Simple Harmonic Motion - 2

1

(a) Define *simple harmonic motion.*

....

....

.... [2]

(b) Fig. 1.1 shows a simple pendulum with the bob at the amplitude of its swing.

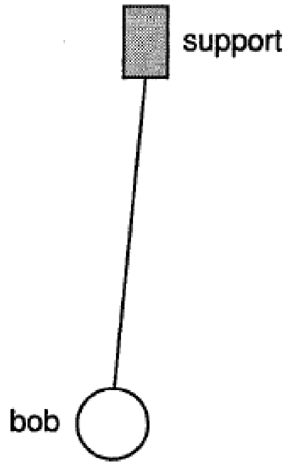

Fig. 1.1

On Fig. 1.1, draw and label arrows to represent the forces acting on the bob. [2]

(c) Fig. 1.2 shows the graph of displacement of the bob against time.

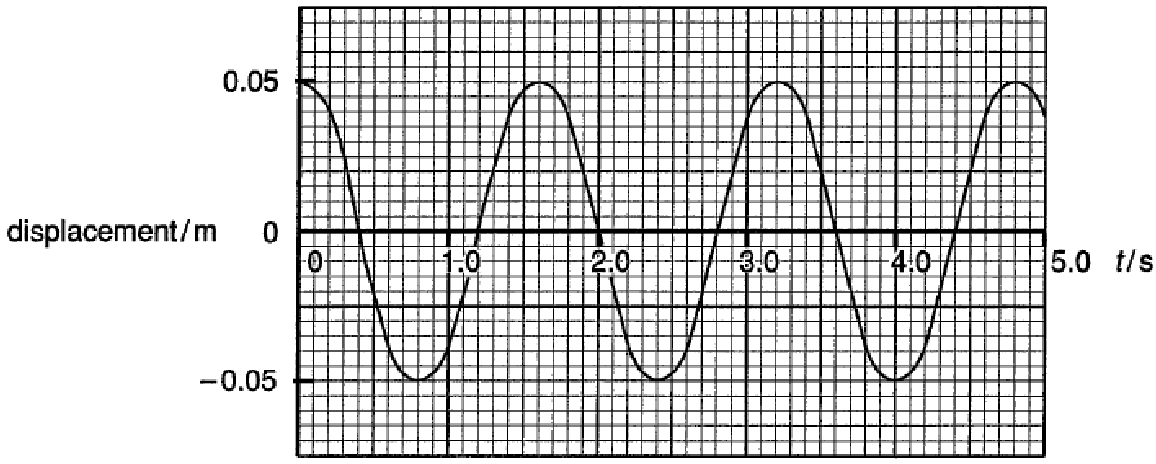

Fig. 1.2

(i) Use Fig. 1.2 to determine the frequency of oscillation of the pendulum. Give a suitable unit for your answer.

frequency = ... unit .... [3]

(ii) Use Fig. 1.2 or otherwise to determine the maximum speed of the bob. Show your method clearly.

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

(d) The bob is now made to oscillate with twice its previous amplitude. The pendulum is still moving in simple harmonic motion.

State with a reason the change, if any, in

(i) the period

....

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.... [2]

(ii) the maximum speed of the bob.

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.... [2]

A mass oscillates on the end of a spring in simple harmonic motion. The graph of the acceleration a of the mass against its displacement x from its equilibrium position is shown in Fig. 1.1.

