4 **(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.

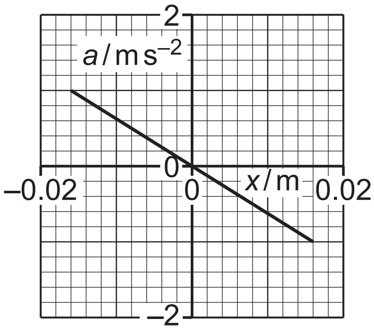

Fig. 4.1

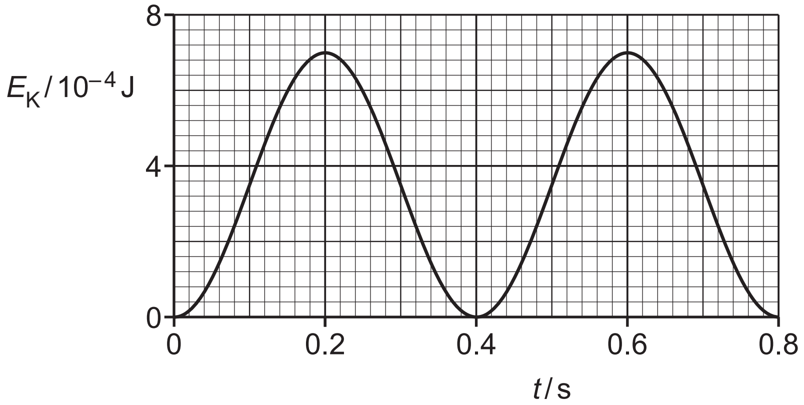

Fig. 4.2

(i) Explain how Fig. 4.2 shows that the period of the oscillations is 0.80 s.

....

....

.... [1]

(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]

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

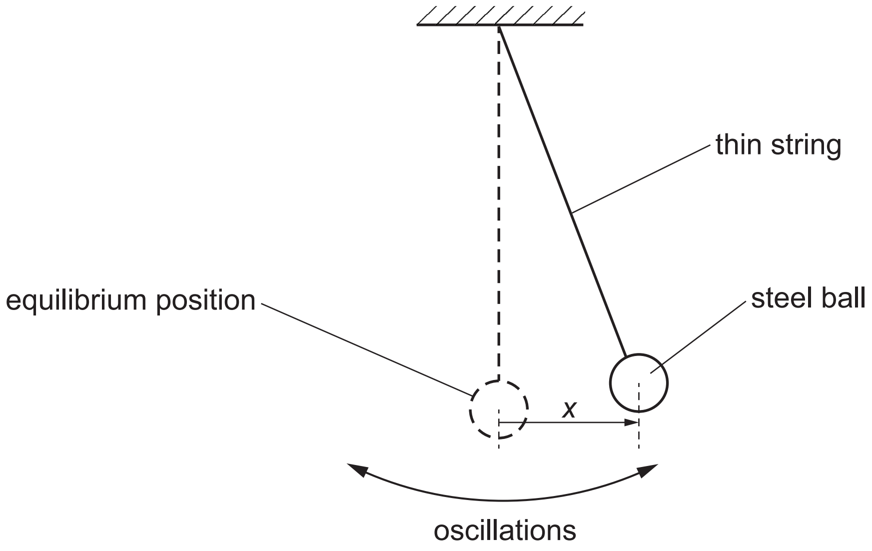

Fig. 5.1 (not to scale)

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

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

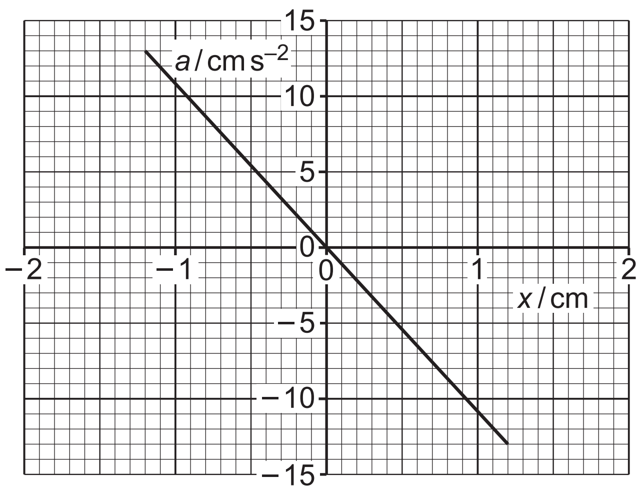

Fig. 5.2

(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.

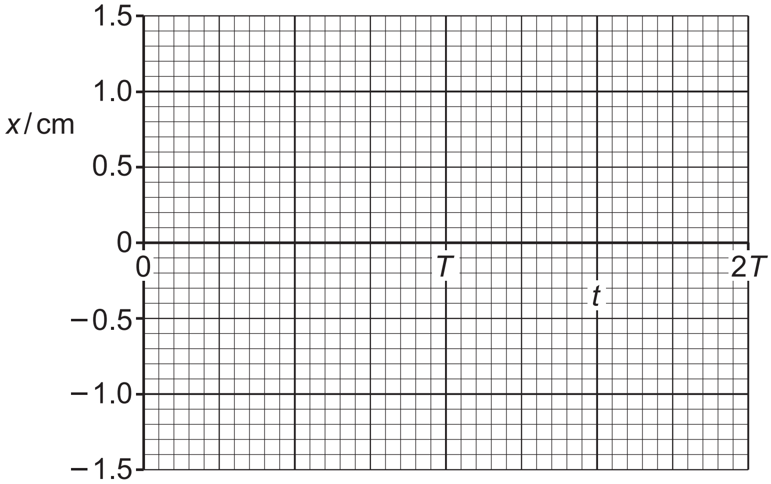

Fig. 5.3

[3]

1 **(a)** In terms of velocity and acceleration, describe uniform circular motion of an object.

....

....

.... [2]

(b) Fig. 1.1 shows the view from above of a polystyrene ball undergoing horizontal circular motion of radius R.

