CAMBRIDGE INTERNATIONAL AS & A LEVEL PHYSICS · 9702

PHYSICS



EXAM QUESTION PACK

17 OSCILLATIONS

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Chapter 5

Oscillations

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83. 9702_m21_qp_42 Q: 4

(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.

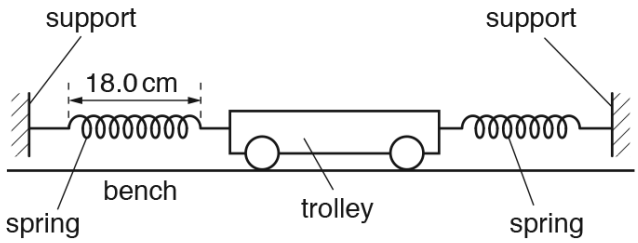


Fig. 4.1

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]

84. 9702_s21_qp_43 Q: 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.

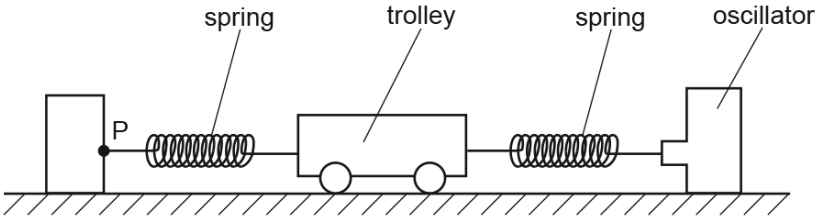


Fig. 3.1

The springs, each having spring constant *k* of 130 N 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]

85. 9702_s20_qp_41 Q: 3

The piston in the cylinder of a car engine moves in the cylinder with simple harmonic motion. The piston moves between a position of maximum height in the cylinder to a position of minimum height, as illustrated in Fig. 3.1.

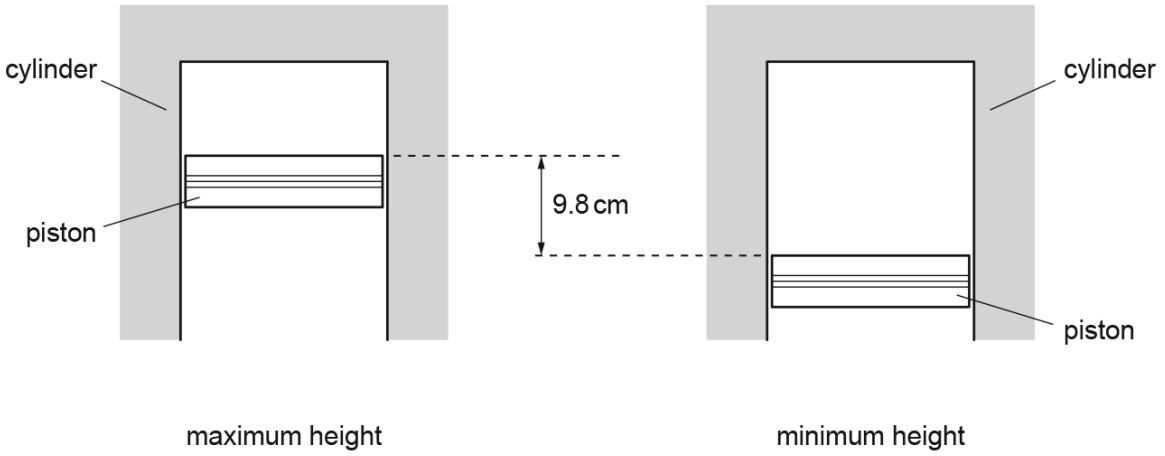


Fig. 3.1

The distance moved by the piston between the positions shown in Fig. 3.1 is 9.8 cm.

The mass of the piston is 640 g.

At one particular speed of the engine, the piston completes 2700 oscillations in 1.0 minute.

(a) For the oscillations of the piston in the cylinder, determine:

(i) the amplitude

amplitude = ... cm [1]

(ii) the frequency

frequency = ... Hz [1]

(iii) the maximum speed

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

(iv) the speed when the top of the piston is 2.3 cm below its maximum height.

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

(b) The acceleration of the piston varies.

Determine the resultant force on the piston that gives rise to its maximum acceleration.

force = ... N [3]

[Total: 9]

86. 9702_s20_qp_43 Q: 3

The piston in the cylinder of a car engine moves in the cylinder with simple harmonic motion. The piston moves between a position of maximum height in the cylinder to a position of minimum height, as illustrated in Fig. 3.1.

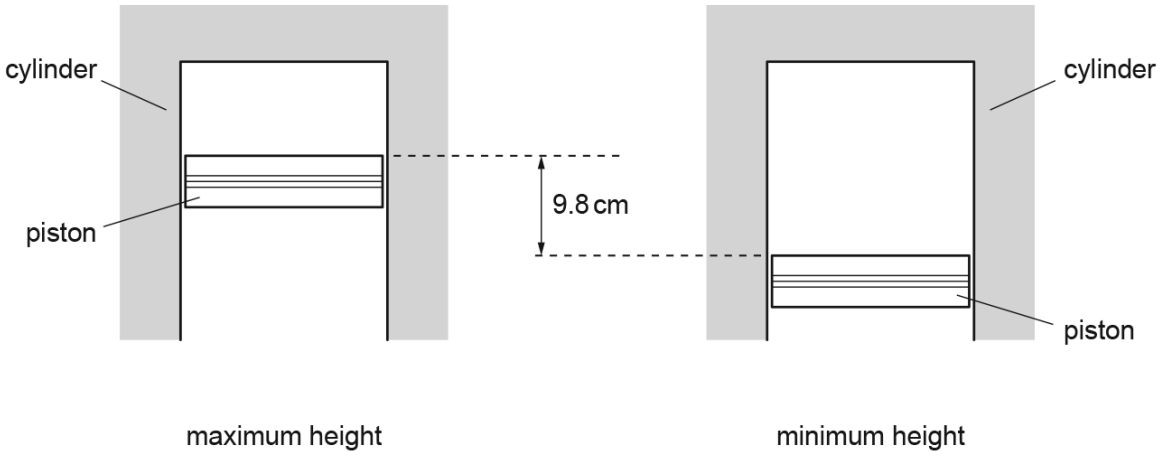


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The mass of the piston is 640 g.

At one particular speed of the engine, the piston completes 2700 oscillations in 1.0 minute.

(a) For the oscillations of the piston in the cylinder, determine:

(i) the amplitude

amplitude = ... cm [1]

(ii) the frequency

frequency = ... Hz [1]

(iii) the maximum speed

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

(iv) the speed when the top of the piston is 2.3 cm below its maximum height.

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

(b) The acceleration of the piston varies.

Determine the resultant force on the piston that gives rise to its maximum acceleration.

force = ... N [3]

[Total: 9]

87. 9702_m19_qp_42 Q: 3

A cylindrical tube, sealed at one end, has cross-sectional area A and contains some sand. The total mass of the tube and the sand is M.

The tube floats upright in a liquid of density ρ, as illustrated in Fig. 3.1.

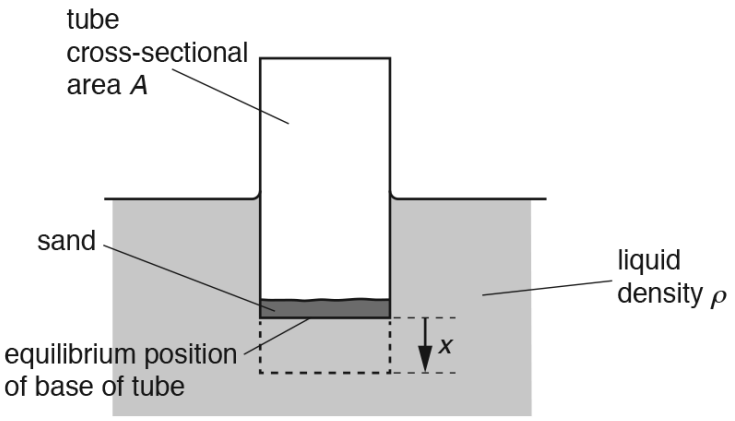


Fig. 3.1

The tube is pushed a short distance into the liquid and then released.

(a) (i) State the two forces that act on the tube immediately after its release.

.....

..... [1]

(ii) State and explain the direction of the resultant force acting on the tube immediately after its release.

.....

.....

..... [2]

(b) The acceleration a of the tube is given by the expression

$$a = -\left(\frac{A\rho g}{M}\right)x$$

where x is the vertical displacement of the tube from its equilibrium position.

Use the expression to explain why the tube undergoes simple harmonic oscillations in the liquid.

.....

.....

..... [2]

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(c) For a tube having cross-sectional area A of 4.5 cm^2 and a total mass M of 0.17 kg, the period of oscillation of the tube is 1.3 s.

(i) Determine the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [2]

(ii) Use your answer in **(i)** and the expression in **(b)** to determine the density ρ of the liquid in which the tube is floating.

ρ = ... kg m^{-3} [3]

[Total: 10]

88. 9702_w19_qp_41 Q: 4

A mass is suspended vertically from a fixed point by means of a spring, as illustrated in Fig. 4.1.

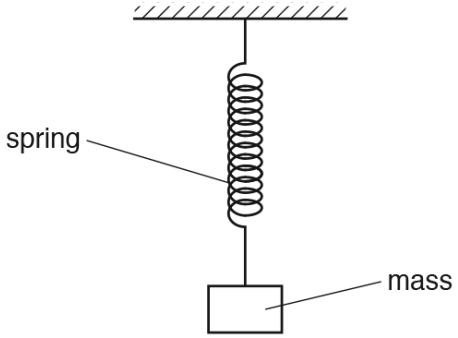


Fig. 4.1

The mass is oscillating vertically. The variation with displacement x of the acceleration a of the mass is shown in Fig. 4.2.

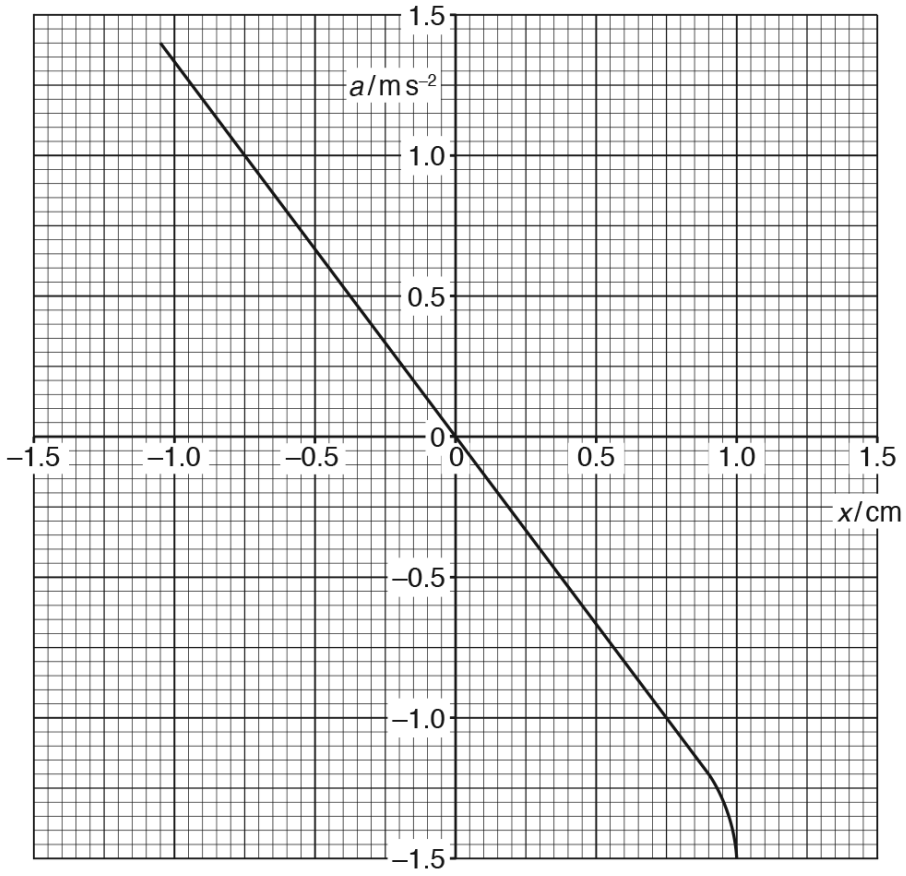


Fig. 4.2

(a) (i) State what is meant by the *displacement* of the mass on the spring.

.....

..... [1]

(ii) Suggest how Fig. 4.2 shows that the mass is not performing simple harmonic motion.

.....

..... [1]

(b) (i) The amplitude of oscillation of the mass may be changed.

State the maximum amplitude x_0 for which the oscillations are simple harmonic.

x_0 = ... cm [1]

(ii) For the simple harmonic oscillations of the mass, use Fig. 4.2 to determine the frequency of the oscillations.

frequency = ... Hz [3]

(c) The maximum speed of the mass when oscillating with simple harmonic motion of amplitude x_0 is v_0.

On Fig. 4.3, show the variation with displacement x of the velocity v of the mass for displacements from $+x_0$ to $-x_0$.

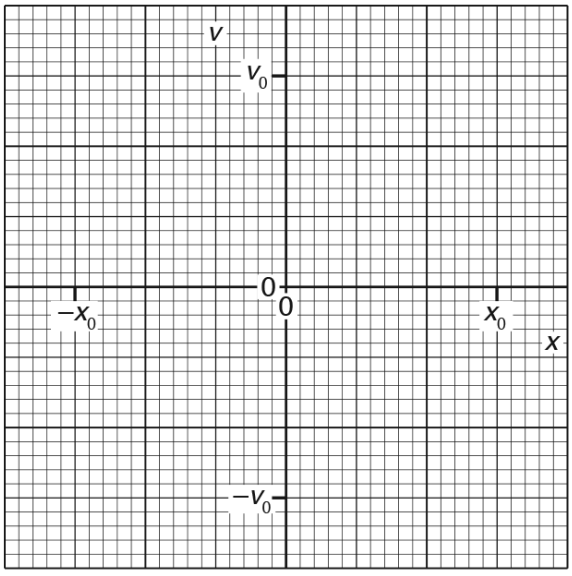


Fig. 4.3

[2]

[Total: 8]

89. 9702_w19_qp_43 Q: 4

A mass is suspended vertically from a fixed point by means of a spring, as illustrated in Fig. 4.1.

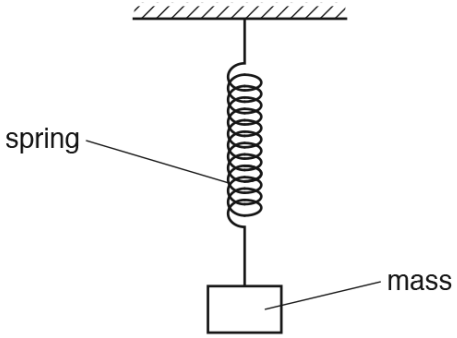


Fig. 4.1

The mass is oscillating vertically. The variation with displacement x of the acceleration a of the mass is shown in Fig. 4.2.

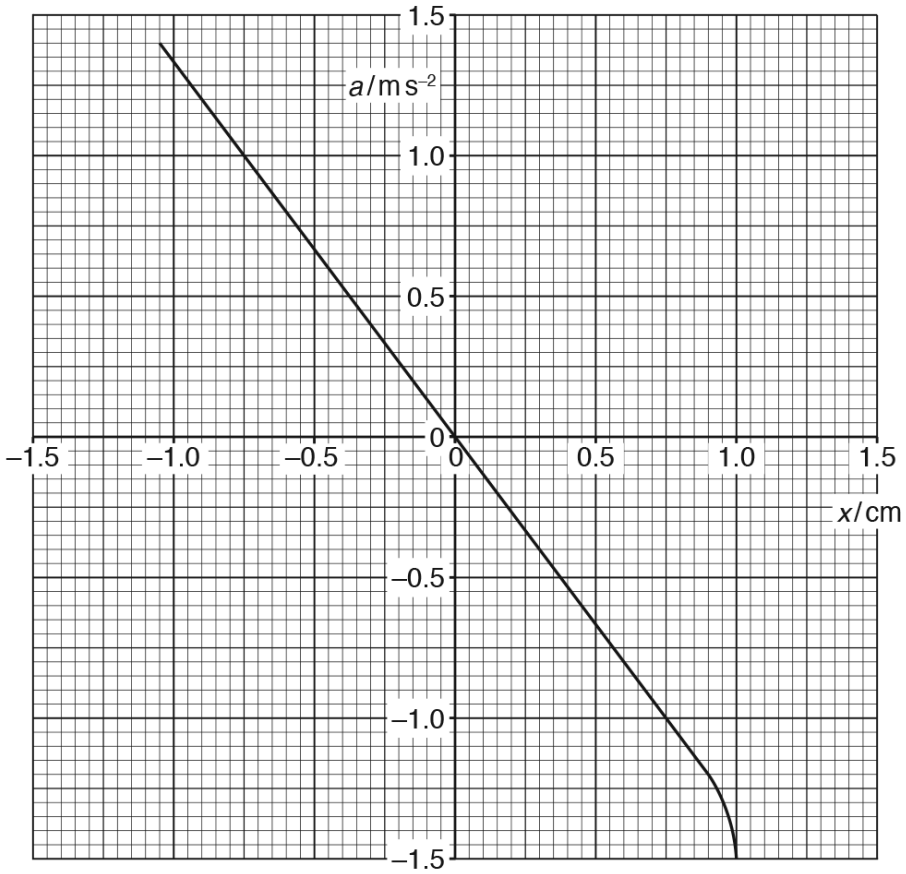


Fig. 4.2

(a) (i) State what is meant by the *displacement* of the mass on the spring.

.....

..... [1]

(ii) Suggest how Fig. 4.2 shows that the mass is not performing simple harmonic motion.

.....

..... [1]

(b) (i) The amplitude of oscillation of the mass may be changed.

State the maximum amplitude x_0 for which the oscillations are simple harmonic.

x_0 = ... cm [1]

(ii) For the simple harmonic oscillations of the mass, use Fig. 4.2 to determine the frequency of the oscillations.

frequency = ... Hz [3]

(c) The maximum speed of the mass when oscillating with simple harmonic motion of amplitude x_0 is v_0.

On Fig. 4.3, show the variation with displacement x of the velocity v of the mass for displacements from $+x_0$ to $-x_0$.

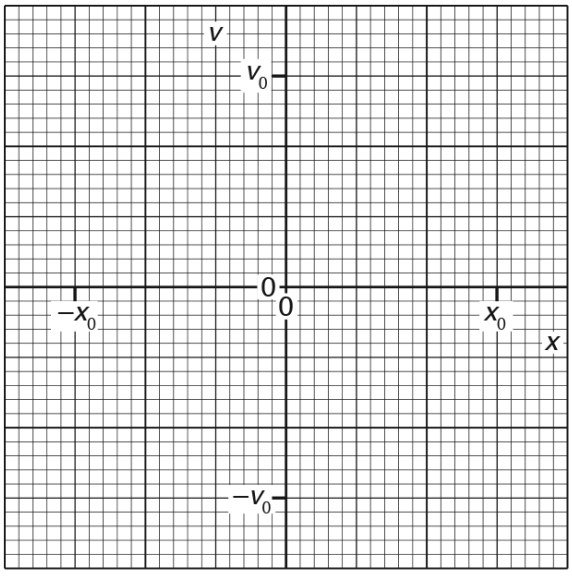


Fig. 4.3

[2]

[Total: 8]

90. 9702_s18_qp_41 Q: 2

A metal plate is made to vibrate vertically by means of an oscillator, as shown in Fig. 2.1.

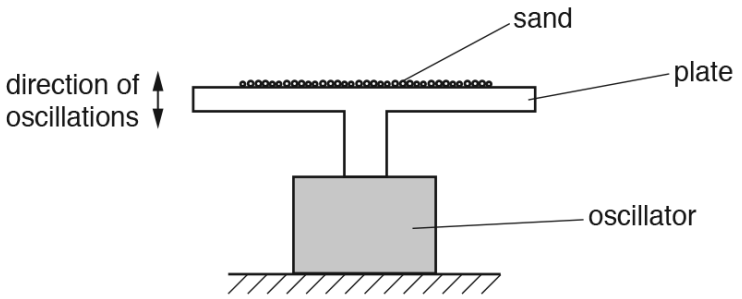


Fig. 2.1

Some sand is sprinkled on to the plate.

The variation with displacement y of the acceleration a of the sand on the plate is shown in Fig. 2.2.

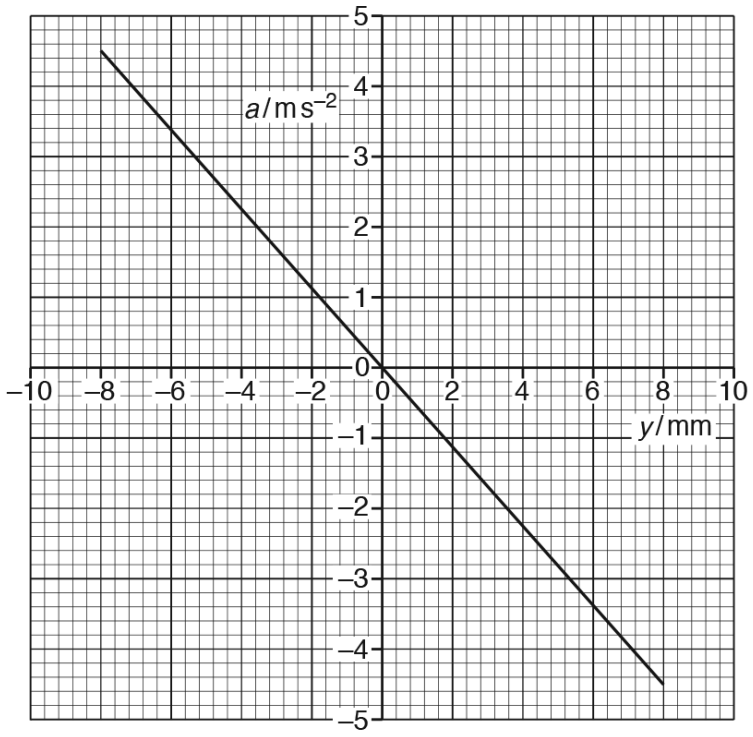


Fig. 2.2

(a) (i) Use Fig. 2.2 to show how it can be deduced that the sand is undergoing simple harmonic motion.

.....

.....

.....

.....[2]

(ii) Calculate the frequency of oscillation of the sand.

frequency = ... Hz [2]

(b) The amplitude of oscillation of the plate is gradually increased beyond 8 mm. The frequency is constant.

At one amplitude, the sand is seen to lose contact with the plate.

For the plate when the sand first loses contact with the plate,

(i) state the position of the plate,

.....[1]

(ii) calculate the amplitude of oscillation.

amplitude = ... mm [3]

[Total: 8]

91. 9702_s18_qp_43 Q: 2

A metal plate is made to vibrate vertically by means of an oscillator, as shown in Fig. 2.1.

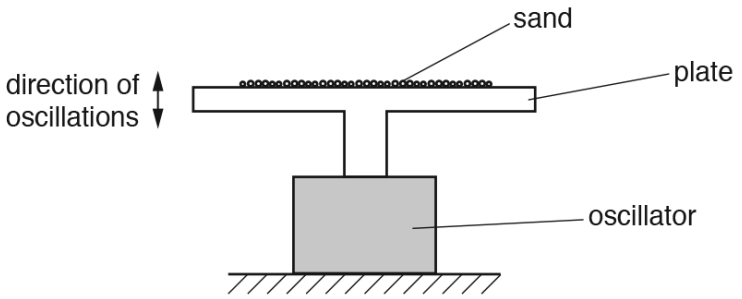


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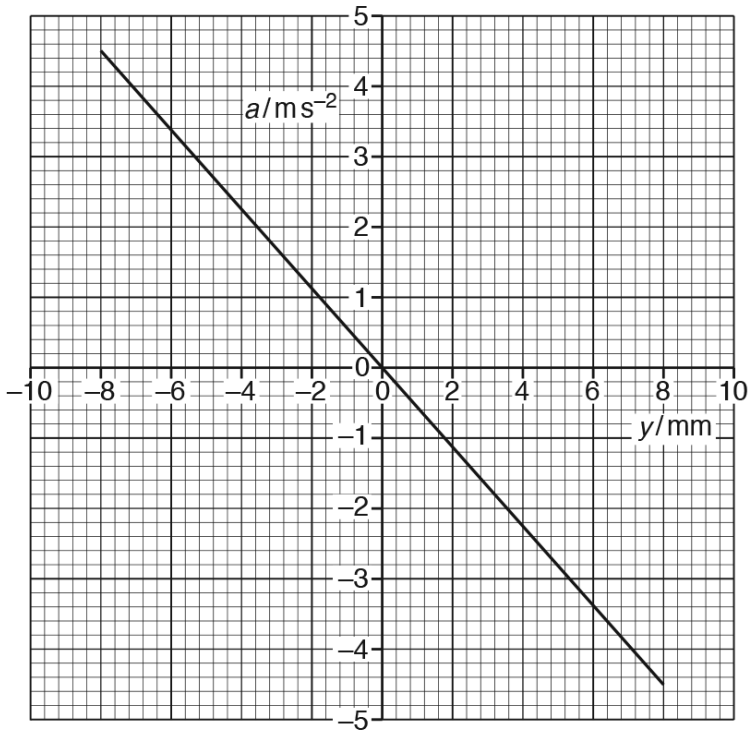


Fig. 2.2

(a) (i) Use Fig. 2.2 to show how it can be deduced that the sand is undergoing simple harmonic motion.

.....

.....

.....

.....[2]

(ii) Calculate the frequency of oscillation of the sand.

frequency = ... Hz [2]

(b) The amplitude of oscillation of the plate is gradually increased beyond 8 mm. The frequency is constant.

At one amplitude, the sand is seen to lose contact with the plate.

For the plate when the sand first loses contact with the plate,

(i) state the position of the plate,

.....[1]

(ii) calculate the amplitude of oscillation.

amplitude = ... mm [3]

[Total: 8]

92. 9702_w18_qp_41 Q: 2

Some energy changes that take place during the cycle PQRP are shown in Fig. 2.2.

	change P → Q	change Q → R	change R → P
thermal energy transferred to gas/J	+97.0	0	.....
work done on gas/J	.....	−42.5	+37.0
increase in internal energy of gas/J	.....	.....	.....

Fig. 2.2

(i) State the total change in internal energy of the gas during the complete cycle PQRP. Explain your answer.

.....

.....

.....[2]

(ii) On Fig. 2.2, complete the energy changes for the gas during

1. the change P → Q,

2. the change Q → R,

3. the change R → P.

[5]

[Total: 9]

A U-tube contains liquid, as shown in Fig. 3.1.

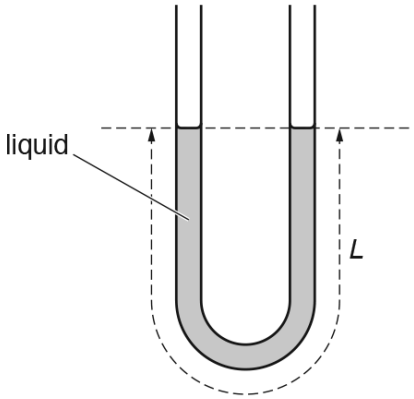


Fig. 3.1

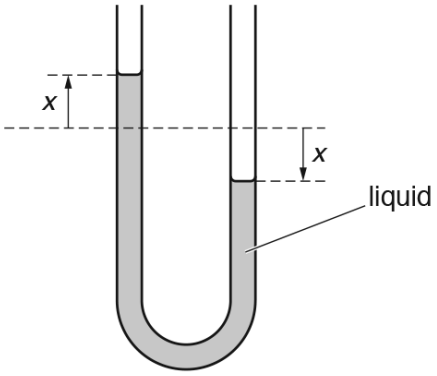


Fig. 3.2

The total length of the column of liquid in the tube is L.

The column of liquid is displaced so that the change in height of the liquid in each arm of the U-tube is x, as shown in Fig. 3.2.

The liquid in the U-tube then oscillates with simple harmonic motion such that the acceleration a of the column is given by the expression

$$a = -\left(\frac{2g}{L}\right)x$$

where g is the acceleration of free fall.

(a) Calculate the period T of oscillation of the liquid column for a column length L of 19.0 cm.

$T =$ ..... s [3]

93. 9702_w17_qp_41 Q: 2

(a) State, by reference to simple harmonic motion, what is meant by *angular frequency*.

.....

..... [1]

(b) A thin metal strip is clamped at one end so that it is horizontal.
A load of mass *M* is attached to its free end. The load causes a displacement *s* of the end of the strip, as shown in Fig. 2.1.

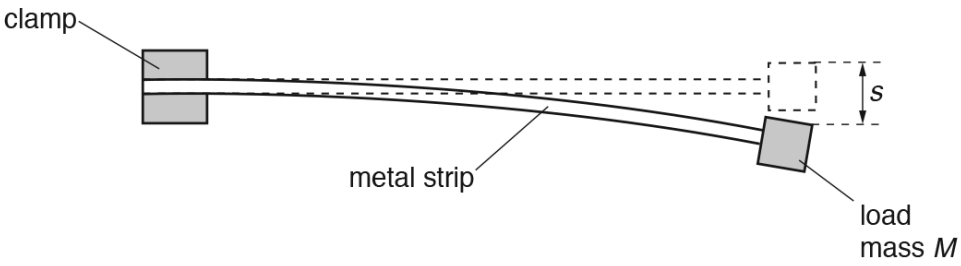


Fig. 2.1

The load is displaced vertically and then released. The load oscillates.
The variation with the acceleration *a* of the displacement *s* of the load is shown in Fig. 2.2.

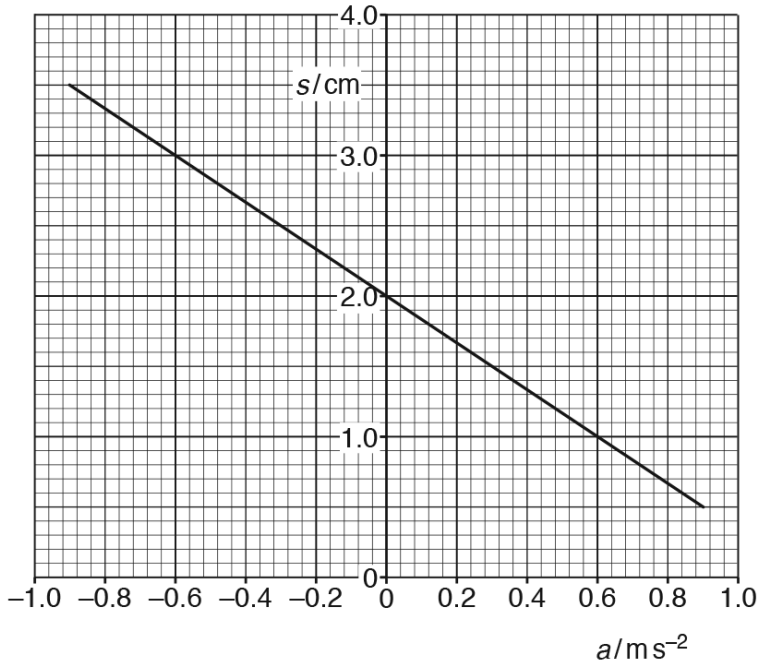


Fig. 2.2

(i) Use Fig. 2.2 to determine

1. the displacement of the load before it is made to oscillate,

displacement = ... cm

2. the amplitude of the oscillations of the load.

amplitude = ... cm
[2]

(ii) Show that the load is undergoing simple harmonic motion.

