CLASS TEST

SL.: 02SPME-ABCD-130723

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FLUID MECHANICS

MECHANICAL ENGINEERING

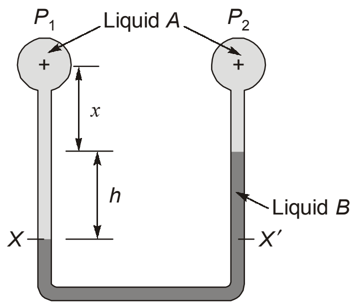
Date of Test : 13/07/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)



Taking point X and X' and equating the pressure on both sides

$$P_1 + (h + x) \times 0.88 \times 9.81 \times 10^3 = P_2 + x \times 0.88 \times 9.81 \times 10^3 + h \times 2.95 \times 9.81 \times 10^3$$

$$\Rightarrow P_1 + h \times 0.88 \times 9.81 \times 10^3 + x \times 0.88 \times 9.81 = x \times 0.88 \times 9.81 + P_2 + h \times 2.95 \times 9.81 \times 10^3$$

$$\Rightarrow P_1 - P_2 = h(2.95 \times 9.81 - 0.88 \times 9.81) \times 10^3$$

$$860 = h(2.3067 \times 10^3)$$

$$42.35 \times 10^{-3} = h$$

$$h = 42.35 \text{ mm}$$

2. (b)

For geometrically similar model and prototype

$$\left(\frac{P}{N^3 D^5}\right)_{\text{model}} = \left(\frac{P}{N^3 D^5}\right)_{\text{prototype}}$$

Given, $N_m = N_p$

$$\Rightarrow \frac{P_m}{N_m^3 D_m^5} = \frac{P_p}{N_p^3 D_p^5}$$

$$\frac{P_m}{P_p} = \frac{N_m^3 D_m^5}{N_p^3 D_p^5}$$

$$\frac{P_m}{P_p} = \frac{2^3 N_p^3}{N_p^3} \times \frac{D_m^5}{16^5 D_m^5}$$

$$P_m = \frac{10 \times 10^6 \times 2^3}{16^5} W = 76.29 \text{ W}$$

3. (a)

$$P_A - H \times 9.81 \times 1 - 0.18 \times 9.81 \times 0.827 = P_B - 13.6 \times 9.81 \times (H + 0.53)$$

$$-H \times 9.81 - 1.4603 = 97 - 13.6 \times 9.81 \times H - 13.6 \times 9.81 \times 0.53$$

$$\Rightarrow H = 0.2245 \text{ m}$$

$$\therefore H = 22.45 \text{ cm}$$

4. (c)

$$\therefore \quad \bar{V} = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4}d^2} \Rightarrow \frac{4Q}{\pi d^2} = \frac{4 \times 880 \times 10^{-9}}{\pi \times 0.50^2 \times 10^{-6}} = 4.48\,\text{m/s}$$

We know,

$$Q = \frac{\pi \Delta p D^4}{128 \mu L}$$

$$\Rightarrow \quad \mu = \frac{\pi \Delta p D^4}{128 Q L} = \frac{\pi \times 10^6 \times (0.5)^4 \times 10^{-12}}{128 \times 880 \times 10^{-9} \times 1}$$

$$\mu = 1.74 \times 10^{-3}$$

5. (c)

Newton's law of viscosity

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

Where τ = shear stress

$\frac{du}{dy}$ = Rate of strain

6. (c)

$$\tau A = mg\sin\theta$$

$$\mu\left(\frac{v}{t}\right)A = mg\sin\theta$$

$$v = \frac{mgt\sin\theta}{\mu A} = \frac{15 \times 9.81 \times 0.1 \times 10^{-3} \times \sin 30^\circ}{8.14 \times 10^{-2} \times 0.25} = 0.36\text{ m/s}$$

7. (c)

