8 **(a)** A test-tube is partially loaded with small ball bearings such that it is able to float upright in water of density ρ as shown in Fig. 8.1. The bottom of the test-tube is a distance H below the water surface.

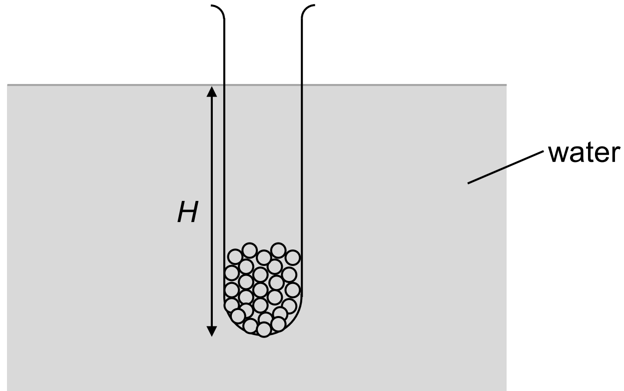

Fig. 8.1

Ignoring its rounded bottom, the test-tube may be regarded as a cylinder of cross sectional area A and mass m. The mass of the ball bearings added is M.

(i) On Fig. 8.2, draw the forces acting on the system of the test-tube and ball bearings when it is floating.

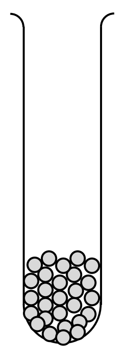

Fig. 8.2

[1]

(ii) The test-tube is displaced vertically downward by displacement y and then released.

Taking downward to be positive and ignoring any dissipative forces, show that the acceleration of the test-tube is given by

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

where g is the acceleration of free fall.

[3]

(iii) It is given that H = 0.062 m.

Show that the period of oscillation of the test-tube is 0.50 s.

[2]

(iv) Given that M = 0.012 kg, m = 0.025 kg and y = 1.0 cm, calculate the maximum vibrational kinetic energy of the oscillating system.

maximum kinetic energy = …………………… J [2]

(v) On Fig. 8.3, show the variation with time of the vibrational kinetic energy of the system.

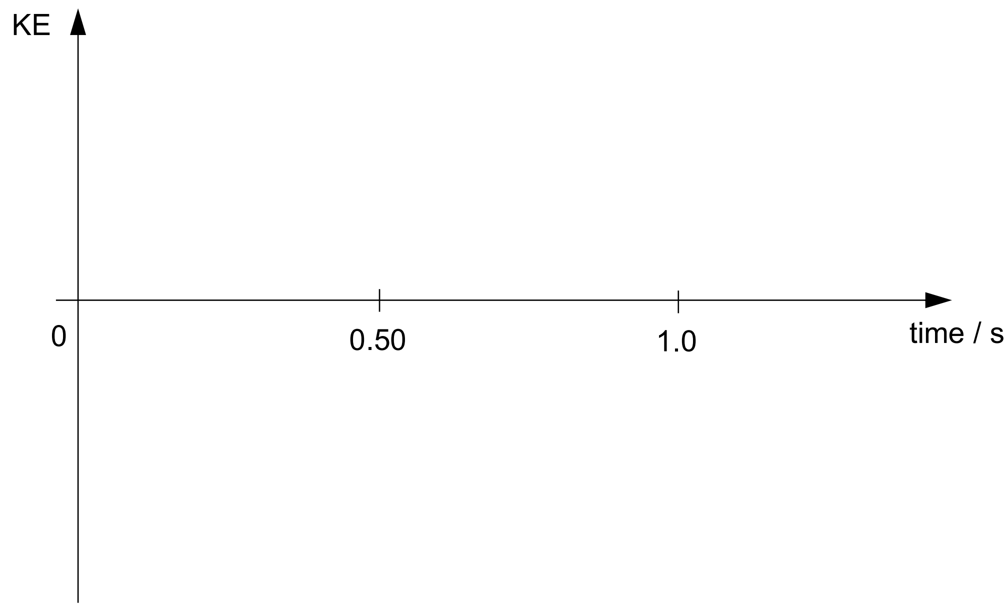

Fig. 8.3

[2]

(vi) In practice, it is observed that the variation with time *t* of the vertical displacement *y* of the test-tube is as shown in Fig. 8.4.

