Module 4. Floating bodies

Lesson 9
ARCHIMEDES PRINCIPLE, STABILITY OF FLOATING BODIES

9.1 Introduction

Archimedes principle can be used in dairy industry for designing equipments to measure density, floating devices for measuring liquid level etc. The stability of conveying packages or milk cans is based on the location of centre of gravity. Some common phenomena encountered in daily life are depicted below:

- Why do a ship weighing tonnes easily floats in sea where as a hammer sinks in water?
- Why a person does not sink in Dead Sea?
- How a life jacket does help in time of emergency?

9.2 Buoyancy

When a body is submerged in fluid, it experiences an upward thrust due to the fluid pressure. This vertical upward force is known as buoyant force (F_B). It is shown in Fig. 9.1.The tendency of anybody to be lifted upward in a fluid against the force of gravity is known as buoyancy.

9.3 Centre of Buoyancy

The point through which the buoyant force acts is called the centre of buoyancy. It is at the centre of gravity of the volume of displaced fluid. Here in Fig. 9.1 point B is known as the centre of buoyancy.

Click for Animation (Fig. 9.1 A wooden block floating in water)

9.4 Archimedes Principle

Archimedes Principle states that the buoyant force acting on the body immersed in fluid is equal to the weight of fluid displaced by the body.

This principle explains the loss of weight in a body immersed in fluid, which is equal to the weight of fluid displaced by it. The volume of fluid displaced by the floating body is just enough to balance its weight.

9.5 Numericals

Q. 1. The dimensions of a wooden block floating in the water is 4 m * 2 m * 1 m (length * width * depth). The density of block is 700 kg/m^3. Determine

(i) Volume of water displaced

(ii) Position of centre of buoyancy

Solution:

(i) W = (4 * 2 * 1) * 700 * 9.81

$F_B = V_f * 1000 * 9.81$

$W = F_B$ (according to Archimedes Principle)

Therefore, 4 * 2 * 1 * 700 * 9.81 = V_f * 1000 * 9.81

$V_f = 5.6$ m^3

(ii) h * 2 * 4 = 5.6

h = 0.7 m

Position of centre of buoyancy = h/2 = 0.35 m

Q2. The dimensions of a wooden block floating in the water is 4 m * 2 m * 1 m having density of block 700 kg/m^3. Calculate the volume of concrete block of specific gravity = 3.5 that may be placed on the block which will:

(a) Completely on the immerse the block into water

(b) Completely immerse the wooden + concrete block together.

Solution:

$$\rho_{concret} = 3500 kg/m^3$$

$$(a)\, W = (4\times2\times1)\times700\times9.81 + V_C\times3500\times9.81$$

$$F_B = (4\times2\times1)\times1000\times9.81$$

$$2\times1\times4\times1000\times9.81 = 2\times1\times4\times700\times9.81 + 3500\times9.81\times V_C$$

$$V_C\times3500 = (1000-700)\times(2\times1\times4)$$

$$V_C = \frac{300\times8}{3500} = \frac{24}{35} m^3 \quad Ans.$$

$$(b)\, W = (2\times1\times4)\times700\times9.81 + V_C\times3500\times9.81)$$

$$F_B = 2\times1\times4\times1000\times9.81 + V_C\times1000\times9.81$$

$$= 2\times1\times4\times700\times9.81 + V_C\times3500\times9.81 = 2\times1\times4\times1000\times9.81 + V_C\times1000\times9.81$$

$$= V_C(3500-1000) = (1000-700)\times2\times1\times4$$

$$V_C = \frac{300\times8}{2500} = \frac{24}{25} = 0.96\, m^3 \quad \text{Ans.}$$

Q3. A metallic cube 30 cm side and weighing 450 N is lowered into a tank containing two fluid layers of water and mercury. Determine the position of block at mercury and

water interface when it has reached at equilibrium.

Solution:

$$W = 450\,N$$

$$450 = F_B = h_1 \times 0.3 \times 0.3 \times 13600 \times 9.81 + h_2 \times 0.3 \times 0.3 \times 1000 \times 9.81 \ldots\ldots\ldots\ldots (i)$$

$$12007.44h_1 + 882.9h_2 = 450 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

$$h_1 + h_2 = 0.3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

$$h_1 + h_2 = 0.3$$

$$12007.44h_1 + 882.9h_2 = 450$$

$$-12007.44h_1 \pm 12007.44h_2 = 3602.232$$

$$11124.54h_2 = 3152.232$$

$$h_2 = 0.2833\,m$$

$$\mathbf{h}_1 + \mathbf{h}_2 = 0.3$$

$$h_1 = 0.3 - h_2$$

$$= 0.3 - 0.2833$$

$$= 0.0167\,m$$

9.6 Stability of Floating Body

Stability of a body can be understood by keeping a solid cone on a table. The different positions are shown in Fig. 9.2. Here the stability of the cone depends on how close the centre of gravity to the plane on which any object is resting. But in case of immersed and floating body the stability or equilibrium is determined by the position of centre of buoyancy. This will be discussed in the lesson 10.

A = Stable B = Unstable C = Neutral

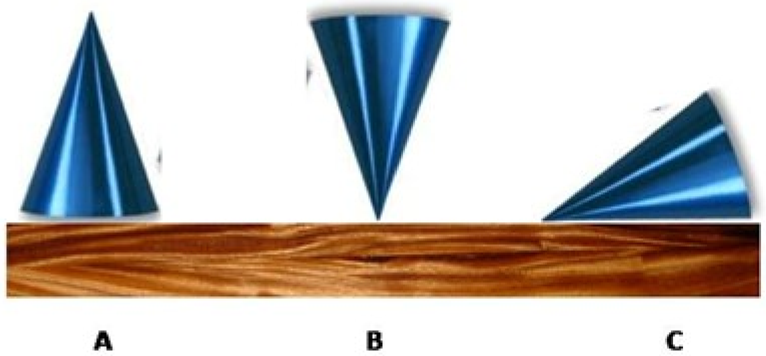

Fig. 9.2 Stability of a solid cone