8. (c)

$$u = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 20} = 19.81\text{ m/s}$$

$$v^2 - u^2 = 2as \qquad (a = -g)$$

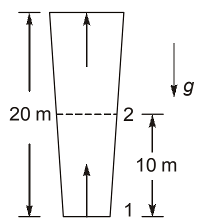
$$v^2 - 19.81^2 = -2 \times 9.81 \times 10$$

or $$v = 14\text{ m/s}$$

$$A_1 v_1 = A_2 v_2$$

$$D_2^2 = \frac{12^2 \times 19.81}{14}$$

or $$D_2 = 14.27\text{ cm}$$



9. (b)

Surface tension is due to cohesion between liquid particles at the surface.

10. (d)

$$P = \rho_{Hg} \times g \times H$$
$$6.8 \times 10^4 = 13.6 \times 10^3 \times 9.81 \times H$$
$$H_{Hg} = 0.5096 \text{ m}$$
$$H_{water} = \frac{13.6}{1} \times 0.5096$$
$$H_{water} = 6.931 \text{ m}$$

11. (b)

For just equilibrium condition,

$$\dot{m}[V\cos\theta] = \mu Mg$$

$1000 \times \pi \times 0.25 \times 0.05^2 \times V^2 \times 0.5 = 0.55 \times M \times 9.81$

$1000 \times \pi \times 0.25 \times 0.05^2 \times 2 \times 9.81 \times 2 \times 0.5 = 0.55 \times M \times 9.81$

$\Rightarrow \quad = 7.1399 \text{ kg}$

12. (d)

$$\text{Volume of cube} = a^3$$
$$a^3 = 125 \times 10^{-3} \times 10^{-3} \text{ m}^3$$
$$\Rightarrow \quad a = 5 \times 10^{-2}$$
$$\Rightarrow \quad a = 0.05 \text{ m}$$
$$F = p \times A$$
$$P_{bottom} = p_{atm} + h_1 g \rho_{oil} + h_2 \rho_{water} g$$
$$= 101325 + 0.5 \times 0.8 \times 1000 \times 9.81 + 0.3 \times 1000 \times 9.81$$
$$P_{bottom} = 108192$$
$$F = P_{bottom} \times A = 108192 \times 0.05^2 = 270.48 \text{ N}$$
$$T = \text{Upthrust} - W$$
$$= 125 \times 10^{-6} \times 1000 \times 9.81 - 125 \times 10^{-6} \times 0.77 \times 1000 \times 9.81$$
$$= 0.282 \text{ N}$$

13. (c)

$$u = \frac{\partial \psi}{\partial y}$$
$$u = 2x^2 + (x + t)\, 2y$$

$\therefore$ for face OB, $\quad x \Rightarrow 0$

$$u_{OB} = 2ty$$

Discharge through AB

$$\therefore \quad Q_{AB} = \int_0^2 u_{OB} \cdot 5dy = \int_0^2 2ty \cdot 5dy$$

At $\quad t = 1$

$$Q_{OB} = 20 \text{ units}$$

$\therefore$ $$V = -\frac{\partial \psi}{\partial x} = -\left[4xy + y^2\right]$$

At $$y = 0$$

$$V = 0$$

$\therefore$ $$Q_{AO} = 0$$

$\therefore$ $$Q_{AB} = Q_{OB} + Q_{OA}$$

$$= 20 + 0$$

$$= 20 \text{ units}$$

14. (d)

$$V_2 = \frac{Q}{A_2} = \frac{1.13 \times 10^{-6}}{\frac{\pi}{4} \times (0.0012)^2} \simeq 1 \text{ m/s}$$

$$\frac{P_1}{\rho g} + \frac{\alpha_1 V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_f$$

$$h_f = z_1 - z_2 - \frac{\alpha_2 V_2^2}{2g}$$

$\Rightarrow$ $$h_f = 0.6 - 0 - \frac{(2)(1)^2}{2 \times 9.81} = 0.5 \text{ m}$$

$$h_f = \frac{32 \mu V L}{\rho g D^2}$$

$\Rightarrow$ $$0.5 = \frac{32 \times \mu \times 0.3 \times 1}{9000 \times 0.0012}$$

