4 A test-tube of cross-sectional area A is loaded with lead shots. It rests in equilibrium in a beaker of water of density ρ as shown in Fig. 4.1, with a length L submerged in the water.

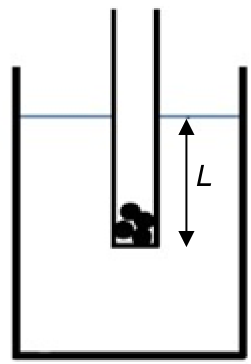

Fig. 4.1

(a) **(i)** On Fig. 4.1, draw and label the forces acting on the loaded test-tube. [2]

(ii) Derive an expression for the mass of the loaded test tube in terms of ρ, A, and L.

[2]

(b) The loaded test-tube is displaced downward and released, which causes it to bob up and down in simple harmonic motion. At a particular instant in time, the loaded test-tube is at a distance x below the equilibrium position, as shown in Fig. 4.2.

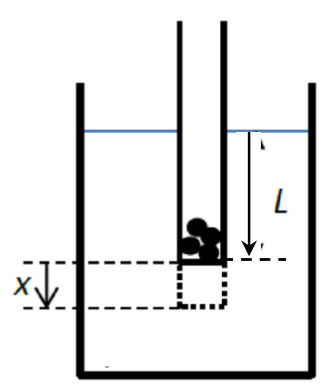

Fig. 4.2

(i) Ignoring resistive forces, show that the resultant force F acting on the loaded test-tube at this instant is given by:

$$F = -\rho A x g$$

where g is the acceleration of free fall.

[2]

(ii) Hence or otherwise, show that the angular frequency 7of oscillation of the loaded test-tube is given by:

$$\omega = \sqrt{\frac{g}{L}}$$

[3]

(iii) Given that the mass of the loaded test-tube is 50 g, L is 12.5 cm and the amplitude of oscillation is 1.5 cm.

Calculate the total energy of oscillation.

Total energy = ………………… J [2]

(iv) The loaded test-tube is at the lowest position at $t = 0$. The period of oscillation is T.

On Fig. 4.3, sketch a clearly labelled graph showing the variation with time of the kinetic energy of the loaded test-tube for two complete oscillations. Ignore resistive forces.

Indicate the maximum kinetic energy of the loaded test-tube along the vertical axis.

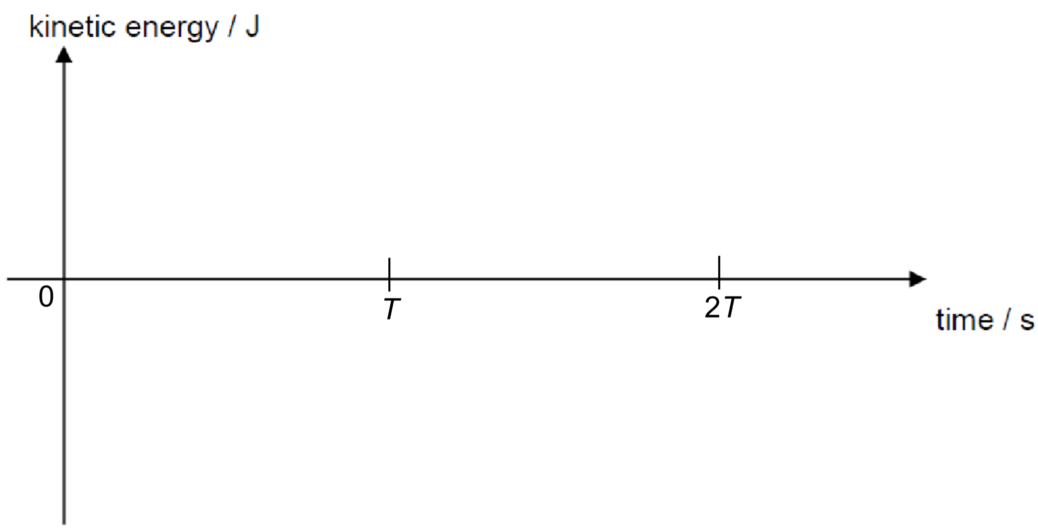

Fig. 4.3

[2]

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