POSTAL Book Package 2023

Mechanical Engineering

Objective Practice Sets

Fluid Mechanics

Contents

MADE EASY Publications

3 CHAPTER Hydrostatic Forces on Surface

Q.1 The following statements relate to the pressure exerted by a fluid on a submerged curved surface:
1. The vertical component of hydrostatic force acting on a submerged curved surface acts through the centre of volume of the fluid directly above the submerged area.
2. The horizontal components of the force acting on a curved surface is the hydrostatic force acting on the vertical projection of the curved surface.
3. The resultant force on a curved surface acts on the bottom of the curved surface.

Of these statements
(a) 1, 2 and 3 are correct
(b) 2 and 3 are correct
(c) 1 and 2 are correct
(d) 1 and 3 are correct

Q.2 Consider the following statement relating to hydrostatic forces on submerged surface:
1. The pressure centre is always below the centroid of any plane submerged surface that is not horizontal.
2. Total force on a curved surface is the product of the average force and the submerged area.
3. The magnitude of hydrostatic pressure at a particular depth is a function of the shape of the surface
4. The vertical component of force on a body completely submerged in a static reservoir of fluid is equal to the weight of the fluid displaced by the body.

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

Q.3 Consider the following statements:
1. The centre of pressure is always above the centroid of any plane submerged surface that is not horizontal.
2. The total force-acting on a submerged plane surface is the product of the area of the surface and the pressure at the centroid of the plane surface.
3. The horizontal component of the resultant force on a curved surface is calculated by horizontally projecting the surface onto a horizontal plane and treating the project area as a submerged horizontal plane surface.
4. The vertical component of force on a curved surface is obtained by calculating the weight of the liquid above and below the surface.

Of these statements:
(a) 1 alone is correct
(b) 2 alone is correct
(c) 2 and 3 are correct
(d) 1 and 4 are correct

Q.4 Consider the following statements about hydrostatic force on a submerged surface:
1. It remains the same even when the surface is turned.
2. It acts vertically even when the surface is turned.

Which of these statements is/are correct?
(a) Only 1 (b) Only 2
(c) Both 1 and 2 (d) Neither 1 nor 2

Q.5 The vertical component of force on a curved surface submerged in a static liquid is equal to the
(a) weight of liquid column above the CG of the curved surface
(b) weight of liquid above the curved surface
(c) product of pressure at CG, multiplied by the area of the curved surface
(d) product of pressure at CG, multiplied by the projected area of the curved surface

Directions : Each of the next items consists of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. Examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) Both Statement (I) and Statement (II) are individually true; and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true; but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true; but Statement (II) is false
(d) Statement (I) is false; but Statement (II) is true

Q.6 **Statement (I):** For a vertically immersed surface, the depth of the centre of pressure is independent of the density of the liquid.
Statement (II): Centre of pressure lies above the centre of area of the immersed surface.

Q.7 **Statement (I):** Depth of centre of pressure of any immersed surface is independent of the density of liquid.
Statement (II): Centre of area of immersed surface lies below the centre of pressure.

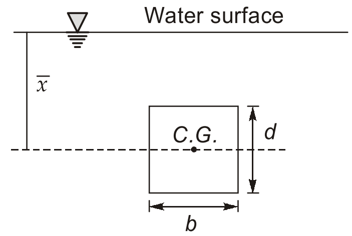
Q.8 The centre of pressure for an inclined surface area
(a) lies below the centroid of the surface
(b) coincides with the centroid
(c) lies above the centroid of the surface
(d) none of the above

Q.9 The depth of centre of pressure of a rectangular lamina immersed vertically in water up to a height *h* is given by

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

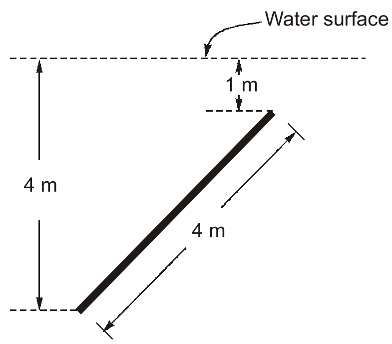
Q.10 A venturimeter has a differential mercury water manometer connected to its inlet and throat. The gauge reading γ of the manometer for a given discharge in pipe
(a) depends on the orientation of the venturimeter.
(b) is independent of the orientation of the venturimeter.
(c) varies as the slope of the venturimeter with respect to the horizontal.
(d) depends on whether the manometer is above or below the centreline.