.....

.....

.....

..... [3]

(iii) Calculate the frequency of oscillation of the load.

frequency = ... Hz [3]

[Total: 9]

94. 9702_w17_qp_42 Q: 3

(a) **(i)** Define the *radian*.

.....

.....

.....[2]

(ii) State, by reference to simple harmonic motion, what is meant by *angular frequency*.

.....

.....[1]

(b) A thin metal strip, clamped horizontally at one end, has a load of mass *M* attached to its free end, as shown in Fig. 3.1.

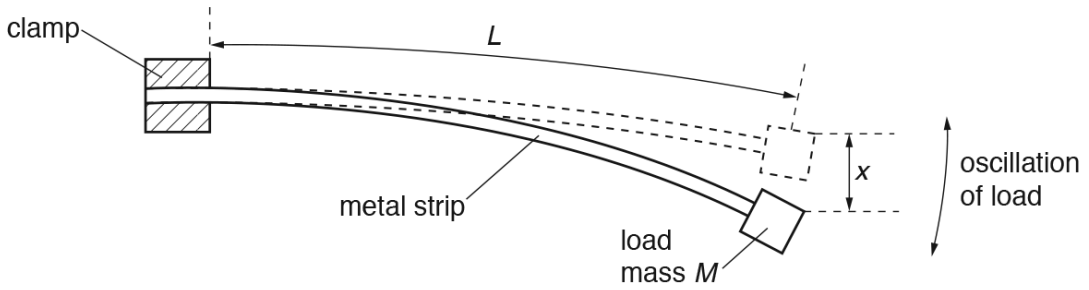


Fig. 3.1

The metal strip bends, as shown in Fig. 3.1.

When the free end of the strip is displaced vertically and then released, the mass oscillates in a vertical plane.
Theory predicts that the variation of the acceleration *a* of the oscillating load with the displacement *x* from its equilibrium position is given by

$$a = -\left(\frac{c}{ML^3}\right) x$$

where *L* is the effective length of the metal strip and *c* is a positive constant.

(i) Explain how the expression shows that the load is undergoing simple harmonic motion.

.....

.....

.....

.....[2]

(ii) For a metal strip of length $L = 65\,\text{cm}$ and a load of mass $M = 240\,\text{g}$, the frequency of oscillation is 3.2 Hz.
Calculate the constant c.

$c =$ ..... $\text{kg m}^3\text{s}^{-2}$ [3]

[Total: 8]

---

95. 9702_w17_qp_43 Q: 2

(a) State, by reference to simple harmonic motion, what is meant by *angular frequency*.

.....

..... [1]

(b) A thin metal strip is clamped at one end so that it is horizontal.
A load of mass *M* is attached to its free end. The load causes a displacement *s* of the end of the strip, as shown in Fig. 2.1.

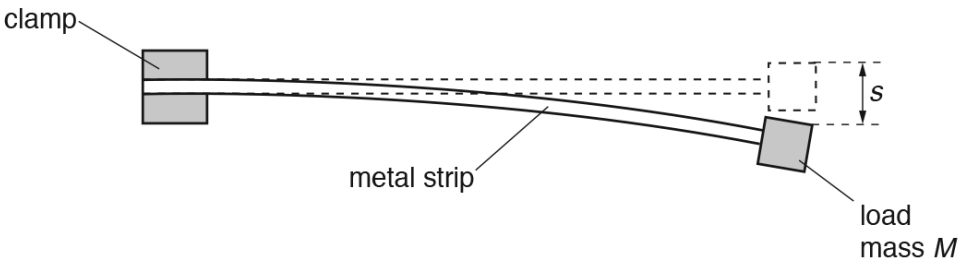


Fig. 2.1

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The variation with the acceleration *a* of the displacement *s* of the load is shown in Fig. 2.2.

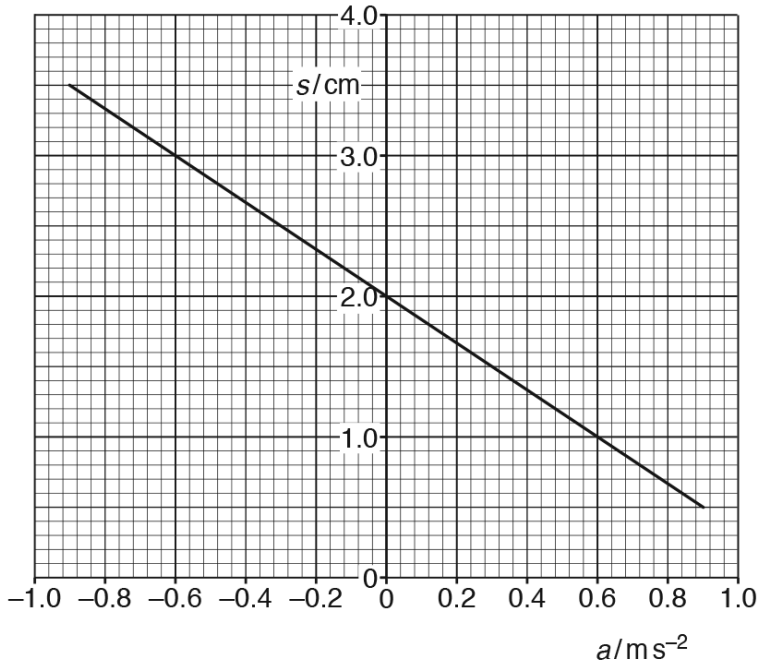


Fig. 2.2

(i) Use Fig. 2.2 to determine

1. the displacement of the load before it is made to oscillate,

displacement = ... cm

2. the amplitude of the oscillations of the load.

amplitude = ... cm
[2]

(ii) Show that the load is undergoing simple harmonic motion.

.....

.....

.....

..... [3]

(iii) Calculate the frequency of oscillation of the load.

frequency = ... Hz [3]

[Total: 9]

96. 9702_w16_qp_41 Q: 3

To demonstrate simple harmonic motion, a student attaches a trolley to two similar stretched springs, as shown in Fig. 3.1.

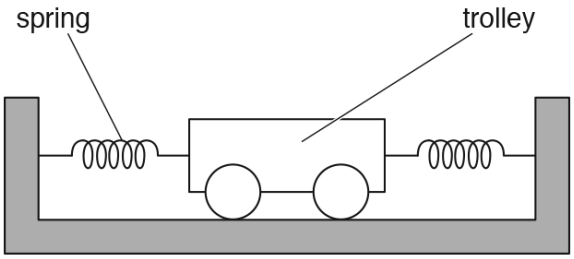


Fig. 3.1

The trolley has mass m of 810 g.

The trolley is displaced along the line of the two springs and then released. The subsequent acceleration a of the trolley is given by the expression

$$a = -\frac{2kx}{m}$$

where the spring constant k for each of the springs is 64 N m^{-1} and x is the displacement of the trolley.

(a) Show that the frequency of oscillation of the trolley is 2.0 Hz.

[3]

(b) The maximum displacement of the trolley is 1.6 cm.
Calculate the maximum speed of the trolley.

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

(c) The mass of the trolley is increased. The initial displacement of the trolley remains unchanged.

Suggest the change, if any, that occurs in the frequency and in the maximum speed of the oscillations of the trolley.

frequency: .....

maximum speed: .....
[2]

[Total: 7]

---

97. 9702_w16_qp_42 Q: 4

A mass hangs vertically from a fixed point by means of a spring, as shown in Fig. 4.1.

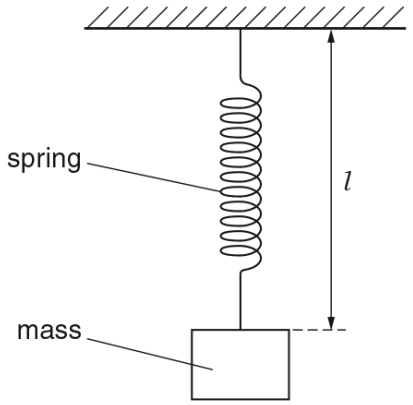


Fig. 4.1

The mass is displaced vertically and then released. The subsequent oscillations of the mass are simple harmonic.

The variation with time t of the length l of the spring is shown in Fig. 4.2.

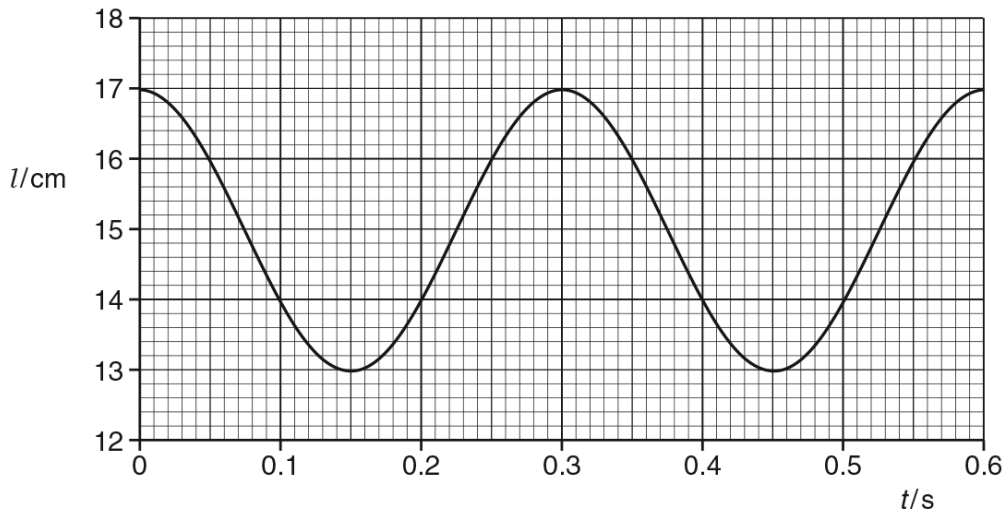


Fig. 4.2

(a) Use Fig. 4.2 to

(i) state two values of t at which the mass is moving downwards with maximum speed,

t = ... s and t = ... s [1]

(ii) determine, for these oscillations, the angular frequency ω,

ω = ... rad s^{-1} [2]

(iii) show that the maximum speed of the mass is 0.42 m s^{-1}.

[2]

(b) Use data from Fig. 4.2 and **(a)(iii)** to sketch, on the axes of Fig. 4.3, the variation with displacement x from the equilibrium position of the velocity v of the mass.

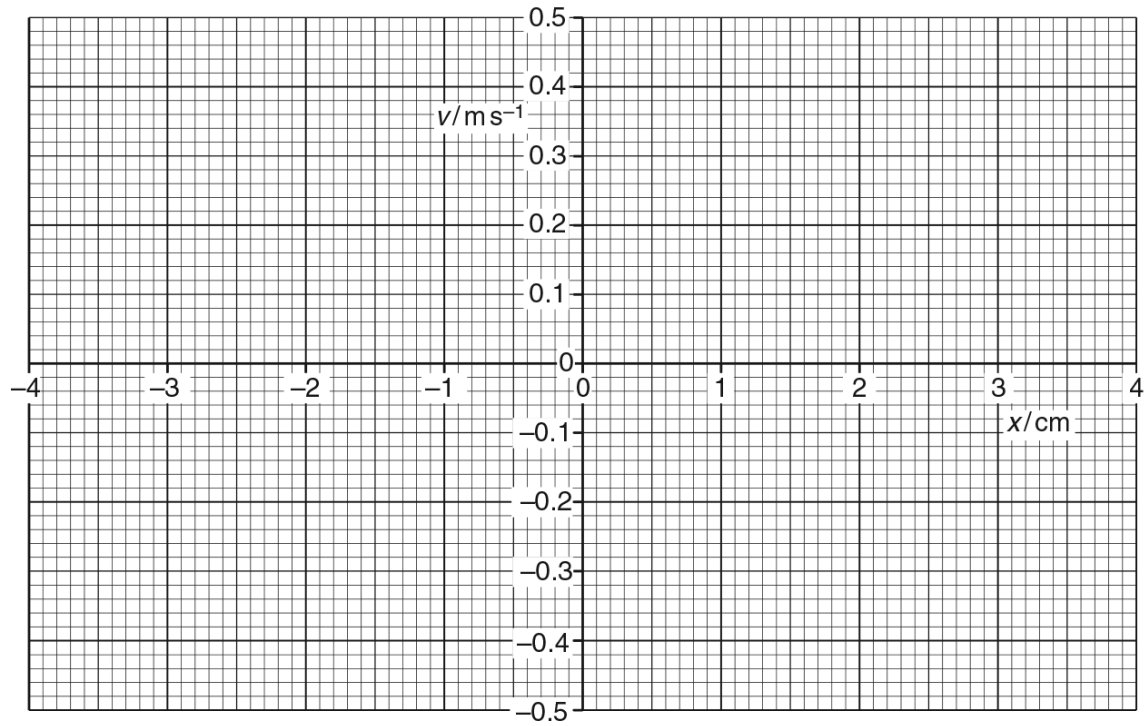


Fig. 4.3

[3]

[Total: 8]

98. 9702_w16_qp_43 Q: 3

To demonstrate simple harmonic motion, a student attaches a trolley to two similar stretched springs, as shown in Fig. 3.1.

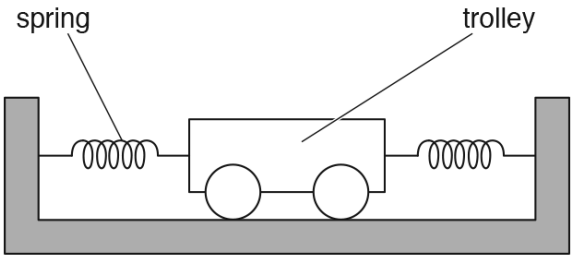


Fig. 3.1

The trolley has mass m of 810 g.

The trolley is displaced along the line of the two springs and then released. The subsequent acceleration a of the trolley is given by the expression

$$a = -\frac{2kx}{m}$$

where the spring constant k for each of the springs is 64 N m^{-1} and x is the displacement of the trolley.

(a) Show that the frequency of oscillation of the trolley is 2.0 Hz.

[3]

(b) The maximum displacement of the trolley is 1.6 cm.
Calculate the maximum speed of the trolley.

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

(c) The mass of the trolley is increased. The initial displacement of the trolley remains unchanged.

Suggest the change, if any, that occurs in the frequency and in the maximum speed of the oscillations of the trolley.

frequency: .....

maximum speed: .....
[2]

[Total: 7]

---

99. 9702_w21_qp_42 Q: 4

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

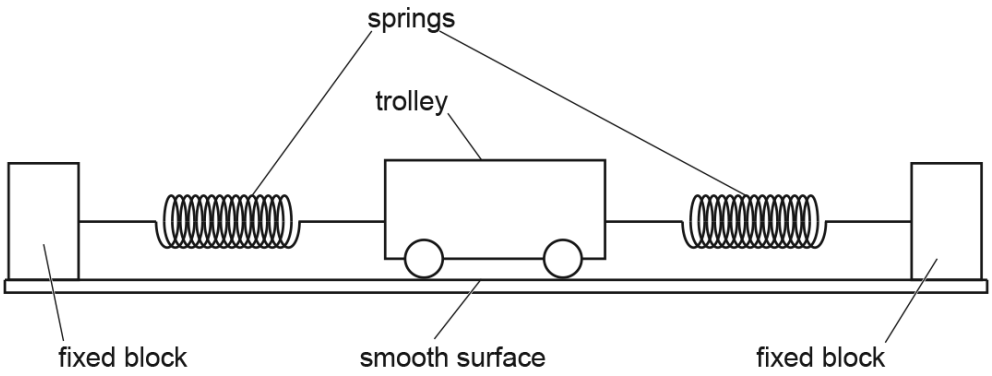


Fig. 4.1

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.

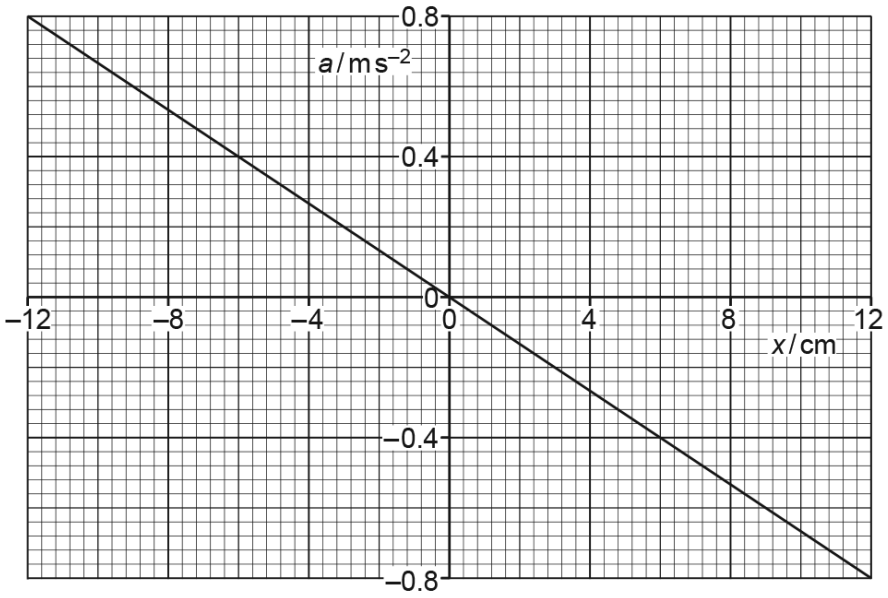


Fig. 4.2

(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]

100. 9702_s19_qp_42 Q: 3

A spring is hung vertically from a fixed point. A mass M is hung from the other end of the spring, as illustrated in Fig. 3.1.

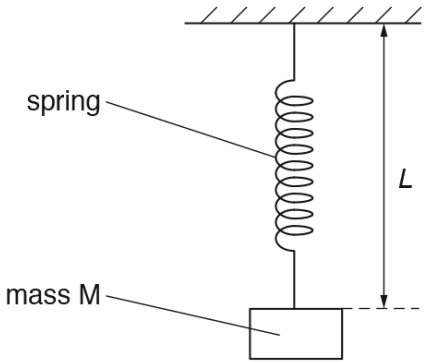


Fig. 3.1

The mass is displaced downwards and then released. The subsequent motion of the mass is simple harmonic.

The variation with time t of the length L of the spring is shown in Fig. 3.2.

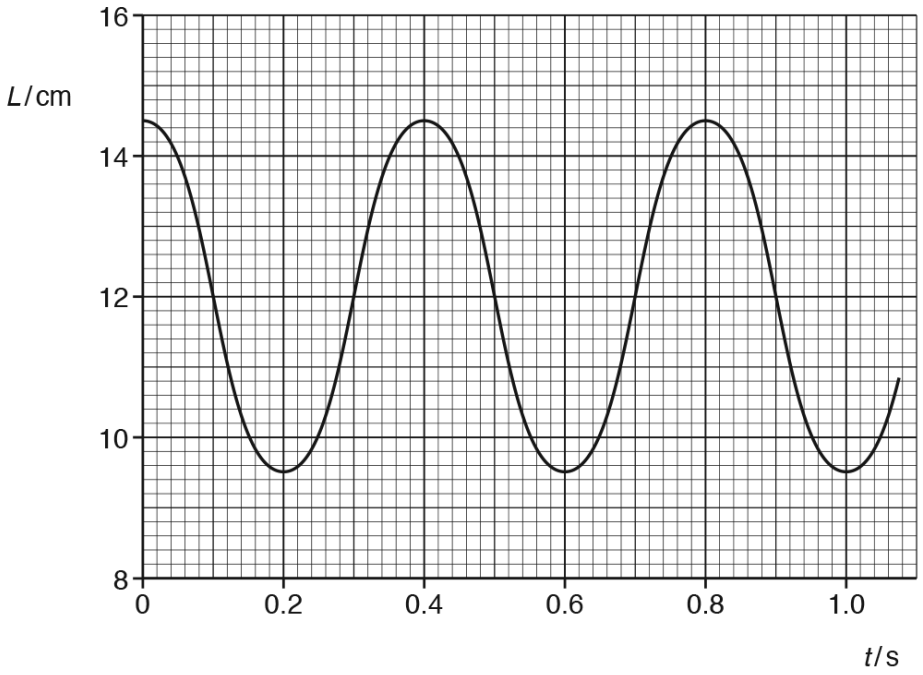


Fig. 3.2

(a) State:

(i) one time at which the mass is moving with maximum speed

time = ... s [1]

(ii) one time at which the spring has maximum elastic potential energy.

time = ... s [1]

(b) Use data from Fig. 3.2 to determine, for the motion of the mass:

(i) the angular frequency ω

ω = ... rad s^{-1} [2]

(ii) the maximum speed

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

(iii) the magnitude of the maximum acceleration.

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

(c) The mass M is now suspended from two springs, each identical to that in Fig. 3.1, as shown in Fig. 3.3.

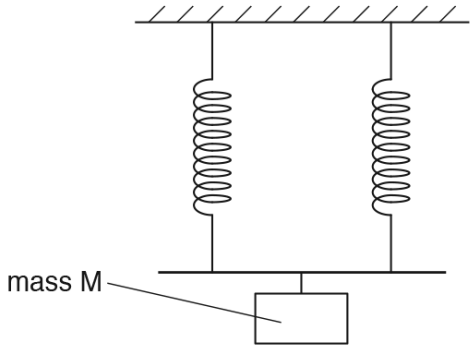


Fig. 3.3

Suggest and explain the change, if any, in the period of oscillation of the mass. A numerical answer is not required.

.....

.....

.....[2]

[Total: 10]

101. 9702_m17_qp_42 Q: 3

A uniform beam is clamped at one end. A metal block of mass m is fixed to the other end of the beam causing it to bend, as shown in Fig. 3.1.

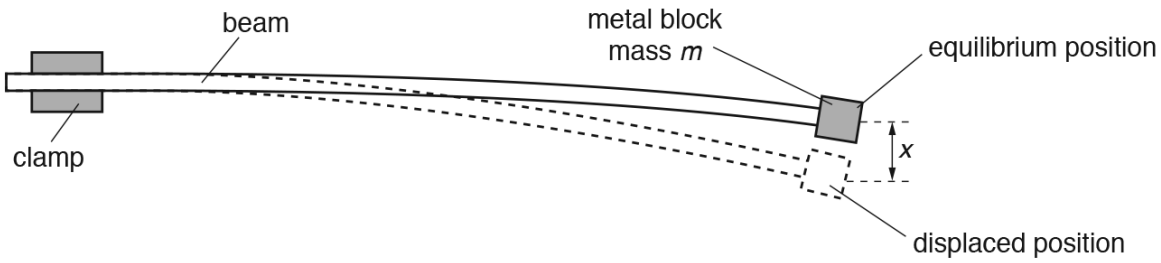


Fig. 3.1

The block is given a small vertical displacement and then released so that it oscillates with simple harmonic motion.

The acceleration a of the block is given by the expression

$$a = -\frac{k}{m}x$$

where k is a constant for the beam and x is the vertical displacement of the block from its equilibrium position.

(a) Explain how it can be deduced from the expression that the block moves with simple harmonic motion.

.....

.....

.....[2]

(b) For the beam, $k = 4.0\,\text{kg}\,\text{s}^{-2}$. Show that the angular frequency ω of the oscillations is given by the expression

$$\omega = \frac{2.0}{\sqrt{m}}.$$

[2]

(c) The initial amplitude of the oscillation of the block is 3.0 cm.

Use the expression in **(b)** to determine the maximum kinetic energy of the oscillations.

maximum kinetic energy = ...J [3]

(d) Over a certain interval of time, the maximum kinetic energy of the oscillations in **(c)** is reduced by 50%. It may be assumed that there is negligible change in the angular frequency of the oscillations.

Determine the amplitude of oscillation.

amplitude = ...m [2]

(e) Permanent magnets are now positioned so that the metal block oscillates between the poles, as shown in Fig. 3.2.

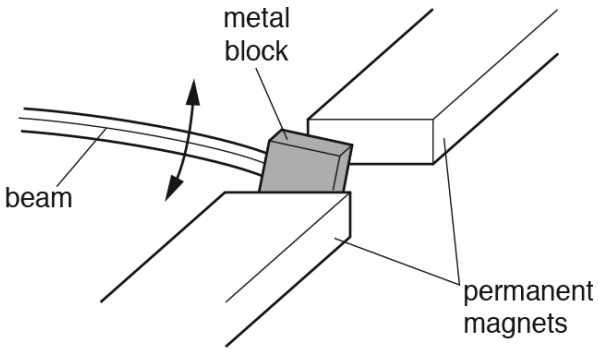


Fig. 3.2

The block is made to oscillate with the same initial amplitude as in **(c)**. Use energy conservation to explain why the energy of the oscillations decreases more rapidly than in **(d)**.

.....

.....

.....

.....

.....[3]

[Total: 12]

102. 9702_m16_qp_42 Q: 4

An object of mass 80 g oscillates with simple harmonic motion. The variation with time t of the displacement x of the object is shown in Fig. 4.1.

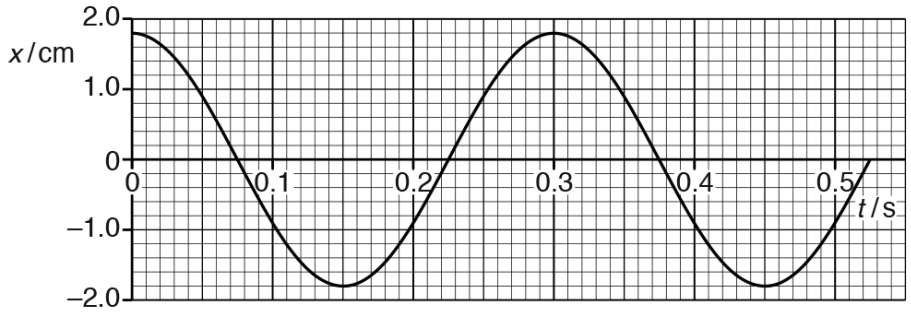


Fig. 4.1

(a) Use Fig. 4.1 to determine the amplitude and the period of the oscillations.

amplitude = ...cm

period = ...s
[1]

(b) Use Fig. 4.1 and your answers in **(a)** to calculate the kinetic energy of the object at time $t = 0.19$ s.

kinetic energy = ...J [3]

[Total: 4]

103. 9702_s21_qp_41 Q: 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.

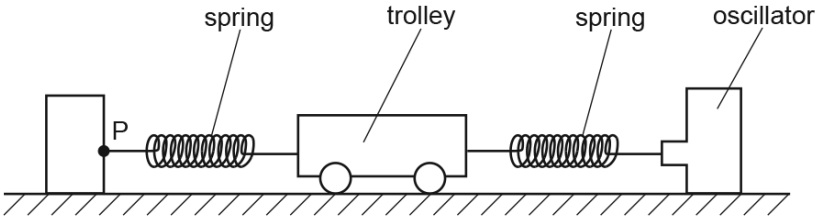


Fig. 3.1

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

104. 9702_s21_qp_42 Q: 3

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.

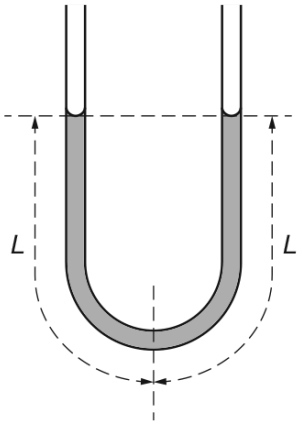


Fig. 3.1

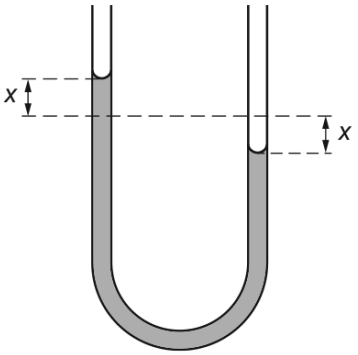


Fig. 3.2

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]

(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]

105. 9702_w21_qp_41 Q: 4

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.

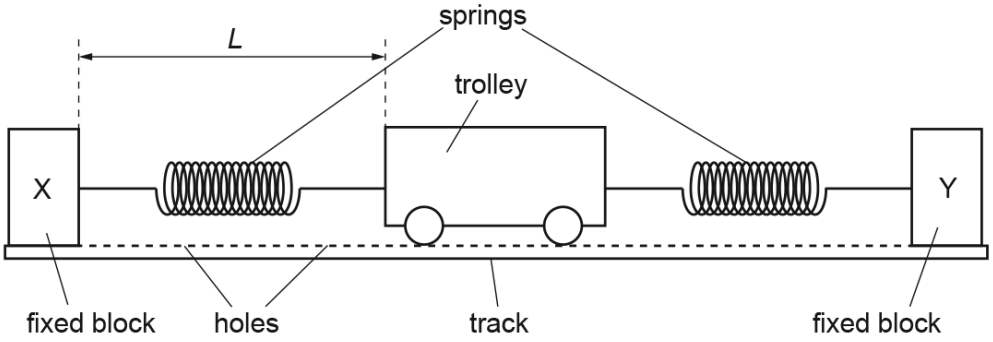


Fig. 4.1

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.

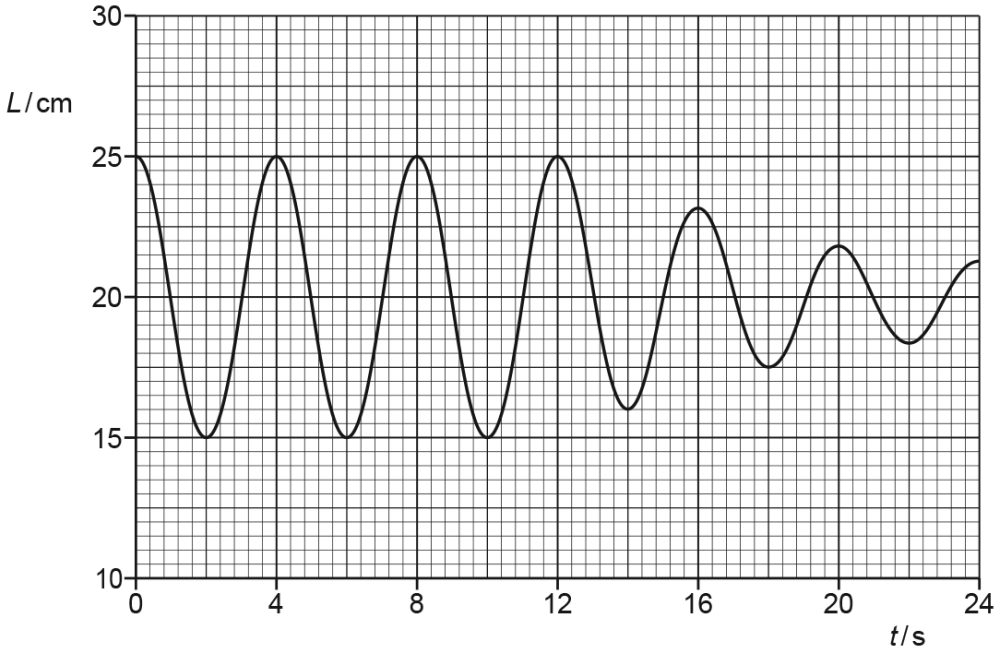


Fig. 4.2

(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.

