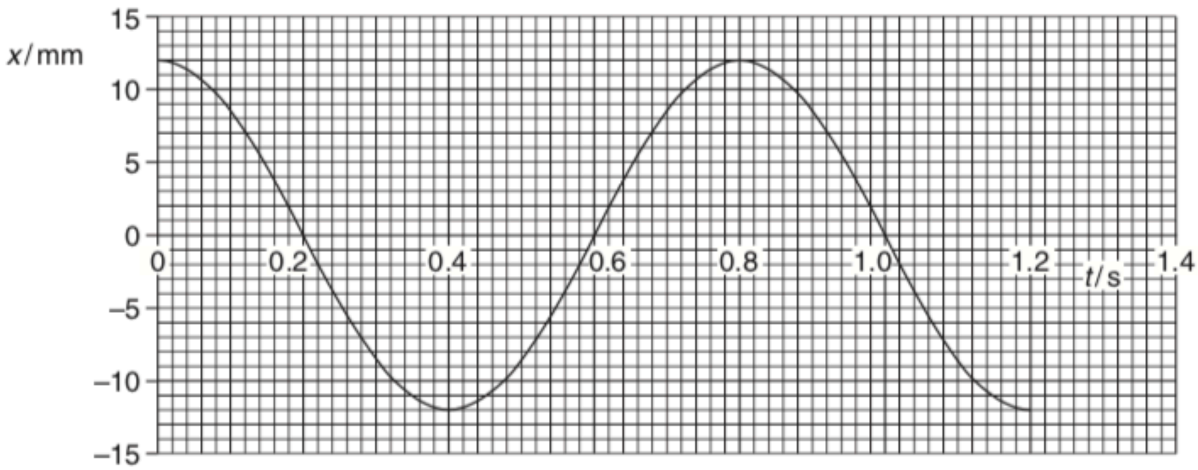

Fig. 4.2

Sketch on Fig. 4.3 the graph of velocity against time for the oscillating mass.

Put a suitable scale on the velocity axis. **[3]**

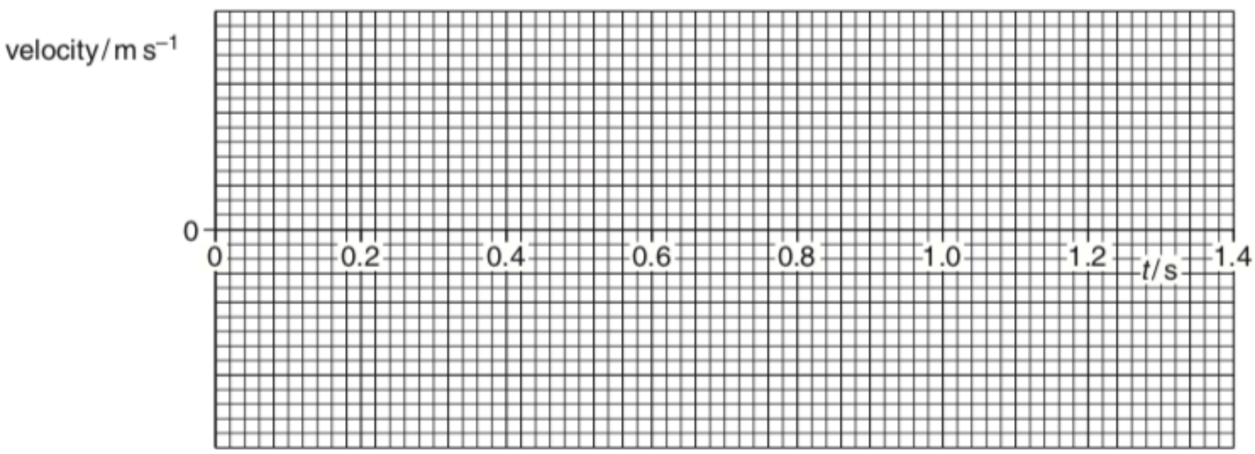

Fig. 4.3

[Total: 11]

2)

Fig. 3.1 shows a metal plate attached to the end of a spiral spring. The end **A** of the spring is fixed to a rigid clamp. The plate is pulled down by a small amount and released. The plate performs simple harmonic motion in a vertical plane at a natural frequency of 8 Hz and the spring remains in tension at all times.

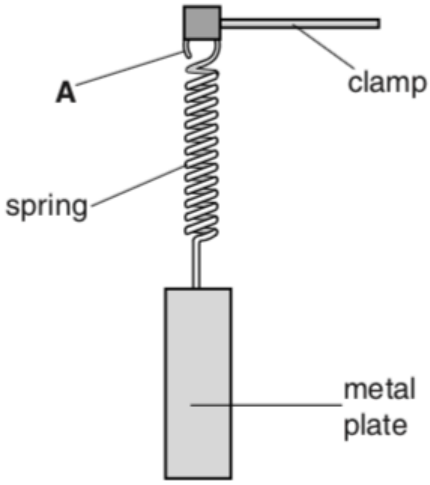

Fig. 3.1

(a) (i) On Fig. 3.2 sketch an acceleration *a* against displacement *x* graph for the motion of the metal plate. You are not required to give values on the axes.

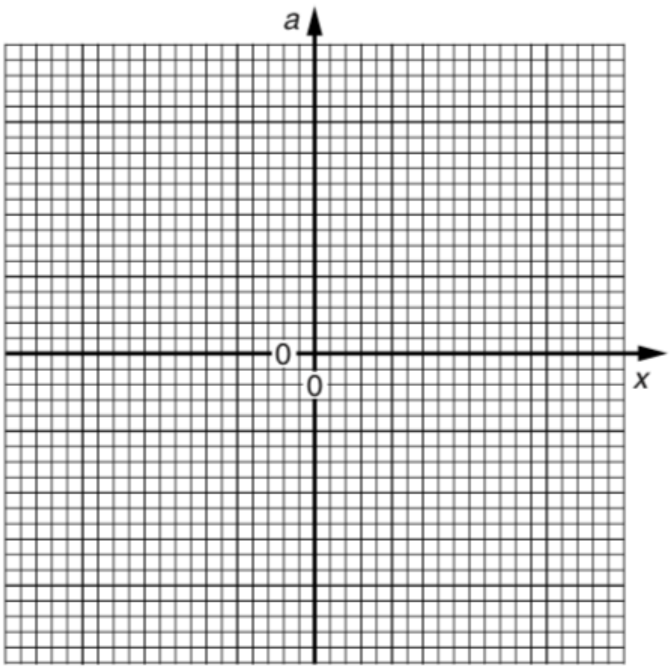

Fig. 3.2

[2]

(ii) Explain how your graph could be used to determine the frequency of oscillation of the metal plate.

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.... **[2]**

(b) Fig. 3.3 shows the variation of the vertical velocity *v* of the plate with time *t* at a frequency of 8 Hz.

