CLASS TEST

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FLUID MECHANICS

MECHANICAL ENGINEERING

Date of Test : 20/05/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. **(a)**

In series connection the flow rate is same and total head loss is sum of head losses in each pipe. In parallel connection, the head loss is same and total flow rate is sum of flow rate in each pipe.

2. **(b)**

Assuming liquid to be incompressible.

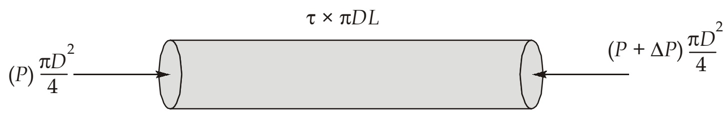
Applying mass conservation.

$$A_1V_1 = A_2V_2 + A_3V_3$$

$$\Rightarrow \quad 450^2 \times 4 = 300^2 \times 3 + 250^2 \times V_3$$

$$V_3 = 8.64 \text{ m/s}$$

3. **(a)**



For equilibrium

$$\tau \times \pi DL + (\Delta P)\frac{\pi D^2}{4} = 0$$

$$\tau = -\frac{D}{4L}(\Delta P)$$

$$= \frac{-0.2}{4 \times 100} \times (-900 \times 9.81 \times 8) = 35.32 \text{ N/m}^2$$

4. **(a)**

A = Ideal Bingham plastic eg. Drilling mud, Toothpaste, Ketchup
B = Pseudoplastic/shear-thining eg. Blood, Paint, Ink
C = Newtonian fluid eg. Water, Kerosene
D = Dilatant/shear-thickening eg. Wet sand, Silica suspension, Corn starch mixture

5. **(b)**

$$F = \rho g \forall$$

$$= \rho g A H$$

$\forall$ = Volume between plate and its projection upto free surface

6. **(b)**

$$\rho_{air}\, gH = \rho_{Hg} \cdot g\left(h_{base} - h_{top}\right)$$

$$H = \frac{13600}{1}(750 - 600) \times 10^{-3}$$

$$= 2040 \text{ m}$$

7. **(b)**

- The center of pressure is always below the centroid for a submerged surface that is not horizontal.
- The hydrostatic force acting on a submerged plane surface is given by

$$F = \rho g A\bar{x}$$
$$= A(\rho g\bar{x})$$

where $\bar{x}$ is vertical distance between the free surface and centroid of the plane surface.

8. **(b)**

Boundary layer thickness is given by

$$\delta \propto \frac{x}{\sqrt{\text{Re}}}$$

Hence as Re no. decreases, boundary layer thickness increases.

9. **(c)**

ψ exist i.e. flow is possible but not necessarily incompressible.

$\nabla^2\psi = 0$ means flow is irrotational.

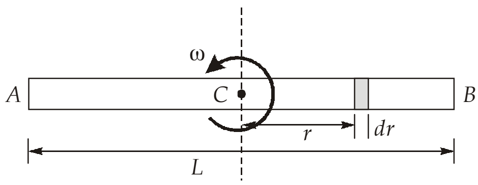
10. **(b)**

$$\tau_W = \frac{f}{8}\rho\bar{U}^2$$
$$= \frac{64}{Re}\cdot\frac{\rho\bar{U}^2}{8} = \frac{64}{\left(\frac{\rho\bar{U}D}{\mu}\right)}\cdot\frac{\rho\bar{U}^2}{8}$$
$$= \frac{8\mu\bar{U}}{D} = \frac{8\times1.5\times5}{0.1}$$
$$= 600 \text{ Pa} = 0.6 \text{ kPa}$$

11. **(a)**

Taking a small element of thickness '*dr*' at a distance of '*r*' from center.

