CLASS TEST

S.No. : 03IGCE-A+C-200823

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 20/08/2023

ANSWER KEY

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

Detailed Explanations

2. (d)

Streamline: A streamline is a curve such that at every point of it tangent gives the instantaneous local velocity vector.

A streamline indicates the direction of velocity of a number of particles at the same instant.

Pathline: Actual path travelled by any individual fluid particle over some time period is called path line.

Streakline: Locus of fluid particles that have passed sequentially through a prescribed point in the flow.

3. (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 = $\text{ML}^{-1}\ \text{T}^{-2}$

4. (d)

In steady uniform flow

Shear friction velocity, $V_* = \sqrt{\dfrac{\tau_0}{\rho}}$ ...(i)

Also, $V_* = \sqrt{\dfrac{f}{8}} \times V_{avg}$ ...(ii)

From eq. (i) and (ii)

$$\sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{f}{8}} \times V_{avg}$$

Squaring both sides, $\dfrac{\tau_0}{\rho} = \dfrac{f}{8} \times V_{avg}^2$

$$\Rightarrow \quad \tau_0 = \frac{0.024}{8} \times 2 \times 2 \times 1000$$

$$= 12\ \text{N/m}^2$$

5. (d)

Given: D_1 = 200 mm, D_2 = 400 mm

Velocity in smaller diameter portion of pipe,

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

Velocity in larger diameter portion of pipe,

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

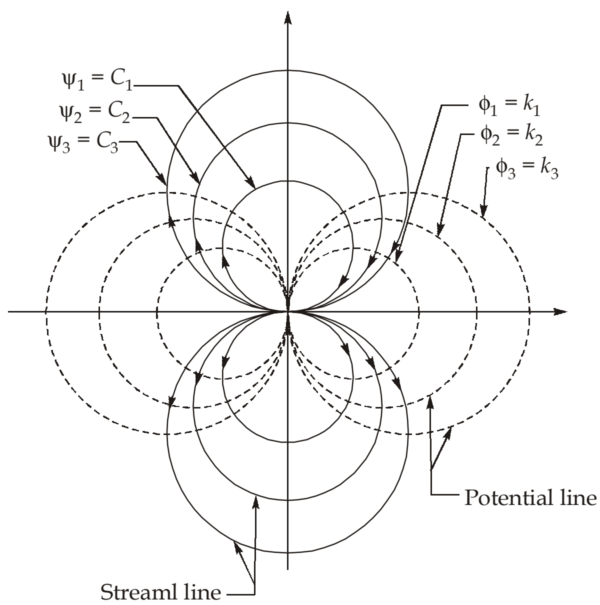
Loss of head due to sudden enlargement is given by,

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

6. (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.

8. (a)



11. (a)

Given, ρ = 981 kg/m^3

and τ = 0.2452 N/m^2

Velocity gradient, $\frac{du}{dy}$ = 0.2 s^{-1}

Now, using the equation

$$\tau = \mu \frac{du}{dy}$$

$$\Rightarrow \quad 0.2452 = \mu \times 0.2$$

$$\Rightarrow \quad \mu = \frac{0.2452}{0.2} = 1.226 \text{ Ns/m}^2$$

Kinematic viscosity is given by

$$\nu = \frac{\mu}{\rho} = \frac{1.226}{981} = 0.125 \times 10^{-2} \text{ m}^2/\text{sec}$$

$$= 12.5 \text{ cm}^2/\text{sec}$$

$$= 12.5 \text{ stokes}$$

12. (c)

Weight of pontoon = Displacement

$$W = 15000 \text{ kN}$$

Movable weight, $w = 375$ kN

The metacentric height, GM is given by

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

$$\Rightarrow \quad 2.2 = \frac{375 \times x}{15000 \times \tan 30°}$$

$$\Rightarrow \quad x = \frac{15000 \times 2.2 \times \tan 30°}{375}$$

$$\Rightarrow \quad x = 50.8 \text{ m}$$

13. (d)