$\Rightarrow$ $$\mu = 6.75 \times 10^{-4} \text{ Pa-s}$$

15. (c)

$$v = \frac{\beta}{4\mu}\left(\frac{D^2}{4} - r^2\right)$$

$$\left.\frac{\delta v}{\delta r}\right|_{r=D/2} = \left.\frac{\beta}{4\mu}(-2r)\right|_{r=D/2} = \left.-\frac{\beta r}{2\mu}\right|_{r=D/2} = -\frac{\beta r}{2\mu}\frac{D}{2} = \frac{-\beta D}{4\mu}$$

$$\tau = \left.-\mu \frac{\delta v}{\delta r}\right|_{r=D/2} = \frac{\beta D}{4}$$

16. (b)

$$Re_L = \frac{UL}{v} = \frac{1.75 \times 5}{1.475 \times 10^5}$$

$$Re_L = 5.932 \times 10^5$$

$$C_f = \frac{0.074}{\mathrm{Re}_L^{1/5}} = \frac{0.074}{(5.932 \times 10^5)^{1/5}} = 5.183 \times 10^{-3}$$

Drag force on one side of the plate,

$$F_d = C_f \times \text{area} \times \frac{1}{2}\rho U^2$$

$$= 5.183 \times 10^{-3} \times (1.8 \times 5) \times 1.22 \times \frac{(1.75)^2}{2}$$

$$F_d = 0.0871 \text{ N}$$

17. (d)

$\because$ Continuity equation holds,

$$\therefore \quad \frac{\pi}{4} \times (5)^2 \times 2 = \frac{\pi}{4} \times 3^2 \times x$$

$$x = 5.55 \text{ m/s}$$

Mars flow rate

$$\Rightarrow \quad \dot{m} = \int_{\dot{m}} A_1 V_1 = 100 \times \frac{\pi}{4} \times 0.05^2 \times 2 = 3.9269 \text{ kg/s}$$

Let f_x and f_y be the force in Right and vertically upward diversion respectively to hold the box in position.

$\therefore$ Now, $\Sigma f_x = 0$ [Box is stationary after applying force]

$$-\dot{m} \times V_1 \cos 65° + f_x = -\dot{m} \times V_2 \cos 0°$$

$$-3.9269 \times 2 \times \cos 65° + f_x = -3.9269 \times 5.55 \times 1$$

$$f_x = -18.475 \text{ N.}$$

f_x must be in left as f_x comes out to be negative.

Similarly for vertical direction $\Sigma f_y = 0$

$$f_y - 3.9269 \times 2 \times \sin 65° = 0$$

$$f_y = 7.11 \text{ N}$$

$\therefore$ It is towards vertically upward direction.

18. (d)

$$Q = a_2 \sqrt{\frac{2(p_1 - p_2)}{\rho\left[1 - \left(\frac{a_2}{a_1}\right)^2\right]}} \quad \text{for a venturimeter}$$

$$\therefore \quad p_1 - p_2 = \frac{Q^2 \rho\left[1 - \left(\frac{a_2}{a_1}\right)^2\right]}{2a_2^2}$$

$$= \frac{0.05^2 \times 850}{2 \times \left[\frac{\pi}{4} 0.06^2\right]^2}\left(1 - \frac{0.06^4}{0.1^4}\right) = 1.16 \times 10^5 \text{ N/m}^2$$

$$= 116 \text{ kPa}$$

19. (b)

$$H_m = H + \frac{fLV_d^2}{2gd} + 1.3 \times \frac{V_d^2}{2g} + \frac{V_d^2}{2g}$$