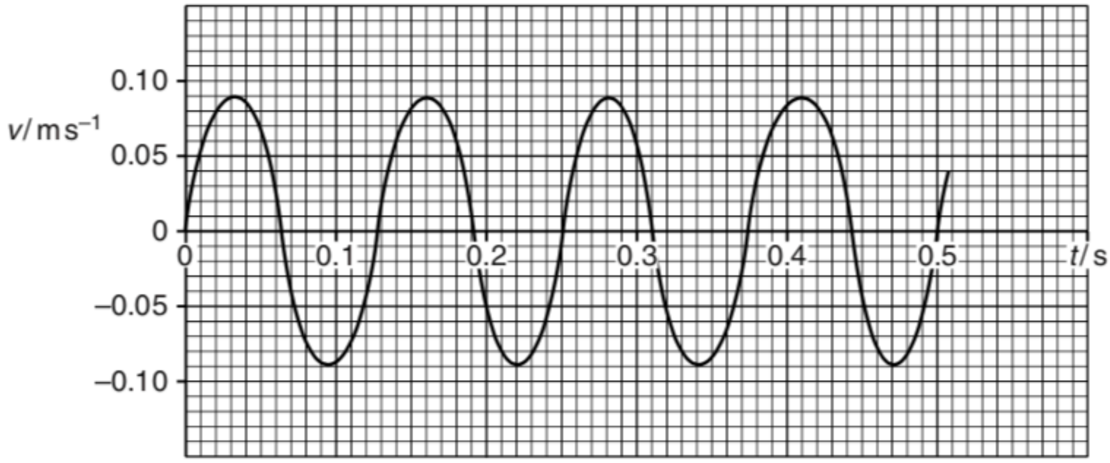


Fig. 3.3

Use the graph to determine

(i) the amplitude of the motion

amplitude = ... m **[2]**

(ii) the maximum vertical acceleration of the plate.

acceleration = ... m s^{-2} **[2]**

(c) The metal plate is now immersed in light oil which provides a constant frictional force to the plate. On Fig. 3.4 draw carefully the graph you would expect to obtain for the variation of the vertical velocity v with time t. As a guide a copy of the graph in Fig. 3.3 is drawn for you.

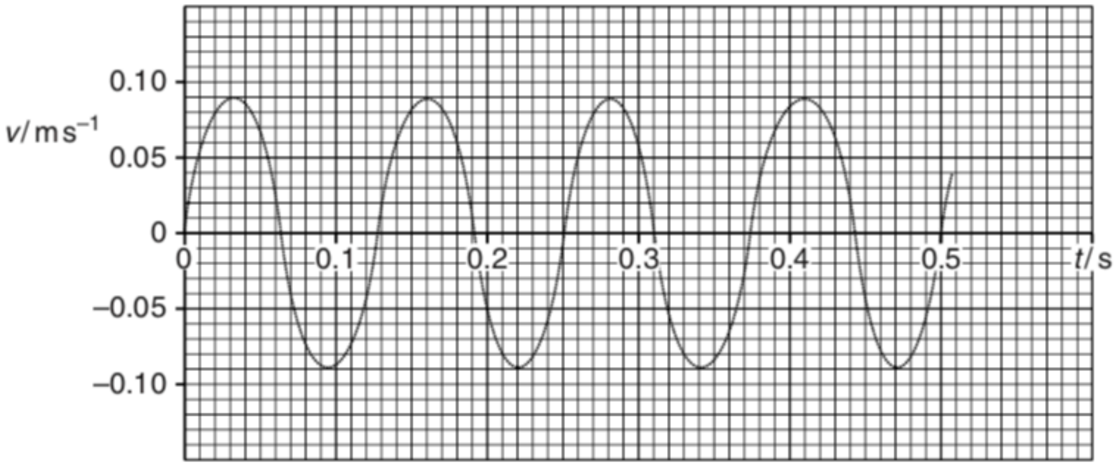


Fig. 3.4

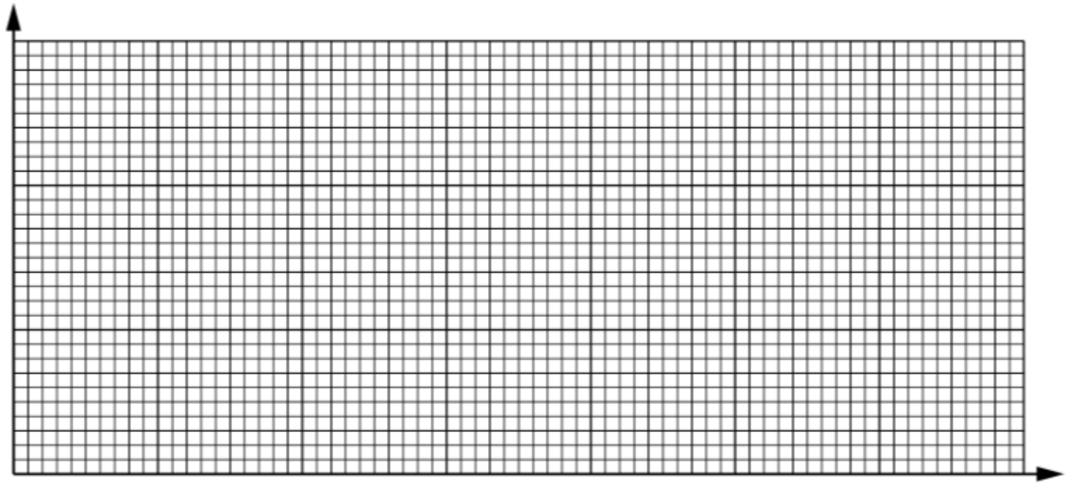
[2]

(d) The plate is now removed from the oil and the point **A** on the spring connected to an oscillator that vibrates vertically with constant amplitude. The frequency of the oscillator is increased slowly from 0 Hz to 12 Hz.

Describe and explain the motion of the metal plate during this procedure.

Sketch a labelled graph to help with your explanation.

In your answer, you should use appropriate technical terms spelled correctly.



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.... **[3]**

3)

(a) Fig. 3.1 shows a displacement against time graph of an object undergoing simple harmonic motion. Seven points, **A** to **G**, have been labelled on the graph.