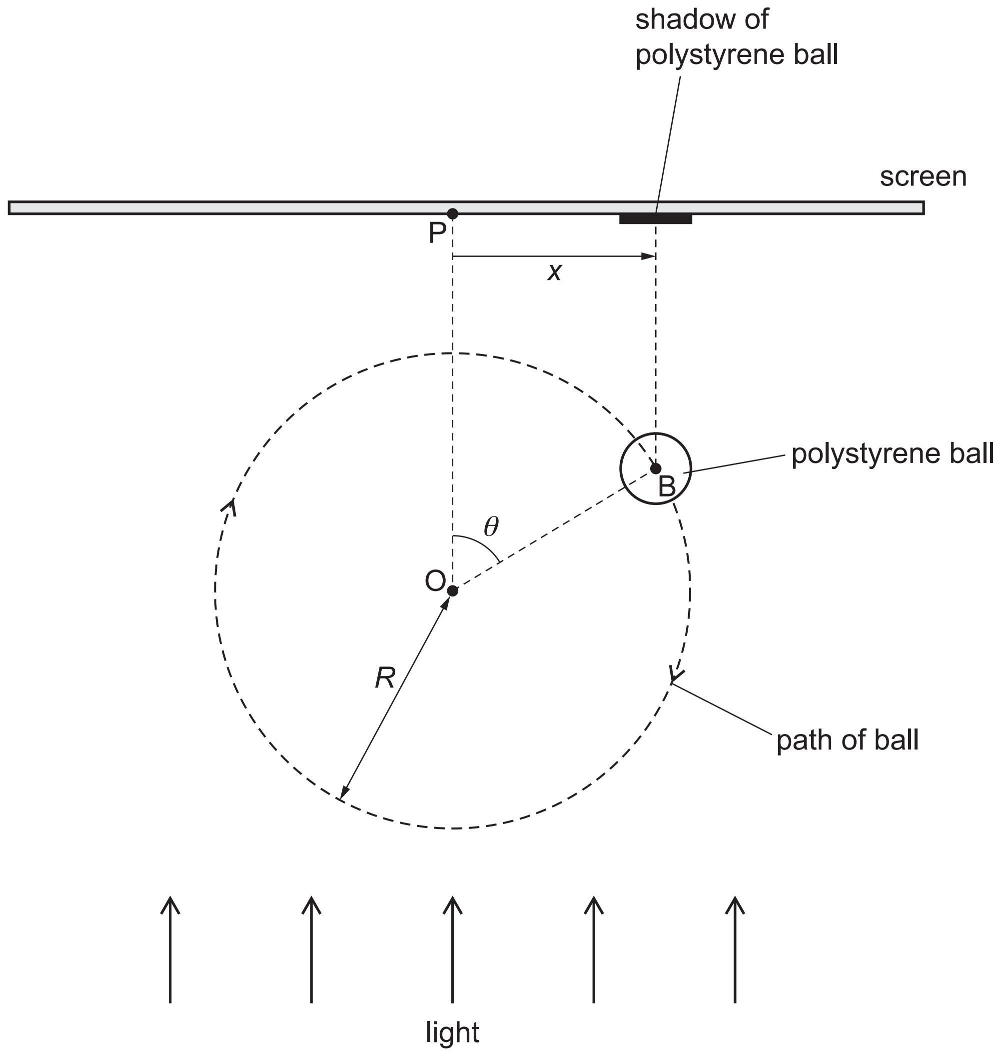

Fig. 1.1

The ball is illuminated by parallel light so that a shadow of the ball forms on a screen placed on the opposite side of the ball from the light source.

The line joining points O and P is perpendicular to the screen.

The angular speed of the circular motion is ω.

(i) State an expression, in terms of R and ω, for the speed v of the ball.

v = ... [1]

(ii) Determine an expression, in terms of v and ω, for the centripetal acceleration of the ball.

centripetal acceleration = ... [2]

(c) The ball in **(b)** is in the position shown in Fig. 1.1, such that line OB is at an angle θ to the line OP.

(i) Determine an expression, in terms of R and θ, for the displacement x of the shadow from P.

x = ... [1]

(ii) The value of θ is zero at time $t = 0$.

State an expression for θ in terms of ω and t.

θ = ... [1]

(iii) Use your answers in **(c)(i)** and **(c)(ii)** to show that x is given by

$$x = R\sin \omega t.$$

[1]

(iv) Explain, with reference to the equation in **(c)(iii)**, why the motion of the shadow of the ball on the screen may be modelled as simple harmonic.

....

.... [1]

(d) The circular motion of the ball in Fig. 1.1 has a diameter of 0.46 m and an angular speed of 1.9 rad s^{-1}.

For the simple harmonic motion of the shadow of the ball in Fig. 1.1, calculate:

(i) the amplitude

amplitude = ... m [1]

(ii) the period

period = ... s [2]

(iii) the maximum acceleration.

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

(e) On Fig. 1.1, draw, and label with the letter A, the position of the shadow on the screen when the shadow has its maximum positive acceleration. [1]

4 **(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.

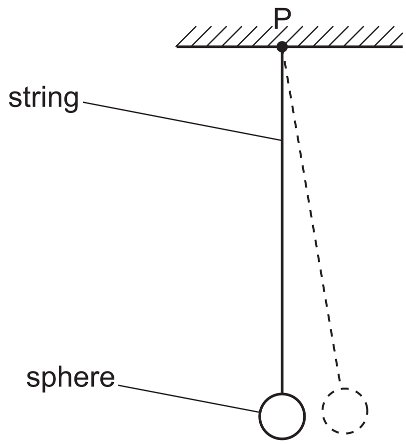

Fig. 4.1

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.

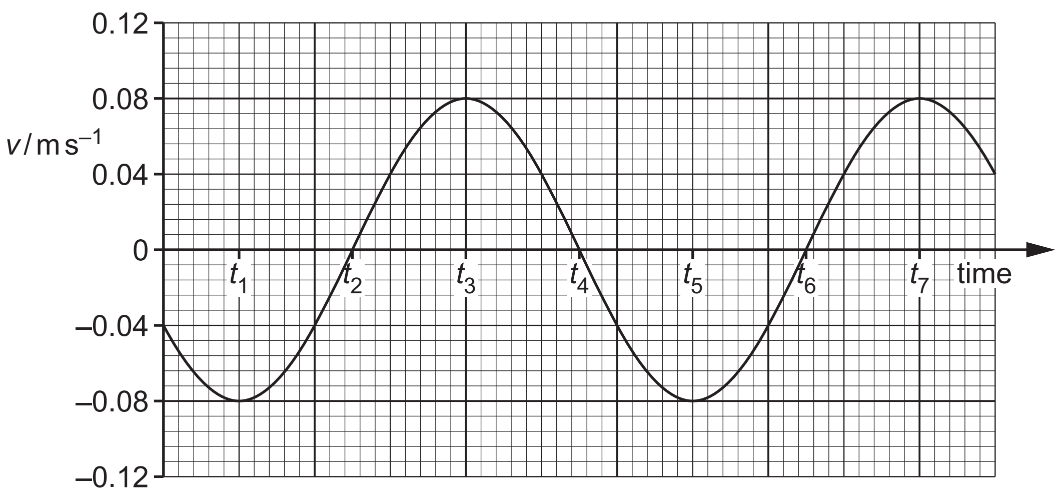

Fig. 4.2

(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]

7 A bar magnet is suspended from a spring. One pole of the magnet oscillates freely in a coil of wire, as shown in Fig. 7.1.

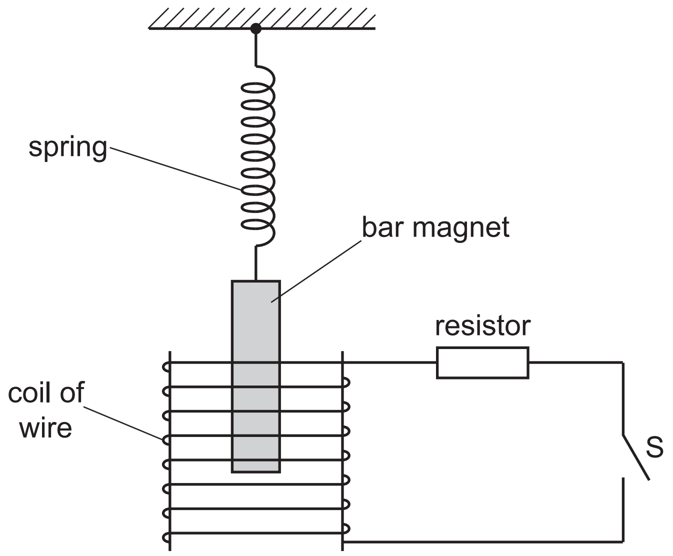

Fig. 7.1

The switch S is initially open.

(a) The switch S is now closed. As a result, the oscillations of the magnet are lightly damped.

(i) State what is meant by damping.

....

....

.... [2]

(ii) Describe what is observed to indicate that the damping is light.

....

.... [1]

(iii) By reference to electromagnetic induction and to conservation of energy, explain why the oscillations are damped.

....

....

....

.... [3]

(b) The procedure in **(a)** is repeated after replacing the resistor with one of greater resistance.

Suggest, with a reason, the effect of this change on the oscillations.

....

....

.... [2]

5 **(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.