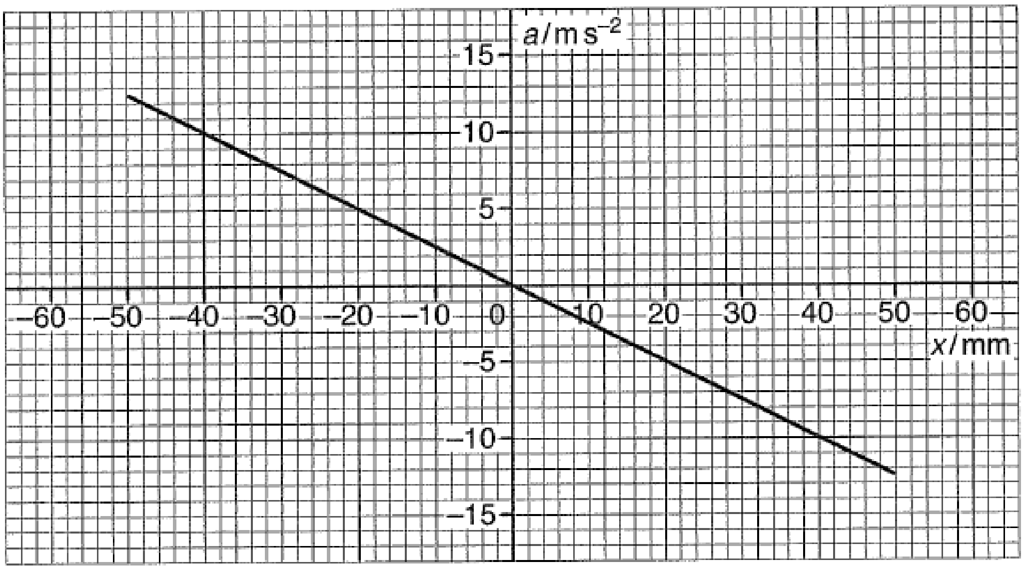

Fig. 1.1

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

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....[2]

(ii) Explain how the graph shows that the object is oscillating in simple harmonic motion.

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....[2]

(b) Use data from the graph

(i) to find the amplitude of the motion

amplitude = ... m [1]

(ii) to show that the period of oscillation is 0.4 s.

[3]

(c) (i) The mass is released at time $t = 0$ at displacement $x = 0.050$ m. Draw a graph on the axes of Fig. 1.2 of the displacement of the mass until $t = 1.0$ s. Add scales to both axes. [3]

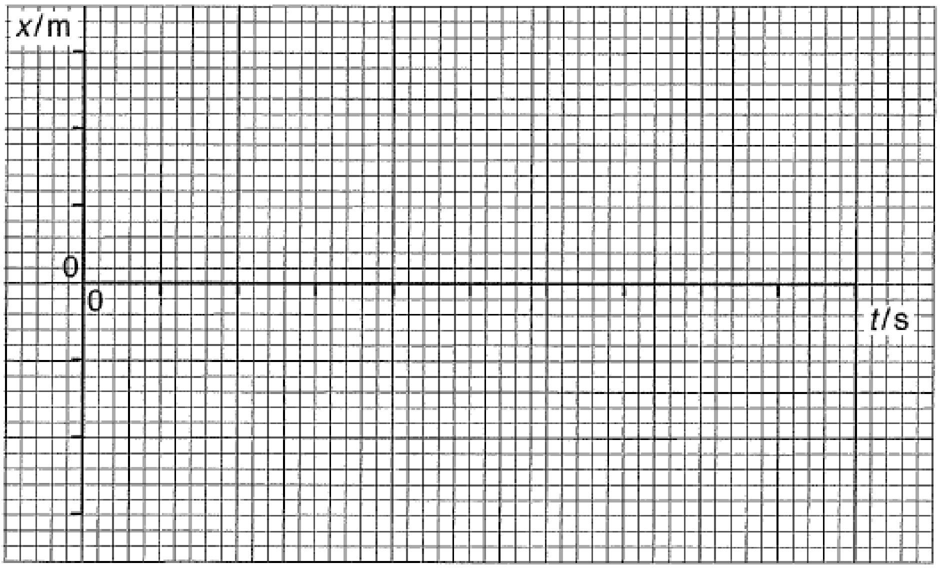

Fig. 1.2

(ii) State a displacement and time at which the system has maximum kinetic energy.

displacement .... m

time .... s [2]

(a) Fig. 6.1 shows a toy consisting of a light plastic aeroplane suspended from a long spring.