Given, $u = 2y^2, \quad v = 3x, \quad w = 0$

Convective acceleration is given by,

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$

where,

$$a_x = \frac{u\partial u}{\partial x} + \frac{v\partial u}{\partial y} + \frac{w\partial u}{\partial z}$$

$$= 2y^2(0) + 3x(4y) + 0$$

$$= 12xy$$

$$a_y = \frac{u\partial v}{\partial x} + \frac{v\partial v}{\partial y} + \frac{w\partial v}{\partial z}$$

$$= 2y^2(3) + 3x(0) + 0$$

$$= 6y^2$$

$$\therefore \quad a_{(1,2,\ 0)} = (12 \times 1 \times 2)i + \left(6 \times 2^2\right)\hat{j}$$

$$\Rightarrow \quad a = 24\hat{i} + 24\hat{j}$$

14. (a)

For laminar flow in pipe,

Head loss, $h_L = \dfrac{32\mu VL}{\gamma d^2}$

$\Rightarrow \quad \dfrac{VL}{d^2} = \text{Constant} = k \qquad [\because h_L \text{ is constant}]$

$\Rightarrow \quad V \propto \dfrac{d^2}{L}$

$\Rightarrow \quad V = \dfrac{kd^2}{L}$

Now the diameter is doubled and length is halved.

Now, $Q = AV$

$\Rightarrow \quad Q = \dfrac{\pi}{4}d^2\left(\dfrac{kd^2}{L}\right) = \dfrac{\pi}{4}\dfrac{kd^4}{L}$

Let, $Q_1 = \left(\dfrac{\pi}{4}k\right)\dfrac{d_1^4}{L_1}$

and $Q_2 = \left(\dfrac{\pi}{4}k\right)\dfrac{d_2^4}{L_2} = \dfrac{\pi k}{4}\dfrac{(2d_1)^4}{(L_1/2)} \qquad [\because d_2 = 2d_1 \text{ and } L_2 = L_1/2]$

$= \left(\dfrac{\pi k}{4}\right)\dfrac{d_1^4}{L_1} \times 32 = 32Q_1$

15. (a)

$P_A + \rho_w g\,(0.7) = \rho_{Hg} g\,(0.61)$

$\Rightarrow \quad P_A = 13.6 \times 10^3 \times 9.81 \times 0.61 - 10^3 \times 4.81 \times 0.7$

$= 74516.76 \text{ Pa}$

$\therefore \quad \dfrac{P_A}{\rho_w g} = \dfrac{74516.76}{1000 \times 9.81} = 7.596 \text{ m of } H_2O \simeq 7.6 \text{ m of } H_2O$

16. (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, $Re = \dfrac{\rho Vx}{\mu} = \dfrac{Vx}{\nu}$

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

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

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

For thickness of laminar boundary layer,

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

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

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

17. (b)

For the free vortex motion,

$$V \times r = \text{Constant}$$

Hence, $V_1 r_1 = V_2 r_2$

$$\Rightarrow \quad V_2 = \frac{V_1 r_1}{r_2} = \frac{10 \times 0.2}{0.4} = 5 \text{ m/s}$$

Using Bernoulli's equation,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\Rightarrow \frac{117.72 \times 10^3}{1.24 \times 9.810} + \frac{10^2}{2 \times 9.81} + 0.1 = \frac{P_2}{\rho g} + \frac{5^2}{2 \times 9.81} + 0.2$$

$$\Rightarrow \quad \frac{P_2}{\rho g} = 9677.42 + 5.097 + 0.1 - 1.274 - 0.2 = 9681.14 \text{ m}$$

$$\Rightarrow \quad P_2 = 9681.14 \times 1.24 \times 9.81$$

$$= 117.8 \times 10^3 \text{ N/m}^2 = 117.8 \text{ kN/m}^2$$

18. (b)

