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.

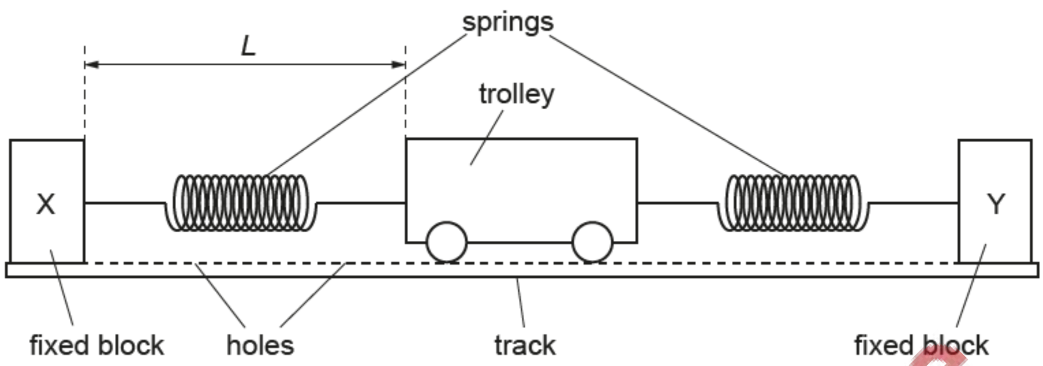

Fig. 4.1

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.

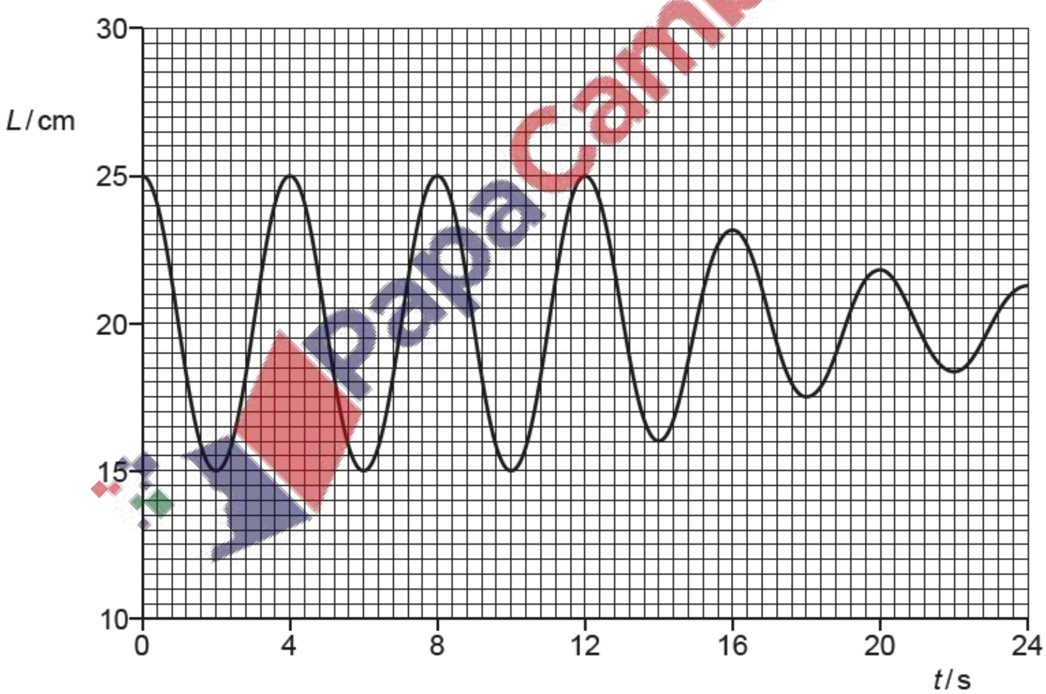

Fig. 4.2

(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 = ... $\mathrm{rad\,s^{-1}}$ [2]

(iii) the maximum speed v_0, in $\mathrm{cm\,s^{-1}}$, of the oscillating trolley.

