H2 Physics Revision Topic : Oscillations

Structured Questions Name: ______________________

1 After a gust of strong wind, a building with a height of 160 m starts to sway. Fig. 4.1 shows the variation with *x* of the force experienced by the top floor of the building *F*, where *x* is the distance to the adjacent building.

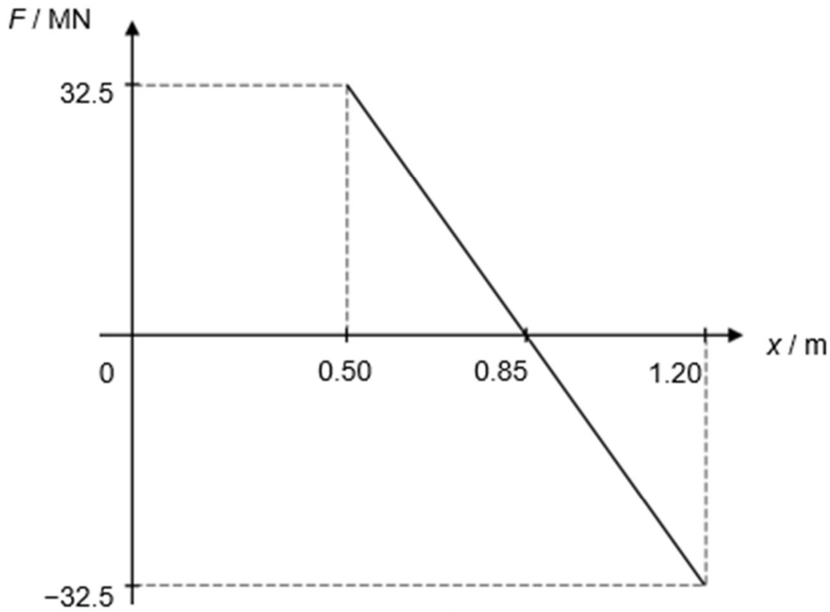

Fig. 4.1

(a) (i) Use Fig. 4.1 to explain how it can be deduced that the top floor of the building oscillates in simple harmonic motion.

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.... [3]

1

(ii) The top floor of the building experiences a maximum acceleration of 3.42 m s^{-2}.

1. Determine the amplitude of the oscillation.

amplitude = ... m [1]

2. Determine the frequency at which the wind is blowing at the building.

Explain your answer

....

.... [3]

(iii) On the same axes, sketch the variation with x of

1. the potential energy of the oscillation. Label this line P.

2. the kinetic energy of the oscillation. Label this line K.

Numerical values for energy are not required.

[2]

1 **(iv)** Determine x when $\dfrac{\text{kinetic energy}}{\text{potential energy}} = \dfrac{1}{2}$.

x = ... m [2]

(b) After an earthquake hit the city, it was found that some buildings swayed more and suffered more damage than others.

Suggest why.

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.... [2]

2 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.

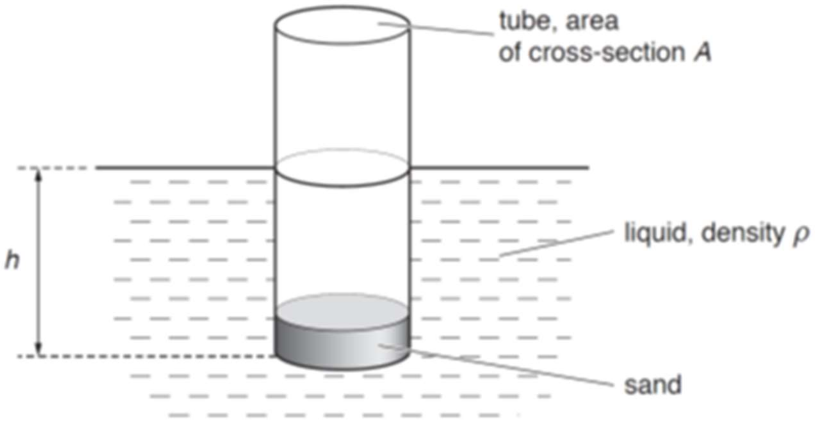

Fig. 3.1

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.

