CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 17: Oscillations

Past Papers 2021 – 2025

QUESTION PAPER 24 Questions

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Damped and Forced Oscillations – Quick Revision (9702)

1 Damping

▸ Definition (Cambridge style)

Damping is the reduction in amplitude of oscillations due to a resistive force that removes energy from the system.

→ The resistive force is usually proportional to velocity.

→ Mechanical energy is converted into thermal energy.

▸ Types of Damping

1. Light Damping (Underdamping)

- Amplitude gradually decreases with time
- Oscillations continue
- Energy decreases slowly

Displacement–time graph: *Exponentially decreasing sinusoidal curve.*

2. Critical Damping

- System returns to equilibrium in the shortest possible time
- No oscillations
- No overshoot

Displacement–time graph: *Smooth curve returning to zero without oscillating.*

3. Heavy Damping (Overdamping)

- No oscillations
- Returns to equilibrium slowly
- Slower than critical damping

Displacement–time graph: *Slow exponential return to zero.*

2 Forced Oscillations

▸ Definition

Forced oscillations occur when an external periodic force is applied to a system.

- The system oscillates at the driving frequency
- Energy is supplied continuously
- Amplitude depends on:
  - Driving frequency
  - Amount of damping

3 Resonance

▸ Definition (Exam Standard – 9702)

Resonance occurs when the driving frequency equals the natural frequency of the system, resulting in maximum amplitude of oscillation.

▸ Key Conditions for Resonance

- Driving frequency = Natural frequency
- Energy transfer is maximum
- Amplitude is maximum
- Phase difference = 90° at resonance

▸ Effect of Damping on Resonance

Damping	Amplitude at Resonance	Sharpness of Peak
Light damping	Large amplitude	Sharp peak
Heavy damping	Small amplitude	Broad peak

→ Less damping → Higher and sharper resonance peak.

4 Important Graphs for Paper 2 & 4

▸ Amplitude vs Frequency Graph

- Shows resonance peak
- Peak becomes:
  - Higher and sharper with less damping
  - Lower and broader with more damping

▸ Phase Difference vs Frequency

- Low frequency → phase difference ≈ 0°
- At resonance → 90°
- High frequency → 180°

Question 1

A trolley on a track is attached by springs to fixed blocks X and Y, as shown in Fig. 4.1. The track contains many small holes through which air is blown vertically upwards. This results in the trolley resting on a cushion of air rather than being in direct contact with the track.

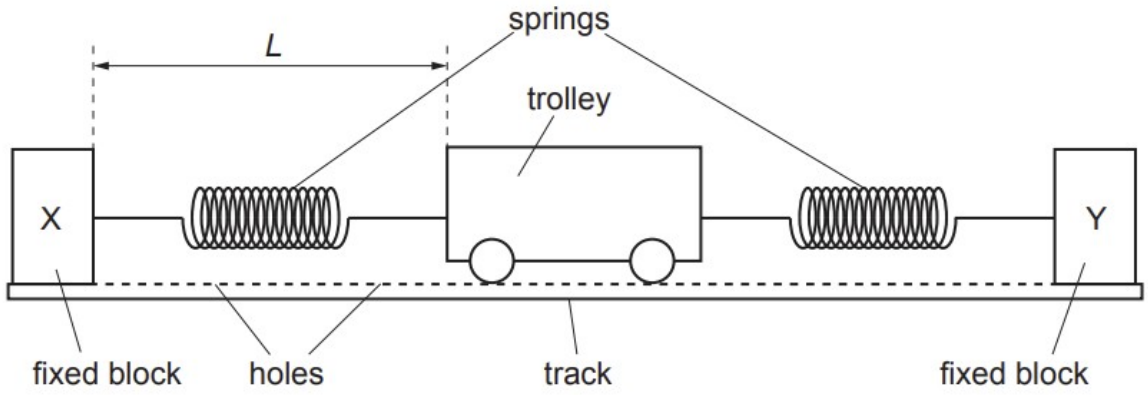
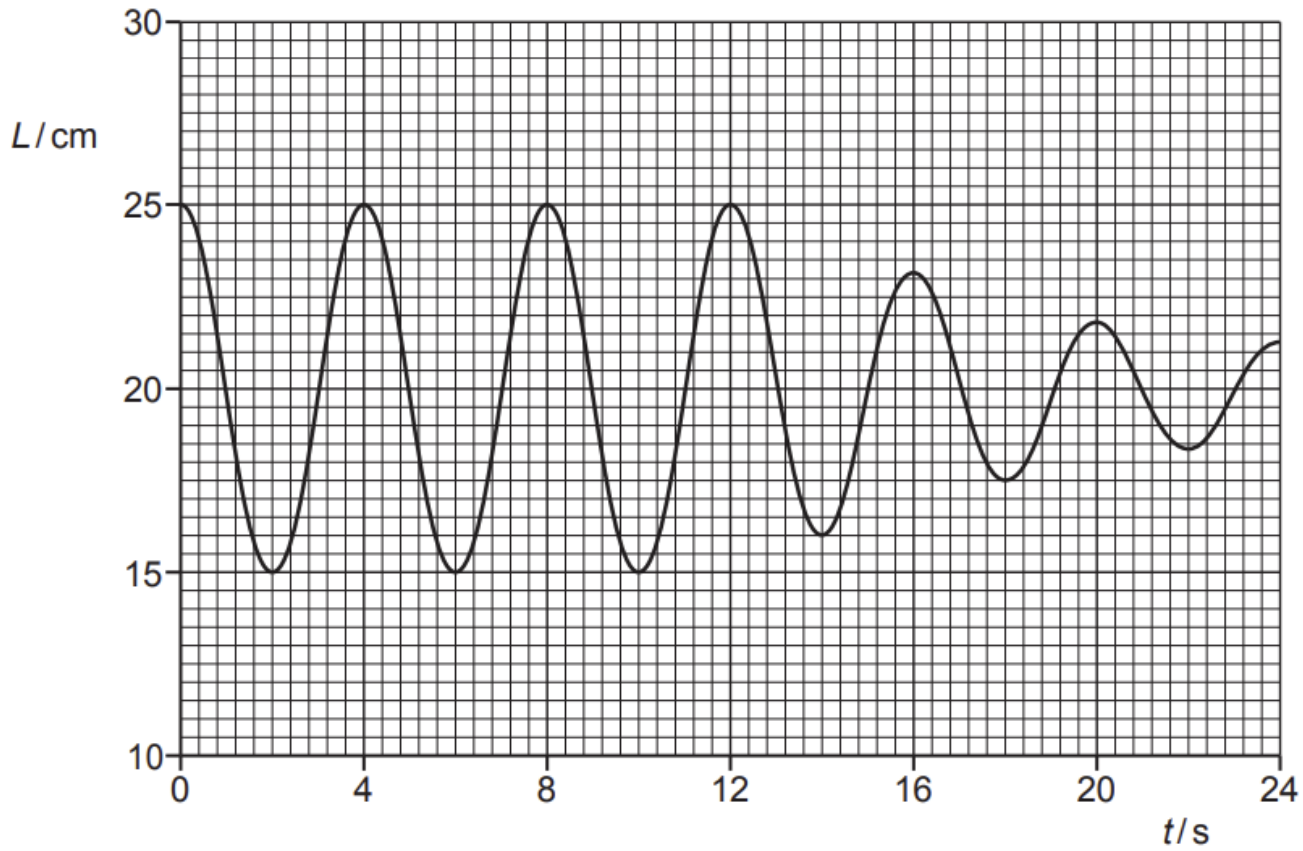


Fig. 4.1

The trolley is pulled to one side of its equilibrium position and then released so that it oscillates initially with simple harmonic motion. After a short time, the air blower is switched off. The variation with time *t* of the distance *L* of the trolley from block X is shown in Fig. 4.2.



(a) Use Fig. 4.2 to determine:

(i) the initial amplitude of the oscillations

amplitude = ... cm [1]

(ii) the angular frequency ω of the oscillations

ω = ... rad s^{-1} [2]

(iii) the maximum speed v_0, in cm s^{-1}, of the oscillating trolley.

v_0 = ... cm s^{-1} [2]

(b) Apart from the quantities in **(a)**, describe what may be deduced from Fig. 4.2 about the motion of the trolley between time t = 0 and time t = 24 s. No calculations are required.

.....

.....

.....

.....

..... [3]

(c) On Fig. 4.3, sketch the variation with L of the velocity v of the trolley for its first complete oscillation.

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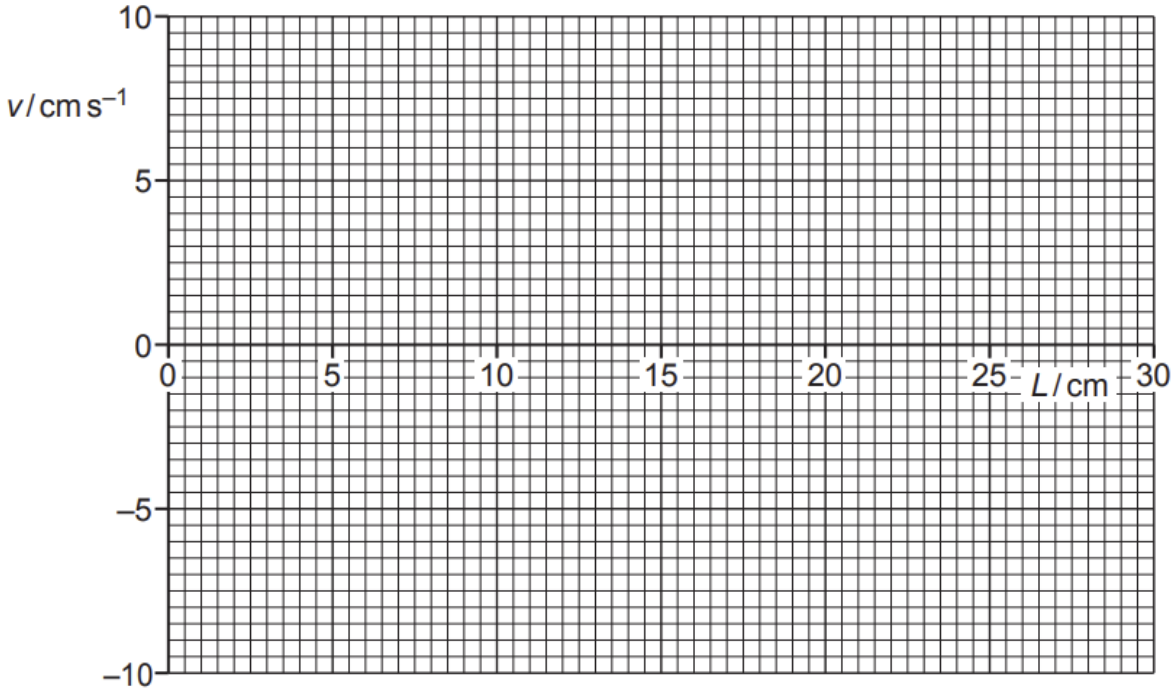


Fig. 4.3

[3]

[Total: 11]

Question 2

A trolley on a smooth surface is attached by springs to fixed blocks as shown in Fig. 4.1.

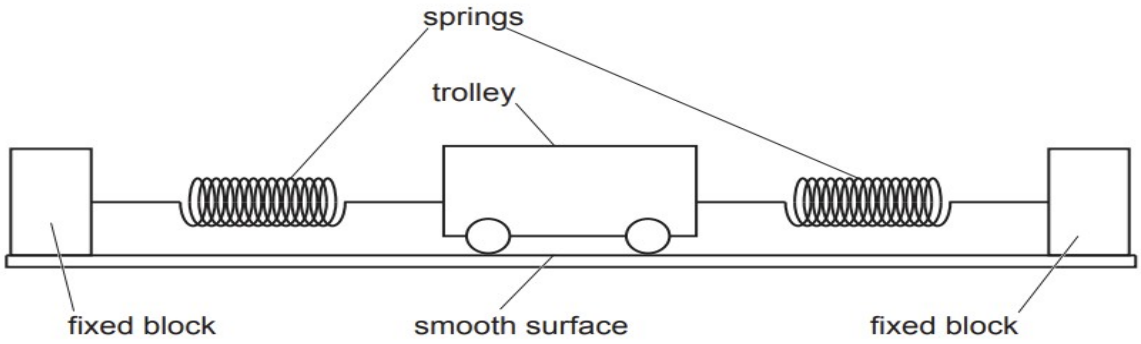


Fig. 4.1

The trolley oscillates horizontally about its equilibrium position with an amplitude of 12 cm. Fig. 4.2 shows the variation of the acceleration *a* of the trolley with displacement *x* from its equilibrium position. Friction between the trolley and the surface can be assumed to be negligible.

A trolley on a smooth surface is attached by springs to fixed blocks as shown in Fig. 4.1.

springs
trolley
fixed block
smooth surface
fixed block

Fig. 4.1

The trolley oscillates horizontally about its equilibrium position with an amplitude of 12 cm. Fig. 4.2 shows the variation of the acceleration a of the trolley with displacement x from its equilibrium position. Friction between the trolley and the surface can be assumed to be negligible.

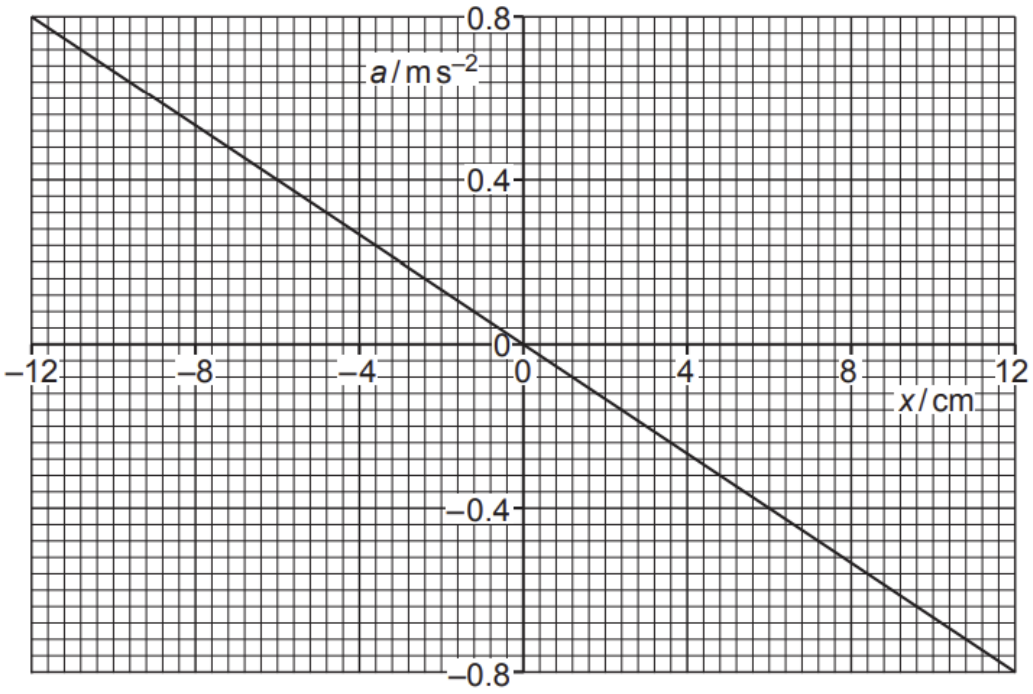


Fig. 4.2

(a) Describe the features of the line in Fig. 4.2 that demonstrate that the motion of the trolley is simple harmonic.