Shear stress at wall, $\tau = -\frac{r}{2}\frac{\partial P}{\partial x} = -\frac{D}{4}\left(\frac{\partial P}{\partial x}\right)$

$$\Rightarrow \quad 196.2 = -\frac{0.1}{4} \times \frac{\partial P}{\partial x}$$

$$\Rightarrow \quad \frac{\partial P}{\partial x} = -7848 \text{ N/m}^2\text{/m}$$

Average velocity, $\bar{u} = \frac{1}{8\mu} \times \left(-\frac{\partial P}{\partial x}\right) \times r^2$

$$= \frac{1}{8 \times 0.7} \times 7848 \times 0.05^2 = 3.5 \text{ m/s}$$

Reynold's number, $\text{Re} = \frac{\rho V D}{\mu} = \frac{1.3 \times 1000 \times 3.5 \times 0.1}{0.7} = 650$

19. (d)

Momentum thickness, θ is given by

$$\theta = \int_0^\delta \frac{u}{U}\left(1-\frac{u}{U}\right)dy$$

$$\Rightarrow \quad \theta = \int_0^\delta \left\{\left(\frac{2y}{\delta}\right)-\frac{y^2}{\delta^2}\right\}\left\{1-\frac{2y}{\delta}+\frac{y^2}{\delta^2}\right\}dy$$

$$= \int_0^\delta \left[\frac{2y}{\delta}-\frac{4y^2}{\delta^2}+\frac{2y^3}{\delta^3}-\frac{y^2}{\delta^2}+\frac{2y^3}{\delta^3}-\frac{y^4}{\delta^4}\right]dy$$

$$= \int_0^\delta \left[\frac{2y}{\delta}-\frac{5y^2}{\delta^2}+\frac{4y^3}{\delta^3}-\frac{y^4}{\delta^4}\right]dy$$

$$= \left[\frac{2y^2}{2\delta}-\frac{5y^3}{3\delta^2}+\frac{4y^4}{4\delta^3}-\frac{y^5}{5\delta^4}\right]_0^\delta$$

$$= \left[\delta-\frac{5\delta}{3}+\delta-\frac{\delta}{5}\right]=\frac{2\delta}{15}$$

20. (a)

Difference in pressure head,

$$h = 2.5 \text{ m of water}$$

The discharge through venturimeter is,

$$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2-a_2^2}}\times\sqrt{2gh}$$

$$\Rightarrow \quad Q = \frac{0.97\times 706.858\times 10^{-4}\times 176.715\times 10^{-4}\times\sqrt{2\times 9.81\times 2.5}}{\sqrt{\left(706.858\times 10^{-4}\right)^2-\left(176.715\times 10^{-4}\right)^2}}$$

$$\Rightarrow \quad Q = 0.124 \text{ m}^3/\text{sec}$$

21. (d)

For maximum power transmission,

$$h_f = \frac{H}{3}=\frac{500}{3}=166.7 \text{ m}$$

Now, $$h_f = \frac{fLV^2}{d\times 2g}=\frac{0.06\times 3500\times V^2}{0.3\times 2\times 9.81}$$

$$\Rightarrow \quad 166.7 = 35.68\ V^2$$

$$\Rightarrow \quad V = 2.162 \text{ m/s}$$

Head available at the end of the pipe, $H_{net} = \dfrac{2H}{3} = 333.33$ m

∴ Maximum power available = $\rho QgH = \rho (AV)\, gH_{net}$

$$\Rightarrow \quad P_{max} = 1000\times\frac{\pi}{4}\times 0.3^2\times 2.162\times 9.81\times 333.33$$

$$\Rightarrow \quad P_{max} = 499.7\times 10^3\text{ W} \simeq 500\text{ kW}$$

22. (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, $$\sqrt{u^2+v^2} = 6$$

