CLASS TEST

Sl. : 01 SK_ME_ ABCDEFGHI_010925

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# FLUID MECHANICS

## MECHANICAL ENGINEERING

Date of Test : 01/09/2025

## ANSWER KEY

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

## DETAILED EXPLANATIONS

**1. (c)**

$$1 \text{ Poise} = 0.1 \text{ N-s/m}^2$$

$$\text{Shear stress, } \tau = \mu \frac{dv}{dy}$$

$$\Rightarrow \quad \tau = \left(0.1 \times 5 \frac{\text{N-s}}{\text{m}^2}\right) \times \left(\frac{5 \text{ m/s}}{0.015 \text{ m}}\right) = 166.67 \text{ N/m}^2$$

**2. (a)**

$$\text{Velocity component in } x\text{-direction, } u = \frac{\partial \psi}{\partial y} = \frac{\partial}{\partial y}\left(ax^2 + by^2 + cy\right)$$

$$u = 2by + c$$

Note that you can use other sign convention also.

**3. (d)**

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

**4. (d)**

The acceleration is not being constant since the force is not constant. The impulse force exerted by the water on the plate is $F = \dot{m}V = (\rho AV) \cdot V = \rho AV^2$, where $V$ is the relative velocity between the water and the plate, which is moving. The magnitude of the plate acceleration is thus a = F/m. But as the plate begins to move, $V$ decreases, so the acceleration must also decrease.

**5. (b)**

At very large Reynolds numbers, the flow is fully rough and the friction factor is independent of the Reynolds number. This is because the thickness of viscous sub layer decreases with increasing Reynolds number, and it becomes so thin that the surface roughness protrudes into the flow. The viscous effects in this case are produced in the main flow primarily by the protruding roughness elements, and the contribution of the viscous sub layer is negligible.

This effect is clearly seen in the Moody chart-at large Re, the curves flatten out horizontally.

**6. (b)**

Arrangement 1 consists of a Pitot probe that measure the stagnation pressure at the pipe centerline, along with a static pressure tap that measures static pressure at the bottom of the pipe. Arrangement 2 is a Pitot-static probe that measures both stagnation pressure and static pressure at nearly the same location at the pipe centerline. Because of this, arrangement 2 is more accurate. However, it turns out that static pressure in a pipe varies with elevation across the pipe cross-section in much the same way as in hydrostatics.


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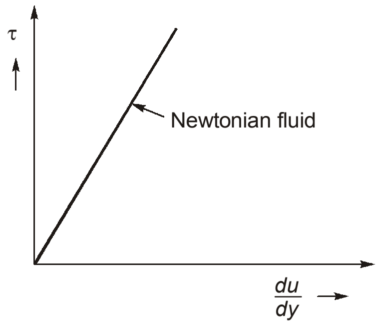
**7. (c)**




**8. (c)**

Let $h$ = difference in water levels in the two limbs

$$\Delta P = \rho g h = \left(\frac{2\sigma}{R_1} - \frac{2\sigma}{R_2}\right) \qquad [\cos\theta = 1 \text{ for } \theta = 0°]$$

$$h \times 1000 \times 10 = \frac{2\times 0.073}{3\times 10^{-3}} - \frac{2\times 0.073}{8\times 10^{-3}} = 2\times 73\left(\frac{1}{3}-\frac{1}{8}\right)$$

$$h = 3.0417 \times 10^{-3} \text{ m} = 3 \text{ mm}$$

**9. (a)**

$$dP = (13.73 - 6.87) \times 10^6 = 6.86 \times 10^6 \text{ N/m}^2$$

$$dV = (11.2 - 11.3)\,\text{L} = -0.1\,\text{L} = -0.0001 \text{ m}^3$$

$$V = 0.0113 \text{ m}^3$$

Bulk modulus of elasticity, $K = -\dfrac{dP}{\left(\dfrac{dV}{V}\right)} = \dfrac{6.86\times 10^6 \times 0.0113}{0.0001} = 7.75 \times 10^8 \text{ N/m}^2 = 0.775 \times 10^9 \text{ N/m}^2$

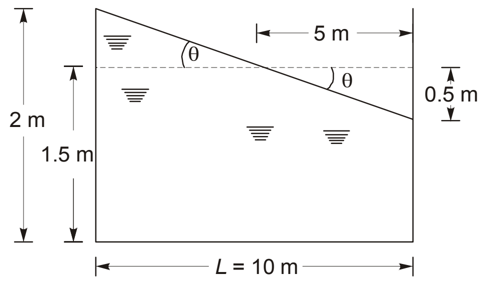
**10. (a)**

Let $t$ be the required time.