Centrifugal force at this element,



$$dF = dmr\omega^2$$
$$= (\rho A dr)r\omega^2$$

Maximum centrifugal force,

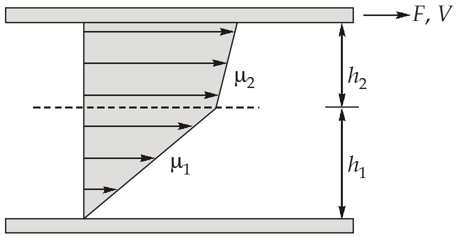
$$F = \int dF = \int_0^{L/2}(\rho A\omega^2)rdr$$

$$F = \rho A\omega^2\left[\frac{r^2}{2}\right]_0^{L/2} = \frac{\rho A\omega^2}{2}\left[\left(\frac{L}{2}\right)^2 - 0^2\right]$$

$$= \frac{\rho A\omega^2 L^2}{8}$$

Maximum stress induced,

$$\sigma_{max} = \frac{F}{A} = \frac{\rho\omega^2 L^2}{8}$$



12. **(c)**

Given μ_1 = 0.1 N.s/m^2 and μ_2 = 0.15 N.s/m^2, A = 2 m^2, h_1 = 0.6 mm, h_2 = 0.3 mm, V = 1 m/s.

Let's take fluid velocity at the interface to be u. The stress due to upper liquid and lower liquid at the interface will be equal, so

$$\tau_1 = \tau_2$$

$$\Rightarrow \quad \mu_1\left(\frac{u-0}{h_1}\right) = \mu_2\left(\frac{V-u}{h_2}\right)$$

$$\Rightarrow \quad 0.1\times\left(\frac{u}{0.6}\right) = 0.15\times\left(\frac{1-u}{0.3}\right)$$

$$\Rightarrow \quad u = \frac{3}{4}\text{ m/ s}$$

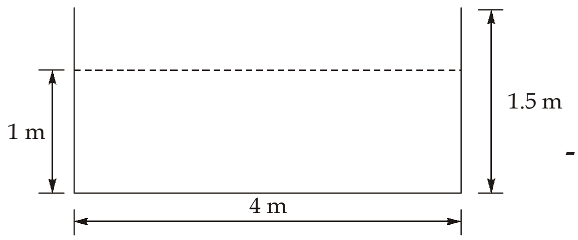
Now, stress at upper plate,

$$\tau = \mu_2\left(\frac{V-u}{h_2}\right) = 0.15\times\left(\frac{1-0.75}{0.3\times10^{-3}}\right) = 125\text{ N/ m}^2$$

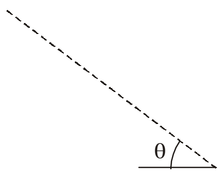
Force at upper plate, $F = \tau \times A = 125 \times 2$
$= 250$ N

13. **(d)**

Given:

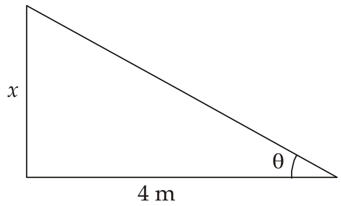


If the tank is accelerated then the surface of water will get inclined at some angle θ,



$$\tan\theta = \frac{a}{g} = \frac{4}{9.81} = 0.4077$$

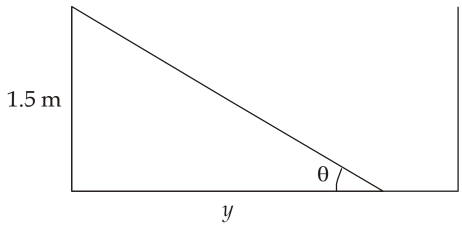
Now we need to check if the liquid will get spilled or not. Lets consider that it doesn't get spilled then,



$$\Rightarrow \qquad \frac{x}{4} = \tan\theta$$

$$\Rightarrow \qquad x = 1.631 \text{ m}$$

We can observe that the maximum x without spill will be 1 m, i.e. (0.5 + 0.5) m. As the tank is 1.5 m deep we can get height of liquid upto that point only. In the given scenario the liquid will be like,



$$y = \frac{1.5}{\tan\theta} = 3.679 \text{ m}$$

$$\text{Spill} = \text{Initial volume} - \text{Final volume}$$

$$= 3 \times 1 \times 4 - 3 \times \frac{1}{2} \times 1.5 \times 3.679 = 3.72 \text{ m}^3$$