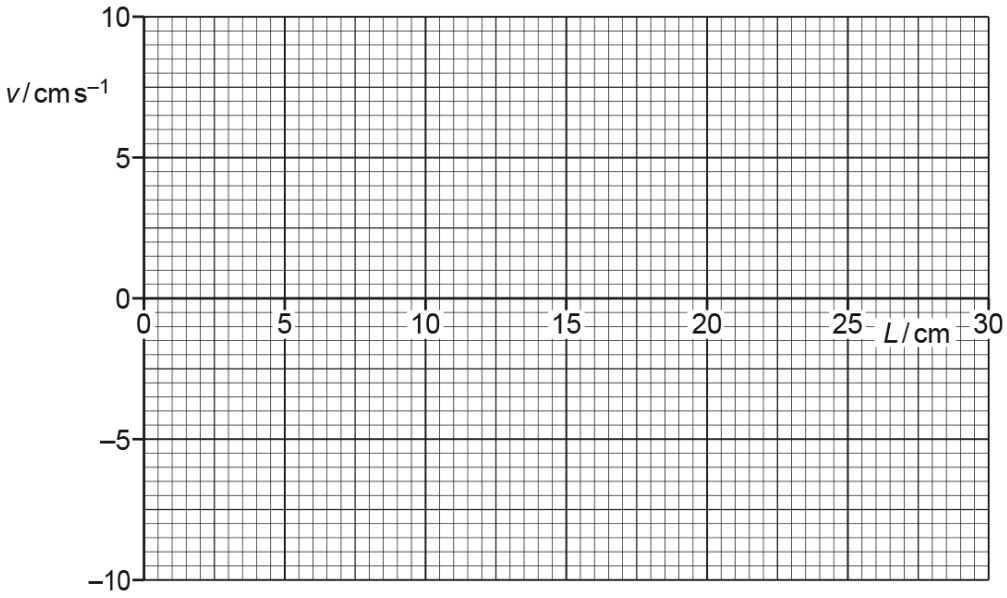


Fig. 4.3

[3]

[Total: 11]

106. 9702_w21_qp_43 Q: 4

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.

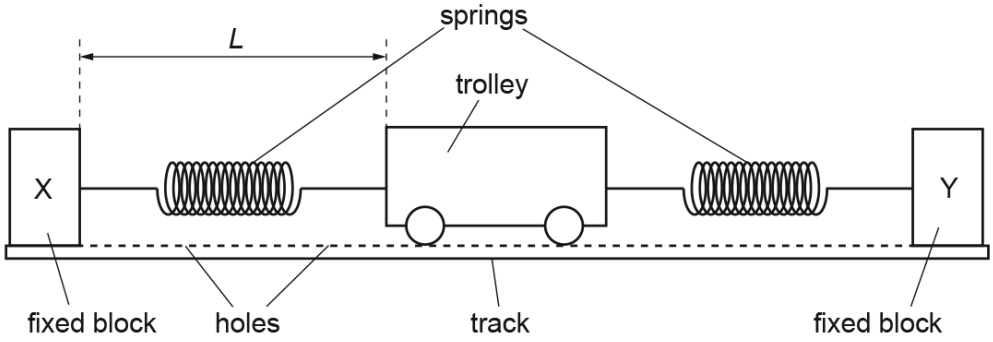


Fig. 4.1

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.

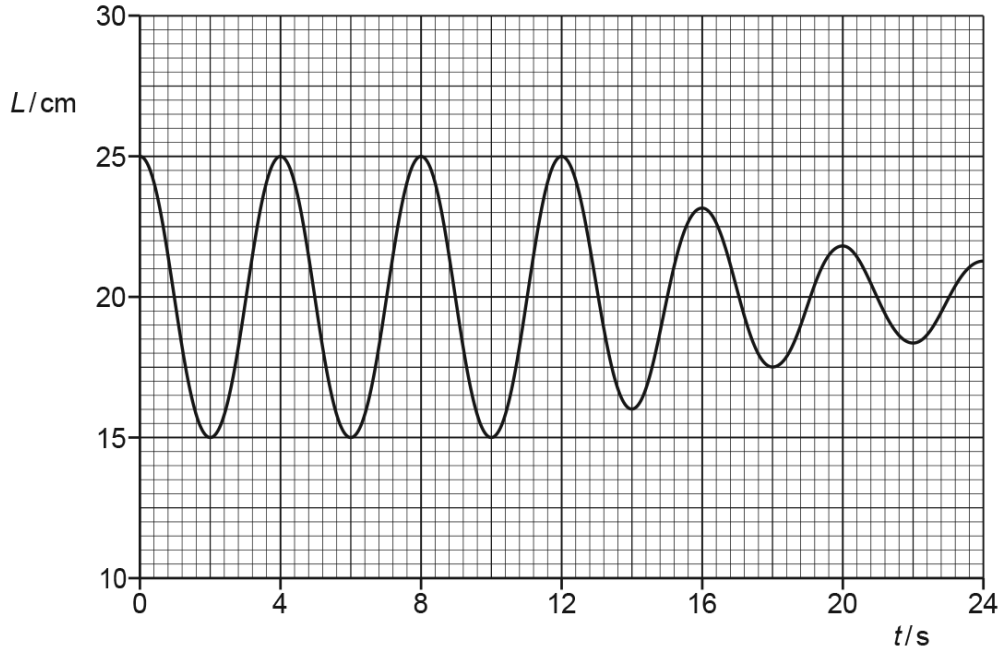


Fig. 4.2

(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.

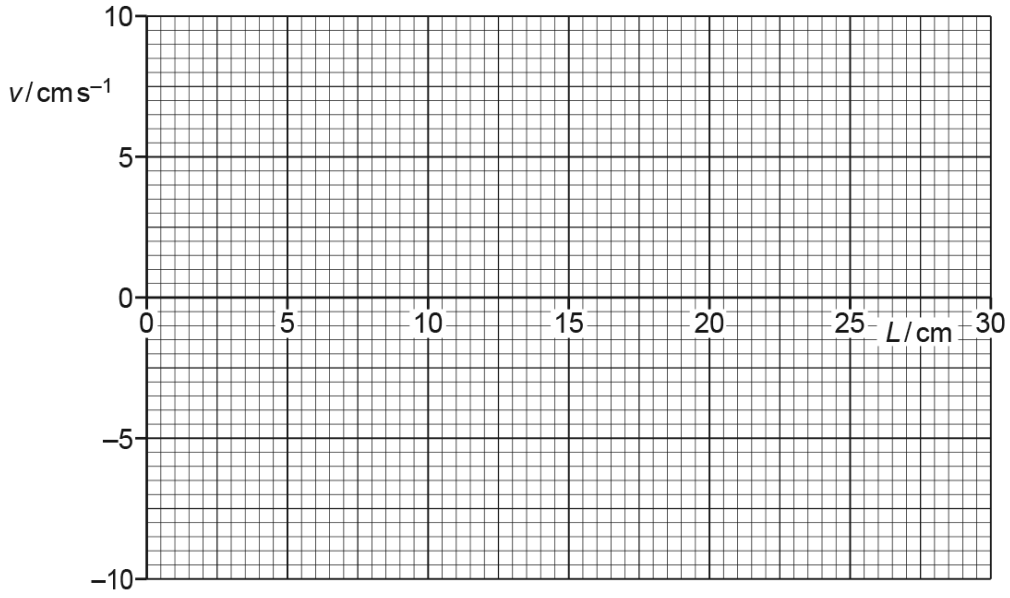


Fig. 4.3

[3]

[Total: 11]

107. 9702_s20_qp_42 Q: 4

A dish is made from a section of a hollow glass sphere.

The dish, fixed to a horizontal table, contains a small solid ball of mass 45 g, as shown in Fig. 4.1.

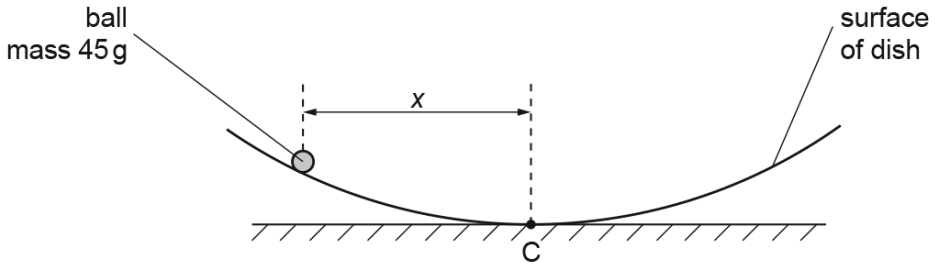


Fig. 4.1

The horizontal displacement of the ball from the centre C of the dish is x.

Initially, the ball is held at rest with distance x = 3.0 cm.

The ball is then released. The variation with time t of the horizontal displacement x of the ball from point C is shown in Fig. 4.2.

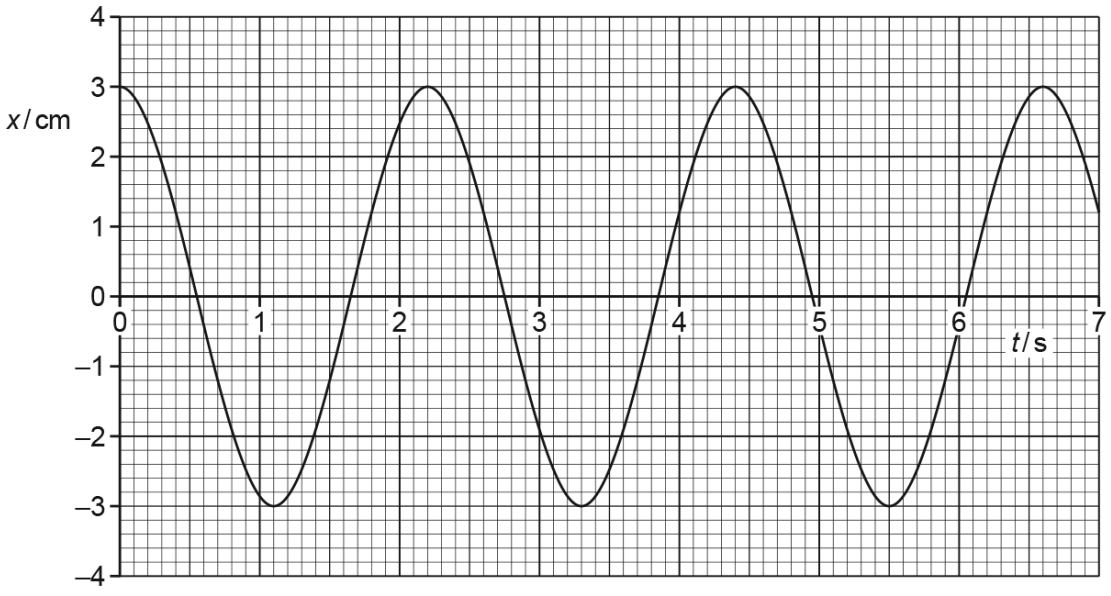


Fig. 4.2

The motion of the ball in the dish is simple harmonic with its acceleration a given by the expression

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

where g is the acceleration of free fall and R is a constant that depends on the dimensions of the dish and the ball.

(a) Use Fig. 4.2 to show that the angular frequency ω of oscillation of the ball in the dish is $2.9\,\text{rad}\,\text{s}^{-1}$.

[1]

(b) Use the information in **(a)** to:

(i) determine R

R = ... m [2]

(ii) calculate the speed of the ball as it passes over the centre C of the dish.

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

(c) Some moisture collects on the surface of the dish so that the motion of the ball becomes lightly damped.

On the axes of Fig. 4.2, draw a line to show the lightly damped motion of the ball for the first 5.0 s after the release of the ball. [3]

[Total: 8]

108. 9702_s19_qp_41 Q: 3

A hollow tube, sealed at one end, has a cross-sectional area A of 24 cm^2.
The tube contains sand so that the total mass M of the tube and sand is 0.23 kg.

The tube floats upright in a liquid of density ρ, as illustrated in Fig. 3.1.

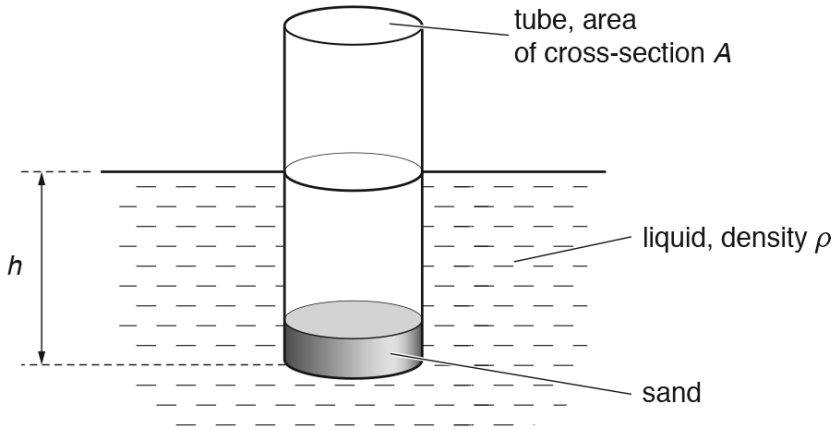


Fig. 3.1

The depth of the bottom of the tube below the liquid surface is h.

The tube is displaced vertically and then released. The variation with time t of the depth h is shown in Fig. 3.2.

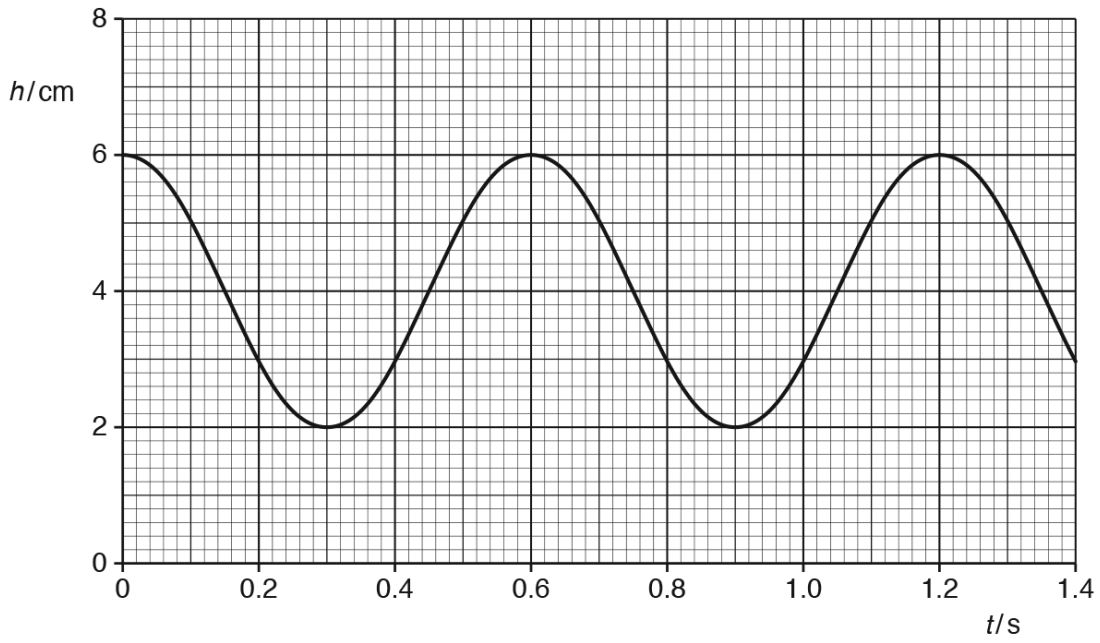


Fig. 3.2

(a) Determine:

(i) the amplitude, in metres, of the oscillations

amplitude = ... m [1]

STEMUP.CO.UK

(ii) the frequency of oscillation of the tube in the liquid

frequency = ...Hz [2]

(iii) the acceleration of the tube when h is a maximum.

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

(b) The frequency f of oscillation of the tube is given by the expression

$$f = \frac{1}{2\pi}\sqrt{\left(\frac{A\rho g}{M}\right)}$$

where g is the acceleration of free fall.

Calculate the density ρ of the liquid in which the tube is floating.

ρ = ...$kg\,m^{-3}$ [2]

(c) The oscillations illustrated in Fig. 3.2 are undamped. In practice, the liquid does cause light damping.

On Fig. 3.2, draw a line to show light damping of the oscillations for time $t = 0$ to time $t = 1.4\,s$. [3]

[Total: 10]

109. 9702_s19_qp_43 Q: 3

A hollow tube, sealed at one end, has a cross-sectional area A of 24 cm^2.
The tube contains sand so that the total mass M of the tube and sand is 0.23 kg.

The tube floats upright in a liquid of density ρ, as illustrated in Fig. 3.1.

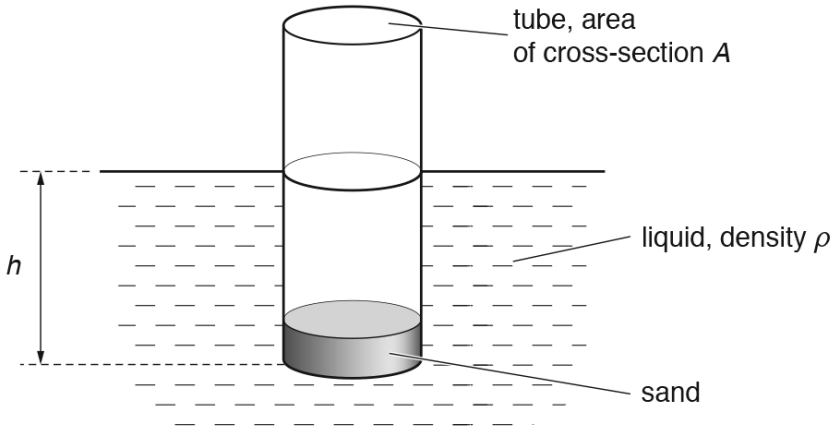


Fig. 3.1

The depth of the bottom of the tube below the liquid surface is h.

The tube is displaced vertically and then released. The variation with time t of the depth h is shown in Fig. 3.2.

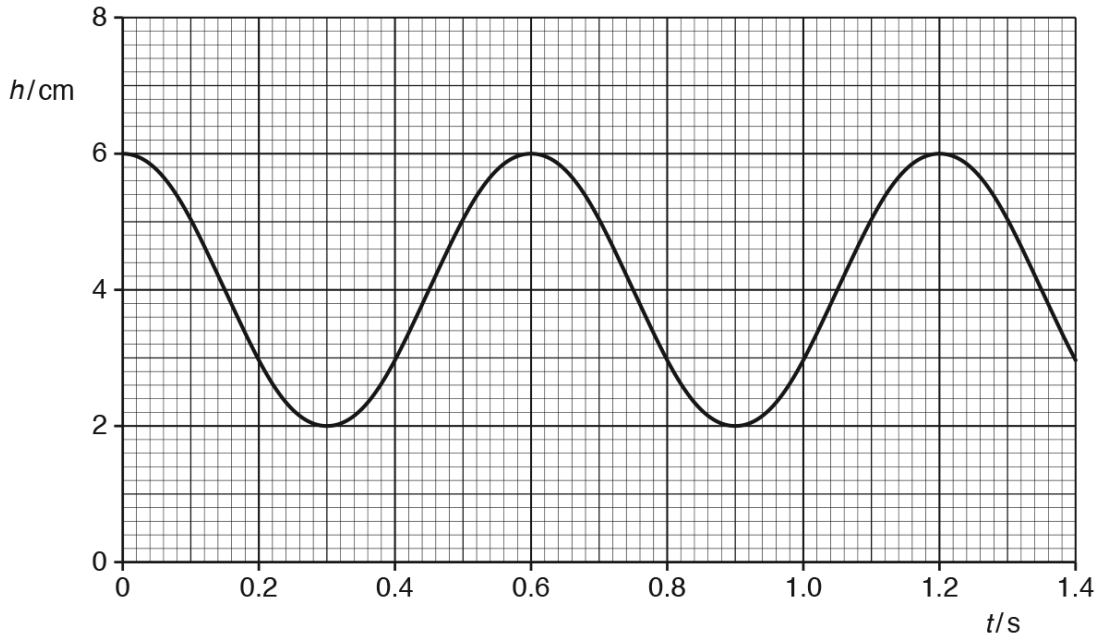


Fig. 3.2

(a) Determine:

(i) the amplitude, in metres, of the oscillations

amplitude = ... m [1]

(ii) the frequency of oscillation of the tube in the liquid

frequency = ...Hz [2]

(iii) the acceleration of the tube when h is a maximum.

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

(b) The frequency f of oscillation of the tube is given by the expression

$$f = \frac{1}{2\pi}\sqrt{\left(\frac{A\rho g}{M}\right)}$$

where g is the acceleration of free fall.

Calculate the density ρ of the liquid in which the tube is floating.

ρ = ...$kg\,m^{-3}$ [2]

(c) The oscillations illustrated in Fig. 3.2 are undamped. In practice, the liquid does cause light damping.

On Fig. 3.2, draw a line to show light damping of the oscillations for time $t = 0$ to time $t = 1.4\,s$. [3]

[Total: 10]

110. 9702_w19_qp_42 Q: 4

A ball of mass *M* is held on a horizontal surface by two identical extended springs, as illustrated in Fig. 4.1.

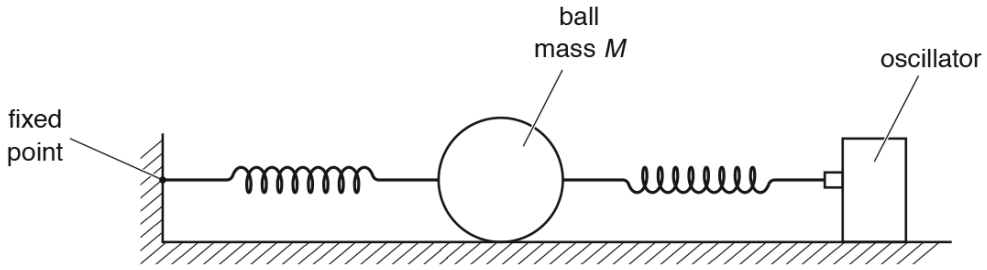


Fig. 4.1

One spring is attached to a fixed point. The other spring is attached to an oscillator.

The oscillator is switched off. The ball is displaced sideways along the axis of the springs and is then released. The variation with time *t* of the displacement *x* of the ball is shown in Fig. 4.2.

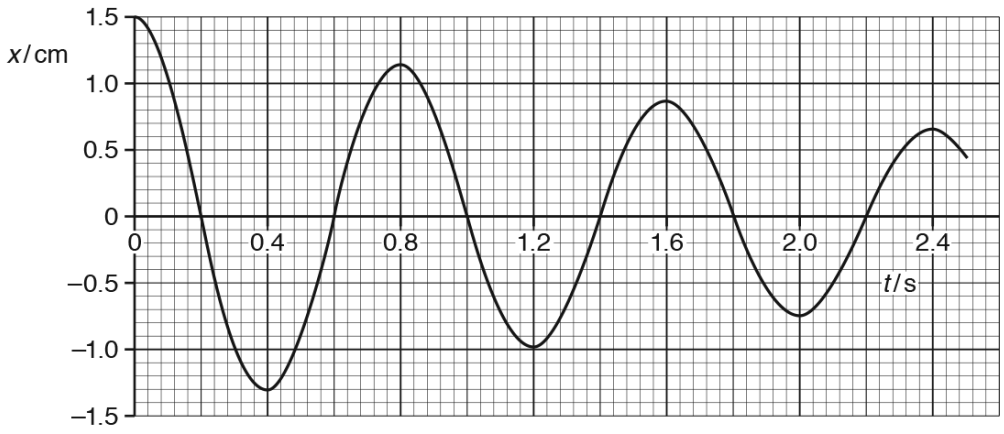


Fig. 4.2

(a) State:

(i) what is meant by *damping*

.....

..... [1]

(ii) the evidence provided by Fig. 4.2 that the motion of the ball is damped.

.....

..... [1]

(b) The acceleration a and the displacement x of the ball are related by the expression

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

where k is the spring constant of one of the springs.

The mass M of the ball is 1.2 kg.

(i) Use data from Fig. 4.2 to determine the angular frequency ω of the oscillations of the ball.

ω = ... rad s^{-1} [2]

(ii) Use your answer in **(i)** to determine the value of k.

k = ... N m^{-1} [2]

(c) The oscillator is switched on. The amplitude of oscillation of the oscillator is constant.

The angular frequency of the oscillations is gradually increased from 0.7ω to 1.3ω, where ω is the angular frequency calculated in **(b)(i)**.

(i) On the axes of Fig. 4.3, show the variation with angular frequency of the amplitude A of oscillation of the ball.

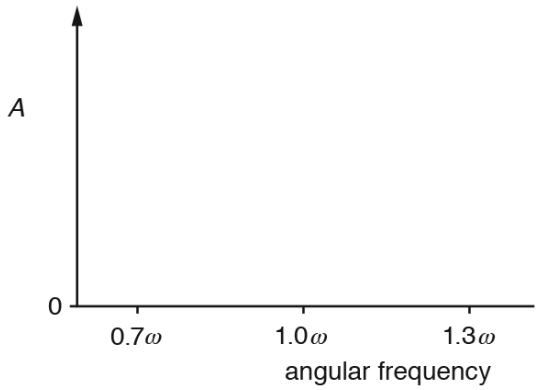


Fig. 4.3

[2]

(ii) Some sand is now sprinkled on the horizontal surface.

The angular frequency of the oscillations is again gradually increased from 0.7ω to 1.3ω.

State **two** changes that occur to the line you have drawn on Fig. 4.3.

1. .....

.....

2. .....

.....

[2]

[Total: 10]

111. 9702_m18_qp_42 Q: 4

(a) Explain what is meant by the *natural frequency of vibration* of a system.

.....

.....

.....[1]

(b) A block of metal is fixed to one end of a vertical spring. The other end of the spring is attached to an oscillator, as shown in Fig. 4.1.

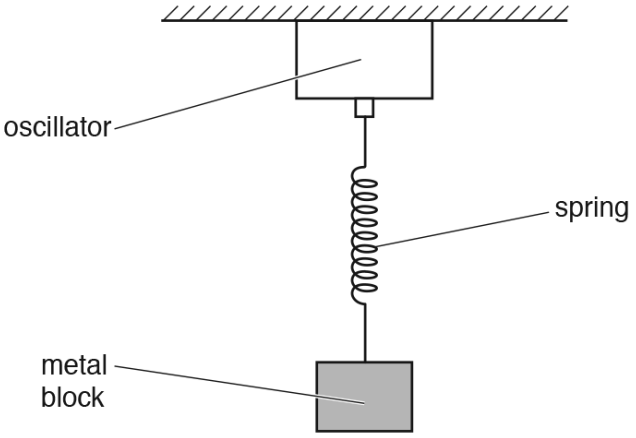


Fig. 4.1

The amplitude of oscillation of the oscillator is constant.

The variation of the amplitude x_0 of the oscillations of the block with frequency f of the oscillations is shown in Fig. 4.2.

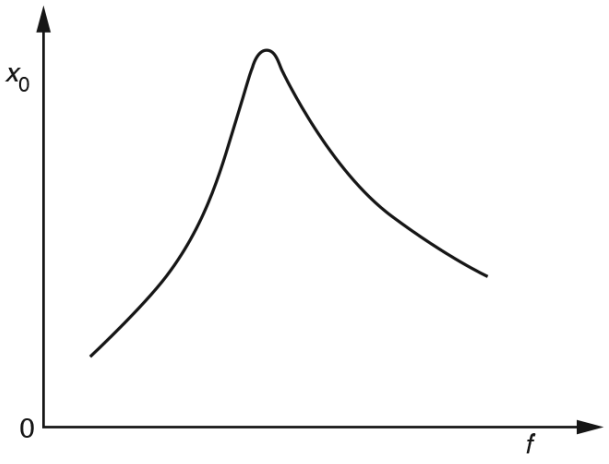


Fig. 4.2

STEMUP.CO.UK

(i) Name the effect shown in Fig. 4.2.

.....[1]

(ii) State and explain whether the block is undergoing damped oscillations.

.....

.....

.....[2]

(c) State **one** example in which the effect shown in Fig. 4.2 is useful.

.....

.....[1]

[Total: 5]

---

112. 9702_s18_qp_42 Q: 4

(a) State two conditions necessary for a mass to be undergoing simple harmonic motion.

1. .....

.....

2. .....

.....

[2]

(b) A trolley of mass 950 g is held on a horizontal surface by means of two springs attached to fixed points P and Q, as shown in Fig. 4.1.

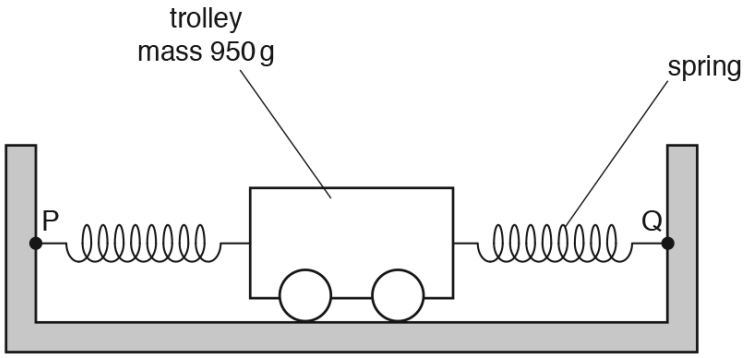


Fig. 4.1

The springs, each having a spring constant k of 230 N m^{-1}, are always extended.

The trolley is displaced along the line of the springs and then released.
The variation with time t of the displacement x of the trolley is shown in Fig. 4.2.

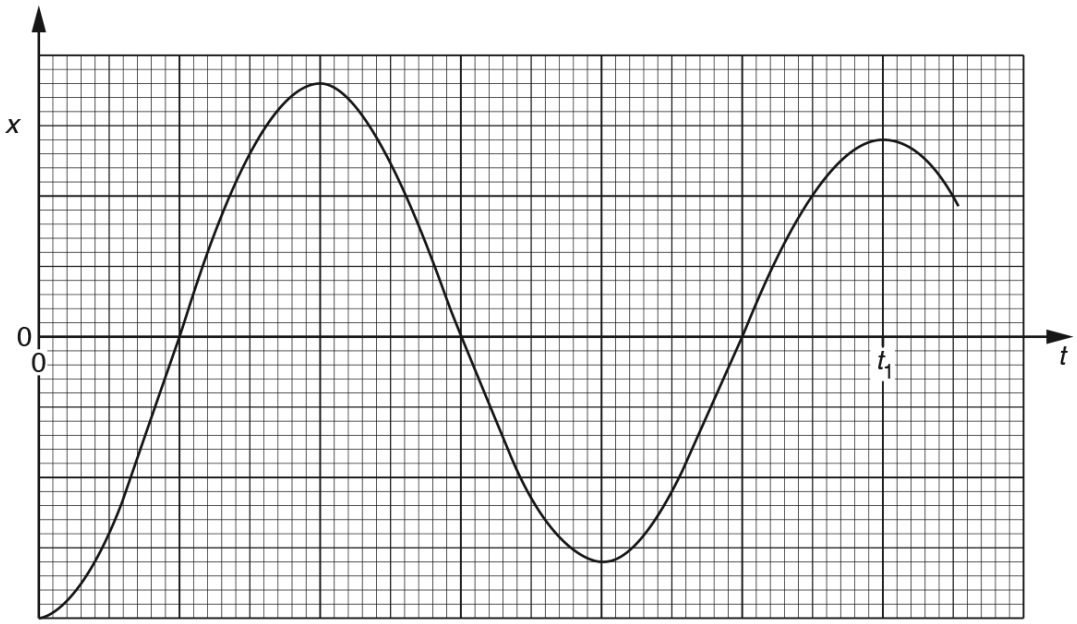


Fig. 4.2

(i) **1.** State and explain whether the oscillations of the trolley are heavily damped, critically damped or lightly damped.