Rate of increase of velocity,

$$\alpha = \frac{20}{t} \text{m/s}^2$$

$$\tan\theta = \frac{0.5}{5} = 0.1$$



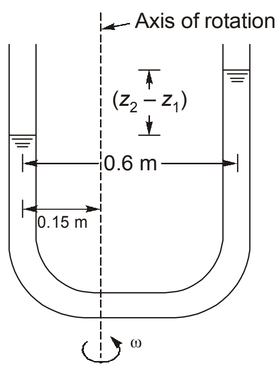

$\tan\theta$ is the maximum slope for no. spilling of water.

$$\tan\theta = \frac{\alpha}{g} = 0.1$$

$$t = \frac{20}{0.1\times 9.81} = 20.4 \text{ sec}$$

**11. (b)**

The difference in elevation of the free surfaces in the two legs is given by




$$(z_2 - z_1) = \frac{\omega^2}{2g}\left(x_2^2 - x_1^2\right)$$

where

$$x_2 = 0.6 - 0.15 = 0.45 \text{ m}$$

$$x_1 = 0.15 \text{ m}$$

$$\omega = \frac{2\pi\times 120}{60} = 4\pi \text{ rad/s}$$

$$z_2 - z_1 = \frac{16\pi^2}{2\times 9.81}\left(0.45^2 - 0.15^2\right) = 1.45 \text{ m}$$

**12.** **(c)**

Vertical force exerted by water,

$$F_y = \text{Weight of water enclosed in BDCOB}$$

$$F_y = \rho g\left(\frac{\pi R^2}{2}\right)\times l$$

$$= 9.81\times\frac{\pi}{2}\times(1.5)^2\times 4 = 138.68 \text{ kN}$$

$$\text{Vertical reaction at } B = \text{weight of cylinder} - F_y$$

$$= 196.2 - 138.68$$

$$= 57.52 \text{ kN}$$

**13.** **(c)**

$$|SA|_{\text{sphere}} = |SA|_{\text{cube}}$$

$$4\pi R^2 = 6a^2$$

$$\left(\frac{R}{a}\right)^2 = \frac{6}{4\pi} = \frac{3}{2\pi}$$

$$F_R = \frac{|\text{Sphere}|_B}{|\text{Cube}|_B} = \frac{V_s}{V_c} = \frac{4}{3}\pi R^3\times\frac{1}{a^3} = \frac{4\pi}{3}\left(\frac{R}{a}\right)^3$$

$$F_R = \frac{4\pi}{3}\left(\frac{3}{2\pi}\right)^{\frac{3}{2}} = \frac{4\pi}{3}\times\frac{3}{2\pi}\left(\frac{3}{2\pi}\right)^{0.5}$$

$$F_R = 2\sqrt{\frac{3}{2\pi}} = \sqrt{\frac{6}{\pi}}$$

**14.** **(d)**

$$\psi|_{(1,3)} = \frac{3}{2}\left(3^2-1^2\right) = 12$$

$$\psi|_{(3,3)} = \frac{3}{2}\left(3^2-3^2\right) = 0$$

$$\text{Discharge} = \psi_1 - \psi_2 = 12 - 0 = 12$$

**15.** **(c)**

As per given data:

$$u^* = \frac{u}{U} \text{ and } y^* = \frac{y}{\delta}$$

$$dy^* = \delta^{-1}\, dy$$

The given parabolic velocity distribution and the expression for the displacement thickness can then be expressed as

$$u^* = 2y^* - y^{*2}, \text{ and } \delta^* = \delta\int_0^1 (1-u^*)\,dy^*$$

Combining these equations gives,

$$\delta^* = \delta\int_0^1\left(1-2y^*+y^{*2}\right)dy^*$$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$$\delta^* = \delta\left[y^* - y^{*2} + \frac{1}{3}y^{*3}\right]_0^1$$

