CLASS TEST

S.No. : 01 PT_CE_ABC_300522

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FLUID MECHANICS

CIVIL ENGINEERING

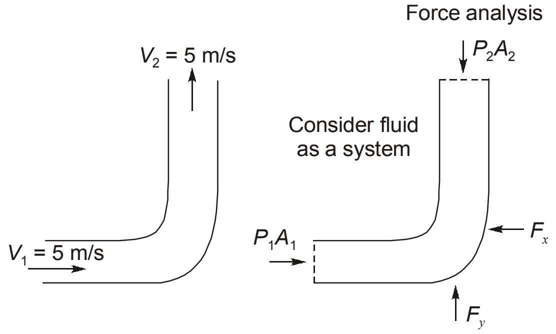
Date of Test : 08/06/2022

ANSWER KEY ➤ Fluid Mechanics

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

DETAILED EXPLANATIONS

1. (d)



$P_1 = P_2 = 4000$ Pa
$D_1 = D_2 = 30$ cm
$F_x\ F_y$ = Force exerted on the fluid

Momentum eq. in y-direction.

$$F_y - P_2A_2 = \dot{m}V_2 - \dot{m}(0)$$

$$F_y = \dot{m}V_2 + P_2A_2$$

$$= (\rho A_2 V_2)V_2 + P_2A_2$$

$$= \left[(1000)(5)^2\right] + 4000\left[\frac{\pi}{4}(0.3)^2\right]$$

$$= 2.05 \text{ kN}$$

2. (c)

Whirlpool is a example of free vortex flow.

So, $v \propto \frac{1}{r}$ i.e. vr = constant

Now, $v_1 = 10$ m/s, $r_1 = 20$ cm
When $r_2 = 50$ cm

$$v_2 = \frac{v_1 r_1}{r_2} = \frac{10 \times 20}{50} = 4 \text{ m/s}$$

According to fundamental equation of vortex flow,

$$dP = \frac{\rho v^2 dr}{r} - \rho g dz \quad \left\{v = \frac{c}{r}\right\}$$

$$0 = \frac{\rho C^2}{r^2 r} dr - \rho g dz$$

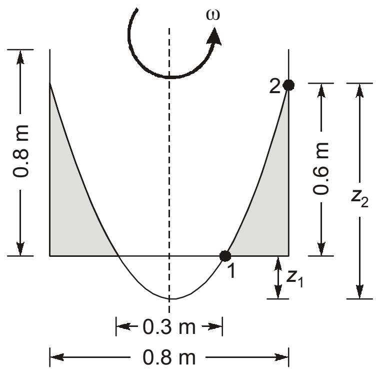
$$dz = \frac{\rho C^2}{r^3 g} dr$$

Int. it

$$z = \frac{c^2}{g} \times -\frac{1}{2} \times \left[\frac{1}{r^2}\right]_{0.5}^{\infty} \qquad [c = vr = 0.2 \times 10]$$

$$z = 0.816 \text{ m}$$

3. (b)



$$z_2 - z_1 = \frac{\omega^2}{2g}\left[R_2^2 - R_1^2\right]$$

$$0.6 = \frac{\omega^2}{2g}\left[0.4^2 - 0.15^2\right]$$

$$\omega = 9.253 \text{ rad/sec}$$

$$\frac{2\pi N}{60} = 9.253$$

$$N = 88.36 \text{ rpm}$$

4. (a)

Shear stress, $\tau = \mu\frac{du}{dy} = 0.44\times\frac{4}{0.018}$

$= 97.8$ Pa

5. (d)

In Navier's-Stoke equation viscous force term is considered and in all the above mentioned flow viscous force can't be neglected.

