6 A cylindrical tube, sealed at one end, has cross-sectional area A and contains some sand. The total mass of the tube and the sand is M.

The tube floats upright in a liquid of density ρ, as illustrated in Fig. 6.1.

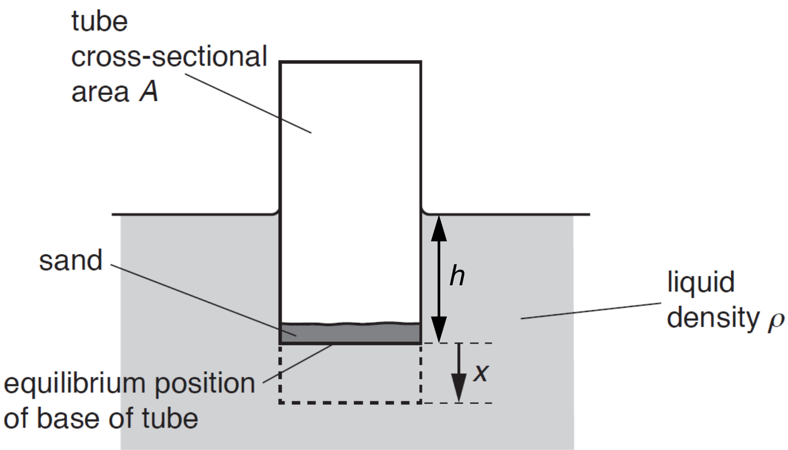

Fig. 6.1

At equilibrium, the tube has a depth h submerged under water. The tube is pushed a short distance downwards into the liquid and then released.

(a) State and explain, by considering the forces acting on the tube, the direction of the resultant force acting on the tube immediately after its release.

....

....

.... [2]

(b) Show that the acceleration a of the tube is given by the expression

$$a = -\left(\frac{A\rho g}{M}\right)x$$

where *x* is the vertical displacement of the tube from its equilibrium position.

[3]

(c) Use the expression in **(b)** to explain why the tube undergoes simple harmonic oscillations in the liquid.

....

....

.... [2]

(d) A student conducted an experiment and obtained the following measurements:

M = 0.17 kg
$A = 4.5 \times 10^{-4}$ m^2
period of oscillation = 1.3 s

(i) Determine the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [2]

(ii) Determine the density ρ of the liquid in which the tube is floating.

ρ = ... kg m^{-3} [3]

(iii) **1.** Show that total energy of the oscillation is given by

$$\frac{1}{2}M\omega^2 {x_o}^2$$

where x_o represents the amplitude of the oscillation.

[3]

2. Hence determine the total energy of the oscillation when the amplitude of the oscillation is 0.20 m.

total energy = ………………………………….. J [1]

(iv) During each complete oscillation the total energy of the system decreases by 8.0% of the total energy at the start of that oscillation.

Determine the decrease in total energy, in mJ, of the system by the end of the first 6 complete oscillations.

energy lost = ... mJ [2]

(v) The variation with time of the depth *h* for undamped oscillation is shown in Fig. 6.2.

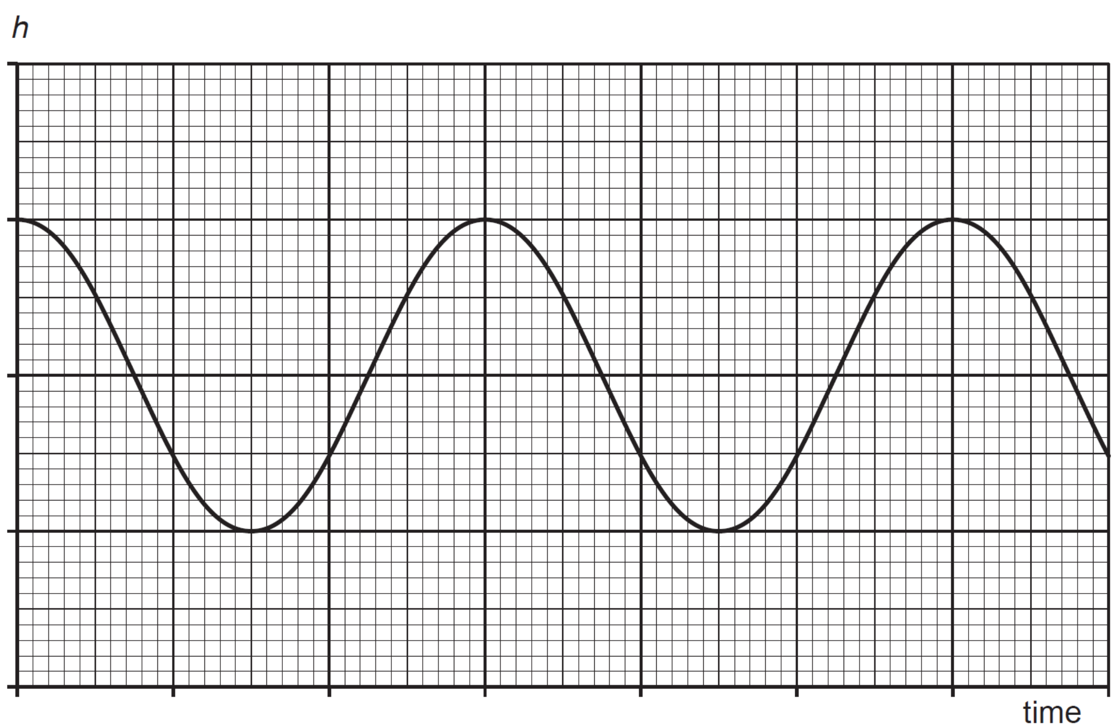

Fig. 6.2

On Fig. 6.2, draw a line to show light damping of the oscillations. Numerical values are not required

[2]

[Total: 20]