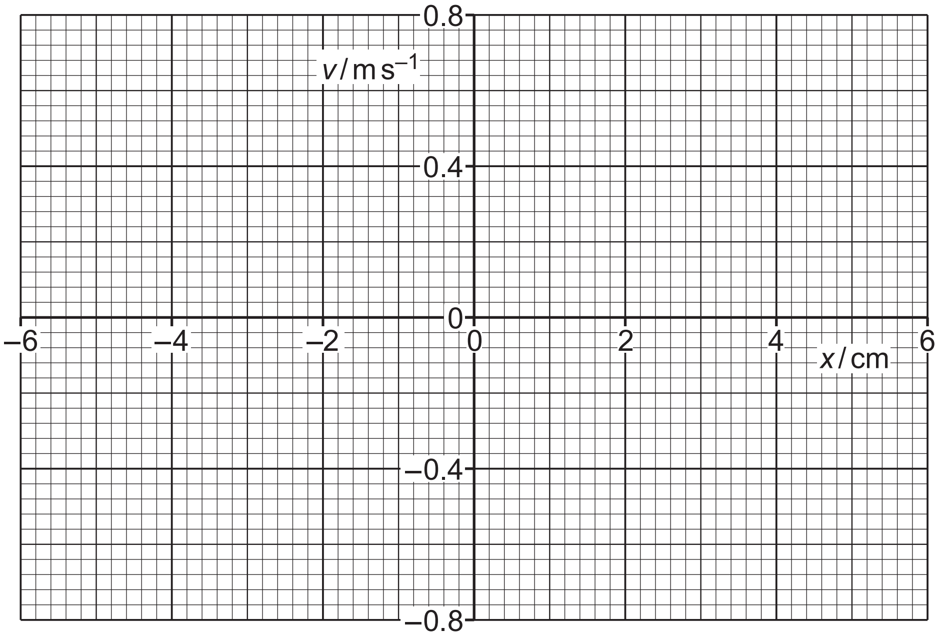

Fig. 5.1

[3]

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

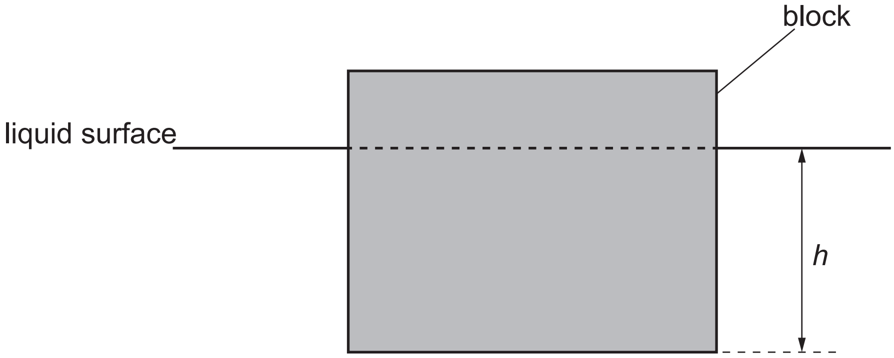

Fig. 5.1

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.

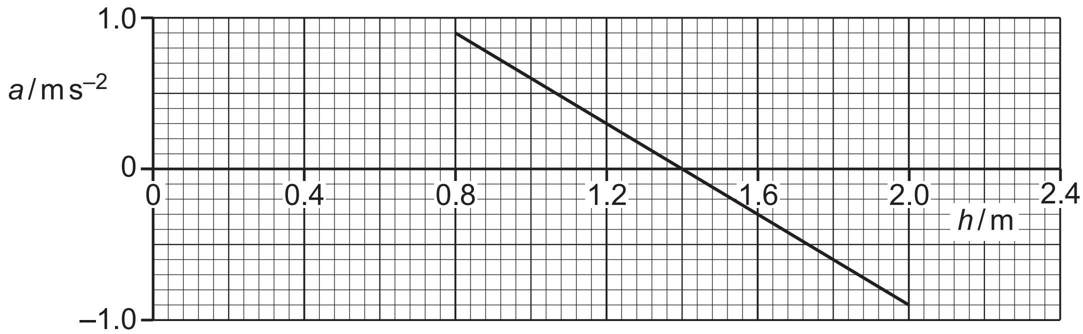

Fig. 5.2

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

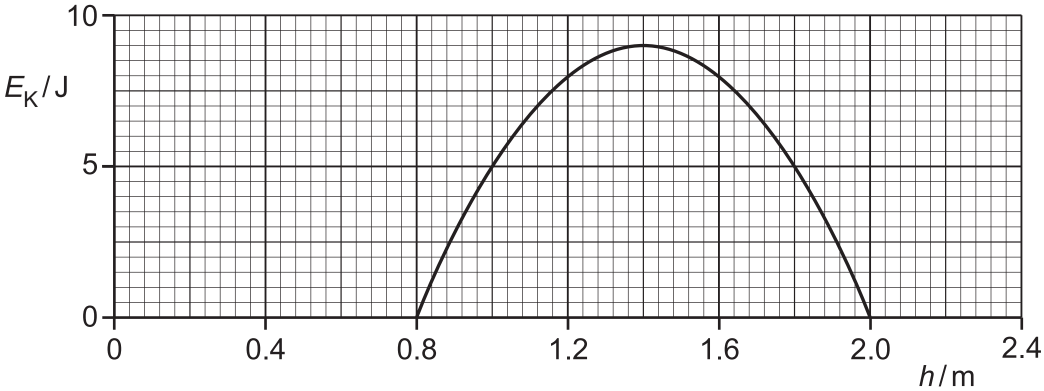

Fig. 5.3

(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.

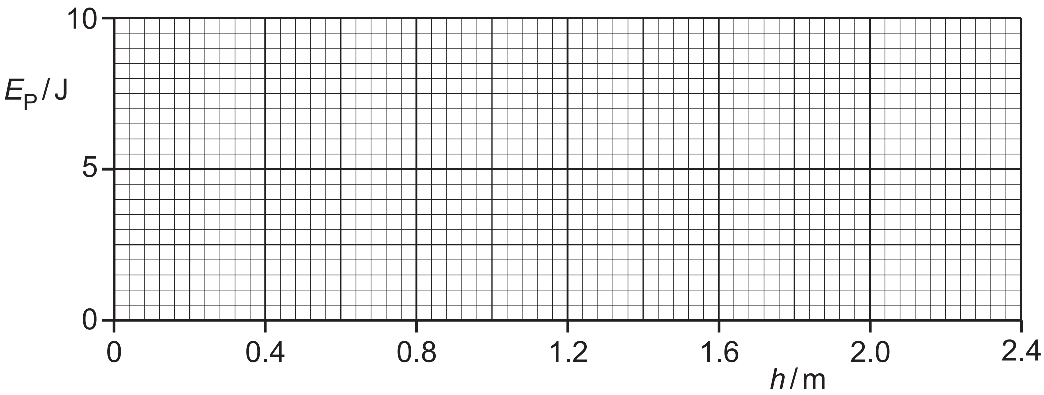

Fig. 5.4

[3]

4 A small crystal is made to vibrate with simple harmonic motion. The variation with time t of the displacement x of one surface of the crystal from its equilibrium position is shown in Fig. 4.1.

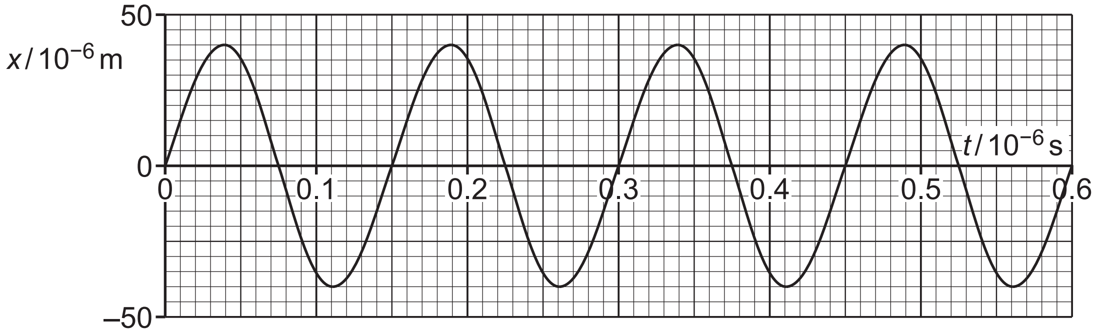

Fig. 4.1

(a) Show that the angular frequency of the vibration of the surface is $4.2 \times 10^{7}\,\text{rad}\,\text{s}^{-1}$.

[2]

(b) Determine the maximum acceleration a_0 of the vibration of the surface.

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

(c) The crystal may be modelled as a single mass of $2.4 \times 10^{-4}\,\text{kg}$ that vibrates as shown in Fig. 4.1.

Calculate the total energy E of the vibrations.

E = ... J [3]

(d) The crystal generates ultrasound waves that are used to obtain diagnostic information about internal structures.

(i) The crystal is made from piezoelectric material.

Explain how the crystal is made to vibrate.

....

....

....

.... [2]

(ii) A parallel beam of ultrasound waves is incident on a muscle-bone boundary. Data for muscle and bone are given in Table 4.1.