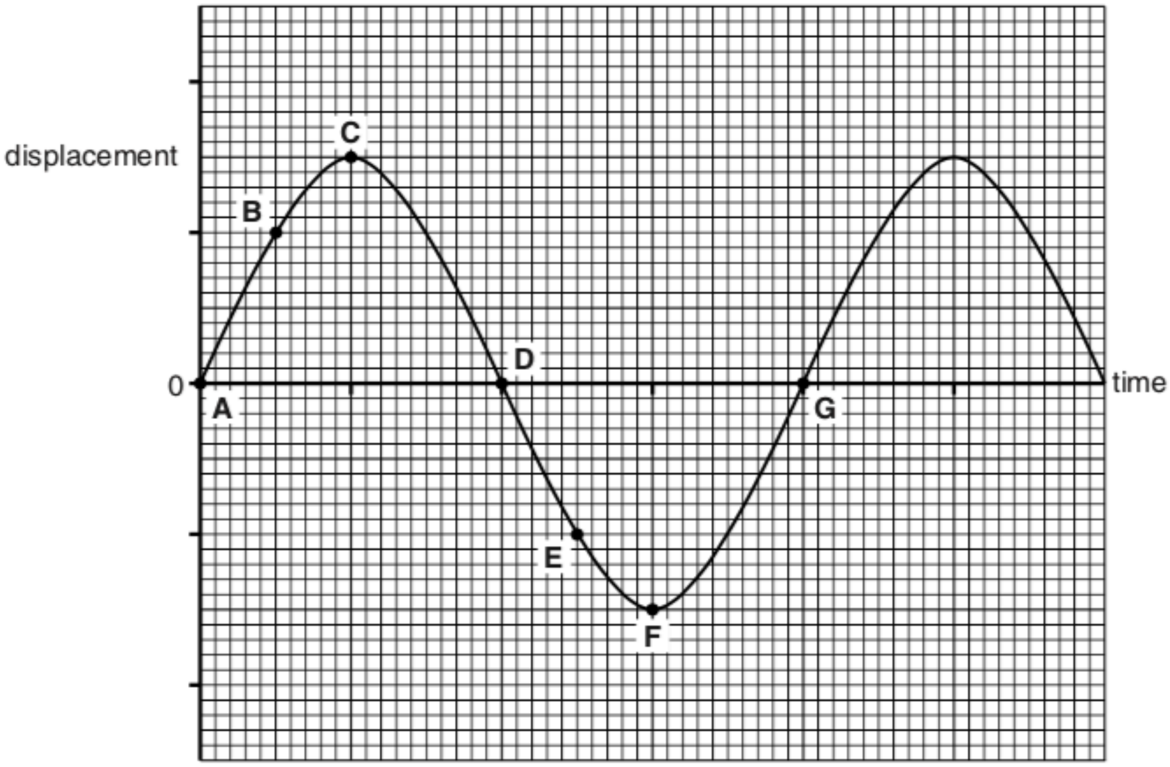

Fig. 3.1

(i) Write down two points that indicate when the object is at its amplitude position.

.... **[1]**

(ii) Write down a point which lags behind **D** by half a period.

.... **[1]**

(iii) Determine the phase difference, in radians, between points **B** and **F**.

phase difference = ... rad **[1]**

(b) Fig. 3.2 shows an airtrack glider of mass 0.45 kg held in equilibrium by two identical stretched springs. The glider is pulled 5.0 cm to the left. When released, it oscillates without friction. The springs are always in tension.

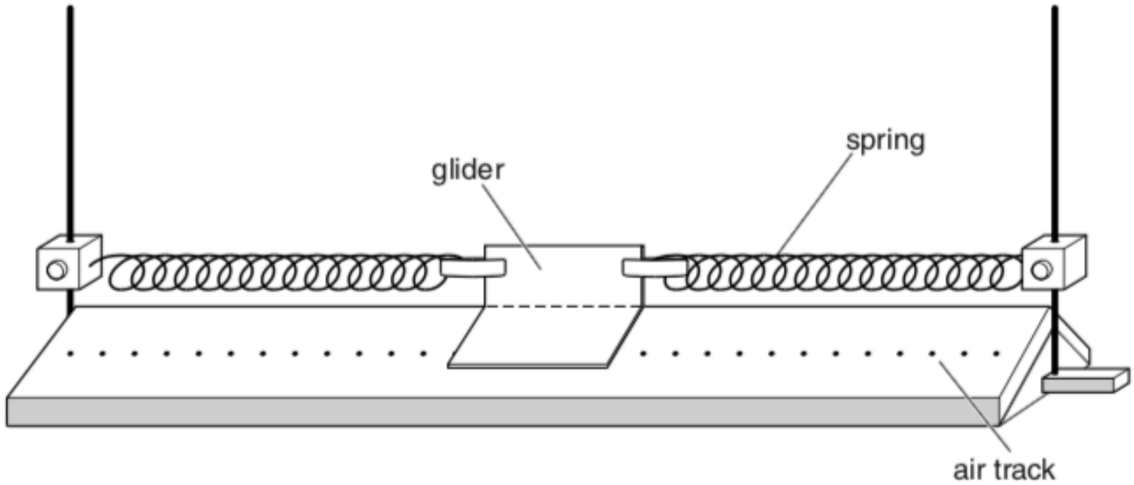

Fig. 3.2

The variation of elastic potential energy stored in the springs with displacement, x, of the glider is shown in Fig. 3.3.

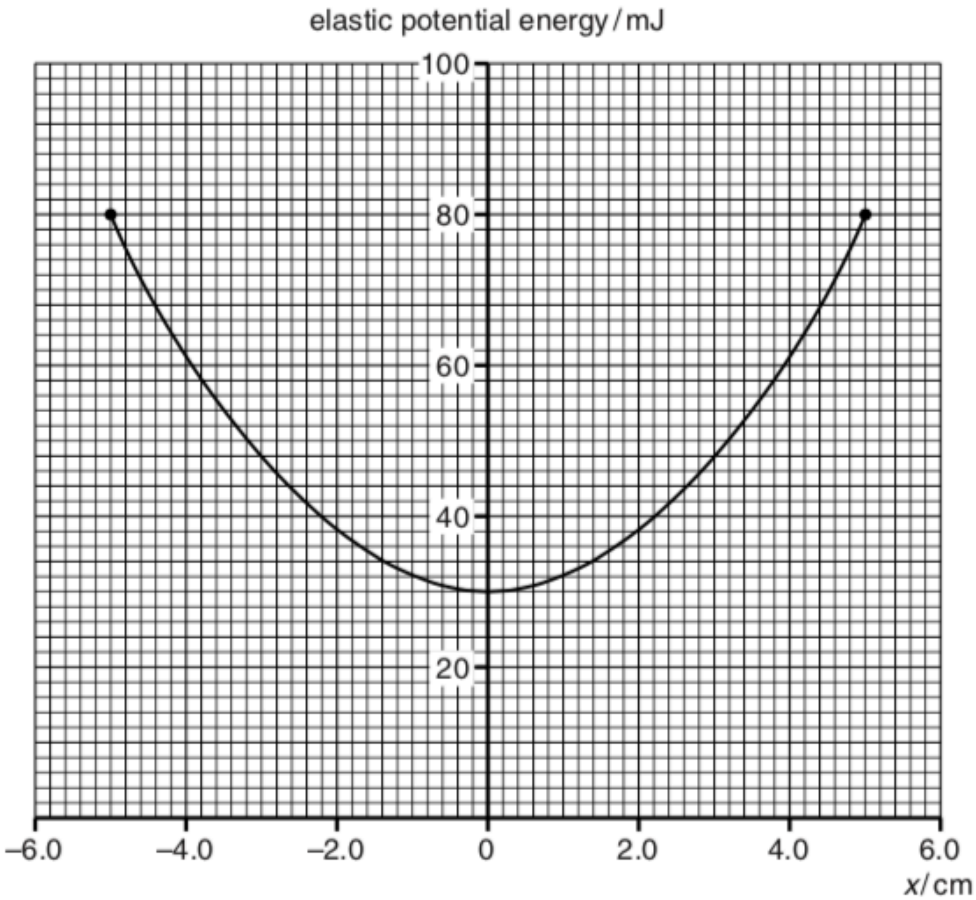

Fig. 3.3

(i) Draw on Fig. 3.3 a graph to show the variation of kinetic energy with displacement of the glider. **[2]**

(ii) Calculate the maximum speed of the glider.

maximum speed = ... $m s^{-1}$ **[1]**

(iii) Determine the period of the oscillations.

period = ... s **[2]**

4)

A cylinder **C** is attached to one end of a spring. The other end of the spring is connected to a block **D** which is fixed at the end of a smooth horizontal **transparent** tube as shown in Fig. 2.1.