.....

.....

..... [2]

(b) Use Fig. 4.2 to determine the period T of the oscillations of the trolley.

T = ... s [3]

(c) **(i)** On the line of the graph of Fig. 4.2, label with the letter P one point where the kinetic energy of the trolley is zero. [1]

(ii) On the line of the graph of Fig. 4.2, label with the letter Q an approximate position of one point where the kinetic energy of the trolley is equal to the potential energy stored in the springs. [1]

[Total: 7]

Question 3

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

.....

.....

..... [2]

(b) A trolley of mass m is held on a horizontal surface by means of two springs. One spring is attached to a fixed point P. The other spring is connected to an oscillator, as shown in Fig. 3.1.

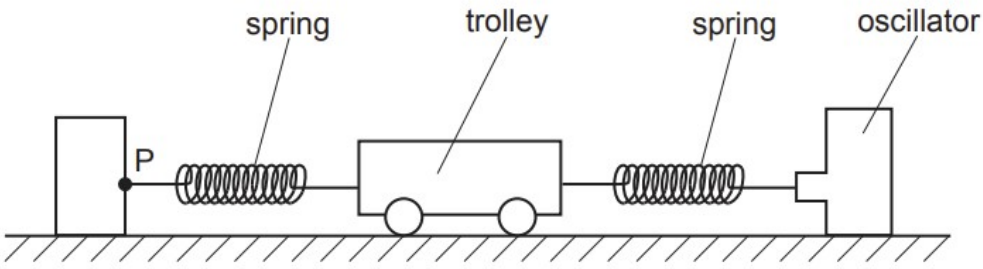


Fig. 3.1

The springs, each having spring constant k of $130\,\text{N}\,\text{m}^{-1}$, are always extended.

The oscillator is switched off. The trolley is displaced along the line of the springs and then released. The resulting oscillations of the trolley are simple harmonic.

The acceleration a of the trolley is given by the expression

$$a = -\left(\frac{2k}{m}\right)x$$

where x is the displacement of the trolley from its equilibrium position.

The mass of the trolley is 840 g.

Calculate the frequency f of oscillation of the trolley.

f = ... Hz [3]

(c) The oscillator in **(b)** is switched on. The frequency of oscillation of the oscillator is varied, keeping its amplitude of oscillation constant.

The amplitude of oscillation of the trolley is seen to vary. The amplitude is a maximum at the frequency calculated in **(b)**.

(i) State the name of the effect giving rise to this maximum.

..... [1]

(ii) At any given frequency, the amplitude of oscillation of the trolley is constant.

Explain how this indicates that there are resistive forces opposing the motion of the trolley.

.....

.....

..... [2]

[Total: 8]

Question 4

A U-shaped tube contains some liquid. The liquid column in each half of the tube has length L, as shown in Fig. 3.1.

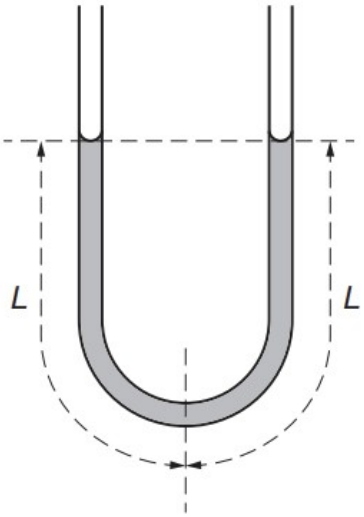


Fig. 3.1

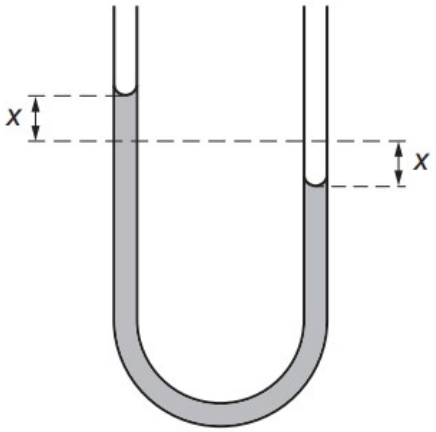


Fig. 3.2

The liquid columns are displaced vertically. The liquid then oscillates in the tube. The liquid levels are displaced from the equilibrium positions as shown in Fig. 3.2.

The acceleration a of the liquid in the tube is related to the displacement x by the expression

$$a = -\left(\frac{g}{L}\right)x$$

where g is the acceleration of free fall.

(a) Explain how the expression shows that the liquid in the tube is undergoing simple harmonic motion.

.....

.....

.....

.....

..... [3]

(b) The length L of each liquid column is 18 cm.

Determine the period T of the oscillations.

T = ... s [3]

(a) Explain how the expression shows that the liquid in the tube is undergoing simple harmonic motion.

.....

.....

.....

.....

..... [3]

(b) The length L of each liquid column is 18 cm.

Determine the period T of the oscillations.

T = ... s [3]

(c) The oscillations of the liquid in the tube are damped.
In any one complete cycle of the oscillations, the amplitude decreases by 6.0% of its value at the beginning of the oscillation.

Determine the ratio

$$\frac{\text{energy of oscillations after 3 cycles}}{\text{initial energy of oscillations}}.$$

ratio = ... [3]

[Total: 9]

Question 5

(a) The defining equation of simple harmonic motion is

$$a = -\omega^2 x.$$

State the significance of the minus (–) sign in the equation.

.....

..... [1]

(b) A trolley rests on a bench. Two identical stretched springs are attached to the trolley as shown in Fig. 4.1. The other end of each spring is attached to a fixed support.

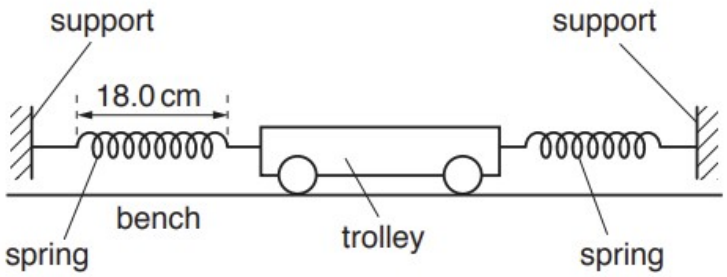


Fig. 4.1

The unstretched length of each spring is 12.0 cm. The spring constant of each spring is 8.0 N m^{-1}. When the trolley is in equilibrium the length of each spring is 18.0 cm.

The trolley is displaced 4.8 cm to one side and then released. Assume that resistive forces on the trolley are negligible.

(i) Show that the resultant force on the trolley at the moment of release is 0.77 N.

[2]

(ii) The mass of the trolley is 250 g.

Calculate the maximum acceleration a of the trolley.

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

(iii) Use your answer in **(ii)** to determine the period T of the subsequent oscillation.

T = ... s [3]

(iv) The experiment is repeated with an initial displacement of the trolley of 2.4 cm.

State and explain the effect, if any, this change has on the period of the oscillation of the trolley.

.....

.....

..... [2]

[Total: 9]

Question 6

A small wooden block (cuboid) of mass *m* floats in water, as shown in Fig. 3.1.

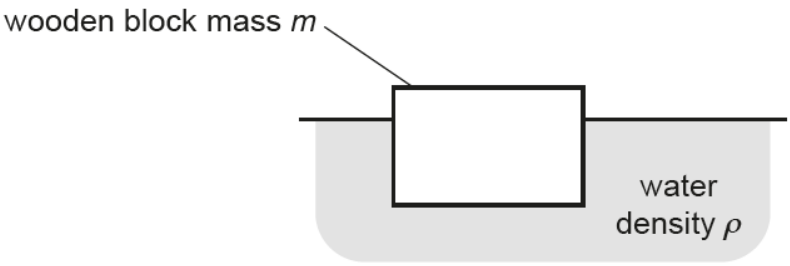


Fig. 3.1

The top face of the block is horizontal and has area *A*. The density of the water is ρ.

(a) State the names of the two forces acting on the block when it is stationary.

..... [1]

(b) The block is now displaced downwards as shown in Fig. 3.2 so that the surface of the water is higher up the block.

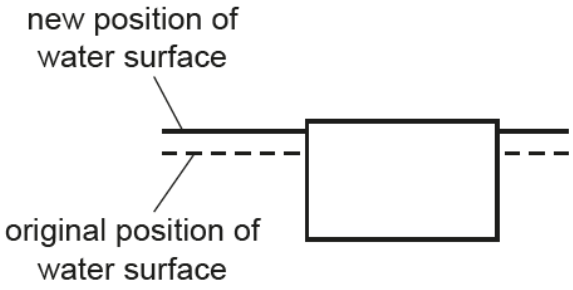


Fig. 3.2

State and explain the direction of the resultant force acting on the wooden block in this position.

.....

..... [1]

(c) The block in **(b)** is now released so that it oscillates vertically.

The resultant force F acting on the block is given by

$$F = -Ag\rho x$$

where g is the gravitational field strength and x is the vertical displacement of the block from the equilibrium position.

(i) Explain why the oscillations of the block are simple harmonic.

.....

.....

..... [2]

(ii) Show that the angular frequency ω of the oscillations is given by

$$\omega = \sqrt{\frac{A\rho g}{m}}.$$

[2]

(d) The block is now placed in a liquid with a greater density. The block is displaced and released so that it oscillates vertically. The variation with displacement x of the acceleration a of the block is measured for the first half oscillation, as shown in Fig. 3.3.

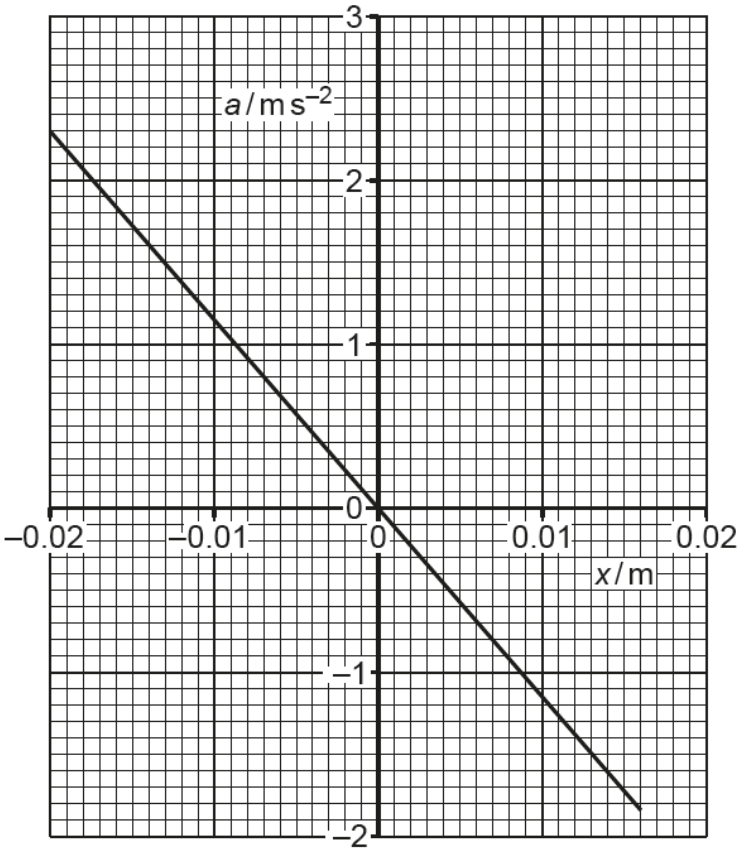


Fig. 3.3

(i) Explain why the maximum negative displacement of the block is not equal to its maximum positive displacement.

.....

.....

..... [1]

(ii) The mass of the block is 0.57 kg.

Use Fig. 3.3 to determine the decrease ΔE in energy of the oscillation for the first half oscillation.

E = ... J [3]

[Total: 10]

Question 7

A pendulum consists of a bob (small metal sphere) attached to the end of a piece of string. The other end of the string is attached to a fixed point. The bob oscillates with small oscillations about its equilibrium position, as shown in Fig. 4.1.

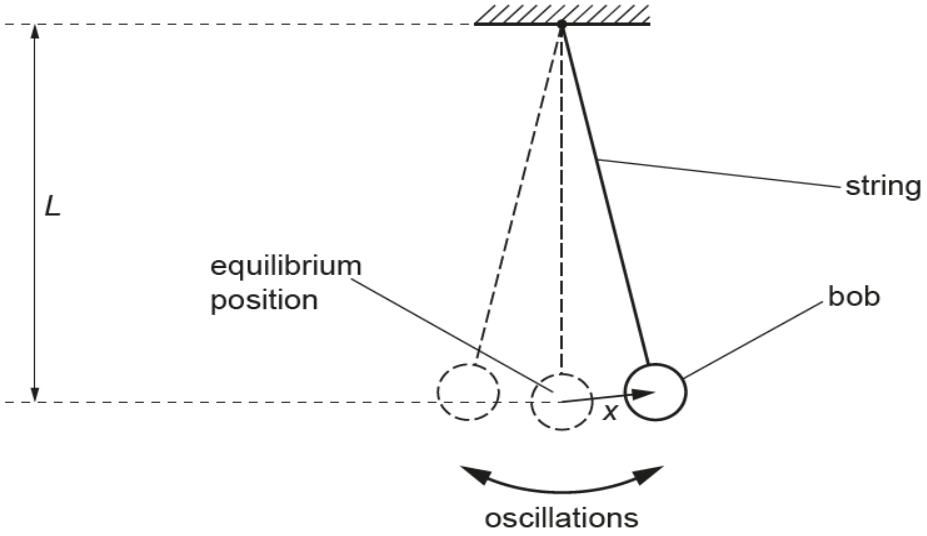


Fig. 4.1 (not to scale)

The length *L* of the pendulum, measured from the fixed point to the centre of the bob, is 1.24 m.