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

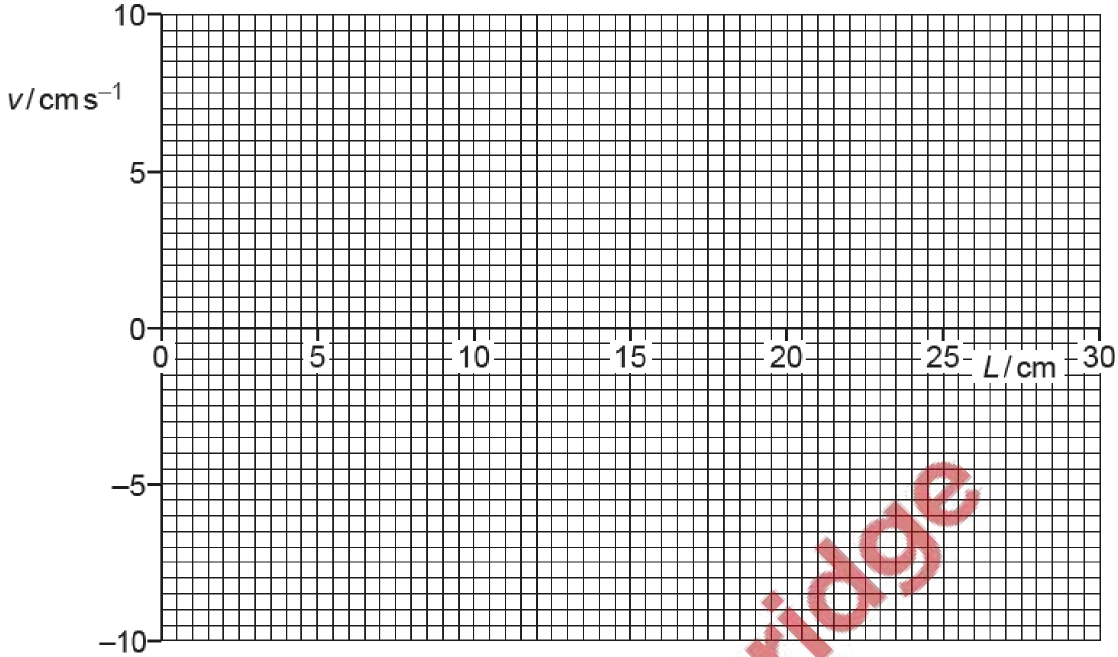

Fig. 4.3

[3]

[Total: 11]

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.

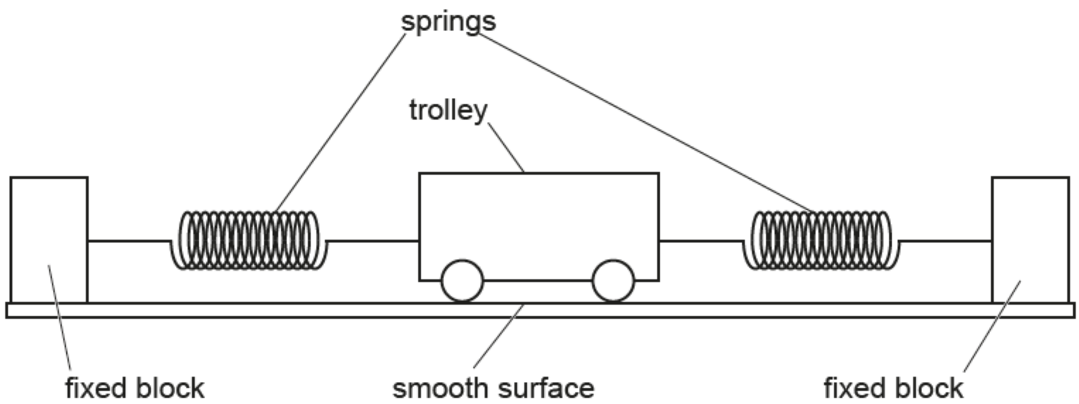

Fig. 4.1

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.

