CLASS TEST

Sl. : 04SKCE_OPQ_25092024

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 25/09/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

2. (c)

According to Buckingham's π theorem,

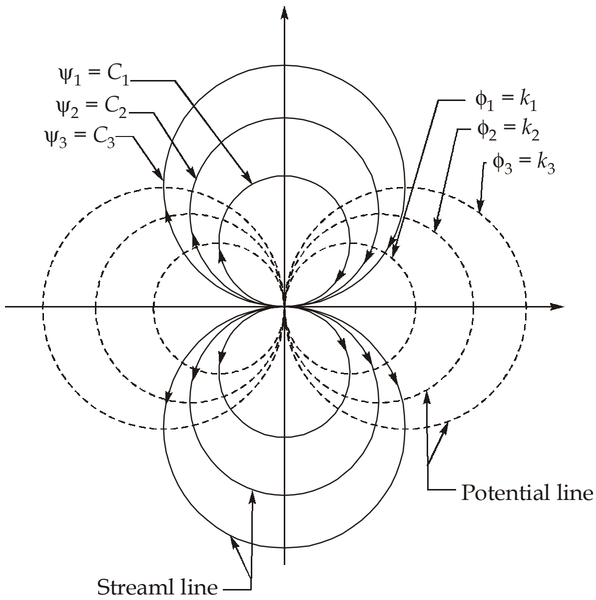
$$\pi \text{ terms} = n - m$$

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

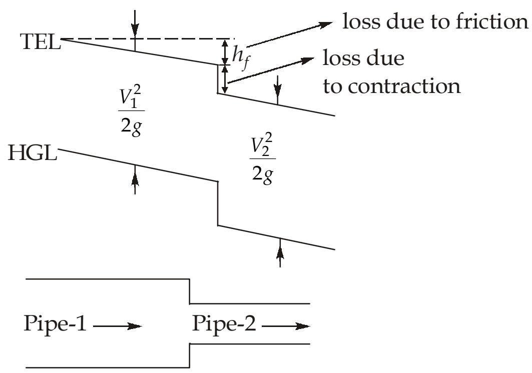
So, no. of independent non-dimensional groups = π terms.

3. (c)

4. (a)



5. (b)



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

6. (d)

More mechanical gauges to measure pressure are:

- Bourdon tube pressure gauge
- Diaphragm pressure gauge
- Bellows pressure gauge
- Piezoelectric transducers

7. (b)

$$\bar{h}_p = \bar{h} + \frac{I_G}{A\bar{h}}$$

$$\bar{h}_p = \left(4 + \frac{2}{3} \times 9\right) + \frac{\left(\frac{b9^3}{36}\right)}{\left(\frac{1}{2} \times b \times 9\right) \times 10}$$

$$\bar{h}_p = 10.45 \text{ cm}$$

8. (b)

$$\sqrt{\frac{\tau_0}{\rho}} = v\sqrt{\frac{f}{8}}$$

$$\frac{\tau}{\rho} = v^2 \frac{f}{8}$$

$$f = \frac{8\tau}{\rho v^2} = \frac{8 \times 20}{800 \times 2.5^2}$$

$$f = 0.032$$

9. (a)

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

$$\frac{\delta_1}{x_1} = \frac{5}{\sqrt{R_{ex_1}}} \text{ and } \frac{\delta_2}{x_2} = \frac{5}{\sqrt{R_{ex_2}}}$$

$$x_1 = x_2 = 81 \text{ cm}$$

$$\frac{\delta_1}{\delta_2} = \sqrt{\frac{R_{ex_2}}{R_{ex_1}}}$$

$$\frac{\delta_1}{\delta_2} = 7$$

10. (c)

$$P = \rho Q g \times h_f$$

$$h_f \propto Q$$

$$\Rightarrow \quad P \propto Q^2$$

$$\frac{P_1}{P_2} = \frac{Q_1^2}{Q_2^2}$$

$$P_2 = (2)^2 P_1$$

$$P_2 = 4P_1$$

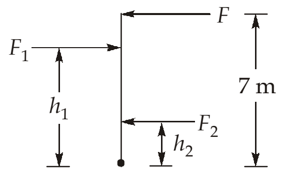
11. (c)

$$v^* = \sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{800}{1000}} = 0.894 \text{ m/s}$$

$$\delta' = \frac{11.6\nu}{v^*} = \frac{11.6 \times 10^{-6}}{0.894} = 12.975 \times 10^{-6} \text{ m}$$

$$\therefore \quad \frac{k_s}{\delta'} = \frac{0.12 \times 10^{-3}}{12.975 \times 10^{-6}} = 9.25$$

