PapaCambridge

Cambridge International AS & A Level

PHYSICS

Paper 4

Topical Past Paper Questions
+ Answer Scheme

2016 - 2021

PapaCambridge

Chapter 5

Oscillations

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.

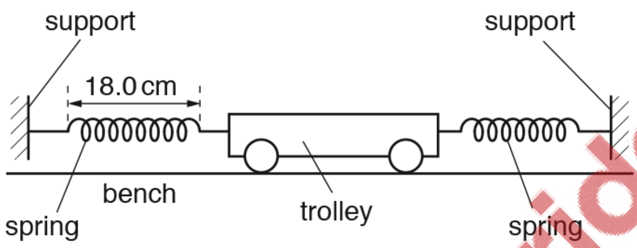


Fig. 4.1

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.

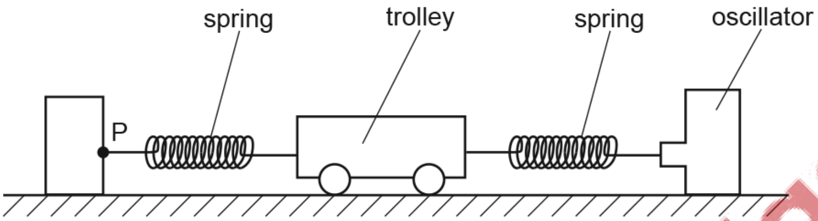


Fig. 3.1

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

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.

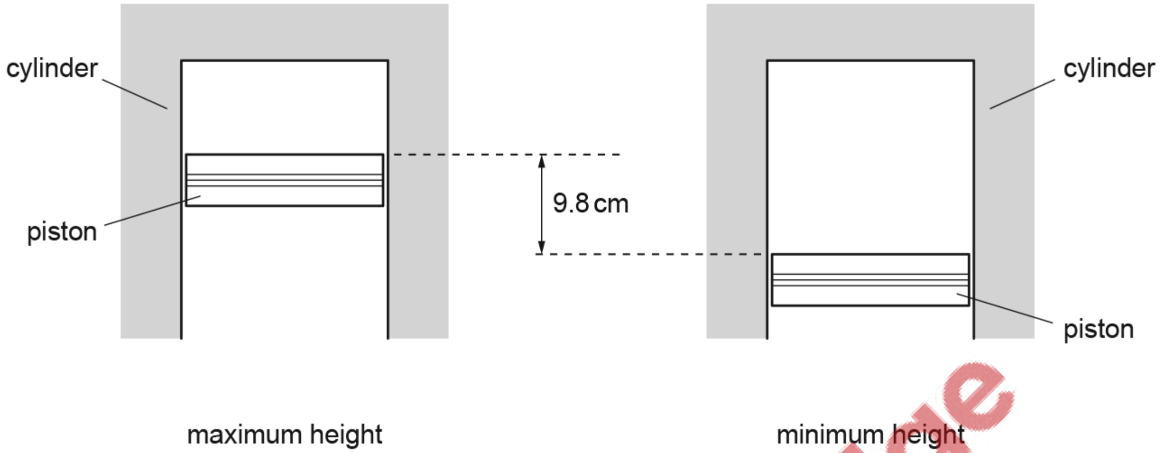


Fig. 3.1

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.

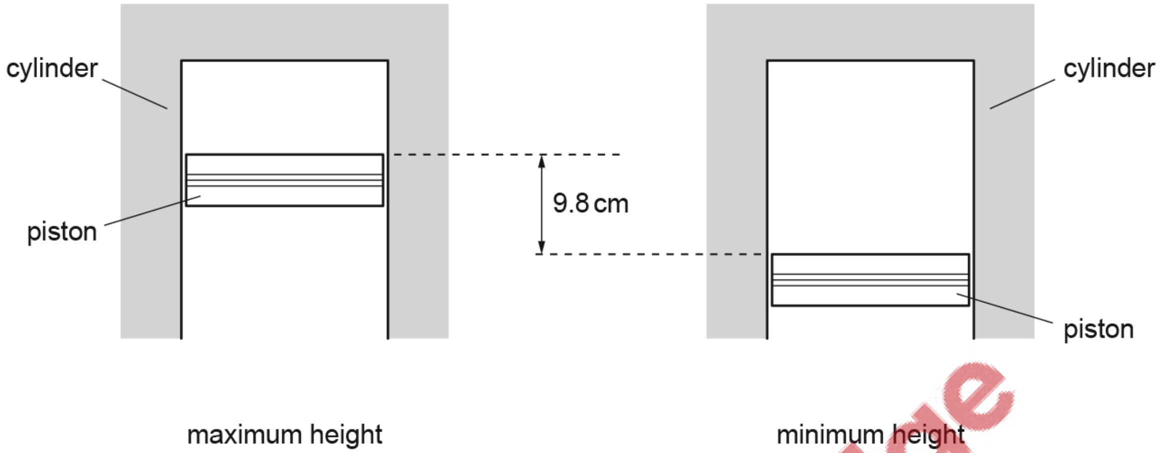
Determine the resultant force on the piston that gives rise to its maximum acceleration.

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.

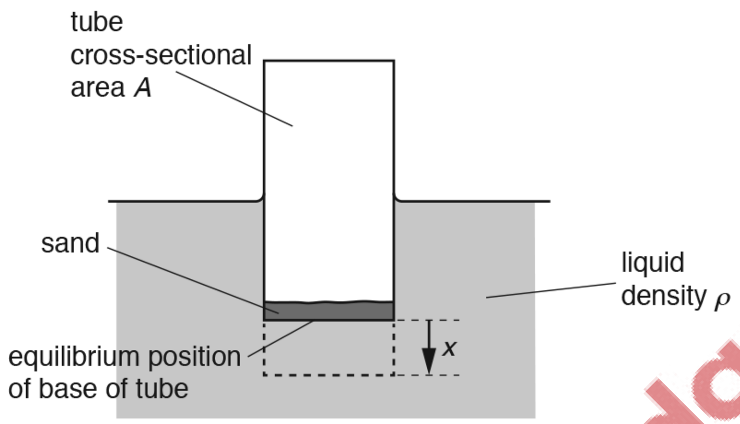

Fig. 3.1

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]

(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.

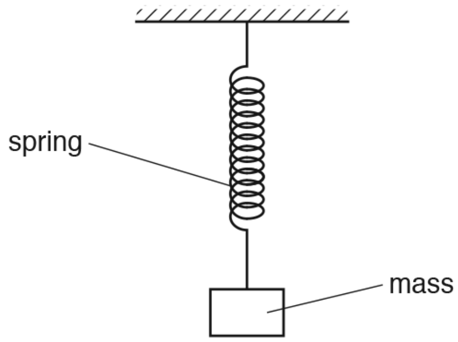

Fig. 4.1

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

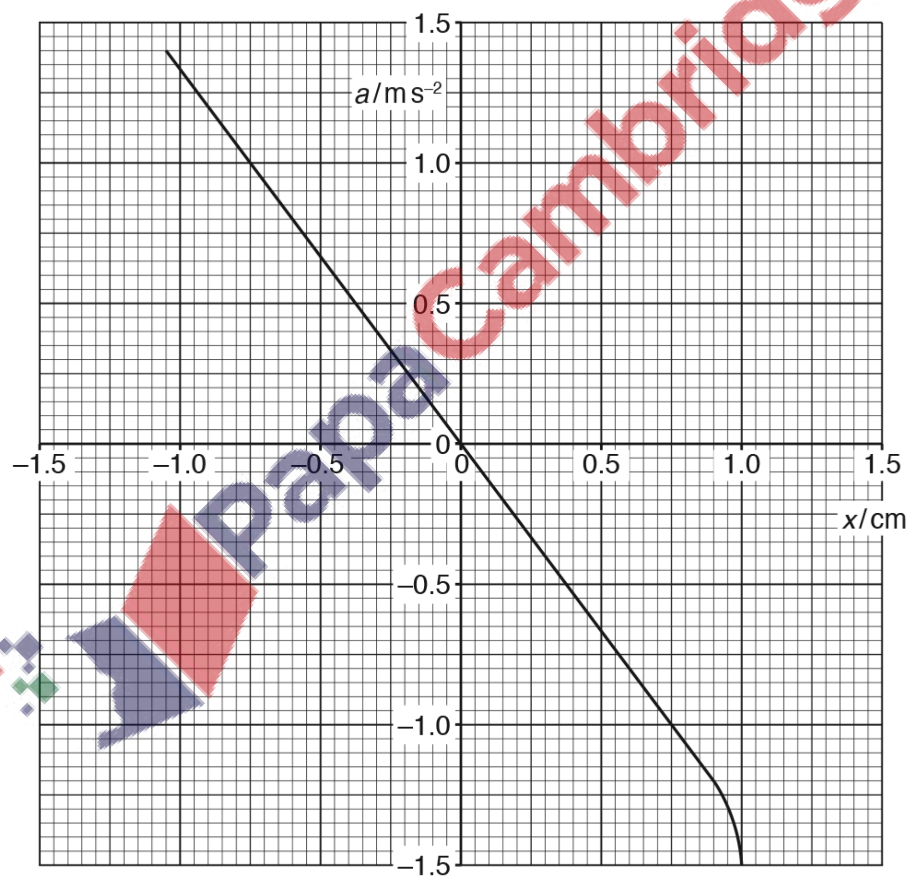

Fig. 4.2

(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 $-x_0$.

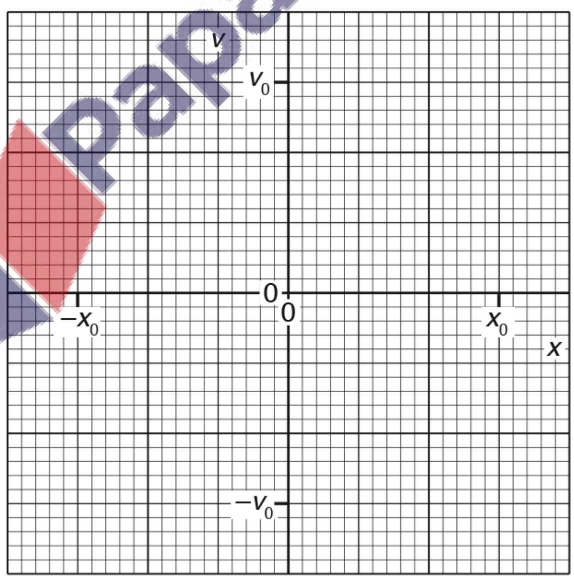

Fig. 4.3

[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.