The length L of the pendulum, measured from the fixed point to the centre of the bob, is 1.24 m.

The acceleration a of the bob varies with its displacement x from the equilibrium position as shown in Fig. 4.2.

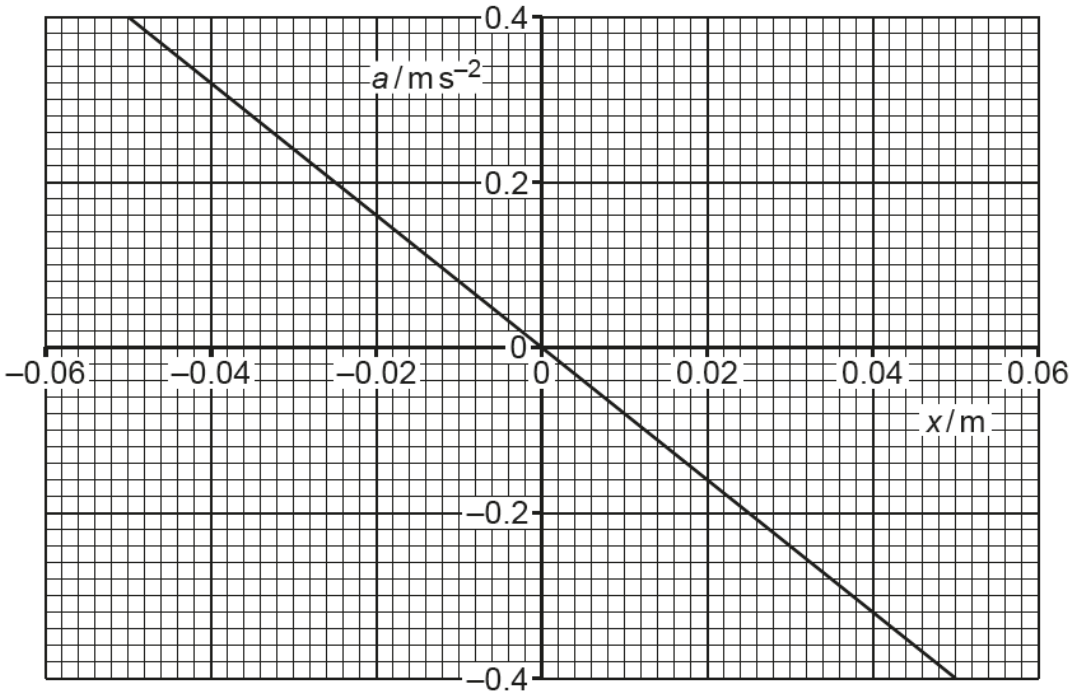


Fig. 4.2

(a) State how Fig. 4.2 shows that the motion of the pendulum is simple harmonic.

.....

.....

..... [2]

(b) **(i)** Use Fig. 4.2 to determine the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [2]

(ii) The angular frequency ω is related to the length L of the pendulum by

$$\omega = \sqrt{\frac{k}{L}}$$

where k is a constant.

Use your answer in **(b)(i)** to determine k. Give a unit with your answer.

k = ... unit ..... [2]

(c) While the pendulum is oscillating, the length of the string is increased in such a way that the total energy of the oscillations remains constant.

Suggest and explain the qualitative effect of this change on the amplitude of the oscillations.

.....

.....

..... [2]

[Total: 8]

Question 8

(a) State what is meant by resonance.

.....

.....

..... [2]

(b) Fig. 4.1 shows a heavy pendulum and a light pendulum, both suspended from the same piece of string. This string is secured at each end to fixed points.

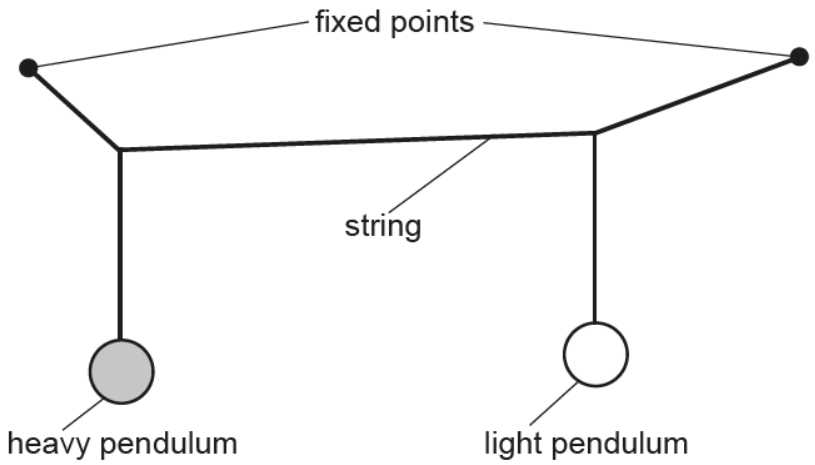


Fig. 4.1

Both pendulums have the same natural frequency.
The heavy pendulum is set oscillating perpendicular to the plane of the diagram. As it oscillates, it causes the light pendulum to oscillate.

Fig. 4.2 shows the variation with time t of the displacements of the two pendulums for three oscillations.

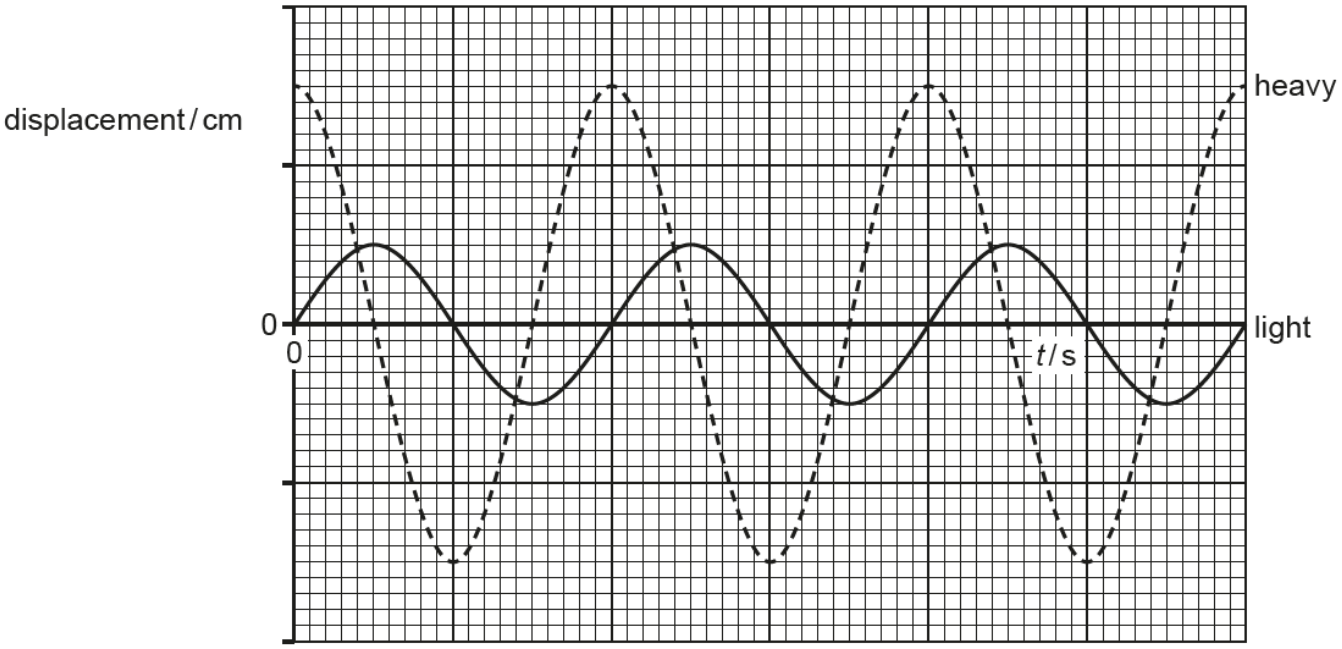


Fig. 4.2

The variation with t of the displacement x of the light pendulum is given by

$$x = 0.25 \sin 5.0\pi t$$

where x is in centimetres and t is in seconds.

(i) Calculate the period T of the oscillations.

T = ... s [2]

(ii) On Fig. 4.2, label both of the axes with the correct scales. Use the space below for any additional working that you need.

[2]

(iii) Determine the magnitude of the phase difference ϕ between the oscillations of the light and heavy pendulums. Give a unit with your answer.

ϕ = ... unit ..... [2]

[Total: 8]

Question 9

An object is suspended from a spring that is attached to a fixed point as shown in Fig. 3.1.

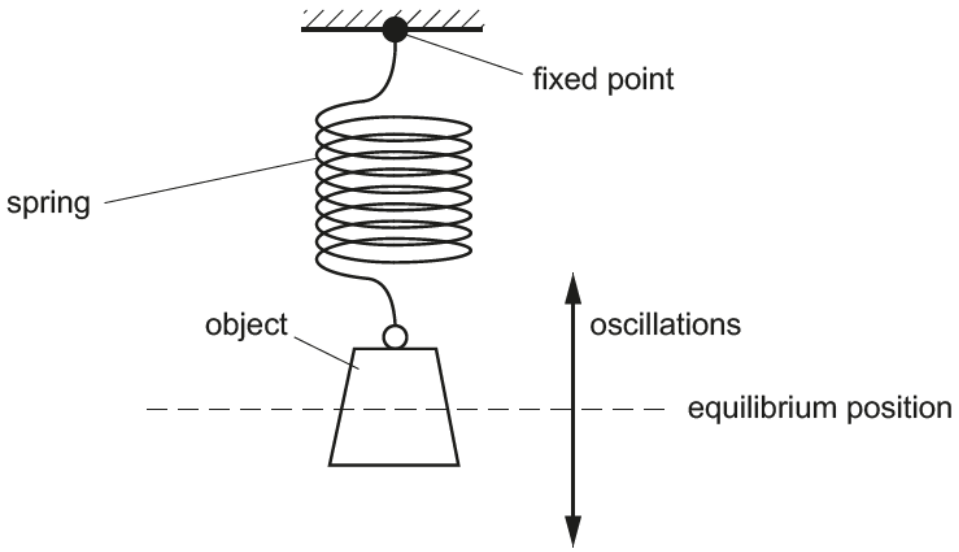


Fig. 3.1

The object oscillates vertically with simple harmonic motion about its equilibrium position.

(a) State the defining equation for simple harmonic motion. Identify the meaning of each of the symbols used to represent physical quantities.

.....

.....

..... [2]

(b) The variation with displacement x from the equilibrium position of the velocity v of the object is shown in Fig. 3.2.

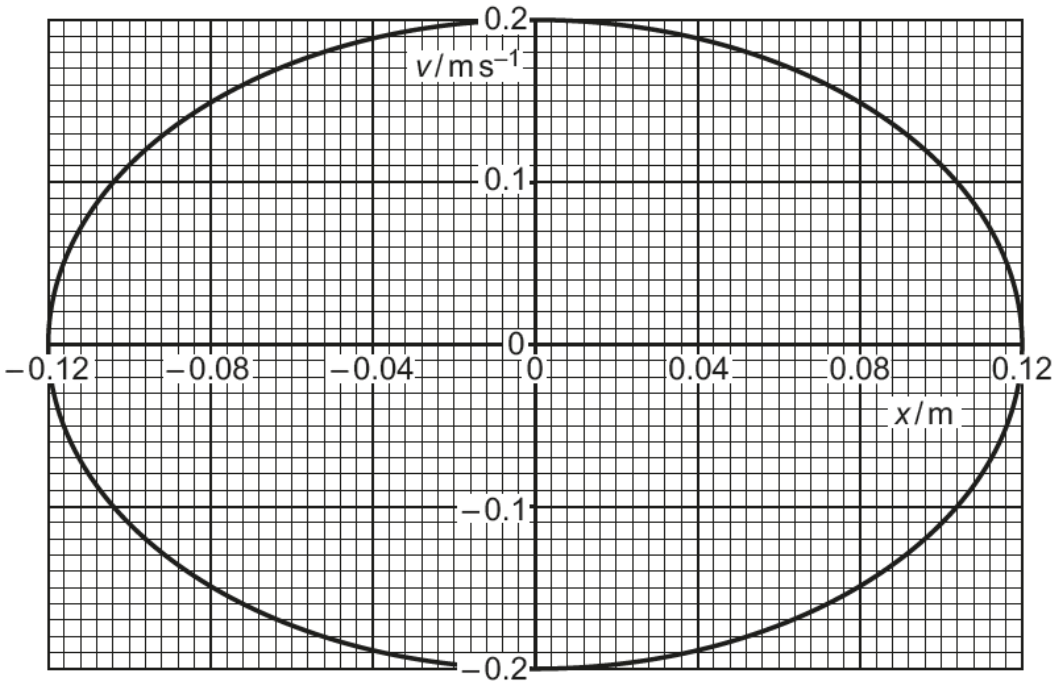


Fig. 3.2

The variation with x of the potential energy E_P of the oscillations of the object is shown in Fig. 3.3.

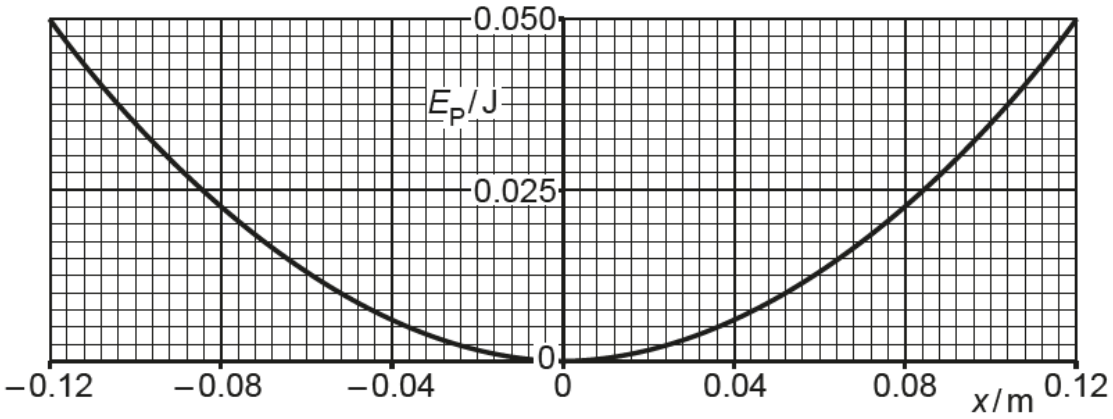


Fig. 3.3

Use Fig. 3.2 and Fig. 3.3 to:

(i) determine the amplitude x_0 of the oscillations

x_0 = ... m [1]

(ii) show that the angular frequency of the oscillations is $1.7\,\text{rad}\,\text{s}^{-1}$

[2]

(iii) determine the mass M of the object.