12. (b)



$$h_1 = \frac{5}{3}\text{m}, \; h_2 = \frac{4}{3}\text{m}$$

$$F_1 = 1000 \times 9.81 \times \frac{5}{2} \times (5 \times 5)$$

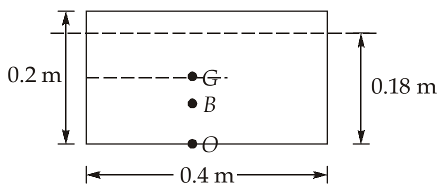
$$F_2 = 800 \times 9.81 \times \frac{4}{2} \times (4 \times 5)$$

Taking moment about

$$F = \frac{9810 \times \frac{125}{2} \times \frac{5}{3} - 800 \times 9.81 \times 40 \times \frac{4}{3}}{7}$$

$$F = 86.19 \text{ kN}$$

13. (a)



$$\overline{GM} = \overline{BM} - \overline{BG} = \frac{I}{V} - \left(\overline{OG} - \overline{OB}\right)$$

$$= \frac{\frac{0.8 \times 0.4^3}{12}}{0.18 \times 0.4 \times 0.8} - \left(\frac{0.2}{2} - \frac{0.18}{2}\right)$$

$$\overline{GM} = 0.064 > 0 \Rightarrow \text{stable equilibrium}$$

14. (c)

$$h_L = E_A - E_B = \left(\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_A\right) - \left(\frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_B\right)$$

$\because \quad D_1 = D_2 \Rightarrow V_1 = V_2$

$$h_L = \frac{100000}{1000 \times 9.81} + 100 - \frac{50000}{1000 \times 9.81} - 104$$

$$h_L = 1.097 \text{ m}$$

15. (d)

It does not tell about correctness of selection of the relevant variable of the particular phenomenon.

16. (b)

$$GM = \frac{wx}{W \tan\theta} = \frac{1000 \times 12}{150 \times 10^3 \times \left(\frac{0.0523}{0.9986}\right)}$$

$$GM = 1.5265 \text{ m}$$

17. (b)

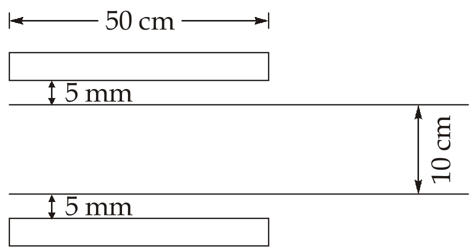
Local or temporal acceleration,

$$\frac{dV}{dt} = 12\left(\frac{x}{6L} + 5\right)^3$$

$$\frac{dV}{dt} = 12\left(\frac{0.8}{6 \times 2} + 5\right)^3$$

$$\frac{dV}{dt} = 1560.8 \text{ m/sec}^2$$

18. (a)



Tangential velocity, $V = rw = \frac{0.1}{2} \times \frac{2\pi \times 100}{60} = 0.524 \text{m/sec}$

Shear stress, $\tau = \frac{\mu V}{h} = 0.3 \times \frac{0.524}{0.005} = 31.416 \text{ N/m}^2$

Shear force on the shaft surface $= \tau \times 2\pi r \times L$

Torque $= F_r \times r = \tau 2\pi r^2 L = T$

Power lost $= Tw = \tau 2\pi r^2 L \times \frac{2\pi N}{60}$

$$P = 31.416 \times 2\pi \times \left(\frac{0.1}{2}\right)^2 \times 0.5 \times \frac{2\pi \times 100}{60} = 2.58 W$$

