17. Oscillations

17.3 Damped and forced oscillations, resonance

Paper 4

Question Paper

1 **(a)** State what is meant by resonance.

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..... [2]

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

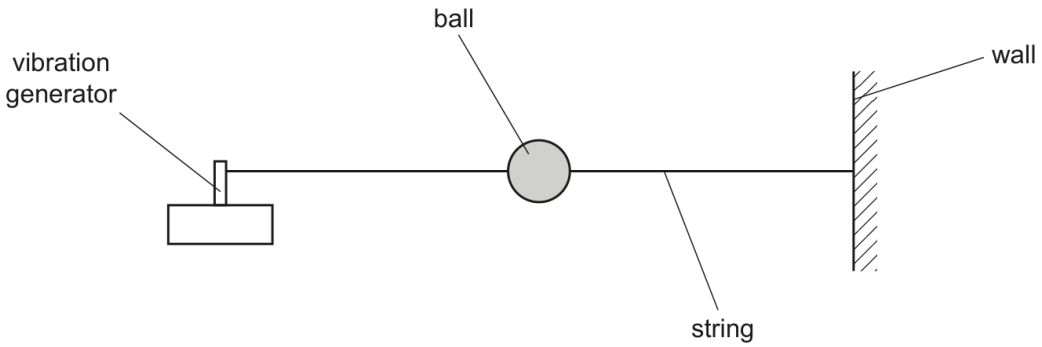


Fig. 4.1

Initially, the vibration generator is switched off.

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

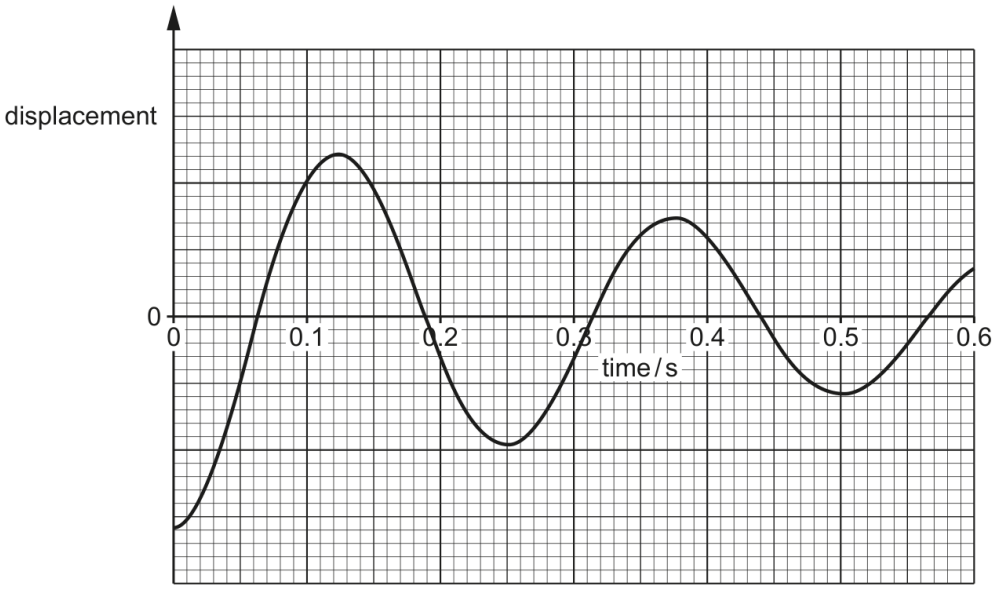


Fig. 4.2

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

..... [1]

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

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..... [2]

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

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

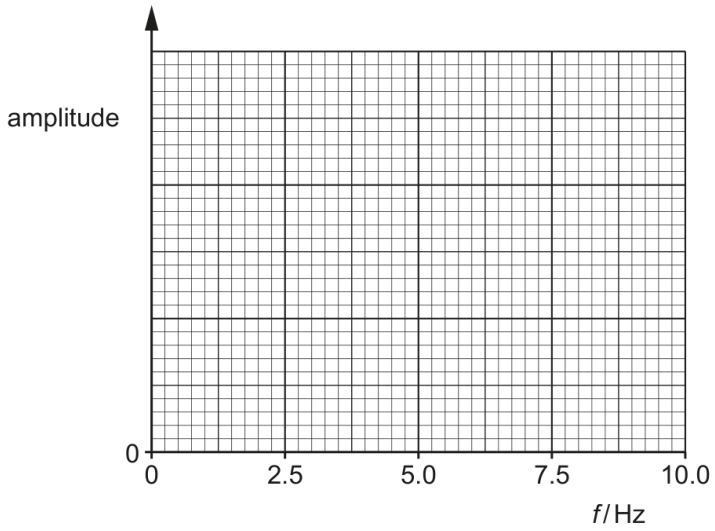


Fig. 4.3

[2]

2 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.