14. (d)

If an opening is made in the top of the tank, then air gauge pressure will be zero. Hence, mercury level will fall by some length to maintain equal pressure at bottom. Let the fall be x meter in the manometer, then rise in liquid level in tank, y will be

$$y = x\left(\frac{0.025}{0.25}\right)^2 = \frac{x}{100}$$

As pressure at bottom of tank will be equal.

$0.1 \times 0.8 + 0.1 \times 1 + (0.1 + y)13.6 = (0.3 - x) \times 13.6$

$$\Rightarrow \qquad \frac{0.08 + 0.1}{13.6} + 0.1 + \frac{x}{100} = 0.3 - x$$

$$\Rightarrow \qquad 1.01x = 0.2 - \frac{0.18}{13.6}$$

$$\Rightarrow \qquad x = 0.184915 \text{ m} \approx 185 \text{ mm}$$

15. (b)

$$\dot{m}_{bc} = \dot{m}_{ab} - \dot{m}_{dc}$$

$$\dot{m}_{ab} = \rho . U_\infty . \delta . w$$

$$= 1.3 \times 20 \times (5 \times 10^{-3}) \times 0.6$$

$$= 0.078 \text{ kg/s}$$

$$\dot{m}_{dc} = \int \rho u \cdot w \cdot dy = \rho \cdot U_\infty w \int_0^\delta 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2 dy$$

$$= \rho \cdot U_\infty w \left(\frac{y^2}{\delta} - \frac{y^3}{3\delta^2}\right)\Bigg|_0^\delta = \rho \cdot U_\infty \cdot w \cdot \delta\left(1 - \frac{1}{3}\right)$$

$$= 0.052 \text{ kg/s}$$

$$\Rightarrow \quad \dot{m}_{bc} = 0.078 - 0.052 = 0.026 \text{ kg/s}$$

16. (d)

The velocity distribution in laminar flow in a circular pipe is given by

$$V = \frac{R^2}{4u}\left(\frac{-\partial P}{\partial x}\right)\left(1 - \frac{r^2}{R^2}\right) = U_0\left(1 - \frac{r^2}{R^2}\right)$$

Average velocity, $$V_{avg} = \frac{\int V dA}{A} = \frac{\int_0^R U_0\left(1 - \frac{r^2}{R^2}\right) 2\pi r dr}{\pi R^2}$$

$$= \frac{2U_0}{R^2}\int_0^R \left(r - \frac{r^3}{R^2}\right) dr = \frac{2U_0}{R^2}\left(\frac{r^2}{2} - \frac{r^4}{4R^2}\right)\Bigg|_0^R = \frac{U_0}{2}$$

for $V = V_{avg}$

$$\Rightarrow \quad U_0\left(1 - \frac{r^2}{R^2}\right) = \frac{U_0}{2}$$

$$\Rightarrow \quad \frac{r^2}{R^2} = \frac{1}{2}$$

$$\Rightarrow \quad r = 0.707R$$

Distance from boundary $= R - r$

$= 0.293R$

17. (a)

$$u = \sin(5\pi y)$$

$$\mu = 10 \text{ poise} = 1 \text{ Pa-s}$$

Wall shear stress $$= \tau_{|y=0} = \mu \frac{du}{dy}\Big|_{y=0}$$

$$= 1 \times \frac{d}{dy}(\sin 5\pi y)\Big|_{y=0} = 5\pi\cos(5\pi y)\big|_{y=0} = 5\pi$$

18. (c)

