CLASS TEST

Sl. : 01IGCE_ABC_22072024

MADE EASY

India's Best Institute for IES, GATE & PSUs

Delhi | Bhopal | Hyderabad | Jaipur | Pune | Kolkata

Web: www.madeeasy.in | **E-mail:** info@madeeasy.in | **Ph:** 011-45124612

FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 22/07/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

Ideal fluid has zero viscosity.

2. (b)

Let V be the volume of fluid

$$\therefore \quad dV = \frac{-6}{100} \times V$$

$$\Rightarrow \quad \frac{-dV}{V} = 0.06$$

$$\therefore \quad \text{Increase in pressure } \Delta P = \frac{-\Delta V}{V} \times K$$

$$= 1.5 \times 10^9 \times 0.06 \text{ Pa}$$

$$= 0.090 \text{ GPa}$$

3. (b)

In the distorted Froude model

$$\text{Time ratio, } T_r = \frac{L_r}{\sqrt{h_r}}$$

where L_r = horizontal length ratio,

h_r = vertical depth ratio

Time between actual high tide = 24 hours = T_p

$$\therefore \quad T_m = T_p \frac{L_r}{\sqrt{h_r}}$$

$$= 24 \times 60 \times \frac{\sqrt{100}}{150} = 96 \text{ min}$$

4. (b)

Buoyancy force acts through center of gravity of displaced liquid.

A large metacentric height in a vessel improves stability and makes time period of oscillation shorter.

5. (c)

6. (d)

For a laminar boundary layer

$$\frac{\delta}{x} = \frac{5}{\sqrt{R_{ex}}}$$

$$\Rightarrow \quad \frac{\delta}{x} = \frac{5}{\sqrt{\frac{\rho v x}{\mu}}}$$

$\therefore \qquad \delta \propto \sqrt{x}$

$$\therefore \qquad \frac{\delta_2}{\delta_1} = \sqrt{\frac{2x_1}{x_1}} \Rightarrow \delta_2 = \sqrt{2}\,\delta_1$$

7. (b)

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

8. (d)

9. (a)

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

as $\qquad \left(I_{xx} = \frac{bd^3}{12} \quad \text{and} \quad A = bd\right)$

10. (d)

11. (b)

$$\text{Total head} = \frac{p}{\rho g} + \frac{\alpha V^2}{2g} + z$$

$$\text{Pressure head} = -2 \text{ cm of mercury}$$

$$= \frac{-2 \times 13.6}{0.75} \text{ cm of oil}$$

$$= -0.363 \text{ m of oil}$$

$$\text{Velocity, } V = \frac{Q}{A} = \frac{0.07}{\frac{\pi}{4} \times 0.15^2} = 3.96 \text{ m/s}$$

$$\text{Velocity head} = \frac{\alpha V^2}{2g} = \frac{1.1 \times 3.96^2}{2 \times 9.81} = 0.879 \text{ m}$$

$$\text{Datum head, } z = 12 \text{ cm} = 0.12 \text{ m}$$

$$\text{Total head} = -0.363 + 0.879 + 0.12$$

$$= 0.636 \text{ m}$$

12. (b)

For laminar flow through circular pipe,

$$u = -\frac{1}{4\mu}\frac{\partial P}{\partial x}\left(R^2 - r^2\right)$$

$$\Rightarrow \qquad 0.75 = -\frac{1}{4\mu}\frac{\partial P}{\partial x}\left(10^2 - 5^2\right) \qquad \text{...(i)}$$

Also, $$u_{max} = -\frac{1}{4\mu}\frac{\partial P}{\partial x}\left(10^2 - 0^2\right) \qquad \text{...(ii)}$$

$$\frac{0.75}{u_{max}} = \frac{10^2 - 5^2}{10^2}$$

$$\Rightarrow \qquad u_{max} = 1.0 \text{ m/s}$$

13. (d)

14. (d)

