3 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. 3.1.

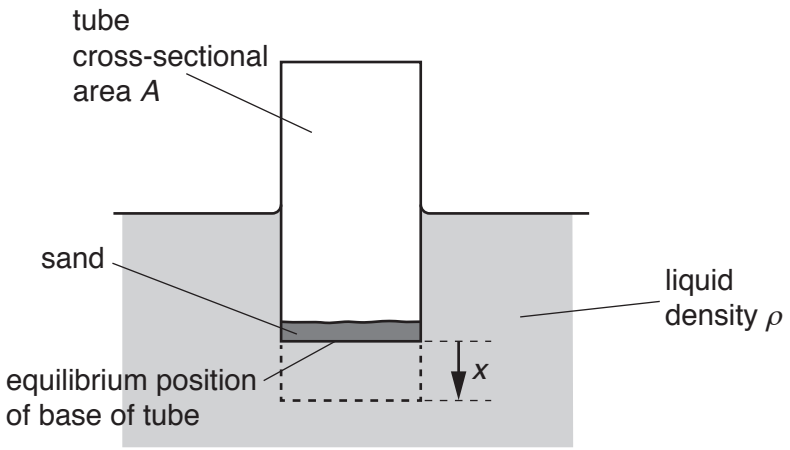

Fig. 3.1

The tube is pushed a short distance into the liquid and then released.

(a) (i) State the two forces that act on the tube immediately after its release.

.....

..... [1]

(ii) State and explain the direction of the resultant force acting on the tube immediately after its release.

.....

.....

..... [2]

(b) 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.

Use the expression to explain why the tube undergoes simple harmonic oscillations in the liquid.

.....

.....

..... [2]

(c) For a tube having cross-sectional area A of $4.5\,\text{cm}^2$ and a total mass M of $0.17\,\text{kg}$, the period of oscillation of the tube is $1.3\,\text{s}$.

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

ω = ... $\text{rad}\,\text{s}^{-1}$ [2]

(ii) Use your answer in **(i)** and the expression in **(b)** to determine the density ρ of the liquid in which the tube is floating.

ρ = ... $\text{kg}\,\text{m}^{-3}$ [3]

[Total: 10]

[Turn over