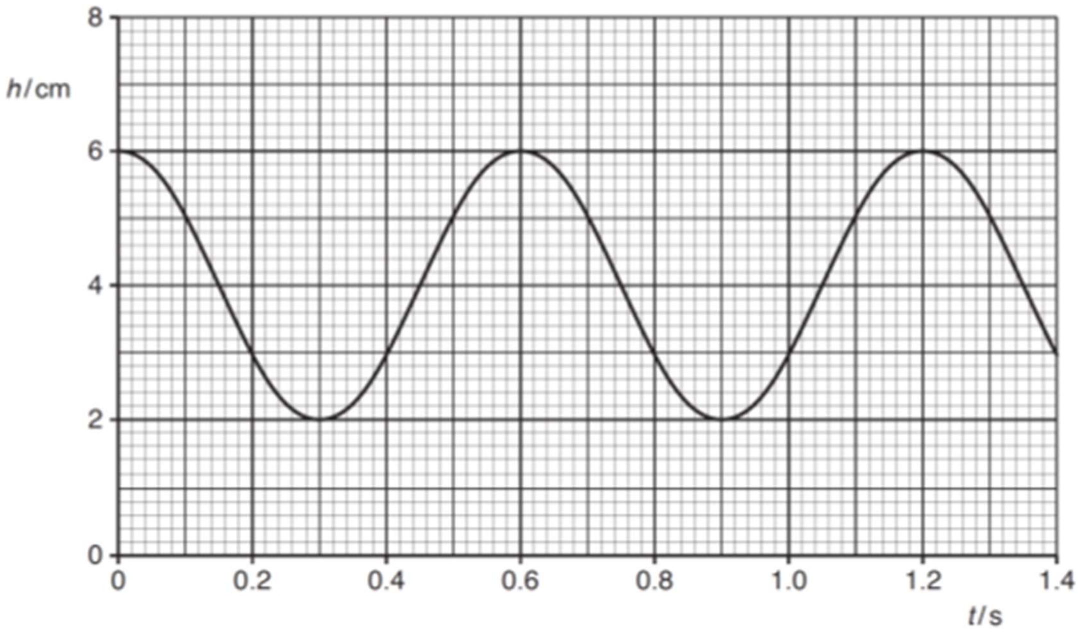

Fig. 3.2

2

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

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

(b) Describe the restoring force that gives rise to the oscillations of the tube.

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....

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.... [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: 8]

3 **(a)** A body undergoes simple harmonic motion.

The variation with displacement x of its velocity v is shown in Fig. 4.1.

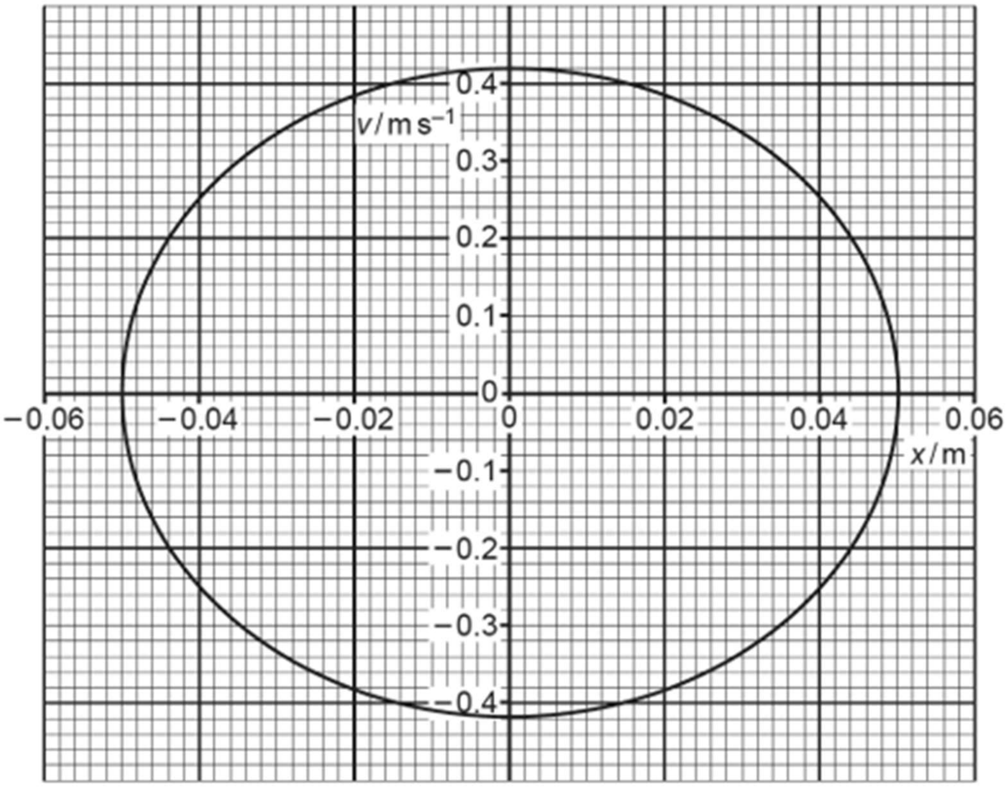

Fig. 4.1

(i) State the amplitude, x_o, of the oscillations.

x_o = …………………… m [1]

(ii) Calculate the period, T, of the oscillations.

T = …………………… s [3]

(b) On Fig. 4.1, label a point with letter P where the body has maximum potential energy. [1]

4 **(a)** 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. 7.1.

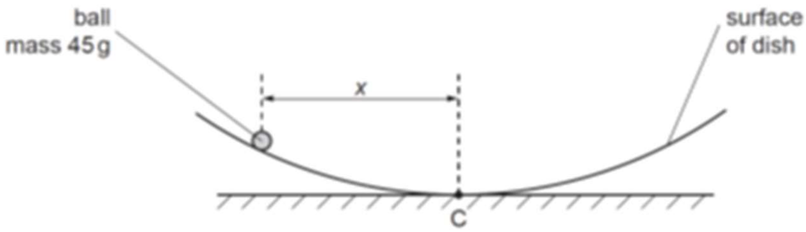

Fig. 7.1

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. 7.2.