Since air column weight is negligible, equating pressures on both sides of dotted line, one gets

$$p_A = p_B + (0.020 \times 0.8 \times 9.81)\sin 30°$$

$$\Rightarrow \quad p_A - p_B = 0.07848 \text{ kN/m}^2$$

$$= 78.48 \text{ N/m}^2 \simeq 78.5 \text{ N/m}^2$$

15. (c)

$$H \propto \frac{Q^2}{D^5} \qquad \text{(Since H is constant)}$$

$$\therefore \quad Q^2 \propto D^5$$

$$\left(\frac{Q_1}{Q_2}\right)^2 = \left(\frac{D_1}{D_2}\right)^5 \qquad (\because \; Q_2 = 2Q_1)$$

$$\left(\frac{Q_1}{2Q_1}\right) = \left(\frac{D_1}{D_2}\right)^{2.5}$$

$$0.7578 = \frac{D_1}{D_2}$$

$$\frac{D_2}{D_1} = 1.3195$$

$$\frac{A_2}{A_1} = \frac{\frac{\pi}{4} \times D_2^2}{\frac{\pi}{4} D_1^2} = (1.3195)^2 = 1.7411$$

$$\therefore \quad A_2 = 1.7411 A_1$$

$\therefore$ Increase in cross-sectional area

$$= \frac{A_2 - A_1}{A_1} \times 100$$

$$= \frac{1.7411 A_1 - A_1}{A_1} \times 100 = 74.11\%$$

16. (c)

Velocity, V = 3 m/s

Kinematic viscosity, ν = 0.9 centistokes = 0.9×10^{-6} m²/s

$$\text{Reynolds number, } Re = \frac{Vd}{\nu} = \frac{3 \times 0.5}{0.9 \times 10^{-6}} = 1.67 \times 10^6$$

Since Re > 4000,

$\therefore$ Flow is turbulent

$$\therefore \quad \frac{1}{\sqrt{f}} = 2\log_{10}\frac{r_0}{k_s} + 1.74$$

$$\Rightarrow \quad \frac{1}{\sqrt{f}} = 2\log_{10}\frac{0.25}{0.25 \times 10^{-3}} + 1.74$$

$$\Rightarrow \quad \frac{1}{\sqrt{f}} = 7.74$$

$$\Rightarrow \quad f = 0.0167$$

$$\therefore \quad h_L = \frac{fLV^2}{2gd} = \frac{0.0167 \times 300 \times (3)^2}{2 \times 9.81 \times 0.5} = 4.596 \text{ m} \simeq 4.6 \text{ m}$$

17. (a)

For 90° V - notch

$$Q = \frac{8}{15} C_d \sqrt{2g} H^{5/2}$$

$$\frac{Q_2}{Q_1} = \left(\frac{H_2}{H_1}\right)^{5/2} = \left(\frac{0.3}{0.15}\right)^{5/2}$$

$$= 5.65$$

18. (c)

The velocity, v = 65 m/s at $y = 1$ and $v = 0$ at $y = 0$

$\therefore \quad V = 65y$ (Linear variation)

Using $v = \dfrac{\partial \psi}{\partial y}$

$$\frac{\partial \psi}{\partial y} = 65y$$

$$\psi = 32.5\, y^2$$

19. (a)

$$V = C_v \sqrt{2g\left(\rho_{stag} - \rho_{static}\right)}$$

$$= 0.98\sqrt{2 \times 9.81 \times (3 - 0.5)} = 6.86 \text{ m/s}$$

20. (d)

At point (1, –2, 1)

$$u = 2x^2 + 3y = 2 - 6 = -4$$

$$v = -2xy + 3y^3 + 3yz = 4 - 24 - 6 = -26$$

$$w = -\frac{3z^2}{2} - 2xz + 9y^2 z = -1.5 - 2 + 36 = 32.5$$

$$\left|\vec{V}\right| = \sqrt{u^2 + v^2 + w^2}$$

$$= \sqrt{(-4)^2 + (-26)^2 + (32.5)^2} = 41.8 \text{ units}$$

21. (b)

$$\text{Reynold's number, } Re = \frac{\rho VD}{\mu} = \frac{1260 \times 10 \times 15}{1.5 \times 100} = 1260$$

