Pressure

- The density of a substance is defined as its mass per unit volume.
- The symbol for density is ρ (Greek rho) and its SI unit is kgm–3.

$$\rho = m/V$$

- **Pressure is defined as force per unit area, where the force F act perpendicularly to the area A.**

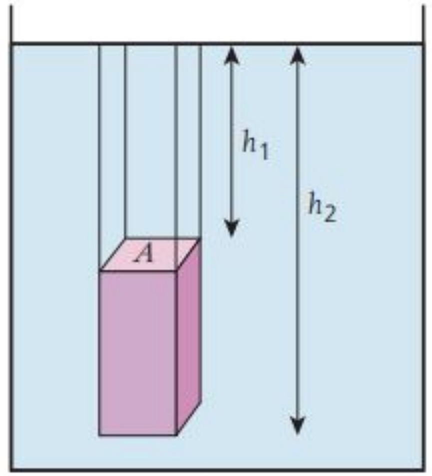
$$p = F/A$$

- The symbol for pressure is p and its SI unit is the pascal (Pa), which is equal to one newton per square metre (Nm^{-2})

Pressure in a liquid

The weight of the column is $W = mg = \rho A h_1 g$, and the pressure ρ_1 is $W/A = \rho g h_1$. The pressure at a depth of h_2 is due the column of liquid above this depth and is given by $p_2 = \rho g h_2$.

$$p = \rho g h$$



▲ **Figure 4.12** Column of liquid above the area *A*

The difference in pressure due to the difference in water depth is Δp (= $p_2 - p_1$) = $\rho g(h_2 - h_1) = \rho g \Delta h$

The pressure in a liquid increases with depth.

The change in pressure in a fluid, Δp due to the change in depth Δh is given by

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

Upthrust(buoyancy force):- Upthrust, It is the resultant force on a submerged object due to pressure difference between higher pressure and lower pressure in fluid.

The pressure at the bottom of the cylinder is greater than the pressure at the top of the cylinder. The pressure difference Δρ is given by

$$\Delta p = \rho g h_2 - \rho g h_1$$

This difference in pressure means that there is a bigger force acting upwards on the base of the cylinder, than there is acting downwards on the top. The difference in these forces is the upthrust or buoyancy force F_b.

$F_b = F_{up} - F_{down}$ and, since $p = F/A$

$F_b = \rho g A(h_2 - h_1) = \rho g A l = \rho g V$

where ρ is the density of the liquid, l is the length of the cylinder,

A is the cross-sectional area of the cylinder, and V is its volume a

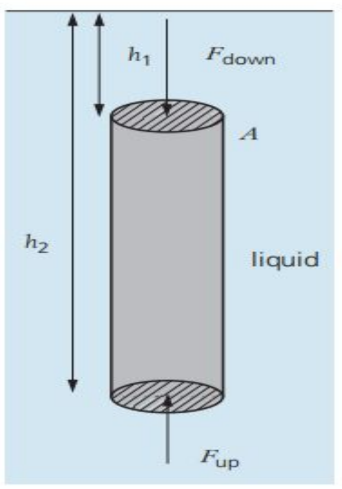
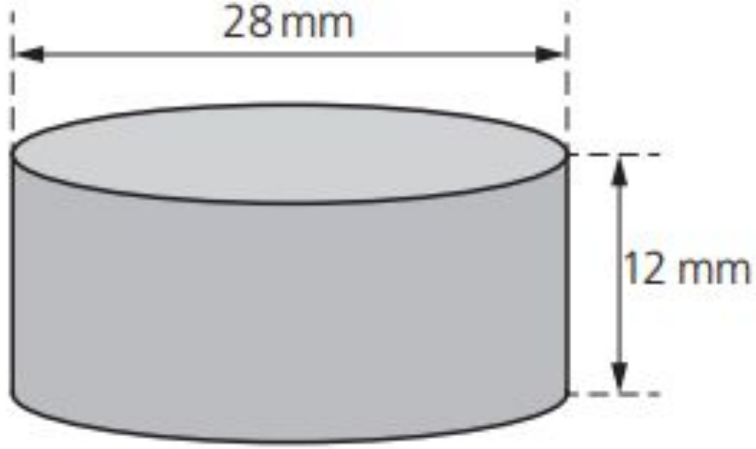


Figure 4.13 Origin of the buoyancy force (upthrust)

The upthrust acting on an object immersed in a fluid is equal to the weight of the fluid displaced is known as Archimedes' principle.