H_m = Net head required

$$H_m = 30 + \frac{4f'LV_d^2}{2gd} + 1.3 \times \frac{V_d^2}{2g} + \frac{V_d^2}{2g}$$

$$f' = 0.02 \qquad A_dV_d = 50 \times 10^{-3} \text{ m}^3\text{/s}$$

$$d = 200 \text{ mm}$$

$$\frac{\pi}{4} \times 0.2^2 \times V_d = 50 \times 10^{-3}$$

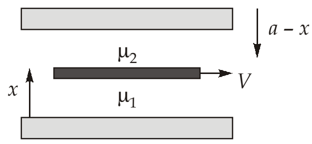
$$V_d = 1.59 \text{ m/s}$$

$$\Rightarrow \quad H_m = 30 + \frac{4 \times 0.02 \times 100 \times 1.59^2}{2 \times 9.81 \times 0.2} + \frac{1.3 \times 1.59^2}{2 \times 9.81} + \frac{1.59^2}{2 \times 9.81}$$

$$= 35.45 \text{ m}$$

$$\Rightarrow \quad \text{Power} = \rho Qg\, H_m = 17388.225 \text{ W} = 17.388 \text{ kW}$$

20. (d)



$$\tau_1 = \text{shear stress at bottom}$$

$$= \mu_1 \times \frac{V}{x}$$

$$\tau_2 = \text{shear stress at top} = \mu_2 \frac{V}{a-x}$$

$$\text{drag force} = (\tau_1 + \tau_2) \times A = F_D$$

$$= F_D = A \times \left[\frac{\mu_1 V}{x} + \frac{\mu_2 V}{a-x}\right]$$

$$\frac{dF_D}{dx} = 0 = \frac{-\mu_1 V}{x^2} + \frac{\mu_2 V}{(a-x)^2} \Rightarrow \frac{\mu_1}{x^2} = \frac{\mu_2}{(a-x)^2}$$

$$a - x = \sqrt{\frac{\mu_2}{\mu_1}}\, x$$

$$\Rightarrow \quad \frac{a\sqrt{\mu_1}}{\sqrt{\mu_1} + \sqrt{\mu_2}} = x$$

21. (b)

Given data:

Stream function,

$$\psi = x^2 - y^2$$

The velocity components u and v in the direction of x and y are given by

$$u = -\frac{\partial \psi}{\partial y} = -\frac{\partial}{\partial y}\left(x^2 - y^2\right) = 2y$$

or $$v = \frac{\partial \psi}{\partial x} = \frac{\partial}{\partial x}\left(x^2 - y^2\right) = 2x$$

The velocity at point (1, 1),

$$\vec{V} = u\hat{i} + v\hat{j} = 2y\hat{i} + 2x\hat{j}$$
$$= 2\times 1\hat{i} + 2\times 1\hat{j} = 2\hat{i} + 2\hat{j}$$

The magnitude of the velocity,

$$V = \sqrt{(2)^2 + (2)^2} = \sqrt{4+4} = \sqrt{8} = 2\sqrt{2}$$

22. (a)

(1) $$u = x^2 \cos y$$
$$v = -2x \sin y$$

Continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial y}{\partial y} = 0$$
$$= \frac{\partial u}{\partial x}\left(x^2 \cos y\right) + \frac{\partial}{\partial y}(-2x \sin y)$$
$$(2x)\cos y - (2x)\cos y = 0$$

hence satisfy the continuity equation.

(2) $$u = x + 2$$
$$v = 1 - y$$

Continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial y}{\partial y} = 0$$
$$= \frac{\partial}{\partial x}(x+2) + \frac{\partial}{\partial y}(1-y) = 1 - 1 = 0$$

hence satisfy the continuity equation.

(3) $$u = xyt$$
$$v = x^3 - y^2\frac{t}{2}$$

Continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$
$$= \frac{\partial}{\partial x}(xyt) + \frac{\partial}{\partial y}\left(x^3 - \frac{y^2 t}{2}\right) = yt - yt = 0$$

(4) $$u = ln(x + y)$$
$$v = xy - \frac{y}{x}$$

Continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$
$$= \frac{\partial}{\partial x} ln(x+y) + \frac{\partial}{\partial y}\left(xy - \frac{y}{x}\right) = \frac{1}{x+y} + x - \frac{1}{x} \neq 0$$

Hence, does not satisfy continuity equation.

