# 4 CHAPTER

# Buoyancy and Floatation

**Q.1** Assertion (A): The buoyant force for a floating body passes through the centroid of the displaced volume.
Reason (R): The force of buoyancy is a vertical force and equal to the weight of fluid displaced.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

**Q.2** A symmetrical right circular cone of wood floats in fresh water with its axis vertical and the apex down. The axial height of the cone is 1 unit. The submerged portion has a height h, measured upwards from the apex. What would be the height of the centre of buoyancy from the apex?

(a) $\frac{h}{2}$ (b) $\frac{5}{8}h$

(c) $\frac{2}{3}h$ (d) $\frac{3}{4}h$

**Q.3** The increase in metacentric height
1. increase stability
2. decrease stability
3. increases comfort for passengers
4. decreases comfort for passengers

The correct answer is
(a) 1 and 3 (b) 1 and 4
(c) 2 and 3 (d) 2 and 4

**Q.4** A small plastic boat loaded with nuts and bolts is floating in a bath tub. If the cargo is dumped into the water, allowing the boat to float empty, then the water level in the tub will
(a) rise (b) fall
(c) not change (d) None of these

**Q.5** When a block of ice floating on water in a container melts, the level of water in the container
(a) rises
(b) first falls and then rises
(c) remains the same
(d) falls

**Q.6** A cubical body is dropped in water and is found to have neutral equilibrium. If it is dropped in sea water (specific gravity = 1.03)
(a) it will be in stable equilibrium
(b) it will be in unstable equilibrium
(c) it will be in neutral equilibrium
(d) the body will sink

**Q.7** Two cubes of size 1.0 m sides, one of relative density = 0.60 and another of relative density = 1.15, are connected by a weightless wire and placed in a large tank of water. Under equilibrium the lighter cube will project above the water surface to a height of
(a) 10 cm (b) zero
(c) 50 cm (d) 25 cm

**Q.8** A rectangular floating body 20 m long is 5 m wide. The water lane is 1.5 m above the bottom. If the centre of gravity is 1.8 m from the bottom, then its metacentric height will be approximately
(a) 3.3 m (b) 1.65 m
(c) 0.34 m (d) 0.30 m

**Q.9** What is buoyant force?
(a) Lateral force acting on a submerged body
(b) Resultant force acting on a submerged body

(c) Resultant force due to water on a body
(d) Resultant hydrostatic force on a body due to fluid surrounding it

**Q.10** For floating bodies, how is the metacentric radius defined?
(a) The distance between centre of gravity and the metacentric
(b) Second moment of area of plane of floation about centroidal axis perpendicular to plane of rotation/immersed volume
(c) The distance between centre of gravity and the centre of buoyancy
(d) Moment of inertia of the body about its axis of rotation/immersed volume

**Q.11** Consider the following statements:
1. Increasing the metacentric height of a ship causes increase in the period of rolling.
2. The frequency of pitching can be reduced by adding more loads along the length of a ship below its centre of gravity
3. A ship has different metacentres in rolling and pitching
4. Stability can be improved by increasing the width and reducing the draft.

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 1, 2 and 4
(c) 1, 2 and 3 (d) 2, 3 and 4

**Q.12** Consider the following statements related to the stability of floating bodies:
1. The metacentre should be above the centre of gravity of the floating body for stable equilibrium during small oscillations.
2. For a floating body, stability is not determined simply by the relative positions of centre of gravity and centre of buoyancy.
3. The position of metacentre of a floating body is fixed irrespective of the axis of oscillations.
4. Large value of metacentric height reduces the period of roll of the vessel.

Which of these statements are correct?
(a) 1 and 3 (b) 2 and 4
(c) 1, 2 and 4 (d) 1, 2, 3 and 4

**Q.13** Assertion (A): Stability of a floating body is determined by the relative position of the centre of gravity and the centre of buoyancy.
Reason (R): If metacentre of the floating body is above the centre of gravity of the body, then the floating body will be in stable equilibrium.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

**Q.14** If $k$ is the radius of gyration, $h$ the metacentric height, $g$ the acceleration due to gravity, the time of oscillation of a floating body, is
(a) $\pi\sqrt{\frac{k^2}{g}}$ (b) $2\pi\sqrt{\frac{k^2}{gh}}$
(c) $2\pi\sqrt{\frac{k}{h^2g}}$ (d) $\pi\sqrt{\frac{k^2}{g^2h^2}}$

**Q.15** Passenger ships are designed to have a relatively small metacentric height which lies in the range of
(a) 0.1-0.3 m (b) 0.3-0.6 m
(c) 0.6-0.9 m (d) 0.9-1.2 m

**Q.16** Match List-I with List-II and select the correct answer using the codes given below the lists:
List-I
A. Submerged body
B. Floating body
C. Metacentric height
D. Buoyancy
List-II
1. Force on a curved surface
2. Moment of inertia
3. Metacentre
4. Force acting vertically up
5. Centre of buoyancy

Codes:

| | A | B | C | D |
|---|---|---|---|---|
| (a) | 5 | 3 | 2 | 1 |
| (b) | 1 | 2 | 3 | 4 |
| (c) | 5 | 3 | 2 | 4 |
| (d) | 1 | 2 | 5 | 4 |

**Q.17** A solid cylinder of length $L$, diameter $D$ and specific gravity 0.6 floats in neutral equilibrium in water with its axis vertical. What is the ratio of $L$ to $D$?
(a) $\frac{\sqrt{3}}{2}$ (b) $\frac{2\sqrt{3}}{5}$
(c) $\frac{4}{5\sqrt{3}}$ (d) $\frac{5}{4\sqrt{3}}$