Table 4.1

material	density / $kg\,m^{-3}$	speed of sound / $m\,s^{-1}$
muscle	1100	1600
bone	1900	4100

Calculate the percentage of the intensity of the ultrasound beam that is transmitted at this boundary.

percentage transmitted = ... % [3]

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

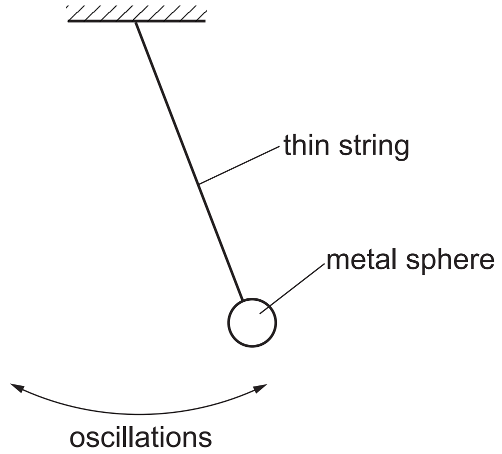

Fig. 5.1 (not to scale)

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.

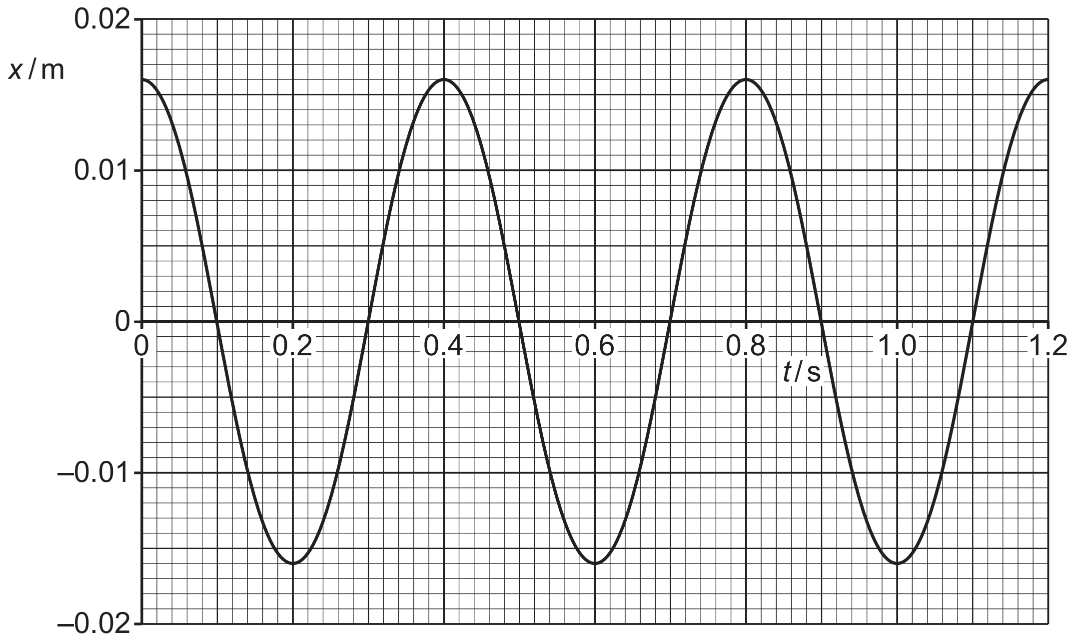

Fig. 5.2

(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.

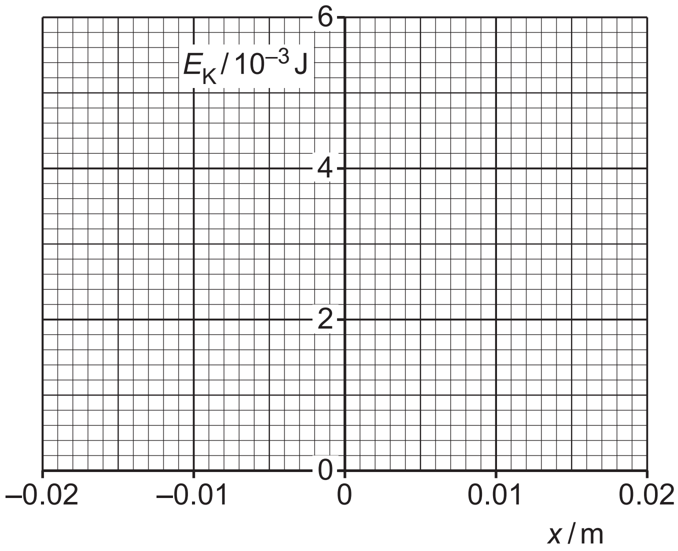

Fig. 5.3

[3]

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

....

....

.... [2]

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

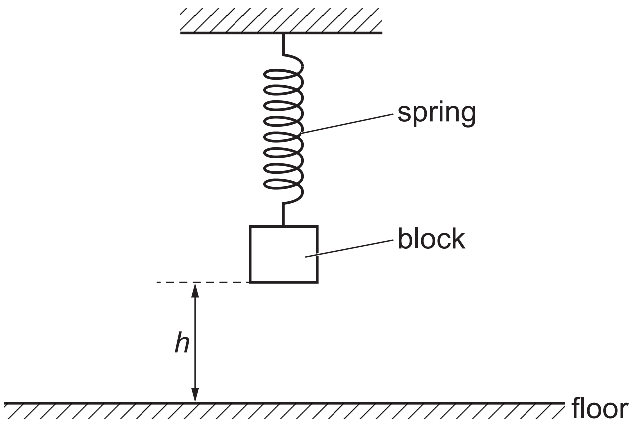

Fig. 4.1

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.

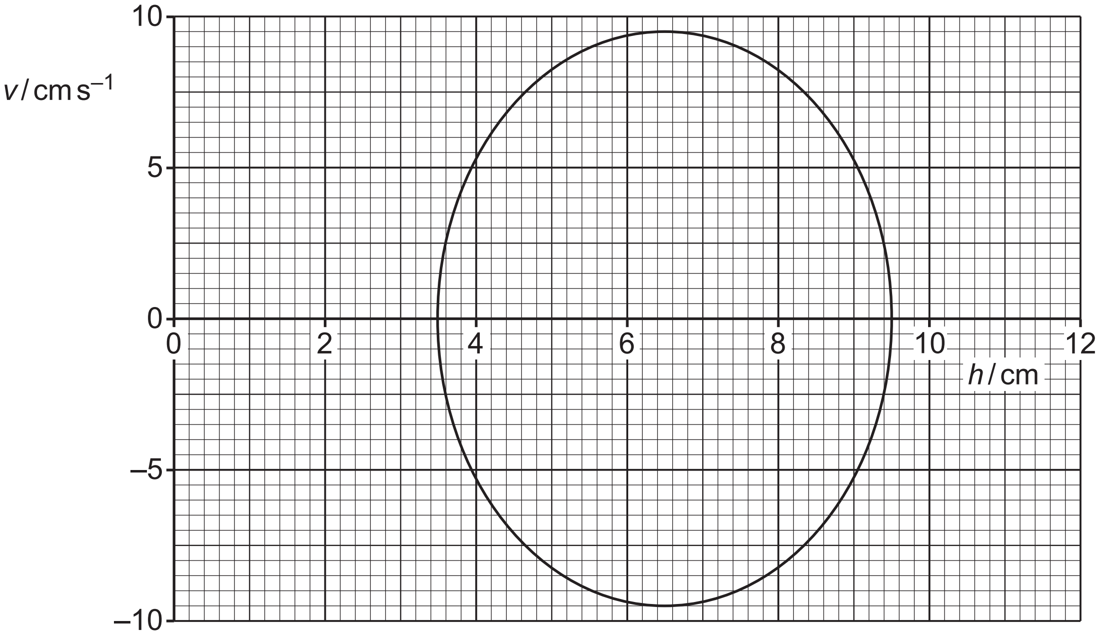

Fig. 4.2

(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.