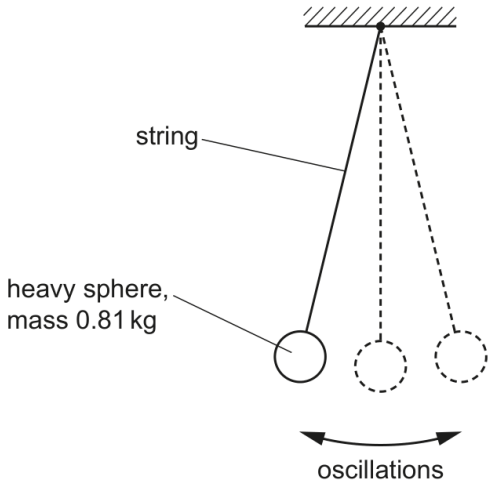


Fig. 4.1

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

(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.

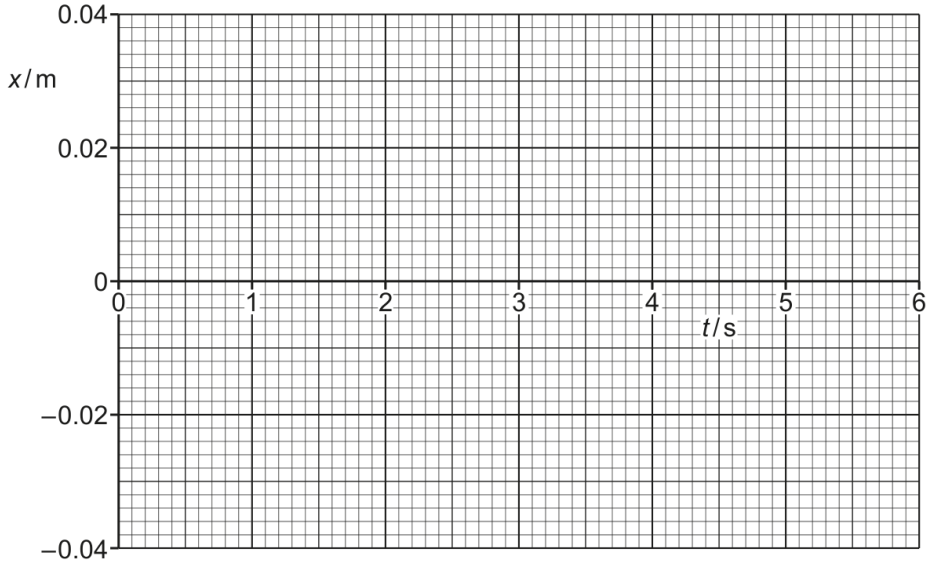


Fig. 4.2

[3]

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

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..... [2]

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

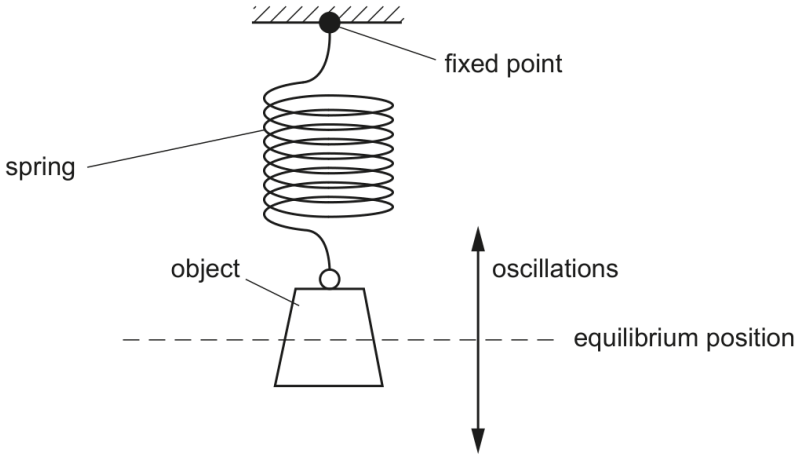


Fig. 3.1

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

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

(i) State what is meant by damping.