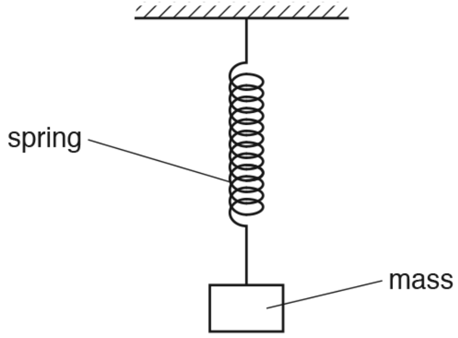

Fig. 4.1

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

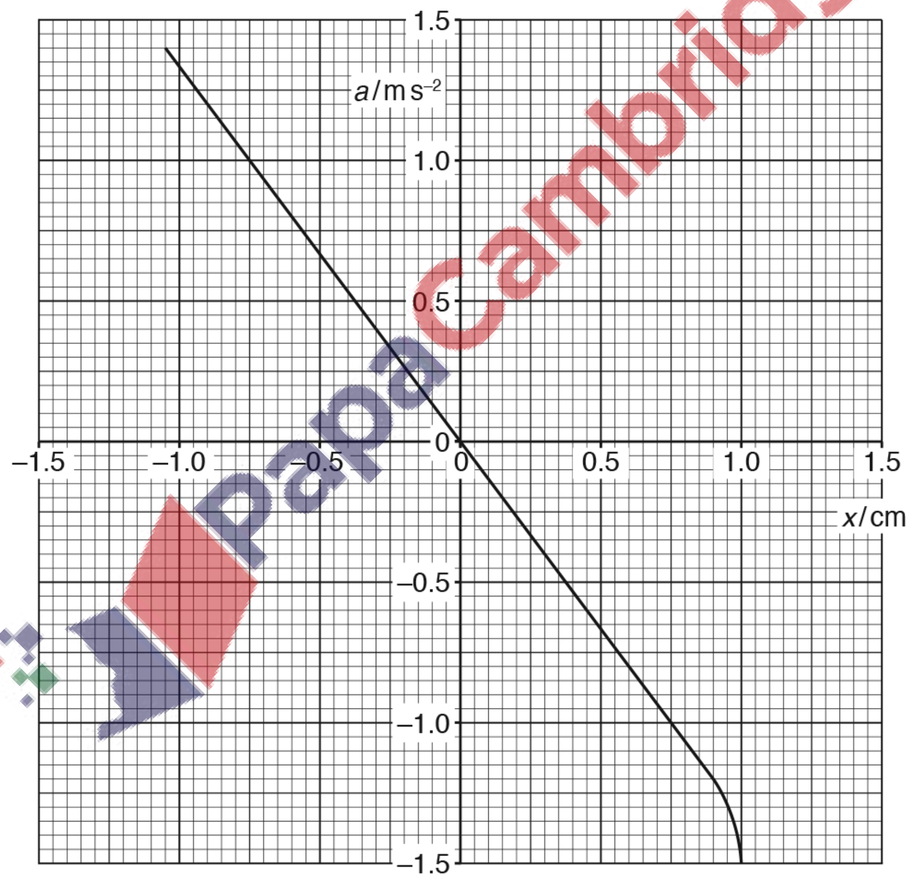

Fig. 4.2

(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 $-x_0$.

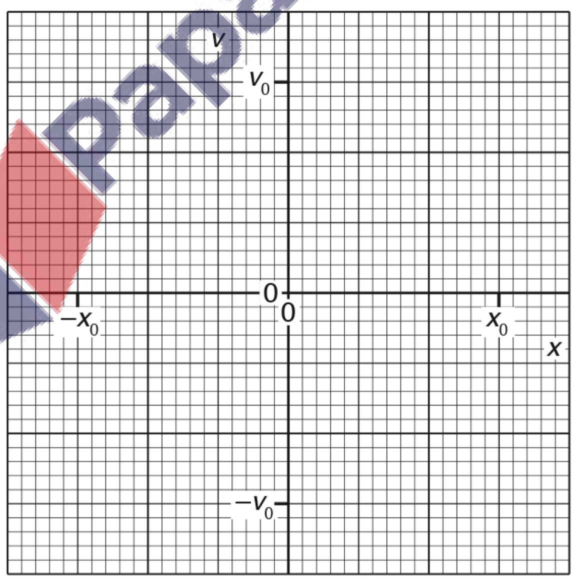

Fig. 4.3

[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.

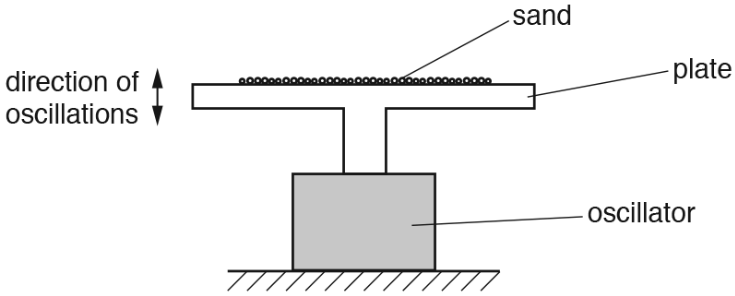

Fig. 2.1

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.

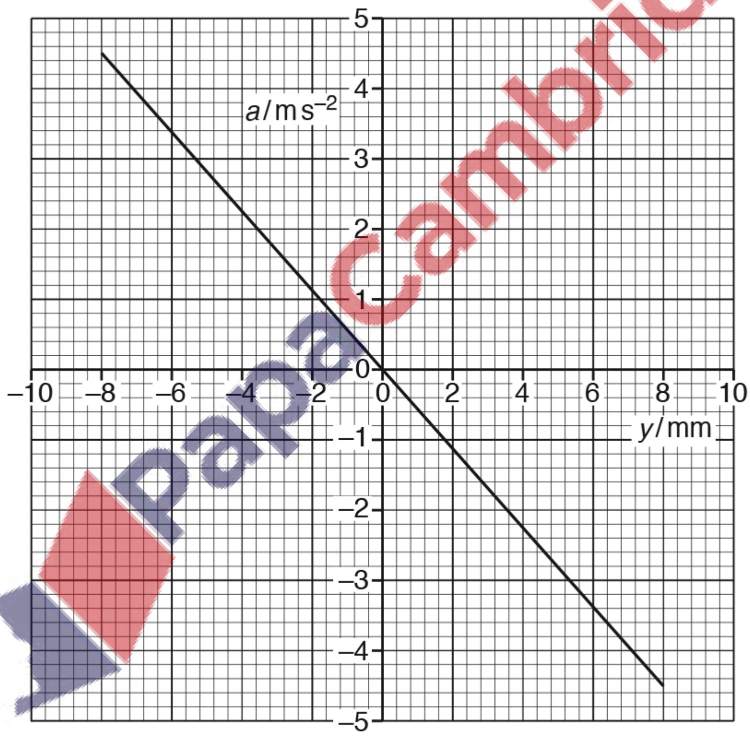

Fig. 2.2

(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.

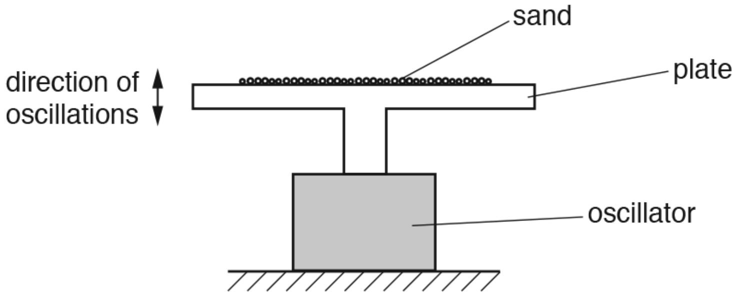

Fig. 2.1

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.

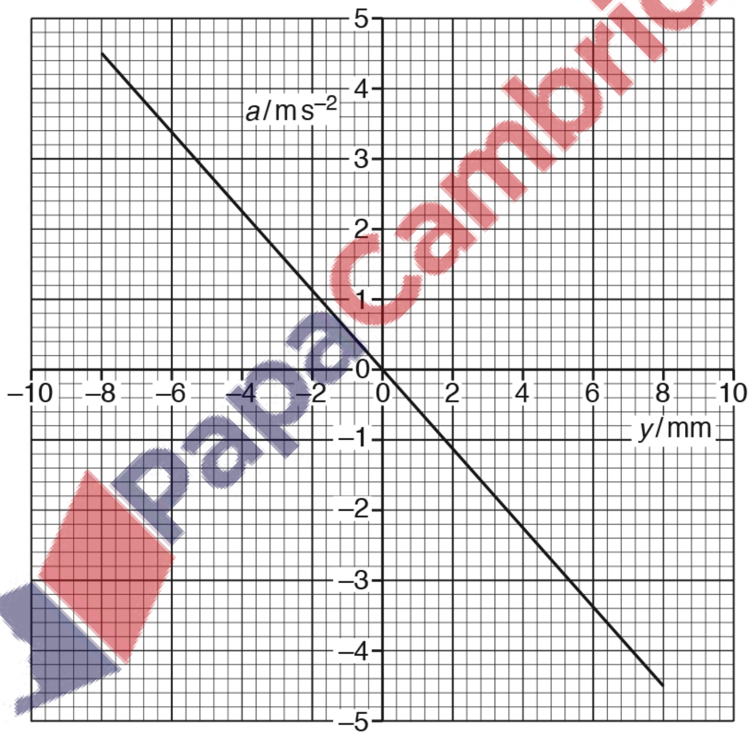

Fig. 2.2

(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]

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.

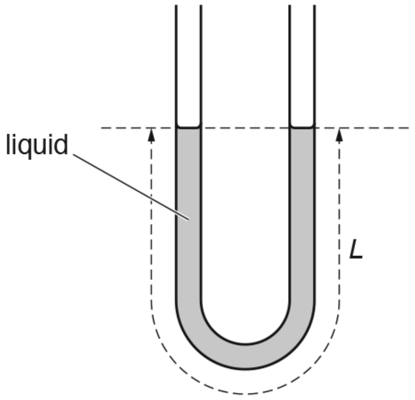

Fig. 3.1

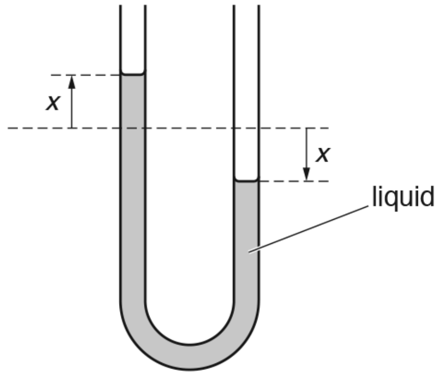

Fig. 3.2

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.

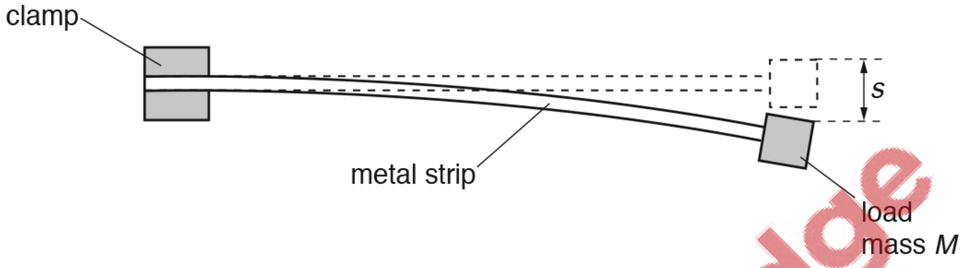

Fig. 2.1

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.