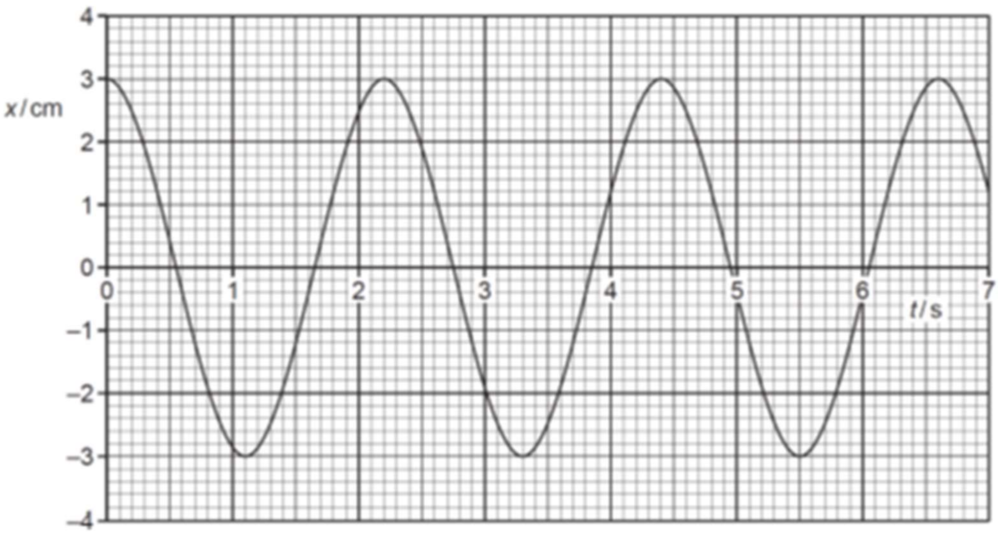

Fig. 7.2

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.

4

(i) Explain how the expression $a = -\left(\frac{g}{R}\right)x$ suggests that the motion is simple harmonic?

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....[2]

(ii) Use Fig. 7.2 to show that the angular frequency ω of the oscillation of the ball in the dish is 2.9 rad s^{-1}.

[1]

(iii) Determine *R*.

R = ... m [1]

(iv) Calculate the speed of the ball when x = 1.5 cm.

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

4 **(v)** Calculate the total energy of the oscillation.

total energy = ... J [3]

(vi) Determine the kinetic energy E_k of the ball in terms of time t.

E_k = ... J [2]

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

On the axes of Fig. 7.3, draw a graph to show variation of x with E_k of the damped motion of the ball for the first 2.2 s after the release of the ball.

No numerical values are required.

[1]

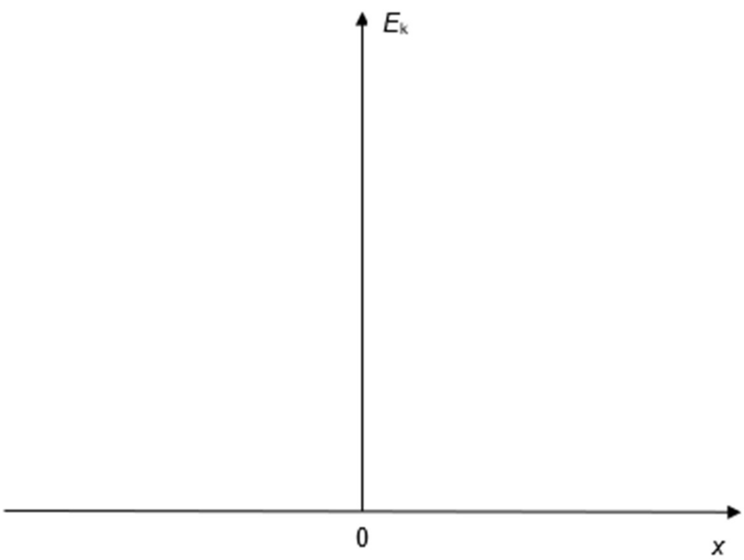

Fig. 7.3

4

(b) A block of wood of mass *m* floats in still water, as shown in Fig. 7.4 below.

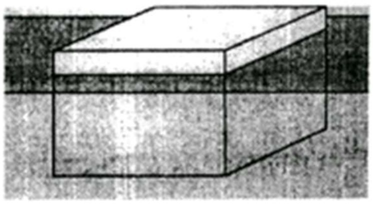

Fig. 7.4

When the block is pushed down into the water, without totally submerging it, and is then released, it bobs up and down in the water with a frequency *f* given by the expression

$$f = \frac{1}{2\pi}\sqrt{\frac{28}{m}}$$

where *f* is measured in Hz and *m* in kg.

Surface water waves of speed 0.90 m s^{-1} and wavelength 0.30 m are then incident on the block. These cause resonance in the up-and-down motion of the block.

(i) Calculate

1. the frequency of the water waves,

frequency = ... Hz [1]

2. the mass of the block.

mass = ... kg [1]

4 **(ii)** Describe and explain what happens to the amplitude of the vertical oscillations of the block after the following changes are made independently:

1. water waves of larger amplitude are incident on the block,

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....[2]

2. the distance between the wave crests increases,

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....[2]

3. the block has absorbed some water.