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..... [2]

5 **(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.

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..... [2]

6 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.

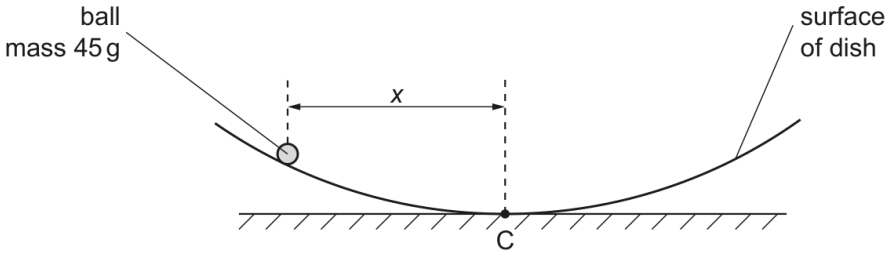


Fig. 4.1

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.

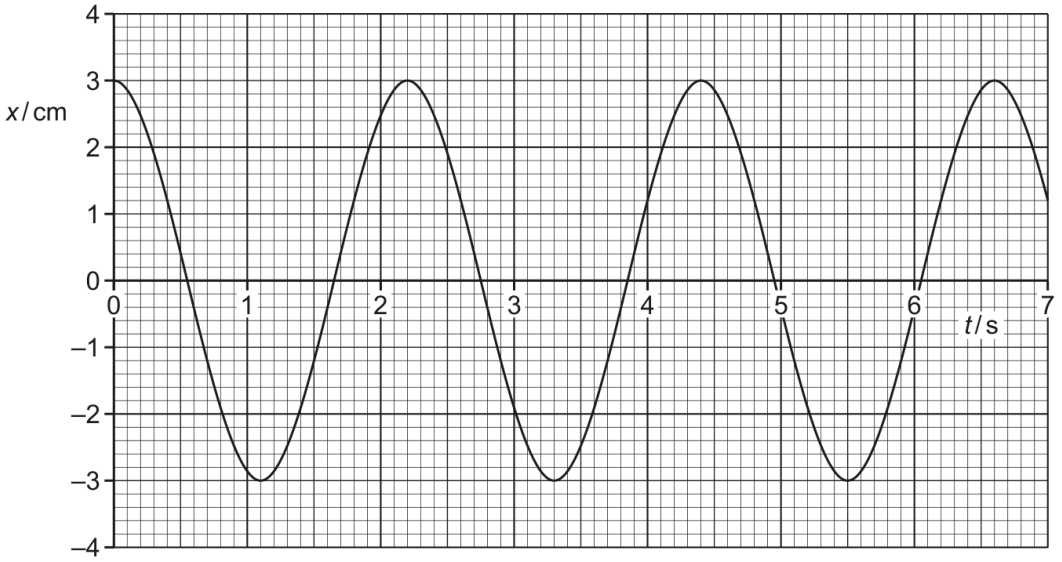


Fig. 4.2

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.

(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]

7 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.

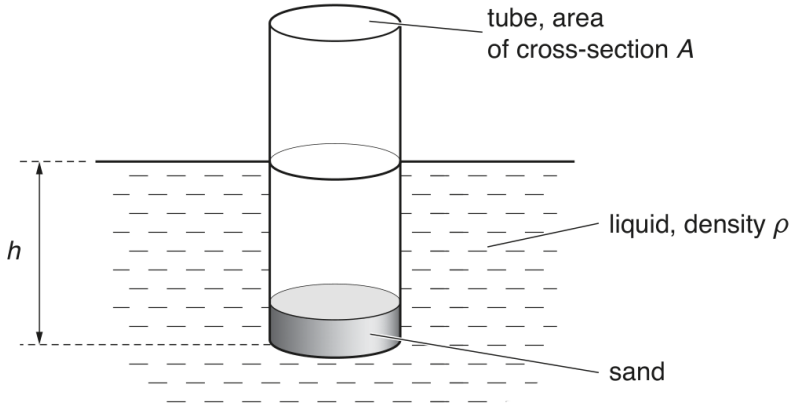


Fig. 3.1

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.

