CLASS TEST

Sl. : 03SKCE_MKNL_14092024

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 14/09/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. **(c)**

2. **(d)**

3. **(c)**

According to Buckingham's π theorem,

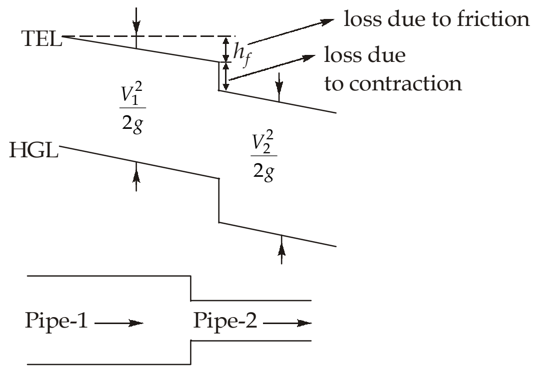
$$\pi \text{ terms} = n - m$$

$$\phi\,[\pi_1, \pi_2, \ldots\ldots] = 0$$

So, no. of independent non-dimensional groups = π terms.

4. **(c)**

5. **(b)**



- As pipe contracts, pressure decreases and velocity increases.
- HGL is always lower and parallel to TEL.

6. **(d)**

7. **(b)**

We know that Kinetic energy correction factor for laminar flow between stationary plates is 1.54 and for laminar flow through pipe is 2.0 .

$$\text{Ratio} = \frac{1.54}{2} = 0.77$$

8. **(b)**

For circular cylindrical jet of liquid,

$$\Delta P = \frac{\sigma}{R}$$

$$\Rightarrow \qquad R = \frac{\sigma}{\Delta P} = \frac{73\times10^{-3}}{40}$$

$$= 1.825 \times 10^{-3} \text{ m} = 1.825 \text{ mm}$$

$$\therefore \qquad \text{Diameter} = 2R = 1.825 \times 2 = 3.65 \text{ mm}$$

9. (a)

10. (b)

Since it is a homogeneous equation so the dimensions of all the terms should be same.

Hence, dimension of P = dimension of C

Dimension of pressure, $P = \dfrac{\text{Force}}{\text{Area}}$

$$= \frac{\text{N}}{\text{m}^2} = \frac{\text{MLT}^{-2}}{\text{L}^2}$$

$$= \frac{\text{M}}{\text{LT}^{+2}}$$

$\therefore$ Dimension of C = $\text{ML}^{-1}\ \text{T}^{-2}$

11. (a)

From the given velocity field,

$$u = \lambda xy^3 - x^2y$$

$$v = xy^2 - \frac{3}{4}y^4$$

For possible, steady and incompressible flow, continuity equation should be satisfied

$$\therefore \quad \left(\frac{\partial u}{\partial x}\right) + \left(\frac{\partial v}{\partial y}\right) + \left(\frac{\partial w}{\partial z}\right) = 0$$

$$\Rightarrow \quad \left(\lambda y^3 - 2xy\right) + 2xy - 3y^3 + 0 = 0$$

$$\Rightarrow \quad y^3(\lambda - 3) = 0$$

$$\therefore \quad \lambda = 3$$

12. (a)

Consider an annular ring with thickness dr at radius r. Velocity variation in the gap is given as linear.

Hence the velocity at radius r from centre = $v = wr$

$\therefore$ Shear stress on the ring,

$$\tau = \mu\frac{du}{dy} = \mu\left(\frac{wr}{h}\right)$$

Force on the ring, $dF = \tau \times dA$

$$= \left(\frac{\mu wr}{h}\right) \times 2\pi r dr = \left(\frac{2\pi\mu w}{h}\right) r^2 dr$$

Torque on the ring, $dT = F \times r$

$$= r\tau dA$$

$$= \left(\frac{2\pi\mu w}{h}\right) r^2 \cdot r dr$$

$$= \left(\frac{2\pi\mu w}{h}\right) r^3 dr$$

$$\therefore \quad \text{Total torque on disc} = \int_0^R dT = \frac{2\pi\mu w}{h}\int_0^R r^3 dr$$

$$\Rightarrow \quad T = \frac{2\pi\mu w}{h}\left[\frac{r^4}{4}\right]_0^R$$

$$= \frac{\pi\mu w R^4}{2h}$$

13. (d)

Given, $\theta = 60°$

Distance, $$AC = \frac{h}{\sin 60°} = \frac{2h}{\sqrt{3}}$$

The gate will start tipping about hinge B if the resultant pressure force acts at B. If the resultant pressure force passes through a point which is lying from B to C anywhere on the gate, the gate will tip over the hinge. Hence for the given position, point B becomes the centre of pressure.