6. (c)

$K = 2.1 \times 10^9$ Pa; $E = 2.1 \times 10^{11}$ Pa

$\rho = 1000$ kg/m^3; $D = 400$ mm

$t = 4$ mm

Velocity of propagation of water hammer pressure

$$= \sqrt{\frac{K/\rho}{1+\frac{KD}{Et}}} = \sqrt{\frac{2.1\times\frac{10^9}{1000}}{1+1}} = 1024.7 \text{ m/s}$$

7. (b)

In a turbulent boundary layer, near the boundary large velocity change occurs in a relatively small vertical distance, and hence at the boundary the velocity gradient $\left(\frac{du}{dy}\right)$ is steeper in turbulent boundary layer than in a laminar boundary layer. The velocity distribution in a turbulent boundary layer follows a logarithm law, which can also be represented by a power law of the type.

$$\frac{u}{U} = \left(\frac{y}{\delta}\right)^n$$

The value of the exponent n is approximately (1/7) for the moderate Reynolds number.

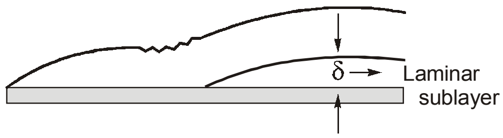
8. (b)

$$\delta^* = \int_0^\delta \left(1 - \frac{u}{U}\right) dy = \int_0^\delta \left(1 - \left(\frac{y}{\delta}\right)^{1/6}\right) dy$$

$$\delta^* = \left[y - \frac{6y^{7/6}}{7\delta^{1/6}}\right]_0^\delta = \delta - \frac{6\delta}{7} = \frac{\delta}{7}$$

$$\therefore \quad \frac{\delta^*}{\delta} = \frac{1}{7}$$

9. (c)



11. (a)

For parallel connection in pipe,

Total discharge, $Q = 250\ lt/s = 0.25\ m^3/s$

$$Q = Q_1 + Q_2$$

$$Q_1 + Q_2 = 0.25\ m^3/s \quad \text{... (i)}$$

For parallel connection head loss in both pipes will be same so,

$$h_{f1} = h_{f2}$$

$$\frac{fL_1Q_1^2}{12.1 \times d_1^5} = \frac{fL_2Q_2^2}{12.1 \times d_2^5} \quad [\because L_1 = L_2]$$

$$\frac{Q_1^2}{0.8^5} = \frac{Q_2^2}{0.6^5}$$

$$\frac{Q_1}{Q_2} = \left(\frac{0.8}{0.6}\right)^{5/2} = 2.05$$

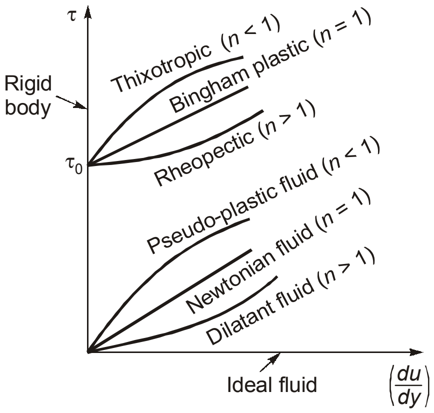
$$Q_1 = 2.05\ Q_2 \quad \text{... (ii)}$$

By equations (i) and (ii),

$$2.05Q_2 + Q_2 = 0.25,\ Q_2 = 0.0814\ m^3/s$$

$$Q_1 = 0.25 - 0.082 = 0.168\ m^3/s$$

12. (b)



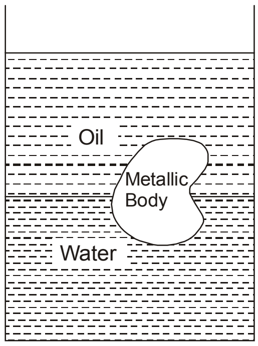
13. (a)