Given : $$\vec{V} = Ax\hat{i} - Ay\hat{j}$$

As streamlines are lines drawn in the flow field such that they are tangent to the direction of flow at every point at a given instant

$$\left.\frac{dy}{dx}\right|_{\text{streamline}} = \frac{v}{u} = -\frac{Ay}{Ax}$$

$$\Rightarrow \quad \int \frac{dy}{y} = \int -\frac{dx}{x}$$

$$\Rightarrow \quad \ln y = -\ln x + \text{constant}$$

$$\Rightarrow \quad \ln xy = \text{constant}$$

$$\Rightarrow \quad xy = \text{constant (hyperbola)}$$

19. (b)

$$K = \frac{dp}{-\left(\frac{dV}{V}\right)} = \frac{2\times10^3}{\frac{0.15}{100}} = \frac{2}{0.15}\times10^5 \text{ kPa}$$

$$C = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{\frac{2\times10^5}{0.15}\times10^3}{1.2\times10^3}} = 1054.09 \text{ m/s} \simeq 1054 \text{ m/s}$$

20. (a)

Let at $t = t$ sec the free surface of in tank is at h from bottom of tank.

Mass conservation,

$$\rho\left(\frac{dV}{dt}\right)_{CV} = \rho(Q_{in} - Q_{out}) \quad \text{...(i)}$$

$$V_{CV} = Ah$$

$$dV_{CV} = Adh \quad \text{...(ii)}$$

$$Q_{out} = a_0\sqrt{2gh} \quad \text{...(iii)}$$

put (ii) and (iii) in (i)

$$A\frac{dh}{dt} = Q_0 - a_0\sqrt{2gh}$$

$$\frac{dh}{dt} = \frac{1}{A}\left(Q_0 - a_0\sqrt{2gh}\right) = \frac{1}{\frac{\pi}{4}(0.5)^2}\left[10^{-3} - \frac{\pi}{4}(0.01)^2\sqrt{2\times9.81\times2}\right]$$

$$= 2.587 \times 10^{-3} \text{ m/s}$$

$$= 2.58 \text{ mm/s}$$

21. (b)

If there is 10% leakage, the piston must deliver both needle flow and leakage:

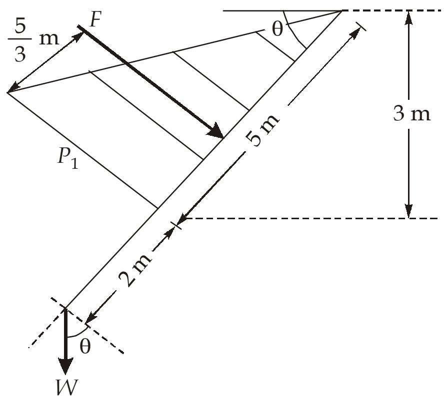
$$A_1V_1 = Q_{needle} + Q_{clearance} = 6 \times 1.1 = 6.6 \text{ cm}^3\text{/s}$$

$$\frac{\pi}{4}\times(1.905)^2\times V_1 = 6.6$$

i.e. $\quad V_1 = 2.32 \text{ cm/s}$

22. (a)

$$b = 2 \text{ m}$$



$$F = \frac{1}{2}P_1(5)(2) = 5\times10^3\times9.81\times3$$

$$= 147.15 \times 10^3 \text{ N}$$

$$\Sigma M_{Pivot} = 0$$

$$W\cos\theta(2) = 147.15\times10^3\left(\frac{5}{3}\right)$$

$$W\left(\frac{4}{5}\right)(2) = 147.15\times10^3\left(\frac{5}{3}\right)$$

$$W = 153.28125 \times 10^3 \text{ N}$$

$$= 153.2813 \text{ kN}$$

23. (a)

$$\text{Discharge, } Q = \frac{kA_1A_2\sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$$Q = \frac{8.1}{60} = 0.135 \text{ m}^3/\text{s}, k = 0.96$$