M = ... kg [2]

(c) The oscillations of the object are now lightly damped.

(i) State what is meant by damping.

.....

.....

..... [2]

(ii) Assume that the damping does not change the angular frequency of the oscillations.

On Fig. 3.2, sketch the variation with x of v when the amplitude of the oscillations is 0.060 m. [2]

[Total: 11]

Question 10

Fig. 4.1 shows the variation with time t of the height h above the ground of an object of mass 36 kg that is undergoing vertical simple harmonic motion.

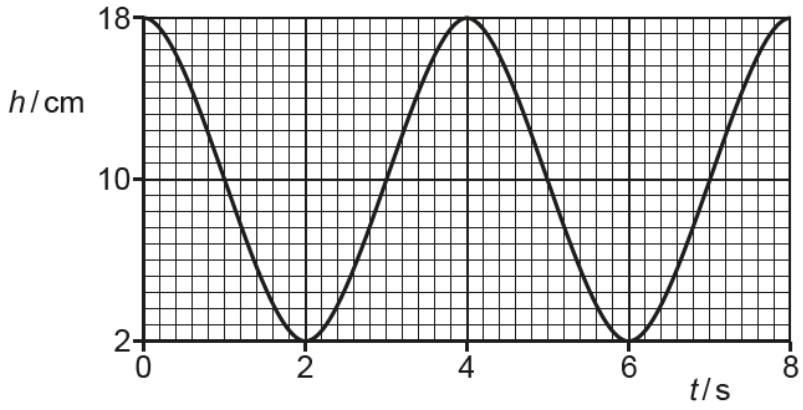


Fig. 4.1

(a) For the oscillations of the object:

(i) determine the amplitude x_0, in cm

x_0 = ... cm [1]

(ii) show that the angular frequency ω is $1.6\,\text{rad}\,\text{s}^{-1}$

[2]

(iii) determine the total energy E.

E = ... J [3]

(b) On Fig. 4.2, sketch the variation with h of the kinetic energy E_K of the object.

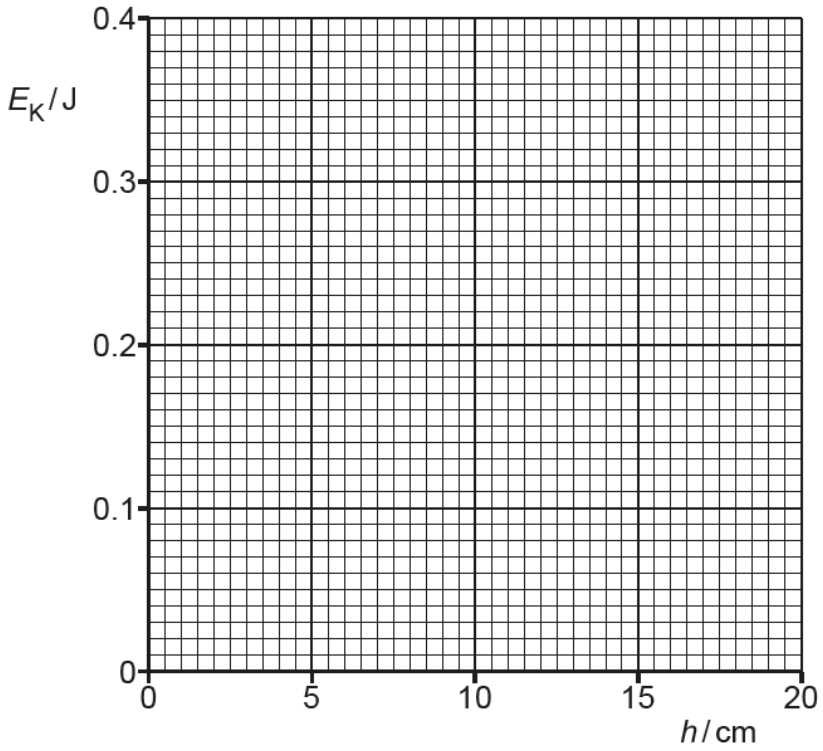


Fig. 4.2

[4]

[Total: 10]

Question 11

An object is suspended from a vertical spring as shown in Fig. 3.1.

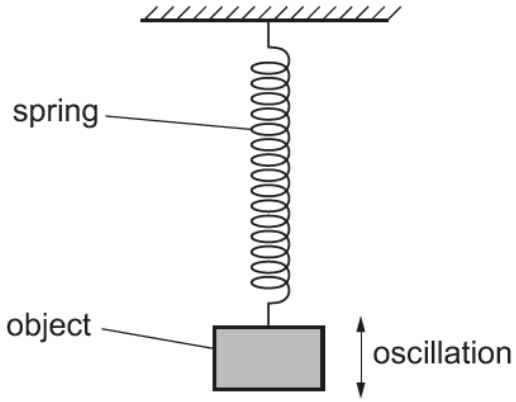


Fig. 3.1

The object is displaced vertically and then released so that it oscillates, undergoing simple harmonic motion.

Fig. 3.2 shows the variation with displacement x of the energy E of the oscillations.

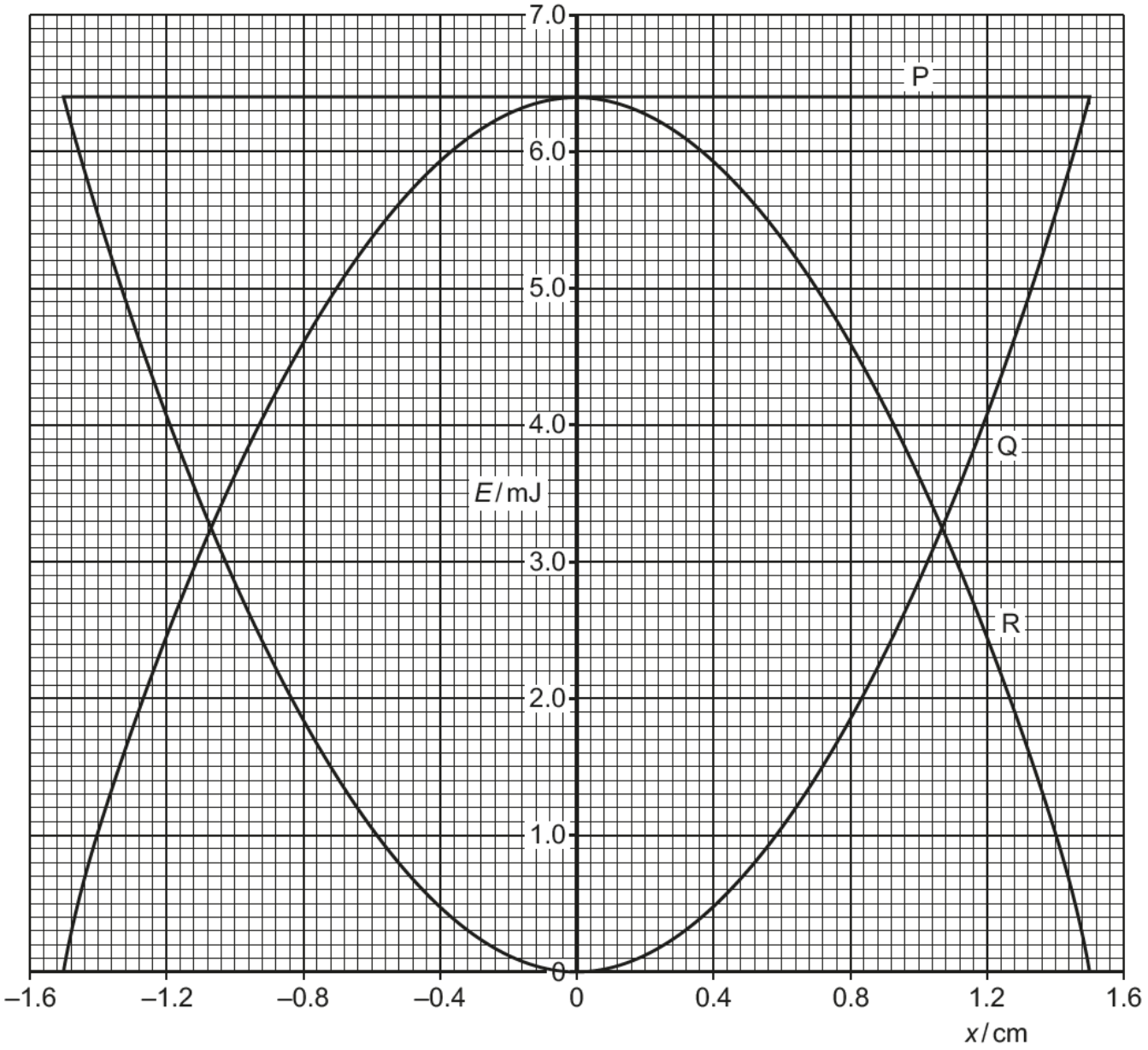


Fig. 3.2

The kinetic energy, the potential energy and the total energy of the oscillations are each represented by one of the lines P, Q and R.

(a) State the energy that is represented by each of the lines P, Q and R.

P .....

Q .....

R .....

[2]

(b) The object has a mass of 130 g.
Determine the period of the oscillations.

period = ... s [4]

(c) **(i)** State the cause of damping.

.....

..... [1]

(ii) A light card is attached to the object. The object is displaced with the same initial amplitude and then released. During each complete oscillation the total energy of the system decreases by 8.0% of the total energy at the start of that oscillation.

Determine the decrease in total energy, in mJ, of the system by the end of the first 6 complete oscillations.

energy lost = ... mJ [2]

(iii) State, with a reason, the type of damping that the card introduces into the system.

.....

.....

..... [1]

[Total: 10]

Question 12

A steel sphere of mass 0.29 kg is suspended in equilibrium from a vertical spring. The centre of the sphere is 8.5 cm from the top of the spring, as shown in Fig. 2.1.

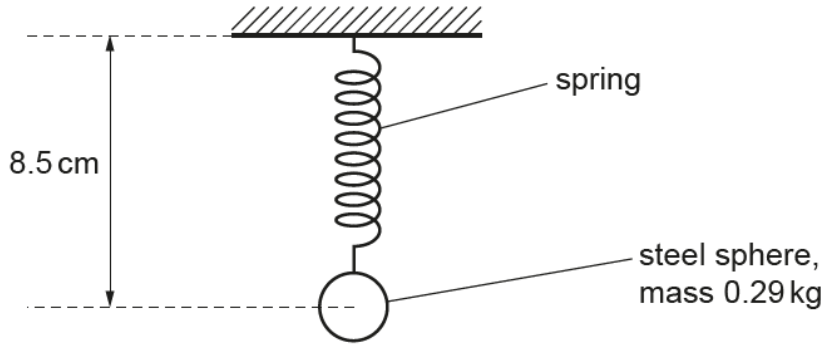


Fig. 2.1

The sphere is now set in motion so that it is moving in a horizontal circle at constant speed, as shown in Fig. 2.2.

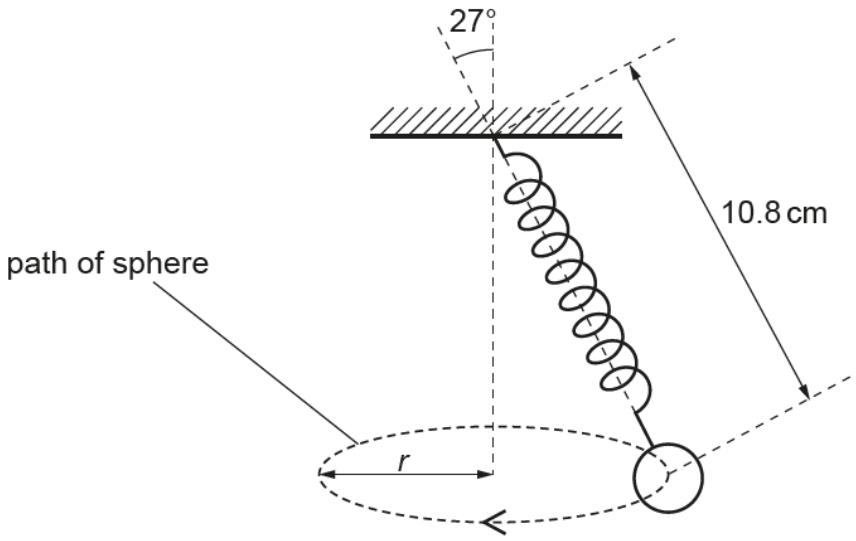


Fig. 2.2

The distance from the centre of the sphere to the top of the spring is now 10.8 cm.

The distance from the centre of the sphere to the top of the spring is now 10.8 cm.

(a) Explain, with reference to the forces acting on the sphere, why the length of the spring in Fig. 2.2 is greater than in Fig. 2.1.

.....

.....

.....

.....

..... [3]

(b) The angle between the linear axis of the spring and the vertical is 27°.

(i) Show that the radius r of the circle is 4.9 cm.

[1]

(ii) Show that the tension in the spring is 3.2 N.

[2]

(iii) The spring obeys Hooke's law.

Calculate the spring constant, in N cm^{-1}, of the spring.

spring constant = ... N cm^{-1} [2]

(c) (i) Use the information in **(b)** to determine the centripetal acceleration of the sphere.

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

(ii) Calculate the period of the circular motion of the sphere.

period = ... s [2]

[Total: 12]

Question 13

A small steel sphere is oscillating vertically on the end of a spring, as shown in Fig. 4.1.