.....

.....

2. Suggest the cause of the damping.

.....

.....

.....

[3]

(ii) The acceleration a of the trolley of mass m may be assumed to be given by the expression

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

1. Calculate the angular frequency ω of the oscillations of the trolley.

ω = ... rad s^{-1} [3]

2. Determine the time t_1 shown on Fig. 4.2.

t_1 = ... s [2]

[Total: 10]

113. 9702_w18_qp_41 Q: 3

(b) The variation with time t of the displacement x is shown in Fig. 3.3.

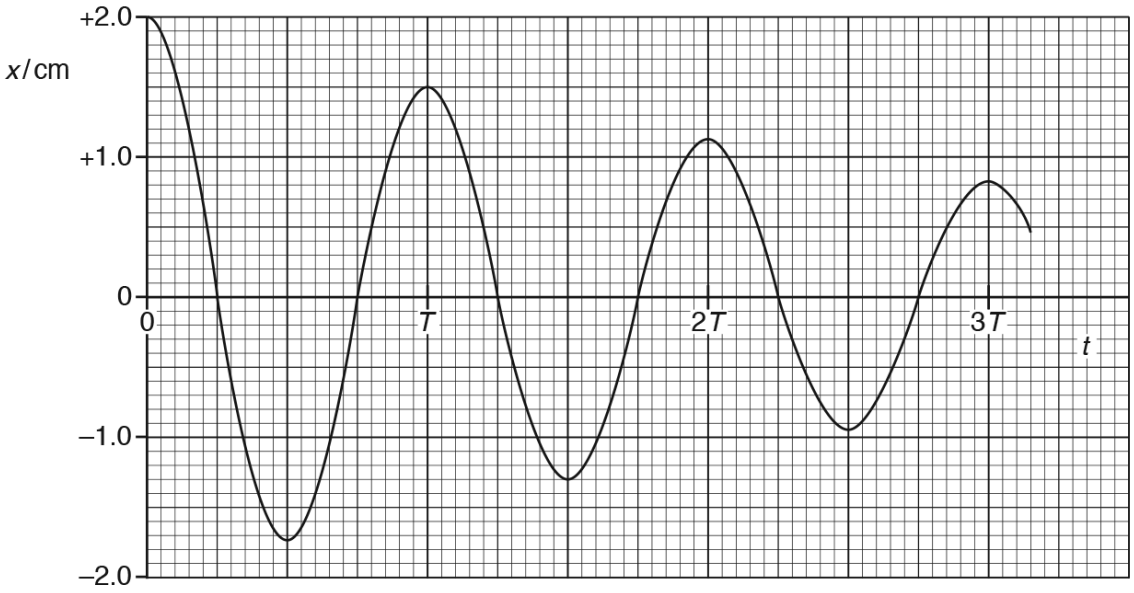


Fig. 3.3

The period of oscillation of the liquid column of mass 18.0 g is T.

The oscillations are damped.

(i) Suggest one cause of the damping.

.....

.....[1]

(ii) Calculate the loss in total energy of the oscillations during the first 2.5 periods of the oscillations.

energy loss = ... J [3]

[Total: 7]

114. 9702_w18_qp_42 Q: 4

A U-tube contains liquid, as shown in Fig. 4.1.

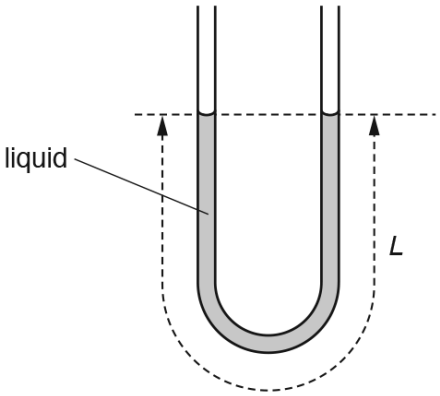


Fig. 4.1

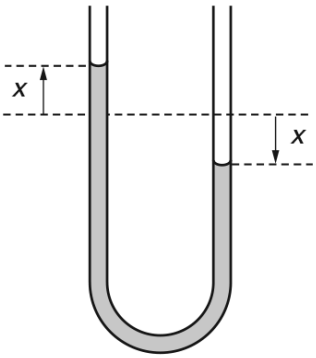


Fig. 4.2

The total length of the liquid column is L.

The column of liquid is displaced so that the change in height of the liquid level from the equilibrium position in each arm of the U-tube is x, as shown in Fig. 4.2.

The liquid in the U-tube then oscillates such that its acceleration a is given by the expression

$$a = -\left(\frac{2g}{L}\right)x$$

where g is the acceleration of free fall.

(a) Show that the liquid column undergoes simple harmonic motion.

[2]

(b) The variation with time t of the displacement x is shown in Fig. 4.3.

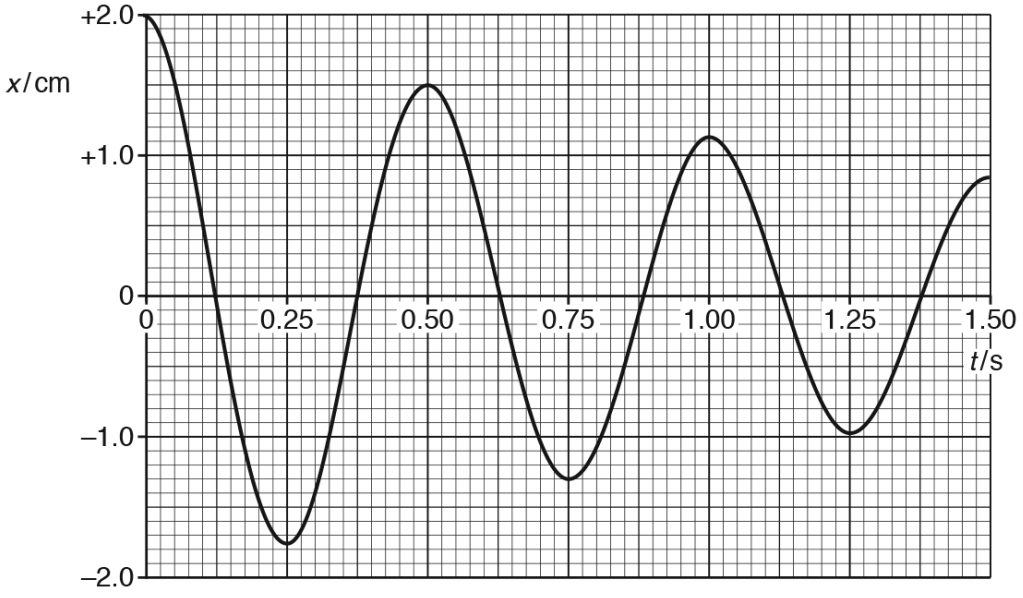


Fig. 4.3

Use data from Fig. 4.3 to determine the length L of the liquid column.

L = ... m [3]

(c) The oscillations shown in Fig. 4.3 are damped.

(i) Suggest one cause of this damping.

.....

.....[1]

(ii) Calculate the ratio

$$\frac{\text{total energy of oscillations after 1.5 complete oscillations}}{\text{total initial energy of oscillations}}$$

ratio = ... [2]

[Total: 8]

115. 9702_w18_qp_43 Q: 3

A U-tube contains liquid, as shown in Fig. 3.1.

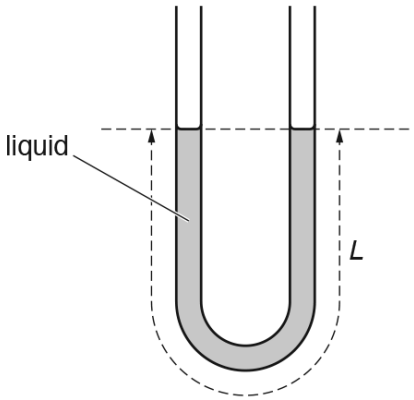


Fig. 3.1

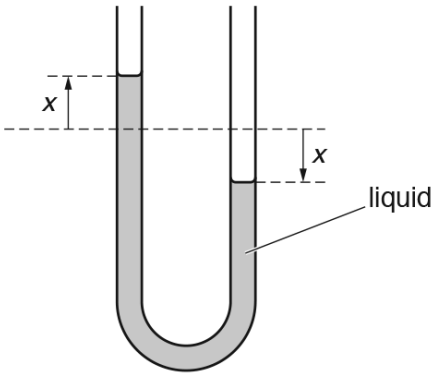


Fig. 3.2

The total length of the column of liquid in the tube is L.

The column of liquid is displaced so that the change in height of the liquid in each arm of the U-tube is x, as shown in Fig. 3.2.

The liquid in the U-tube then oscillates with simple harmonic motion such that the acceleration a of the column is given by the expression

$$a = -\left(\frac{2g}{L}\right)x$$

where g is the acceleration of free fall.

(a) Calculate the period T of oscillation of the liquid column for a column length L of 19.0 cm.

T = ... s [3]

(b) The variation with time t of the displacement x is shown in Fig. 3.3.

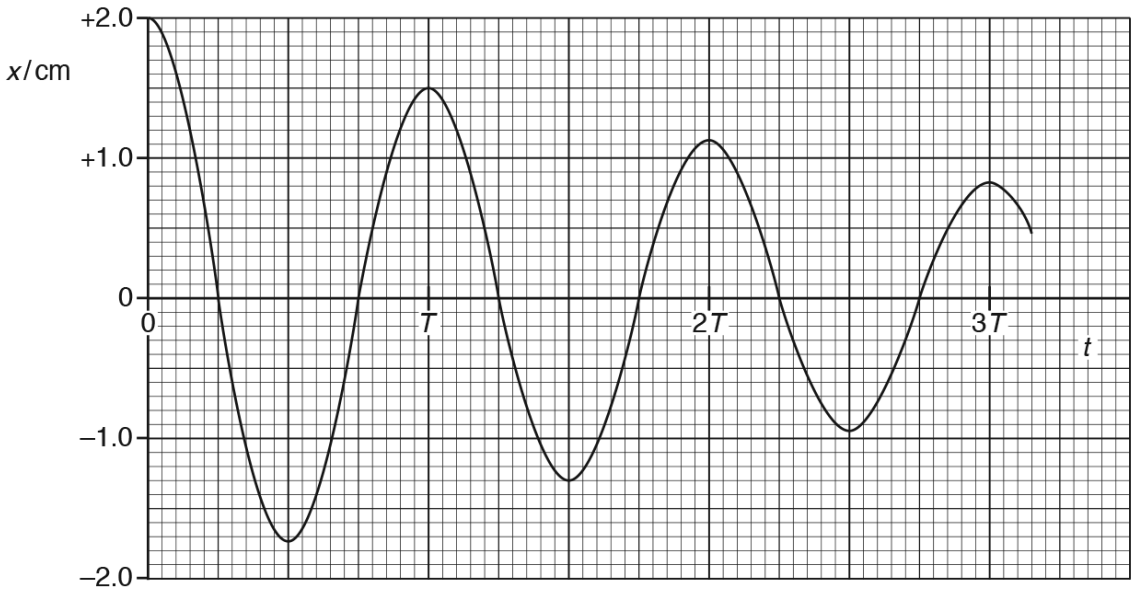


Fig. 3.3

The period of oscillation of the liquid column of mass 18.0 g is T.

The oscillations are damped.

(i) Suggest one cause of the damping.

.....

.....[1]

(ii) Calculate the loss in total energy of the oscillations during the first 2.5 periods of the oscillations.

energy loss = ... J [3]

[Total: 7]

116. 9702_s17_qp_41 Q: 2

A bar magnet of mass 180 g is suspended from the free end of a spring, as illustrated in Fig. 2.1.

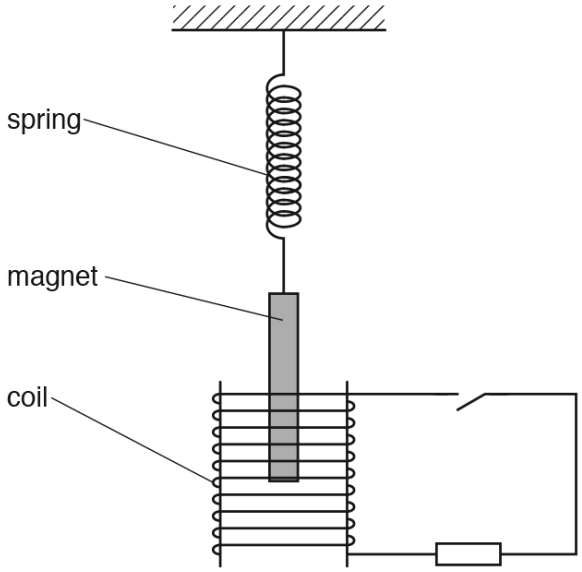


Fig. 2.1

The magnet hangs so that one pole is near the centre of a coil of wire.

The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate with one pole remaining inside the coil. The other pole remains outside the coil.

At time $t = 0$, the magnet is oscillating freely as it passes through its equilibrium position. At time $t = 3.0$ s, the switch in the circuit is closed.

The variation with time t of the vertical displacement y of the magnet is shown in Fig. 2.2.

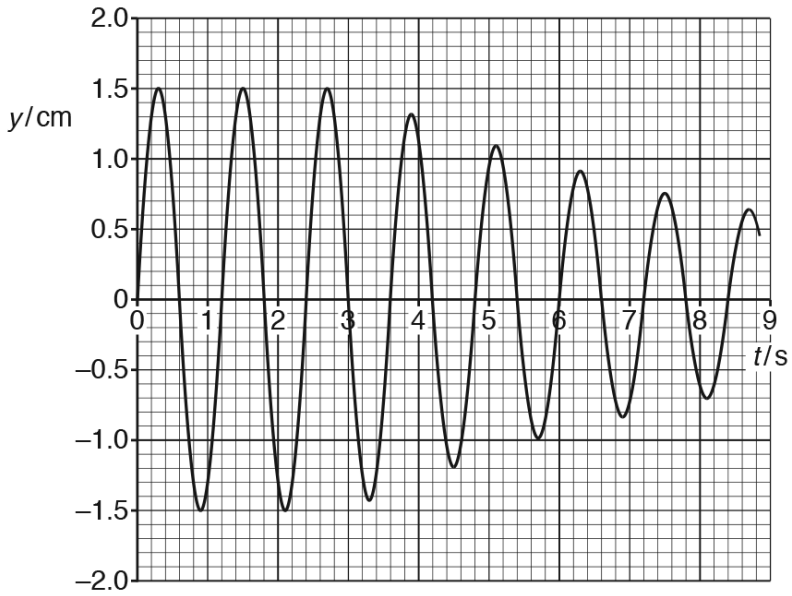


Fig. 2.2

(a) Determine, to two significant figures, the frequency of oscillation of the magnet.

frequency = ... Hz [2]

(b) State whether the closing of the switch gives rise to light, heavy or critical damping.

.....[1]

(c) Calculate the change in the energy ΔE of oscillation of the magnet between time $t = 2.7\,\text{s}$ and time $t = 7.5\,\text{s}$. Explain your working.

ΔE = ... J [6]

[Total: 9]

---

117. 9702_s17_qp_43 Q: 2

A bar magnet of mass 180 g is suspended from the free end of a spring, as illustrated in Fig. 2.1.

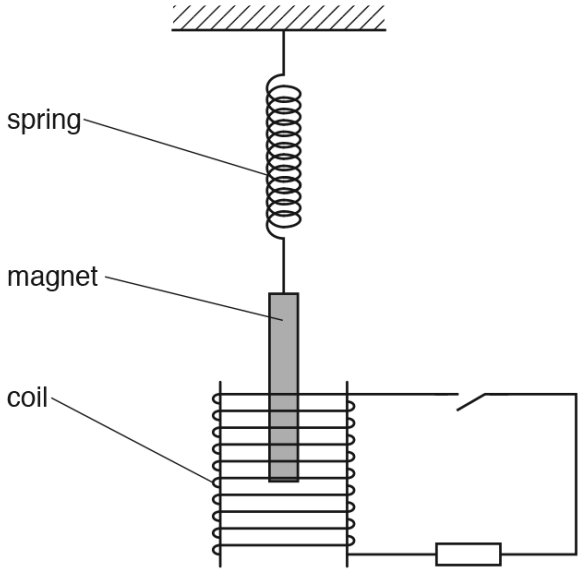


Fig. 2.1

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At time $t = 0$, the magnet is oscillating freely as it passes through its equilibrium position. At time $t = 3.0$ s, the switch in the circuit is closed.

The variation with time t of the vertical displacement y of the magnet is shown in Fig. 2.2.

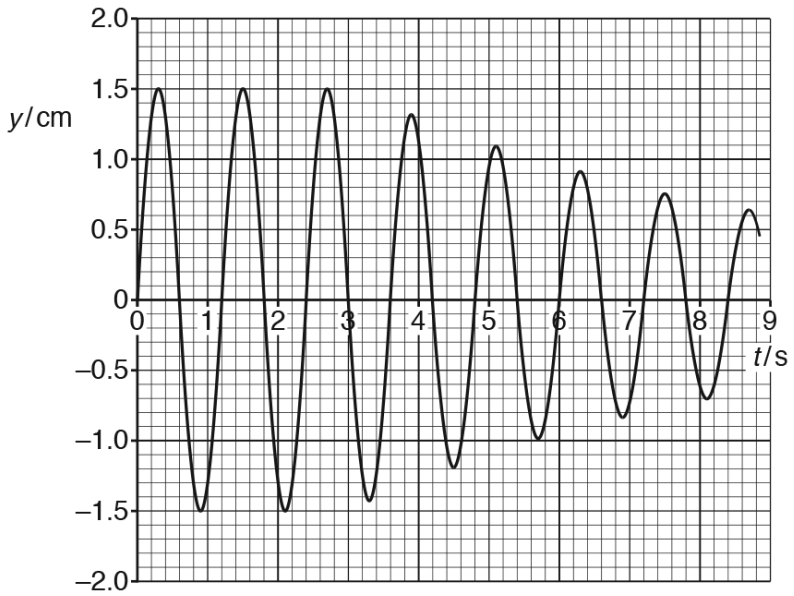


Fig. 2.2

(a) Determine, to two significant figures, the frequency of oscillation of the magnet.

frequency = ... Hz [2]

(b) State whether the closing of the switch gives rise to light, heavy or critical damping.

.....[1]

(c) Calculate the change in the energy ΔE of oscillation of the magnet between time $t = 2.7\,\text{s}$ and time $t = 7.5\,\text{s}$. Explain your working.

ΔE = ... J [6]

[Total: 9]

Q1.

3 An aluminium sheet is suspended from an oscillator by means of a spring, as illustrated in Fig. 3.1.

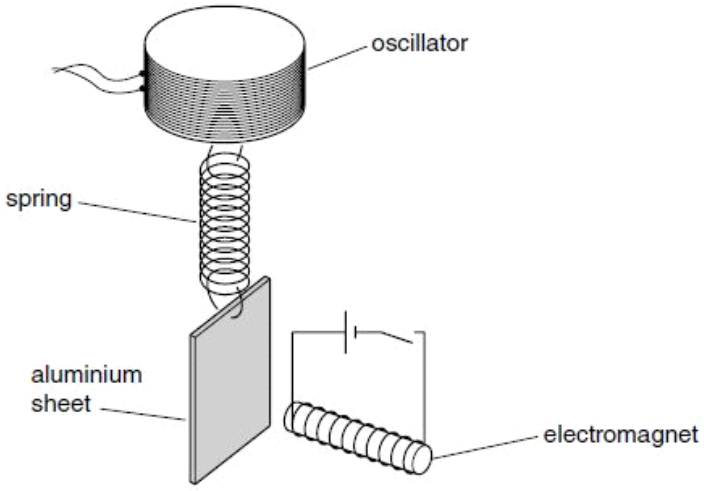


Fig. 3.1

An electromagnet is placed a short distance from the centre of the aluminium sheet.

The electromagnet is switched off and the frequency f of oscillation of the oscillator is gradually increased from a low value. The variation with frequency f of the amplitude a of vibration of the sheet is shown in Fig. 3.2.

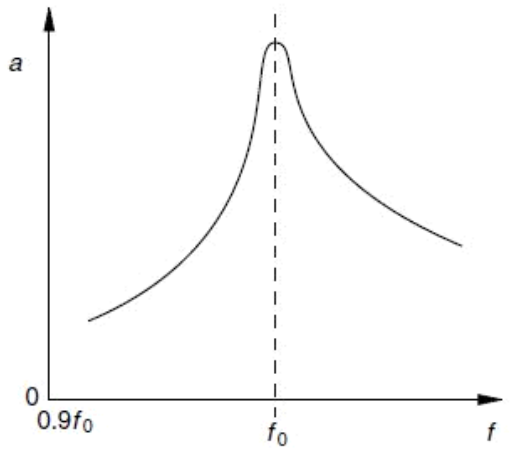


Fig. 3.2

A peak on the graph appears at frequency f_0.

(a) Explain why there is a peak at frequency f_0.

.....

.....

..... [2]

(b) The electromagnet is now switched on and the frequency of the oscillator is again gradually increased from a low value. On Fig. 3.2, draw a line to show the variation with frequency f of the amplitude a of vibration of the sheet. [3]

(c) The frequency of the oscillator is now maintained at a constant value. The amplitude of vibration is found to decrease when the current in the electromagnet is switched on.

Use the laws of electromagnetic induction to explain this observation.

.....

.....

.....

.....

.....

..... [4]

Q2.

4 A vertical spring supports a mass, as shown in Fig. 4.1.

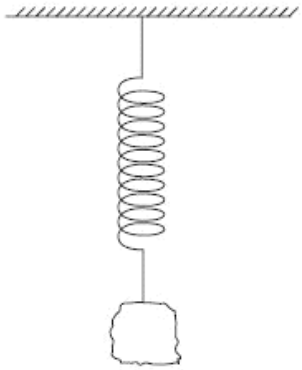


Fig. 4.1

The mass is displaced vertically then released. The variation with time t of the displacement y from its mean position is shown in Fig. 4.2.

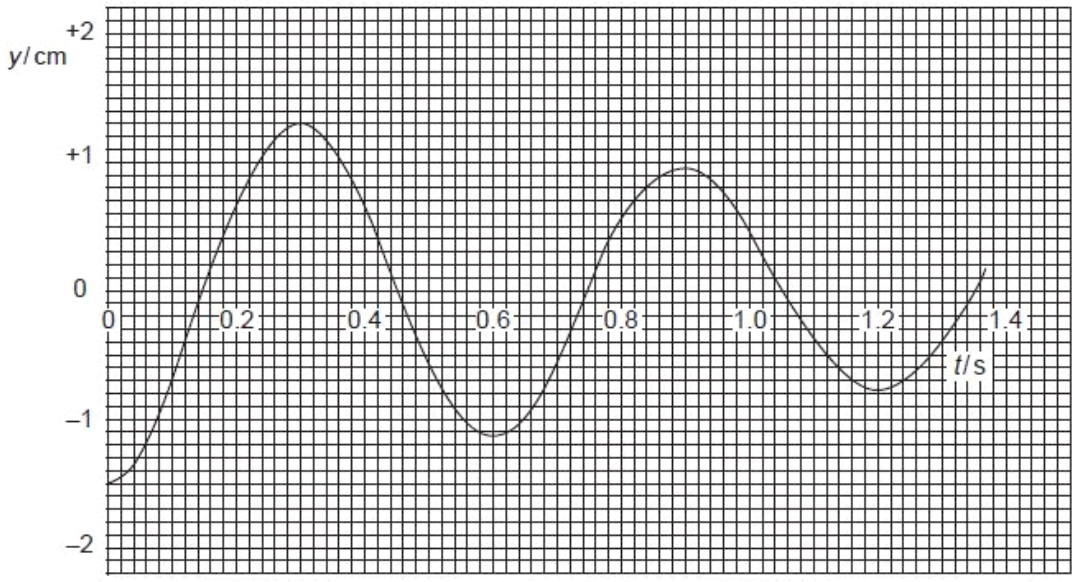


Fig. 4.2

A student claims that the motion of the mass may be represented by the equation

$$y = y_0 \sin \omega t.$$

(a) Give two reasons why the use of this equation is inappropriate.

1. .....

.....

2. .....

..... [2]

(b) Determine the angular frequency ω of the oscillations.

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

(c) The mass is a lump of plasticine. The plasticine is now flattened so that its surface area is increased. The mass of the lump remains constant and the large surface area is horizontal.
The plasticine is displaced downwards by 1.5 cm and then released.
On Fig. 4.2, sketch a graph to show the subsequent oscillations of the plasticine. [3]

Q3.

4 A tube, closed at one end, has a constant area of cross-section A. Some lead shot is placed in the tube so that the tube floats vertically in a liquid of density ρ, as shown in Fig. 4.1.

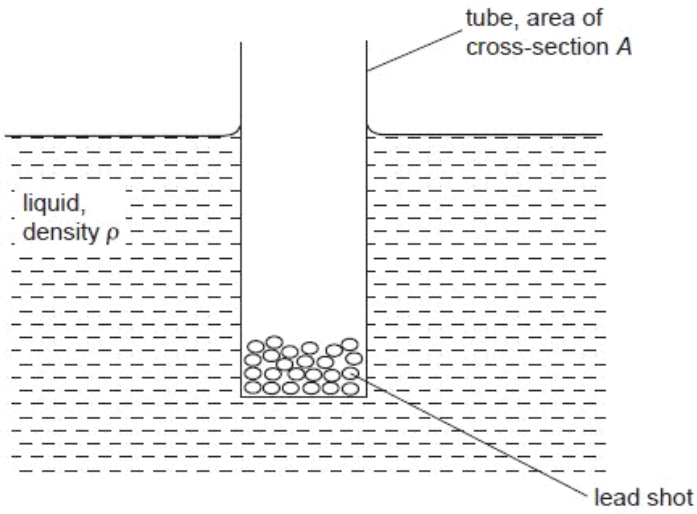


Fig. 4.1

The total mass of the tube and its contents is M.
When the tube is given a small vertical displacement and then released, the vertical acceleration a of the tube is related to its vertical displacement y by the expression

$$a = -\frac{A\rho g}{M} y,$$

where g is the acceleration of free fall.

(a) Define *simple harmonic motion*.

.....

.....

.....[2]

(b) Show that the tube is performing simple harmonic motion with a frequency f given by

$$f = \frac{1}{2\pi}\sqrt{\frac{A\rho g}{M}}.$$

[3]

(c) Fig. 4.2 shows the variation with time t of the vertical displacement y of the tube in another liquid.

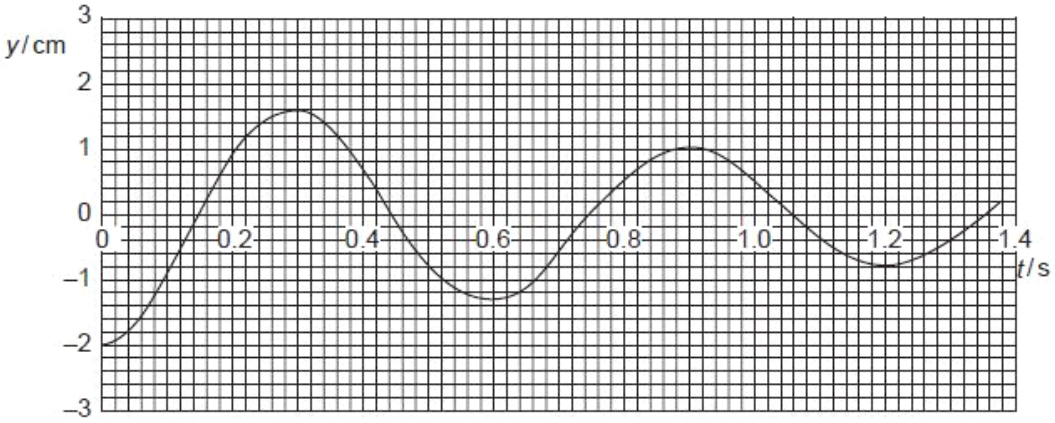


Fig. 4.2

(i) The tube has an external diameter of 2.4 cm and is floating in a liquid of density 950 kg m^{-3}. Assuming the equation in **(b)**, calculate the mass of the tube and its contents.

mass = ... kg [3]

(ii) State what feature of Fig. 4.2 indicates that the oscillations are damped.

.....

.....[1]

Q4.

4 A piston moves vertically up and down in a cylinder, as illustrated in Fig. 4.1.

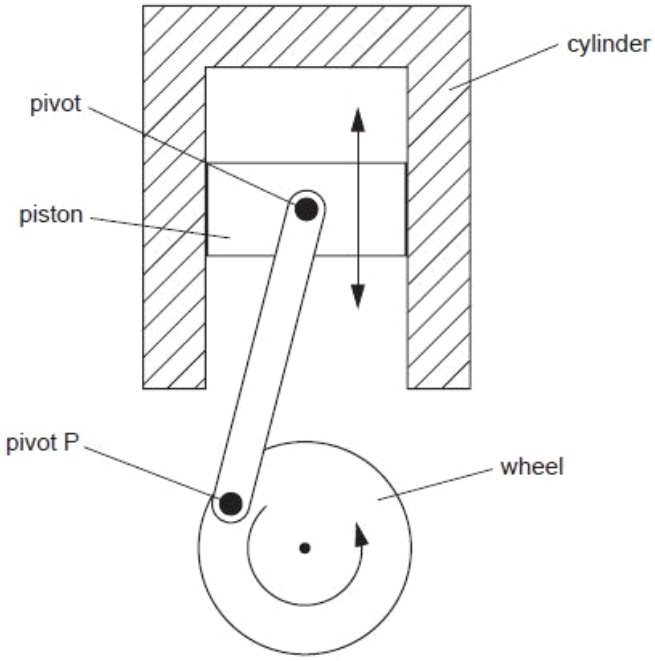


Fig. 4.1

The piston is connected to a wheel by means of a rod that is pivoted at the piston and at the wheel. As the piston moves up and down, the wheel is made to rotate.

(a) **(i)** State the number of oscillations made by the piston during one complete rotation of the wheel.

number = ... [1]

(ii) The wheel makes 2400 revolutions per minute. Determine the frequency of oscillation of the piston.

frequency = ... Hz [1]

(b) The amplitude of the oscillations of the piston is 42 mm.

Assuming that these oscillations are simple harmonic, calculate the maximum values for the piston of

(i) the linear speed,

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

(ii) the acceleration.

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

(c) On Fig. 4.1, mark a position of the pivot P for the piston to have

(i) maximum speed (mark this position S), [1]

(ii) maximum acceleration (mark this position A). [1]

Q5.

7 A magnet is suspended vertically from a fixed point by means of a spring, as shown in Fig. 7.1.

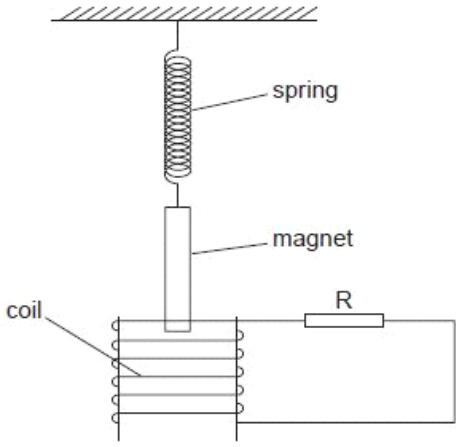


Fig. 7.1

One end of the magnet hangs inside a coil of wire. The coil is connected in series with a resistor R.