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....[2]

[Total: 20]

5 **(a)** Define simple harmonic motion (s.h.m.).

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....[2]

(b) A trolley of mass 700 g oscillates between two stands as shown in Fig. 2.1. As the trolley moves from right to left, it pulls the ticker tape for half a cycle. The timer marks 50 dots per second.

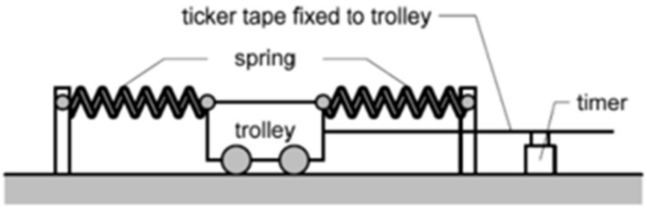

Fig. 2.1

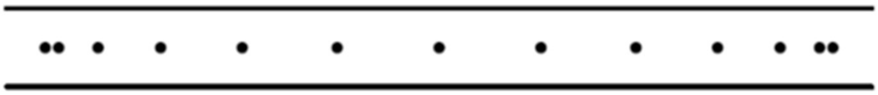

Fig. 2.2 (drawn to scale)

The ticker tape in Fig. 2.2 is drawn to full scale. By making appropriate measurements,

(i) show that the period of oscillation is 0.48 s.

[1]

(ii) determine the amplitude of the oscillation,

amplitude = ... cm [1]

5 **(c)** Hence, calculate

(i) the maximum velocity of the trolley,

maximum velocity = ……………………. cm s^{-1} [1]

(ii) the maximum resultant force acting on the trolley,

maximum resultant force = ……………………. N [2]

(d) Sketch in Fig. 2.3 the graph of velocity against displacement for the half-cycle that that ticker tape was pulled through, taking leftward to be the positive direction.

Indicate the starting point on your sketch. There is no need to indicate values.

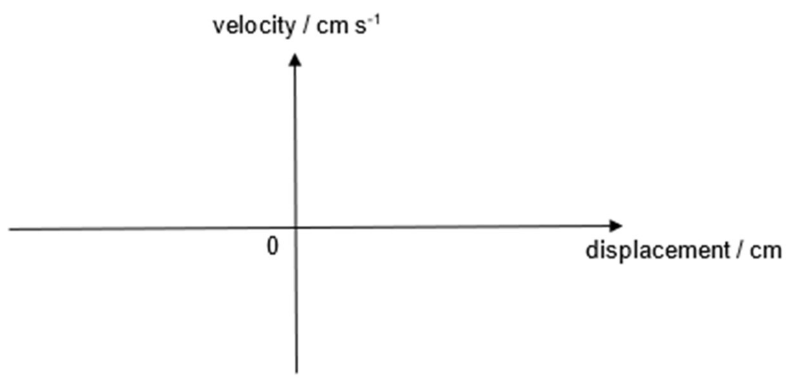

Fig. 2.3

[2]

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

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.... [2]

(b) A spring hangs vertically from a fixed point.

A mass of 1.2 kg is attached to the free end of the spring, as shown in Fig. 4.1.

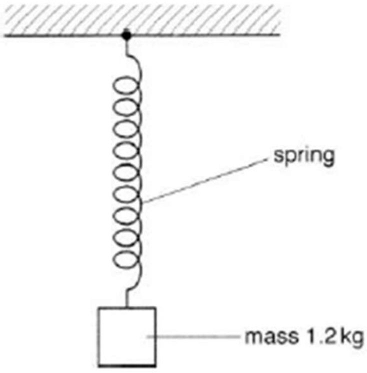

Fig. 4.1

The mass undergoes vertical simple harmonic motion with frequency 1.5 Hz and amplitude 3.4 cm.

(i) Determine the maximum resultant force on the mass.

maximum resultant force = ... N [2]

(ii) Determine the maximum kinetic energy of the mass.

maximum kinetic energy = ... J [2]

6 **(c)** A luggage weighing sensor measures the weight of a luggage using a spring. The luggage is hung in the same manner as how the mass in Fig. 4.1 is hung.

Suggest the advantages for the luggage weighing sensor to be **critically** damped.

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.... [2]

[Total: 8]

7 The piston in the cylinder of a car engine is made to move in the cylinder with simple harmonic motion.

Fig. 4.1 shows the highest and lowest positions of the piston.