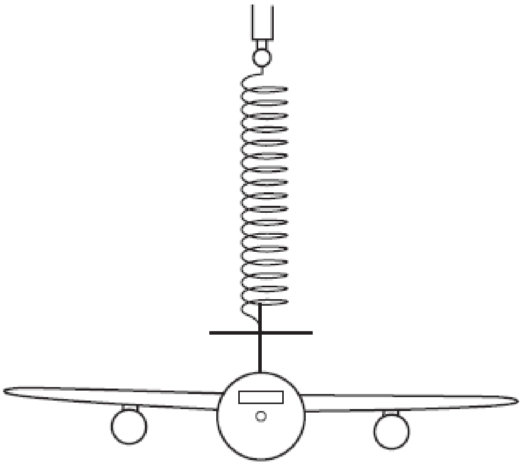

Fig. 6.1

(i) The aeroplane is pulled down 0.040 m and released. It undergoes a vertical harmonic oscillation with a period of 1.0 s. The oscillations are lightly damped. Sketch on the axes of Fig. 6.2 the displacement y of the aeroplane against time t from the moment of release. [3]

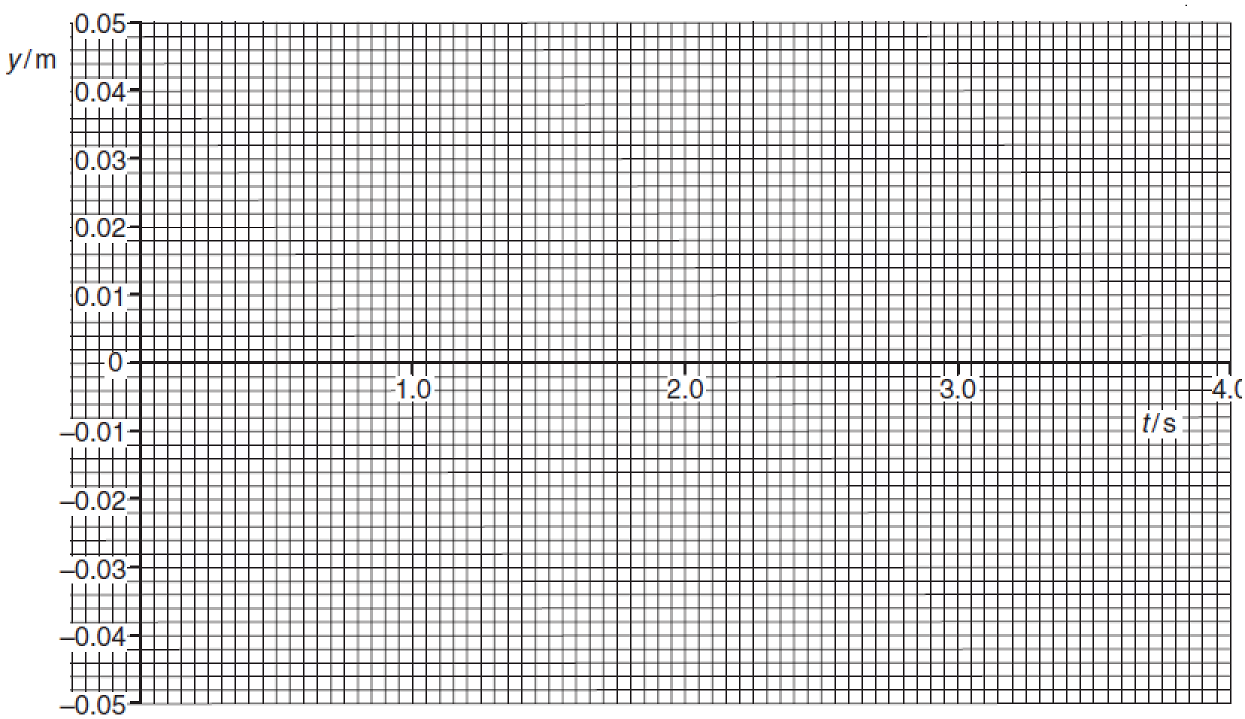

Fig. 6.2

(ii) The aeroplane is replaced by a heavier model made of the same plastic having the same fuselage but larger wings. State and explain **two** changes which this substitution will make to the displacement against time graph that you have drawn on Fig. 6.2.