(a) The magnet is displaced vertically a small distance *D* and then released.
Fig. 7.2 shows the variation with time *t* of the vertical displacement *d* of the magnet from its equilibrium position.

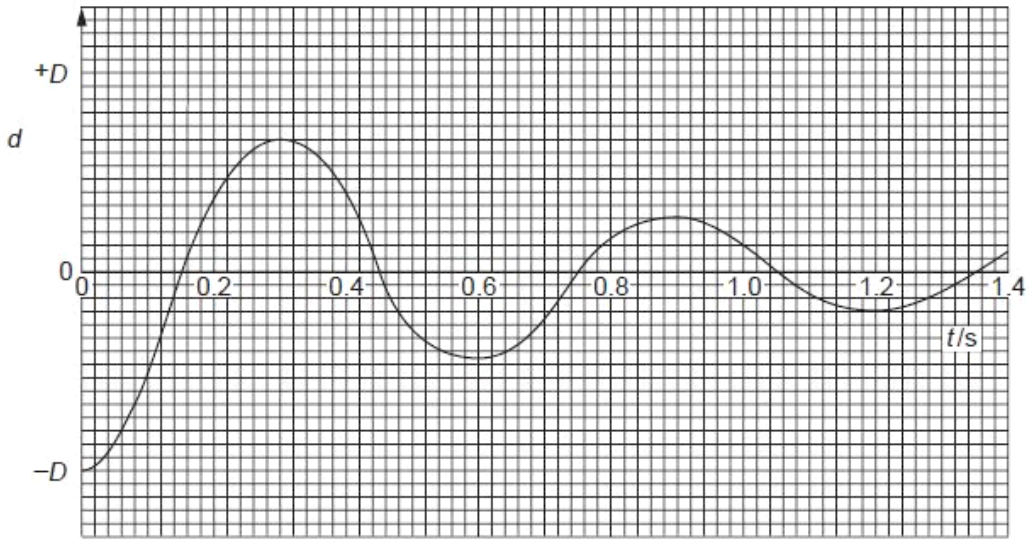


Fig. 7.2

(i) State and explain, by reference to electromagnetic induction, the nature of the oscillations of the magnet.

.....

.....

.....

.....

.....

..... [5]

(ii) Calculate the angular frequency ω_0 of the oscillations.

ω_0 = ... rad s^{-1} [2]

(b) The resistance of the resistor R is increased.
The magnet is again displaced a vertical distance *D* and released.
On Fig. 7.2, sketch the variation with time *t* of the displacement *d* of the magnet. [2]

(c) The resistor R in Fig. 7.1 is replaced by a variable-frequency signal generator of constant r.m.s. output voltage.
The angular frequency ω of the generator is gradually increased from about $0.7\omega_0$ to about $1.3\omega_0$, where ω_0 is the angular frequency calculated in **(a)(ii)**.

(i) On the axes of Fig. 7.3, sketch a graph to show the variation with ω of the amplitude A of the oscillations of the magnet. [2]

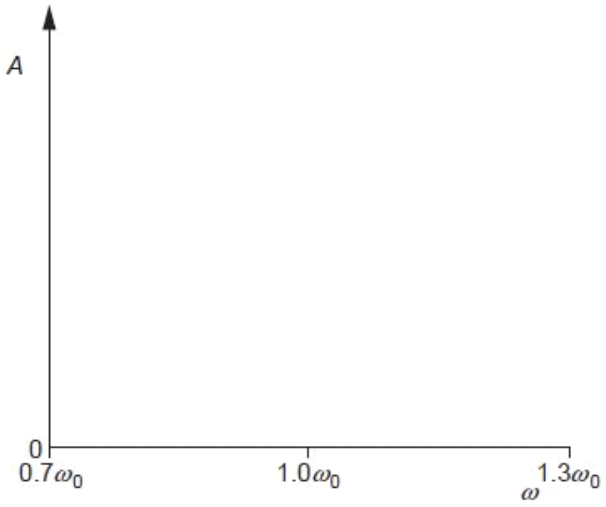


Fig. 7.3

(ii) State the name of the phenomenon illustrated in the graph of Fig. 7.3.

..... [1]

(iii) Briefly describe one situation where the phenomenon named in **(ii)** is useful and one situation where it should be avoided.

useful: .....

.....

avoid: .....

..... [2]

Q6.

3 A tube, closed at one end, has a uniform area of cross-section. The tube contains some sand so that the tube floats upright in a liquid, as shown in Fig. 3.1.

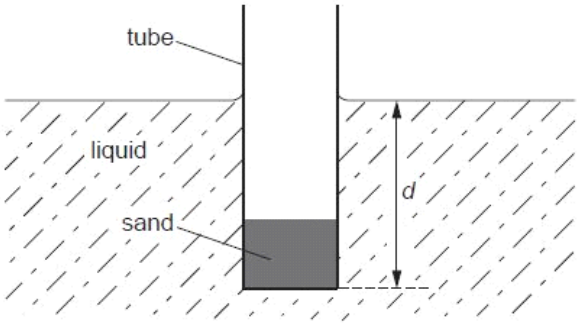


Fig. 3.1

When the tube is at rest, the depth d of immersion of the base of the tube is 16 cm.
The tube is displaced vertically and then released.
The variation with time t of the depth d of the base of the tube is shown in Fig. 3.2.

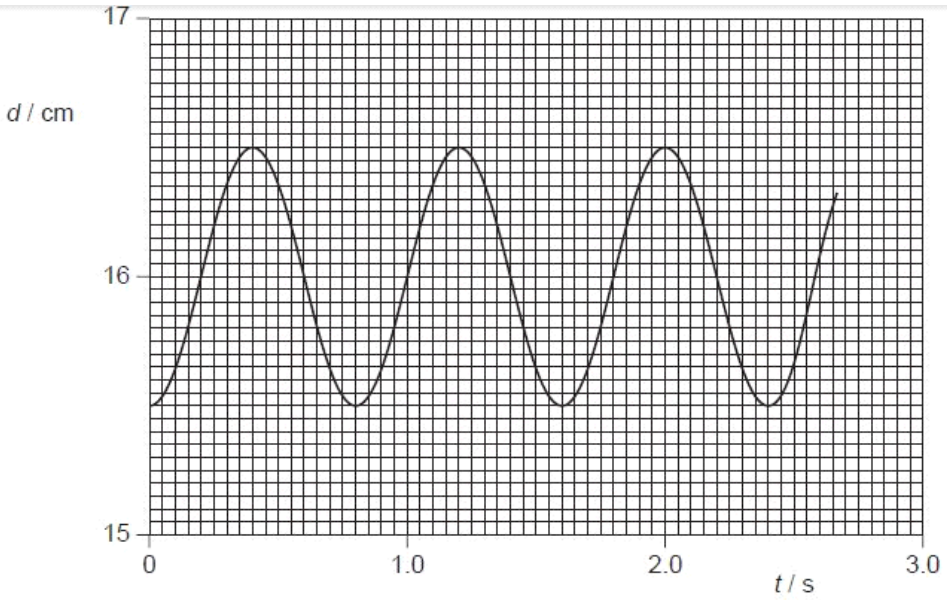


Fig. 3.2

(a) Use Fig. 3.2 to determine, for the oscillations of the tube,

(i) the amplitude,

amplitude = ... cm [1]

(ii) the period.

period = ... s [1]

(b) **(i)** Calculate the vertical speed of the tube at a point where the depth d is 16.2 cm.

F
Exam
U

speed = ... cm s^{-1} [3]

(ii) State **one** other depth d where the speed will be equal to that calculated in **(i)**.

d = ... cm [1]

(c) **(i)** Explain what is meant by *damping*.

.....

.....

.....

.....[2]

(ii) The liquid in **(b)** is now cooled so that, although the density is unchanged, there is friction between the liquid and the tube as it oscillates. Having been displaced, the tube completes approximately 10 oscillations before coming to rest.
On Fig. 3.2, draw a line to show the variation with time t of depth d for the first 2.5 s of the motion. [3]

Q7.

3 **(a)** State what is meant by

(i) *oscillations*,

.....

.....[1]

(ii) *free* oscillations,

.....

.....[1]

(iii) *simple harmonic motion*.

.....

.....

.....[2]

(b) Two inclined planes RA and LA each have the same constant gradient. They meet at their lower edges, as shown in Fig. 3.1.

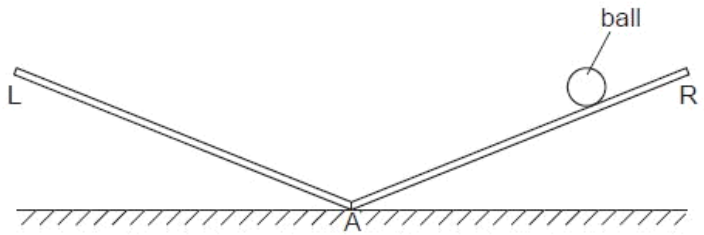


Fig. 3.1

A small ball moves from rest down plane RA and then rises up plane LA. It then moves down plane LA and rises up plane RA to its original height. The motion repeats itself.

State and explain whether the motion of the ball is simple harmonic.

.....

.....

.....[2]

Q8.

2 A long strip of springy steel is clamped at one end so that the strip is vertical. A mass of 65 g is attached to the free end of the strip, as shown in Fig. 2.1.

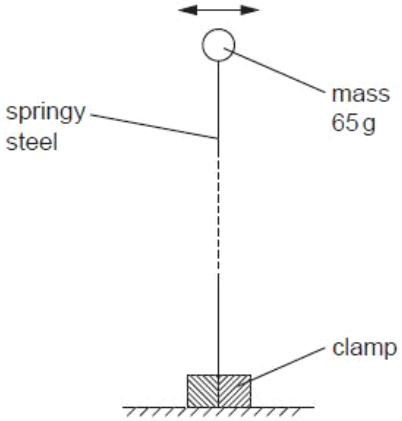


Fig. 2.1

The mass is pulled to one side and then released. The variation with time t of the horizontal displacement of the mass is shown in Fig. 2.2.

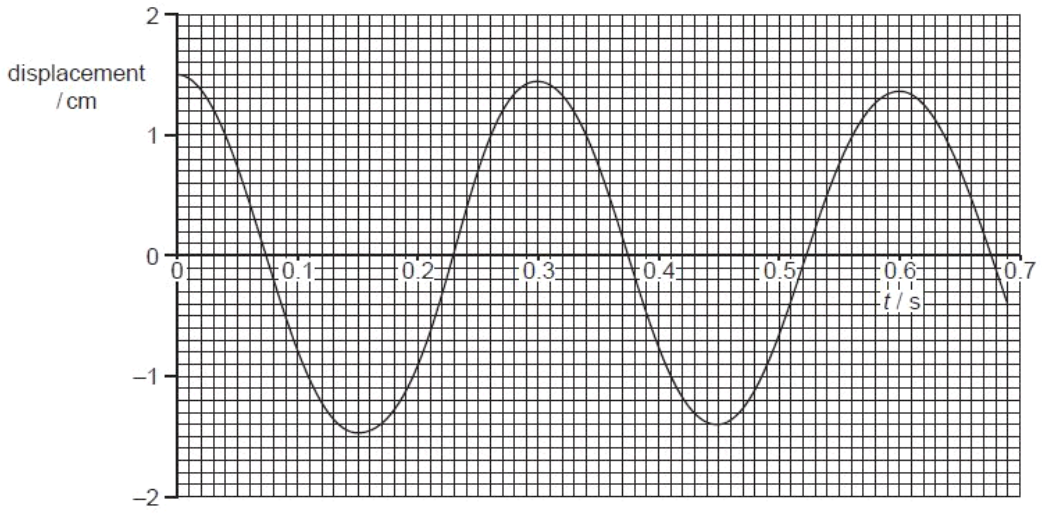


Fig. 2.2

The mass undergoes damped simple harmonic motion.

(a) (i) Explain what is meant by *damping*.

.....

.....

..... [2]

(ii) Suggest, with a reason, whether the damping is light, critical or heavy.

For Examiner's Use

.....

.....

..... [2]

(b) (i) Use Fig. 2.2 to determine the frequency of vibration of the mass.

frequency = ... Hz [1]

(ii) Hence show that the initial energy stored in the steel strip before the mass is released is approximately 3.2 mJ.

[2]

(c) After eight complete oscillations of the mass, the amplitude of vibration is reduced from 1.5 cm to 1.1 cm. State and explain whether, after a further eight complete oscillations, the amplitude will be 0.7 cm.

.....

.....

..... [2]

Q9.

3 **(a)** Define *simple harmonic motion*.

.....

.....

.....[2]

(b) A tube, sealed at one end, has a total mass m and a uniform area of cross-section A. The tube floats upright in a liquid of density ρ with length L submerged, as shown in Fig. 3.1a.

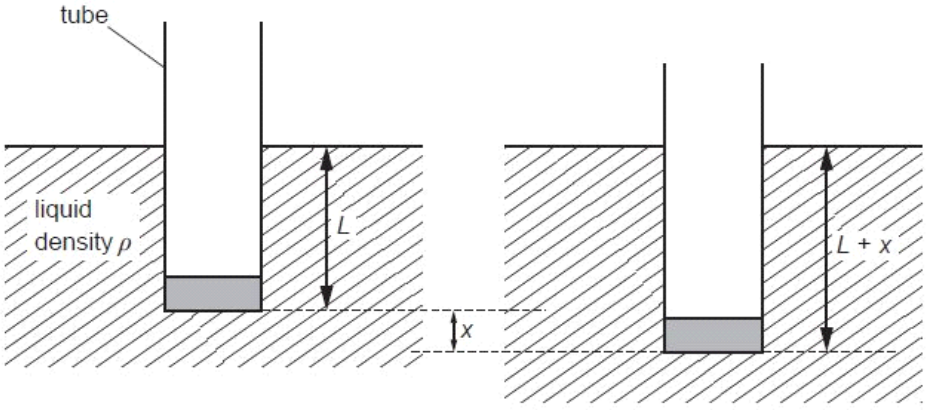


Fig. 3.1a **Fig. 3.1b**

The tube is displaced vertically and then released. The tube oscillates vertically in the liquid.
At one time, the displacement is x, as shown in Fig. 3.1b.

Theory shows that the acceleration a of the tube is given by the expression

$$a = -\frac{A\rho g}{m}x.$$

(i) Explain how it can be deduced from the expression that the tube is moving with simple harmonic motion.

.....

.....

.....[2]

(ii) The tube, of area of cross-section $4.5\,cm^2$, is floating in water of density $1.0 \times 10^3\,kg\,m^{-3}$.

Calculate the mass of the tube that would give rise to oscillations of frequency 1.5 Hz.

mass = ... g [4]

For Examin Use

Q10.

4 A small metal ball is suspended from a fixed point by means of a string, as shown in Fig. 4.1.

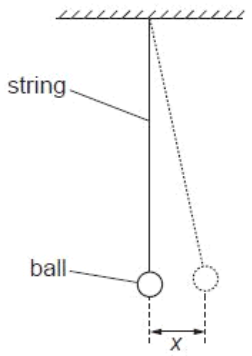


Fig. 4.1

The ball is pulled a small distance to one side and then released. The variation with time t of the horizontal displacement x of the ball is shown in Fig. 4.2.

For Examine Use

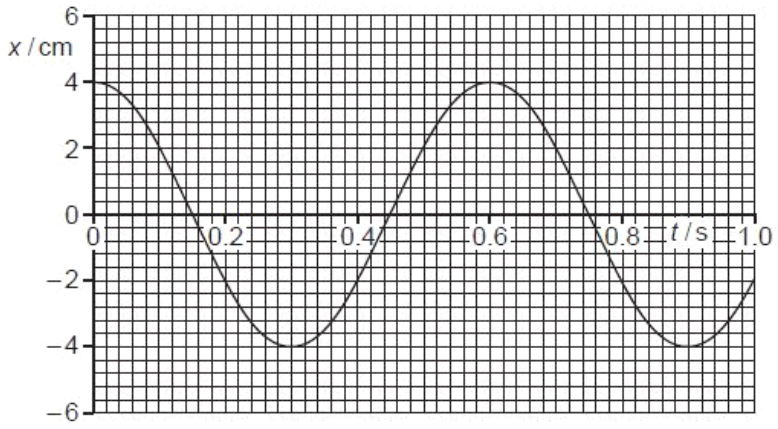


Fig. 4.2

The motion of the ball is simple harmonic.

(a) Use data from Fig. 4.2 to determine the horizontal acceleration of the ball for a displacement x of 2.0 cm.

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

(b) The maximum kinetic energy of the ball is E_K.
On the axes of Fig. 4.3, sketch a graph to show the variation with time t of the kinetic energy of the ball for the first 1.0 s of its motion.

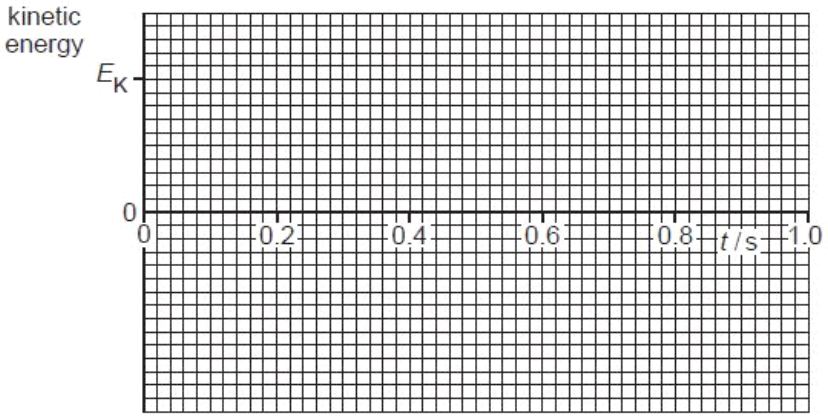


Fig. 4.3

[3]

Q11.

2 A ball of mass 37 g is held between two fixed points A and B by two stretched helical springs, as shown in Fig. 2.1.

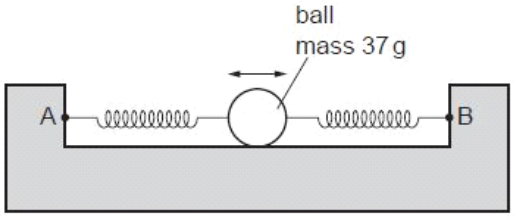


Fig. 2.1

The ball oscillates along the line AB with simple harmonic motion of frequency 3.5 Hz and amplitude 2.8 cm.

(a) Show that the total energy of the oscillations is 7.0 mJ.

[2]

(b) At two points in the oscillation of the ball, its kinetic energy is equal to the potential energy stored in the springs.
Calculate the magnitude of the displacement at which this occurs.

displacement = ... cm [3]

(c) On the axes of Fig. 2.2 and using your answers in **(a)** and **(b)**, sketch a graph to show the variation with displacement *x* of

(i) the total energy of the system (label this line T), [1]

(ii) the kinetic energy of the ball (label this line K), [2]

(iii) the potential energy stored in the springs (label this line P). [2]

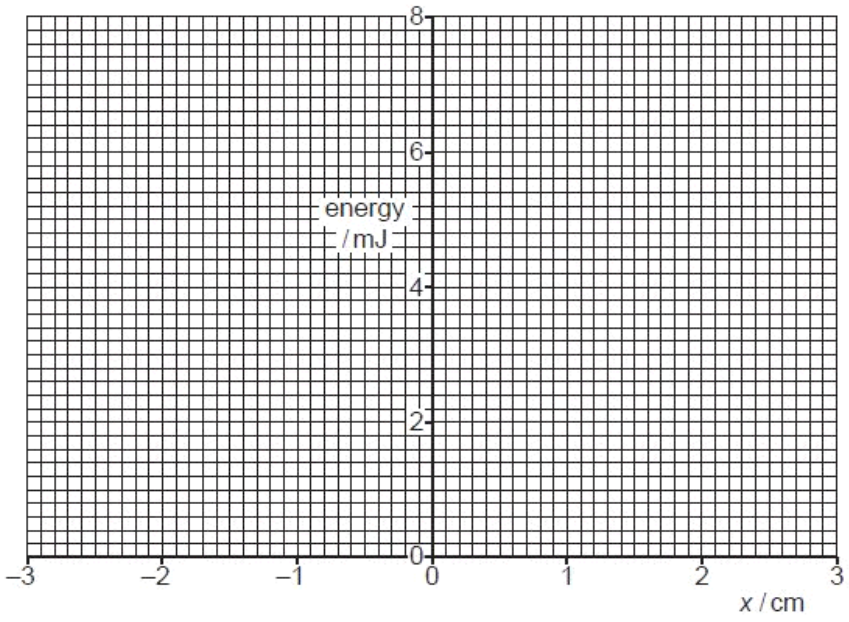


Fig. 2.2

(d) The arrangement in Fig. 2.1 is now rotated through 90° so that the line AB is vertical and the ball oscillates in a vertical plane.

Suggest one form of energy, other than those in **(c)**, that must be taken into consideration when plotting new graphs to show energy changes with displacement.

.....[1]

Q12.

3 A ball is held between two fixed points A and B by means of two stretched springs, as shown in Fig. 3.1.

For Examiner Use

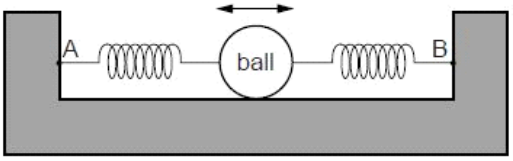


Fig. 3.1

The ball is free to oscillate along the straight line AB. The springs remain stretched and the motion of the ball is simple harmonic.

The variation with time t of the displacement x of the ball from its equilibrium position is shown in Fig. 3.2.

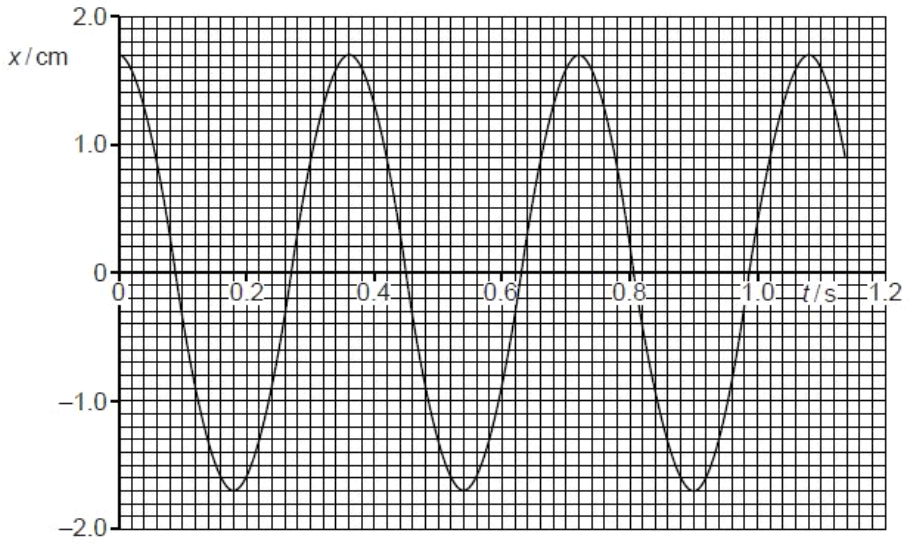


Fig. 3.2

(a) **(i)** Use Fig. 3.2 to determine, for the oscillations of the ball,

1. the amplitude,

amplitude = ... cm [1]

2. the frequency.

frequency = ... Hz [2]

(ii) Show that the maximum acceleration of the ball is $5.2\,m\,s^{-2}$.

[2]

(b) Use your answers in **(a)** to plot, on the axes of Fig. 3.3, the variation with displacement x of the acceleration a of the ball.

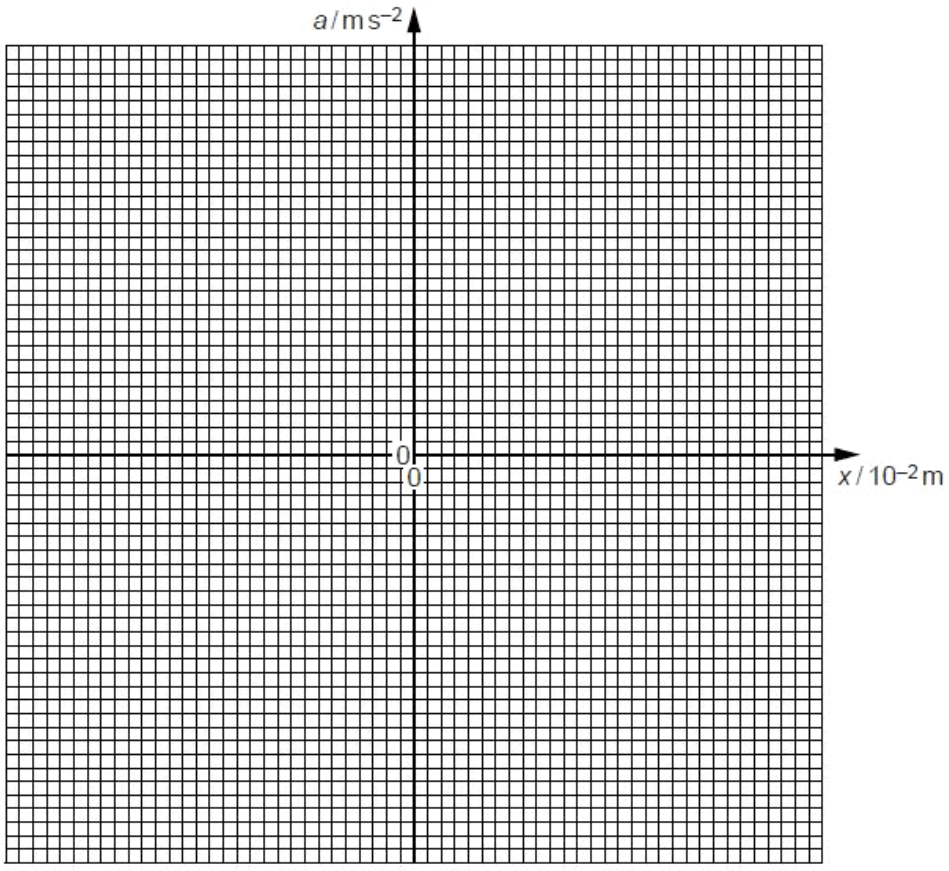


Fig. 3.3 [2]

(c) Calculate the displacement of the ball at which its kinetic energy is equal to one half of the maximum kinetic energy.

For Examin Use

displacement = ... cm [3]

Q13.

3 A mass of 78 g is suspended from a fixed point by means of a spring, as illustrated in Fig. 3.1.

For Examiner's Use

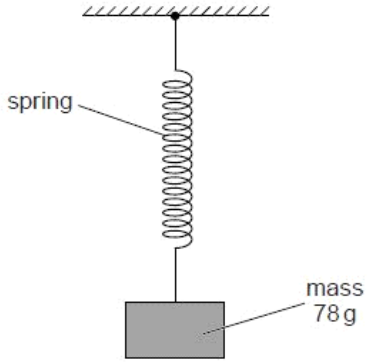


Fig. 3.1

The stationary mass is pulled vertically downwards through a distance of 2.1 cm and then released.
The mass is observed to perform simple harmonic motion with a period of 0.69 s.

(a) The mass is released at time $t = 0$.

For the oscillations of the mass,

(i) calculate the angular frequency ω,

$\omega =$ ..... rad s^{-1} [2]

(ii) determine numerical equations for the variation with time t of

1. the displacement x in cm,

.....

..... [2]

2. the speed v in m s^{-1}.

.....

..... [2]

(b) Calculate the total energy of oscillation of the mass.

For Examiner Use

energy = ... J [2]

Q14.

3 A student sets out to investigate the oscillation of a mass suspended from the free end of a spring, as illustrated in Fig. 3.1.

Use

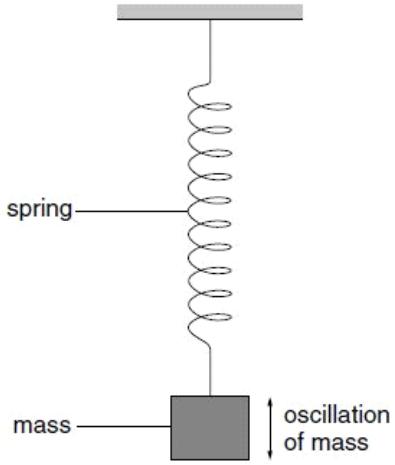


Fig. 3.1

The mass is pulled downwards and then released. The variation with time t of the displacement y of the mass is shown in Fig. 3.2.

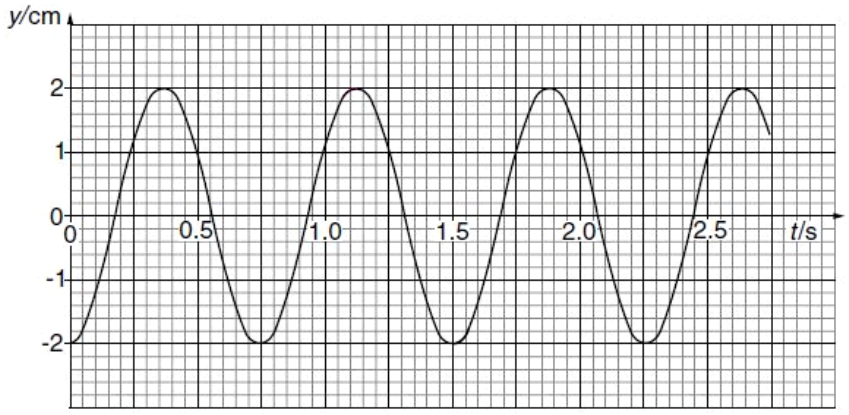


Fig. 3.2

(a) Use information from Fig. 3.2

(i) to explain why the graph suggests that the oscillations are undamped,

.....

Use

(ii) to calculate the angular frequency of the oscillations,

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

(iii) to determine the maximum speed of the oscillating mass.

speed = ... m s^{-1}

[6]

(b) (i) Determine the resonant frequency f_0 of the mass-spring system.

f_0 = ... Hz

(ii) The student finds that if short impulsive forces of frequency $\frac{1}{2}f_0$ are impressed on the mass-spring system, a large amplitude of oscillation is obtained. Explain this observation.

.....

.....

.....

[3]

Q15.

2 (a) The defining equation of simple harmonic motion is

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

(i) Identify the symbols in the equation.

a .....

ω .....

x .....

(ii) State the significance of the negative (–) sign in the equation.

.....

.....

[3]

(b) A frictionless trolley of mass m is held on a horizontal surface by means of two similar springs, each of spring constant k. The springs are attached to fixed points as illustrated in Fig. 2.1.

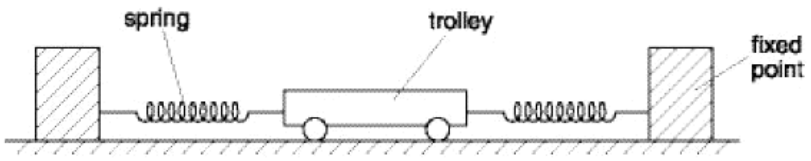


Fig. 2.1

When the trolley is in equilibrium, the extension of each spring is e.

The trolley is then displaced a small distance x to the right along the axis of the springs. Both springs remain extended.