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

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

Given, $$\theta = 135°$$

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

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

$$\tan(135°) = \frac{v}{u}$$

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

$$x = y \qquad ...(ii)$$

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

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

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

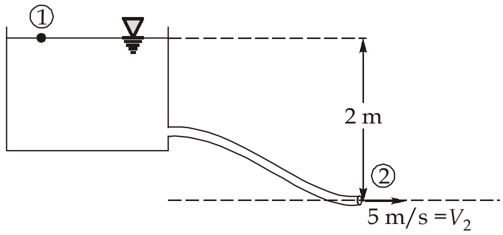
$$6x = 6$$

$$x = 1$$

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)

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

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

$h_f = 0.75$ m

From Darcy-Weisbach equation,

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

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

$L = 3$ m

24. (b)

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

Pressure head = –2 cm of mercury

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

= –0.363 m of oil

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

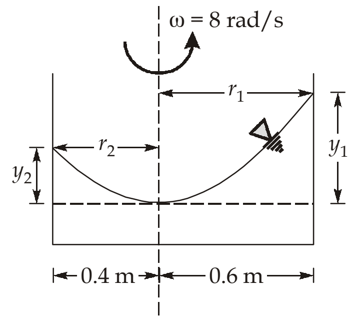
$$\text{Velocity head} = \frac{\alpha v^2}{2g} = \frac{1.1 \times 3.96^2}{2 \times 9.81} = 0.879 \text{ m}$$

Datum head, z = 12 cm = 0.12 m

Total head = –0.363 + 0.879 + 0.12

= 0.636 m

25. (b)



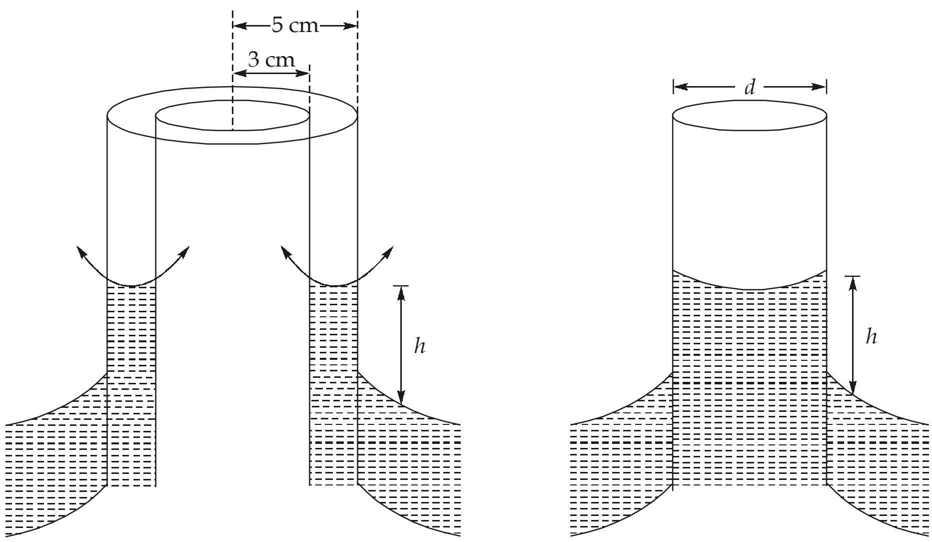
Difference in level of water,

$$y_1 - y_2 = \frac{\omega^2\left(r_1^2 - r_2^2\right)}{2g}$$

$$y_1 - y_2 = \frac{8^2\left(0.6^2 - 0.4^2\right)}{2 \times 10}$$

$$y_1 - y_2 = \frac{64 \times (0.36 - 0.16)}{20} = 0.64 \text{ m}$$

26. (c)



For fluid rise between 2 concentric capillary tubes, we know that,

$$h = \frac{2\sigma\cos\theta}{\rho g\left(r_o - r_i\right)}$$

$$h = \frac{2\sigma\cos\theta}{\rho g(5-3)} = \frac{\sigma\cos\theta}{\rho g} \quad \text{...(i)}$$