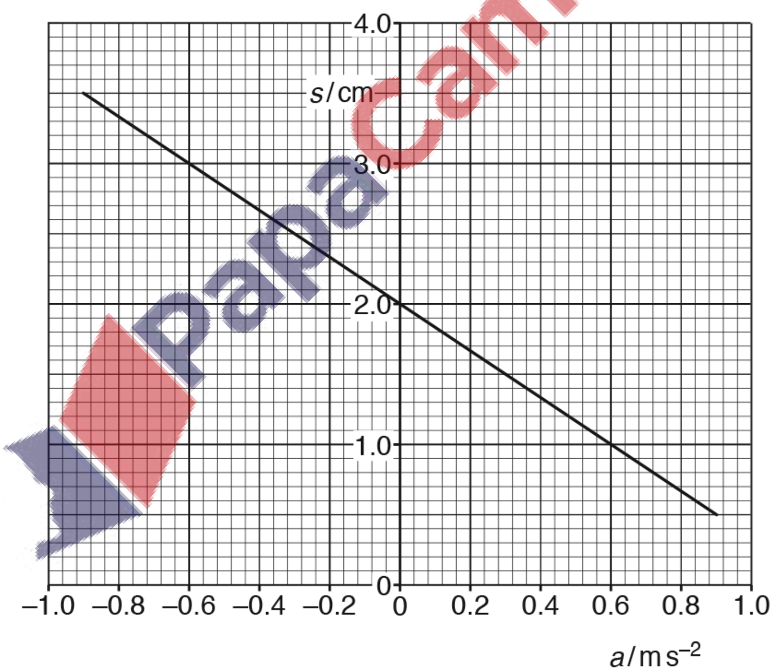

Fig. 2.2

(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.

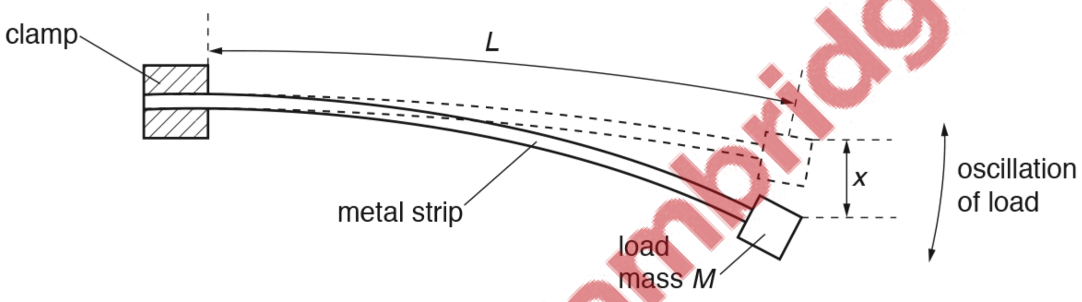

Fig. 3.1

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 cm and a load of mass M = 240 g, the frequency of oscillation is 3.2 Hz.
Calculate the constant c.

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

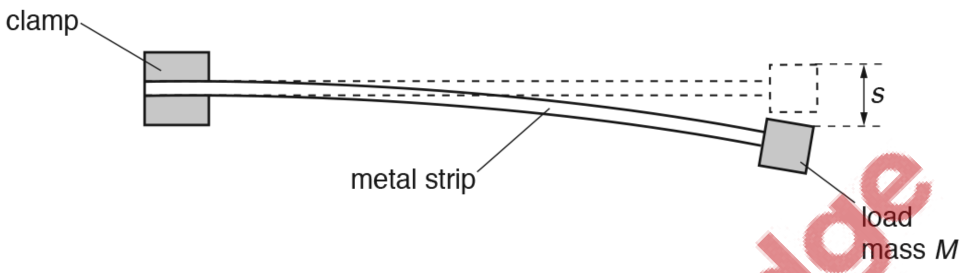

Fig. 2.1

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.

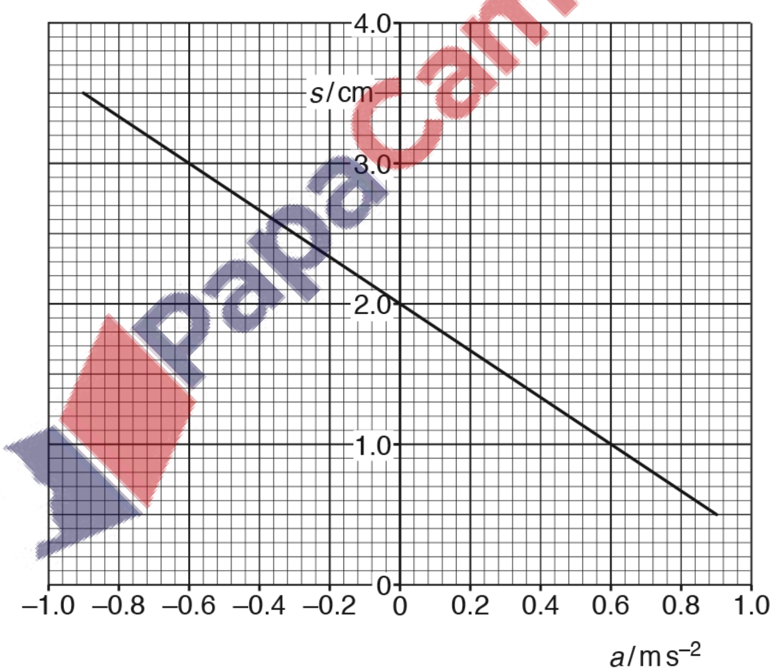

Fig. 2.2

(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]

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.

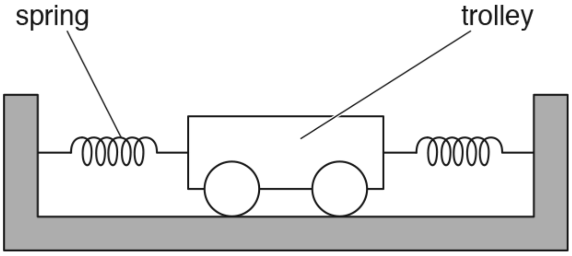

Fig. 3.1

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]

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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.

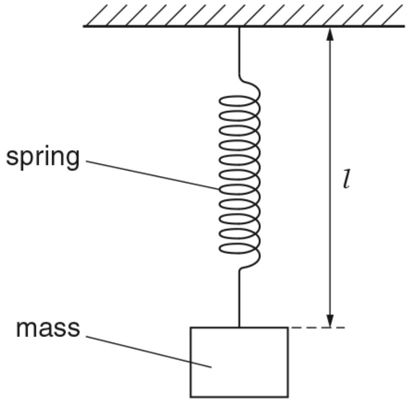


Fig. 4.1

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.

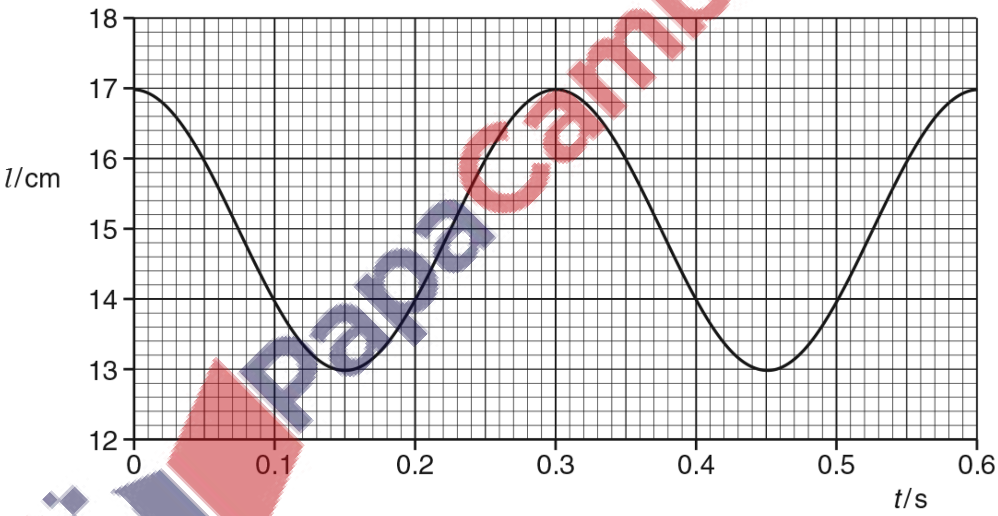


Fig. 4.2

(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.

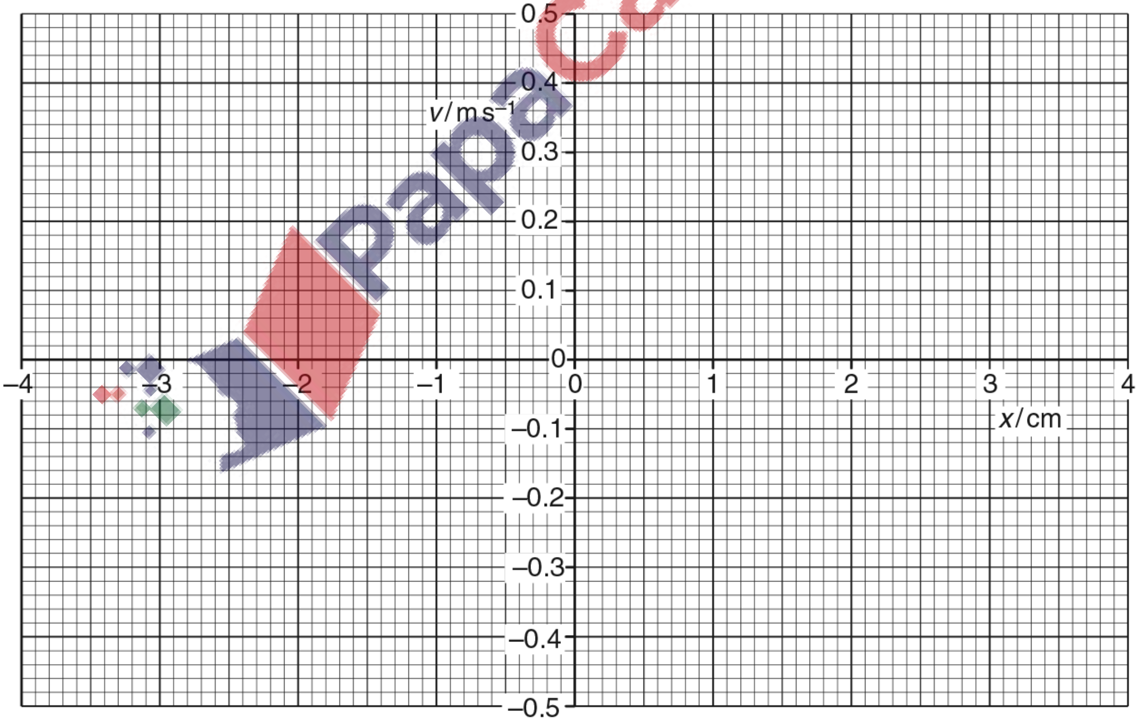


Fig. 4.3

[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.