Let V = Volume of metallic body

45% of volume is in oil

i.e., V_{oil} = 45% of V = $0.45V$

and $V_{water} = 0.55V$



For equilibrium condition,

Net buoyant force = $(F_B)_w + (F_B)_{oil}$

= Weight of body

$$M_b g = \rho_w V_w g + \rho_{oil} V_{oil} g$$

$$M_b = \rho_w V_w + \rho_{oil} V_{oil}$$

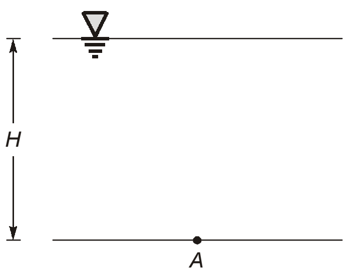
$$\rho_b V = \rho_w \times 0.55V + \rho_{oil} \times 0.45V$$

or $$\rho_b = \rho_w \times 0.55 + \rho_{oil} \times 0.45$$

$$= 1000 \times 0.55 + 700 \times 0.45$$

$$= 550 + 315 = 865 \text{ kg/m}^3$$

15. (b)



$$P_A = 4.2 \text{ MPa} \quad \text{[Absolute pressure]}$$
$$P_{atm} = 101 \text{ kPa}$$
$$\rho = 1050 \text{ kg/m}^3$$
$$g = 9.8 \text{ m/s}^2$$
$$P_A = P_{atm} + \rho g H$$
$$4.2 \times 10^6 = (101 \times 10^3) + [1050 \times 9.81 \times H]$$
$$H = 397.94 \text{ or } 398 \text{ m}$$

16. (b)

For 2D-flow velocity field is:

$$\vec{V} = \frac{x}{x^2 + y^2}\hat{i} + \frac{y}{x^2 + y^2}\hat{j}$$

so $u = \frac{x}{x^2 + y^2}$ and $v = \frac{y}{x^2 + y^2}$

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}$$
$$= \frac{x}{x^2 + y^2}\frac{\partial}{\partial x}\left[\frac{x}{x^2 + y^2}\right] + \frac{y}{x^2 + y^2}\frac{\partial}{\partial y}\left[\frac{x}{x^2 + y^2}\right]$$
$$= \frac{x}{x^2 + y^2}\left[\frac{x(-2x)}{(x^2 + y^2)^2} + \frac{1}{x^2 + y^2}\right] + \frac{y}{x^2 + y^2}\left[\frac{-x(2y)}{(x^2 + y^2)^2}\right]$$
$$= \frac{-2x^3}{(x^2 + y^2)^3} + \frac{x}{(x^2 + y^2)^2} - \frac{2xy^2}{(x^2 + y^2)^3}$$
$$= \frac{-2x^3 + x(x^2 + y^2) - 2xy^2}{(x^2 + y^2)^3}$$
$$= \frac{-2x^3 + x^3 + xy^2 - 2xy^2}{(x^2 + y^2)^3} = \frac{-x^3 - xy^2}{(x^2 + y^2)^3}$$
$$= \frac{-x(x^2 + y^2)}{(x^2 + y^2)^3}$$
$$a_x = \frac{x}{(x^2 + y^2)^2}$$
$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}$$
$$= \frac{x}{x^2 + y^2}\frac{\partial}{\partial x}\left[\frac{y}{x^2 + y^2}\right] + \frac{y}{x^2 + y^2}\frac{\partial}{\partial y}\left[\frac{y}{x^2 + y^2}\right]$$
$$= \frac{x}{x^2 + y^2}\frac{(-2xy)}{(x^2 + y^2)^2} + \frac{y}{x^2 + y^2} \times \left[\frac{-2y^2}{(x^2 + y^2)^2} + \frac{1}{x^2 + y^2}\right]$$
$$= \frac{-2x^2y}{(x^2 + y^2)^3} - \frac{2y^3}{(x^2 + y^2)^3} + \frac{y}{(x^2 + y^2)^2}$$
$$= \frac{-2x^2y - 2y^3 + y(x^2 + y^2)}{(x^2 + y^2)^3} = \frac{-x^2y - y^3}{(x^2 + y^2)^3} = \frac{-y(x^2 + y^2)}{(x^2 + y^2)^3}$$
$$a_y = \frac{-y}{(x^2 + y^2)^2}$$

17. (c)

Given velocity field,

$$\vec{V} = (-x^2 + 3y)\hat{i} + (2xy)\hat{j}$$

where $u = -x^2 + 3y$ and $v = 2xy$

The acceleration components along x and y-axis.

