

Density and Pressure – 2017 Nov AS

1. 9702/22/ON/17/No.3

A spring is attached at one end to a fixed point and hangs vertically with a cube attached to the other end. The cube is initially held so that the spring has zero extension, as shown in Fig. 3.1.

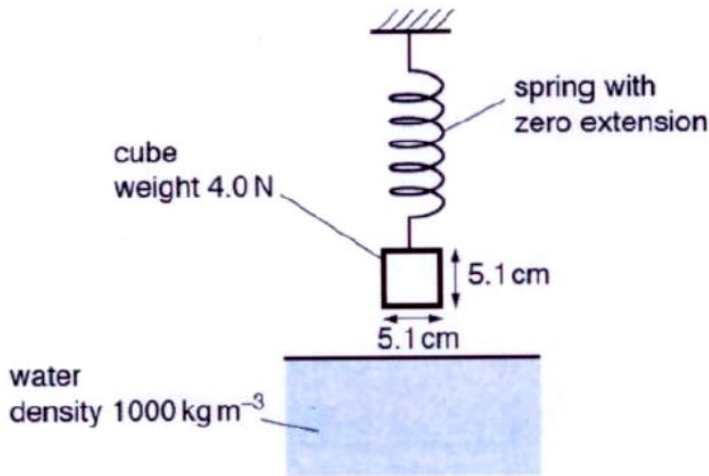


Fig. 3.1

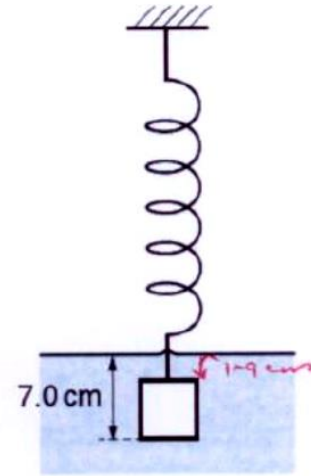


Fig. 3.2

The cube has weight 4.0N and sides of length 5.1 cm. The cube is released and sinks into water as the spring extends. The cube reaches equilibrium with its base at a depth of 7.0cm below the water surface, as shown in Fig. 3.2.

The density of the water is 1000kgm^{-3} .

- (a) Calculate the difference in the pressure exerted by the water on the bottom face and on the top face of the cube.

$$\begin{aligned} \Delta p &= \rho g h \\ &= 1000 \times 9.81 \times (7 \times 10^{-2} - 1.9 \times 10^{-2}) \\ &= 500.31 \text{ Pa} \end{aligned}$$

$7 - 5.1 = 1.9 \text{ cm}$

difference in pressure = 500 Pa [2]

- (b) Use your answer in (a) to show that the upthrust on the cube is 1.3N.

$$\begin{aligned} \Delta F &= \text{up thrust} \\ &= \Delta p \times A \\ \text{up thrust} &= 500 \times (5.1 \times 10^{-2})^2 \\ &= 1.3 \text{ N} \end{aligned}$$

$A = 5.1 \text{ cm} \times 5.1 \text{ cm}$

[2]

(c) Calculate the force exerted on the spring by the cube when it is in equilibrium in the water.

$$F = 4.0\text{ N} - 1.3 \quad (\text{down force} - \text{upward force})$$

$$= 2.7\text{ N}$$

force = 2.7 N [1]

(d) The spring obeys Hooke's law and has a spring constant of 30 N m^{-1} .

Determine the initial height above the water surface of the base of the cube before it was released.

$$F = ke$$

$$e = \frac{F}{k} = \frac{2.7\text{ N}}{30\text{ N m}^{-1}}$$

$$= 0.09\text{ m}$$

$$= 9\text{ cm}$$

height above surface = 9 - 7 = 2 cm

height above surface = 2 cm [3]

(e) The cube in the water is released from the spring.

(i) Determine the initial acceleration of the cube.

$$m = \frac{W}{g} = \frac{4.0\text{ N}}{9.81\text{ N kg}^{-1}} = 0.4077\text{ kg}$$

$$a = \frac{F}{m} = \frac{2.7}{0.4077}$$

$$= 6.6\text{ m s}^{-2}$$

acceleration = 6.6 ms^{-2} [2]

(ii) Describe and explain the variation, if any, of the acceleration of the cube as it sinks in the water.