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....

....[4]

(b) The top end of the spring in Fig. 6.1 is then vibrated vertically with a small constant amplitude. The motion of the aeroplane changes as the frequency of oscillation of the top end of the spring is increased slowly from zero through resonance to 2.0 Hz.
Explain the conditions for resonance to occur and describe the changes in the motion of the aeroplane as the frequency changes from zero to 2.0 Hz.

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....[5]

4

This question is about a mass-spring system.

Fig. 2.1 shows a mass attached to two springs. The mass moves along a horizontal tube with one spring stretched and the other compressed. An arrow marked on the mass indicates its position on a scale. Fig. 2.1 shows the situation when the mass is displaced through a distance *x* from its equilibrium position. The mass is experiencing an acceleration *a* in the direction shown. Fig. 2.2 shows a graph of the **magnitude** of the acceleration *a* against the displacement *x*.

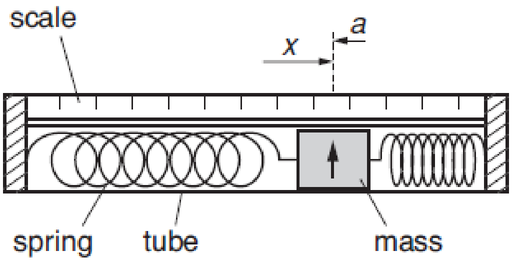

Fig. 2.1

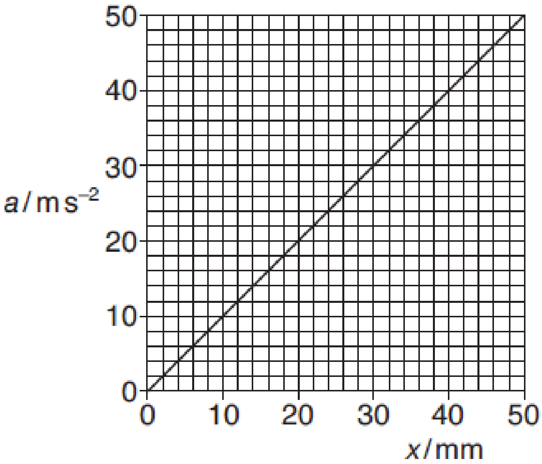

Fig. 2.2

(a) **(i)** State **one** feature from each of Fig. 2.1 and 2.2 which shows that the mass performs harmonic motion when released.

....

....

....[2]

(ii) Use data from Fig. 2.2 to show that the frequency of simple harmonic oscillations of the mass is about 5 Hz.

[3]

(iii) The mass oscillates in damped harmonic motion before coming to rest. On the axes of Fig. 2.3, sketch a graph of the damped harmonic oscillation of the mass, from an initial displacement of 25.0 mm. [3]