$$\delta^* = \frac{1}{3}\delta$$

$$\frac{\delta^*}{\delta} = \frac{1}{3}$$

**16. (a)**

Applying Bernoulli's equation between the two reservoirs, we get

$$12.5 = 0.5\frac{V^2}{2g} + \frac{fLV^2}{2gD} + \frac{V^2}{2g}$$

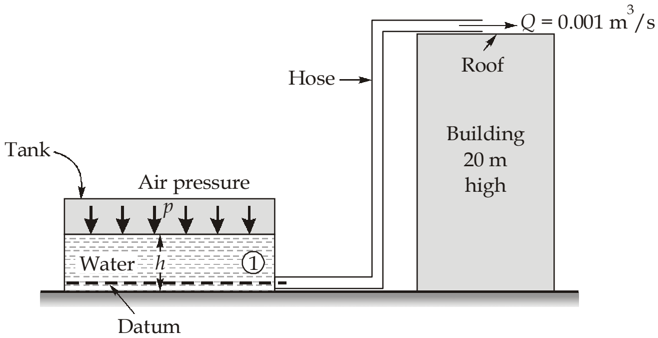
$$\Rightarrow \quad 12.5 = \frac{V^2}{2g}\left[1.5 + \frac{fL}{D}\right]$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{2\times 10}\left[1.5 + \frac{0.04\times 1000}{0.5}\right]$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{20}\times 81.5$$

$$\Rightarrow \quad V = 1.75 \text{ m/s}$$

**17. (c)**




Let '$p$' be the air pressure inside the tank.
The velocity of water in the hose,

$$V = \frac{Q}{A} = \frac{0.001}{\frac{\pi}{4}\times(0.05)^2} = 0.509 \text{ m/s}$$

Applying the Bernoulli's equation to the inlet end (1) and the output end of the hose at 15 m height above the bottom level, (Assuming the horizontal line passing through (1) as the datum).

$$\frac{p}{\gamma} + h = 20 + \frac{V^2}{2g} + 0.06$$

where, $p$ is the pressure of air in the tank, $h$ is the water depth.
Now, $h << 20$ m (given)

$$\frac{p}{\gamma} = 20 + \frac{(0.509)^2}{2\times 9.81} + 0.06 = 20.073 \text{ m of water}$$

**18. (c)**

As per given data: $Q = 2.5\,l/s = 2.5 \times 10^{-3}\ \text{m}^3/\text{s}$

$D = 45$ mm, $d = 25$ mm

$\rho = 1000$ kg/m$^3$

From continuity, $V_1 = \dfrac{Q}{\left(\dfrac{\pi D^2}{4}\right)} = 1.57\ \text{m/s}$

$$V_2 = \frac{Q}{\left(\dfrac{\pi d^2}{4}\right)} = 5.09\ \text{m/s}$$

Hence, applying Bernoulli between (1) and (2)

$$\frac{p_1}{\rho} + \frac{V_1^2}{2} = \frac{p_2}{\rho} + \frac{V_2^2}{2}$$

or, in gauge pressure, $p_{1g} = \dfrac{\rho}{2}\left(V_2^2 - V_1^2\right) = \left(\dfrac{1000}{2}\right) \times (5.09^2 - 1.57^2) = 11.721$ kPa

**19. (d)**

$$\rho_{water} = 1000\ \text{kg/m}^3.$$

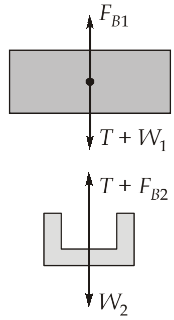
Apply the hydrostatic relation from the oil surface to the water surface, skipping the 8 cm part:

$p_{atm} + (898)(9.81)(h + 0.12) - (1000)(9.81)(0.06 + 0.12) = p_{atm}$

On solving, $h = 0.08$ m

**20. (d)**

As the given data: Free body diagram




From $\Sigma F_y$

$T = F_{B1} - W_1$

$F_{B1} = \rho g (V)_{submerged}$

$= (9.8 \times 1000)(50 \times 50 \times 7.5)(10^{-9})$

$F_{B1} = 0.18375$ N

$W_1 = \gamma$(Specific gravity of block) × Volume of block

$= (9.8 \times 1000)(0.3)(50 \times 50 \times 10)(10^{-9}) = 0.0735$ N

$T = (0.18375 - 0.0735) = 0.11025$ N

3. Force equilibrium (vertical direction) applied to metal part:

$F_{B2} = \gamma V_2 = (9800)(6600)(10^{-9})$

$= 0.06468$ N

$W_2 = T + F_{B2} = (0.1102\ \text{N}) + (0.06468\ \text{N})$

Mass of metal part, $m_2 = \dfrac{W_2}{g} = 0.01785\ \text{kg}$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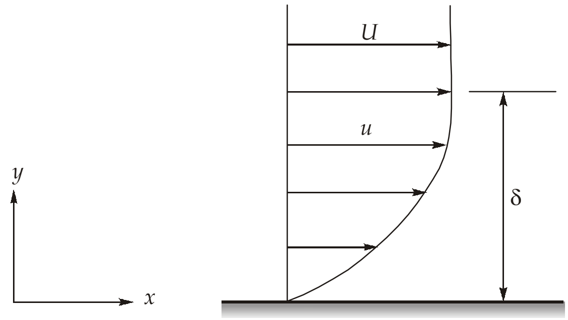
**21.** **(a)**




For the boundary layer, the following conditions apply:

$u = 0$, at $y = 0$

$u = U$, at $y = \delta$

Applying these boundary conditions:

$$u(0) = A\sin(0) + C = 0, \quad C = 0$$

$$u(\delta) = A\sin(B - \delta) = U$$

$$\frac{\partial}{\partial y}u(y) = A.B.\cos(By)$$

Thus, $$\frac{\partial}{\partial y}u(\delta) = A.B.\cos(B\delta) = 0$$

Therefore, $$B\delta = \frac{\pi}{2} \quad \text{or,} \quad B = \frac{\pi}{2\delta}$$

$$A\sin\left(\frac{\pi}{2\delta}\times\delta\right) = U$$

Therefore, $$A = U$$

**22.** **(b)**

The frontal area of a sphere is $A = \frac{\pi D^2}{4}$.

The drag force acting on the balloon is

$$F_D = C_D A\frac{\rho V^2}{2} = (0.2)\left[\frac{\pi(7)^2}{4}\right]\frac{(1.20)\left(\frac{40\times 5}{18}\right)^2}{2} = 570.14\text{ N}$$

Acceleration in the direction of the winds

$$a = \frac{F_D}{m} = \frac{570.14}{350} = 1.63\text{ m/s}^2$$

**23.** **(b)**

$$\text{Shape factor, } H = \frac{\delta^*}{\theta} = \frac{\int_0^\delta\left(1-\frac{u}{U}\right)dy}{\int_0^\delta\frac{u}{U}\left(1-\frac{u}{U}\right)dy} \quad \text{... (i)}$$

But for the limiting case under consideration, $\frac{u}{U}=1$ through out the entire boundary layer, yielding, $\delta^* = 0$ and $\theta = 0$. To calculate the ratio in equation (i), use $L'$ Hospital's rule, where the variable $u$ approaches $U$ in the limit.

$$H = \lim_{u\to U}\frac{\frac{d}{du}\int_0^\delta\left(1-\frac{u}{U}\right)dy}{\frac{d}{du}\int_0^\delta\frac{u}{U}\left(1-\frac{u}{U}\right)dy} = \lim_{u\to U}\frac{-\int_0^\delta\frac{1}{U}dy}{\int_0^\delta\left(\frac{1}{U}-2\frac{u}{U}\frac{1}{U}\right)dy} = \frac{\int_0^\delta\frac{1}{U}dy}{\int_0^\delta\frac{1}{U}dy} = 1$$

**24. (b)**

$$Re_{max} = 2000 \text{ for flow to be laminar}$$

$$2000 = \frac{VD}{\nu}$$

$$V = \frac{2000\times8\times10^{-2}}{950}\times\frac{1}{0.15} = 1.123 \text{ m/s}$$

$$\text{Head loss, } h_f = \frac{32\mu VL}{\rho g D^2}$$

$$= \frac{32\times8\times10^{-2}\times1.123\times200}{950\times9.81\times0.15^2} = 2.742 \text{ m}$$