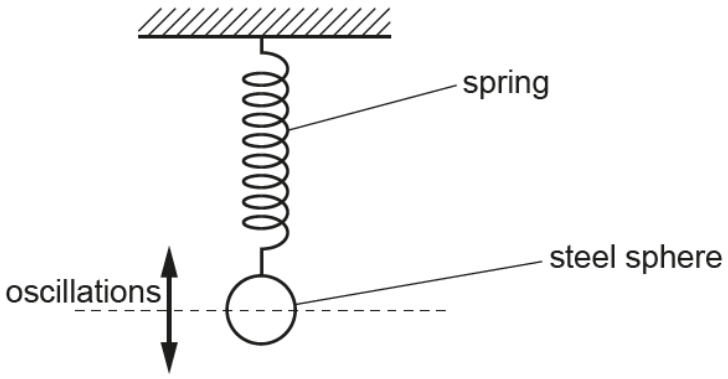


Fig. 4.1

The velocity v of the sphere varies with displacement x from its equilibrium position according to

$$v = \pm 9.7\sqrt{(11.6 - x^2)}$$

where v is in cm s^{-1} and x is in cm.

(a) (i) Calculate the frequency of the oscillations.

frequency = ... Hz [2]

(ii) Show that the amplitude of the oscillations is 3.4 cm.

[1]

(iii) Calculate the maximum acceleration a_0 of the sphere.

a_0 = ... $m\,s^{-2}$ [2]

(b) On Fig. 4.2, sketch the variation with x of the acceleration a of the sphere.

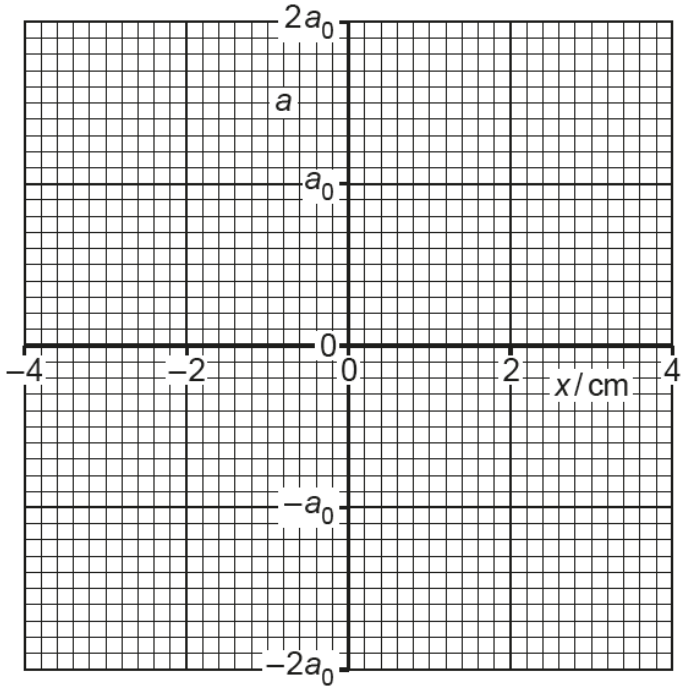


Fig. 4.2

[3]

(c) Describe, without calculation, the interchange between the potential energy and the kinetic energy of the oscillations.

.....

.....

.....

.....

..... [3]

[Total: 11]

Question 14

A heavy metal sphere of mass 0.81 kg is suspended from a string. The sphere is undergoing small oscillations from side to side, as shown in Fig. 4.1.

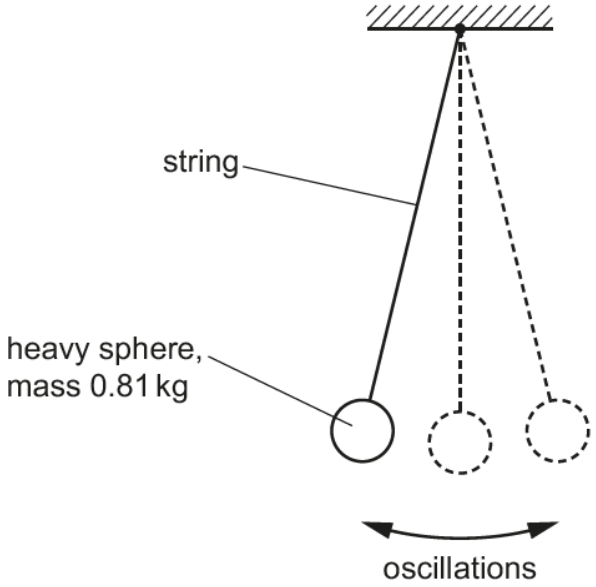


Fig. 4.1

The oscillations of the sphere may be considered to be simple harmonic with amplitude 0.036 m and period 3.0 s.

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

.....

.....

..... [2]

(b) Calculate:

(i) the angular frequency of the oscillations

angular frequency = ... rad s^{-1} [2]

(ii) the total energy of the oscillations.

total energy = ... J [2]

(c) The suspended sphere is now lowered into water. The sphere is given a sideways displacement of +0.036 m from its equilibrium position and is then released at time $t = 0$. The water causes the motion of the sphere to be critically damped.

On Fig. 4.2, sketch the variation of the displacement x of the sphere from its equilibrium position with t from $t = 0$ to $t = 6.0$ s.

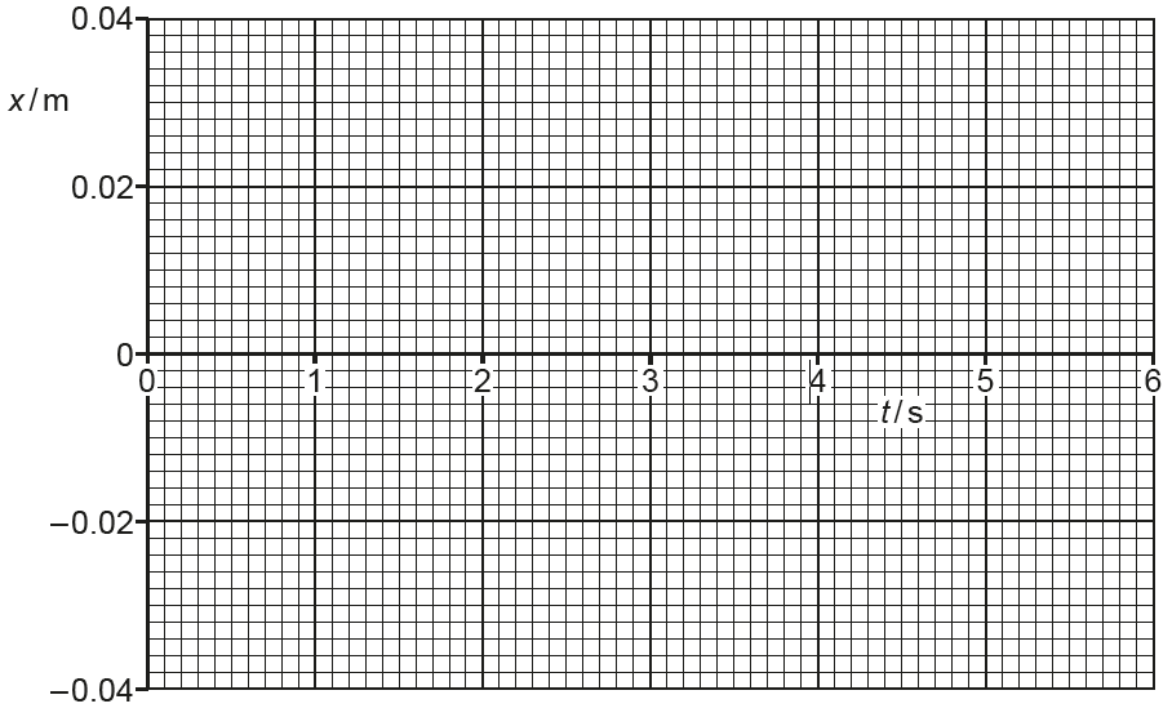


Fig. 4.2

[3]

[Total: 9]

Question 15

A small object of mass 24 g rests on a platform. The platform is attached to an oscillator, as shown in Fig. 3.1.

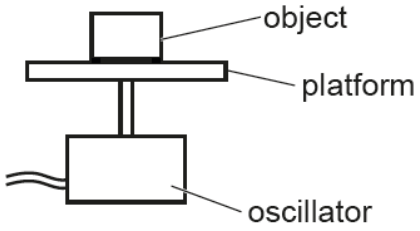


Fig. 3.1

The oscillator moves the platform up and down.

(a) The total energy of the oscillations of the object is 2.2×10^{-4} J.
In one oscillation the object travels a total distance of 14 mm.

Calculate the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [3]

(b) The frequency of the oscillator is fixed, and the amplitude of the oscillations is gradually increased.

(i) Calculate the maximum amplitude of the oscillations so the object does not lose contact with the platform.

amplitude = ... m [2]

(ii) The amplitude of the oscillations is increased so it is greater than the value in **(b)(i)**.

State and explain the position in an oscillation where the object first loses contact with the platform.

.....

.....

.....

..... [2]

[Total: 7]

Question 16

(a) State what is meant by resonance.

.....

.....

..... [2]

(b) A small ball is held in place using a stretched string. One end of the string is fixed to a wall and the other end is attached to a vibration generator, as shown in Fig. 4.1.

(b) A small ball is held in place using a stretched string. One end of the string is fixed to a wall and the other end is attached to a vibration generator, as shown in Fig. 4.1.

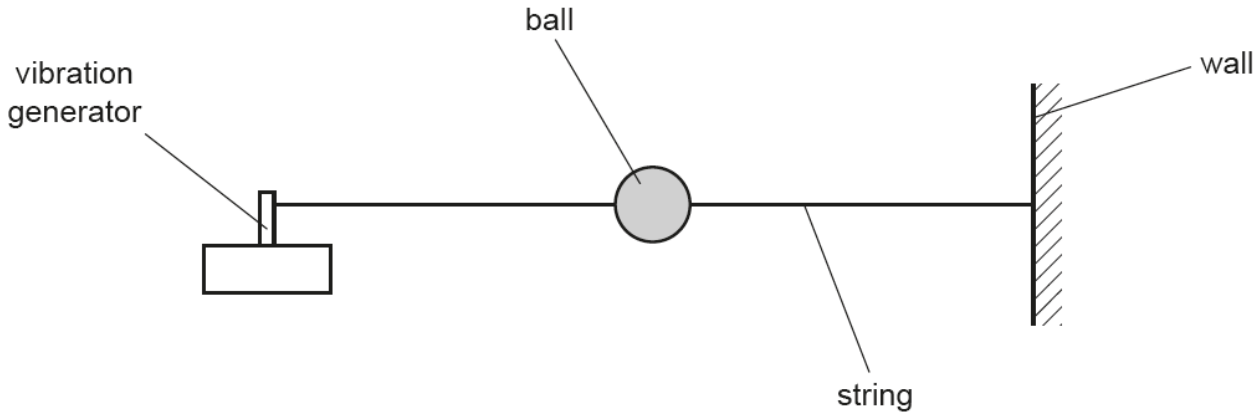


Fig. 4.1

Initially, the vibration generator is switched off.

A student displaces the ball vertically and then releases it. Fig. 4.2 shows the variation of the displacement of the ball with time after it is released.

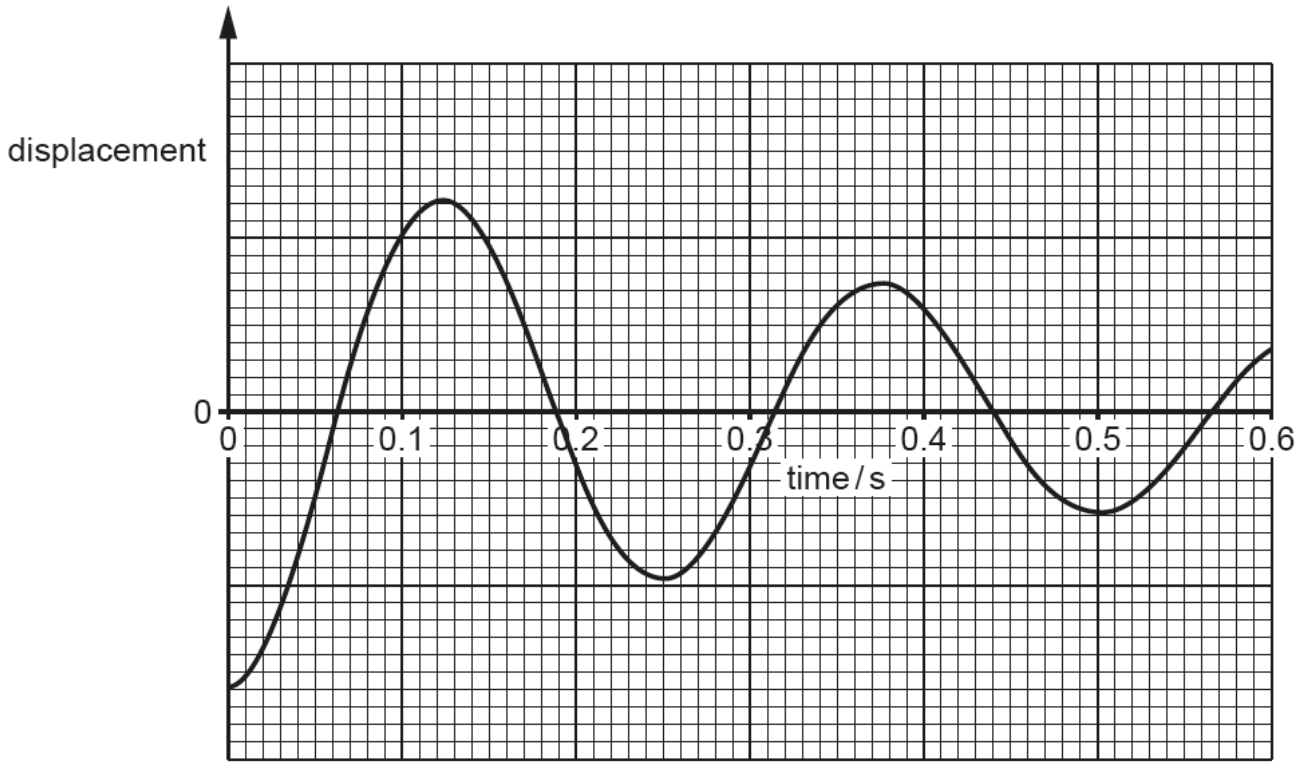


Fig. 4.2

(i) State the name of the phenomenon illustrated by the decrease in the amplitude of the oscillations in Fig. 4.2.

..... [1]

(ii) Explain the decrease with time of the amplitude of the oscillations of the ball.