Q.11 A vertically immersed surface is shown in figure. The distance of its centre of pressure from the water surface is



(a) $\bar{x}+\frac{d^2}{12\bar{x}}$ (b) $\frac{b^2}{12\bar{x}}+d$
(c) $\frac{d}{12}+\bar{x}$ (d) $\frac{d^2}{1-b}+\bar{x}$

Q.12 If a rectangular plate 4 m × 3 m is completely submerged under water as shown in the given figure, then the hydraulic thrust on the plate would be nearly:

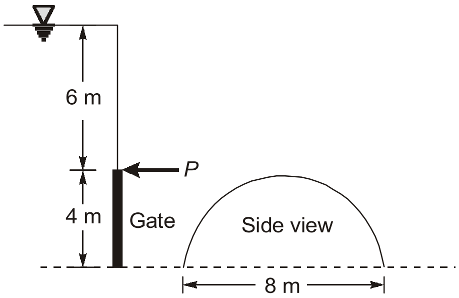


(a) 220 kN (b) 264 kN
(c) 294 kN (d) 353 kN

Q.13 A tank is 2 m deep with cross-sectional length of 5.5 m at top of 3.5 m at bottom. The four sides are plane and each has the same trapezoidal shape. The tank is completely full of water. The resultant pressure on each side is
(a) 96.28 kN (b) 91.41 kN
(c) 84.62 kN (d) 78.34 kN

Q.14 An isosceles triangular plate of base 5 meters and altitude 5 meters is immersed vertically in a fluid of specific gravity 0.75. The base of the triangle is touching the top of the surface of the

P(kN) is required at point A to establish equilibrium condition?



Q.30 A rigid angled triangular lamina with height 3 m and base 4 m submerged in water at an inclination of 30° below 5 m from water surface. What is the total pressure force on the lamina _______ kN.

Answers Hydrostatic Forces on Surface

1. (c)	2. (d)	3. (b)	4. (d)	5. (b)	6. (c)	7. (c)	8. (a)	9. (a)	10. (b)
11. (a)	12. (c)	13. (b)	14. (d)	15. (a)	16. (d)	17. (a)	18. 235.42		19. 294.3
20. 78.01	21. (b)	22. (b)	23. (c)	24. (b)	25. (a)	26. (d)	27. (c)	28. (d)	
29. 790.61		30. 265							

Explanations Hydrostatic Forces on Surface

1. (c)

The pressure exerted by a fluid on a submerged curved surface can be calculated by considering the horizontal and vertical components of the force separately.

(i) **Horizontal component of hydrostatic force:** It is the force acting on the vertical projection of the curved surface. It acts through the centre of pressure of the vertical projection.

(ii) **Vertical component of hydrostatic force :** The vertical component of hydrostatic force acting on any surface (plane or curved), is equal to the weight of the liquid extending above the surface of object upto the free surface. It passes through the centre of gravity of the fluid volume considered. The volume considered and the free surface can be real or imaginary.

(iii) **Resultant :** The resultant force is the resultant of horizontal and vertical component of hydrostatic force and its position also depend on their position only. Hence, it does not act on the bottom of the curved surface.

2. (d)

- For a plane area submerged in a static liquid, making an angle θ with the free structure of the liquid, the total hydrostatic force on one side of the area is given by

$$F = \rho g A\bar{h}$$

where, ρ = density of the liquid
A = area of submerged plane
$\bar{h}$ = depth of centre of gravity of the submerged plane below the free surface

Centre of pressure,

$$h_p = \bar{h} + \frac{I_G}{A_G}$$

Hence, centre of pressure is always below the centroid of any plane submerged. Hence, statement 1 is correct.