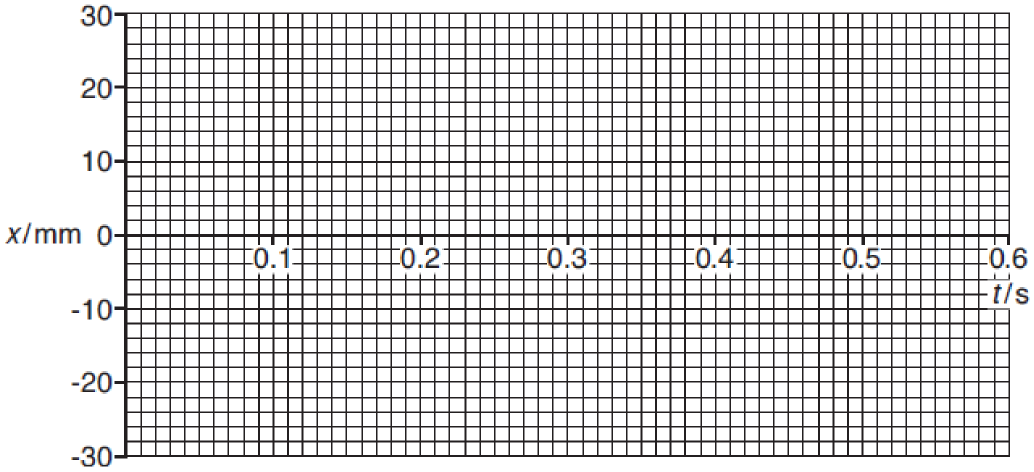

Fig. 2.3

(b) The mass-spring system of Fig. 2.1 can be used as a device to measure acceleration, called an accelerometer. It is mounted on a rotating test rig, used to simulate large g-forces for astronauts. Fig. 2.4 shows the plan view of a long beam rotating about axis **A** with the astronaut seated at end **B**, facing towards **A**. The accelerometer is parallel to the beam and is fixed under the seat 10 m from **A**.

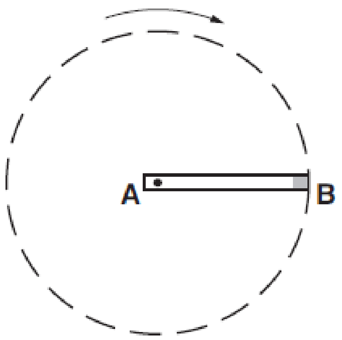

Fig. 2.4

(i) When the astronaut is rotating at a constant speed, the arrow marked on the mass has a constant deflection. Explain why.

....

....

....[2]

(ii) Calculate the speed v of rotation of the astronaut when the deflection is 50 mm.

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

5.

(a) Define *simple harmonic motion.*

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....[2]

(b) Fig. 3.1 shows a mass suspended from a spring beside a ruler. When the mass is pulled down and released, it oscillates with simple harmonic motion. Fig. 3.2 shows the variation of the position of the mass with time, starting at the moment of release.

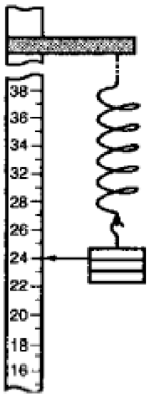

Fig. 3.1

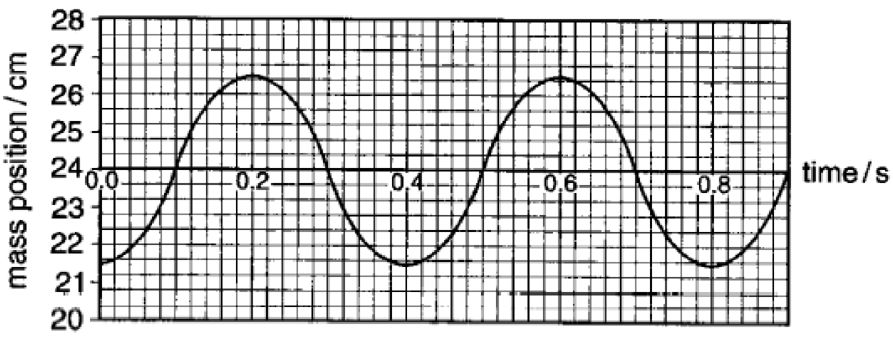

Fig.3.2

(i) Use Fig. 3.2 to determine,

1 the amplitude of the oscillation

amplitude = ...m [2]

2 the frequency of the oscillation.

frequency= ....Hz [2]

(ii) Hence find the maximum acceleration of the mass.

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

(iii) Use Fig. 3.2. to state a time at which

1 the mass has maximum speed

time = ...s [1]

2 the mass has maximum acceleration.

time= ....s [1]

(c) On the axes of Fig. 3.3 sketch the variation with time *t* of the acceleration *a* of the mass. Add a suitable scale on the *y*-axis.