$$A_1 = \frac{\pi}{4}\times(0.25)^2 = 0.049 \text{ m}^2$$

$$h = 7.6 \text{ m}$$

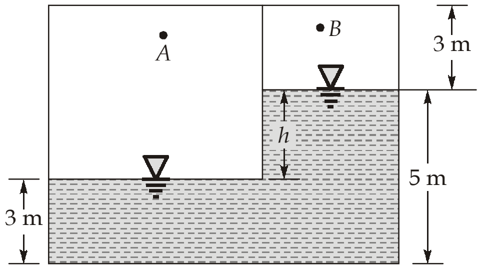
$$0.135 = \frac{0.96\times(0.049)\times A_2\sqrt{2\times9.81\times7.6}}{\sqrt{(0.049)^2 - A_2^2}}$$

$$A_2 = 0.0112 \text{ m}^2$$

$$d_2 = \sqrt{\frac{0.0112\times4}{\pi}} = 0.1195 \text{ m}$$

$$d_2 = 119.5 \text{ mm}$$

24. (b)



Neglecting density of air,

$$P_A = P_B + \rho g h$$

Here, $h = 2$ m

$$150 = P_B + 9.81 \times 2 \times 0.85 \text{ kPa}$$

$$P_B = 133.32 \text{ kPa (abs)}$$

Now atmospheric pressure

$$P_{atm} = 13.6 \times 9.81 \times 0.76 = 101.4 \text{ kPa}$$

So, $$(P_B)_{gauge} = (P_B)_{abs} - P_{atm} = 133.32 - 101.4 = 31.92 \text{ kPa}$$

25. (b)

$$P_A = 4 \text{ kPa (abs)}$$ {For limiting condition to cavitation}

$$P_1 = P_2 = 100 \text{ kPa (abs)}$$

By applying Bernoulli equation to point 1 and A.

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A$$

$$\Rightarrow \quad \frac{100 \times 10^3}{10^3 \times 10} + 0 + 2 = \frac{4 \times 10^3}{10^3 \times 10} + \frac{V_A^2}{2g} + 0$$

$$\therefore \quad \frac{V_A^2}{2g} = 11.6 \text{ m}$$

as given $V_A = 1.5\ V_2$

$$(1.5)^2 \frac{V_2^2}{2g} = 11.6$$

$$\frac{V_2^2}{2g} = \frac{232}{45} \text{m}$$

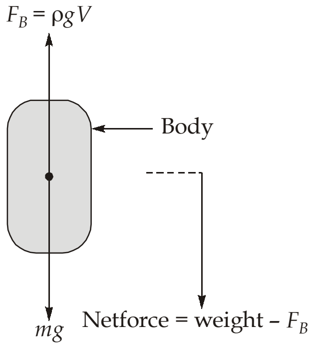
By applying Bernoulli's equation to point 1 and 2.

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

$$2 + L = \frac{232}{45}$$

$$L = 3.16 \text{ m}$$

26. (b)

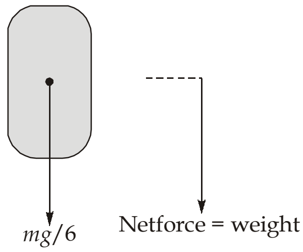


On earth

$$mg - \rho g V = 700 \quad \text{... (i)}$$

$$mg = 700 + 1.1 \times 9.81 \times 1.2$$

$$= 712.95 \text{ N}$$



On moon no buoyancy because no air

$$\frac{mg}{6} = \text{Weight on moon}$$

$$\text{Weight on moon} = 118.82 \text{ N}$$

27. (b)

$$x = x_0 e^{-kt}$$

$$u = \frac{dx}{dt} = x_0(-k)e^{-kt} = -kx_0 e^{-kt} = -kx$$

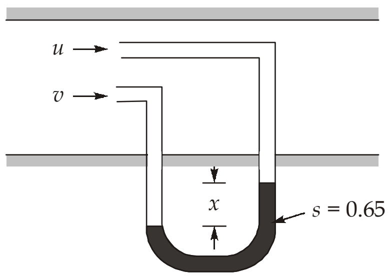
$$y = y_0 e^{-kt}$$

$$v = \frac{dy}{dt} = -ky_0 e^{-kt} = -ky$$

$$= -kx\hat{i} - ky\hat{j}$$

the given velocity field is independent of time i.e. steady flow.