**Q.18** Match the following
Column-I
A. $M$ below $G$
B. $M$ and G at same location
C. $M$ above $G$
$M$ = Metacenter
$G$ = Centre of gravity
Column-II
1. Stable equilibrium
2. Unstable equilibrium
3. Neutral equilibrium

Codes:

| | A | B | C |
|---|---|---|---|
| (a) | 1 | 3 | 2 |
| (b) | 2 | 3 | 1 |
| (c) | 1 | 2 | 3 |
| (d) | 3 | 1 | 2 |

**Q.19** A homogeneous circular cylinder of length h and radius r and specific gravity '$S$' floats in water. It is noted that $r = \frac{2h}{3}$. Under which of the following condition, floatation will be unstable
(a) $S < 0.22$, $S > 0.11$
(b) $0.22 < S < 0.33$
(c) $0.33 < S < 0.66$
(d) $0.66 < S < 0.99$

**Q.20** The least radius of gyration of a ship is 8 m and metacentre height 70 cm. The time period of oscillation of the ship is
(a) 3.05 sec (b) 6.78 sec
(c) 60.08 sec (d) 19.18 sec

**Q.21** A metal cube of size 15 cm x 15 cm x 15 cm and specific gravity 8.6 is submerged in a two-layered liquid, the bottom layer being mercury and the top layer being water. The percentage of the volume of the cube remaining above the interface will be, approximately.
(a) 68 (b) 63
(c) 40 (d) 25

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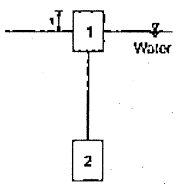
## Answers Buoyancy and Floatation

1. (a) 2. (d) 3. (b) 4. (b) 5. (c) 6. (a) 7. (d) 8. (c) 9. (d) 10. (a)
11. (d) 12. (c) 13. (d) 14. (b) 15. (b) 16. (b) 17. (d) 18. (b) 19. (c) 20. (d)
21. (c)

## Explanations Buoyancy and Floatation

7. (d)




Weight of blocks = Weight of displaced liquid
$1 \times 1 \times 1 \times 0.6 + 1 \times 1 \times 1 \times 1.15$
$= 1 \times 1 \times 1 \times 1 + (1 - x) \times 1 \times 1 \times 1$
$\Rightarrow \quad 1.75 = 2 - x$
$\Rightarrow \quad x = 0.25\ \text{m} = 25\text{cm}$

8. (c)

$$GM = \frac{I}{\forall} - BG$$

$$BG = 1.8 - \frac{1.5}{2} = 1.05$$

$$\therefore \quad GM = \frac{20 \times 5^3}{12 \times 20 \times 5 \times 1.5} - 1.05$$

$$= 0.34 \text{ m}$$

11. (d)

$$T = 2\pi\sqrt{\frac{k^2}{g \times GM}}$$

$$\Rightarrow \quad T \propto \frac{1}{\sqrt{GM}}$$

15. (b)

For passenger ships metacentric height is 0.3 m to 0.6 m and for cargoships metacentric height 0.9 to 1.2 m

17. (d)

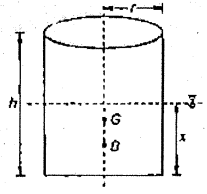
For neutral equilibrium GM = 0

$$\frac{L}{D} = \frac{1}{\sqrt{8S(1-S)}}$$

$$= \sqrt{8 \times 0.6 \times 0.4} = \frac{1}{4} \times \frac{1}{\sqrt{0.3 \times 0.4}}$$

$$= \frac{1}{4} \times \sqrt{\frac{100}{3 \times 4}} = \frac{5}{4\sqrt{3}}$$

19. (c)




For unstable equilibrium

$$GM < 0$$

$$BM - BG < 0$$

$$\frac{I}{V} - \frac{(h-x)}{2} < 0$$

$$\frac{\pi(2r)^4}{64 \times \pi r^2 x} - \frac{h-x}{2} < 0$$

$$\Rightarrow \frac{16\pi r^4}{64\pi r^2 x} - \frac{h-x}{2} < 0$$

$$\frac{r^2}{4x} - \frac{h-x}{2} < 0$$

$$\Rightarrow \frac{\frac{4}{9}r^2}{4 \times h \times S} - \frac{h - h \times S}{2} < 0$$

$$\Rightarrow \frac{h}{9S} - \frac{h(1-S)}{2} < 0$$

$$\Rightarrow \frac{1}{9s} - \frac{1-S}{2} < 0$$

$$\Rightarrow (2S-2)(3S-1) < 0$$

$$\Rightarrow \frac{1}{3} < S < \frac{2}{3}$$

20. (d)

$$T = 2\pi\sqrt{\frac{k^2}{GMg}}$$

$$= 2\pi\sqrt{\frac{8 \times 8}{0.7 \times 9.81}} = 19.16 \text{ sec}$$

21. (c)

Let the percentage of cube remain above interface is $p$.

The buoyancy force is

$$p_w = (0.01p) \times 15^3 g + 13.6\, \rho_w (1 - 0.01p) \times 15^3 g$$

This force will be equal to the weight of the cube

$$= 8.6\, \rho_w 15^3 g$$

$\therefore \quad 0.01p + 13.6(1 - 0.01p) = 8.6$

$\Rightarrow \quad 12.6 \times 0.01p = 13.6 - 8.6 = 5$

$\therefore \quad p = 39.7\% \equiv 40\%$

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