- Water resistance increases until the speed is constant; when weight equals upthrust

- So acceleration decreases to zero. [2]

[Total: 12]

2. 9702/23/ON/17/No.2

A liquid of density ρ fills a container to a depth h , as shown in Fig. 2.1.

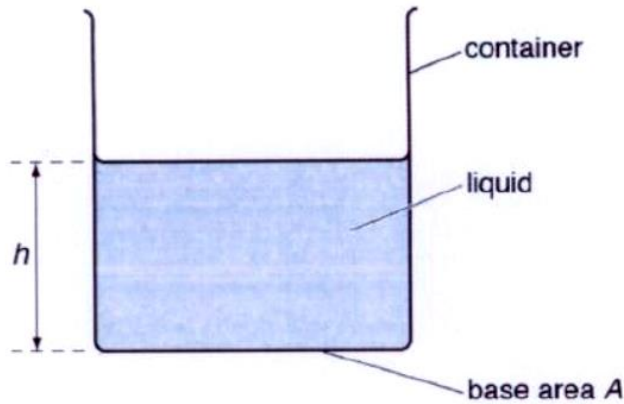


Fig. 2.1

The base of the container has area A .

(a) Derive, from the definitions of pressure and density, the equation

$$p = \rho gh$$

where p is the pressure exerted by the liquid on the base of the container and g is the acceleration of free fall.

$$\begin{aligned}
 \rho &= \frac{m}{V} & V &= Ah \\
 &= \frac{m}{Ah} & W &= mg \\
 & & m &= \rho V = \rho Ah \\
 p &= \frac{F}{A} = \frac{W}{A} = \frac{mg}{A} & p &= \frac{\rho Ahg}{A} \\
 & & & \boxed{p = \rho hg}
 \end{aligned}$$

[3]

(b) A small solid sphere falls with constant velocity through the liquid.

(i) State

1. the names of the three forces acting on the sphere,

- weight

- upthrust and drag force.

2. a word equation that relates the magnitudes of these forces.

weight = upthrust + drag force.

[2]

(ii) State and explain the changes in energy that occur as the sphere falls.

- g.p.e decreases due to decrease in height
- thermal energy increases due to work done against drag force
- loss of g.p.e equal to gain in thermal energy. [2]

(c) The liquid in the container is liquid L. Liquid M is now added to the container. The two liquids do not mix. The total depth of the liquids is 0.17 m.

Fig. 2.2 shows how the pressure p inside the liquids varies with height x above the base of the container.

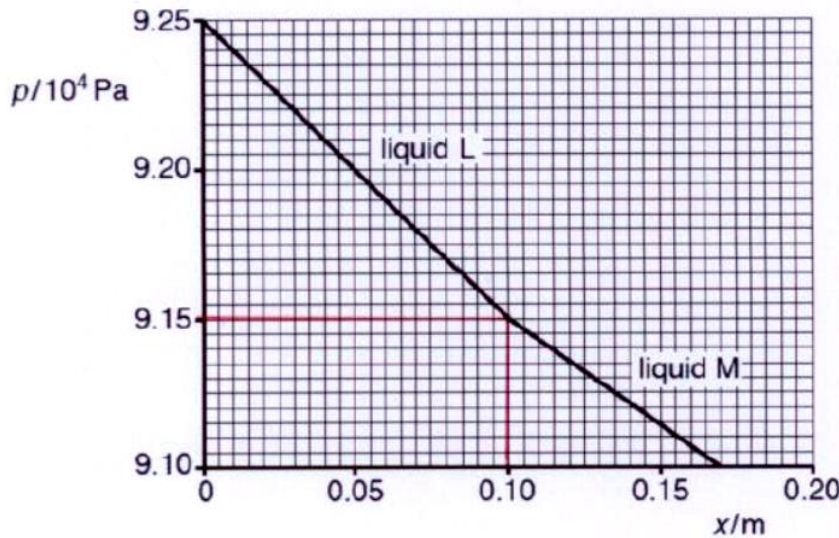


Fig. 2.2

Use Fig. 2.2 to

(i) state the value of atmospheric pressure,

atmospheric pressure = 9.1×10^4 Pa [1]

(ii) determine the density of liquid M.

$$\Delta p = \rho g \Delta h$$

$$(9.15 - 9.10) \times 10^4 = \rho \times 9.81 \times (0.17 - 0.1)$$

$$\rho = 728 \text{ kg m}^{-3}$$

density = 728 kg m⁻³ [2]

[Total: 10]