23. (a)

$$\text{Pressure head} = \frac{p}{\rho g} = \frac{19.62 \times 10^3}{1000 \times 9.81 \times 0.8} = 2.5 \text{ m of oil}$$

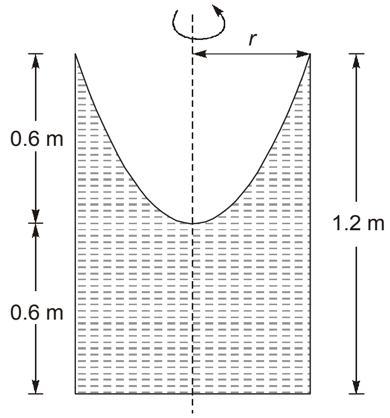
$$\text{Velocity head} = \frac{V^2}{2g} = \frac{Q^2}{2A^2 g} = \frac{(0.12)^2}{2 \times \left(\frac{\pi}{4} \times 0.25^2\right)^2 \times 9.81} = 0.3 \text{ m of oil}$$

$$\text{Datum head} = 2.7 \text{ m}$$

$$\text{Total head} = \text{Pressure head + Velocity head + Datum head}$$

$$= 2.5 + 0.3 + 2.7 = 5.5 \text{ m}$$

24. (a)



Original volume of

$$\text{Cylinder} = \pi r^2 h$$

$$V_1 = \pi r^2 \times 1.2$$

Volume of liquid spilled out

$$= \frac{1}{2} \pi r^2 \times h$$

$$V_2 = \frac{1}{2} \pi r^2 \times 0.6$$

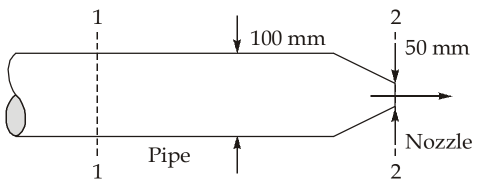
$$\therefore \quad \frac{V_2}{V_1} = \frac{\frac{1}{2} \times 0.6 \pi r^2}{\pi r^2 \times 1.2} = \frac{1}{4}$$

25. (b)

$$V_1 A_1 = V_2 A_2$$

$$5 \times \frac{\pi}{4}(0.1)^2 = V_2 \times \frac{\pi}{4}(0.05)^2$$

$$\Rightarrow \quad V_2 = 20 \text{ m/s}$$



From force balance in x-diagram

$$P_1A_1 + R_x - P_2A_2 = \rho Q(V_2 - V_1)$$

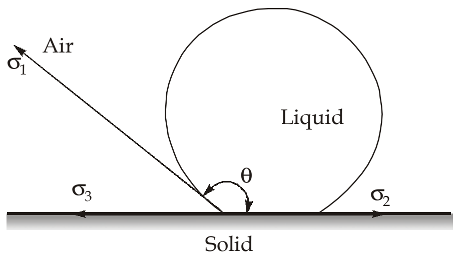
$$\Rightarrow \quad R_x = \rho Q(V_2 - V_1) + P_2A_2 - P_1A_1$$

$$= 1000\times\frac{\pi}{4}(0.1)^2\times5(20-5)+100\times10^3\times\frac{\pi}{4}(0.05)^2-500\times10^3\times\frac{\pi}{4}(0.1)^2$$

Force required to hold the nozzle, $R_x = -3141.6$ N

26. (c)