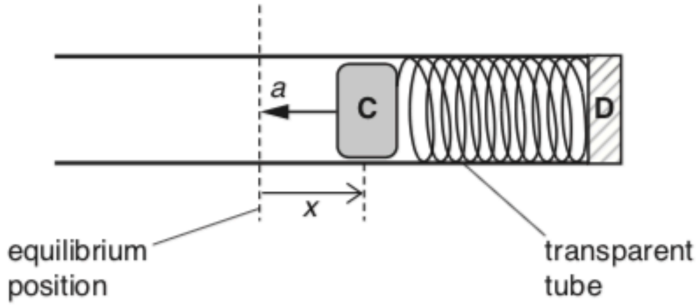

Fig. 2.1

The cylinder **C** is moved to the right, compressing the spring. **C** is then released and it oscillates at its natural frequency about the equilibrium position.
Fig. 2.1 also shows the displacement and acceleration vectors for the cylinder **C** at an instant in time. The magnitude of the displacement is x and the magnitude of the acceleration is a.
Fig. 2.2 shows the variation of a with x.

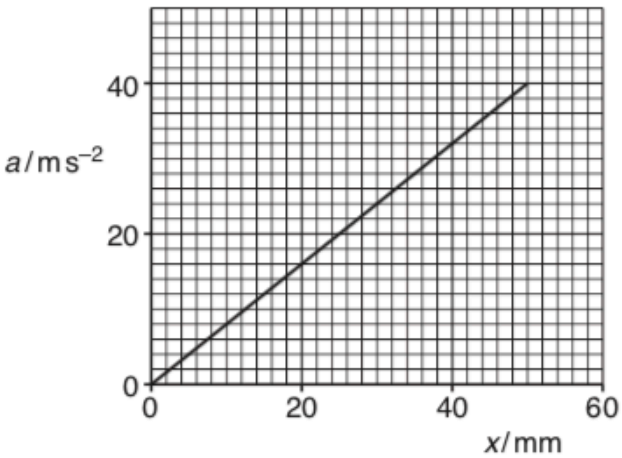

Fig. 2.2

(a) State one feature from Fig. 2.1 and one feature from Fig. 2.2 that suggests that the motion of the cylinder **C** is simple harmonic.

....

....

.... **[2]**

(b) Use Fig. 2.2 to determine the period T of the oscillations.

T = ... s **[2]**

(c) The equation for the motion of the cylinder **C** is

$$ma = -kx$$

where m is the mass of the cylinder **C** and k is the force constant of the spring.

(i) Determine the units for k in terms of kg, m and s.

units = ... **[2]**

(ii) Determine a value for $\frac{k}{m}$.

$\frac{k}{m}$ = ... s^{-2} **[1]**

(d) Describe and explain how you would expect the oscillations of the cylinder **C** to change, if at all, should a small amount of friction exist between the cylinder **C** and the walls of the tube.

In your answer, you should use appropriate technical terms, spelled correctly.

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.... **[3]**

(e) The point **D** in the arrangement shown in Fig. 2.1 is now attached to the shaft of an electric motor. The tube is rotated in a horizontal circle as shown in Fig. 2.3.

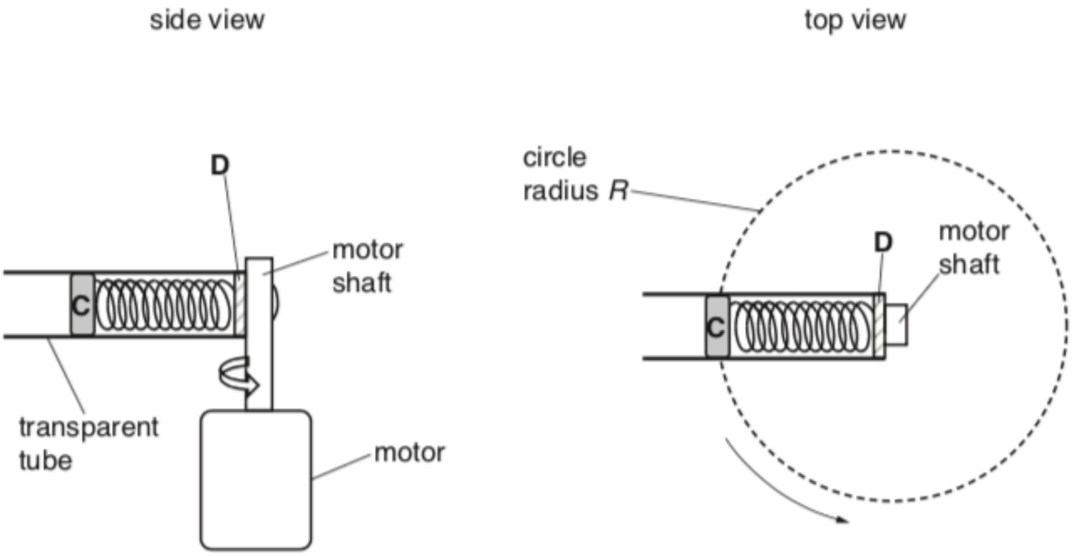

Fig. 2.3

(i) The rotational speed of the cylinder **C** is increased.
Use Newton's laws to explain why the spring stretches and the cylinder **C** moves radially outwards.

....

....

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.... **[2]**

(ii) The apparatus shown in Fig. 2.3 is used by a student to investigate the relationship between the force *F* acting on the cylinder **C**, its speed *v* and the radius *R* of its circular path.
The force constant *k* of the spring is known.
Describe how the student can use a video camera and a ruler to determine the values of *R*, *F* and *v*.

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(iii) The student has been asked to use their results from **(e)(ii)** to determine the mass of the cylinder **C** by plotting a straight line graph.
This straight line graph is shown in Fig. 2.4.