(i) Show that the magnitude F of the restoring force acting on the trolley is given by

$$F = 2kx.$$

[2]

(ii) The trolley is then released. Show that the acceleration a of the trolley is given by

$$a = \frac{-2kx}{m}.$$

[2]

(iii) The mass m of the trolley is 900 g and the spring constant k is 120 $N\,m^{-1}$. By comparing your answer to **(a)(i)** and the equation in **(b)(ii)**, determine the frequency of oscillation of the trolley.

frequency = ... Hz [3]

(c) Suggest why the trolley in **(b)** provides a simple model for the motion of an atom in a crystal.

.....

.....

..... [2]

Q16.

Use

3 The vibrations of a mass of 150 g are simple harmonic. Fig. 3.1 shows the variation with displacement x of the kinetic energy E_k of the mass.

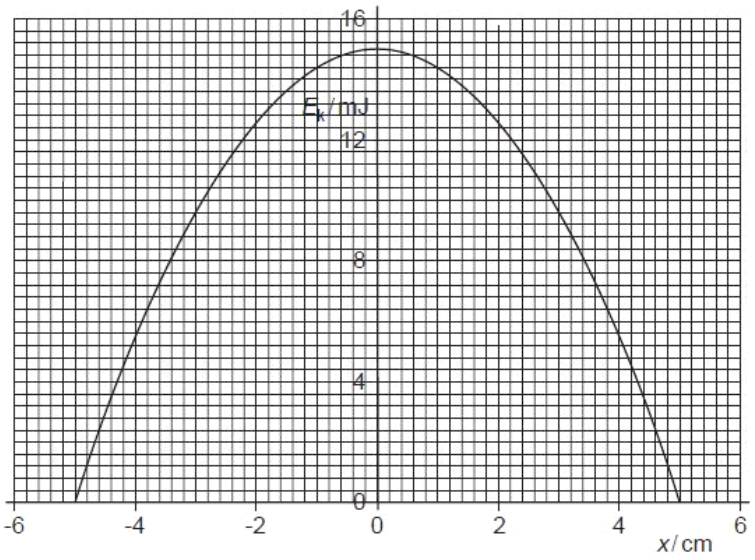


Fig. 3.1

(a) On Fig. 3.1, draw lines to represent the variation with displacement x of

(i) the potential energy of the vibrating mass (label this line P),

(ii) the total energy of the vibrations (label this line T).

[2]

(b) Calculate the angular frequency of the vibrations of the mass.

angular frequency = ... rad s^{-1} [3]

Use

(c) The oscillations are now subject to damping.

(i) Explain what is meant by *damping*.

.....

.....

.....[2]

(ii) The mass loses 20% of its vibrational energy. Use Fig. 3.1 to determine the new amplitude of oscillation. Explain your working.

amplitude = ... cm [2]

Q17.

Use

4 The centre of the cone of a loudspeaker is oscillating with simple harmonic motion of frequency 1400 Hz and amplitude 0.080 mm.

(a) Calculate, to two significant figures,

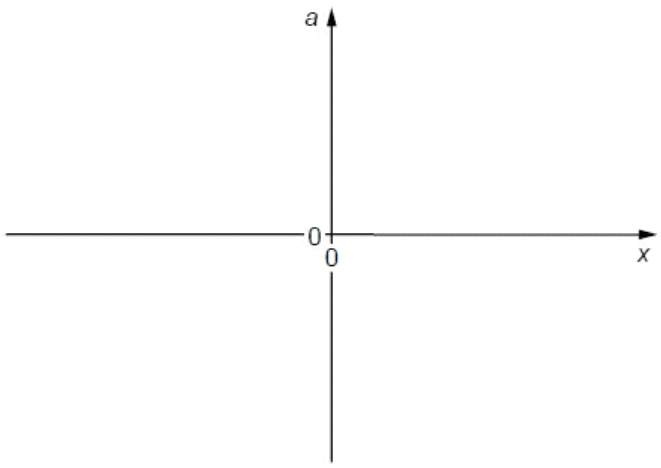
(i) the angular frequency ω of the oscillations,

ω = ... rad s^{-1} [2]

(ii) the maximum acceleration, in m s^{-2}, of the centre of the cone.

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

(b) On the axes of Fig. 4.1, sketch a graph to show the variation with displacement x of the acceleration a of the centre of the cone.



[2]

Fig. 4.1

(c) **(i)** State the value of the displacement x at which the speed of the centre of the cone is a maximum.

x = ... mm [1]

(ii) Calculate, in $m\,s^{-1}$, this maximum speed.

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

Q18.

3 Two vertical springs, each having spring constant k, support a mass. The lower spring is attached to an oscillator as shown in Fig. 3.1.

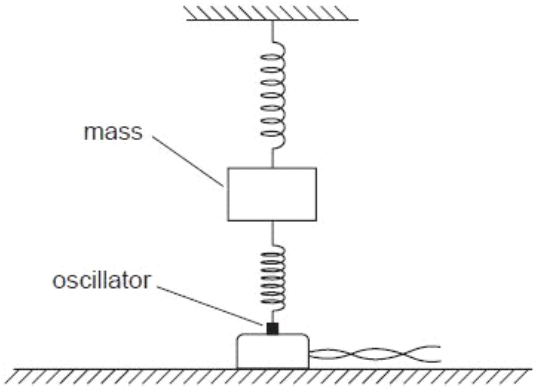


Fig. 3.1

The oscillator is switched off. The mass is displaced vertically and then released so that it vibrates. During these vibrations, the springs are always extended. The vertical acceleration a of the mass m is given by the expression

$$ma = -2kx,$$

where x is the vertical displacement of the mass from its equilibrium position.

(a) Show that, for a mass of 240 g and springs with spring constant 3.0 N cm^{-1}, the frequency of vibration of the mass is approximately 8 Hz.

[4]

(b) The oscillator is switched on and the frequency f of vibration is gradually increased. The amplitude of vibration of the oscillator is constant.

Fig. 3.2 shows the variation with f of the amplitude A of vibration of the mass.

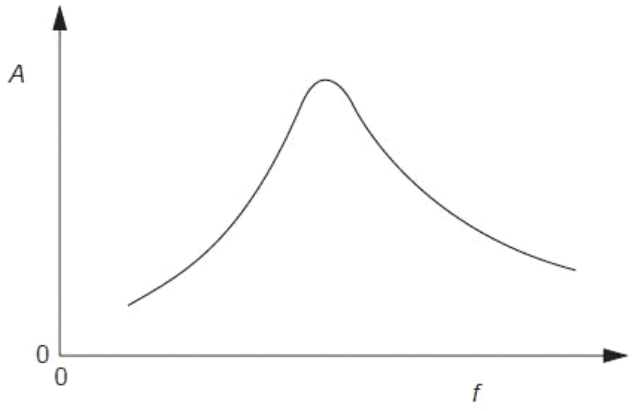


Fig. 3.2

State

(i) the name of the phenomenon illustrated in Fig. 3.2,

..... [1]

(ii) the frequency f_0 at which maximum amplitude occurs.

frequency = ... Hz [1]

(c) Suggest and explain how the apparatus in Fig. 3.1 could be modified to make the peak on Fig. 3.2 flatter, without significantly changing the frequency f_0 at which the peak occurs.

.....

.....

.....

..... [3]

Q19.

Use

3 A spring is hung from a fixed point. A mass of 130 g is hung from the free end of the spring, as shown in Fig. 3.1.

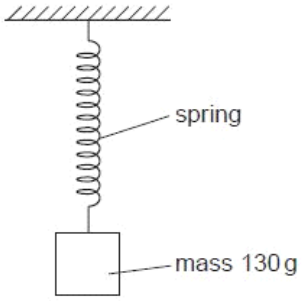


Fig. 3.1

The mass is pulled downwards from its equilibrium position through a small distance *d* and is released. The mass undergoes simple harmonic motion.
Fig. 3.2 shows the variation with displacement *x* from the equilibrium position of the kinetic energy of the mass.

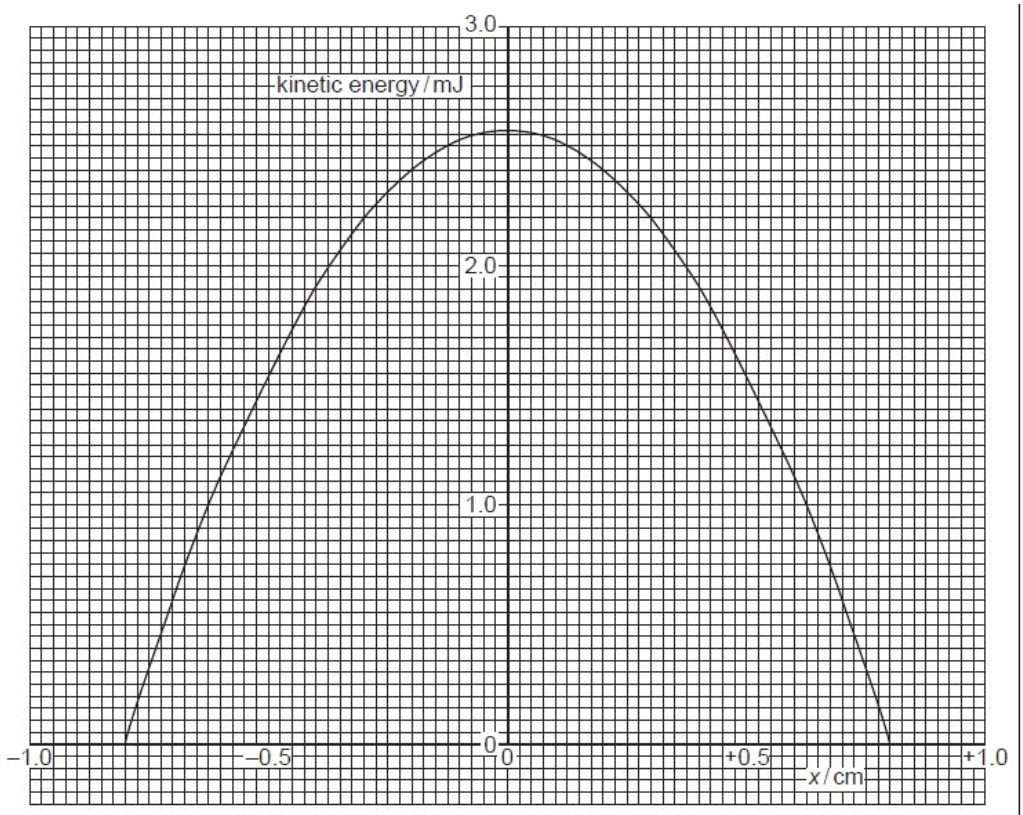


Fig. 3.2

Use

(a) Use Fig. 3.2 to

(i) determine the distance *d* through which the mass was displaced initially,

d = ... cm [1]

(ii) show that the frequency of oscillation of the mass is approximately 4.0 Hz.

[6]

(b) **(i)** On Fig. 3.2, draw a line to represent the total energy of the oscillating mass. [1]

(ii) After many oscillations, damping reduces the total energy of the mass to 1.0 mJ. For the oscillations with reduced energy,

1. state the frequency,

frequency = ...Hz

2. using the graph, or otherwise, state the amplitude.

amplitude = ... cm [2]

Q20.

3 The needle of a sewing machine is made to oscillate vertically through a total distance of 22 mm, as shown in Fig. 3.1.

For Examin Use

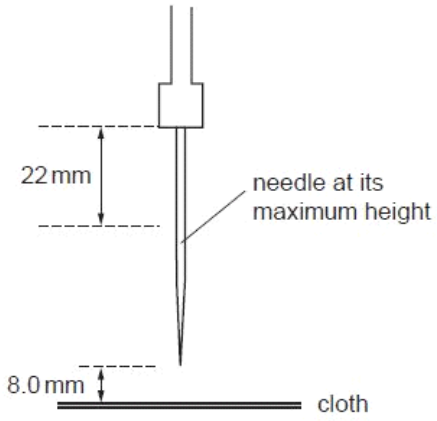


Fig. 3.1

The oscillations are simple harmonic with a frequency of 4.5 Hz.
The cloth that is being sewn is positioned 8.0 mm below the point of the needle when the needle is at its maximum height.

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

.....

.....

.....[2]

(b) The displacement y of the point of the needle may be represented by the equation

$$y = a\cos\omega t.$$

(i) Suggest the position of the point of the needle at time $t = 0$.

.....[1]

(ii) Determine the values of

1. a,

$a =$ ..... mm [1]

2. ω.

$\omega =$ ..... rad s^{-1} [2]

(c) Calculate, for the point of the needle,

For Examiner's Use

(i) its maximum speed,

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

(ii) its speed as it moves downwards through the cloth.

speed = ... $m\,s^{-1}$ [3]

Q21.

4 The variation with time t of the displacement x of the cone of a loudspeaker is shown in Fig. 4.1.

For Examiner Use

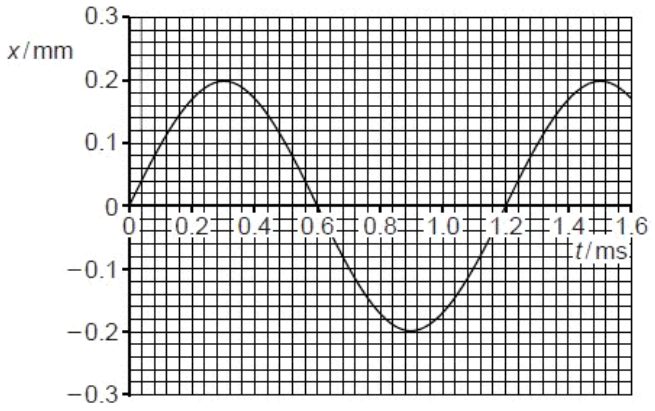


Fig. 4.1

(a) Use Fig. 4.1 to determine, for these oscillations,

(i) the amplitude,

amplitude = ... mm [1]

(ii) the frequency.

frequency = ... Hz [2]

(b) State two times at which

(i) the speed of the cone is maximum,

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

(ii) the acceleration of the cone is maximum.

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

(c) The effective mass of the cone is 2.5 g.

Use your answers in **(a)** to determine the maximum kinetic energy of the cone.

kinetic energy = ... J [3]

(d) The loudspeaker must be designed so that resonance of the cone is avoided.

(i) State what is meant by *resonance*.

.....

.....

..... [2]

(ii) State and briefly explain one other situation in which resonance should be avoided.

.....

.....

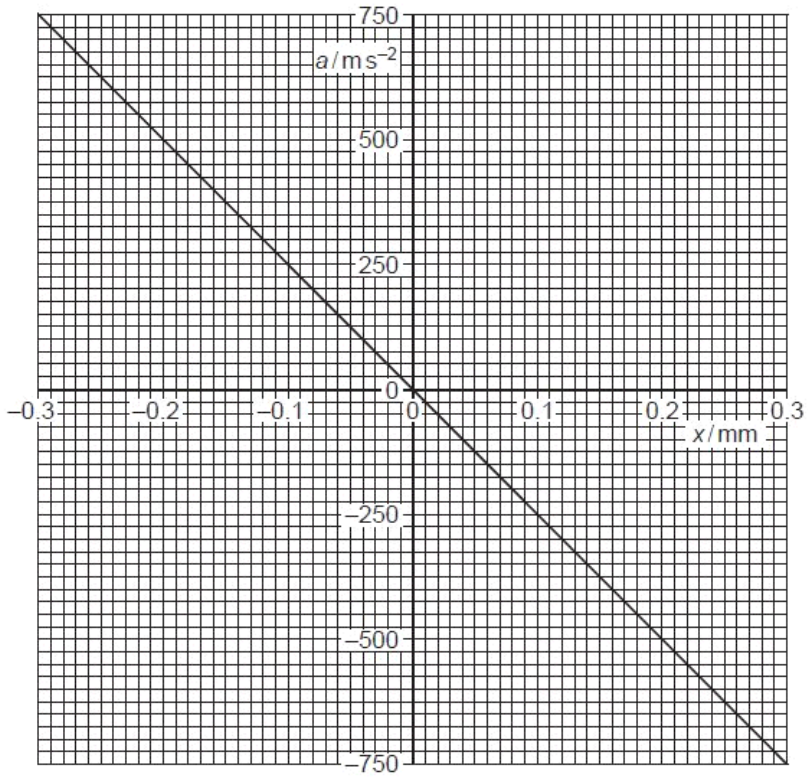
.....

..... [2]

Q22.

3 The variation with displacement x of the acceleration a of the centre of the cone of a loudspeaker is shown in Fig. 3.1.

For Examiner Use



(a) State the two features of Fig. 3.1 that show that the motion of the cone is simple harmonic.

1. .....

2. .....

[2]

(b) Use data from Fig. 3.1 to determine the frequency, in hertz, of vibration of the cone.

frequency = ... Hz [3]

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(c) The frequency of vibration of the cone is now reduced to one half of that calculated in **(b)**.

The amplitude of vibration remains unchanged.

On the axes of Fig. 3.1, draw a line to represent the variation with displacement x of the acceleration a of the centre of the loudspeaker cone.

[2]

For Examiner Use

Q23.

3 A student sets up the apparatus illustrated in Fig. 3.1 in order to investigate the oscillations of a metal cube suspended on a spring.

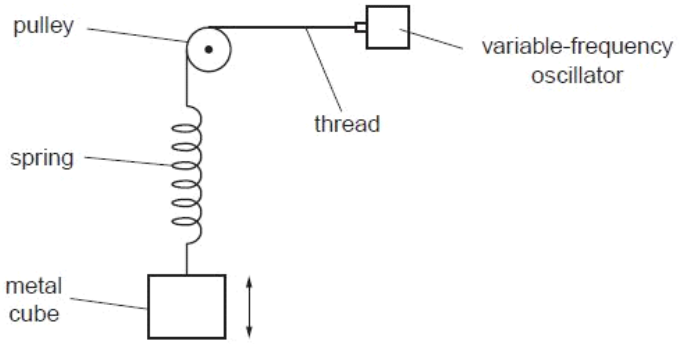


Fig. 3.1

The amplitude of the vibrations produced by the oscillator is constant.
The variation with frequency of the amplitude of the oscillations of the metal cube is shown in Fig. 3.2.

For Examiner's Use

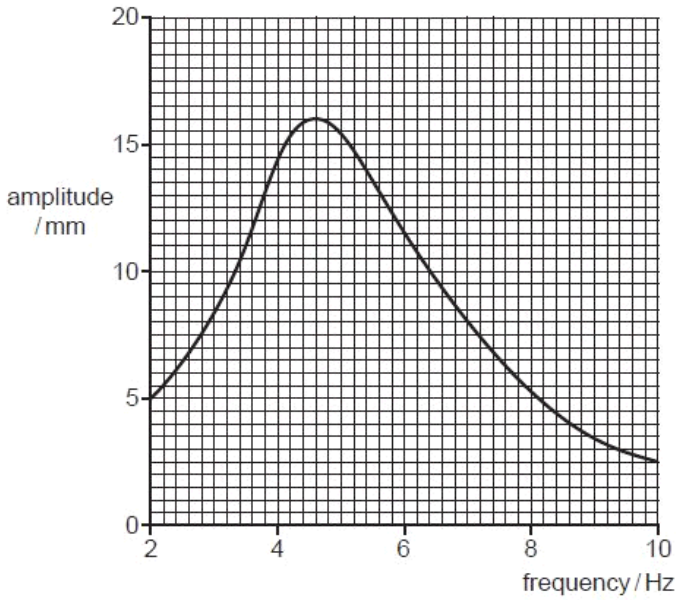


Fig. 3.2

(a) (i) State the phenomenon illustrated in Fig. 3.2.

.....[1]

(ii) For the maximum amplitude of vibration, state the magnitudes of the amplitude and the frequency.

amplitude = ... mm

frequency = ... Hz

[1]

(b) The oscillations of the metal cube of mass 150 g may be assumed to be simple harmonic.
Use your answers in **(a)(ii)** to determine, for the metal cube,

For Examiner's Use

(i) its maximum acceleration,

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

(ii) the maximum resultant force on the cube.

force = ... N [2]

(c) Some very light feathers are attached to the top surface of the cube so that the feathers extend outwards, beyond the vertical sides of the cube.
The investigation is now repeated.
On Fig. 3.2, draw a line to show the new variation with frequency of the amplitude of vibration for frequencies between 2 Hz and 10 Hz. [2]

Q24.

3 A cylinder and piston, used in a car engine, are illustrated in Fig. 3.1.

For Examiner Use

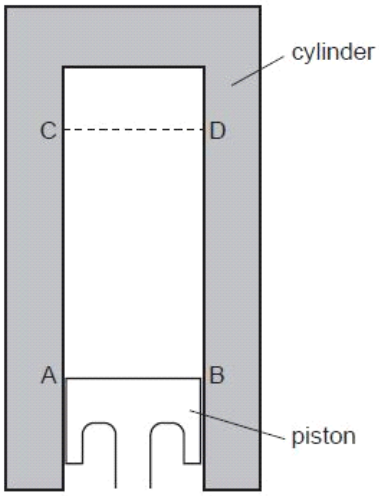


Fig. 3.1

The vertical motion of the piston in the cylinder is assumed to be simple harmonic.
The top surface of the piston is at AB when it is at its lowest position; it is at CD when at its highest position, as marked in Fig. 3.1.

(a) The displacement d of the piston may be represented by the equation

$$d = -4.0\cos(220t)$$

where d is measured in centimetres.

(i) State the distance between the lowest position AB and the highest position CD of the top surface of the piston.

distance = ... cm [1]

(ii) Determine the number of oscillations made per second by the piston.

For Examiner's Use

number = ... [2]

(iii) On Fig. 3.1, draw a line to represent the top surface of the piston in the position where the speed of the piston is maximum. [1]

(iv) Calculate the maximum speed of the piston.

speed = ... $cm\ s^{-1}$ [2]

(b) The engine of a car has several cylinders. Three of these cylinders are shown in Fig. 3.2.

For Examiner's Use

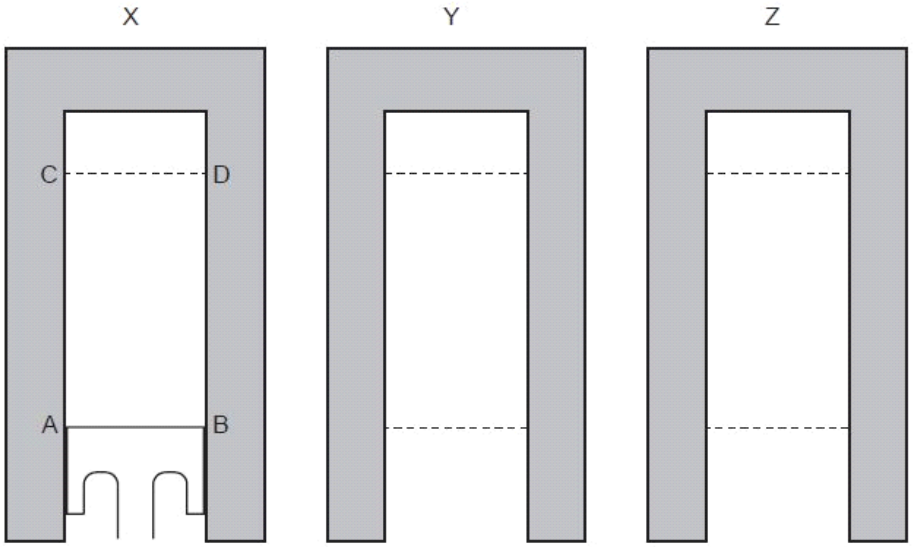


Fig. 3.2

X is the same cylinder and piston as in Fig. 3.1.
Y and Z are two further cylinders, with the lowest and the highest positions of the top surface of each piston indicated.
The pistons in the cylinders each have the same frequency of oscillation, but they are not in phase.
At a particular instant in time, the position of the top of the piston in cylinder X is as shown.

(i) In cylinder Y, the oscillations of the piston lead those of the piston in cylinder X by a phase angle of 120° ($\frac{2}{3}\pi$ rad).
Complete the diagram of cylinder Y, for this instant, by drawing

1. a line to show the top surface of the piston, [1]

2. an arrow to show the direction of movement of the piston. [1]

(ii) In cylinder Z, the oscillations of the piston lead those of the piston in cylinder X by a phase angle of 240° ($\frac{4}{3}\pi$ rad).

For Examiner's Use

Complete the diagram of cylinder Z, for this instant, by drawing

1. a line to show the top surface of the piston, [1]

2. an arrow to show the direction of movement of the piston. [1]

(iii) For the piston in cylinder Y, calculate its speed for this instant.

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

Q25.

3 A bar magnet is suspended from the free end of a helical spring, as illustrated in Fig. 3.1.

For Examiner's Use

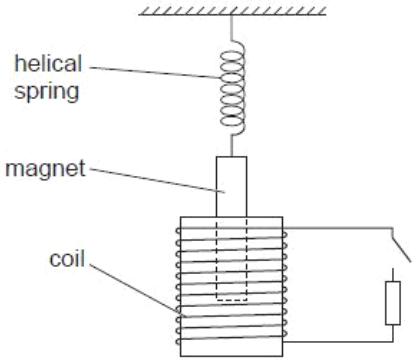


Fig. 3.1

One pole of the magnet is situated in a coil of wire. The coil is connected in series with a switch and a resistor. The switch is open.

The magnet is displaced vertically and then released. As the magnet passes through its rest position, a timer is started. The variation with time t of the vertical displacement y of the magnet from its rest position is shown in Fig. 3.2.

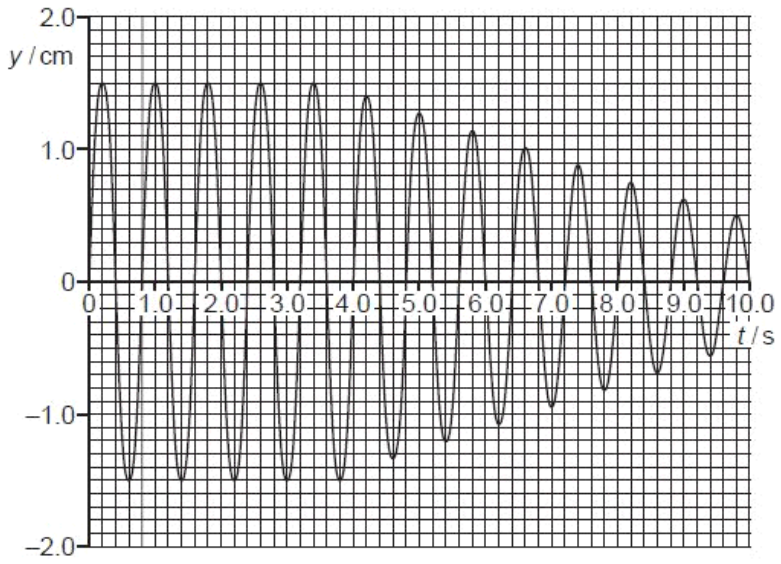


Fig. 3.2

At time t = 4.0 s, the switch is closed.

For Examiner's Use

(a) Use Fig. 3.2 to

(i) state the evidence for the magnet to be undergoing free oscillations during the period t = 0 to t = 4.0 s,

.....

..... [1]

(ii) state, with a reason, whether the damping after time t = 4.0 s is light, critical or heavy,

.....

.....

..... [2]

(iii) determine the natural frequency of vibration of the magnet on the spring.

frequency = ... Hz [2]

Q26.

For Examiner's Use

3 **(a)** Define *simple harmonic motion*.

.....

.....

..... [2]

(b) A horizontal plate is vibrating vertically, as shown in Fig. 3.1.

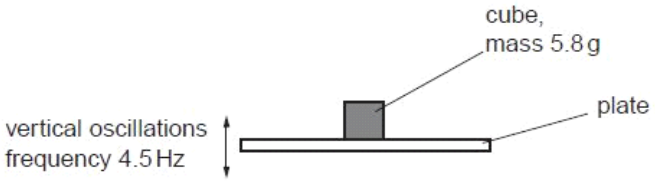


Fig. 3.1

The plate undergoes simple harmonic motion with a frequency of 4.5 Hz and amplitude 3.0 mm.
A metal cube of mass 5.8 g rests on the plate.

Calculate, for the cube, the energy of oscillation.

energy = ... J [3]

(c) The amplitude of oscillation of the plate in **(b)** is gradually increased. The frequency remains constant.
At one particular amplitude, the cube just loses contact momentarily with the plate.

(i) State the position of the plate in its oscillation at the point when the cube loses contact.

.....

.....

..... [2]

(ii) Calculate this amplitude of oscillation.

For Exam Us

amplitude = ... m [2]

Q27.

4 A ball is held between two fixed points A and B by means of two stretched springs, as shown in Fig. 4.1.

For Examiner's Use

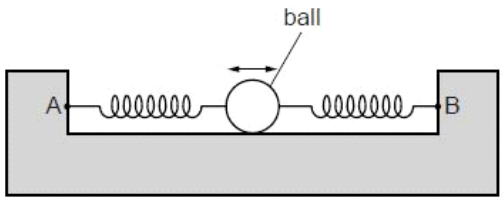


Fig. 4.1

The ball is free to oscillate horizontally along the line AB. During the oscillations, the springs remain stretched and do not exceed their limits of proportionality.

The variation of the acceleration *a* of the ball with its displacement *x* from its equilibrium position is shown in Fig. 4.2.

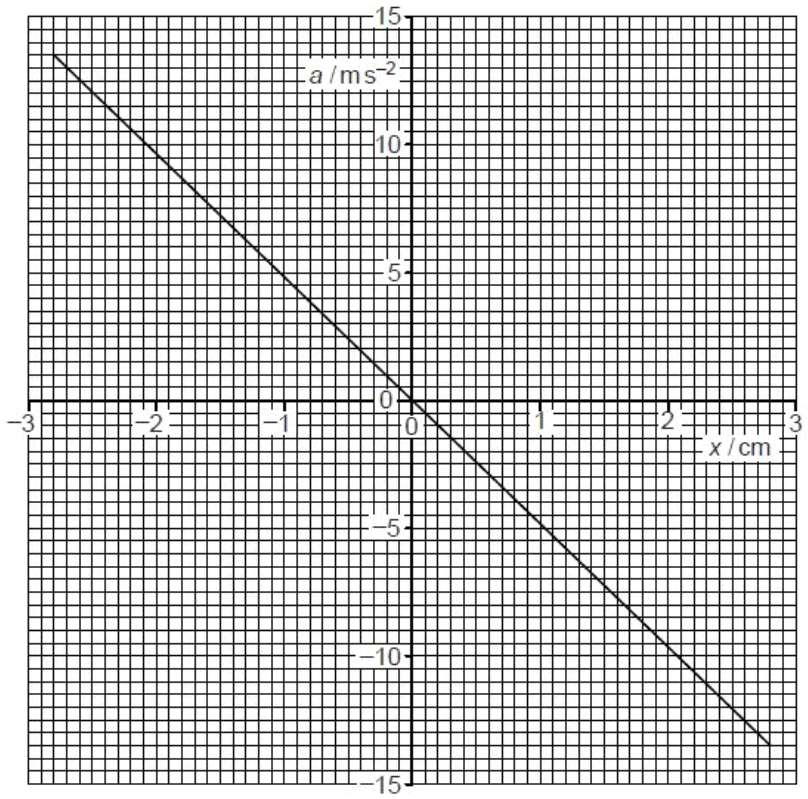


Fig. 4.2

(a) State and explain the features of Fig. 4.2 that indicate that the motion of the ball is simple harmonic.

For Examiner Use

.....

.....

.....

.....