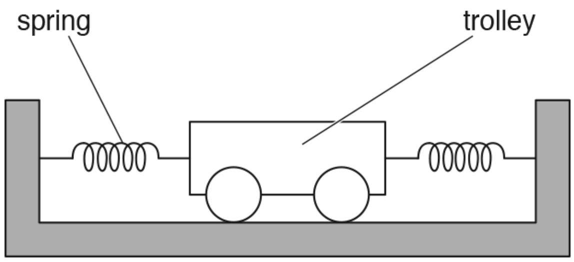


Fig. 3.1

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.

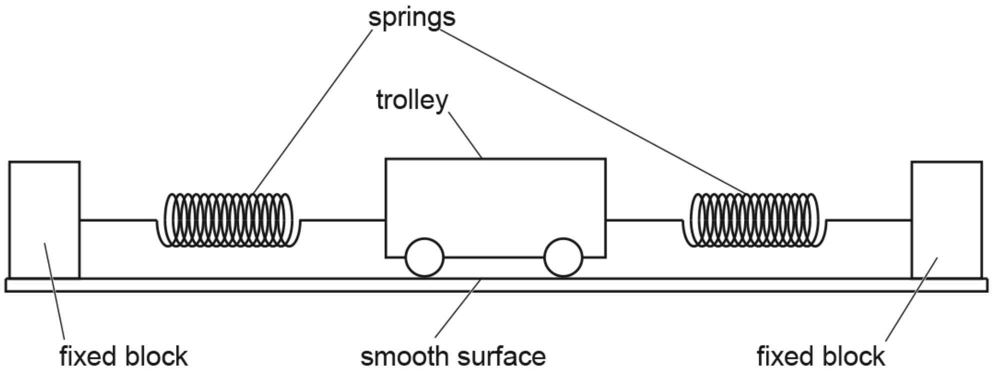


Fig. 4.1

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.

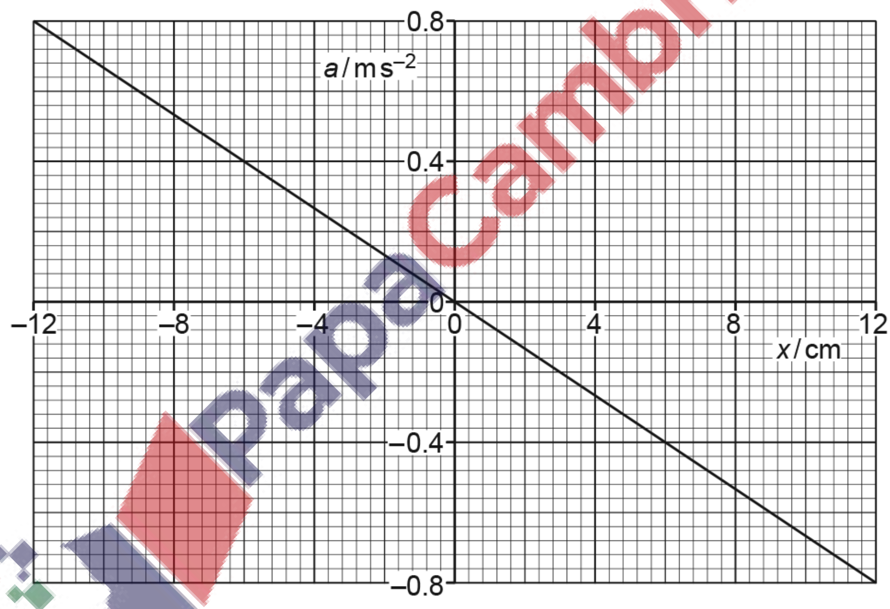


Fig. 4.2

(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.

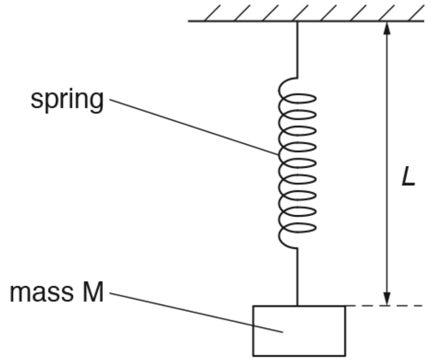


Fig. 3.1

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.

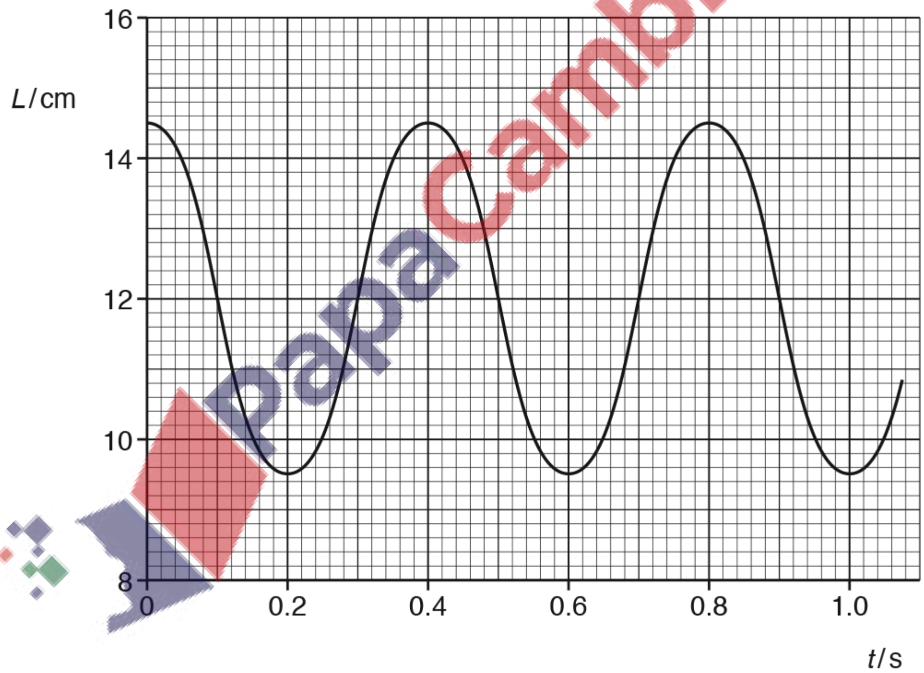


Fig. 3.2

(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]

PapaCambridge

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

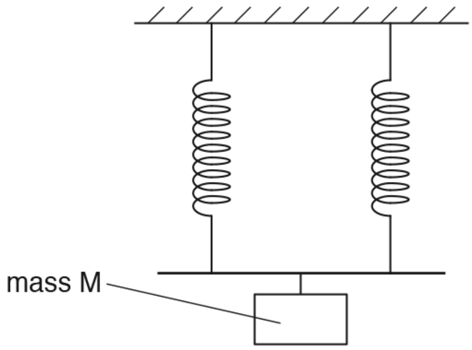


Fig. 3.3

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.

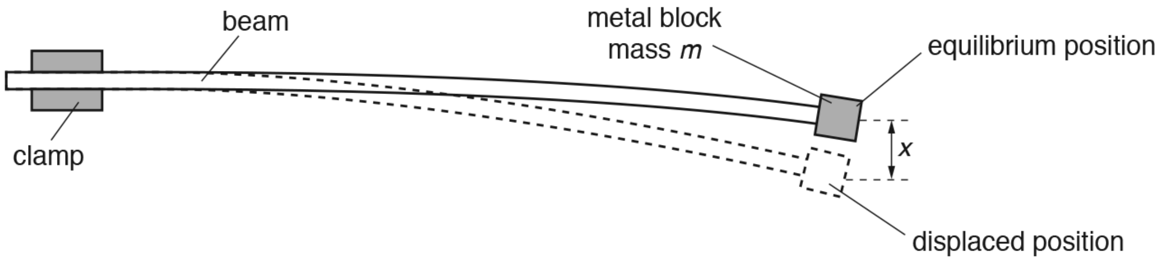


Fig. 3.1

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.

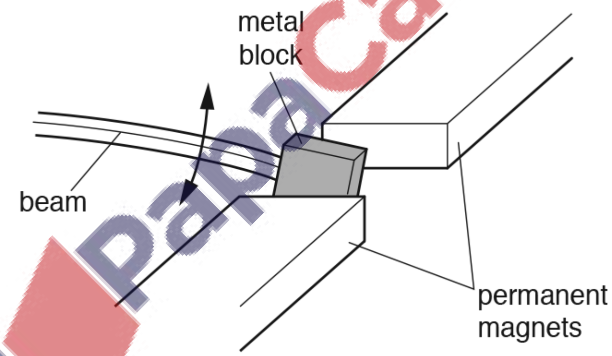


Fig. 3.2

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.

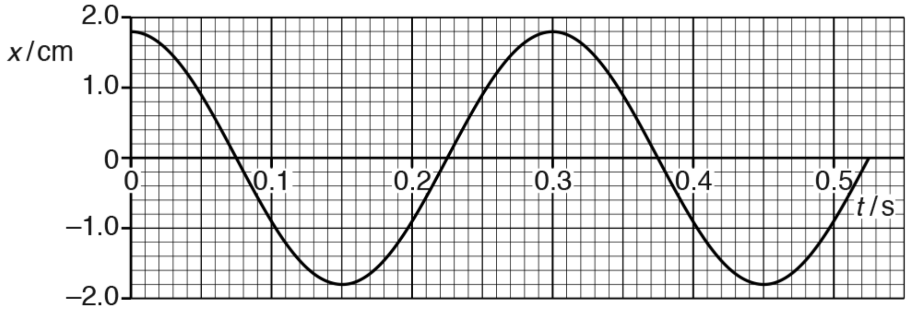


Fig. 4.1

(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.

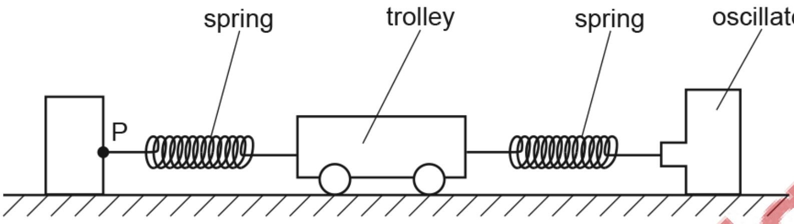


Fig. 3.1

The springs, each having spring constant *k* of 130 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.