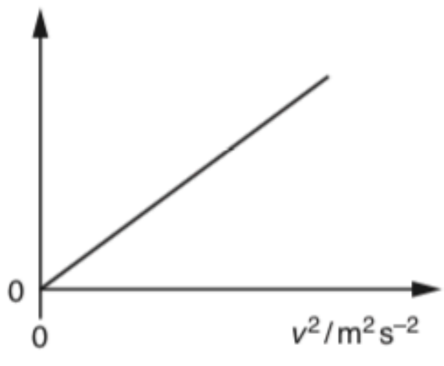

Fig. 2.4

1 Complete Fig. 2.4 by correctly labelling the vertical axis. **[1]**

2 Explain how the mass of the cylinder **C** can be determined from Fig. 2.4.

....

....

.... **[2]**

5)

(a) For a body undergoing simple harmonic motion describe the difference between

(i) *displacement* and *amplitude*

In your answer, you should use appropriate technical terms spelled correctly.

....

....

.... **[2]**

(ii) *frequency* and *angular frequency*.

....

....

.... **[2]**

(b) A harbour, represented in Fig. 4.1, has vertical sides and a flat bottom. The surface of the water in the harbour is calm.

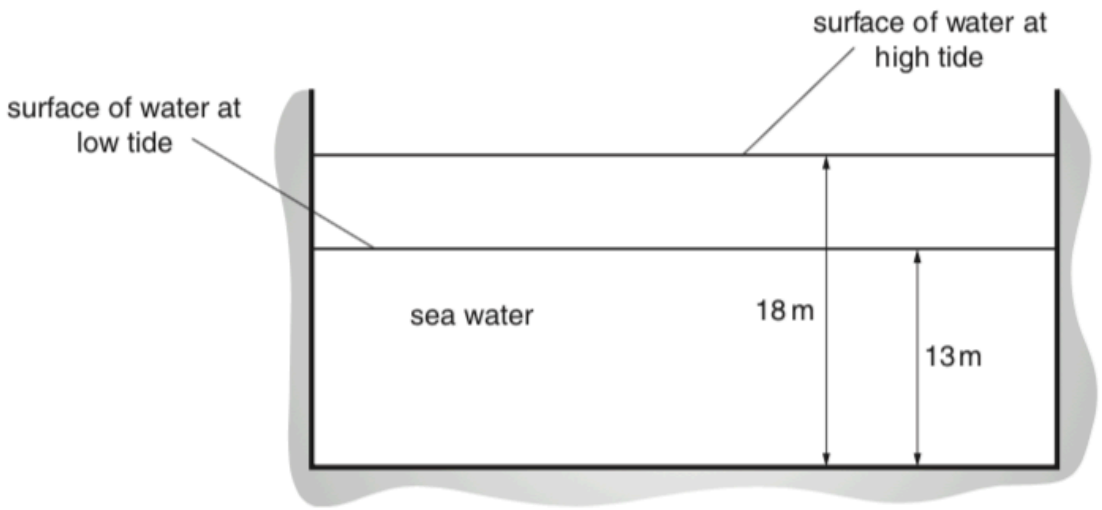

Fig. 4.1

The tide causes the surface of the water to perform simple harmonic motion with a period of 12.5 hours. The maximum depth of the water is 18 m and the minimum depth is 13 m.

(i) For the oscillation of the water surface, calculate

1 the amplitude

amplitude = ... m **[1]**

2 the frequency.

frequency = ... Hz **[2]**

(ii) Calculate the maximum vertical speed of the water surface.

maximum speed = ... $m\,s^{-1}$ **[2]**

(iii) Write an expression for the depth *d* in metres of water in the harbour in terms of time *t* in seconds.

[2]

[Total: 11]

6)

Fig. 2.1 shows a displacement against time graph for an oscillating mass.

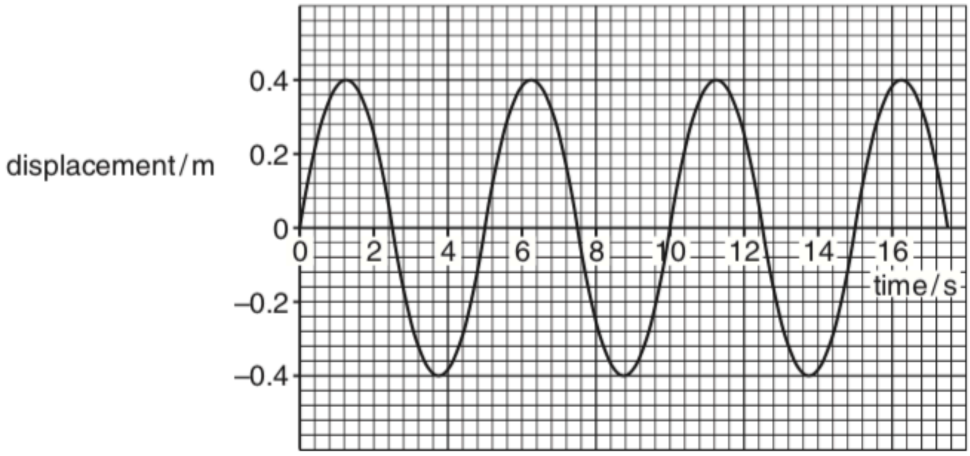

Fig. 2.1

(a) Use Fig. 2.1 to determine, for the oscillations of the mass,

(i) the amplitude and period

amplitude = ... m

period = ... s **[1]**

(ii) the angular frequency, ω.

ω = ... rad s^{-1} **[2]**

(b) Mark with a cross (**X**) on Fig. 2.1, using a different position in each case,

(i) a point where the velocity of the mass is a maximum; label it **V** **[1]**

(ii) a point where the acceleration of the mass is zero; label it **A** **[1]**

(iii) a point where the potential energy of the mass is a minimum; label it **P**. **[1]**

(c) The cone of a loudspeaker oscillates with simple harmonic motion. It vibrates with a frequency of 2.4 kHz and has an amplitude of 1.8 mm.

(i) Calculate the maximum acceleration of the cone.

acceleration = ... $m s^{-2}$ **[3]**

(ii) The cone experiences a mean damping force of 0.25 N. Calculate the average power needed to be supplied to the cone to keep it oscillating with a constant amplitude.

power = ... W **[3]**

[Total: 12]

7)

Fig. 4.1 shows slotted masses suspended from a spring. The spring is attached to a fixed support at its upper end.

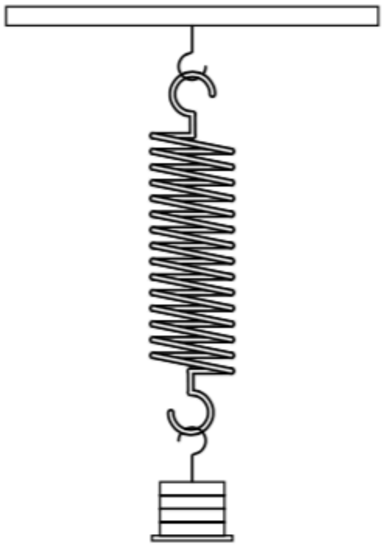

Fig. 4.1

When the masses are pulled down a short distance from the equilibrium position and released they oscillate vertically with simple harmonic motion. The frequency f of these oscillations depends on the mass m of the masses.
Two students make different predictions about the relationship between f and m.
One suggests f is proportional to $1/m$ and the other believes f is proportional to $1/\sqrt{m}$.