.....[4]

(b) Use Fig. 4.2 to determine, for the oscillations of the ball,

(i) the amplitude,

amplitude = ... cm [1]

(ii) the frequency.

frequency = ... Hz [3]

(c) The arrangement in Fig. 4.1 is now rotated through 90° so that the line AB is vertical. The ball now oscillates in a vertical plane.

Suggest one reason why the oscillations may no longer be simple harmonic.

.....

.....[1]

Q28.

2 A small frictionless trolley is attached to a fixed point A by means of a spring. A second spring is used to attach the trolley to a variable frequency oscillator, as shown in Fig. 2.1.

For Examiner's Use

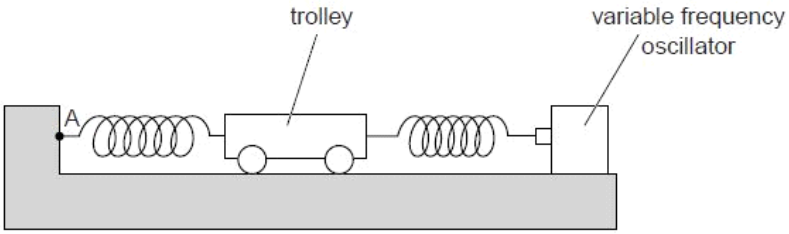


Fig. 2.1

Both springs remain extended within the limit of proportionality.
Initially, the oscillator is switched off. The trolley is displaced horizontally along the line joining the two springs and is then released.
The variation with time t of the velocity v of the trolley is shown in Fig. 2.2.

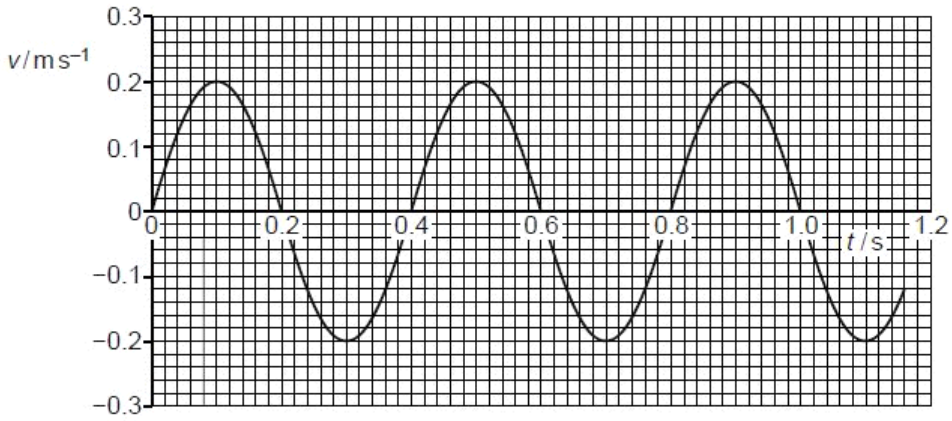


Fig. 2.2

(a) (i) Using Fig. 2.2, state two different times at which

1. the displacement of the trolley is zero,

time = ... s and time = ... s [1]

2. the acceleration in one direction is maximum.

time = ... s and time = ... s [1]

(ii) Determine the frequency of oscillation of the trolley.

For Examiner's Use

frequency = ... Hz [2]

(iii) The variation with time of the displacement of the trolley is sinusoidal. The variation with time of the velocity of the trolley is also sinusoidal.

State the phase difference between the displacement and the velocity.

phase difference = ... [1]

(b) The oscillator is now switched on. The amplitude of vibration of the oscillator is constant. The frequency f of vibration of the oscillator is varied.
The trolley is forced to oscillate by means of vibrations of the oscillator.
The variation with f of the amplitude a_0 of the oscillations of the trolley is shown in Fig. 2.3.

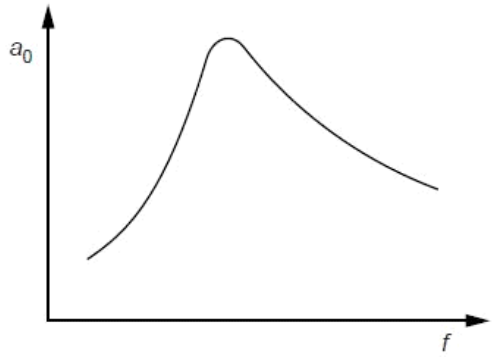


Fig. 2.3

By reference to your answer in **(a)**, state the approximate frequency at which the amplitude is maximum.

frequency = ... Hz [1]

(c) The amplitude of the oscillations in **(b)** may be reduced without changing significantly the frequency at which the amplitude is a maximum. State how this may be done and give a reason for your answer.
You may draw on Fig. 2.1 if you wish.

.....

.....

.....

.....

.....[2]

Q29.

3 A metal ball is suspended from a fixed point by means of a string, as illustrated in Fig. 3.1.

For Examiner Use

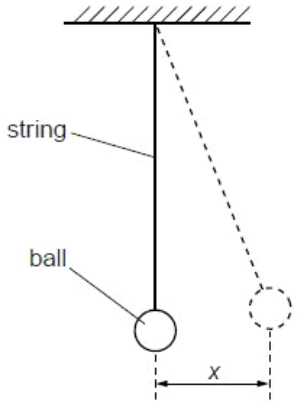


Fig. 3.1

The ball is given a small displacement and then released. The variation with time t of the displacement x of the ball is shown in Fig. 3.2.

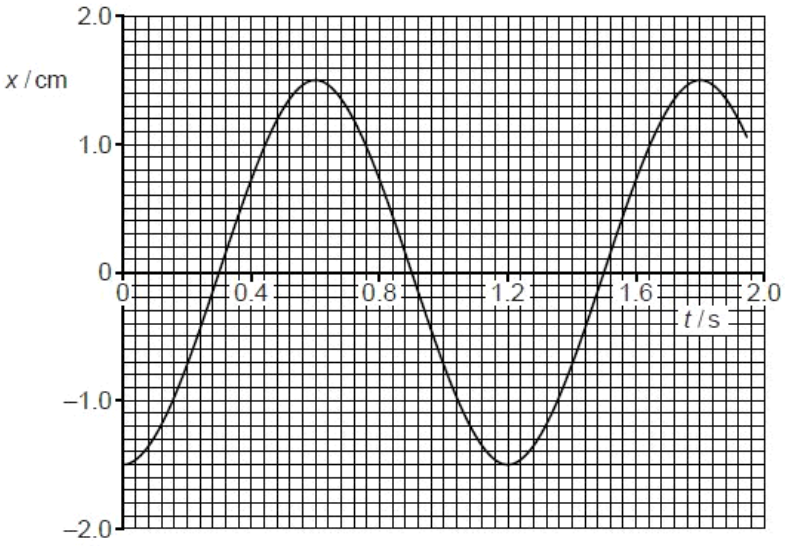


Fig. 3.2

(a) (i) State two times at which the speed of the ball is a maximum.

time = ... s and time = ... s [1]

(ii) Show that the maximum speed of the ball is approximately $0.08\,m\,s^{-1}$.

[2]

(b) The variation with displacement x of the potential energy E_P of the oscillations of the ball is shown in Fig. 3.3.

For Examiner's Use

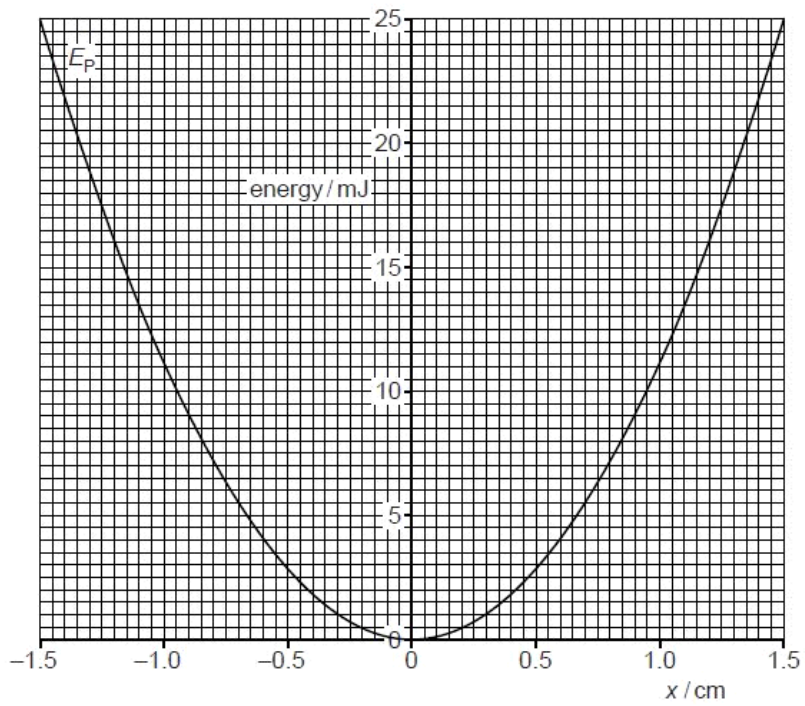


Fig. 3.3

(i) On the axes of Fig. 3.3, sketch a graph to show the variation with displacement x of the kinetic energy of the ball. [2]

(ii) The amplitude of the oscillations reduces over a long period of time.
After many oscillations, the amplitude of the oscillations is 0.60 cm.

Use Fig. 3.3 to determine the total energy of the oscillations of the ball for oscillations of amplitude 0.60 cm. Explain your working.

energy = ... J [2]

Q30.

4 A student investigates the energy changes of a mass oscillating on a vertical spring, as shown in Fig. 4.1.

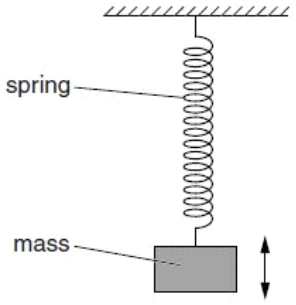


Fig. 4.1

The student draws a graph of the variation with displacement x of energy E of the oscillation, as shown in Fig. 4.2.

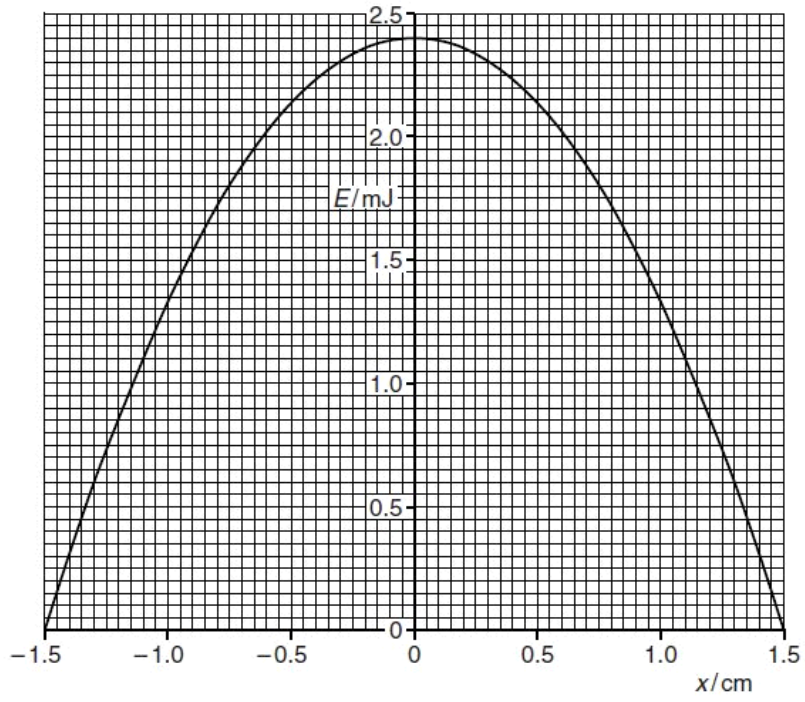


Fig. 4.2

(a) State whether the energy E represents the total energy, the potential energy or the kinetic energy of the oscillations.

..... [1]

(b) The student repeats the investigation but with a smaller amplitude. The maximum value of E is now found to be 1.8 mJ.

Use Fig. 4.2 to determine the change in the amplitude. Explain your working.

change in amplitude = ... cm [3]

Q31.

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

.....

.....

..... [2]

(b) A small ball rests at point P on a curved track of radius r, as shown in Fig. 4.1.

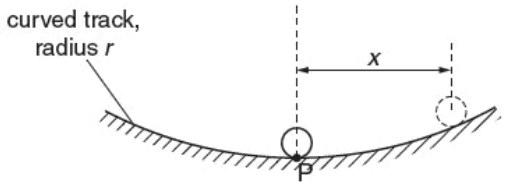


Fig. 4.1

The ball is moved a small distance to one side and is then released. The horizontal displacement x of the ball is related to its acceleration a towards P by the expression

$$a = -\frac{gx}{r}$$

where g is the acceleration of free fall.

(i) Show that the ball undergoes simple harmonic motion.

.....

.....

.....

..... [2]

(ii) The radius r of curvature of the track is 28 cm.

Determine the time interval τ between the ball passing point P and then returning to point P.

τ = ... s [3]

(c) The variation with time t of the displacement x of the ball in **(b)** is shown in Fig. 4.2.

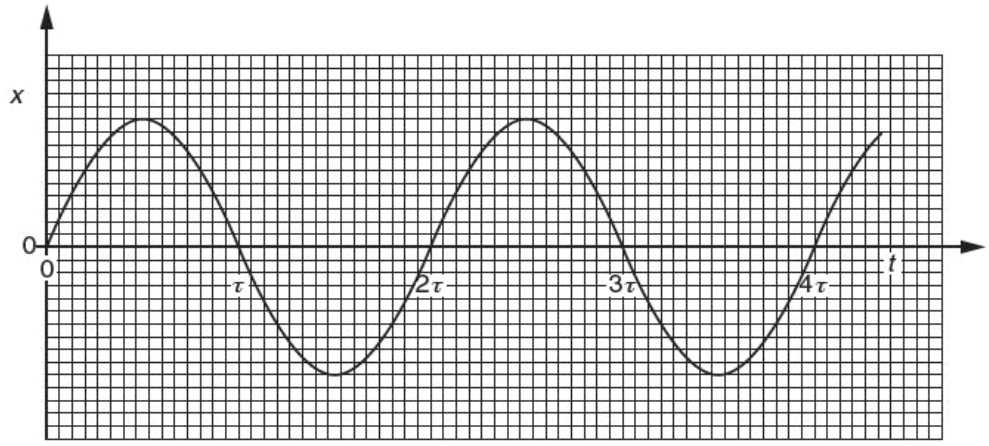


Fig. 4.2

Some moisture now forms on the track, causing the ball to come to rest after approximately 15 oscillations.

On the axes of Fig. 4.2, sketch the variation with time t of the displacement x of the ball for the first two periods after the moisture has formed. Assume the moisture forms at time $t = 0$.
[3]

Q32.

1 A light spring is suspended from a fixed point. A bar magnet is attached to the end of the spring, as shown in Fig. 1.1.

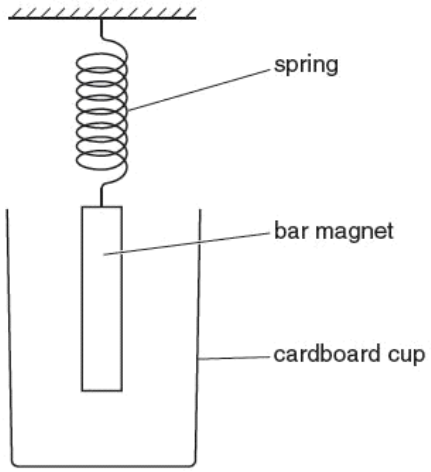


Fig. 1.1

In order to shield the magnet from draughts, a cardboard cup is placed around the magnet but does not touch it.
The magnet is displaced vertically and then released. The variation with time t of the vertical displacement y of the magnet is shown in Fig. 1.2.

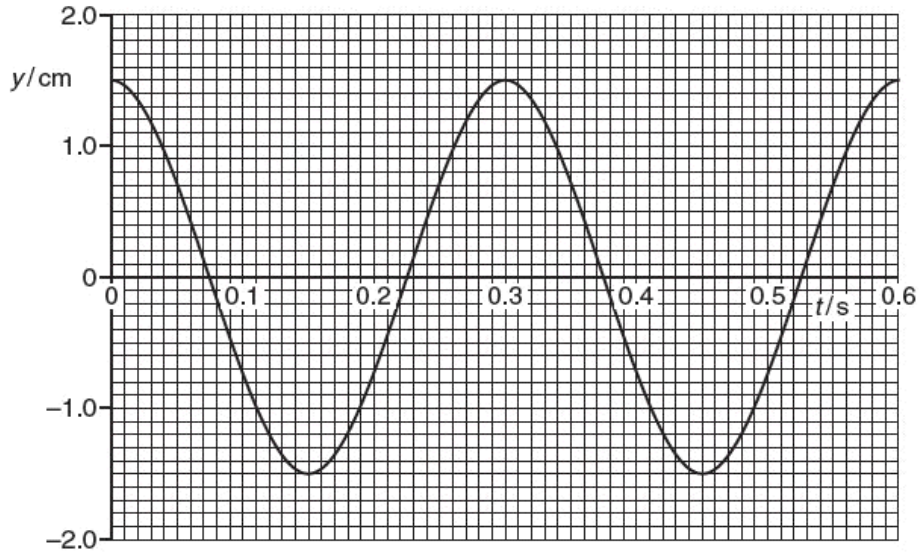


Fig. 1.2

The mass of the magnet is 130 g.

(a) For the oscillations of the magnet, use Fig. 1.2 to

(i) determine the angular frequency ω,

ω = ... rad s^{-1} [2]

(ii) show that the maximum kinetic energy of the oscillating magnet is 6.4 mJ.

[2]

(b) The cardboard cup is now replaced with a cup made of aluminium foil.
During 10 complete oscillations of the magnet, the amplitude of vibration is seen to decrease to 0.75 cm from that shown in Fig. 1.2. The change in angular frequency is negligible.

(i) Use Faraday's law of electromagnetic induction to explain why the amplitude of the oscillations decreases.

.....

.....

.....

.....

..... [3]

(ii) Show that the loss in energy of the oscillating magnet is 4.8 mJ.

[2]

(c) The mass of the aluminium cup in **(b)** is 6.2 g. The specific heat capacity of aluminium is $910\,J\,kg^{-1}\,K^{-1}$.
The energy in **(b)(ii)** is transferred to the cup as thermal energy.
Calculate the mean rise in temperature of the cup.

temperature rise = ... K [2]

Q33.

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

.....

.....

..... [2]

(b) A trolley is attached to two extended springs, as shown in Fig. 4.1.

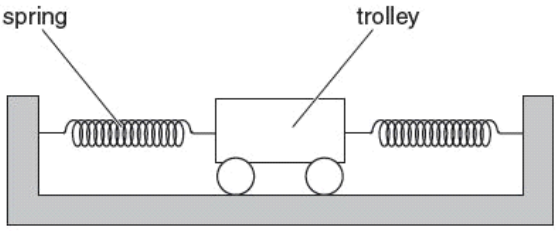


Fig. 4.1

The trolley is displaced along the line joining the two springs and is then released. At one point in the motion, a stopwatch is started. The variation with time t of the velocity v of the trolley is shown in Fig. 4.2.

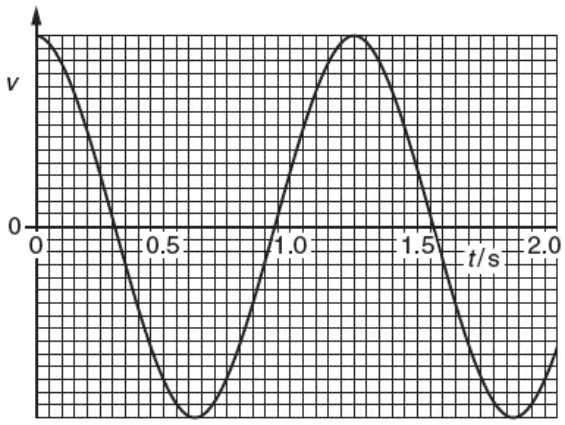


Fig. 4.2

The motion of the trolley is simple harmonic.

(i) State one time at which the trolley is moving through the equilibrium position and also state the next time that it moves through this position.

.....s and .....s [1]

(ii) The amplitude of vibration of the trolley is 3.2 cm.

Determine

1. the maximum speed v_0 of the trolley,

v_0 = ... $cm\,s^{-1}$ [3]

2. the displacement of the trolley for a speed of $\frac{1}{2}v_0$.

displacement = ... cm [2]

(c) Use your answers in **(b)** to sketch, on the axes of Fig. 4.3, a graph to show the variation with displacement x of the velocity v of the trolley.

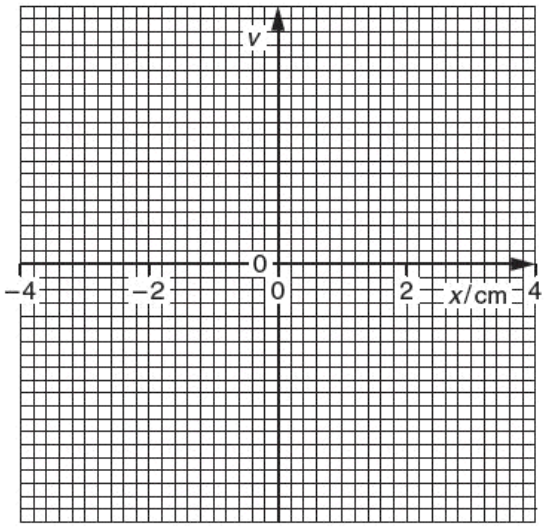


Fig. 4.3

[2]

1. Nov/2020/Paper_41/No.3

A pendulum consists of a metal sphere P suspended from a fixed point by means of a thread, as illustrated in Fig. 3.1.

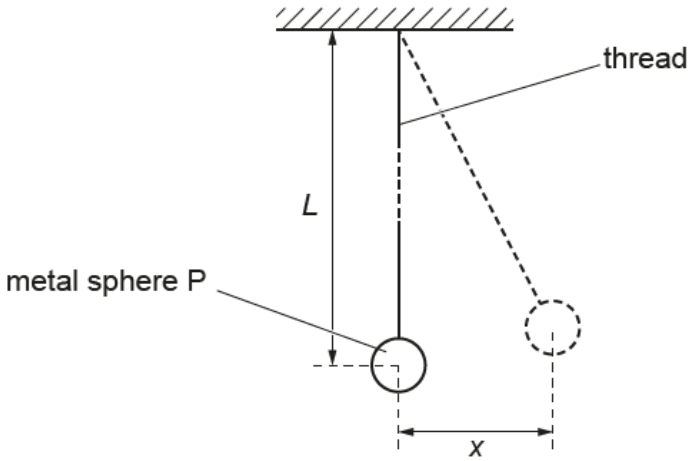


Fig. 3.1

The centre of gravity of sphere P is a distance *L* from the fixed point.

The sphere is pulled to one side and then released so that it oscillates. The sphere may be assumed to oscillate with simple harmonic motion.

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

.....

.....

..... [2]

(b) The variation of the velocity *v* of sphere P with the displacement *x* from its mean position is shown in Fig. 3.2.

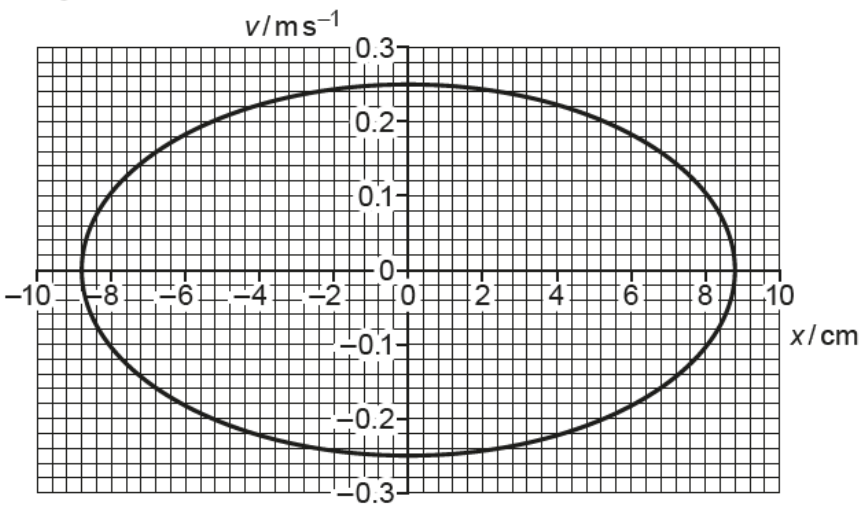


Fig. 3.2

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Use Fig. 3.2 to determine the frequency f of the oscillations of sphere P.

f = ... Hz [3]

(c) The period T of the oscillations of sphere P is given by the expression

$$T = 2\pi\sqrt{\left(\frac{L}{g}\right)}$$

where g is the acceleration of free fall.

Use your answer in **(b)** to determine the length L.

L = ... m [2]

(d) Another pendulum consists of a sphere Q suspended by a thread. Spheres P and Q are identical. The thread attached to sphere Q is longer than the thread attached to sphere P.

Sphere Q is displaced and then released. The oscillations of sphere Q have the same amplitude as the oscillations of sphere P.

On Fig. 3.2, sketch the variation of the velocity v with displacement x for sphere Q. [2]

[Total: 9]

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2. Nov/2020/Paper_42/No.3

A simple pendulum consists of a metal sphere suspended from a fixed point by means of a thread, as illustrated in Fig. 3.1.

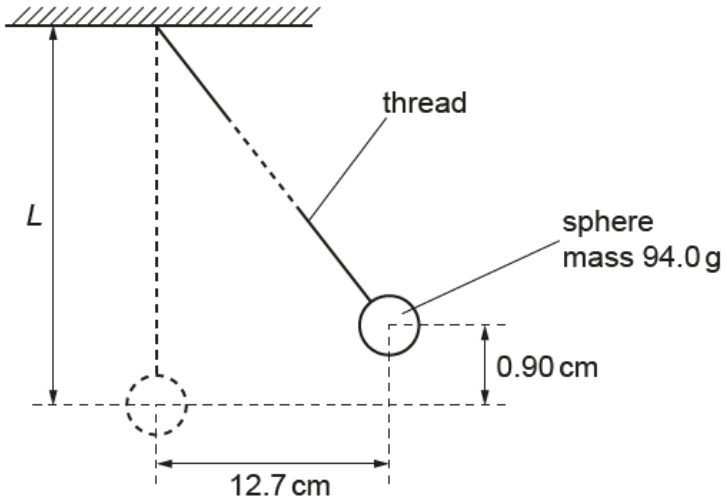


Fig. 3.1 (not to scale)

The sphere of mass 94.0 g is displaced to one side through a horizontal distance of 12.7 cm. The centre of gravity of the sphere rises vertically by 0.90 cm.

The sphere is released so that it oscillates. The sphere may be assumed to oscillate with simple harmonic motion.

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

.....

.....

..... [2]

(b) **(i)** State the kinetic energy of the sphere when the sphere returns to the displaced position shown in Fig. 3.1.

kinetic energy = ... J [1]

(ii) Calculate the total energy E_T of the oscillations.

E_T = ... J [2]

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(iii) Use your answer in **(ii)** to show that the angular frequency ω of the oscillations of the pendulum is $3.3\,\text{rad}\,\text{s}^{-1}$.

[2]

(c) The period T of oscillation of the pendulum is given by the expression

$$T = 2\pi\sqrt{\left(\frac{L}{g}\right)}$$

where g is the acceleration of free fall and L is the length of the pendulum.

Use data from **(b)** to determine L.

L = ... m [3]

[Total: 10]

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3. June/2020/Paper_41/No.3

The piston in the cylinder of a car engine moves in the cylinder with simple harmonic motion. The piston moves between a position of maximum height in the cylinder to a position of minimum height, as illustrated in Fig. 3.1.

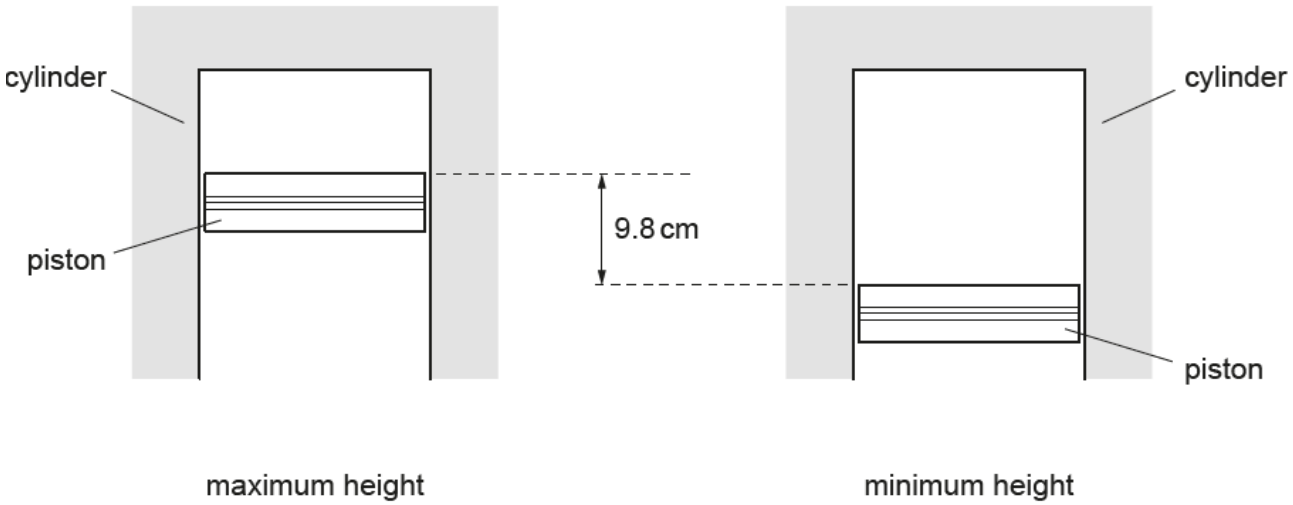


Fig. 3.1

The distance moved by the piston between the positions shown in Fig. 3.1 is 9.8 cm.

The mass of the piston is 640 g.

At one particular speed of the engine, the piston completes 2700 oscillations in 1.0 minute.

(a) For the oscillations of the piston in the cylinder, determine:

(i) the amplitude

amplitude = ... cm [1]

(ii) the frequency

frequency = ... Hz [1]

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(iii) the maximum speed

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

(iv) the speed when the top of the piston is 2.3 cm below its maximum height.

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

(b) The acceleration of the piston varies.

Determine the resultant force on the piston that gives rise to its maximum acceleration.

force = ... N [3]

[Total: 9]

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4. June/2020/Paper_42/No.4

A dish is made from a section of a hollow glass sphere.

The dish, fixed to a horizontal table, contains a small solid ball of mass 45 g, as shown in Fig. 4.1.

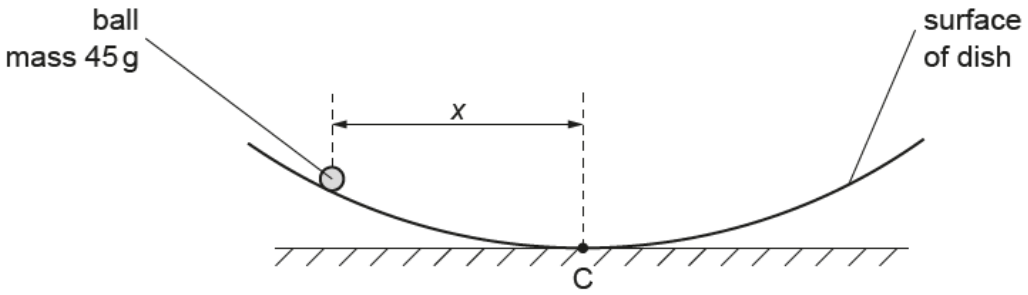


Fig. 4.1

The horizontal displacement of the ball from the centre C of the dish is x.

