Notes and formulas – Lecture 3

Buoyancy

When a body is partially or fully immersed in a fluid, an upward force acts on it, which is called buoyant force, the phenomena is called buoyancy.

The buoyant force acts at the centre of gravity of the liquid displaced by the immersed part of the body and this point is called the centre of buoyancy. The magnitude of buoyant force, $F = v\rho g$.

Pascal's Law

The increase in pressure at a point in the enclosed liquid in equilibrium is transmitted equally in all directions in liquid and to the walls of the container.

The working of hydraulic lift and hydraulic brakes arebased on Pascal's law.

Archimedes' Principle

When a body is partially or fully immersed in a liquid, it loses some of its weight and it is equal to the weight of the liquid displaced by the immersed part of the body. If a is loss of weight of a body in water and b is loss of weight in another liquid, then

$$\frac{a}{b} = \frac{w_{\text{air}} - w_{\text{liquid}}}{w_{\text{air}} - w_{\text{water}}}$$

If T is the observed weight of a body of density σ when it is fully immersed in a liquid of density ρ, then real weight of the body

$$w = \frac{T}{\left(1 - \frac{\rho}{\sigma}\right)}$$

If w_1 = weight of body in air, w_2 = weight of body in liquid,

V_i = immersed of volume of liquid,

ρ_L = density of liquid and g = acceleration due to gravity

$$\Rightarrow \quad V_i = \frac{w_1 - w_2}{\rho_L g}$$

Laws of Floatation

A body will float in a liquid, if the weight of the body is equal to the weight of the liquid displaced by the immersed part of the body.

If W is the weight of the body and w is the buoyant force, then

(a) If $W > w$, then body will sink to the bottom of the liquid.

(b) If $W < w$, then body will float partially submerged in the liquid.

(c) If $W = w$, then body will float in liquid if its whole volume is just immersed in the liquid.

The floating body will be in stable equilibrium, if meta-centre (centre of buoyancy) lies vertically above the centre of gravity of the body.

The floating body will be in unstable equilibrium, if meta-centre (centre of buoyancy) lies vertically below the centre of gravity of the body. The floating body will be in neutral equilibrium, if meta-centre (centre of buoyancy) coincides with the centre of gravity of the body.

Fraction of volume of a floating body outside the liquid

$$\left(\frac{V_{\text{out}}}{V}\right) = \left[1 - \frac{\rho}{\sigma}\right]$$

where, ρ = density of body and σ = density of liquid

If two different bodies A and B are floating in the same liquid, then

$$\frac{\rho_A}{\rho_B} = \frac{(v_{\text{in}})_A}{(v_{\text{in}})_B}$$

If the same body is made to float in different liquids of densities σ_A and σ_B respectively, then

$$\frac{\sigma_A}{\sigma_B} = \frac{(V_{\text{in}})_B}{(V_{\text{in}})_A}$$

Density and Relative Density

Density of a substance is defined as the ratio of its mass to its volume.

$$\text{Density of a liquid} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Density of water} = 1 \text{ g/cm}^3 \text{ or } 10^3 \text{ kg/m}^3$$

In case of homogneous (isotropic) substance it has no directional properties, so it is scalar quantity and its dimensional formula is $[ML^{-3}]$.