From force balance at point of contact,



$$\sigma_1\cos(180-\theta) + \sigma_3 = \sigma_2$$

or $$\cos(180-\theta) = \frac{\sigma_2-\sigma_3}{\sigma_1} = -\cos\theta$$

$\therefore$
$$\sigma_1 = 0.0720 \text{ N/m} \quad \text{(liquid and air)}$$
$$\sigma_2 = 0.0418 \text{ N/m} \quad \text{(liquid and solid)}$$
$$\sigma_3 = 0.0008 \text{ N/m} \quad \text{(air and solid)}$$

$$\cos\theta = \frac{0.0008-0.0418}{0.072} = -0.56944$$

$$\theta = 124.7°$$

27. (b)

$$\therefore \quad \text{Re} = \frac{16}{f} = \frac{16}{0.04} = 400$$

$\therefore$ The flow is viscous.

The shear stress in case of viscous flow through a pipe is given by

$$\tau = \frac{-\partial p}{\partial x}\left(\frac{r}{2}\right)$$

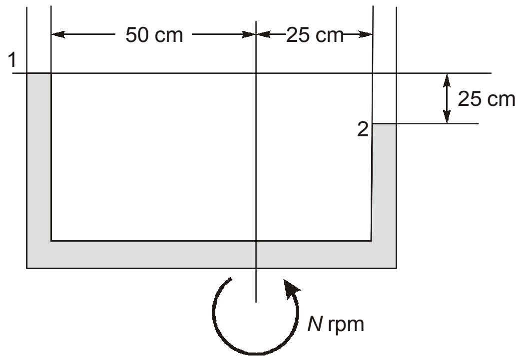
$\therefore$ $\frac{\partial p}{\partial x}$ is constant across a section.

$$\therefore \quad \tau \propto r$$

$$\therefore \quad \frac{\tau}{r} = \frac{\tau_0}{R} = \frac{0.00981}{40} = \frac{\tau_0}{100}$$

$$\therefore \quad \tau_0 = \frac{100\times0.00981}{40} = 0.0245 \text{ N/cm}^2$$

28. (c)



$$\frac{\overset{0}{\cancel{P_1}}}{\cancel{\rho g}} - \frac{V_1^2}{2g} + Z_1 = \frac{\overset{0}{\cancel{P_2}}}{\cancel{\rho g}} - \frac{V_2^2}{2g} + Z_2$$

$$Z_1 - Z_2 = \frac{V_1^2}{2g} - \frac{V_2^2}{2g}$$

$$0.25 = \frac{1}{2g}\left\{r_1^2\omega^2 - r_2^2\omega^2\right\}$$

$$0.25 \times 2 \times 9.81 = \omega^2\left\{\left(\frac{50}{100}\right)^2 - \left(\frac{25}{100}\right)^2\right\}$$

$$\omega = 5.115 \text{ rad/s}$$

$$N = \frac{60\omega}{2\pi} = \frac{60 \times 5.515}{2 \times \pi}$$

$$= 48.8 \text{ rpm}$$

29. (a)

$$\text{Re}_L \leq 2000$$

$$\Rightarrow \quad \frac{\rho VD}{\mu} \leq 2000$$

$$\Rightarrow \quad \frac{(0.92 \times 1000) \times \frac{Q}{A} \times (10 \times 10^{-2})}{0.9 \times 10^{-1}} \leq 2000$$

$$\Rightarrow \quad Q \leq \frac{2000 \times 0.9 \times 10^{-1} \times A}{(0.92 \times 1000) \times (10 \times 10^{-2})}$$

$$\Rightarrow \quad Q \leq 1.95652 \times \frac{\pi}{4} \times \left\{\frac{10}{100}\right\}^2$$

$$\Rightarrow \quad Q \leq 0.015366 \text{ m}^3\text{/s}$$

$$\Rightarrow \quad Q \leq 15.36 \simeq 15.4 \text{ L/s}$$

30. (c)

$$f = \frac{64}{\text{Re}}$$

$$Re = \frac{UD}{\nu} = \frac{0.1 \times 0.1}{10^{-5}} = 1000$$

$$f = \frac{64}{1000} = 0.064$$

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