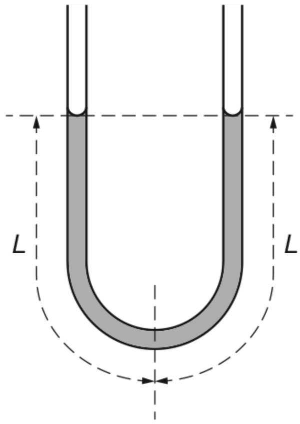


Fig. 3.1

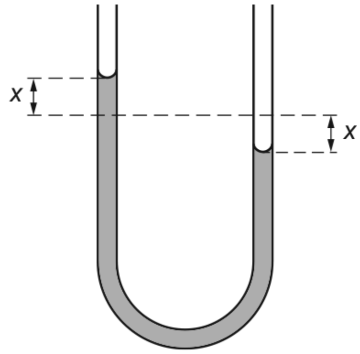


Fig. 3.2

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.

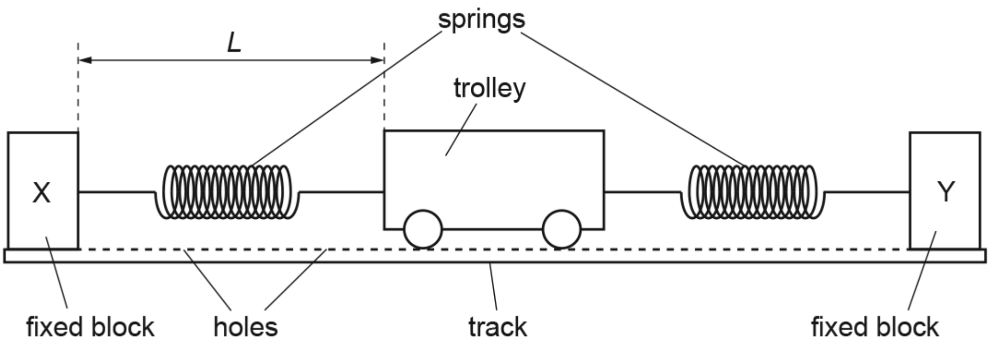


Fig. 4.1

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.

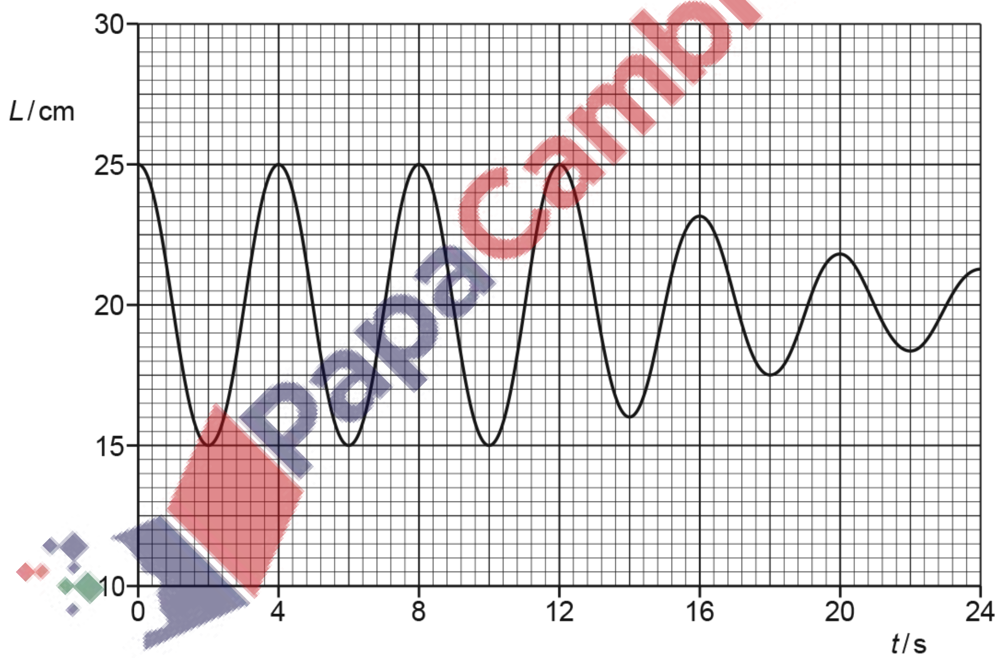


Fig. 4.2

(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.

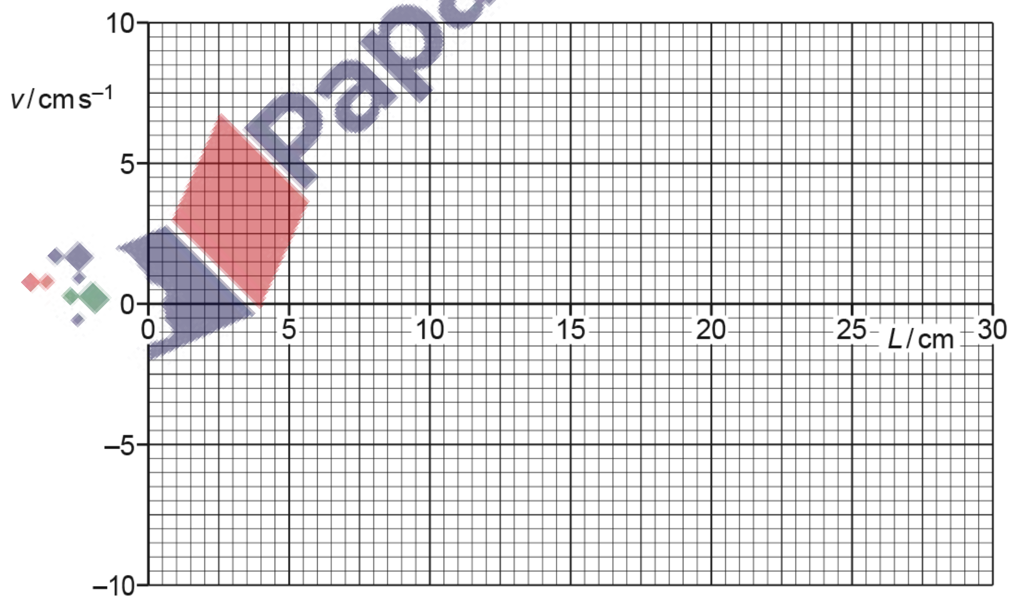


Fig. 4.3

[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.

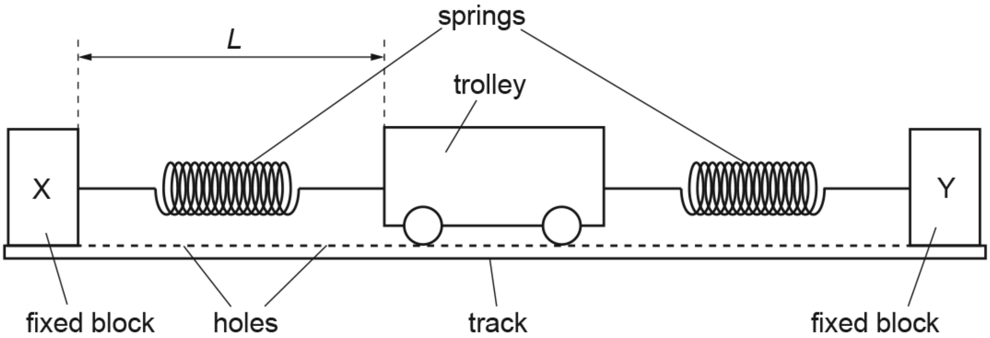


Fig. 4.1

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.

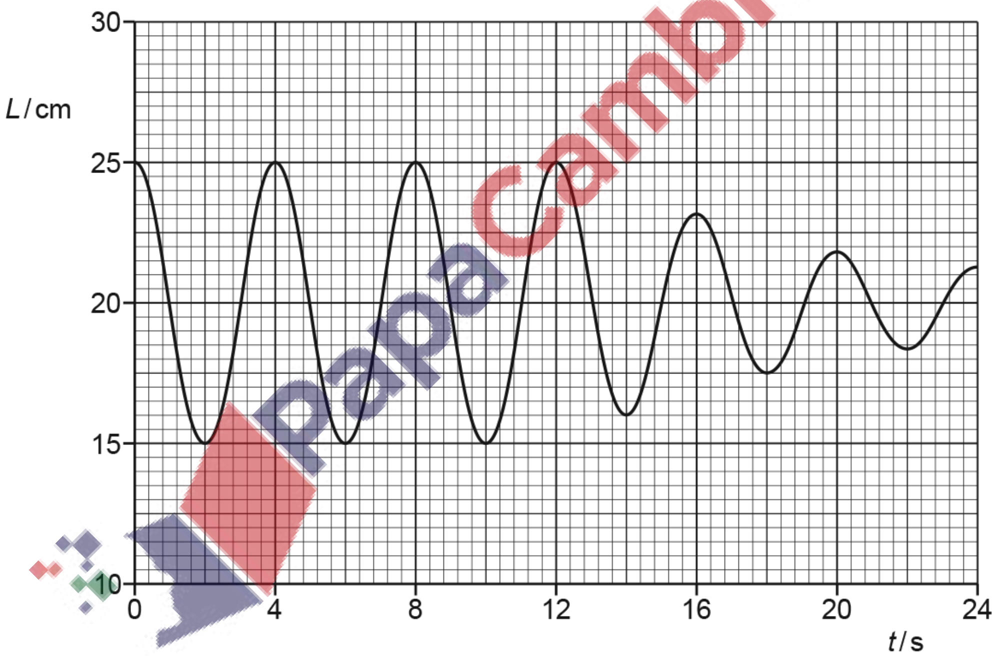


Fig. 4.2

(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.

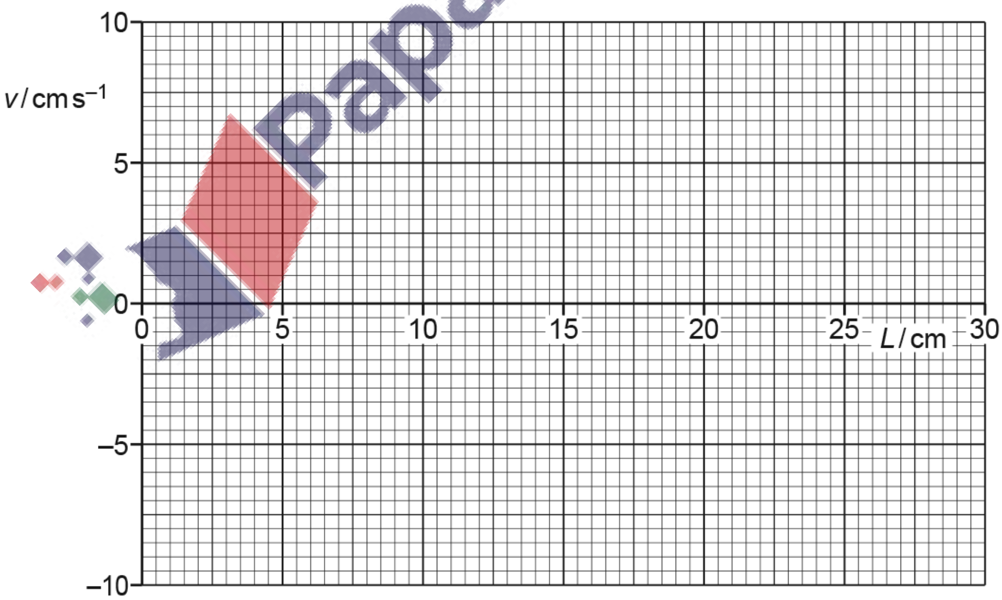


Fig. 4.3

[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.