As Re < 2000, ∴ Flow is laminar

$$\tau_0 = \frac{8\mu V}{D}$$

$$= \frac{8 \times 1.5 \times 10}{0.15} = 800 \text{ Pa}$$

22. (a)

We know that, $u = -\frac{\partial\psi}{\partial y}$ and $v = \frac{\partial\psi}{\partial x}$

$$u = -\frac{\partial\left(3\sqrt{2}xy\right)}{\partial y} = -3\sqrt{2}x$$

$$v = \frac{\partial\left(3\sqrt{2}xy\right)}{\partial x} = 3\sqrt{2}y$$

Given, $\sqrt{u^2 + v^2} = 6$

$$\sqrt{\left(-3\sqrt{2}x\right)^2 + \left(3\sqrt{2}y\right)^2} = 6$$

$$\sqrt{18x^2 + 18y^2} = 6 \quad \text{...(i)}$$

Given, $\theta = 135°$

And we know, slope of stream function i.e.

$$\tan\theta = \frac{v}{u}$$

$$\tan(135°) = \frac{v}{u}$$

$$-1 = \frac{3\sqrt{2}y}{-3\sqrt{2}x}$$

$$x = y \quad \text{...(ii)}$$

By putting equation (ii) in equation (i),

$$\sqrt{18x^2 + 18\left(x^2\right)} = 6$$

$$\sqrt{36x^2} = 6$$

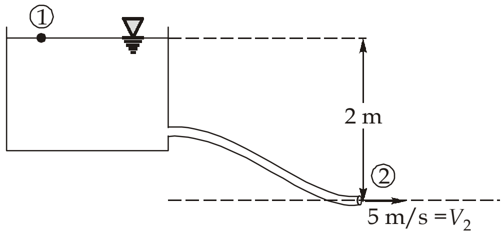
$$6x = 6$$

$$x = 1$$

By equation (ii), $y = 1$

So, point is (1, 1).

23. (b)



Applying Bernaulli's equation between (1) and (2),

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1 = \frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2+h_f$$

Here, $V_1 \simeq 0$

$P_1 = P_2 = 0$ (Gauge Pressure)

$z_1 = 2$ m (given)

$$2 = \frac{5^2}{2g}+h_f$$

$$2 = \frac{25}{2\times 10}+h_f$$

$$h_f = 0.75 \text{ m}$$

From Darcy-Weisbach equation,

$$h_f = \frac{fLV^2}{2gd}$$

$$\Rightarrow \quad 0.75 = \frac{0.01\times L\times 5^2}{2\times 10\times 0.05}$$

$$L = 3 \text{ m}$$

24. (c)

$$\text{Ratio} = \frac{\alpha_{\text{Round pipe}}}{\alpha_{\text{Parallel plates}}} = \frac{2}{1.543} = 1.3$$

25. (c)

Weight of block = 25 kg

Block dimensions = 30 × 30 × 30 cm^3

Driving force along the plane,

$$F = W \sin 30°$$
$$= 30 \times 9.81 \times 0.5$$
$$= 147.15 \text{ N}$$

$$\text{Shear force, } \tau = \frac{F}{A} = \frac{147.15}{(0.3)^2} = 1635 \text{ N/m}^2$$

Contact area, $A = 0.3 \times 0.3 \text{ m}^2$

Also, $$\tau = \mu\frac{dv}{dy}$$

$$\Rightarrow \quad 1635 = 2\times10^{-3}\times\frac{V}{0.025\times10^{-3}}$$

$$\Rightarrow \quad V = \frac{1635\times0.025}{2} = 817.5\times0.25 = 20.44 \text{ m/s}$$

26. (b)

Let x be the distance from the leading edge such that the drag force in distance x is one-third of the total drag force.