18 A cylindrical disc is shown in Fig. 4.28.



▲ **Figure 4.28**

The disc has diameter 28 mm and thickness 12 mm. The material of the disc has density $6.8 \times 10^3\ \text{kg m}^{-3}$. Calculate, to two significant figures, the weight of the disc. [4]

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19 a Define *pressure*.

b A solid sphere of diameter 30.0 cm is fully immersed near the surface of the sea. The sphere is released from rest and moves vertically downwards through the seawater. The weight of the sphere is 1100 N. An upthrust U acts on the sphere. The upthrust remains constant as the sphere moves downwards.

The density of the seawater is $1030\,\text{kg m}^{-3}$.

i Calculate the density of the material of the sphere.

ii Briefly explain the origin of the upthrust acting on the sphere.

iii Show that the upthrust U is 140 N.

iv Calculate the initial acceleration of the sphere.

v The viscous (drag) force D acting on the sphere is given by

$D = \frac{1}{2} C\rho\pi r^2 v^2$

where r is the radius of the sphere and v is its speed. ρ is the density of the seawater.

The constant C has no units and is equal to 0.50.

Determine the constant (terminal) speed reached by the sphere.

- The total pressure p at a point at a depth h below the surface of a fluid of density ρ is $p = p_A + \rho g h$,

where, p_A being the atmospheric pressure and $\rho g h$ is the difference in pressure between the surface and a point at a depth h.

- The upthrust F on an object immersed in a fluid

is equal to the weight of the fluid displaced ($F = \rho g V$).

Pressure increases with depth in a fluid.

- The difference in pressure is proportional to the difference in depth between two points in the fluid, and the pressure difference is given by $\Delta p = \rho g \Delta h$.

(b) A non-uniform rod XY is

pivoted at point P, as shown in Fig. 2.1.

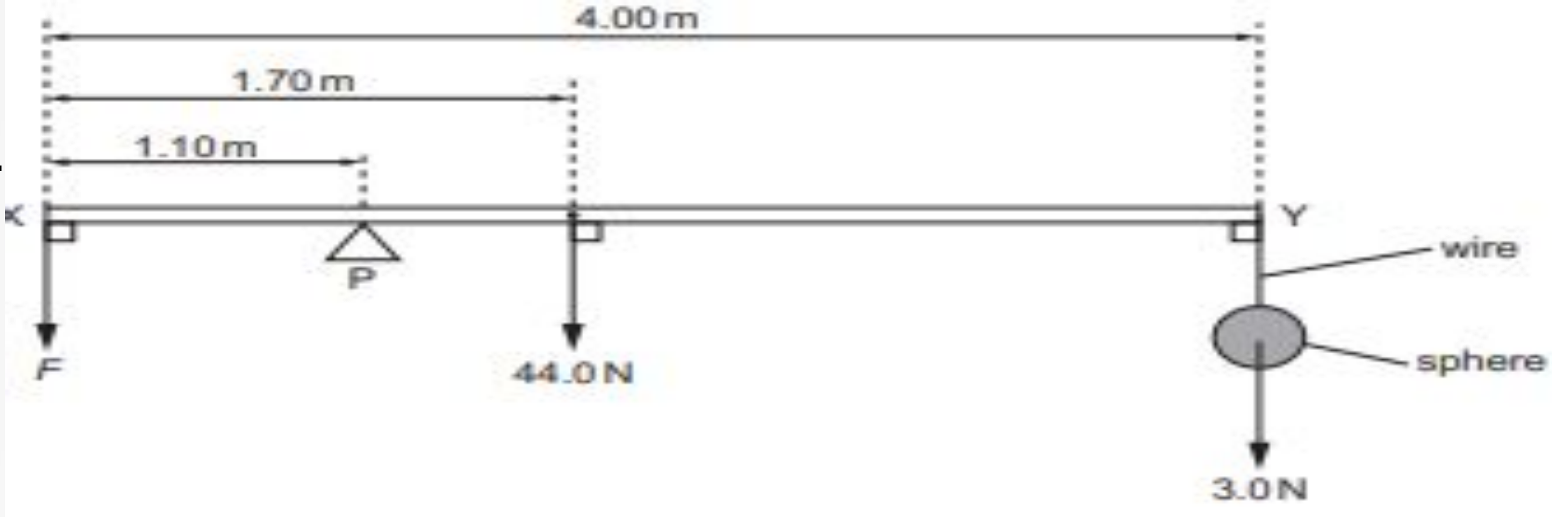

Fig. 2.1 (not to scale)

The rod has length 4.00m and weight 44.0N. The centre of gravity of the rod is 1.70m from end X of the rod. Point P is 1.10m from end X. A sphere hangs by a wire from end Y of the rod. The weight of the sphere is 3.0N.