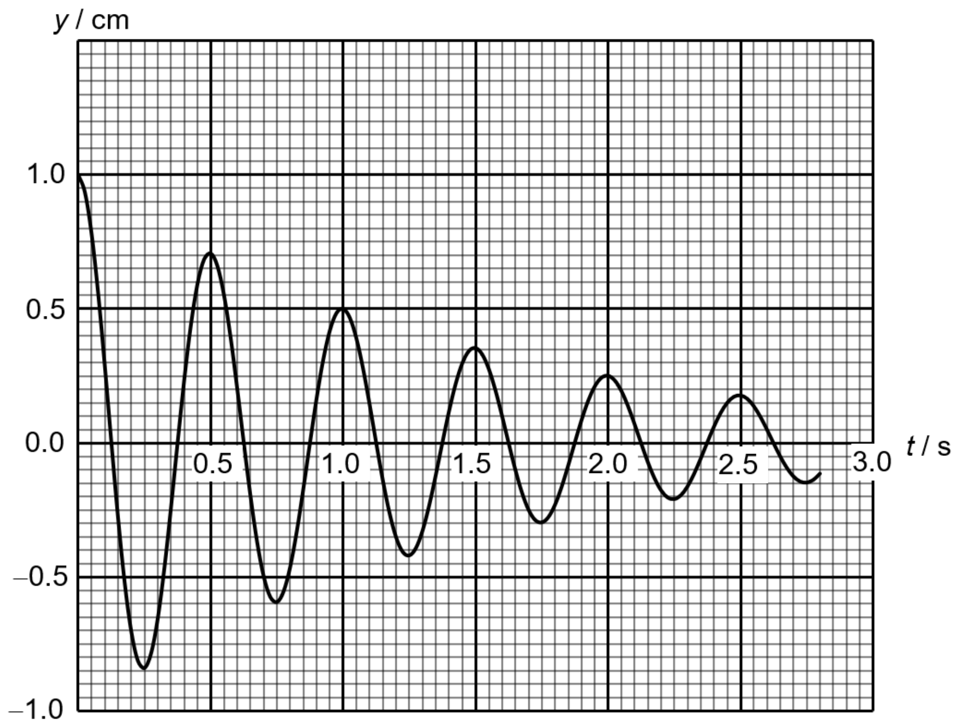

Fig. 8.4

Explain why the amplitude of the oscillations decreases gradually over time.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………… [2]

(vii) To sustain the oscillations of the test-tube, low-amplitude water waves of variable frequency are generated on the surface of the water.

1. On Fig. 8.5, show the variation with driving frequency of the amplitude of the test-tube.

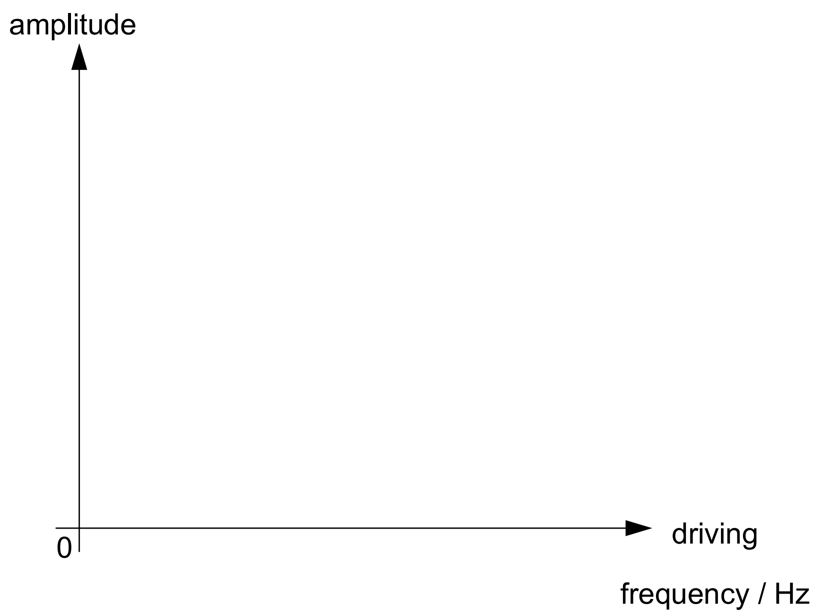

Fig. 8.5 [1]

2. When water waves of frequency 0.30 Hz are generated on the surface of the water, it is observed that the amplitude of the vertical oscillations of this test-tube is rather small.

Without changing the frequency of the water waves, suggest with reasoning how the amplitude of the oscillations of this test-tube may be increased.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

(b) Fig. 8.6 shows unpolarised light of intensity I_0 incident, at right angles, on a polarising filter F_1. A second polarising filter F_2 is identical to F_1. It is placed parallel to F1.

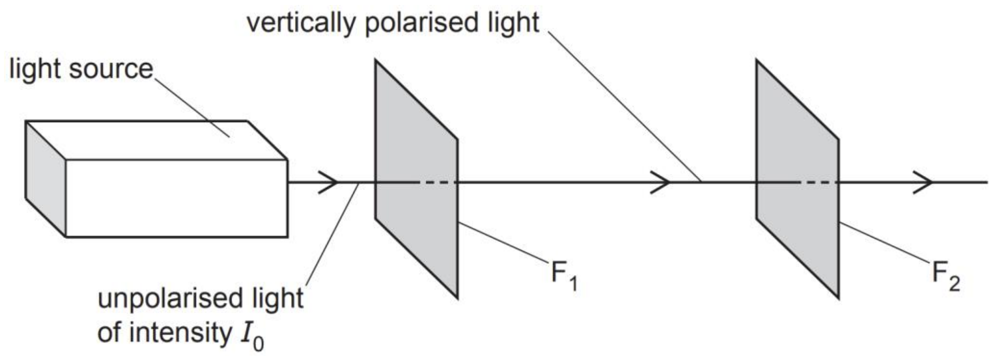

Fig. 8.6

The light that emerges from F_1 is completely vertically polarised and strikes F_2 at 90° to its surface.