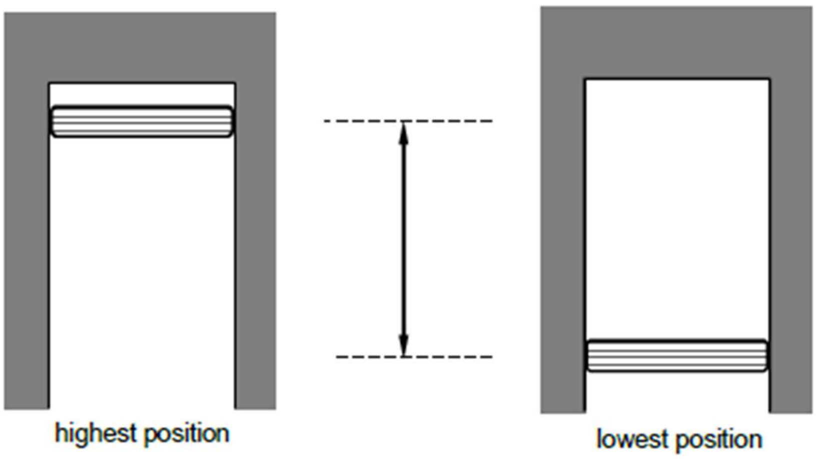

Fig. 4.1

7 The variation of the acceleration a of the piston with its displacement x from position O is as shown in Fig. 4.2.

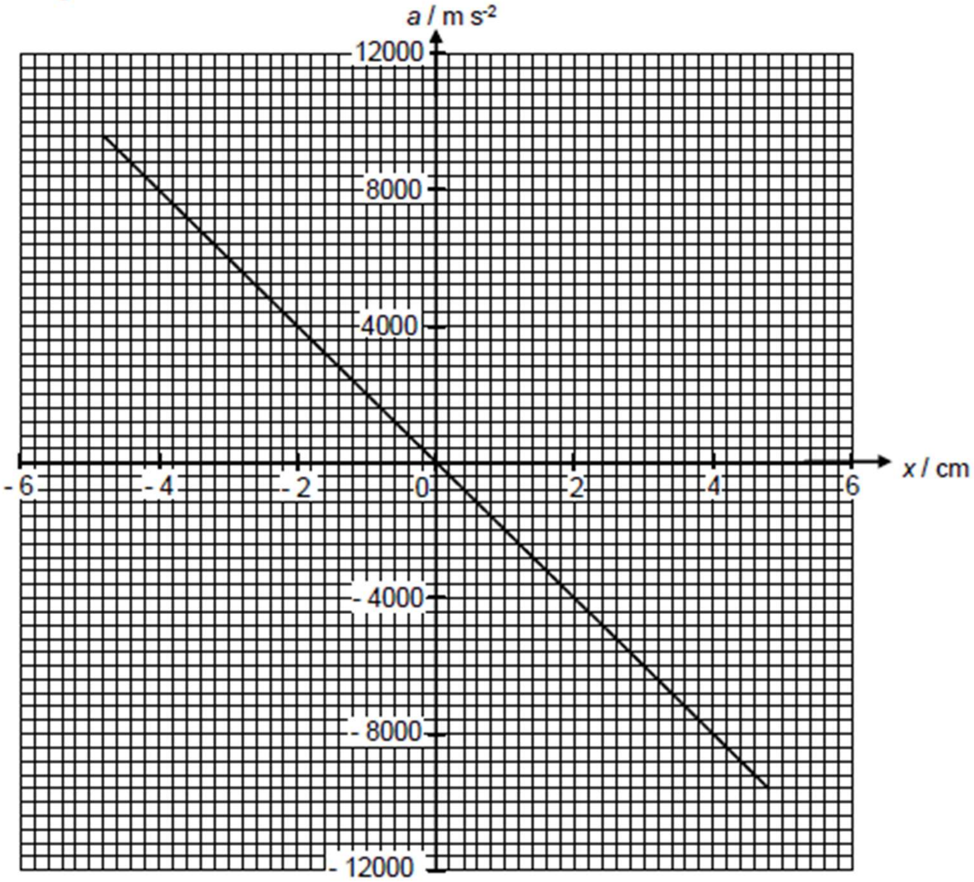

Fig. 4.2

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

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....[2]

7 **(b)** Determine the maximum speed of the piston.

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

(c) With reference to Fig. 4.2,

(i) explain why the time taken for the piston to move from x = 3.3 cm to x = 0 cm is the same as that from x = 0 cm to x = -3.3 cm.

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....[2]

(ii) The area under the graph in Fig. 4.2 from x = 0 to x = 4.8 cm is given by Z.

A student calculates K, the maximum kinetic energy of the piston, using the relationship

$$K = Z \times M$$

where M is the mass of the piston.

Explain why this relationship is valid.

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....[2]

7 **(d)** The piston is made to move by connecting a rod to a rotating crankshaft as shown in Fig. 4.3. As the pivot P on the crankshaft rotates, the piston will move up and down.

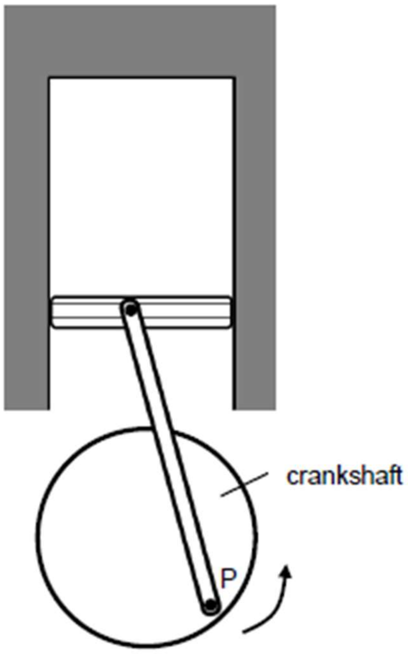

Fig. 4.3

When pivot P is at the position shown in Fig. 4.3, the piston is moving upward with a position of x = -3.3 cm.