Initially, the ball is held at rest with distance x = 3.0 cm.

The ball is then released. The variation with time t of the horizontal displacement x of the ball from point C is shown in Fig. 4.2.

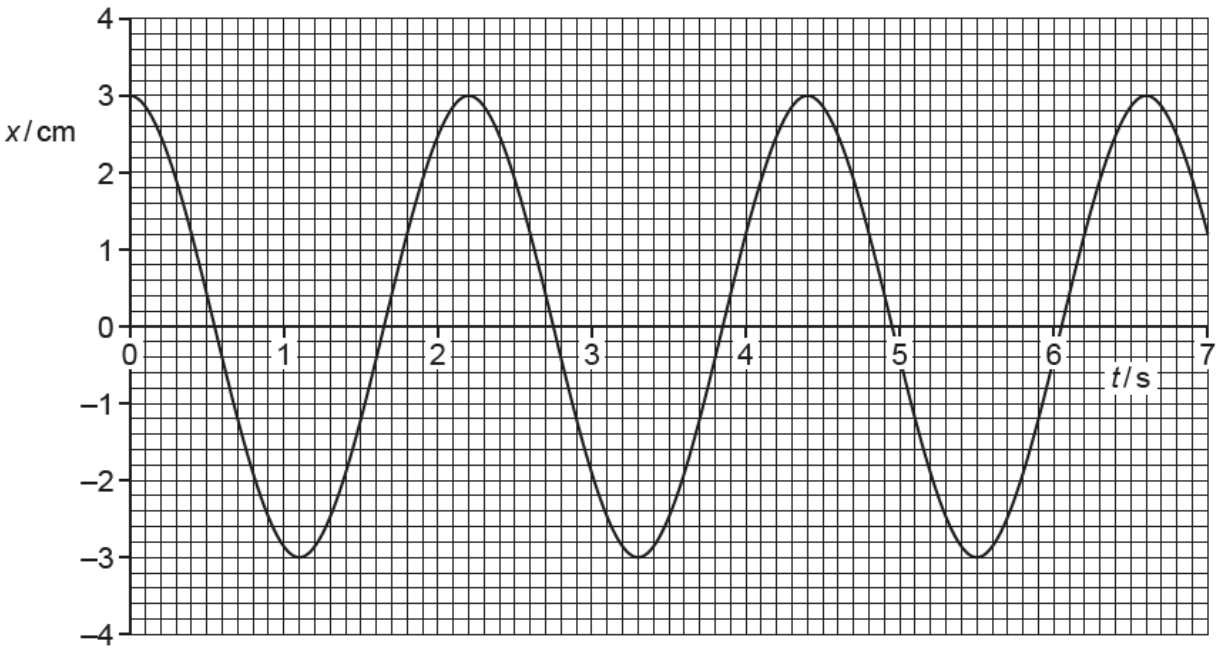


Fig. 4.2

The motion of the ball in the dish is simple harmonic with its acceleration a given by the expression

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

where g is the acceleration of free fall and R is a constant that depends on the dimensions of the dish and the ball.

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(a) Use Fig. 4.2 to show that the angular frequency ω of oscillation of the ball in the dish is $2.9\,\text{rad}\,\text{s}^{-1}$.

[1]

(b) Use the information in **(a)** to:

(i) determine R

R = ... m [2]

(ii) calculate the speed of the ball as it passes over the centre C of the dish.

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

(c) Some moisture collects on the surface of the dish so that the motion of the ball becomes lightly damped.

On the axes of Fig. 4.2, draw a line to show the lightly damped motion of the ball for the first 5.0 s after the release of the ball. [3]

[Total: 8]

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5. March/2020/Paper_42/No.3

(a) A body undergoes simple harmonic motion.

The variation with displacement x of its velocity v is shown in Fig. 3.1.

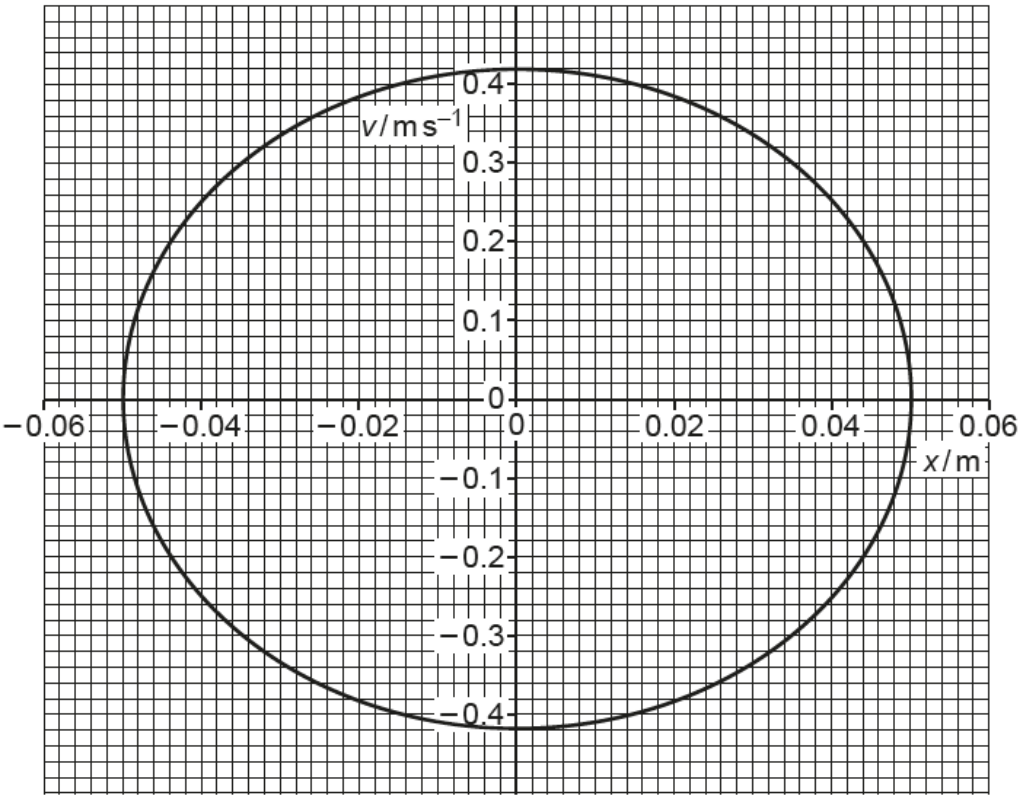


Fig. 3.1

(i) State the amplitude x_o of the oscillations.

x_o = ... m [1]

(ii) Calculate the period T of the oscillations.

T = ... s [3]

(iii) On Fig. 3.1, label with a P a point where the body has **maximum** potential energy. [1]

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(b) A bar magnet is suspended from the free end of a spring, as shown in Fig. 3.2.

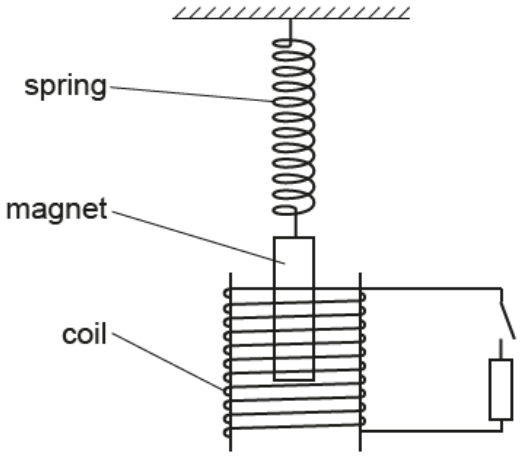


Fig. 3.2

One pole of the magnet is situated in a coil of wire. The coil is connected in series with a switch and a resistor. The switch is open.

The magnet is displaced vertically and then released. The magnet oscillates with simple harmonic motion.

(i) State Faraday's law of electromagnetic induction.

.....

.....

.....

..... [2]

(ii) The switch is now closed. Explain why the oscillations of the magnet are damped.

.....

.....

.....

.....

.....

..... [3]

[Total: 10]

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1. Nov/2021/Paper_41/No.4

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.

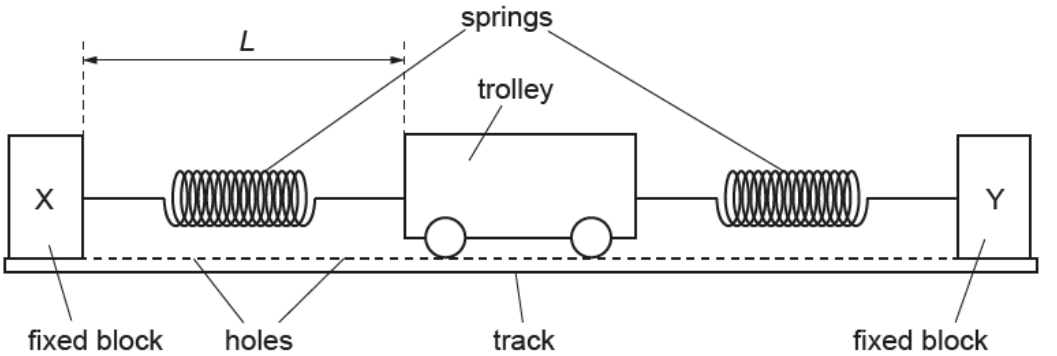


Fig. 4.1

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.

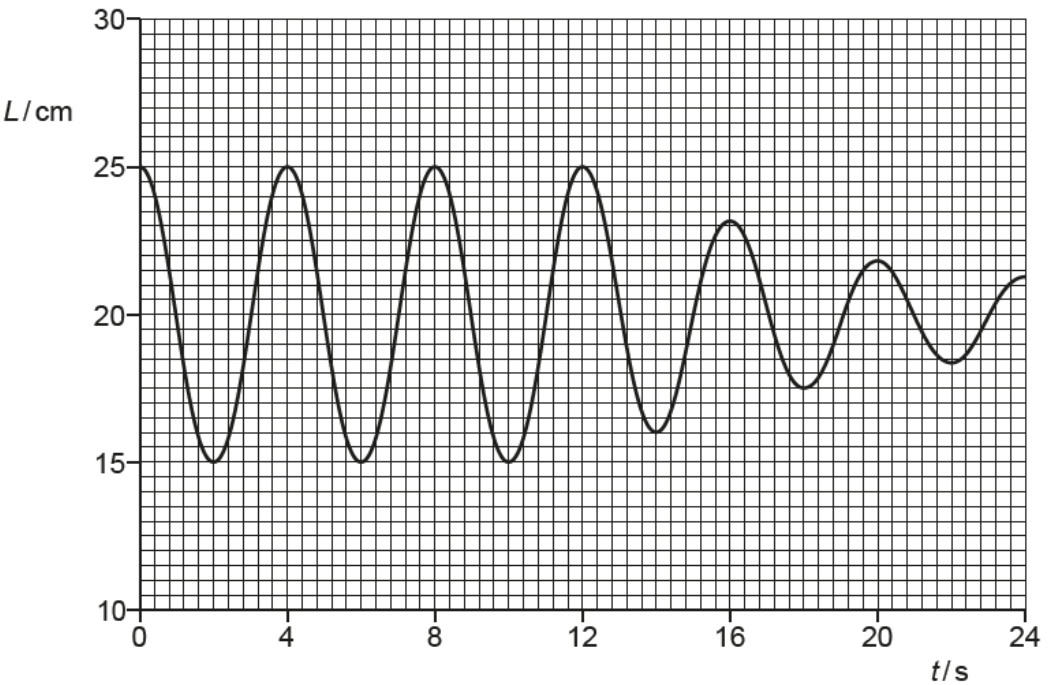


Fig. 4.2

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(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]

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

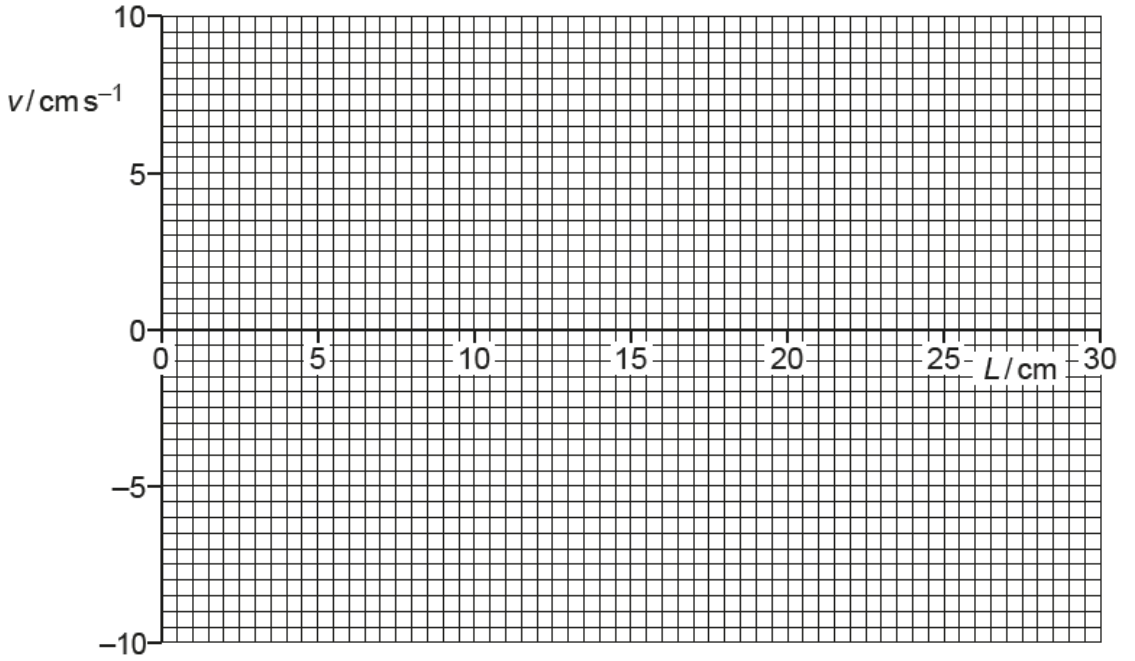


Fig. 4.3

[3]

[Total: 11]

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2. Nov/2021/Paper_42/No.4

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

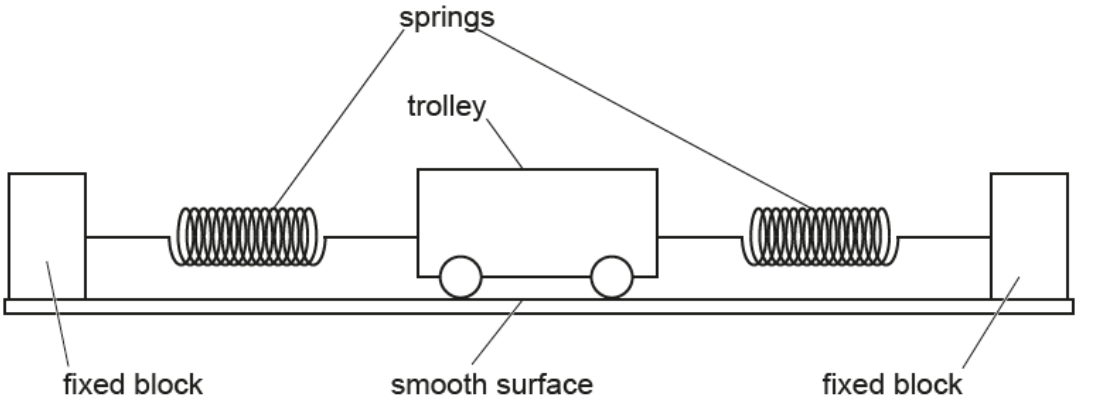


Fig. 4.1

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.

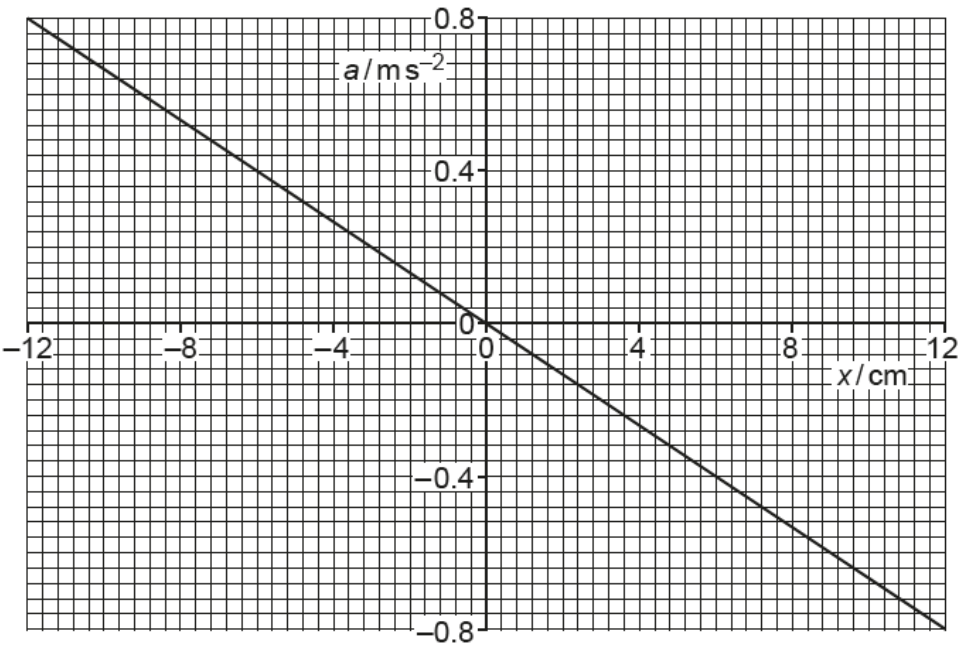


Fig. 4.2

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

.....

.....

..... [2]

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(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]

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3. June/2021/Paper_41/No.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.

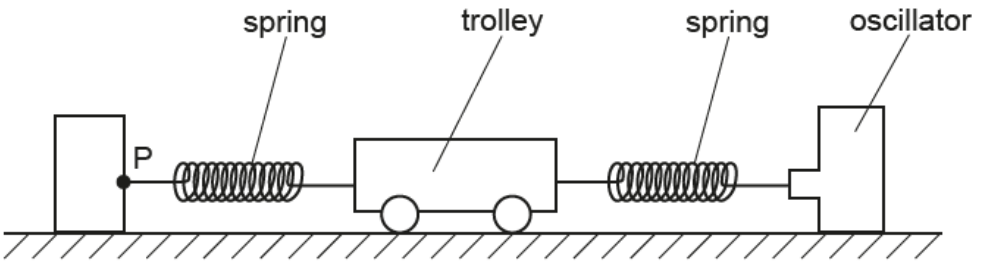


Fig. 3.1

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

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(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]

4. June/2021/Paper_42/No.3

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.

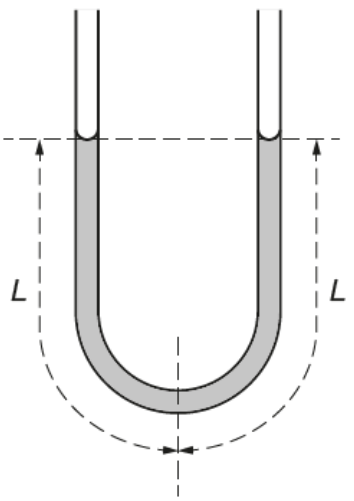


Fig. 3.1

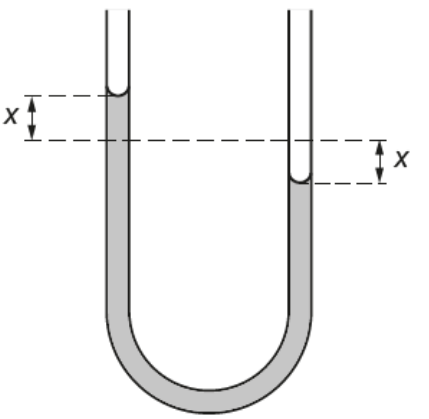


Fig. 3.2

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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]

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(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]

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5. March/2021/Paper_42/No.4

(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.

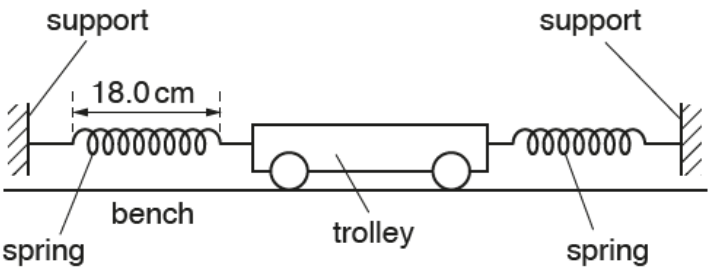


Fig. 4.1

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]

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(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]

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1. Nov/2023/Paper_9702/41/No.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.

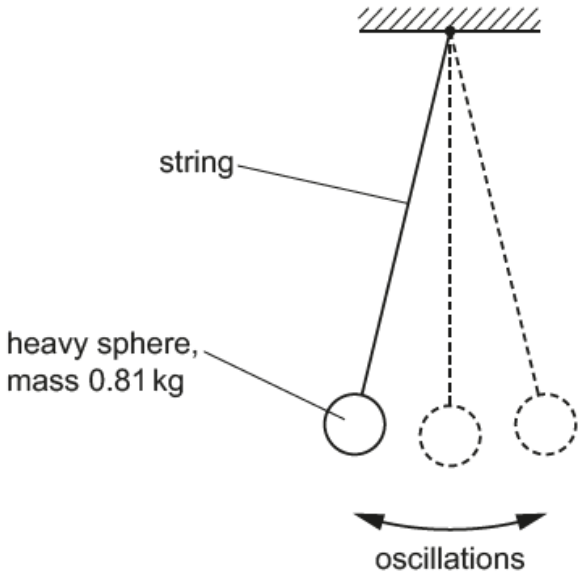


Fig. 4.1

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]

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(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.

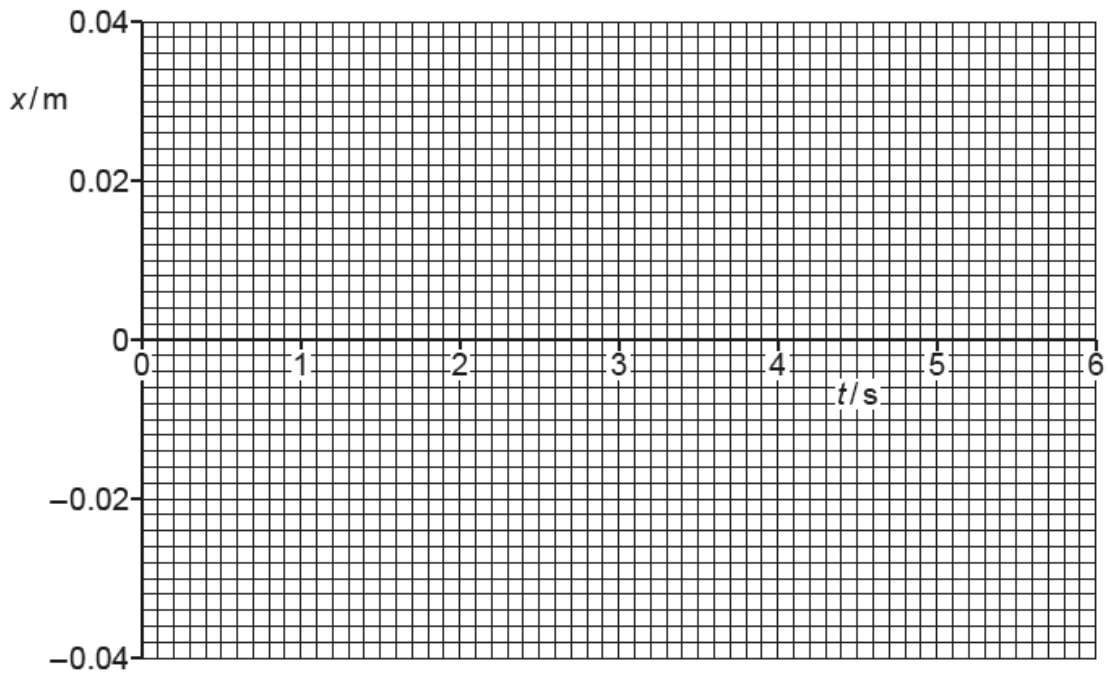


Fig. 4.2

[3]

[Total: 9]

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2. June/2023/Paper_9702/42/No.4

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

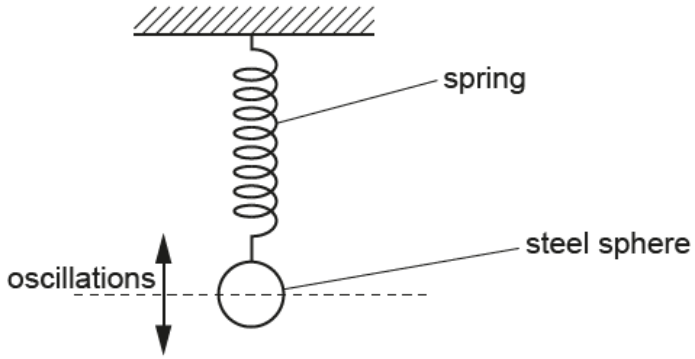


Fig. 4.1

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 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]

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

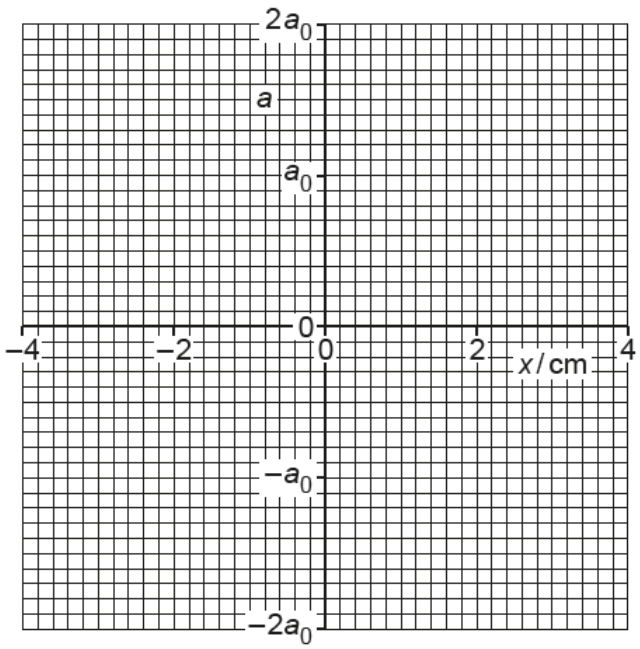


Fig. 4.2

[3]

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

.....

.....

.....

.....

..... [3]

[Total: 11]

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3. March/2023/Paper_9702/42/No.3

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

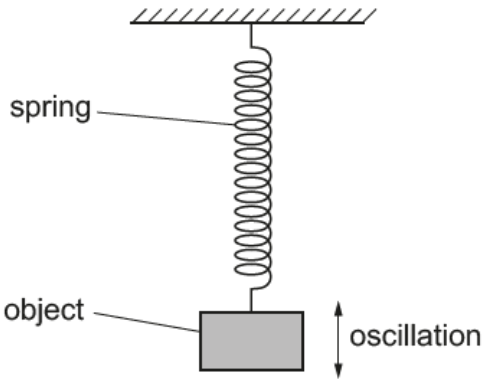


Fig. 3.1

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

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

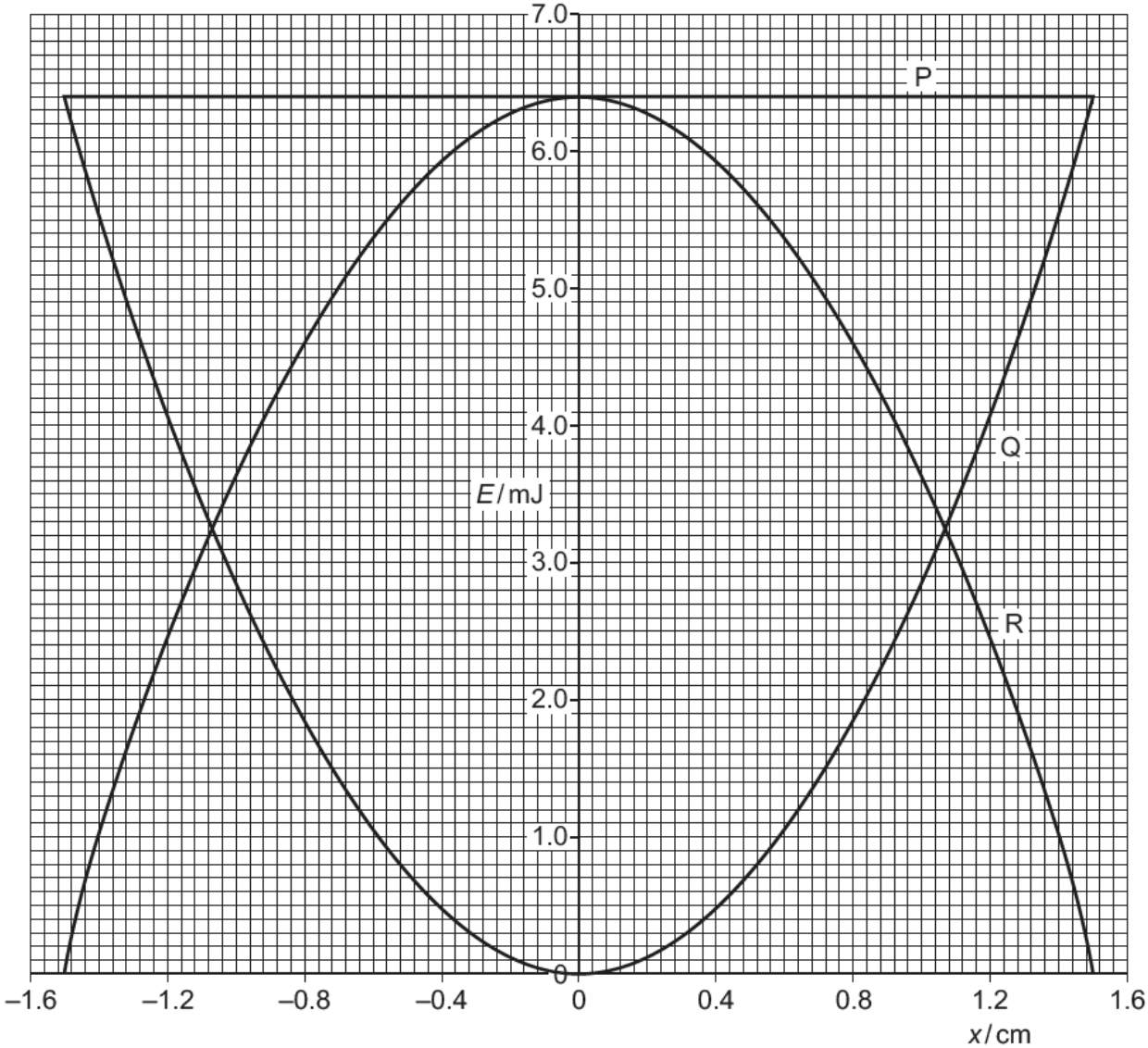


Fig. 3.2

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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]

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

.....

.....

..... [1]

[Total: 10]

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