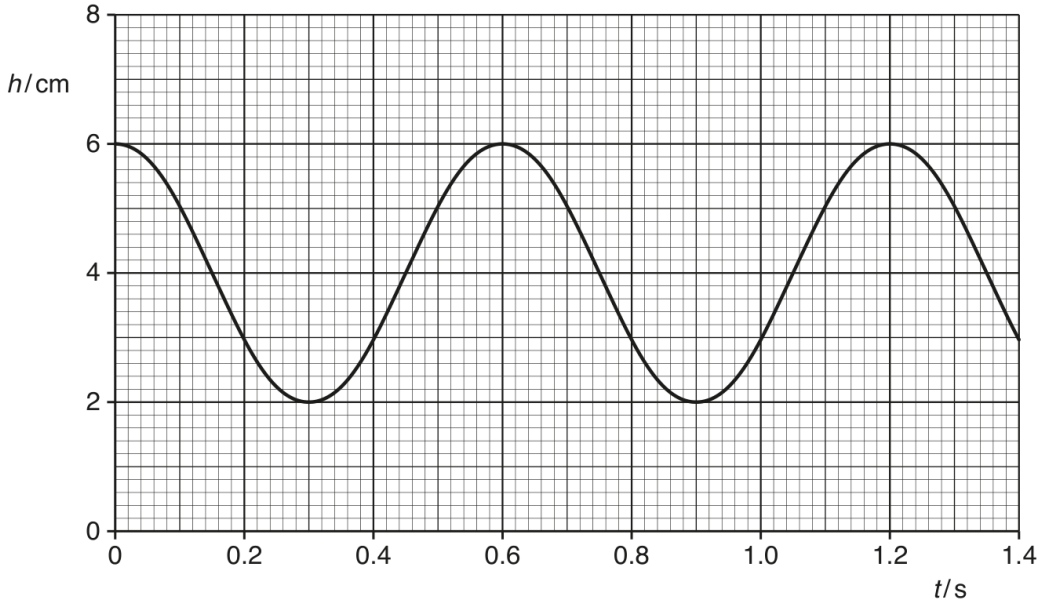


Fig. 3.2

(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]

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

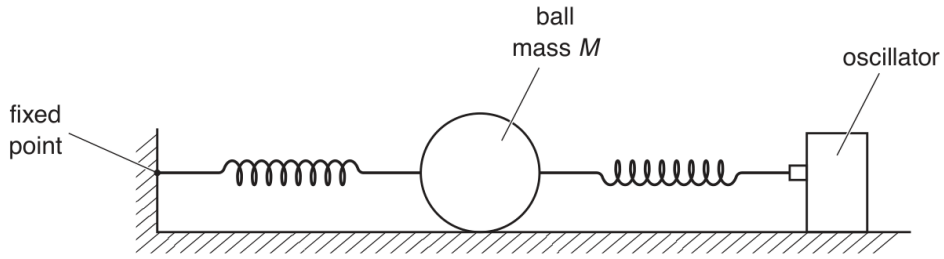


Fig. 4.1

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.

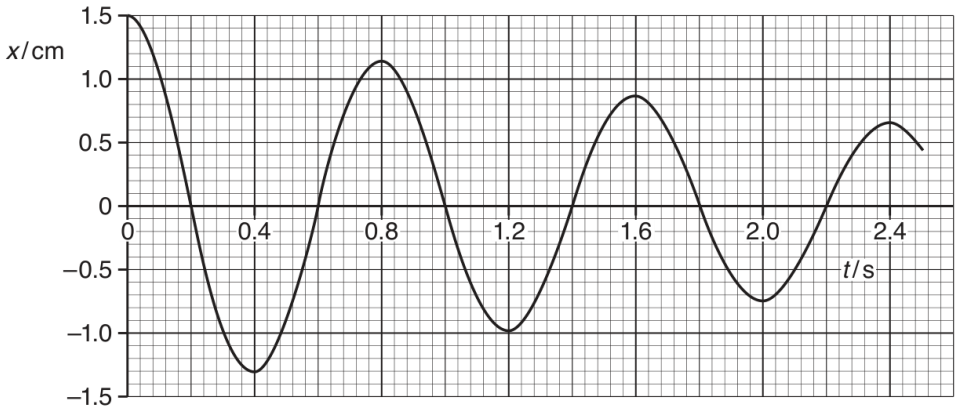


Fig. 4.2

(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]

(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.