19. (a)

Pipes are placed in parallel

$$h_{fA} = h_{fB}$$

$$\frac{f_A L_A \theta_A^2}{12.1 D_A^5} = \frac{f_B L_B \theta_B^2}{12.1 D_B^5}$$

$$\frac{D_A}{D_B} = 3;\ \frac{L_A}{L_B} = \frac{1}{2}, F_A = F_B$$

$$\frac{Q_A^2}{Q_B^2} = \frac{L_B}{L_A} \times \left(\frac{D_A}{D_B}\right)^5$$

$$\frac{Q_A}{Q_B} = \sqrt{2 \times 3^5}$$

$$\frac{Q_A}{Q_B} = 22.05$$

20. (b)

$$\text{Re}_L = \frac{U_\infty L}{\nu} = \frac{9 \times 0.6}{0.6 \times 10^{-4}} = 9 \times 10^4$$

$$Re_L < 5 \times 10^5$$

$$F_D = C_D \times \frac{1}{2} \rho U_\infty^2 \times (LB)$$

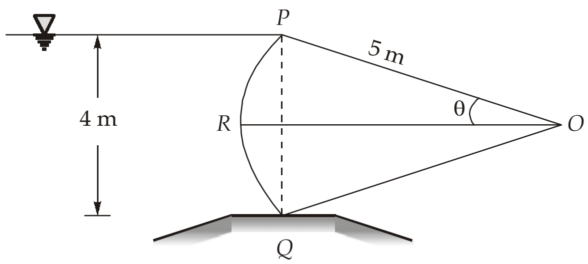
$$F_D = \frac{1.328}{\sqrt{\text{Re}_L}} \times \frac{1}{2} \times 800 \times 9^2 \times (0.6 \times 0.3)$$

$$F_D = \frac{1.328}{300} \times 400 \times 81 \times 0.18$$

$$F_D = 25.8 \text{ N}$$

Drag on both sides $F_D' = 2 \times 25.8 = 51.6$ N

21. (d)



Consider the gate width as 1 m

$$\sin\theta = \frac{2}{5},\ \theta = 23.57°$$

$$F_H = \gamma \times (\text{Projected area}) \times \bar{h}$$

$$= 9.81 \times (4 \times 1) \times \frac{4}{2} = 78.48 \text{ kN}$$

$$F_V = \gamma \times \forall$$

$$= \gamma \times \text{Area}[\text{Sector POQR} - \text{Triangle POQ}]$$

$$= 9.81 \times \left[\pi \times 5^2 \times \left(\frac{2 \times 23.57}{360}\right) - \frac{1}{2} \times 4 \times 5 \cos 23.57°\right]$$

$$= 10.97 \text{ kN}$$

$$F_r = \sqrt{F_H^2 + F_V^2} = \sqrt{(78.48)^2 + (10.97)^2} = 79.24 \text{ kN}$$

22. (d)

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

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

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

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

23. (c)

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

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

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

$(\because \quad Q_2 = 2Q_1)$

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

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

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

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

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

$\therefore$ Increase in cross-sectional area

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

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

24. (a)

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

As Re < 2000, $\therefore$ Flow is laminar

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

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

25. (a)

$$\text{Velocity, } V = 3 \text{ m/s}$$

$$\text{Kinematic viscosity, } \nu = 0.9 \text{ centistokes} = 0.9 \times 10^{-6} \text{ m}^2/\text{s}$$

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

Since Re > 4000,

∴ Flow is turbulent

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

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

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

$$\Rightarrow \quad f = 0.0167$$

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

26. (c)

At point (1, –2, 1)