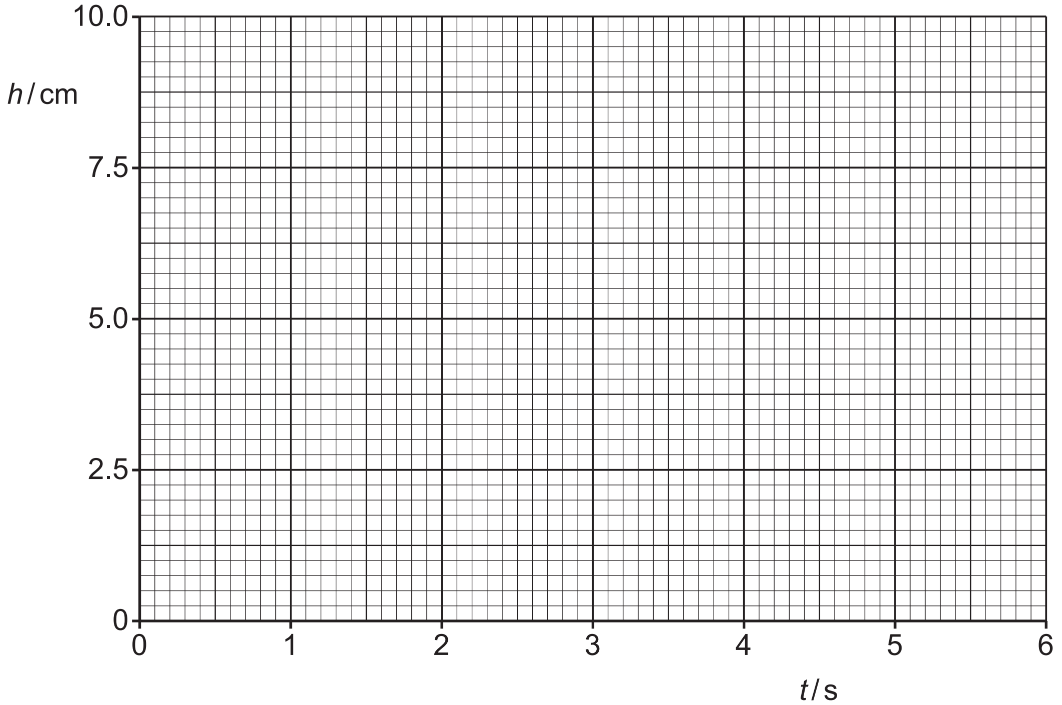

Fig. 4.3

[4]

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

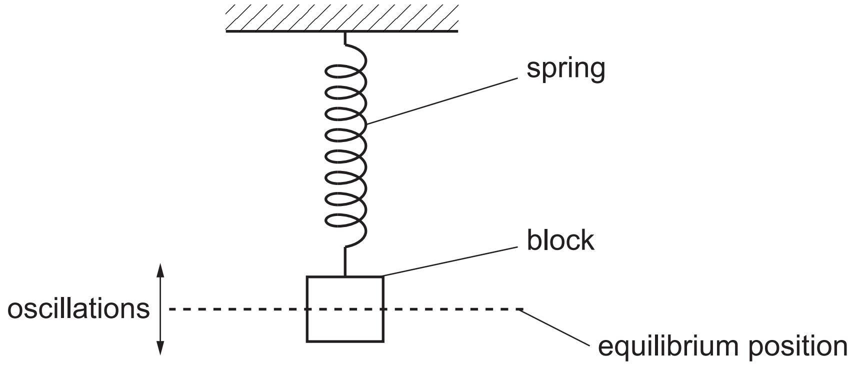

Fig. 4.1

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

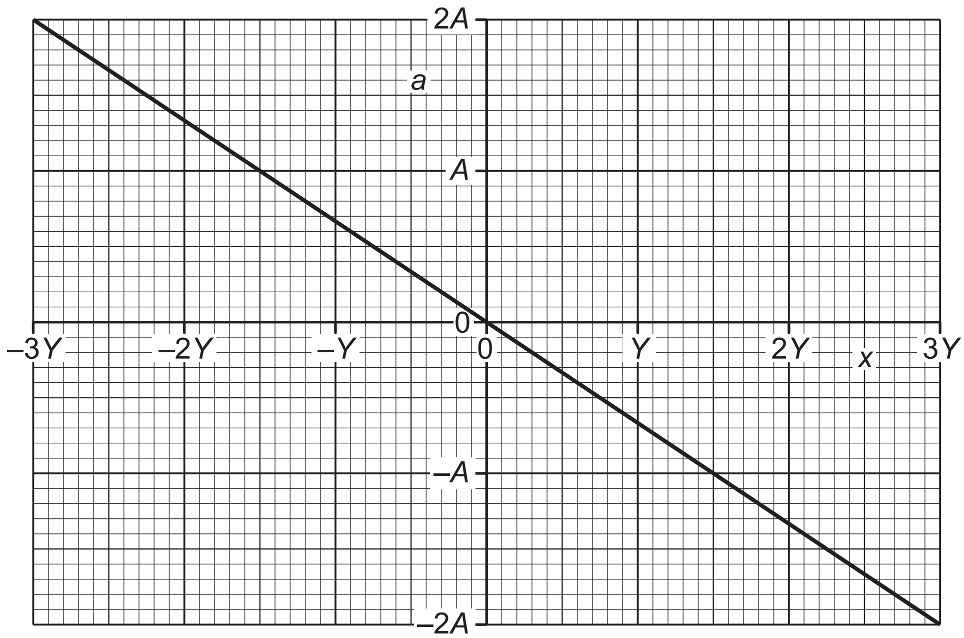

Fig. 4.2

The amplitude of the oscillations is $3Y$ 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]

4 **(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.

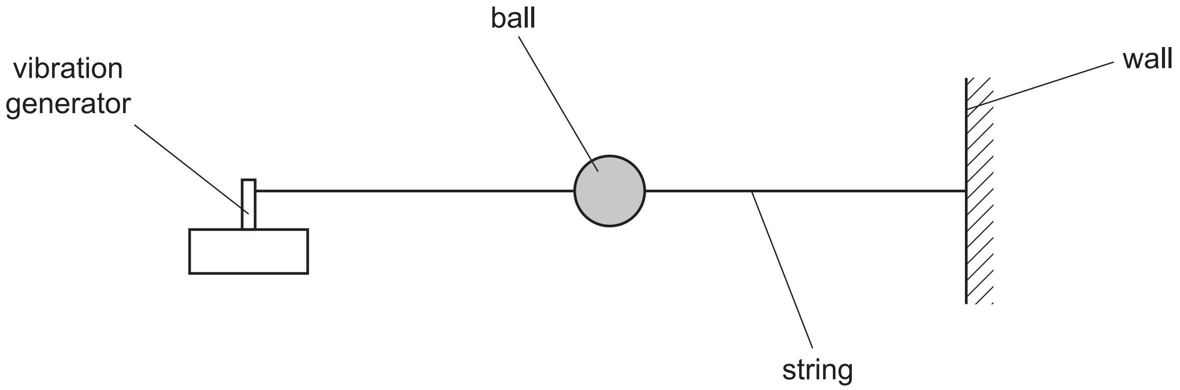

Fig. 4.1

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.

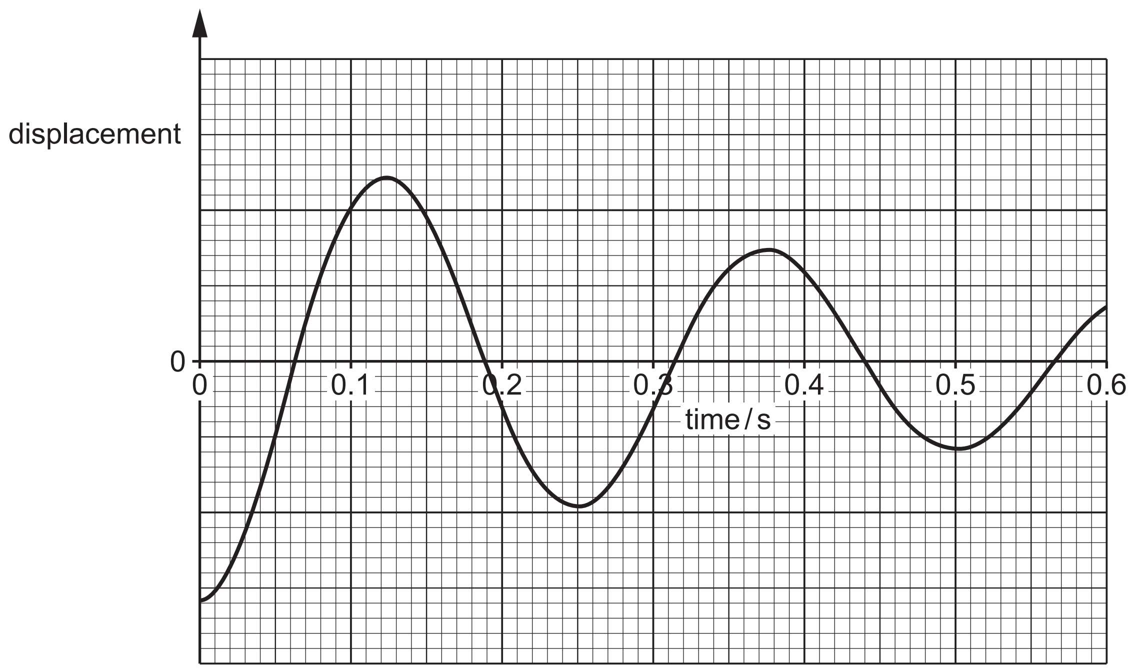

Fig. 4.2

(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]

(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.