Depth of centre of pressure,

$$h^* = (h - 3)\text{ m} \quad \ldots\text{(i)}$$

But h^* is also given by, $$h^* = \frac{I_G \sin^2\theta}{A\bar{h}} + \bar{h}$$

Taking width of gate unity, then

Area, $$A = AC \times 1 = \frac{2h}{\sqrt{3}} \times 1;\ \bar{h} = \frac{h}{2}$$

$$I_G = \frac{bd^3}{12} = \frac{1 \times AC^3}{12} = \frac{1 \times \left(\frac{2h}{\sqrt{3}}\right)^3}{12}$$

$$= \frac{8h^3}{12 \times 3 \times \sqrt{3}} = \frac{2h^3}{9 \times \sqrt{3}}$$

$$h^* = \frac{2h^3}{9\sqrt{3}} \times \frac{\sin^2 60}{\frac{2h}{\sqrt{3}} \times \frac{h}{2}} + \frac{h}{2}$$

$$\Rightarrow \quad h^* = \frac{2h^3 \times \frac{3}{4}}{9h^2} + \frac{h}{2} = \frac{2h}{3} \quad \ldots\text{(ii)}$$

From (i) and (ii)

$$h - 3 = \frac{2h}{3}$$

$$\Rightarrow \quad h = 9\text{ m}$$

$\therefore$ Height of water required for tipping the gate = 9 m

14. (b)

Reynolds number upto which laminar boundary exists = 2×10^5

Kinematic viscosity for air

$$\nu = 0.15\text{ stokes} = 0.15 \times 10^{-4}\text{ m}^2/\text{s}$$

Reynold's number, $\text{Re} = \frac{\rho V x}{\mu} = \frac{V x}{\nu}$

If $\text{Re}_x = 2 \times 10^5$, then x denotes the distance from the leading edge upto which laminar boundary layer exists

$$\therefore \quad 2 \times 10^5 = \frac{10 \times x}{0.15 \times 10^{-4}}$$

$$\Rightarrow \quad x = 0.30 \text{ m} = 300 \text{ mm}$$

For thickness of laminar boundary layer,

$$\frac{\delta}{x} = \frac{5}{\sqrt{\text{Re}_x}}$$

$$\Rightarrow \quad \delta = \frac{5 \times x}{\sqrt{\text{Re}_x}} = \frac{5 \times 0.30}{\sqrt{2 \times 10^5}}$$

$$= 3.354 \times 10^{-3} \text{ m} = 3.354 \text{ mm}$$

15. (b)

Local velocity at a point = Average velocity

$$u = \bar{U}$$

For a smooth or rough pipe,

$$\frac{u - \bar{U}}{V_*} = 5.75 \log\left(\frac{y}{R}\right) + 3.75$$

$$\frac{\bar{U} - \bar{U}}{V_*} = 5.75 \log\left(\frac{y}{R}\right) + 3.75$$

$$\log\left(\frac{y}{R}\right) = -\frac{3.75}{5.75} = -0.6521$$

$$\frac{y}{R} = 10^{-0.6521} = 0.2228$$

$$y = 0.223\, R$$

16. (a)

$$dQ = |d\psi| = |\psi_2 - \psi_1|$$

At (1, 1); $\quad \psi_1 = 3 \times 1^2 \times 1 - 1^3 = 2$ units

At $(\sqrt{3}, 1)$; $\quad \psi_2 = 3 \times (\sqrt{3})^2 \times 1 - 1^3 = 8$ units

So, $\quad dQ = |8 - 2|$

$$= 6 \text{ units}$$

17. (d)

Given: $D_1 = 200$ mm, $D_2 = 400$ mm

Velocity in smaller diameter pipe,

$$V_1 = \frac{Q}{A_1} = \frac{0.250 \text{ m}^3/\text{s}}{\frac{\pi}{4} \times (0.2)^2} = 7.96 \text{ m/s}$$

Velocity in larger diameter pipe,

$$V_2 = \frac{Q}{A_2} = \frac{0.250\ \text{m}^3/\text{s}}{\frac{\pi}{4}\times(0.4)^2} = 1.99\ \text{m/s}$$

Loss of head due to sudden enlargement is given by,

$$h_L = \frac{(V_1 - V_2)^2}{2g} = \frac{(7.96-1.99)^2}{2g} = 1.817\ \text{m of water}$$

18. **(b)**

Pipe flow is a case of application of Reynold's model law and Weber model law is applicable in capillary rise in narrow passages.