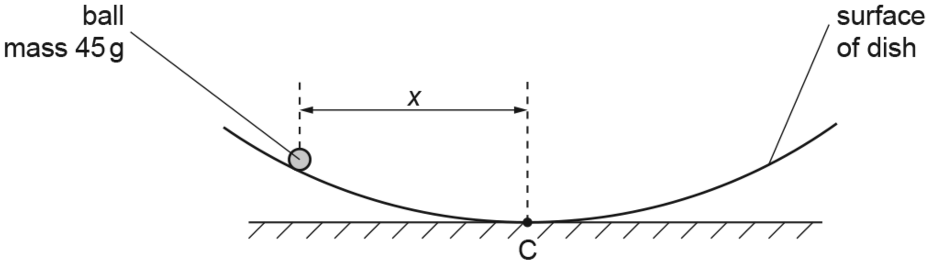


Fig. 4.1

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.

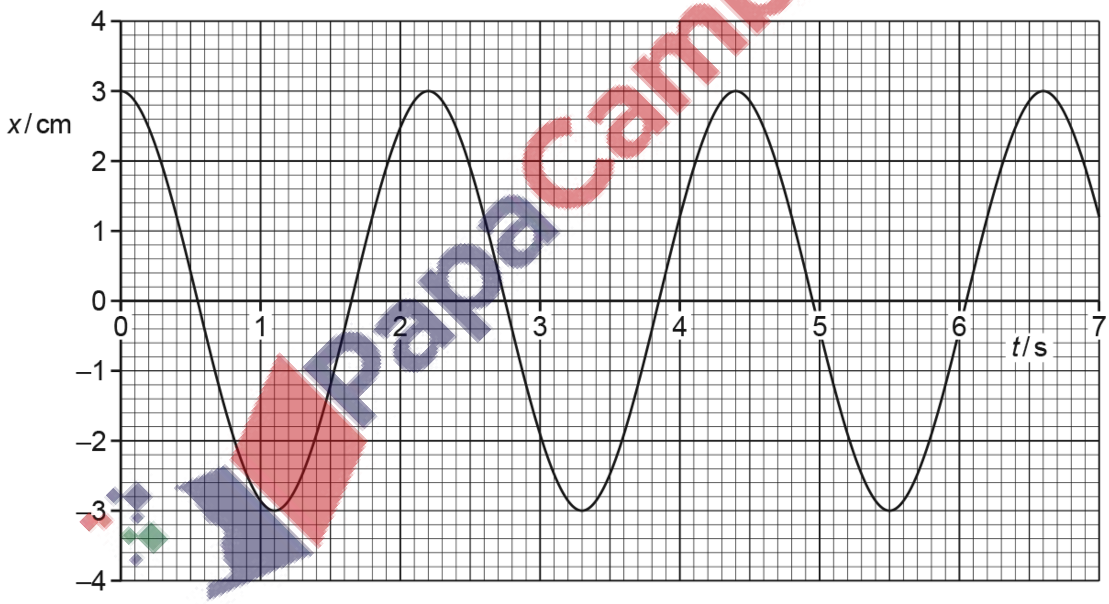


Fig. 4.2

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.

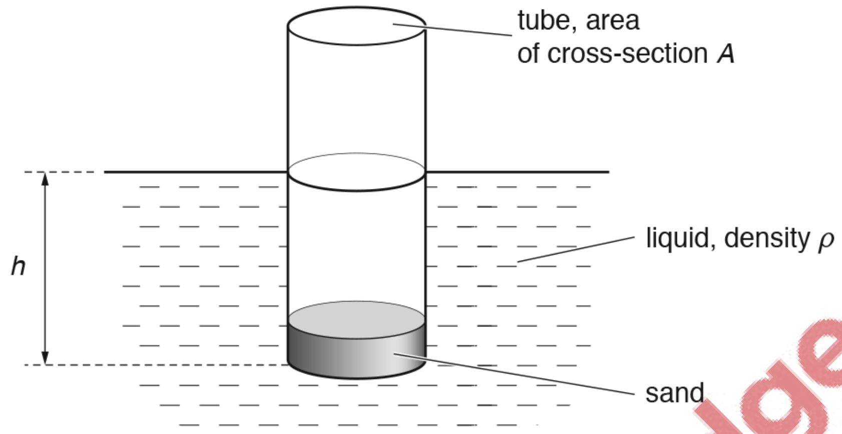


Fig. 3.1

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.

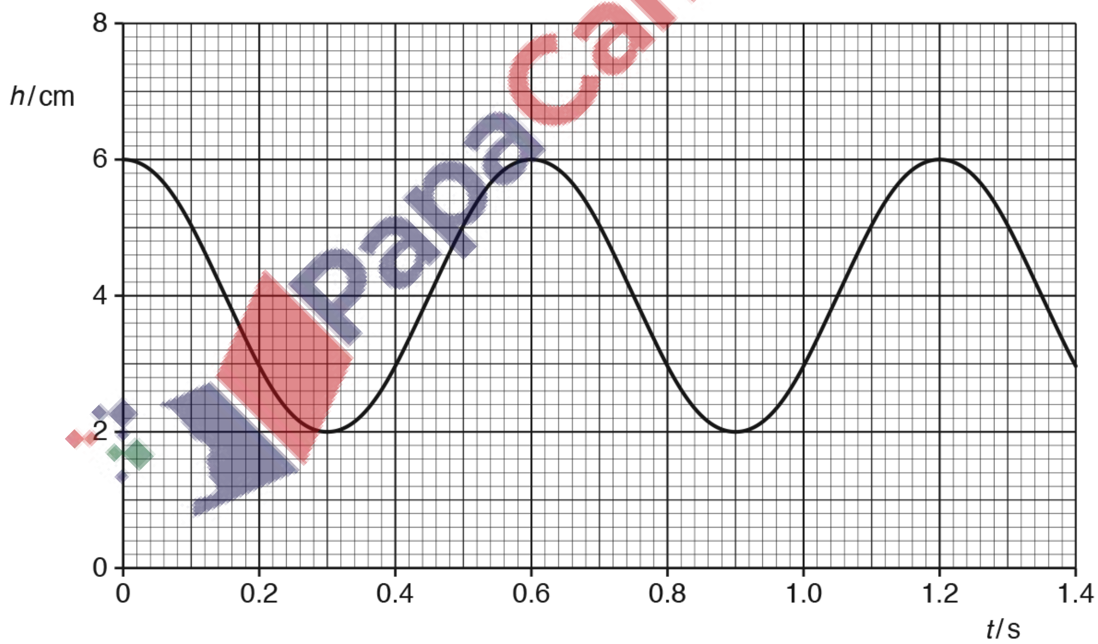


Fig. 3.2

(a) Determine:

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

amplitude = ... m [1]

(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.

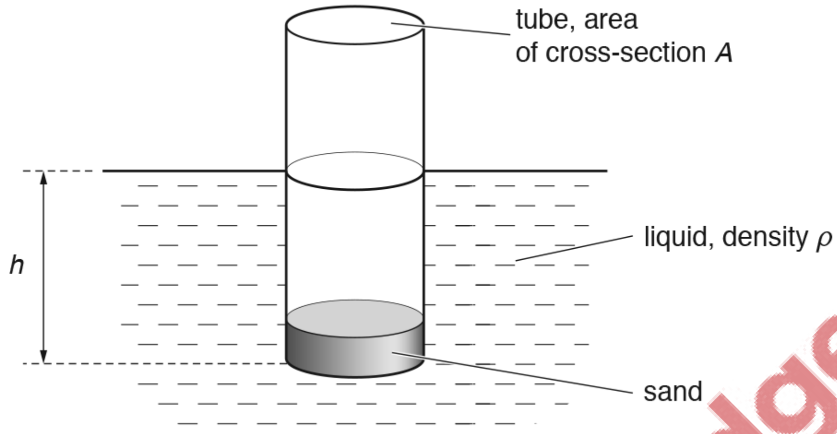


Fig. 3.1

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.

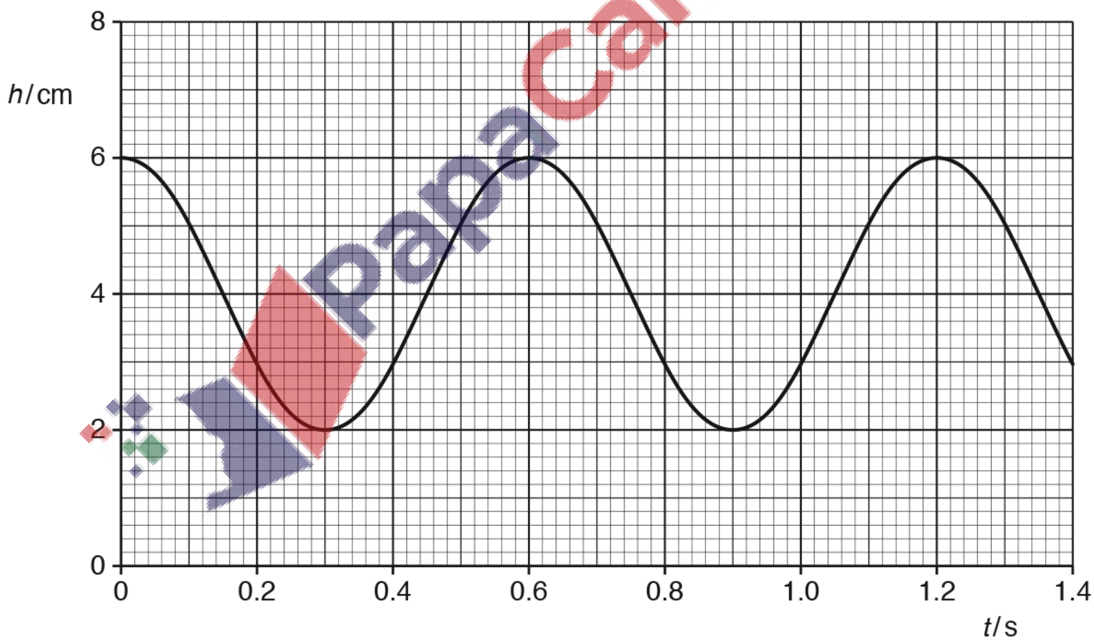


Fig. 3.2

(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.