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

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

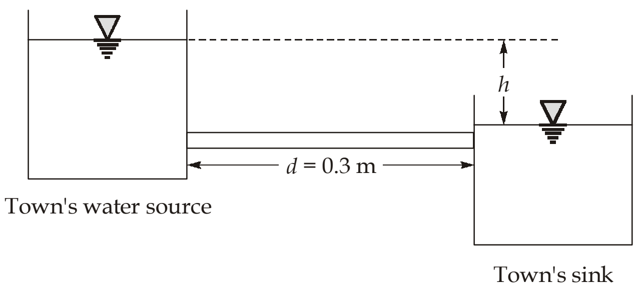
$$w = -\frac{3z^2}{2} - 2xz + 9y^2 z = -1.5 - 2 + 36 = 32.5$$

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

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

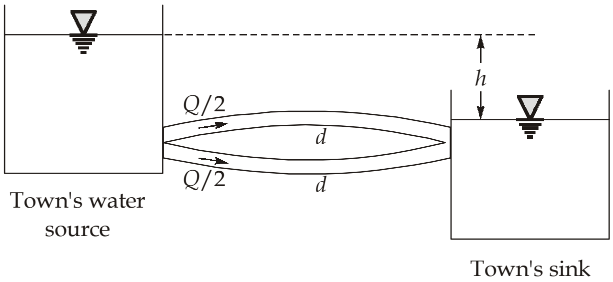
27. (d)

Case 1: Single pipe connection



$$h = \frac{fQ^2}{12(0.3)^5} \quad \text{... (i)}$$

Case 2: Dual pipe connection



$$h = \frac{fl(Q/2)^2}{12d^5} \quad \text{... (ii)}$$

Using (i) and (ii)

$$\frac{flQ^2}{12(0.3)^5} = \frac{fl(Q/2)^2}{12d^5}$$

$\Rightarrow$ $d = 0.2274 \text{ m} = 22.74 \text{ cm}$

$\Rightarrow$ $\text{d} = 227.4 \text{ mm} \simeq 227 \text{ mm}$

28. (b)

Given data:

Relative density of glass sphere = 2.7

Diameter of glass sphere = 1 mm

Velocity of sphere = 1.25 cm/s

Density of oil = 920 kg/m^3

$$\text{Reynold's number} = \frac{\rho v d}{\mu}$$

Let us assume that Stokes' law is valid then,

$$V = \frac{1}{18} D^2 \left(\frac{\gamma_s - \gamma_f}{\mu}\right)$$

$$\frac{1.25}{100} = \frac{1}{18} \times \frac{\left(10^{-3}\right)^2 (2.7 \times 1000 \times 9.81 - 920 \times 9.81)}{\mu}$$

$$\mu = 0.0776 \text{ Pa.S}$$

$$\text{Reynold's number} = \frac{\rho VD}{\mu} = \frac{920 \times \frac{1.25}{100} \times 10^{-3}}{0.0776} = 0.148 < 1$$

Hence Stokes law is valid.

Therefore dynamic viscosity, $\mu = 0.0776$ Pa.S

29. (b)

Given: $d = 10$ cm $= 0.1$ m, $r = 0.05$ m, $\sigma = 0.05$ N/m

The soap bubble has two interfaces.

$$\begin{aligned} \text{Work done} &= \text{Surface tension} \times \text{Total surface area} \\ &= 0.05 \times (2 \times 4\pi r^2) \\ &= 0.05 \times 2 \times 4 \times \pi \times (0.05)^2 \\ &= 3.14 \text{ Nmm} \end{aligned}$$

30. **(a)**

Since one plate is moving with respect to other with the flow occurring simultaneously it is a case of general Couette's flow.

Velocity distribution in a Couette flow is given as

$$u = \frac{Uy}{B} - \frac{By}{2\mu}\left(\frac{dP}{dx}\right)\left(1 - \frac{y}{B}\right)$$

Given: $\frac{dP}{dx} = 0$, this is a case of plain Couette flow,

$U = 3$ m/s, $B = 3$ m, $\mu = 0.8$ Pa.s

$$\frac{dP}{dx} = 0$$

$$\Rightarrow \quad \frac{u}{y} = \frac{U}{B}$$

Shear stress, $\tau = \mu \frac{du}{dy} = 0.8 \times \frac{3}{0.03} = 80\ \text{N/m}^2 = 80\ \text{Pa}$

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