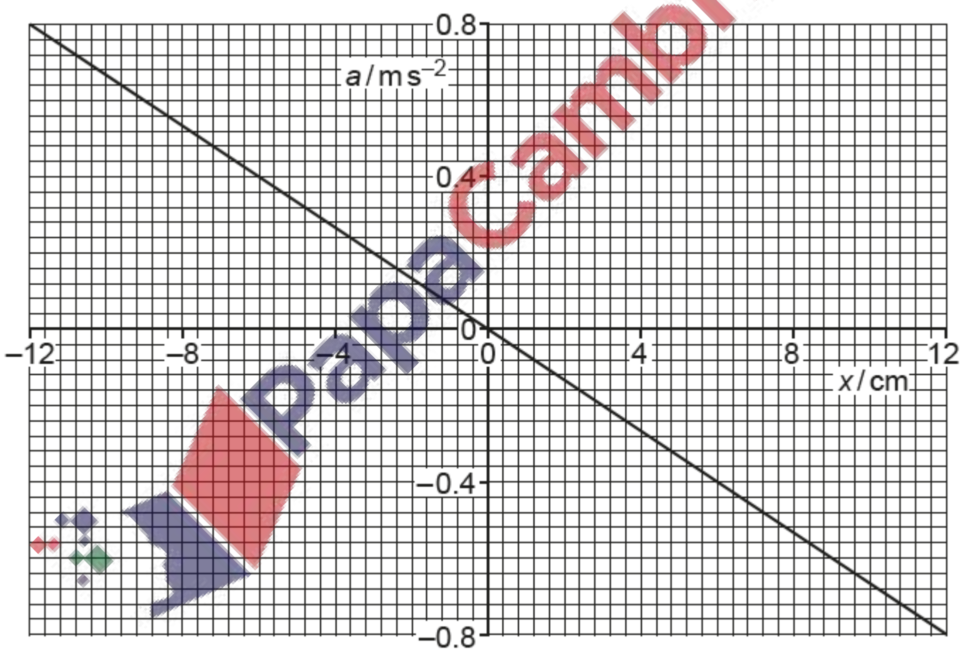

Fig. 4.2

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

....

....

.... [2]

(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]

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.

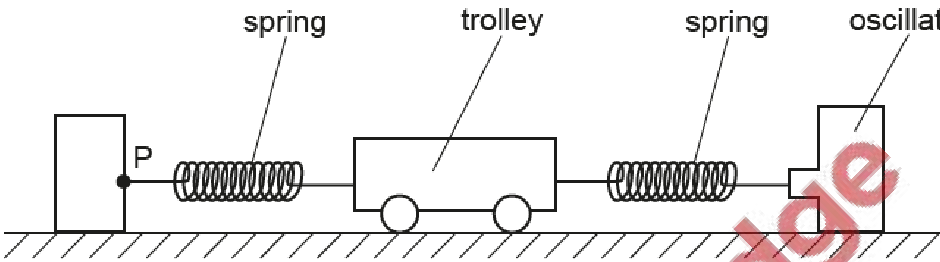

Fig. 3.1

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

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.

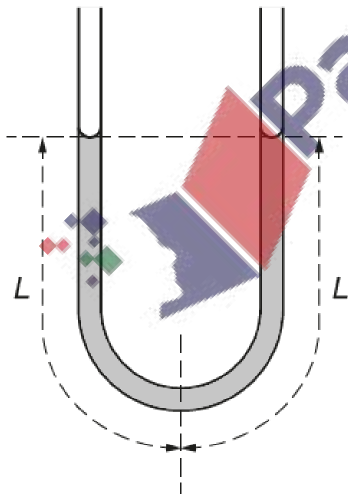

Fig. 3.1

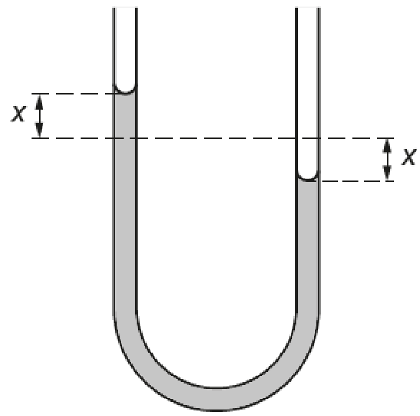

Fig. 3.2

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]

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.

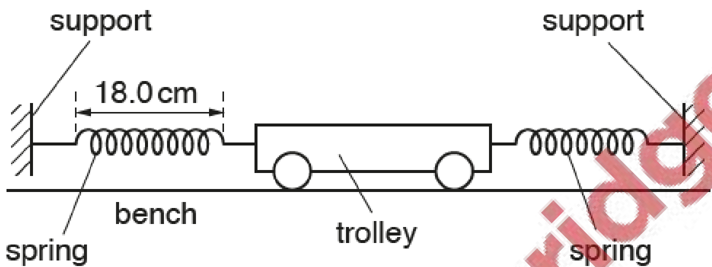

Fig. 4.1

The unstretched length of each spring is 12.0 cm. The spring constant of each spring is $8.0\,\text{N m}^{-1}$. 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]