19. **(c)**

When $\frac{dh}{dx} > 0,$ it means that depth of water increases in the direction of flow. The profile of water so obtained is called back water curve.

When $\frac{dh}{dx} < 0,$ it means that the depth of water decrease in the direction of flow. The profile of the water so obtained is called drop down curve.

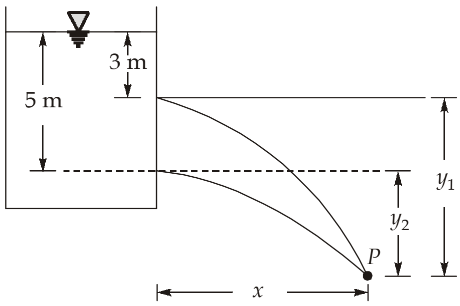
20. **(a)**

Let P is the point of intersection of the two jets coming from orifice (1) and (2), such that

x = Horizontal distance of P

y_1 = Vertical distance of P from orifice (1)

y = Vertical distance of P from orifice (2)



Then, $y_1 = y_2 + (5 - 3) = (y_2 + 2)$ m ...(1)

The equation of C_V is given by

For orifice (1), $$C_{V_1} = \frac{x}{\sqrt{4y_1H_1}} = \frac{x}{\sqrt{4y_1\times 3}}$$

For orifice (2), $$C_{V_2} = \frac{x}{\sqrt{4y_2H_2}} = \frac{x}{\sqrt{4\times y_2\times 5}}$$

Since, $$C_{V_1} = C_{V_2}$$

Hence, $$\frac{x}{\sqrt{4y_1\times 3}} = \frac{x}{\sqrt{4y_2\times 5}}$$

$\Rightarrow$ $3y_1 = 5y_2$ ...(2)

From (1) and (2),

$$y_2 = 3.0 \text{ m}$$

So, $$C_{V_2} = \frac{x}{\sqrt{4y_2 \times 5}}$$

$\Rightarrow$ $$x = 0.96 \times \sqrt{4 \times 3 \times 5}$$
$$= 7.436 \text{ m}$$

21. **(a)**

In Venturimeter,

Rate of flow, $$Q = \frac{C_d A_1 A_2}{\sqrt{A_1^2 - A_2^2}}\sqrt{2gh}$$

Here, $$h = 20\left(\frac{\rho_{Hg}}{\rho_w} - 1\right) = 20\left(\frac{13.6 \times 10^3}{10^3} - 1\right) = 20(13.6 - 1) = 252 \text{ cm}$$

$\therefore$ $$Q = \frac{0.98 \times \frac{\pi}{4} \times 30^2 \times \frac{\pi}{4} \times 15^2}{\sqrt{\left[\frac{\pi}{4} \times 30^2\right]^2 - \left[\frac{\pi}{4} \times 15^2\right]^2}} \times \sqrt{2 \times 981 \times 252}$$

$$= \frac{0.98 \times 30^2 \times \frac{\pi}{4} \times 15^2}{\sqrt{30^4 - 15^4}} \times \sqrt{2 \times 981 \times 252} = 125.76\ lps$$

22. **(c)**

Given, D = 50 mm = 0.05 m

L = 1.0 m

Projected area, $A = L \times D = 1 \times 0.05 = 0.05 \text{ m}^2$

Velocity of air, U = 0.1 m/s

Total drag is given by, $$F_{DT} = C_{DT} \times A \times \frac{\rho U^2}{2}$$

Shear drag is given by, $$F_{DS} = C_{DS} \times A \times \frac{\rho U^2}{2}$$

Hence, Pressure drag = Total drag – Shear drag

$$= C_{DT} \times A \times \frac{\rho U^2}{2} - C_{DS} \times A \times \frac{\rho U^2}{2}$$

$$= (C_{DT} - C_{DS}) \times A \times \frac{\rho U^2}{2}$$

$$= (1.5 - 0.2) \times 0.05 \times 1.25 \times \frac{(0.1)^2}{2}$$

Pressure drag = 4.0625×10^{-4} N = 0.406 kN $\simeq$ 0.41 kN

23. **(d)**

1 and 3 are correct

A submerged body becomes unstable if the centre of gravity is above the centre of buoyancy.