.....

.....

..... [2]

(iii) Determine the frequency of the oscillations of the ball.

frequency = ... Hz [1]

(i) State the name of the phenomenon illustrated by the decrease in the amplitude of the oscillations in Fig. 4.2.

..... [1]

(ii) Explain the decrease with time of the amplitude of the oscillations of the ball.

.....

.....

..... [2]

(iii) Determine the frequency of the oscillations of the ball.

frequency = ... Hz [1]

(c) The vibration generator in **(b)** is switched on and its frequency f of vibration is gradually increased from 0 to 10 Hz.

On Fig. 4.3, sketch the variation with f of the amplitude of the oscillations of the ball.

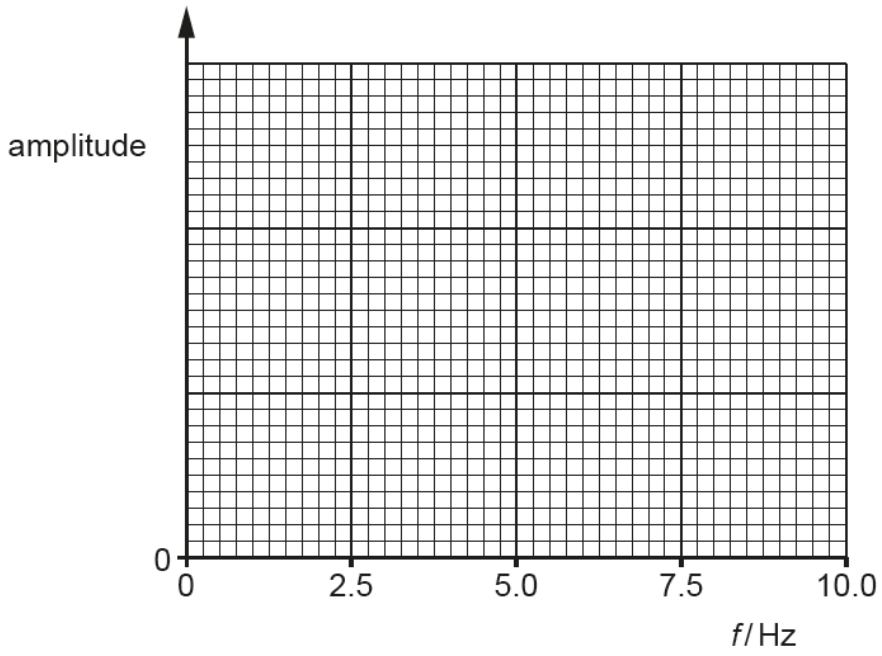


Fig. 4.3

[2]

[Total: 8]

Question 17

A block of mass *m* oscillates vertically on a spring, as shown in Fig. 4.1.

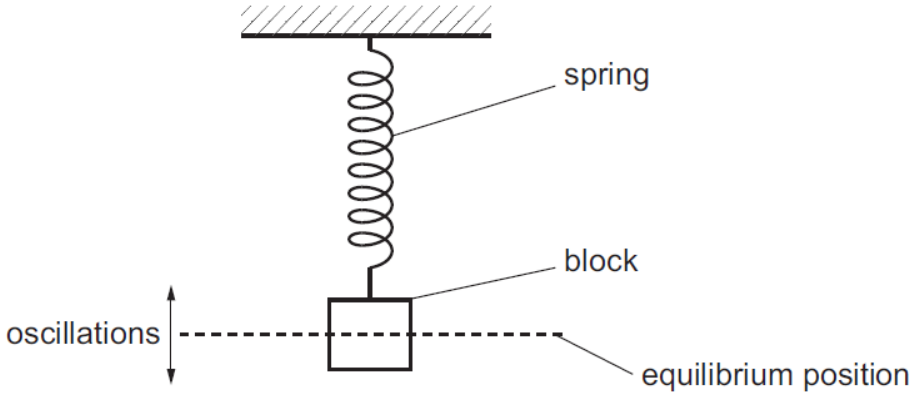


Fig. 4.1

The acceleration *a* of the block varies with displacement *x* from its equilibrium position, as shown in Fig. 4.2.

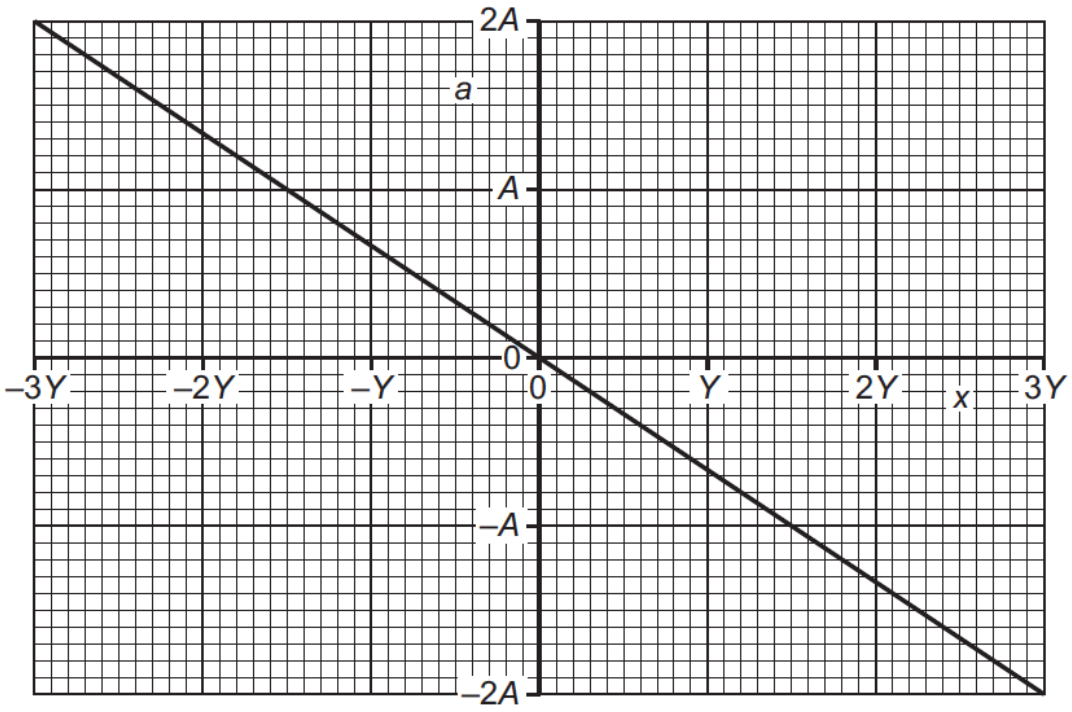


Fig. 4.2

The amplitude of the oscillations is 3*Y* and the maximum acceleration is 2*A*.

The amplitude of the oscillations is $3Y$ and the maximum acceleration is $2A$.

(a) Explain how Fig. 4.2 shows that the oscillations of the block are simple harmonic.

.....

.....

..... [2]

(b) Deduce expressions, in terms of some or all of m, A and Y, for:

(i) the angular frequency ω of the oscillations

ω = ... [1]

(ii) the maximum speed v_0 of the oscillations

v_0 = ... [2]

(iii) the energy E of the oscillations.

E = ... [2]

(c) The period of the oscillations is 0.75 s and the value of $3Y$ is 1.8 cm.

Determine an expression for x in terms of time t, where x is in cm and t is in seconds.

x = ... [2]

[Total: 9]

Question 18

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

.....

.....

..... [2]

(b) A block is suspended from a spring, as shown in Fig. 4.1.

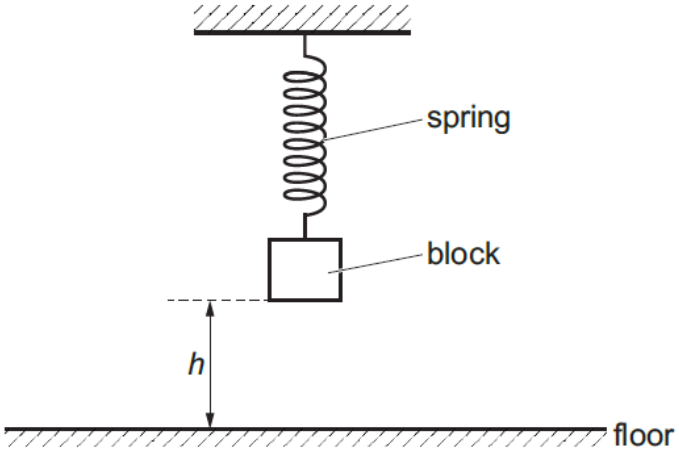


Fig. 4.1

The block is pulled down and released at time $t = 0$. It then oscillates vertically with simple harmonic motion.

Fig. 4.2 shows the variation of the velocity v of the block with height h of the base of the block above the floor.

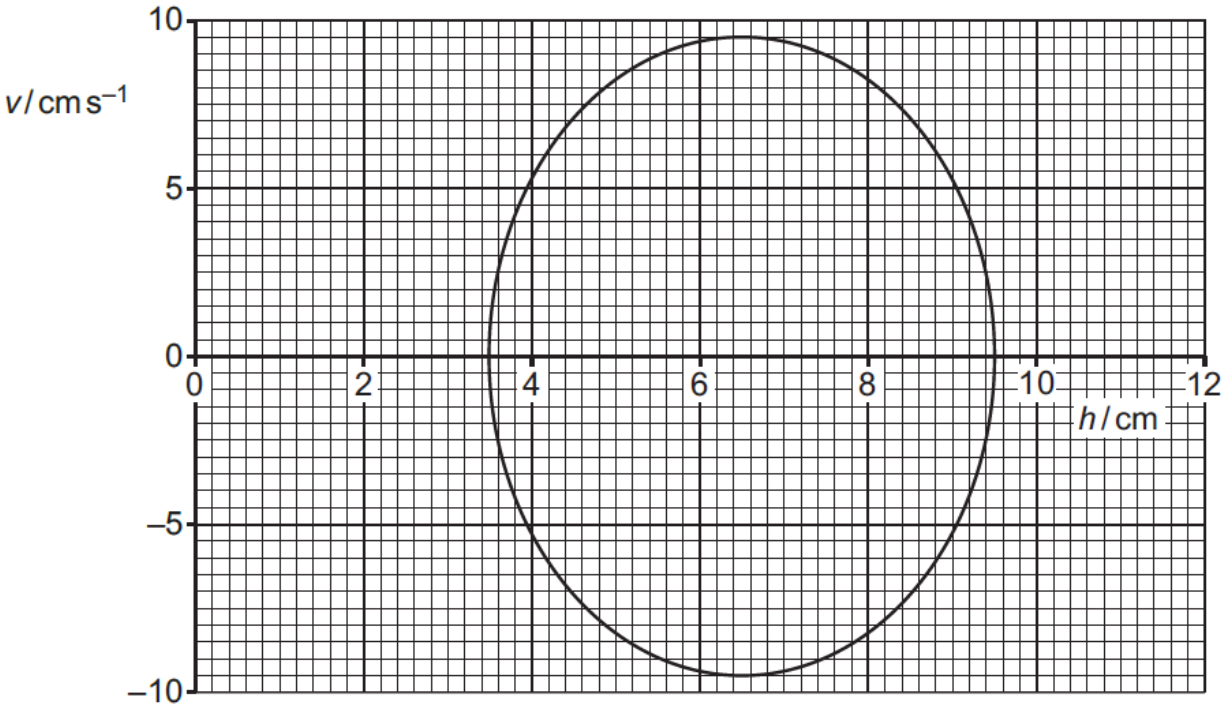


Fig. 4.2

(i) Determine the amplitude, in cm, of the oscillations.

amplitude = ... cm [1]

(ii) Show that the angular frequency of the oscillations is 3.2 rad s^{-1}.

[2]

(iii) Calculate the period T of the oscillations.

T = ... s [2]

(iv) On Fig. 4.3, sketch the variation of h with time t from $t = 0$ to $t = 6.0$ s.

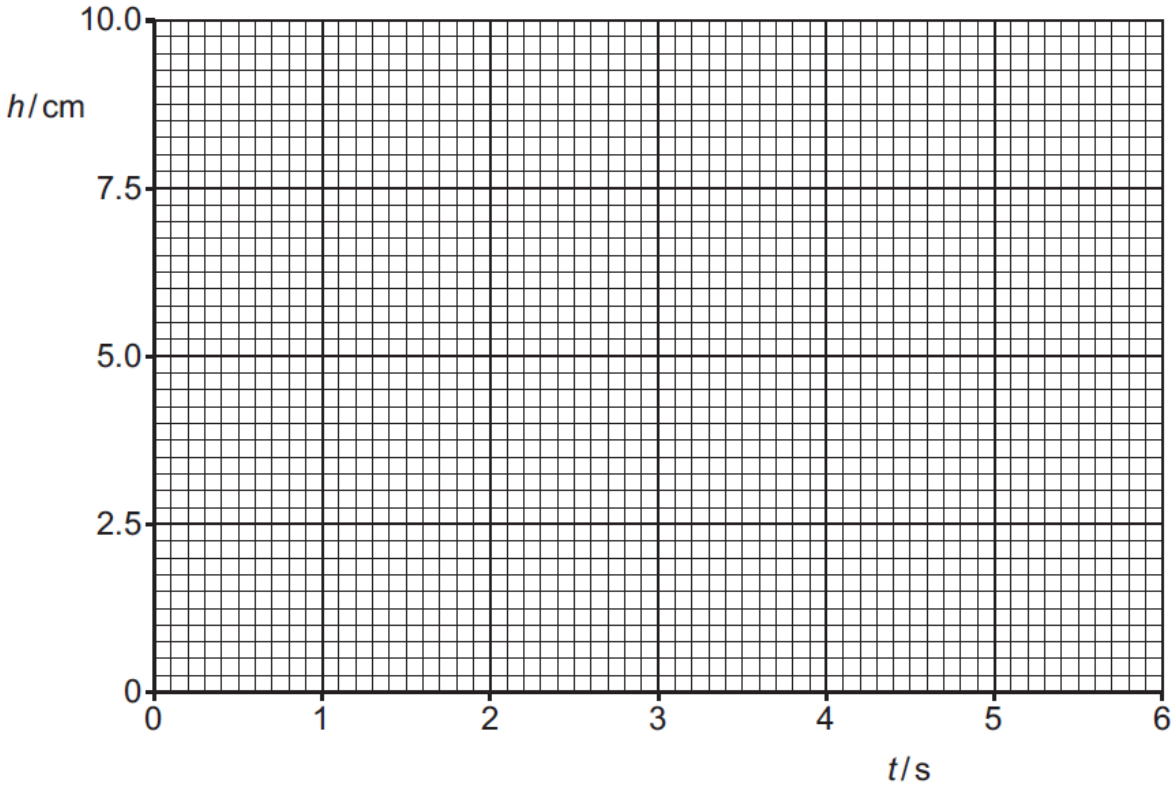


Fig. 4.3

[4]

[Total: 11]

Question 19

Fig. 5.1 shows a pendulum consisting of a metal sphere suspended by a thin string.