28. (a)



$$\frac{v^2}{2g} - \frac{u^2}{2g} = \left(\frac{\rho_{oil} \times g}{\rho_{air} \times g} - 1\right)x$$

$$\frac{16^2 - 14^2}{2 \times 9.81} = \left(\frac{650 \times 9.81 \times 10^{-3}}{0.075} - 1\right)x$$

$$3.058 = 84.02x$$

$$x = 0.036396 \text{ m}$$

or $x = 0.036396 \times 1000$ mm

$$x = 36.39 \text{ mm}$$

29. (b)

Length of stick below water,

$$y = \frac{2.5}{\sin\theta} \text{ m}$$

Volume of stick submerged in water ($\forall$)

$$\forall = \left(0.1 \times 0.1 \times \frac{2.5}{\sin\theta}\right)$$

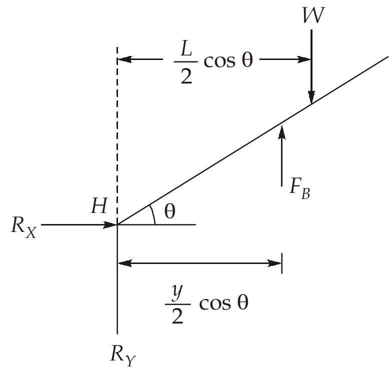
Buoyant force (F_b)

$$F_b = \rho \forall g = 10^3 \times 0.01 \times \frac{2.5}{\sin\theta} \times 10$$

$$= \frac{250}{\sin\theta} \text{N}$$

FBD

at equilibrium



$$\Sigma M_H = 0$$

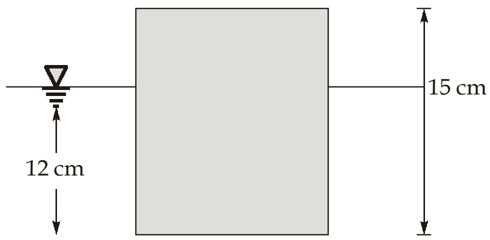
$$W \frac{L}{2} \cos\theta = F_B \frac{y}{2} \cos\theta$$

$$500 \times 5 = \frac{250}{\sin\theta} \times \frac{2.5}{\sin\theta}$$

$$\sin\theta = \frac{1}{2}$$

$$\theta = 30°$$

30. (d)



$$mg = F_B$$

$$\rho_w A(15)g = \rho_f A(12)g$$

$$\frac{\rho_w}{\rho_f} = \frac{12}{15} = \frac{4}{5} = 0.8$$

BM = Minimum metacentric radius

$$= \frac{I_{min}}{V_d} = \frac{\frac{1}{12}(10)^3(20)}{20 \times 10 \times 12} = 0.69 \text{ cm}$$

BM′ = Maximum metacentric radius

$$= \frac{I_{max}}{V_d} = \frac{\frac{1}{12}(10)(20)^3}{10 \times 20 \times 12} = 2.78 \text{ cm}$$

$$GB = \frac{15}{2} - \frac{12}{2} = 1.5 \text{ cm}$$

$$GM = BM - BG = 0.69 - 1.5 = -0.81 \text{ cm (unstable)}$$

■■■■

$$u(t) \leftrightarrow \frac{1}{s}$$

$$u(t-2) \leftrightarrow \frac{e^{-2s}}{s} = X_1(s)$$