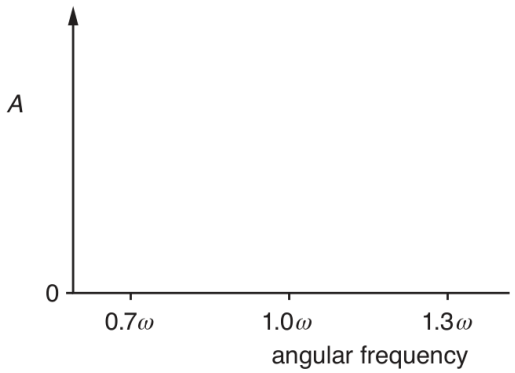


Fig. 4.3

[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. .....

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2. .....

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[2]

9 **(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.

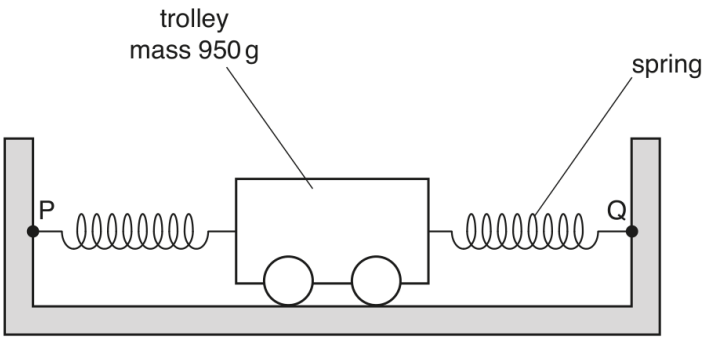


Fig. 4.1

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.

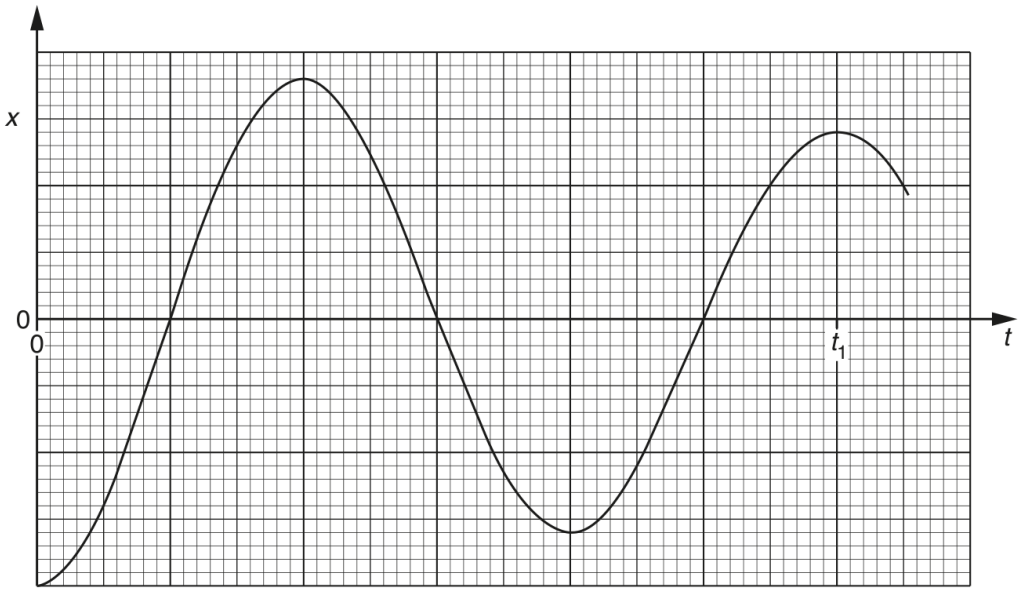


Fig. 4.2

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

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2. Suggest the cause of the damping.