The weight of the wire is negligible. A force F is applied vertically downwards at end X so that the horizontal rod is in equilibrium.

(i) By taking moments about P, calculate F.

F = ... N [3]

(ii) Calculate the force exerted on the rod by the pivot.

force = ... N [1]

(c) The sphere in (b) is now immersed in a liquid in a container, as shown in Fig. 2.2.

Fig. 2.2

The density of the liquid is 1100kgm^{-3}. The upthrust acting on the sphere due to the liquid is 2.5N. The magnitude of F is unchanged so that the horizontal rod is not in equilibrium.

(i) Use Archimedes' principle to determine the radius r of the sphere.

r = ... m [3]

(ii) Calculate the magnitude and direction of the resultant moment of the forces on the rod about P.

magnitude of resultant moment = ... Nm

direction of resultant moment ....

3 A jet of water hits a vertical wall at right angles, as shown in Fig. 3.1.

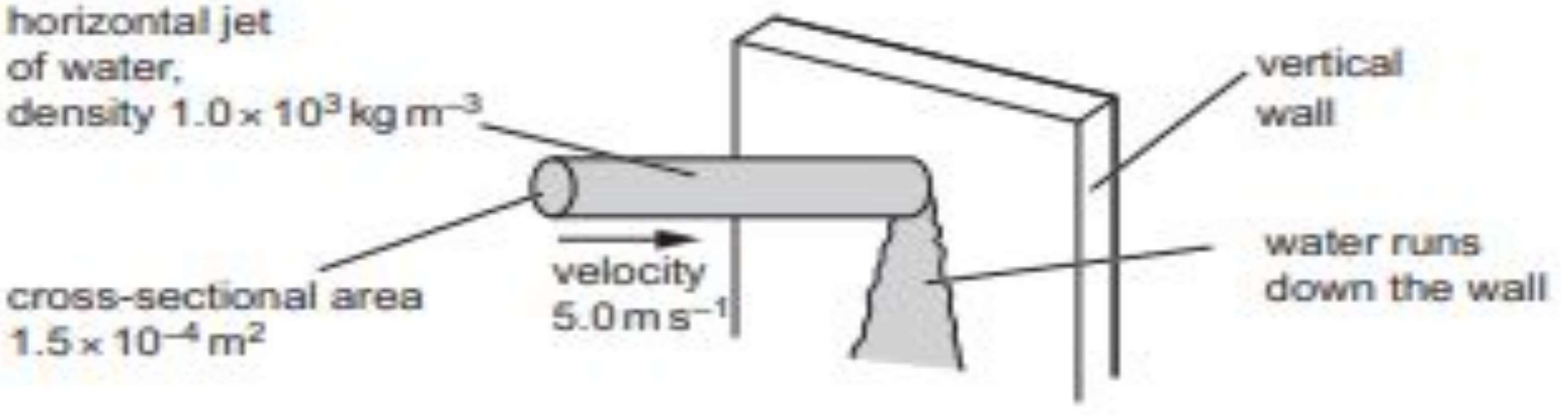

Fig. 3.1 (not to scale)

The water hits the vertical wall with a velocity of 5.0ms^{-1} in a horizontal direction. The cross-sectional area of the jet is 1.5 × 10–4m^2. The density of the water is 1.0 × 103 kgm^{-3}. The water runs down the wall after hitting it.

(a) Show that, over a time of 1.6s, the mass of water hitting the wall is 1.2kg.

(b) Calculate: (i) the decrease in the horizontal momentum of the mass of water in (a) due to hitting the wal (ii) the magnitude of the horizontal force exerted on the water by the wall.

(c) State and explain the magnitude of the horizontal force exerted on the wall by the water.

(d) Calculate the pressure exerted on the wall by the water.