For simple capillary tube,

$$h = \frac{4\sigma\cos\theta}{\rho g d} \quad \text{...(ii)}$$

By equating equation (i) and (ii),

$$\frac{\sigma\cos\theta}{\rho g} = \frac{4\sigma\cos\theta}{\rho g\, d}$$

$$d = 4 \text{ cm}$$

27. (a)

Since the pipes are connected in series

$$\therefore \quad \frac{L}{d^5} = \frac{L_1}{d_1^5} + \frac{L_2}{d_2^5} + \frac{L_3}{d_3^5}$$

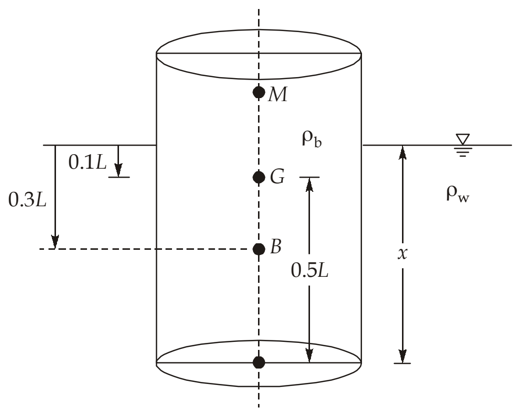
$$\Rightarrow \quad \frac{1700}{d^5} = \frac{800}{0.500^5} + \frac{500}{0.4^5} + \frac{400}{0.3^5}$$

$$\Rightarrow \quad d^5 = \frac{1700}{239037.18}$$

$$\Rightarrow \quad d = 0.3719 \text{ m}$$

$$= 371.9 \text{ mm} \simeq 372 \text{ mm}$$

28. (d)



Applying equilibrium condition

Buoyant force = Weight of solid cylinder

$$\Rightarrow \quad \rho_w \times \frac{\pi}{4} D^2 \times xg = \rho_b \times \frac{\pi}{4} D^2 \times Lg$$

$$\Rightarrow \quad \rho_w \times \frac{\pi}{4} D^2 \times x \times g = 0.6\rho_w \times \frac{\pi}{4} D^2 \times L \times g \quad (\rho_b = 0.6\rho_w)$$

$$\Rightarrow \quad x = 0.6\, L$$

Metacentric height is given by $GM = BM - BG$

For neutral equilibrium, centre of gravity G of body coincides with metacentre i.e.,

$$\Rightarrow \quad GM = 0$$

$$\Rightarrow \quad BM = BG$$

$$BM = \frac{I}{\forall} = \frac{\frac{\pi}{64}D^4}{\frac{\pi}{4}D^2 \times (0.6L)} = \frac{1}{16} \times \frac{D^2}{(0.6L)} = \frac{D^2}{16L} \times \frac{5}{3}$$

$$BG = 0.5L - 0.5x$$

$$= 0.5L - 0.5 \times 0.6L$$

$$= 0.2L$$

$$BM = BG$$

$$\Rightarrow \quad \frac{D^2}{16L} \times \frac{5}{3} = \frac{L}{5}$$

$$\Rightarrow \quad \frac{L^2}{D^2} = \frac{25}{48}$$

$$\Rightarrow \quad \frac{L}{D} = \frac{5}{4\sqrt{3}}$$

29. (d)

Separation of flow: If the surface of the immersed object, along which the boundary layer forms, is such that it curves away from the flow, there exists a tendency for the flowing fluid to leave the boundary. This phenomenon is known as the separation of flow.

Wake of flow: On the downstream side of the body, on account of separation, a region of low pressure is developed which is known as wake.

Cavitation: When the pressure in any part of the flow passage reaches the vapour pressure of the flowing liquid, it starts vaporising and small bubbles of vapour form in large numbers.

30. (c)

$$dp = \frac{\partial p}{\partial z}dz + \frac{\partial p}{\partial r}dr$$

But $$\frac{\partial p}{\partial z} = (-\rho g), \quad \frac{\partial p}{\partial r} = \rho\omega^2 r$$

$\therefore$ $$dp = \rho r\omega^2 dr - \rho g dz$$

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