(a) Describe how you would test experimentally which prediction is correct.
Include in your answer:

- the measurements you would take, and
- how you would use these measurements to test each prediction.

You should also discuss ways of making the test as reliable as possible.

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.... **[4]**

(b) When the masses hanging on the spring are 400 g in total, they oscillate with an amplitude of 36 mm and a period of 1.2 s. Calculate

(i) the maximum kinetic energy of the masses

maximum kinetic energy = ... J **[3]**

(ii) the maximum acceleration of the masses.

maximum acceleration = ... ms^{-2} **[2]**

(c) List the different types of energy involved in the oscillations of this mass-spring system. Describe the energy changes when the masses move from the lowest point of the oscillation to the highest point.
In your answer you should use appropriate technical terms spelled correctly.

....

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.... **[4]**

[Total: 13]

8)

(a) State two conditions concerning the **acceleration** of an oscillating object that must apply for simple harmonic motion.

1. ....

....

2. ....

....

.... **[2]**

(b) Fig. 3.1 shows how the potential energy, in mJ, of a simple harmonic oscillator varies with displacement.

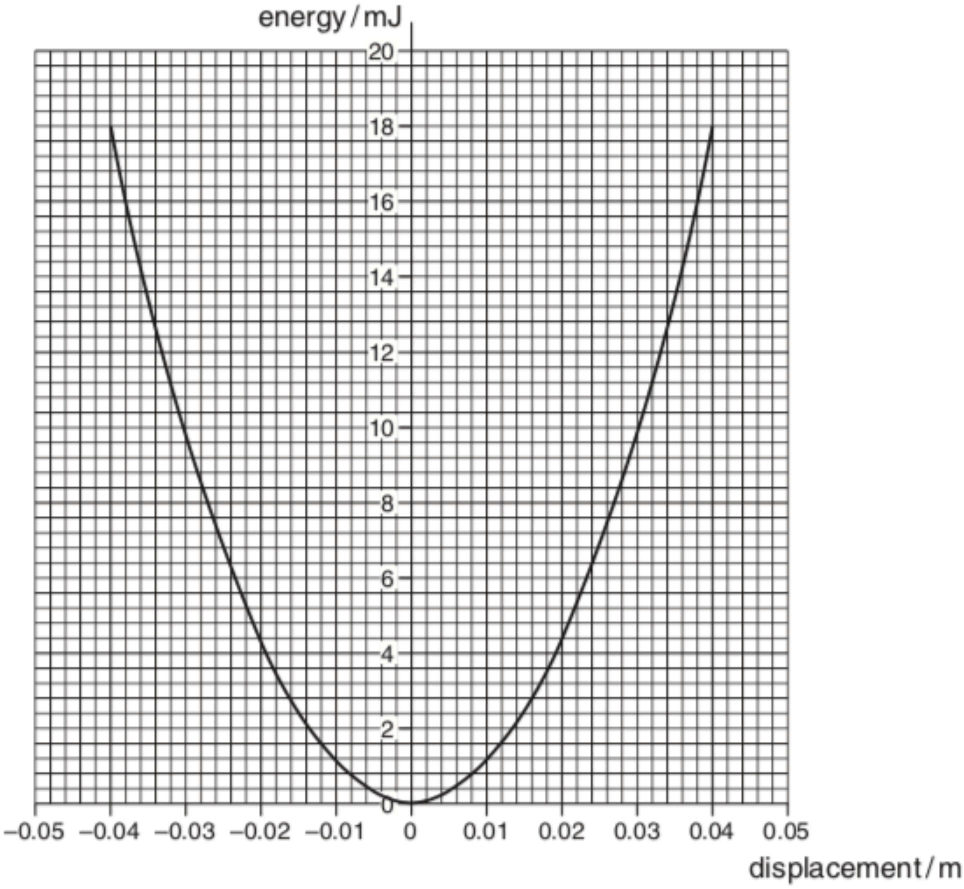

Fig. 3.1

On Fig. 3.1 sketch graphs to show the variation of

(i) kinetic energy of the oscillator with displacement – label this graph **K** **[2]**

(ii) the total energy of the oscillator with displacement – label this graph **T**. **[1]**

(c) Use Fig. 3.1 to determine

(i) the amplitude of the oscillations

amplitude = ... m **[1]**

(ii) the maximum speed of the oscillator of mass 0.12 kg

maximum speed = ... m s^{-1} **[2]**

(iii) the frequency of the oscillations.

frequency = ... Hz **[2]**

(d) Resonance can either be useful or a problem. Describe one example where resonance has a useful application and one example where resonance is a problem or nuisance. For each example identify what is oscillating and what causes these oscillations.

(i) useful application

....

....

....

....

.... **[2]**

(ii) problem

....

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....

....

.... **[2]**

[Total: 14]

9)

(a) Fig. 2.1 shows a mass attached to the end of a spring. The mass is pulled down and then released. The mass performs vertical simple harmonic motion.

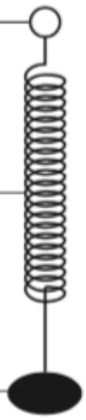

Fig. 2.1

(i) Define *simple harmonic motion*.

....

....

....

.... **[2]**

(ii) Mark the following statements about the oscillating mass-spring system as *true* or *false*. **[2]**

statement	**true/false**
The period of oscillation is constant.	
The net force on the mass is equal to its weight.	
The acceleration of the mass is a maximum at the mid-point of the oscillations.	
The velocity of the mass is proportional to the displacement.	

(b) A student wishes to investigate whether the period of oscillation of a simple pendulum is constant for all angles of swing. Describe how the student should carry out the investigation. Include the following in your description:

- a sketch of the apparatus with angle of swing labelled
- details of how the measurements would be made
- how these results would be used to form a conclusion
- the major difficulty likely to be encountered and how this might be overcome.

Sketch:

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.... **[5]**

[Total: 9]

10)

(a) A body moves with simple harmonic motion. Define, in words, *simple harmonic motion*.

In your answer, you should use appropriate technical terms, spelled correctly.

....

....

.... **[2]**

(b) A horizontal metal plate connected to a vibration generator is oscillating vertically with simple harmonic motion of period 0.080 s and amplitude 1.2 mm. There are dry grains of sand on the plate. Fig. 2.1 shows the arrangement.