- As, $F = \rho g A\bar{h}$

It is clearly visible that it does not depend upon the shape of the surface. Hence, statement 3 is incorrect.

3. (b)

Centre of pressure (h_p) is always below the centre of gravity (h_c) because hydrostatic pressure increases with depth for any submerged surface.

Total force $= (\rho g h_c)A$.

Where ($\rho g h_c$) is the pressure at the centroid.

To calculate horizontal component of resultant force on a curved surface, the projection of surface will be taken in vertical direction normal to the horizontal direction. For vertical component of the force, the weight of liquid above the surface only is considered.

4. (d)
Magnitude of hydrostatic force on plane surface is independent of the inclination of the surface. Only when surface is rotated about its centroid.

5. (b)
Vertical component of a curved surface is equal to the weight of the liquid contained in that portion extending vertically above the curved surface upto the free surface of the liquid.

6. (c)

Depth of C. P. (h^*) = $\bar{h} + \dfrac{I_G \sin^2\theta}{A\bar{h}}$

Which is independent of the density of the liquid.

$$h^* - \bar{h} = \frac{I_G \sin^2\theta}{A\bar{h}} > 0$$

$\therefore$ $\qquad h^* > \bar{h}$

Centre of pressure lies below the centre of area of the immersed surface

7. (c)
Depth of centre of pressure is proportional to second moment of area about the water surface area of surface, and depth of centre of gravity, i.e.

$$h^* = \bar{h} + \frac{I_G \sin^2\theta}{A\bar{h}}$$

where,
h^* = depth of pressure
$\bar{h}$ = centroid of surface area
A = surface area
I_G = moment of inertia of the area about an axis passing through the centroid of the area.
θ = inclination of surface from horizontal

Centre of area of immersed surface lies above the centre of pressure.

8. (a)

$$h^* = \bar{h} + \frac{I_G}{A\bar{h}}\sin^2\theta$$

$\bar{h}$ = Centre of gravity
I_G = Area moment of inertia of surface about its centroidal axis and parallel to free surface.

9. (a)
As the pressure increases with depth centre of pressure lies below geometrical centre, its depth is $2h/3$ from surface.

10. (b)
The piezometric head difference depends upon the gauge reading regardless of the orientation of venturimeter whether it is horizontal, vertical or inclined.

11. (a)

$$h_p = \bar{x} + \frac{I_{xx}}{A\bar{x}} = \bar{x} + \frac{d^2}{12\bar{x}}$$

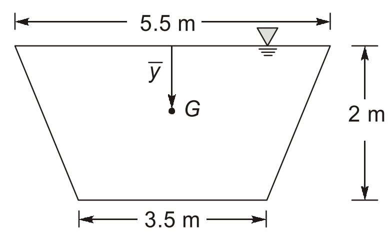
as $\left(I_{xx} = \dfrac{bd^3}{12}\right.$ and $\left.A = bd\right)$

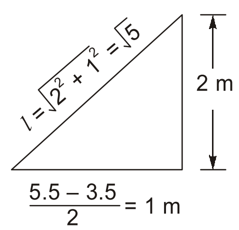
12. (c)
Hydraulic thrust
$F = \rho g h_c A$
Area $\quad A = 4 \times 3 = 12\ \text{m}^2$
$\rho g = 9.81\ \text{kN/m}^3$
The depth of centroid

$$h_c = \frac{1+4}{2} = 2.5\ \text{m}$$

$F = 9.81 \times 2.5 \times 12 = 294.3\ \text{kN}$

13. (b)