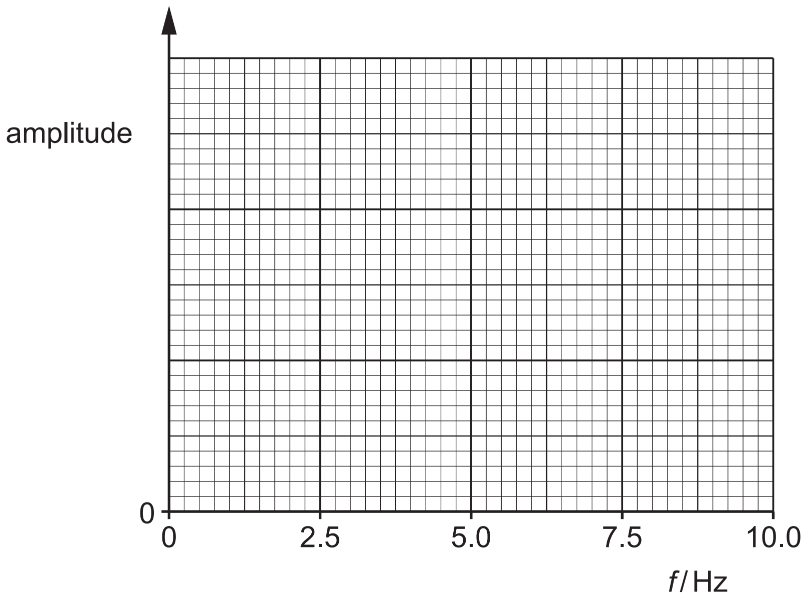

Fig. 4.3

[2]

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

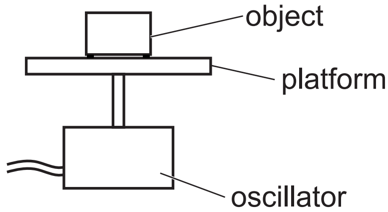

Fig. 3.1

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]

4 An electron in a metal rod moves randomly about a mean position. When an alternating voltage is applied to the ends of the rod, the mean position can be considered to oscillate with simple harmonic motion along the axis of the rod. Fig. 4.1 shows the variation with time t of the displacement x of the mean position from a fixed point on the axis of the rod.

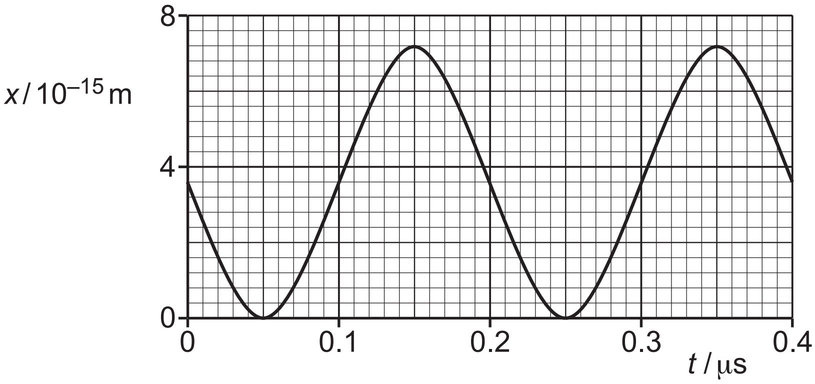

Fig. 4.1

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

amplitude = ... m [1]

(ii) Determine the angular frequency of the oscillations.

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

(iii) Use your answers in **(a)(i)** and **(a)(ii)** to show that the maximum drift speed v_0 of the electron is 1.1×10^{-7} m s^{-1}.

[2]

(b) The rod has a cross-sectional area of $4.3\,\text{cm}^2$ and contains a number density of conduction electrons (charge carriers) of $8.5 \times 10^{28}\,\text{m}^{-3}$.

All of the conduction electrons in the rod may be assumed to be oscillating in phase with, and with the same amplitude as, the oscillation shown in Fig. 4.1.

(i) Use the information in **(a)(iii)** to calculate the magnitude I_0 of the maximum current in the rod.

I_0 = ...A [2]

(ii) On Fig. 4.2, sketch the variation of the current I in the rod with time t between $t = 0$ and $t = 0.40\,\mu\text{s}$.

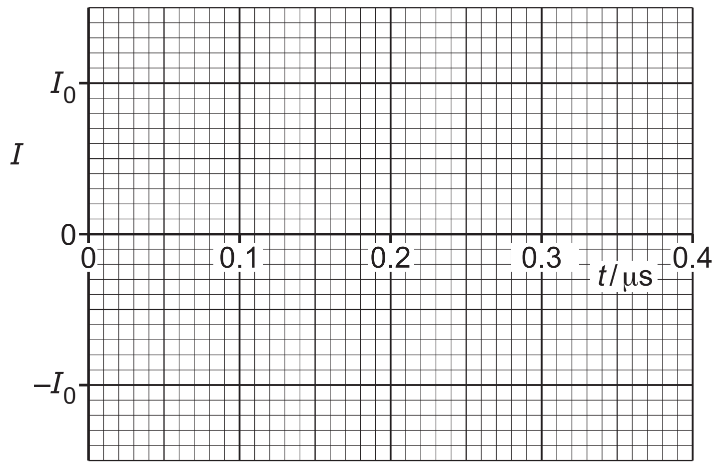

Fig. 4.2

[2]

(iii) Use your answers in **(a)(ii)** and **(b)(i)** to determine an expression for I in terms of t, where I is in A and t is in s.

I = ... [2]

(iv) Determine the root-mean-square (r.m.s.) current in the rod.

r.m.s. current = ...A [1]

4 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.

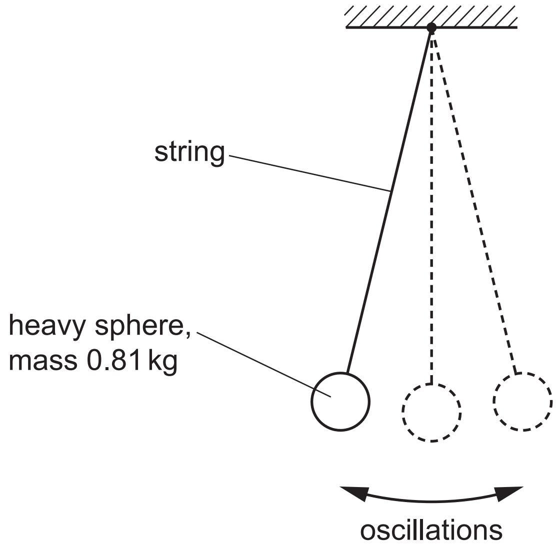

Fig. 4.1

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.