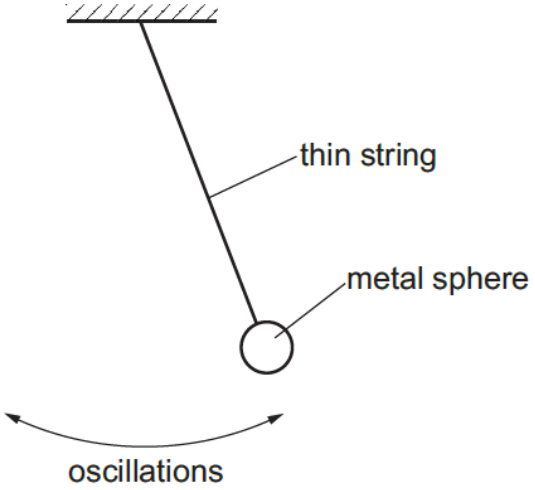


Fig. 5.1 (not to scale)

The sphere undergoes small oscillations about its equilibrium position. The oscillations may be considered to be simple harmonic.

Fig. 5.2 shows the variation with time t of the displacement x of the sphere from its equilibrium position.

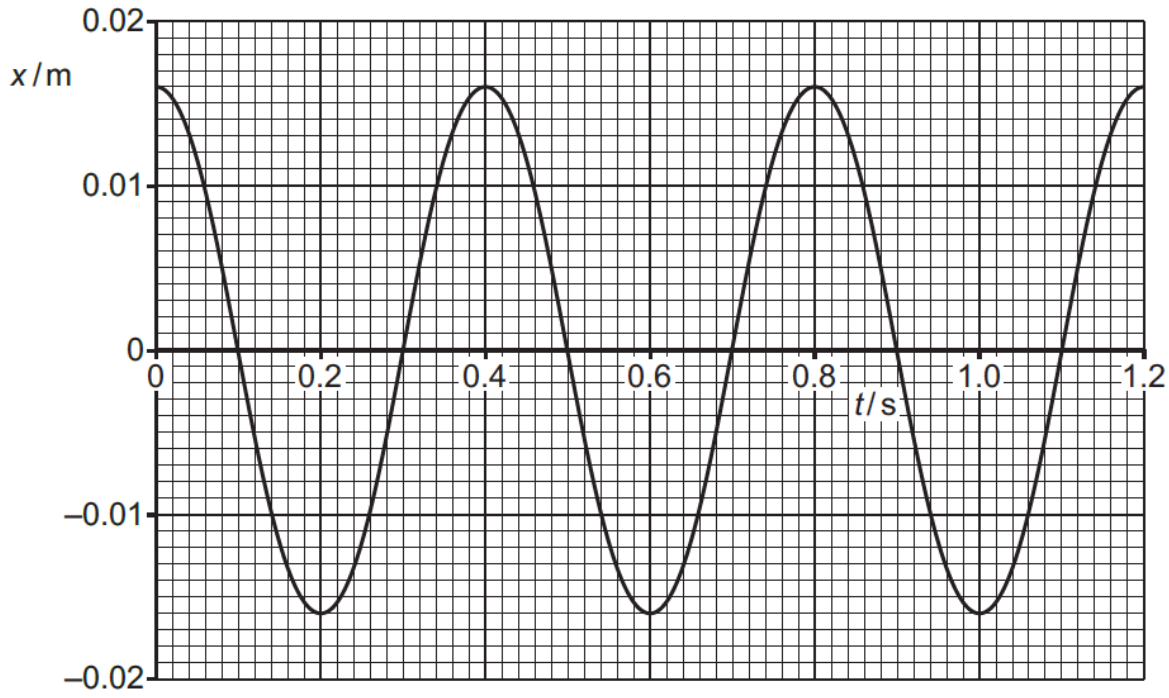


Fig. 5.2

(a) On Fig. 5.1, draw an arrow, from the centre of the sphere, to represent the direction of the resultant force acting on the sphere when it is in the position shown. [1]

(b) The mass of the sphere is 0.15 kg.

(i) State the amplitude of the oscillations.

amplitude = ... m [1]

(ii) Determine the angular frequency of the oscillations.

angular frequency = ... rad s^{-1} [2]

(iii) Calculate the total energy of the oscillations.

total energy = ... J [2]

(c) On Fig. 5.3, sketch the variation with x of the kinetic energy E_K of the sphere.

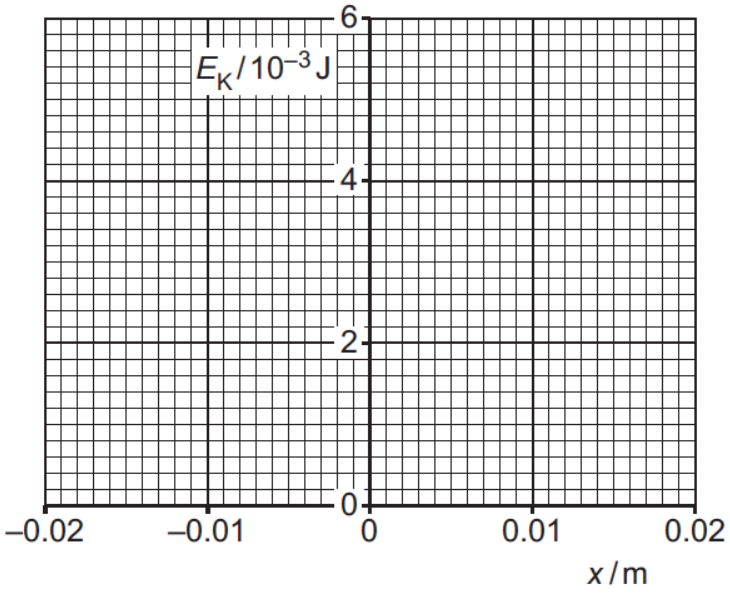


Fig. 5.3

[3]

[Total: 9]

Question 20

A cuboidal block floats in a liquid with its base horizontal, as shown in Fig. 5.1.

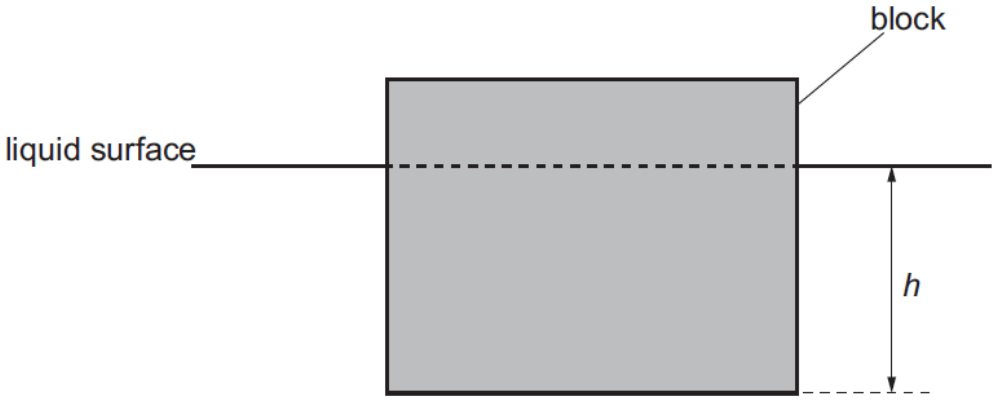


Fig. 5.1

The base of the block is at a depth h below the surface of the liquid.

The block is displaced downwards by a small distance and then released so that it oscillates.

Fig. 5.2 shows the variation with h of the acceleration a of the block.

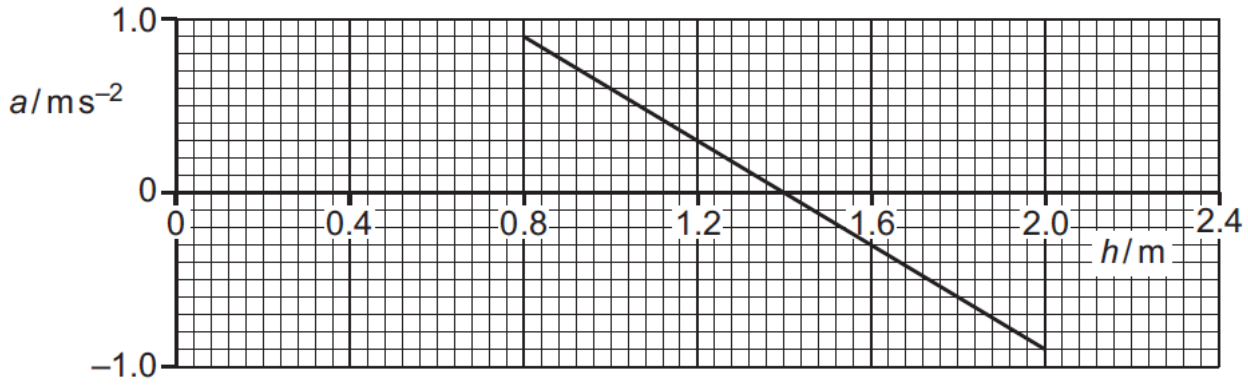


Fig. 5.2

Fig. 5.3 shows the variation with h of the kinetic energy E_K of the block.

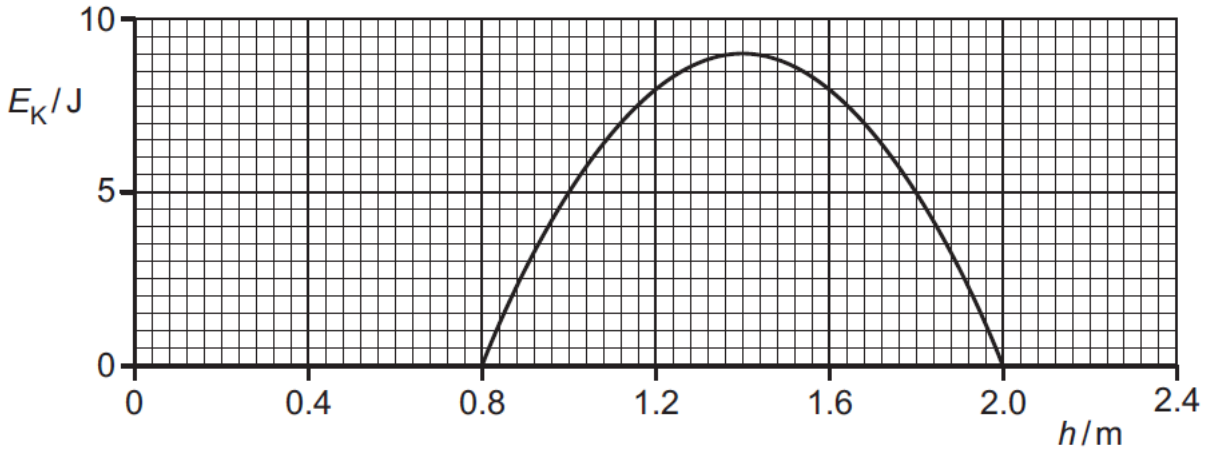


Fig. 5.3

(a) (i) Determine the amplitude of the oscillations.

amplitude = ... m [1]

(ii) State what the line in Fig. 5.2 shows about the nature of the oscillations.

..... [1]

(b) State **three** other quantitative conclusions that can be drawn from Fig. 5.2 and Fig. 5.3 about the block and its oscillations. Use the space for any working.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(c) On Fig. 5.4, sketch the variation with h of the potential energy E_P of the oscillations.

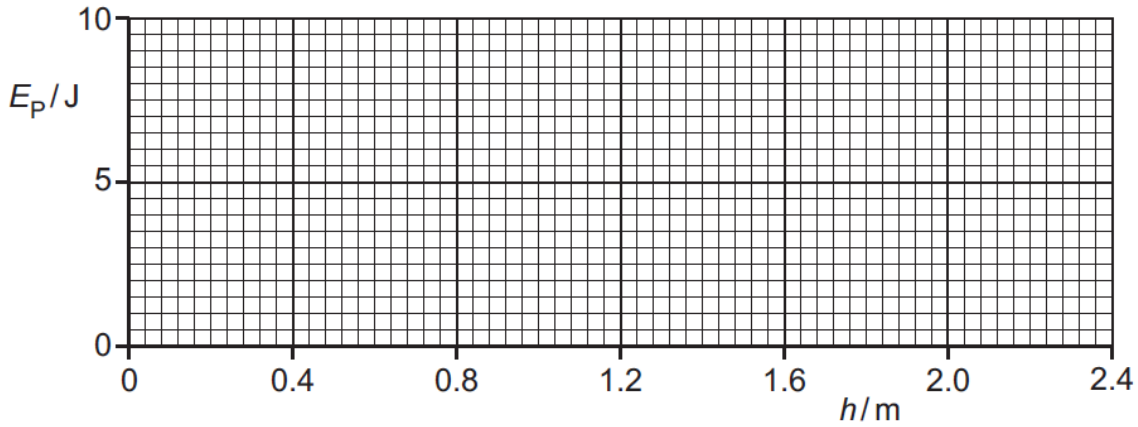


Fig. 5.4

[3]

[Total: 8]

Question 21

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

.....

.....

..... [2]

(b) A block is suspended by a spring. The block oscillates vertically with simple harmonic motion.

The velocity v of the block varies with time t according to

$$v = 0.56 \cos 16t$$

where v is in m s^{-1} and t is in s.

(i) Calculate the period of the oscillation.

period = ... s [1]

(ii) Determine the amplitude x_0 of the oscillation.

x_0 = ... m [2]

(iii) Use your answer in **(b)(ii)** to determine the equation for v in terms of the displacement x of the block, where v is in m s^{-1} and x is in m.

v = ... [1]

(iv) On Fig. 5.1, sketch the variation of v with x.