$$F_{Dx} = \frac{1}{3}F_{DL}$$

Now, $$F_{Dx} = C_{Dfx}(Bx)\left(\frac{\rho U^2}{2}\right)$$

Also, $$F_{DL} = C_{DfL}(BL)\left(\frac{\rho U^2}{2}\right)$$

$$\therefore \quad \frac{C_{Dfx}}{C_{DfL}}\cdot\frac{x}{L} = \frac{F_{Dx}}{F_{DL}} = \frac{1}{3}$$

But from $$C_{Dfx} = \frac{1.328}{\sqrt{Ux/V}}$$

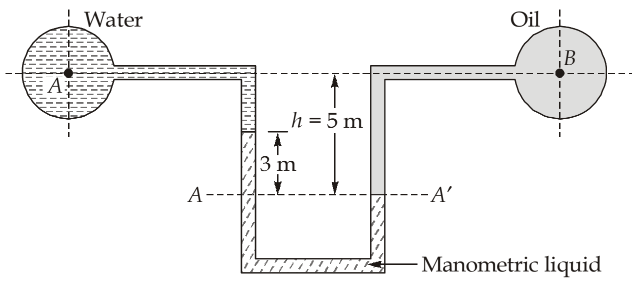
$$C_{DfL} = \frac{1.328}{\sqrt{UL/V}}$$

$$\therefore \quad \left(\frac{L}{x}\right)^{1/2}\frac{x}{L} = \frac{1}{3}$$

$$\Rightarrow \quad \left(\frac{x}{L}\right)^{1/2} = \frac{1}{3}$$

$$\Rightarrow \quad x = \frac{L}{9}$$

27. (a)



Height difference = 3 m

Specific gravity of oil = 0.9

Specific gravity of manometric liquid = 1.5

Equating pressure head at section (A-A′) which is located 5 m below the centerline of pipes.

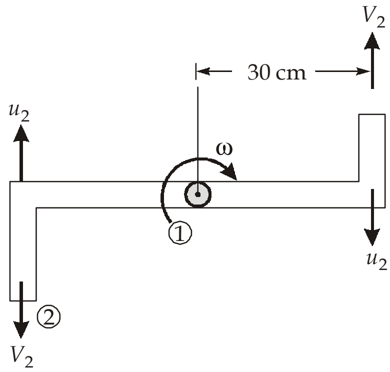
$$p_A + 3\times1.5\,\rho_w g + (5-3)\rho_w g = p_B + 5\times0.9\times\rho_w g$$

$$\Rightarrow \quad p_A - p_B = 2.5\rho_w g - 4.5\rho_w g = -2\rho_w g$$

$$\Rightarrow \quad p_A - p_B = -2\times1000\times9.81 = -19620 \text{ N/m}^2$$

$$\Rightarrow \quad p_A - p_B = -19.62 \text{ kN/m}^2$$

28. (a)



Let ω be angular velocity

$$\therefore \quad u_2 = \omega r$$

Given $\quad a = 0.8 \text{ cm}^2$

$$Q = 3.2\ l/\text{s} = 3200 \text{ cm}^3/\text{s}$$

$$\therefore \quad V_2 = \frac{3200}{2 \times 0.8} = 2000 \text{ cm/s}$$

$$= 20 \text{ m/s} = \text{relative velocity of jet}$$

$$\text{Torque, } T = -\rho Q r(u_2 - V_2) = 0$$

$$\Rightarrow \quad u_2 = V_2$$

$$\therefore \quad w = \frac{u_2}{r} = \frac{V_2}{r} = \frac{20}{0.3} = 66.67 \text{ radian/s}$$

29. (c)

For valid potential function, Laplace equation should be satisfied i.e. $\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0$

$$\frac{\partial^2 \phi}{\partial x^2} = -12y^2, \quad \frac{\partial^2 \phi}{\partial y^2} = 12(y^2 - x^2)$$

Since $\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} \neq 0$, so given function is not valid since Laplace equation is based on continuity.

For irrational flow $\frac{\partial^2 \phi}{\partial x \partial y} - \frac{\partial^2 \phi}{\partial y \partial x} = -24xy - (-24xy) = 0$.

So, irrationality condition is satisfied but not the continuity equation.

30. (b)

■■■■