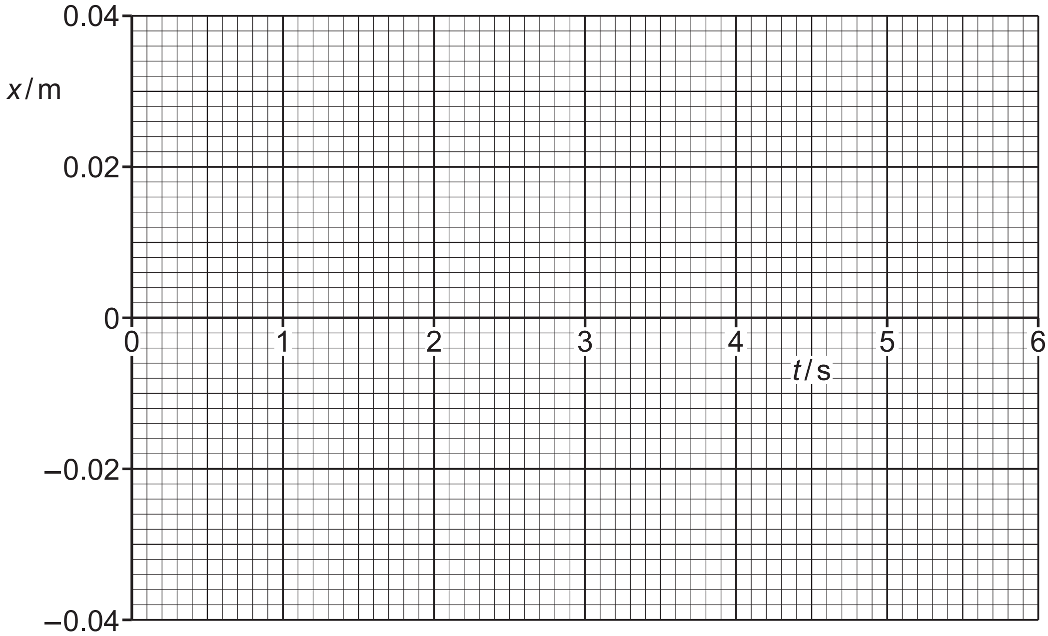

Fig. 4.2

[3]

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

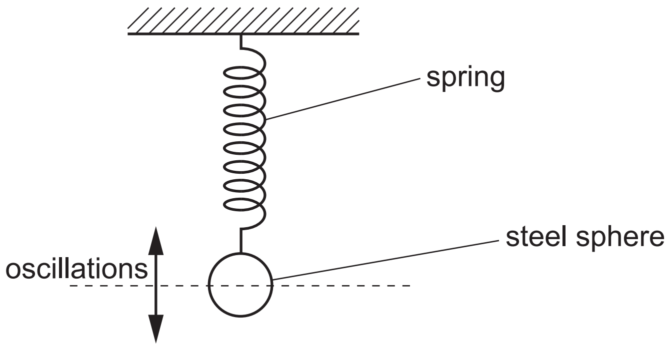

Fig. 4.1

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 $\text{cm}\,\text{s}^{-1}$ 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 = ... $\text{m}\,\text{s}^{-2}$ [2]

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

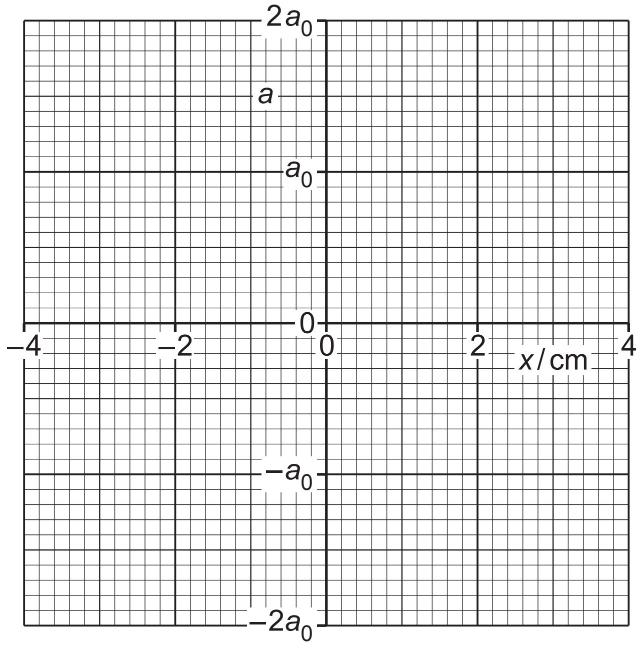

Fig. 4.2

[3]

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

....

....

....

....

.... [3]

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

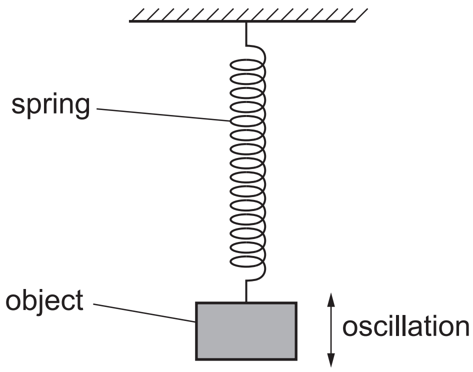

Fig. 3.1

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.

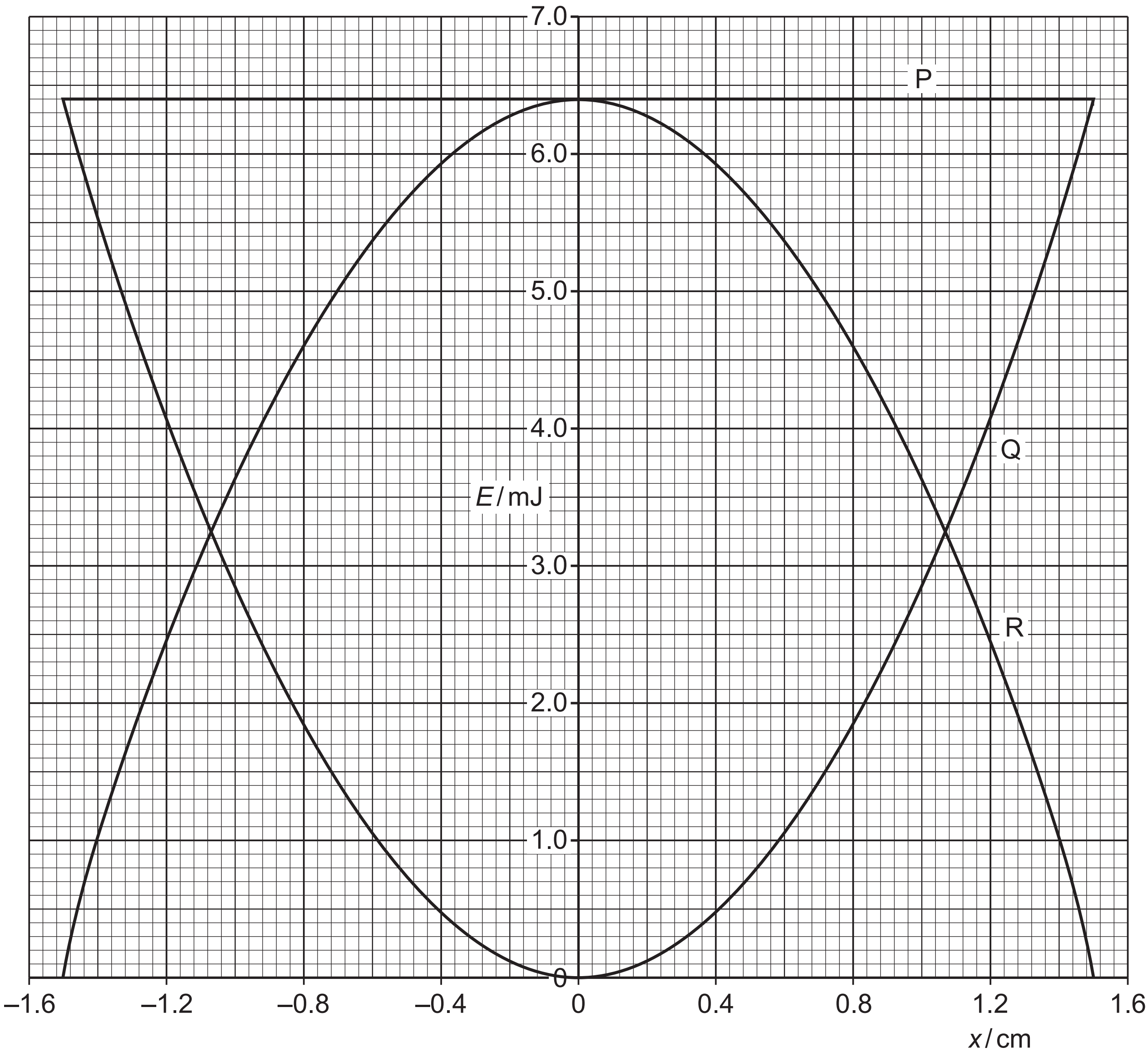

Fig. 3.2

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]

4 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.