**25. (c)**

$$(P_A)_{gauge} = \rho g h+\frac{2\sigma}{d}$$

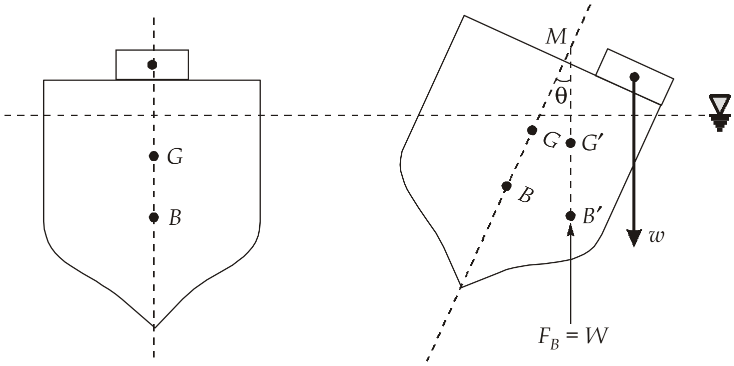
$$1000\times5.01 = 1000\times9.81\times0.51+\frac{2\times0.075}{d}$$

$$5010-5003.1 = \frac{2\times0.075}{d}$$

$$d = 21.74 \text{ mm}$$

$$\text{So radius of curvature, } r = \frac{d}{2} = 10.87 \text{ mm}$$

**26. (b)**





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My moment balance,

$$wx = W(GG')$$

$$\overline{GG} = \overline{GM}\tan\theta$$

$$\overline{GM} = \frac{wx}{W\tan\theta}$$

$$5000\times 9.81\times x\tan\left(0.025\times\frac{180}{\pi}\right) = 60 \times 9.81 \times 1.5$$

Metacentric height, $x = 0.72$ m

**27.** **(c)**

For stagnation points, velocity = 0

$$1 + 2.5x + y = 0 \quad ...(1)$$

$$-0.5 - 3x - 2.5y = 0 \quad ...(2)$$

equation (1) × 2.5 + equation (2)

$$2.5 + 6.25x + 2.5y = 0$$

$$-0.5 - 3x - 2.5y = 0$$

on adding

$$2 + 3.25x = 0$$

$$x = \frac{-2}{3.25} = -\quad 0.6154 \text{ m}$$

$$y = -1 - 2.5x$$

$$= -1 - 2.5 \times (-0.6154)$$

$$y = 0.5384 \text{ m}$$

**28.** **(a)**

$$E_A = \frac{P}{\rho g} + z + \frac{V^2}{2g}$$

Let $V_1 = 1$ m/s

$$E_A = \frac{98\times 10^3}{1000\times 10} + 0 + \frac{1^2}{2\times 10}$$

$$A_1V_1 = A_2V_2$$

$\Rightarrow$ $$V_2 = \frac{A_1}{A_2}V_1 = 4$$

$$E_B = \frac{20\times 10^3}{1000\times 10} + 2 + \frac{4^2}{20}$$

$\Rightarrow$ $$E_A = 9.8 \text{ m}$$

$$E_B = 4.8 \text{ m}$$

∴ Flow is from $A$ to $B$.

**29. (b)**

**30. (a)**

$$V_{mean} = \frac{Q}{A} = \frac{\int v dA}{A} = \frac{\int_0^R V_{max}\left(\frac{R^3 - r^3}{R^3}\right)2\pi r dr}{\pi R^2}$$

$$V_{mean} = \frac{2V_{max}}{R^5}\left[\int_0^R (rR^3 - r^4)dr\right] = \frac{2V_{max}}{R^5}\left[\frac{R^3 r^2}{2} - \frac{r^5}{5}\right]_0^R$$

$$= \frac{2V_{max}}{R^5}\left[\frac{R^5}{2} - \frac{R^5}{5}\right]$$

$$V_{mean} = \frac{3}{5}V_{max}$$

$$\alpha = \frac{\int_0^R (V_{max})^3\left(\frac{R^3 - r^3}{R^3}\right)^3 2\pi r dr}{(V_{mean})^3 \pi R^2}$$

$$= \frac{(5)^3 (V_{max})^3 \times 2\int_0^R [R^9 - 3R^6 r^3 + 3R^3 r^6 - r^9] r dr}{(3)^3 \times (V_{max})^3 R^2 \times R^9}$$

$$= \frac{2\times 125}{27}\left[\frac{R^{11}}{2} - \frac{3R^{11}}{5} + \frac{3R^{11}}{8} - \frac{R^{11}}{11}\right]$$

$$= \frac{2\times 125}{27\times R^{11}}\left[\frac{40\times 11 - 3\times 16\times 11 + 3\times 10\times 11 - 80}{80\times 11}\right]R^{11}$$

$$\alpha = \frac{2\times 125\times 162}{27\times 880} = 1.7045$$

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