When F_2 is in this position, the light that emerges from it is equal in intensity to the light that is incident on it.

(i) F_2 is now rotated about an axis perpendicular to its surface, as shown in Fig. 8.7.

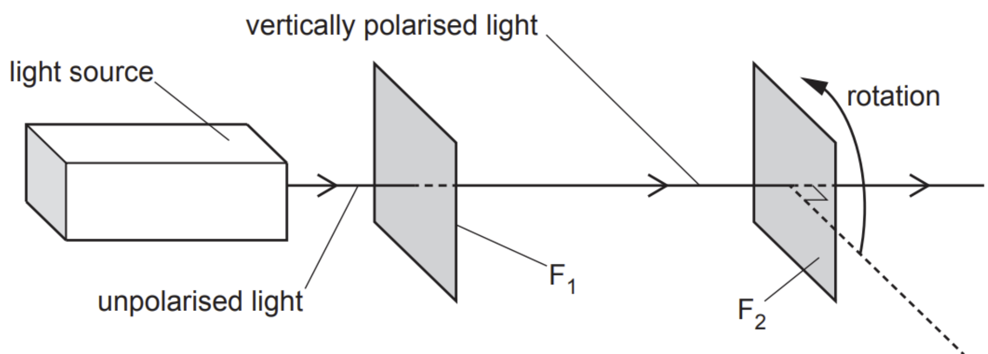

Fig. 8.7

On Fig. 8.8, sketch a graph to show how the intensity of the light emerging from F_2 varies with angle as F_2 is rotated through 360°

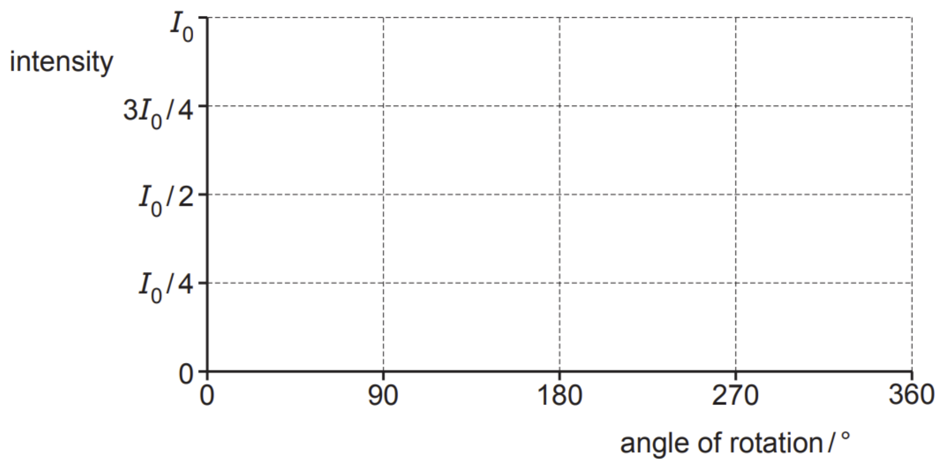

Fig. 8.8 [2]

(ii) F_2 is rotated until no light emerges from it.

Then, a third identical polarising filter F_3 is placed between F_1 and F_2. Fig. 8.9 shows that F_3 is parallel to both F_1 and F_2.

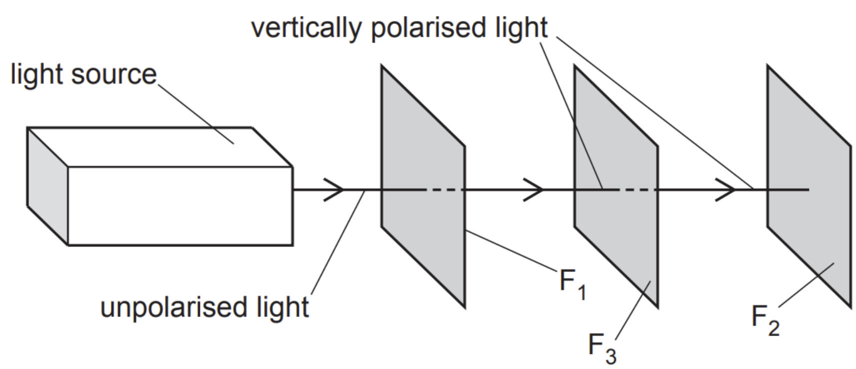

Fig. 8.9

The light that emerges from F_3 is equal in intensity to the light that is incident on it and still no light emerges from F_2.

F_3 is now rotated through 45° about an axis perpendicular to its surface.

Explain why some light now emerges from F_2.

....

....

.... [2]

(iii) Calculate the intensity of light that emerges from F_2 when F_3 is fixed at 45°.

intensity = …………………….. I_0 [1]

End of Paper