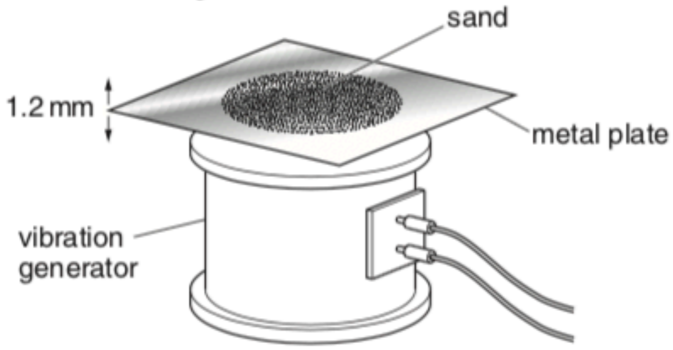

Fig. 2.1

(i) Calculate the maximum speed of the oscillating plate.

maximum speed = ... $m\,s^{-1}$ **[2]**

(ii) The frequency of the vibrating plate is kept constant and its amplitude is slowly increased from zero. The grains of sand start to lose contact with the plate when the amplitude is A_0. State and explain the necessary conditions when the grains of sand first lose contact with the plate. Hence calculate the value of A_0.

....

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....

A_0 = ...m **[4]**

(c) The casing of a poorly designed washing machine vibrates violently when the drum rotates during the spin cycle. Fig. 2.2 shows how the amplitude of vibration of the casing varies with the frequency of rotation of the drum.

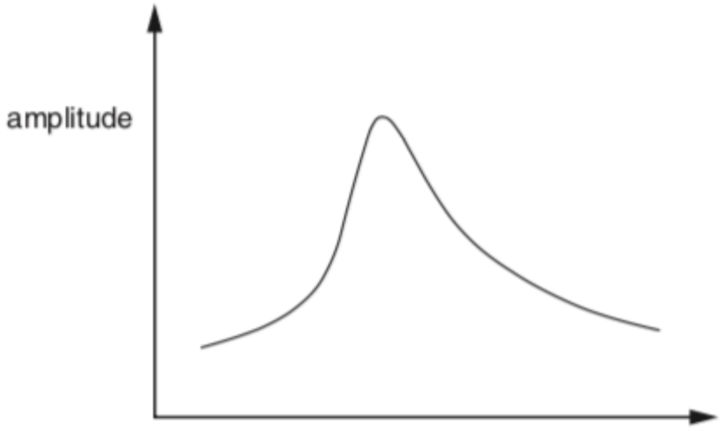

Fig. 2.2

(i) State the name of this effect and describe the conditions under which it occurs.

....

....

....

.... **[2]**

(ii) The design of the washing machine is improved to reduce the effect by adding a damping mechanism to the inside of the machine. Sketch on Fig. 2.2 the new graph of amplitude against frequency of rotation expected for this improved design. **[2]**

[Total: 12]

11)

(a) An object is oscillating with simple harmonic motion. Place a tick (✓) in the box against each true statement that applies to the acceleration of the object.

The acceleration …

… is in the opposite direction to the displacement. ☐

… is directly proportional to the amplitude squared. ☐

… increases as the displacement decreases. ☐

… increases as the speed of the object decreases. ☐

[2]

(b) The graph in Fig. 3.1 shows the variation of the velocity v of the object with time t.

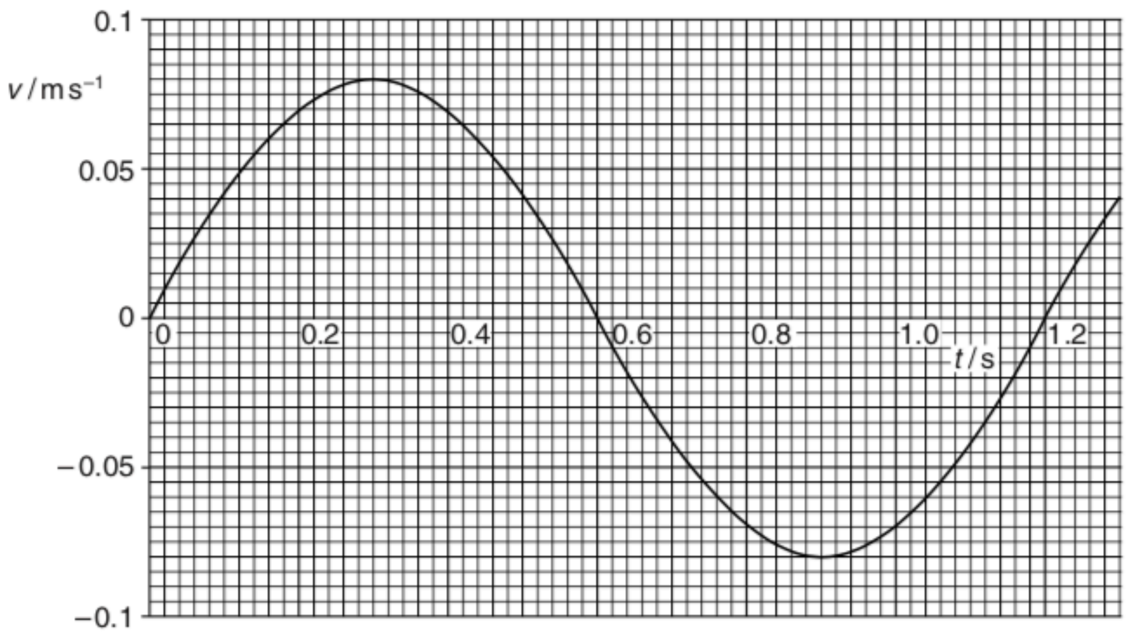

Fig. 3.1

Using the graph, determine

(i) the frequency of the motion

frequency = ... Hz **[1]**

(ii) the amplitude of the motion

amplitude = ... m **[2]**

(iii) the maximum acceleration of the object.

acceleration = ... $m\,s^{-2}$ **[2]**

(c) **(i)** With the help of a suitably labelled graph, explain what is meant by *resonance* of a mechanical system.

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.... **[4]**

(ii) State and explain an everyday example of resonance.

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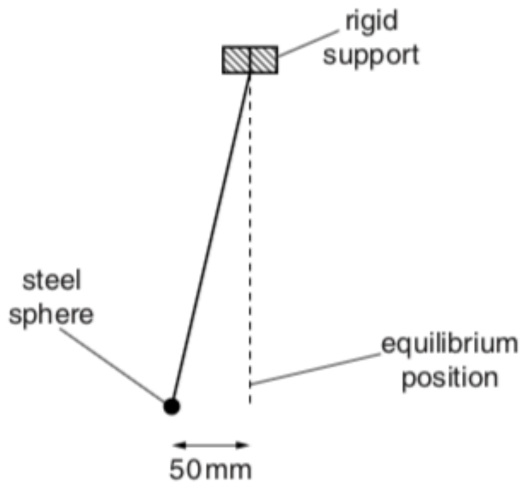
.... **[2]**

[Total: 13]

12)

(a) Fig. 3.1 shows a simple pendulum consisting of a steel sphere suspended by a light string from a rigid support. The sphere is displaced 50 mm from its vertical equilibrium position and released at time $t = 0$.



not to scale

Fig. 3.1

Fig. 3.2 shows the graph of displacement x of the sphere against time t.