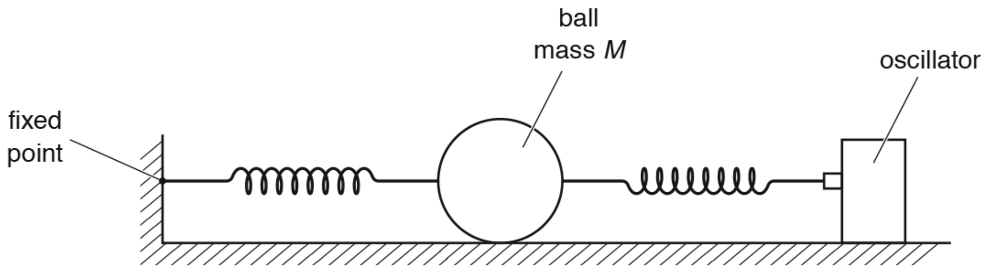


Fig. 4.1

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.

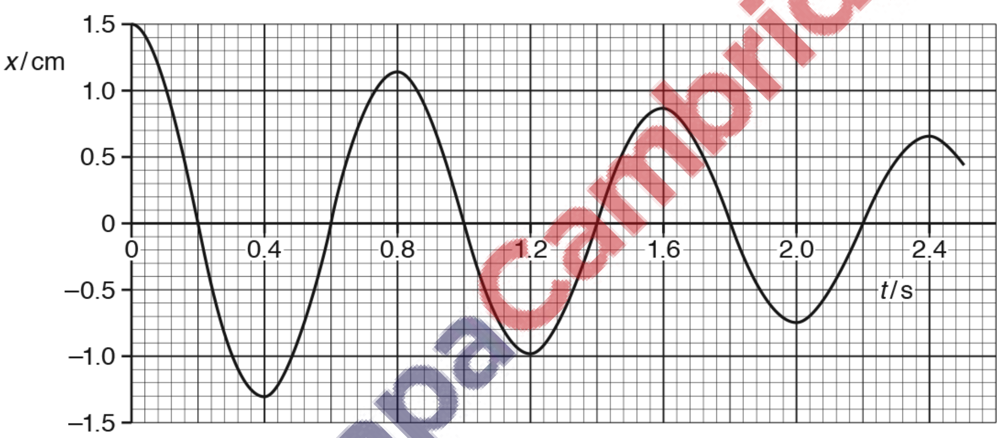


Fig. 4.2

(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.

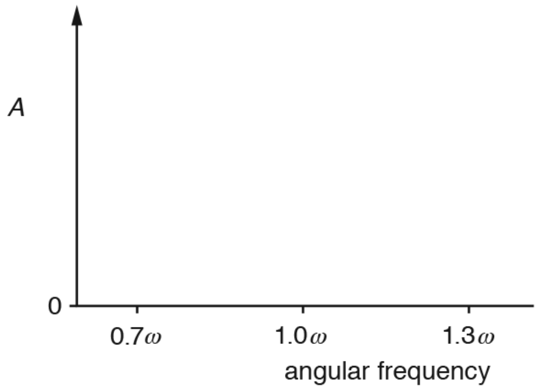


Fig. 4.3

[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.

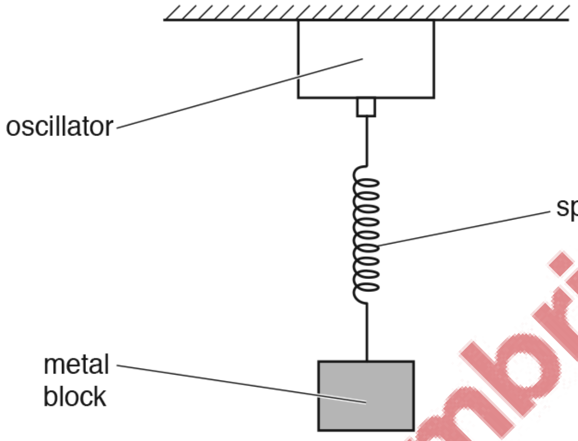


Fig. 4.1

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.

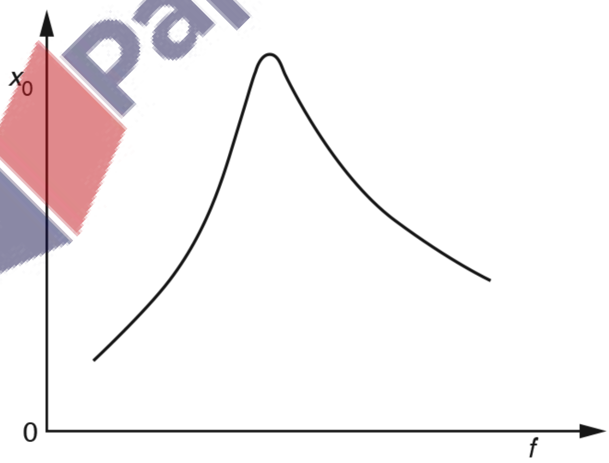


Fig. 4.2

(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.

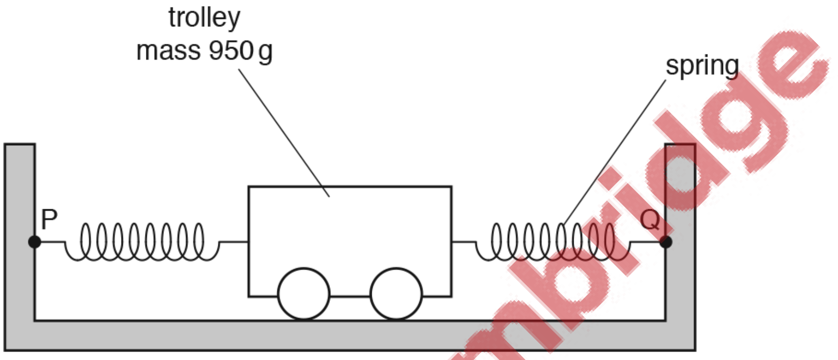


Fig. 4.1

The springs, each having a spring constant k of $230\,\mathrm{N\,m^{-1}}$, 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.

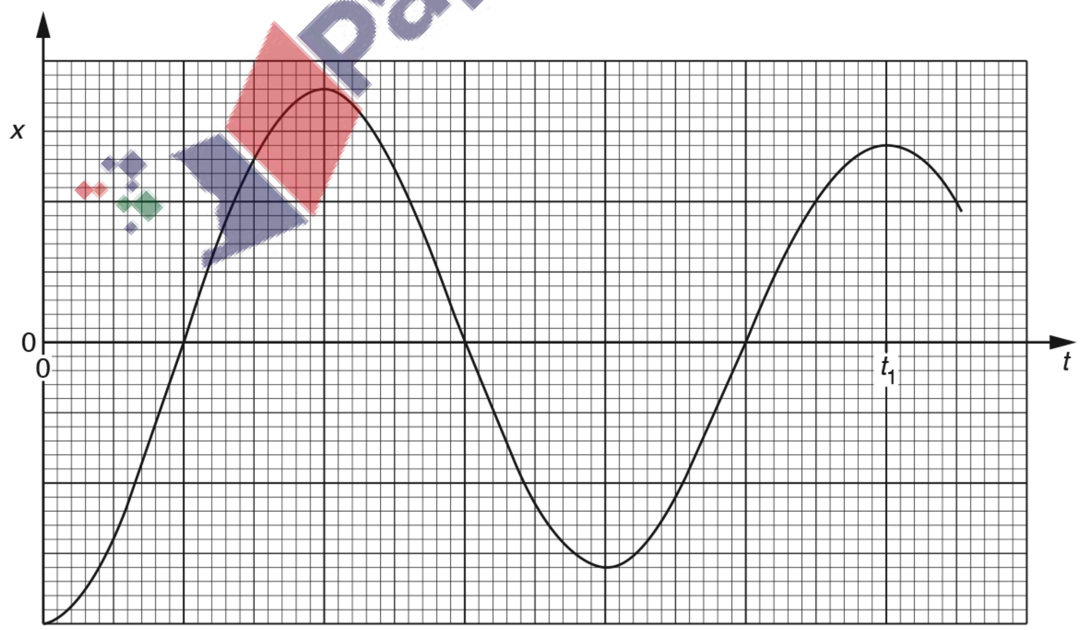


Fig. 4.2

(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.

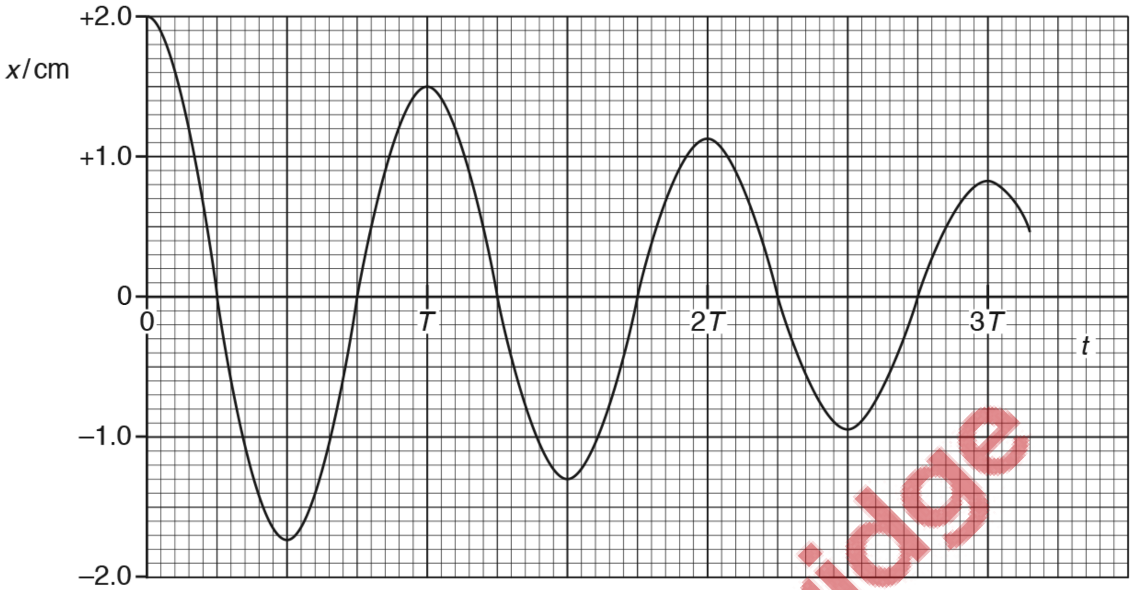


Fig. 3.3

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.

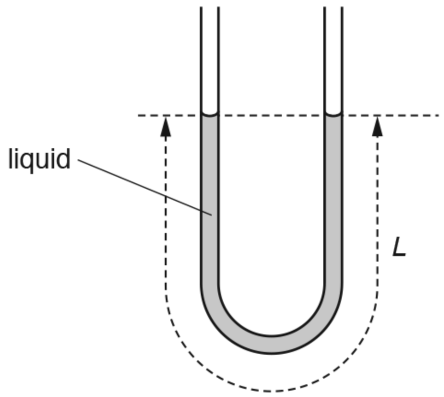


Fig. 4.1

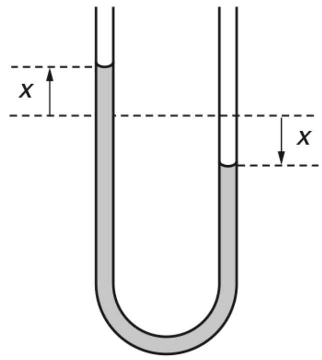


Fig. 4.2

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.