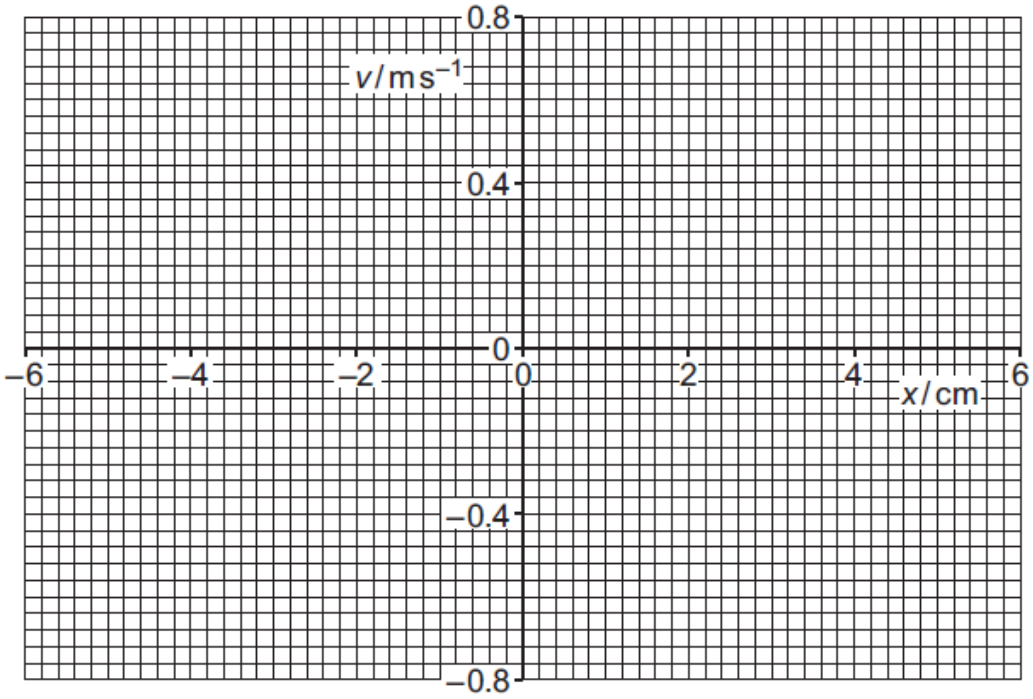


Fig. 5.1

[3]

[Total: 9]

Question 22

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

.....

.....

..... [2]

(b) A small sphere is suspended from a fixed point P by a string of negligible mass, as shown in Fig. 4.1.

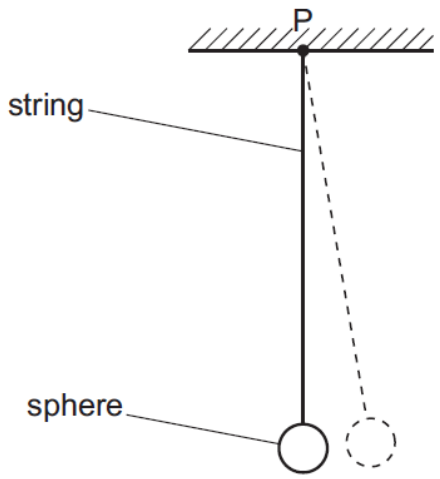


Fig. 4.1

The sphere is given a small horizontal displacement and is then released.

The variation with time of the horizontal velocity v of the sphere is shown in Fig. 4.2.

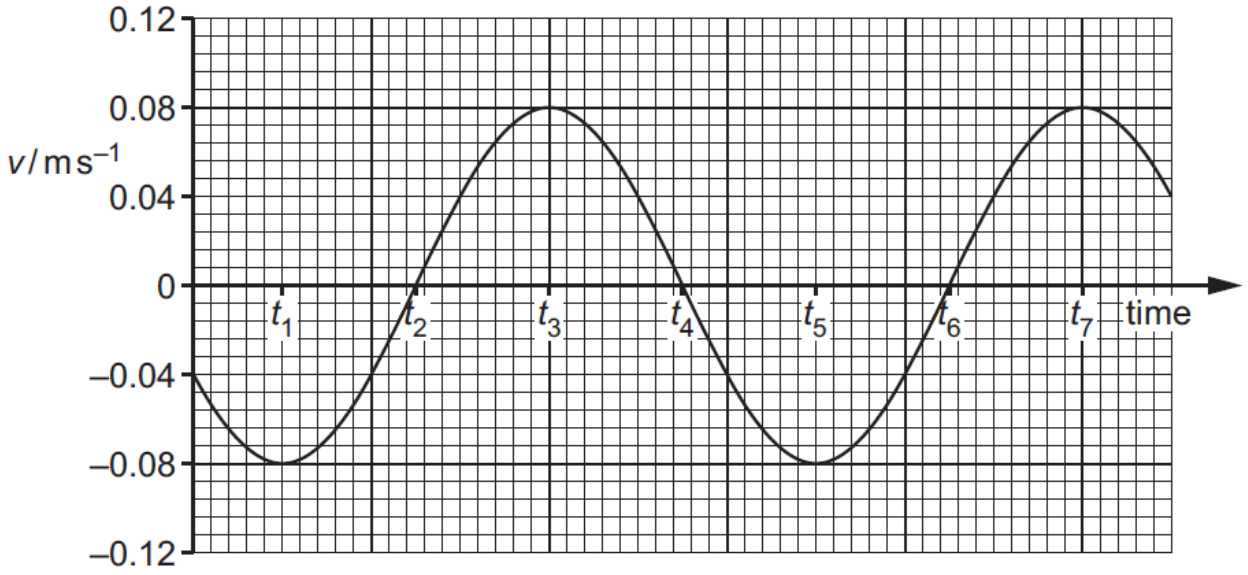


Fig. 4.2

(i) State two times at which the sphere is passing in the same direction through the equilibrium position.

time ..... and time ..... [1]

(ii) The time interval between t_1 and t_6 is 2.2 s.

Calculate the frequency of oscillation of the sphere.

frequency = ... Hz [2]

(c) The sphere in **(b)** is undergoing simple harmonic motion.

Use your answer in **(b)(ii)** and data from Fig. 4.2 to determine the maximum displacement of the sphere from its equilibrium position.

maximum displacement = ... m [3]

[Total: 8]

Question 23

A steel ball on the end of a thin string oscillates with small oscillations, as shown in Fig. 5.1.

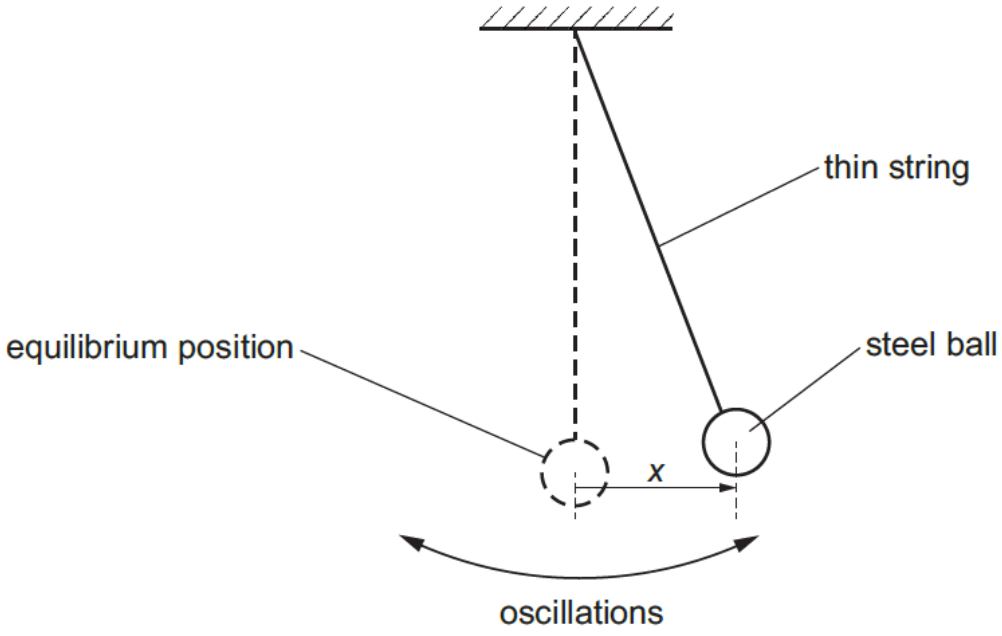


Fig. 5.1 (not to scale)

The displacement of the centre of the ball from its equilibrium position is x.

The displacement of the centre of the ball from its equilibrium position is x.

(a) Fig. 5.2 shows the variation with x of the acceleration a of the ball.

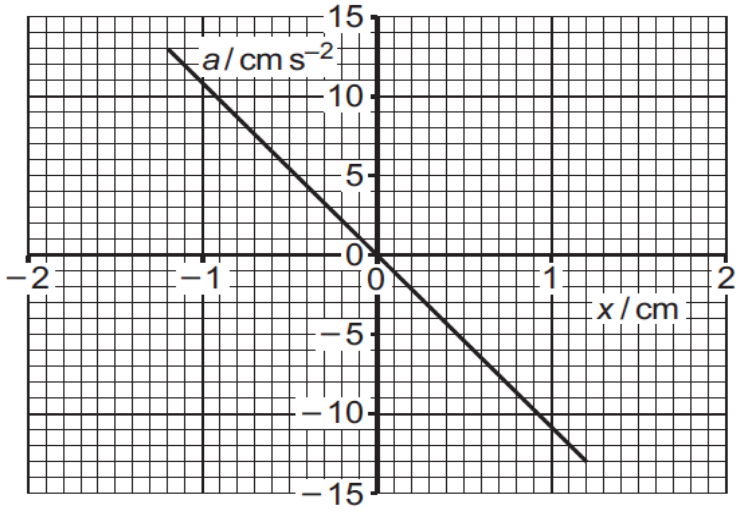


Fig. 5.2

(i) Explain how Fig. 5.2 shows that the oscillations of the ball are simple harmonic.

.....

.....

..... [2]

(ii) Determine the period T of the oscillations.

T = ... s [3]

(b) At time $t = 0$, when the displacement of the ball has its maximum value, the ball is immersed in a trough containing thick oil so that the ball is just below the surface of the oil. This results in the subsequent motion of the ball being heavily damped.

(i) State what is meant by damping.

.....

.....

..... [2]

(ii) On Fig. 5.3, sketch a possible variation of the displacement x of the ball with t between $t = 0$ and $t = 2T$.

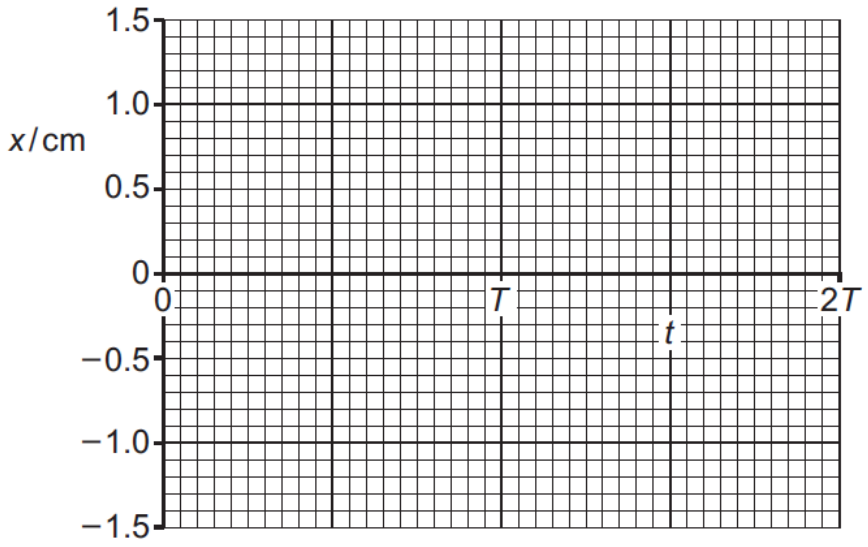


Fig. 5.3

[3]

[Total: 10]

Question 24

(a) State what is meant by the frequency of the oscillations of an oscillating object.

.....

..... [1]

(b) An object is oscillating.

Fig. 4.1 shows the variation of the acceleration a of the object with its displacement x from the equilibrium position.

Fig. 4.2 shows the variation of the kinetic energy E_K of the object with time t.

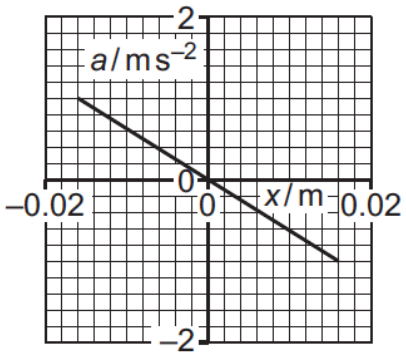


Fig. 4.1

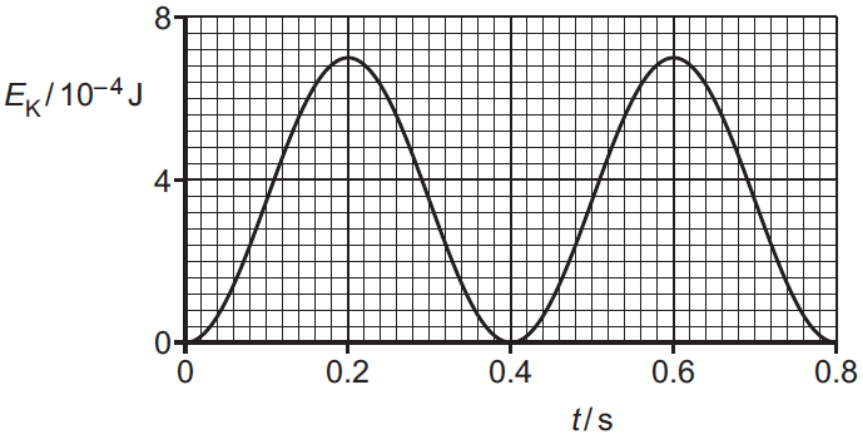


Fig. 4.2

(ii) Calculate the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [2]

(iii) Apart from the period, frequency and angular frequency of the oscillations, determine **three** other conclusions about the object and its oscillations that may be drawn from Fig. 4.1 and Fig. 4.2. The conclusions may be qualitative or quantitative. Use the space below for any working.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(iv) Describe the interchange between kinetic energy and potential energy during the oscillations. Numerical values are **not** required.

.....

.....

.....

.....

..... [3]

[Total: 10]

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