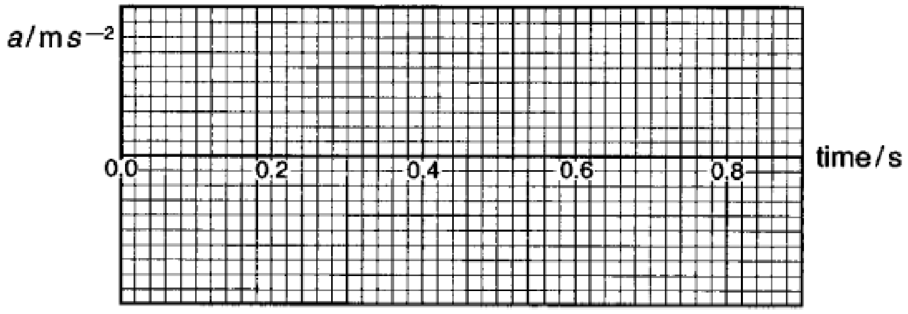

Fig. 3.3

[3]

6

Fig. 2.1 shows an airtrack glider of mass 0.40 kg held by two stretched springs. When the glider is pulled 0.050 m to the left and released, it oscillates freely without friction.

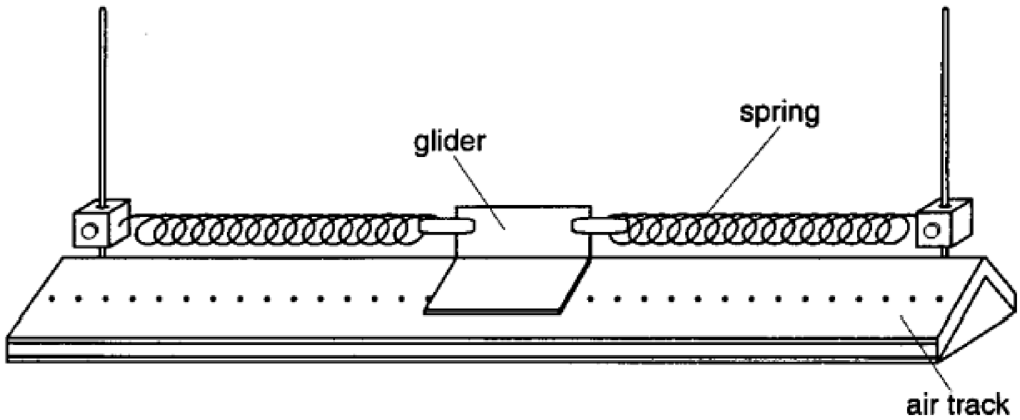

Fig. 2.1

Fig. 2.2 shows the variation of the elastic strain energy stored in the springs with the displacement *x* from the equilibrium position. Note that the strain energy is 70 mJ when the glider is not oscillating.