Indicate on Fig. 4.3 the position of pivot P when the piston is at the following positions,

(i) x = 3.3 cm moving upwards. (Indicate this position with A)

(ii) x = 3.3 cm moving downwards. (indicate this position with B) [2]

[Total: 10]

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

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.... [2]

(b) Fig. 8.1 shows a U-tube containing a liquid that was initially at rest. The U-tube has a uniform cross-sectional area *A*. The density of the liquid is *ρ* and the total length of the liquid is *L*.

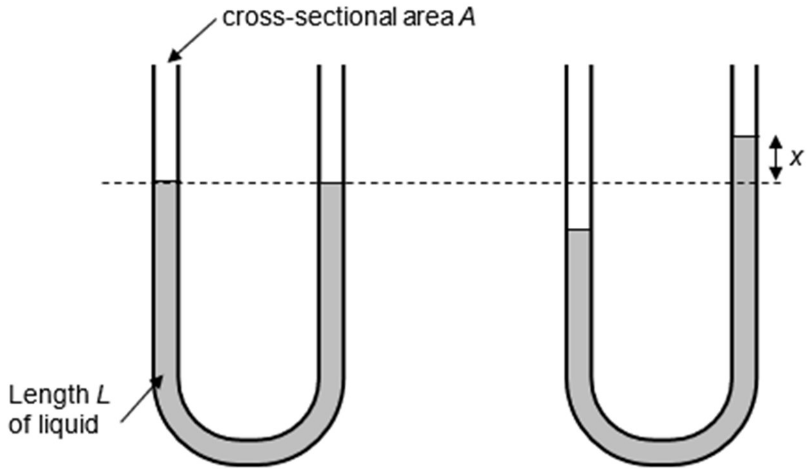

Fig. 8.1 **Fig. 8.2**

Due to a small disturbance, the liquid level on the right limb is displaced upwards by a distance *x* as shown in Fig. 8.2. The difference in the liquid levels between the two limbs will produce a pressure difference and this in turn will cause a restoring force to act on the length of liquid to accelerate it back towards its equilibrium position.

(i) In terms of *A*, *L* and *ρ*, write down the expression for the total mass *M* of the liquid.

[1]

8

(ii) Derive the expression for the magnitude of the restoring force F acting on the liquid in terms of ρ, g and x and A.

[2]

(iii) Using the relationship

$$F = Ma$$

where a is the acceleration of the liquid, and your answers in parts **(i)** and **(ii)**, show that the liquid will oscillate with simple harmonic motion after it is disturbed from its equilibrium state. You may assume that viscous forces in the liquid are negligible.

[3]

(iv) Hence, show that the angular frequency of the oscillations is $\omega = \sqrt{\dfrac{2g}{L}}$.

[1]

8 **(c)** The liquid shown in Fig. 8.2 has a length L of 0.92 m, mass M of 1.2 kg and an initial displacement of 0.080 m.

(i) Calculate the angular frequency ω.

ω = ... rad s^{-1} [1]

(ii) Determine the period T of the oscillations.

T = ... s [1]

(iii) Determine the maximum kinetic energy $E_{K,max}$ of the oscillating liquid.

$E_{K,max}$ = ... J [2]

8 **(d)** Viscous forces in the liquid in **(c)** are assumed to be negligible. In practice, there will be damping due to small viscous forces in the liquid.

(i) Explain what is meant by damping.

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.... [1]

(ii) On the axes in Fig. 8.3, sketch the variation with time t of the displacement x of the liquid in **(c)** for the first two cycles of oscillations.

Assume that the period of oscillations is unaffected by the viscous forces.

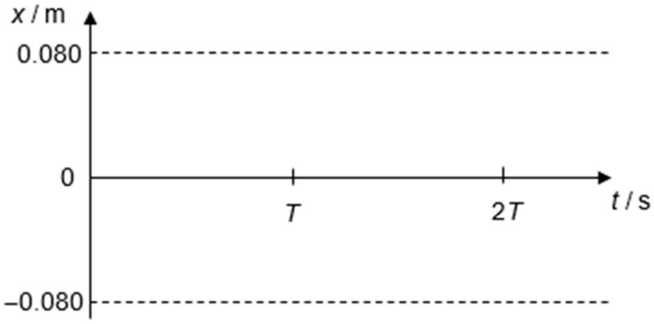

Fig. 8.3 [2]

(iii) On the axes in Fig. 8.4, sketch the corresponding variation with time t of the kinetic energy of the liquid for the first two cycles of oscillation.

You need not label any numerical values on your graph.

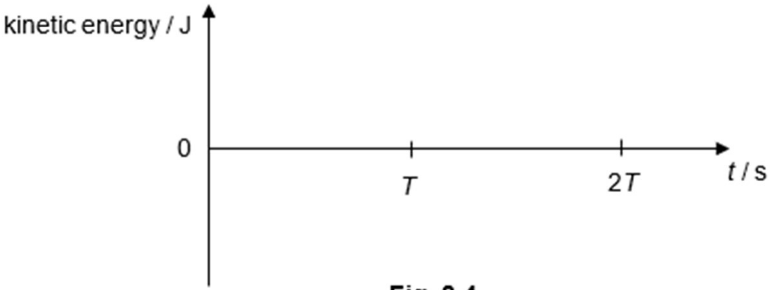

Fig. 8.4 [2]

(e) Damping is important in some applications. State one such application and explain why damping is important.