While a floating body may remain stable even if centre of gravity is above the centre of buoyancy so statement 2 is wrong.

For a submerged body if the centre of gravity coincides with the centre of buoyancy, the equilibrium is said to be neutral stability so statement 4 is wrong.

24. (a)

Since for flow of fluids through pipes only viscous and inertia forces predominant, Reynolds model law is the criterion for similarity. Thus

$$\left(\frac{Vd}{\upsilon}\right)_m = \left(\frac{Vd}{\upsilon}\right)_p$$

By substitution, we get

$$\frac{4\times 150\times 10^{-3}}{1.145\times 10^{-6}} = \frac{V\times 75\times 10^{-3}}{3.0\times 10^{-6}}$$

$$\therefore \quad V = 20.96 \text{ m/s}$$

25. (c)

Given,
$$K = 2500\text{MPa}$$
$$\rho_{surface} = 1250 \text{ kg/m}^3$$

We know that,
$$K = \frac{-dP}{\frac{dV}{V}} = \frac{dP}{\frac{d\rho}{\rho_{surface}}}$$

Here,
$$dP = 80 - 0 = 80\text{MPa}$$
$$d\rho = \rho_{surface}\cdot\frac{dP}{K}$$
$$d\rho = 1250\times\frac{80}{2500}$$
$$d\rho = \frac{80}{2} = 40\text{MPa}$$
$$\rho_{final} - \rho_{surface} = 40$$
$$\rho_{final} = (40 + 1250)\text{ kg/m}^3 = 1290 \text{ kg/m}^3$$

26. (a)

We know that,
$$u = -\frac{\partial\psi}{\partial y} \text{ and } v = \frac{\partial\psi}{\partial x}$$
$$u = -\frac{\partial\left(3\sqrt{2}xy\right)}{\partial y} = -3\sqrt{2}x$$
$$V = \frac{\partial\left(3\sqrt{2}xy\right)}{\partial x} = 3\sqrt{2}y$$

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 equatio (i),

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

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

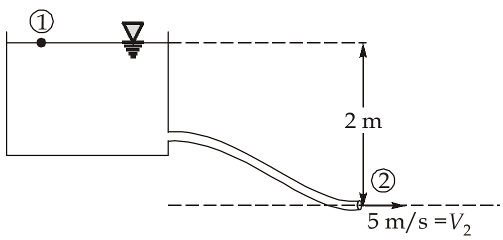
$$6x = 6$$

$$x = 1$$

By equation (ii), $y = 1$

So, point is (1, 1).

27. (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)

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

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

From Darcy-Weisbach equation,

$$h_f = \frac{f\,LV_2}{2gd}$$

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

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

28. (a)

Given

$$\tau_{wall} = 0.3\text{kPa}$$

$$\mu = 9 \text{ Poise} = 0.9 \text{ Pa-s}$$

$$R = 15 \text{ cm} = 0.15 \text{ m}$$

We know that,

$$\tau_{wall} = \frac{R}{2}\left(\frac{\partial P}{\partial x}\right)$$

$$0.3 \times 10^3 \text{ Pa} = \frac{0.15 \text{ m}}{2}\left(\frac{\partial P}{\partial x}\right)$$

$$\left(\frac{\partial P}{\partial x}\right) = 4 \text{ kPa/m}$$

For laminar flow in pipe,

$$u_{max} = \frac{1}{4\mu}\left(\frac{\partial P}{\partial x}\right)\left(R^2\right)$$

$$u_{max} = \frac{1}{4 \times 0.9 \text{ Pa-s}} \times \left(4 \times 10^3 \text{Pa/m}\right) \times (0.15)^2 \text{ m}^2$$

$$u_{max} = 25 \text{ m/s}$$

We know,

$$u_{mean} = \frac{u_{max}}{2} \qquad \text{(For laminar flow in pipe)}$$

$$u_{mean} = 12.5 \text{ m/s}$$

29. (b)

- Cavitation can be prevented by reducing the velocity head as pressure head increases.
- When the flow contracts, it becomes rotational due to Eddie formation and pressure decreased after contraction instead of increase.

30. (d)

- Venturimeter alignment doesn't affect the dischargement measurement.
- Flow nozzle is used for discharge measurement.
- Coefficient of velocity for an orifice is $C_v = \dfrac{X}{2\sqrt{y.H}}$
- Pitot static tube measures dynamic pressure.

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