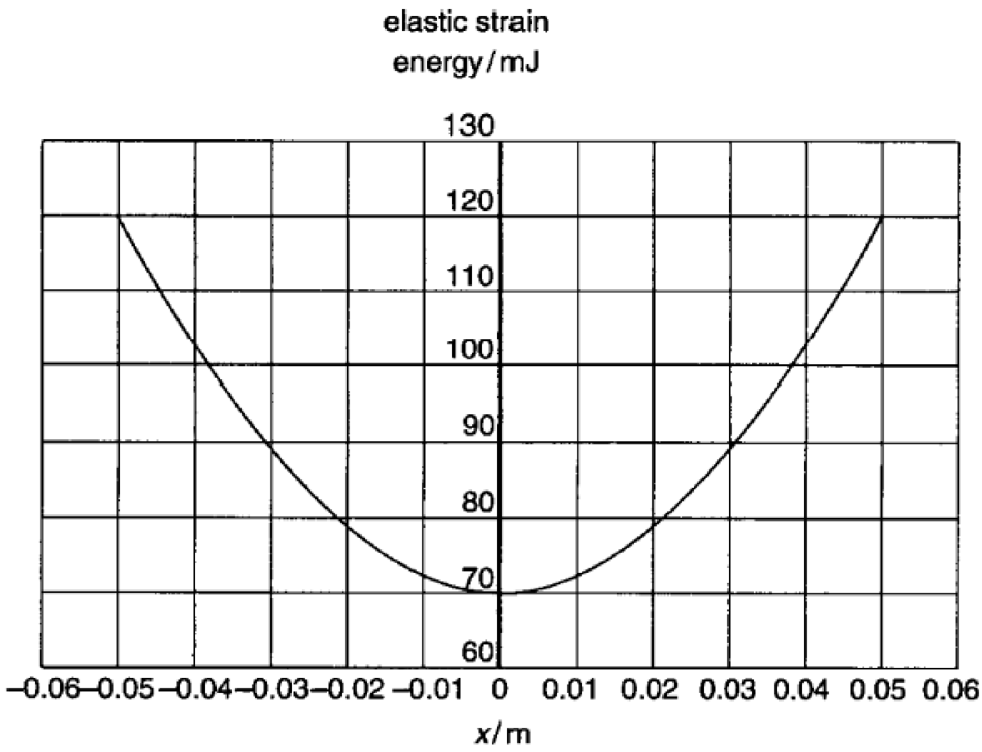

Fig. 2.2

(a) Write down

(i) the total energy stored in the system when oscillating .... mJ [1]

(ii) the maximum kinetic energy of the glider .... mJ [2]

(b) **(i)** Show that the maximum speed of the glider is $0.50\,\mathrm{m\,s^{-1}}$.

[2]

(ii) Use Fig. 2.2 or otherwise to find the amplitude of oscillation required to halve the maximum speed of the glider. Show your reasoning.

amplitude = ... m [2]

(c) The equation of motion of the glider relating its acceleration a in $m\,s^{-2}$ to its displacement x in m is

$$a = -110\,x$$

(i) Use this equation to show that the period of oscillation is 0.60 s.

[2]

(ii) Use the data from **(b)(i)** and **(c)(i)** to sketch on Fig. 2.3 the velocity-time graph for the glider. It is released at $x = 0.050$ m at $t = 0$. [3]

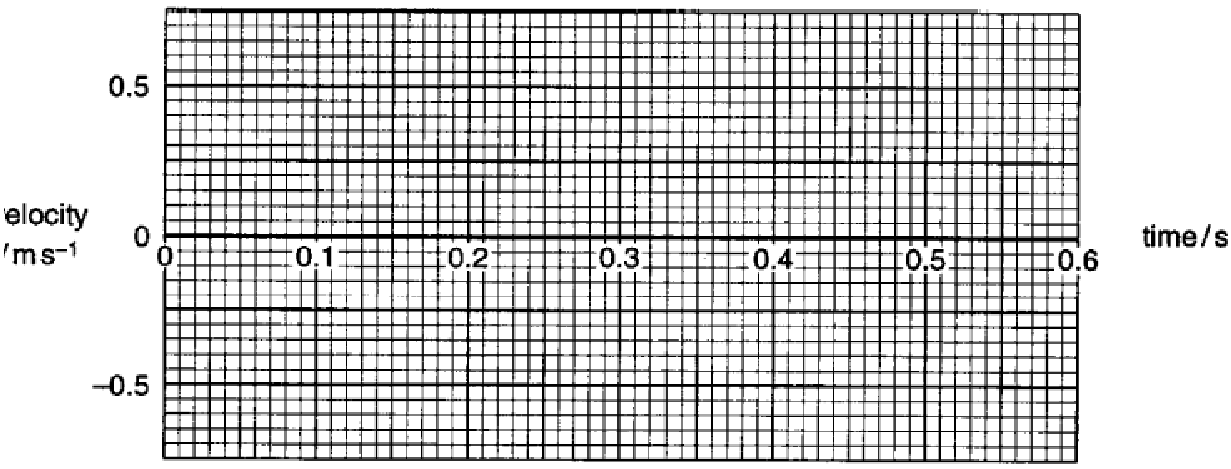

Fig. 2.3