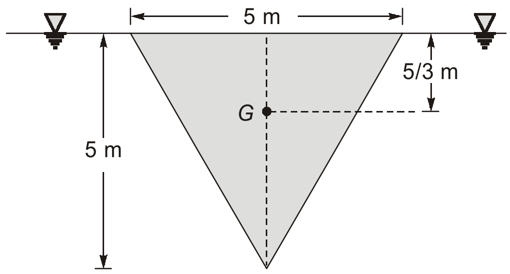
$$\bar{h} \text{ or } \bar{y} = \left(\frac{2 \times 3.5 + 5.5}{3.5 + 5.5}\right)\frac{2}{3} = 0.926\ \text{m}$$

$$F = \rho g\bar{h}A \text{ or } \rho g\bar{y}A$$

$$= 1000\times 9.81\times 0.926\times \frac{1}{2}\left[(3.5+5.5)\times\sqrt{5}\right]$$

$$= 91.41 \text{ kN}$$

14. (d)



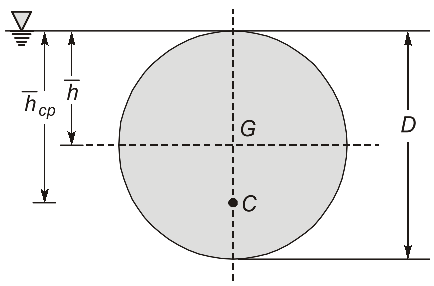
Total pressure on the triangle,

$$F = pA = \gamma h_c A$$

$$= (1000\times 0.75\times 9.81)\times\left(\frac{5}{3}\right)\times\left(\frac{1}{2}\times 5\times 5\right)$$

$$= 750\times 9.81\times\frac{5}{3}\times\frac{25}{2} = 1250\times\frac{25}{2} \simeq 153.28 \text{ kN}$$

15. (a)



Let the centre of pressure be C and centre of gravity be G.

Since the plane is vertical and therefore

$$\bar{y} = \bar{h} = \frac{D}{2}$$

Centre of pressure,

$$\bar{h}_{cp} = \bar{h} + \frac{I_{GG}\sin^2\theta}{A\bar{h}} = \bar{h} + \frac{I_{GG}\sin^2 90}{A\bar{h}}$$

Now, $\bar{h} = \dfrac{D}{2}$ and $I_{GG} = \left(\dfrac{\pi D^4}{64}\right)$

Hence, $\bar{h}_{cp} = \dfrac{D}{2} + \dfrac{\left(\dfrac{\pi D^4}{64}\right)}{\left(\dfrac{\pi D^2}{4}\right)\times\left(\dfrac{D}{2}\right)} = \dfrac{D}{2} + \dfrac{D}{8}$

$$= \frac{5}{8}D = 0.625D$$

16. (d)

$$\text{Area} = A = a^2\left(\sqrt{2}\right)^2 = 2 \text{ m}^2$$

Vertical distance of centroid from water surface,

$$\bar{h} = 0.6 + \frac{a}{\sqrt{2}} = 0.6 + \frac{\sqrt{2}}{\sqrt{2}}$$

$$= 1.6 \text{ m}$$

Force on one side of lamina,

$$F = \rho g\bar{h}A$$

$$= 10^3\times 9.81\times 1.6\times\left(\sqrt{2}\right)^2$$

$$= 31.4 \text{ kN}$$

17. (a)

The gate will open just when the centre of pressure coincides with the location of the pivot.

By symmetry, the centre of pressure lies on vertical axis of symmetry. Consider unit width of the gate.

Depth of centre of pressure below the water surface,

$$y_p = \bar{h} + \frac{I_{GG}}{A\bar{h}}$$

$\bar{h}$ = depth of CG of the plate from the water surface = (5 – 1) = 4 m

$$I_{GG} = \frac{(1.0)\times 2^3}{12} = \frac{2}{3} = 0.67 \text{ m}^4$$

Depth of centre of pressure,

$$y_p = 4 + \frac{0.67}{(1\times 2)\times 4}$$

$$y_p = 4 + \frac{0.67}{8} = 4.084 \text{ m}$$

$$\therefore \quad y = 5 - y_p = 5 - 4.084 = 0.916 \text{ m}$$

18. (235.42)