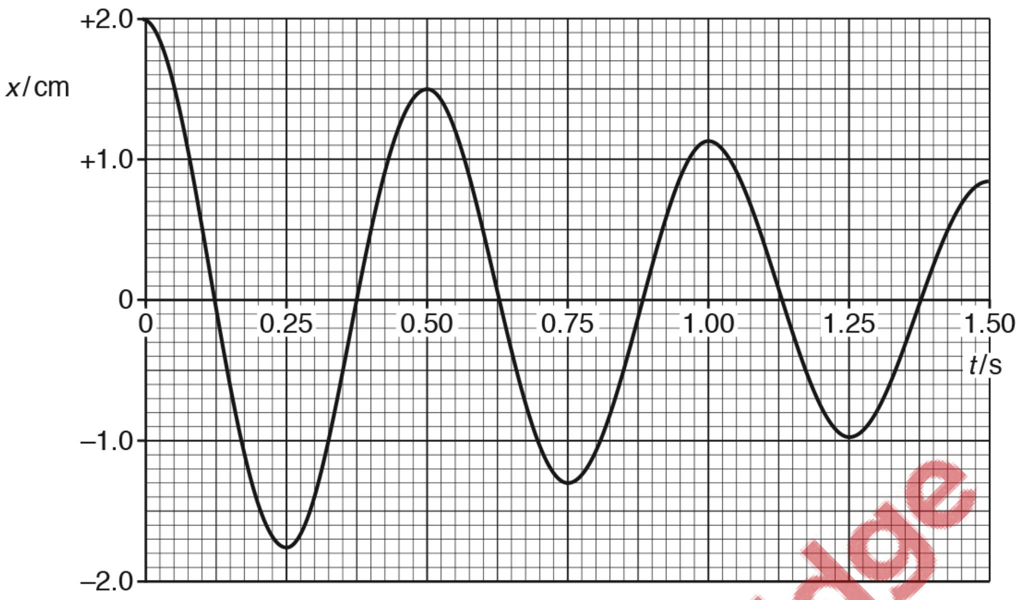


Fig. 4.3

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.

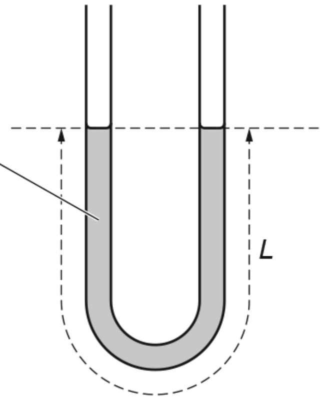


Fig. 3.1

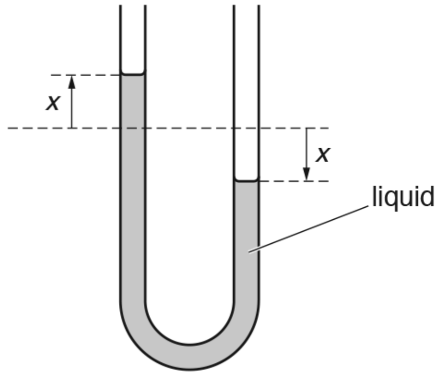


Fig. 3.2

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.

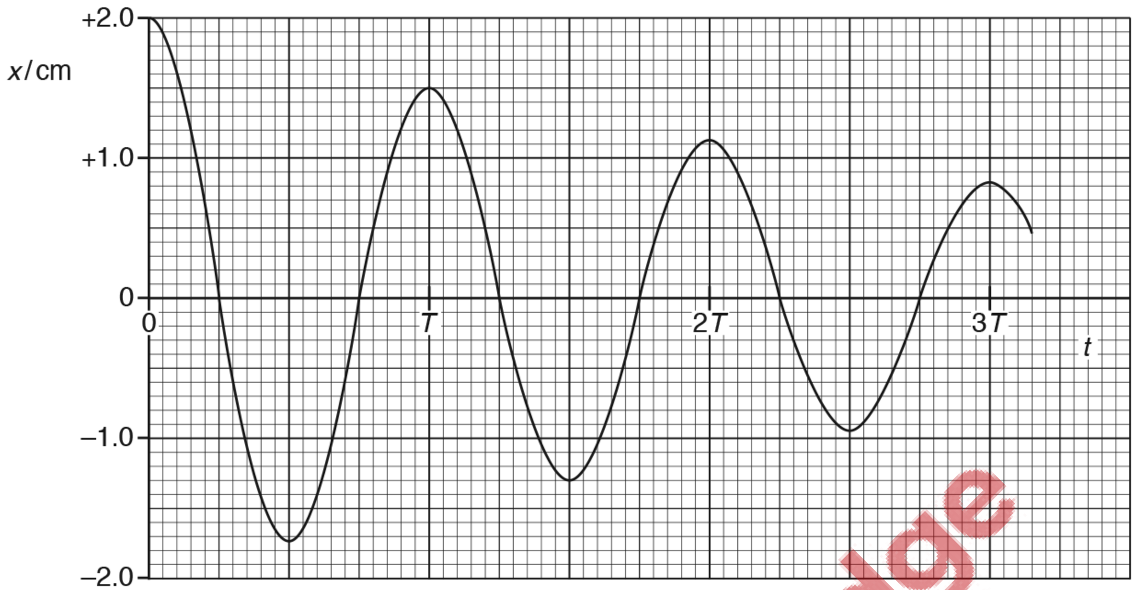


Fig. 3.3

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.

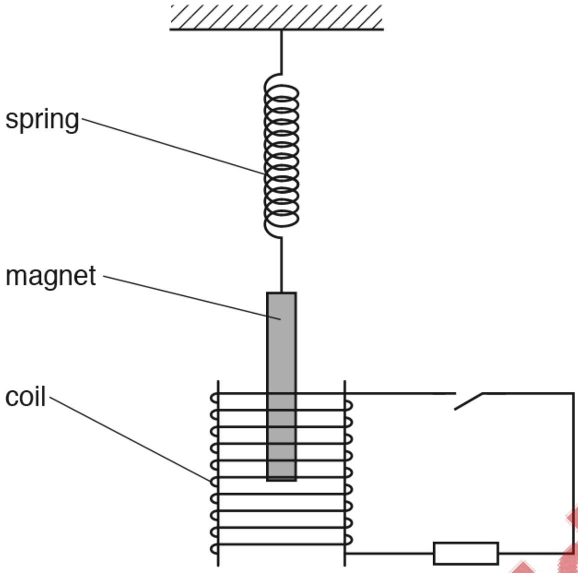


Fig. 2.1

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.

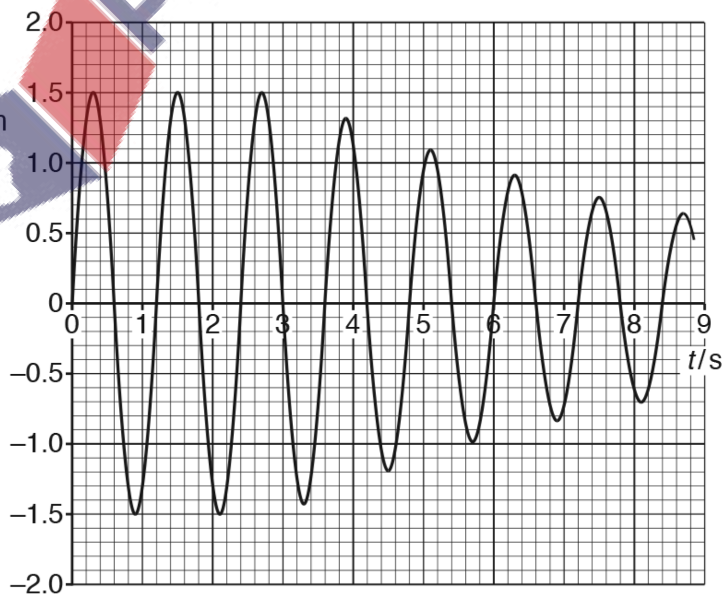


Fig. 2.2

(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]

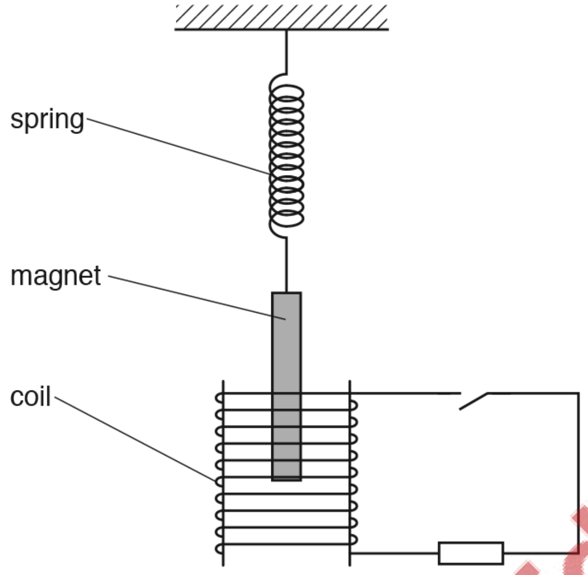
(c) Calculate the change in the energy ΔE of oscillation of the magnet between time $t = 2.7$ s and time $t = 7.5$ s. Explain your working.

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.



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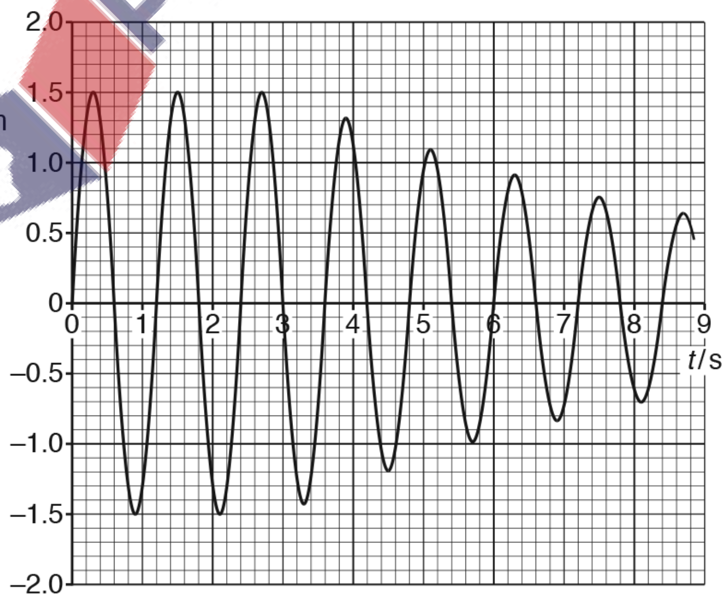

Fig. 2.2

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

frequency = ... Hz [2]

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....[1]

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ΔE = ... J [6]

[Total: 9]