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.... [2]

9 A mass P is attached to the free end of a horizontal spring on a smooth surface. The spring-mass system is set into simple harmonic motion by pulling P to the right of the equilibrium position and is released from rest as shown in Fig. 3.1.

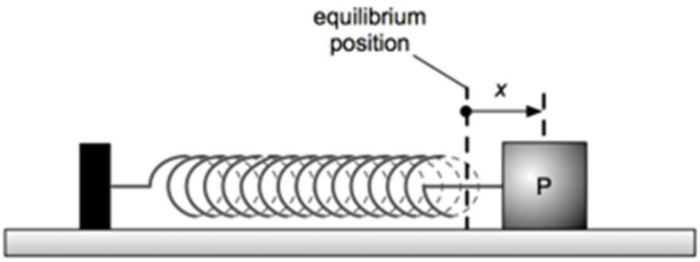

Fig. 3.1

If the air resistance on P is negligible, the variation of the velocity v of P with displacement x is shown in Fig. 3.2. Vectors to the right are taken to be positive.

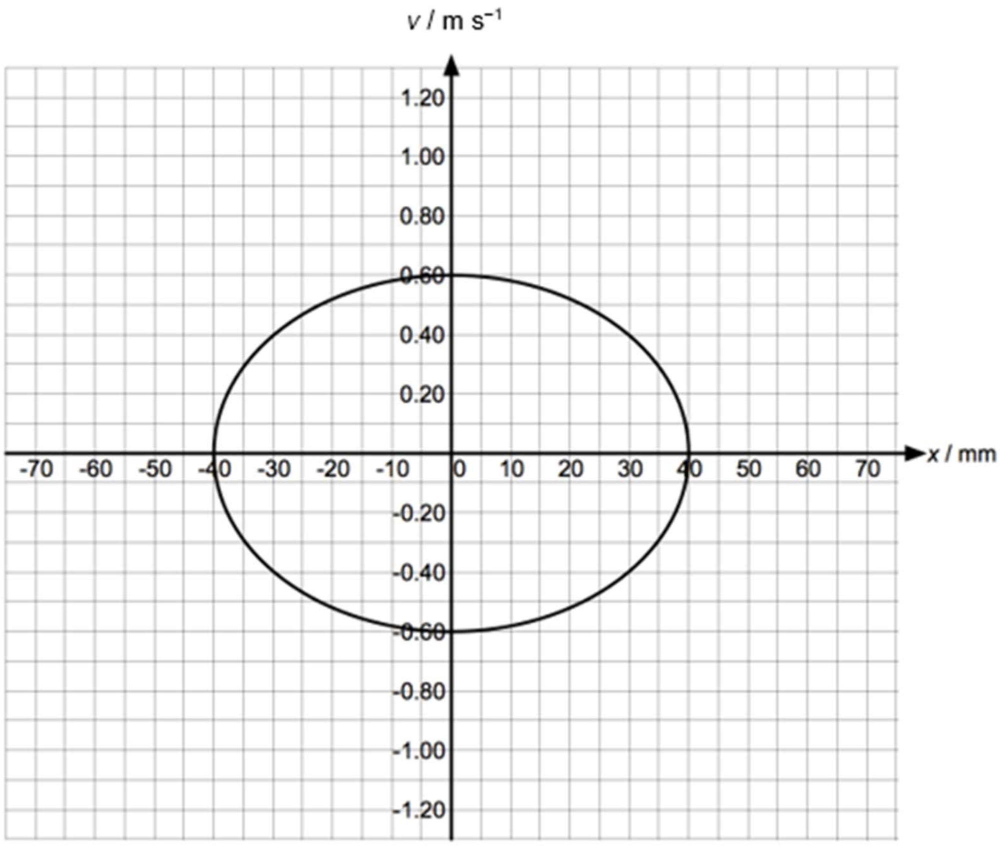

Fig. 3.2

(a) For the motion of P, determine

(i) the amplitude and

amplitude = ... mm [1]

9

(ii) the frequency.

frequency = ... Hz [2]

(b) If the air resistance on P is not negligible, sketch on Fig. 3.2 the variation of the velocity of P with displacement *x*. Label it "air resistance". [3]

(c) A periodic force is now exerted on the spring-mass system. When the periodic force is at a certain frequency, P is in resonance.

(i) Given that the total energy of the spring-mass system at steady state is doubled.

Determine the new maximum speed of P.

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

(ii) On Fig. 3.2, sketch the variation of the velocity of P, at resonance, with displacement *x*. Label it "resonance".

[2]

10 **(a)** Define simple harmonic motion

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....

.... [1]

(b) A spring, which hangs from a fixed support, extends by 40 mm when a mass of 0.25 kg is suspended from it.

(i) Determine the spring constant k of the spring.

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

(ii) An additional mass of 0.44 kg is then placed on the spring and the system is set into vertical oscillations with an amplitude of 20 mm.