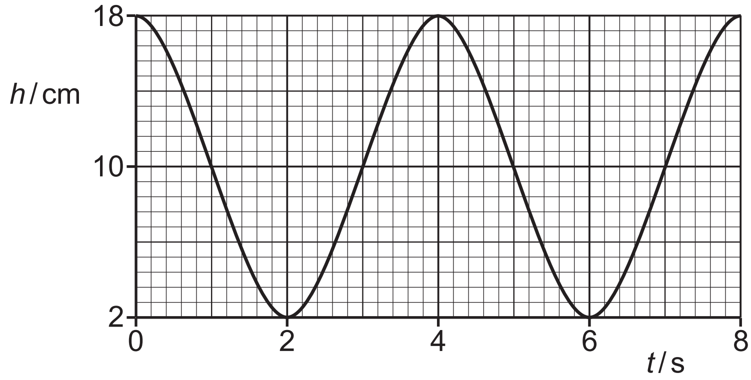

Fig. 4.1

(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 rad 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.

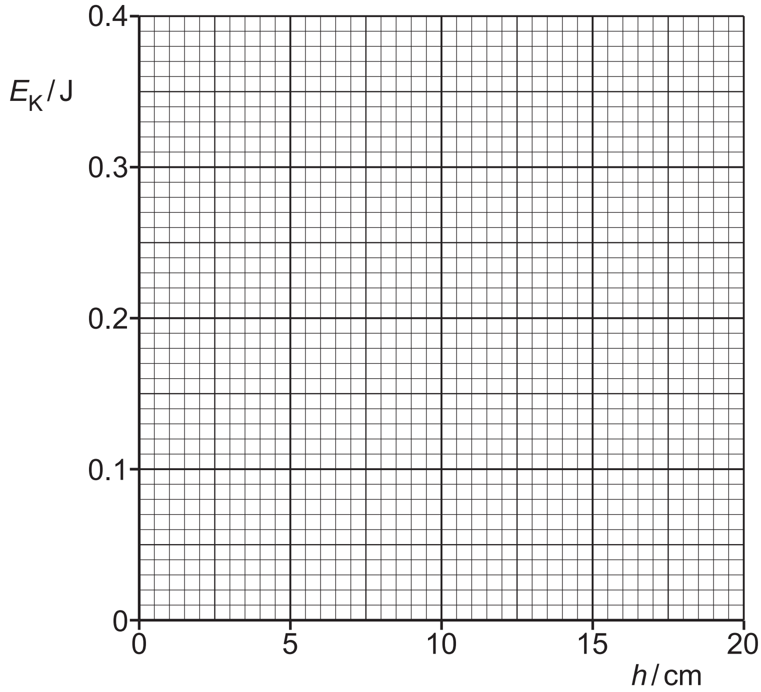

Fig. 4.2

[4]

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

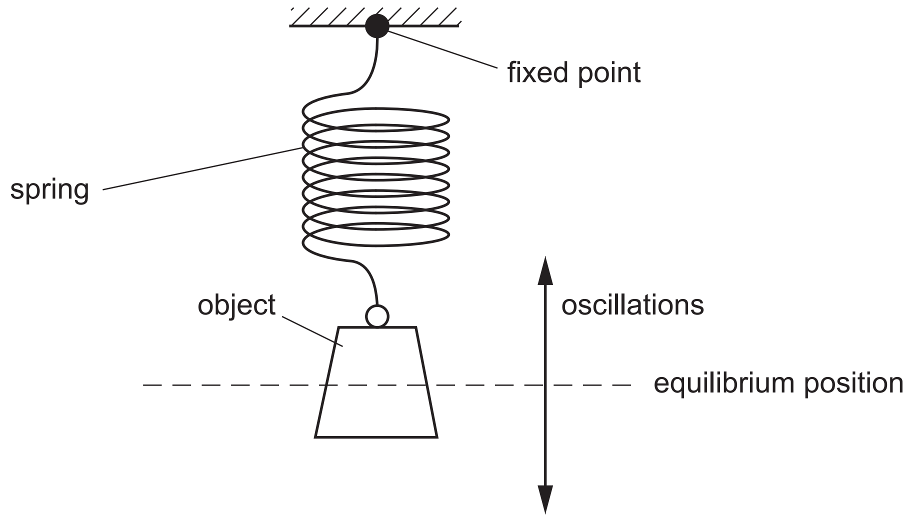

Fig. 3.1

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.

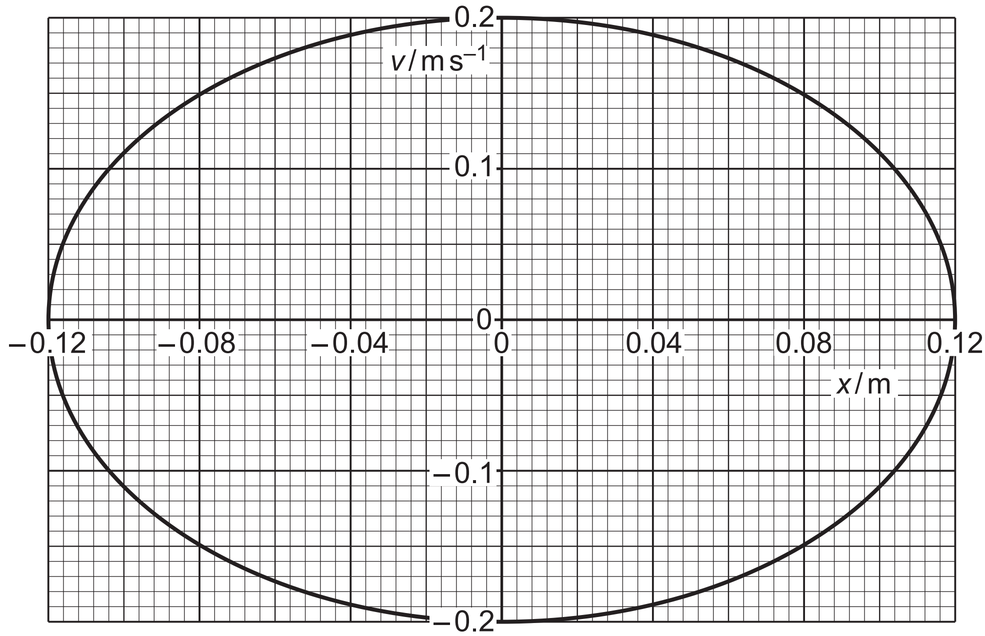

Fig. 3.2

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

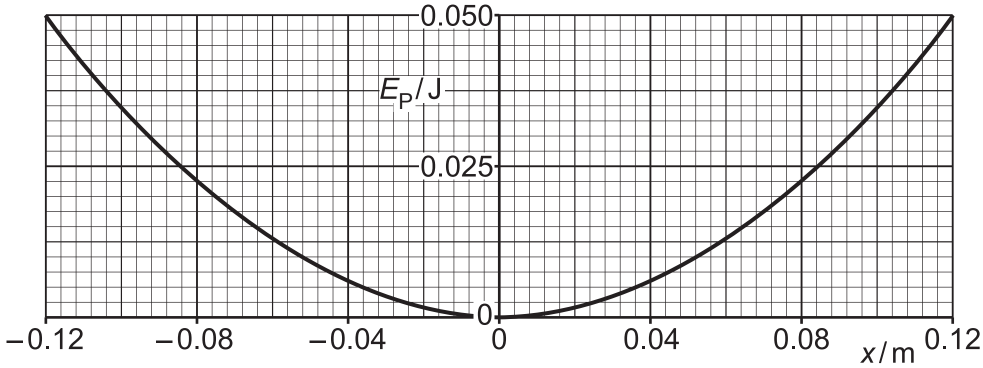

Fig. 3.3

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 rad 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]