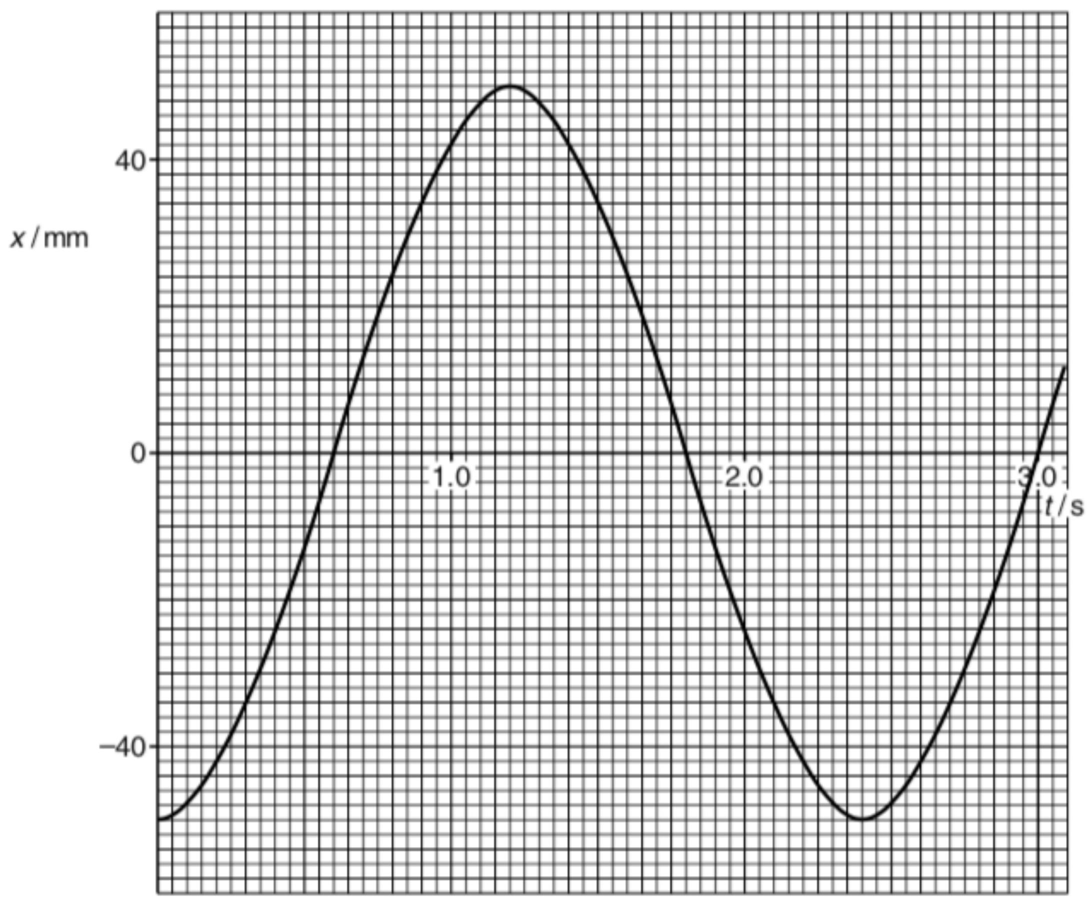


Fig. 3.2

(i) Use Fig. 3.2 to determine the frequency of oscillation of the pendulum.

frequency = ... Hz **[1]**

(ii) Use Fig. 3.2, or otherwise, to determine the maximum speed of the sphere.
Show your method clearly.

speed = ... $m s^{-1}$ **[2]**

(b) The sphere is now released from rest with a displacement $x = 25$ mm.
State with a reason, the change if any in

(i) the frequency of the oscillations

....

....

.... **[1]**

(ii) the maximum kinetic energy of the sphere.

....

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.... **[2]**

(c) In turbulent air the wingtip of an aircraft can vibrate vertically. To investigate this effect, the acceleration and the vertical displacement of the wingtip are measured. Fig. 3.3 shows how the acceleration of the wingtip varies with displacement.

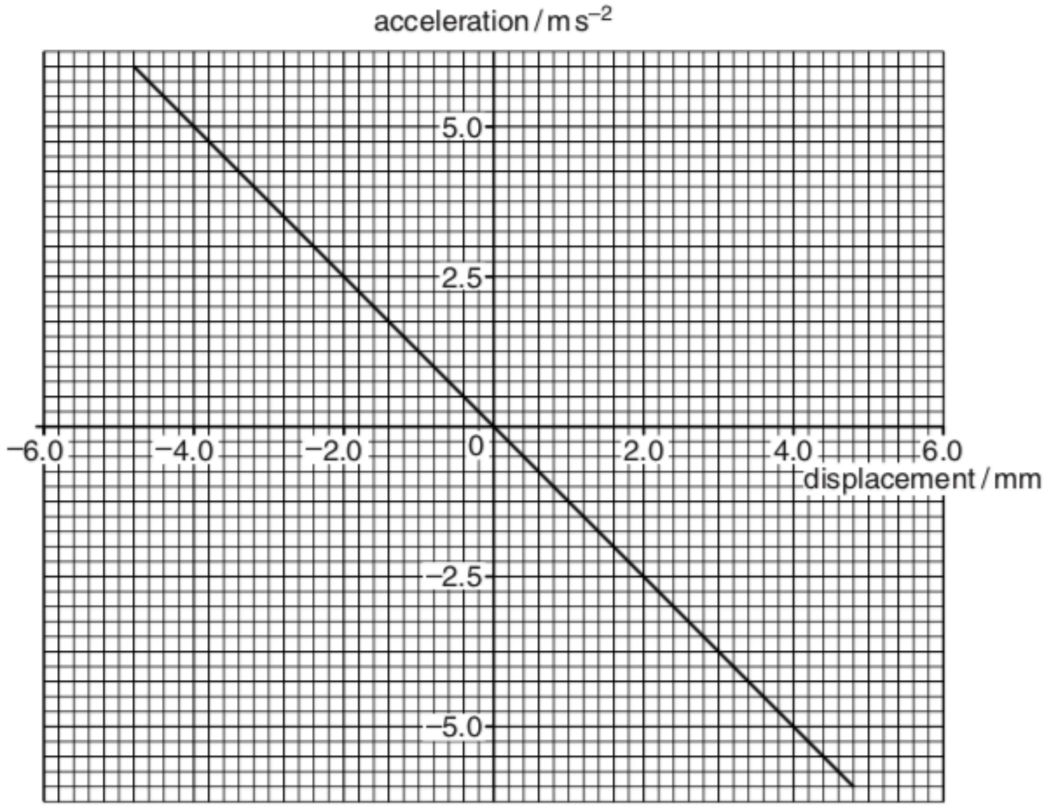

Fig. 3.3

(i) Explain how Fig. 3.3 suggests that the wingtip undergoes simple harmonic motion under the test conditions.

....

....

....

.... **[2]**

(ii) Use Fig. 3.3 to determine the frequency of the vibration.

frequency = ... Hz **[2]**

[Total: 10]