Given that $$a = -\frac{kx}{m}$$

where a is the acceleration of the mass, x is the displacement of the mass from equilibrium and m is the total mass of the oscillating system.

1. Show that the oscillation frequency is 1.5 Hz. [2]

2. Determine the displacement at which the potential energy and the kinetic energy of the oscillations are equal.

displacement = ... mm [2]

10

3. With both masses still in place, the spring is now suspended from a horizontal support rod that can be made to oscillate vertically at varying frequencies, as shown in Fig. 3.1.

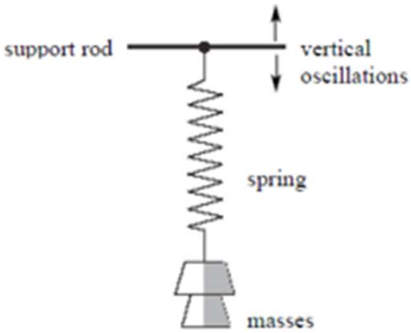

Fig. 3.1

The response of the masses suspended from the spring to the vertical oscillations of the support rod varies with frequency.

Describe and explain the motion of the masses when the support rod oscillates at a frequency from 0.2 Hz to 3.0 Hz.

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.... [4]

11 Fig. 2.1 shows a box with a piece of plasticine attached outside it. A light spring is attached to the box and the box is initially at rest. After some time, the plasticine detaches and falls, as shown in Fig. 2.2.

The box in Fig. 2.2 starts to oscillate in simple harmonic motion.

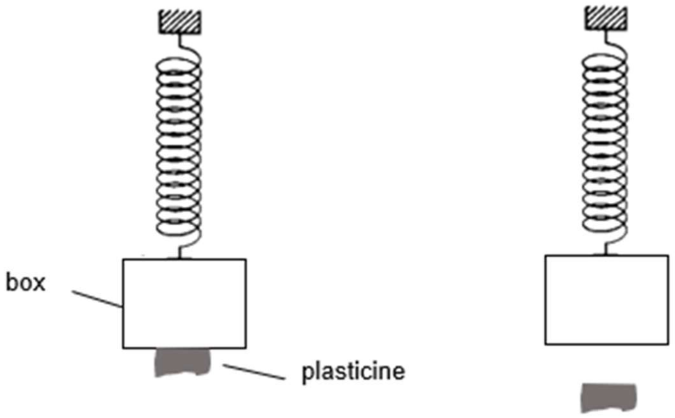

Fig. 2.1 **Fig. 2.2**

(a) Explain why the box in Fig. 2.2 starts to oscillate.

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.... [3]

(b) The mass of the plasticine is 20.0 g and the mass of the box is 100.0 g.

(i) Show that the magnitude of the maximum acceleration of the box's oscillation in Fig. 2.2 is 1.96 m s^{-2}.

[2]

11 **(ii)** The box in Fig. 2.2 moves a distance 5.00 cm from its lowest position to its highest position. Calculate the period of the oscillation.

period = ... s [3]

(c) The box in Fig. 2.2 continues to oscillate after the plasticine detaches. The box is at its lowest position at time t = 0.0 s.

On Fig. 2.3, sketch the variation with time t of the displacement x of the box for at least two cycles of its oscillation.

Assume negligible air resistance.

Fig. 2.4 [2]

[Total: 10]

12 A mass damper can be used to stabilise a building during earthquakes. A mass-spring system shown in **Fig. 3.1** can be used to model a mass damper.

A 600 g mass is placed on a smooth surface and is attached horizontally to two unstretched identical springs X and Y each with a spring constant of 20 N m^{-1}.

When the mass is displaced by 5.0 cm from its equilibrium position and released from rest as shown in **Fig. 3.2**, it undergoes simple harmonic motion.

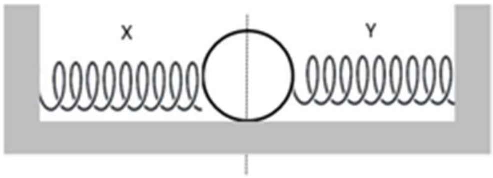

Fig. 3.1

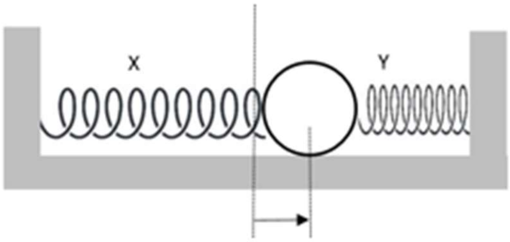

Fig. 3.2

(a) **(i)** Using energy consideration, calculate the maximum speed of the mass.

Maximum speed = …………………. m s^{-1} [2]

12 **(ii)** Hence, determine the period of the oscillating spring-mass system.

Period = ……………….. s [2]

(iii) Sketch for one complete oscillation, on **Fig. 3.3**, a labelled graph to show the variation with time *t* from the point of release of the mass

1 of the kinetic energy of the mass. Label this graph M.
2 of the elastic potential energy of spring Y. Label this graph S.

Fig. 3.3

[4]

(b) Suggest how a big mass damper can help stabilise a building during an earthquake.

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