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[3]

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

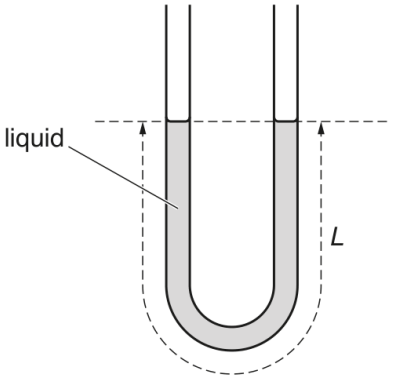


Fig. 3.1

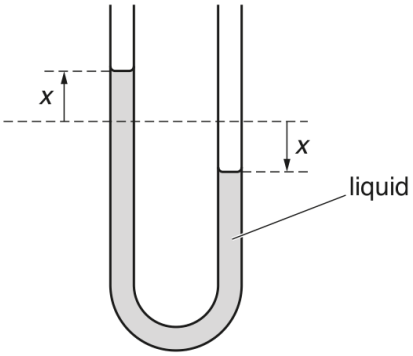


Fig. 3.2

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.

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

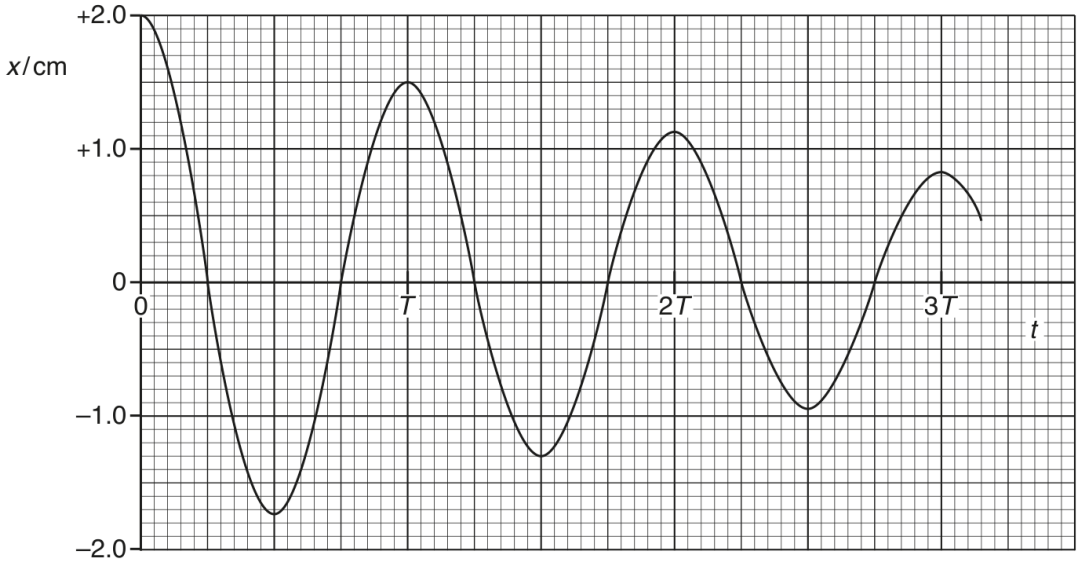


Fig. 3.3

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.

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.....[1]

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

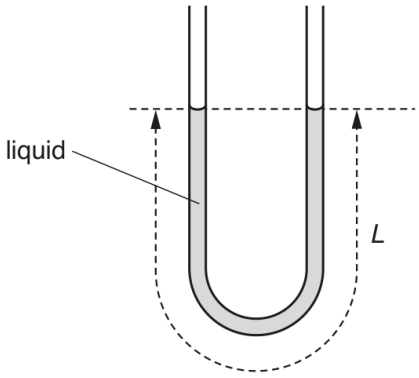


Fig. 4.1

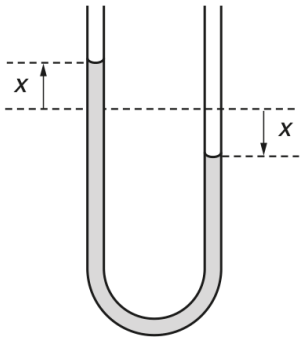


Fig. 4.2

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.

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

(i) Suggest one cause of this damping.

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.....[1]