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

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

$$= (-x^2 + 3y) \times (-2x) + 2xy \times 3$$

$$= 2x^3 - 6xy + 6xy = 2x^3$$

and $$a_y = (-x^2 + 3y) \times 2y + 2xy \times 2x$$

$$= -2yx^2 + 6y^2 + 4x^2y = 2yx^2 + 6y^2$$

At point (1, –1),

$$a_x = 2$$

and $$a_y = 2 \times (-1) \times 1 + 6 \times (-1)^2$$

$$= -2 + 6 = 4$$

$$\vec{a} = a_x\hat{i} + a_y\hat{j} = 2i + 4\hat{j}$$

Resultant acceleration,

$$a = \sqrt{4+16} = \sqrt{20}$$

$$= \sqrt{4 \times 5} = 2\sqrt{5}$$

18. (c)

$$\frac{\partial(u^2)}{\partial x} + \frac{\partial(uv)}{\partial y}$$

By differentiating:

$$\Rightarrow \quad 2u\left[\frac{\partial u}{\partial x}\right] + u\frac{\partial v}{\partial y} + v\frac{\partial u}{\partial y}$$

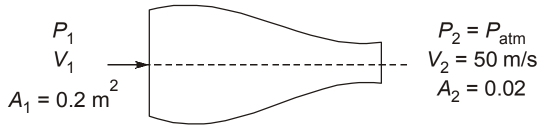
$$\Rightarrow \quad u\frac{\partial u}{\partial x} + \left[u\frac{\partial u}{\partial x} + u\frac{\partial v}{\partial y}\right] + v\frac{\partial u}{\partial y}$$

According to continity eq. : $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

So, $$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}$$

19. (c)

As per given data, $\rho_{air} = 1.23$ kg/m^3



$$A_1V_1 = A_2V_2$$

$$0.2 \times V_1 = 0.02 \times 50$$

$$V_1 = \frac{1}{10} \times 50 = 5 \text{ m/s}$$

Applying BE

$$\frac{P_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + z_2 \qquad (\because z_1 = z_2)$$

$$\frac{P_1 - P_2}{\rho_{air} g} = \frac{V_2^2 - V_1^2}{2g}$$

Pressure difference,

$$P_1 - P_2 = \left(\frac{50^2 - 5^2}{2}\right) \times 1.23$$

$$= 1522.125 \text{ Pa}$$

$$= 1.52 \text{ kPa}$$

20. (c)

Reynold number,

$$\text{Re}_x = \frac{u_\infty x}{\nu} = \frac{2 \times 1}{1.5 \times 10^{-5}} = 1.33 \times 10^5$$

$$\delta = \frac{4.64x}{\sqrt{\text{Re}_x}} = \frac{4.64 \times 1}{\sqrt{1.33 \times 10^5}} = 0.0127$$

Now, $\frac{du}{dy} = u_\infty \left[\frac{3}{2} \cdot \frac{1}{\delta} - \frac{3}{2}\left(\frac{y^2}{\delta^3}\right)\right]$

$$\left.\frac{du}{dy}\right|_{y=0} = \frac{3u_\infty}{2\delta}$$

Now, shear stress,

$$\tau_0 = \mu\left(\frac{du}{dy}\right)_{y=0} = \mu \times \frac{3u_\infty}{2\delta}$$

$$= \frac{3u_\infty \times \nu \times \rho}{2\delta} \qquad \because \mu = \nu\rho$$

$$= \frac{3 \times 2 \times 1.5 \times 10^{-5} \times 1.23}{2 \times 0.0127}$$

$$= \mathbf{4.36 \times 10^{-3} \ N/m^2}$$

21. (d)

Radius: $r = 10$ mm

$\therefore$ Diameter: $d = 2r = 2 \times 10 = 20$ mm $= 0.02$ m

$$\dot{m} = 36 \text{ kg/hr} = \frac{36}{3600} = 0.01 \text{ kg/s}$$

$$\mu = 0.001 \text{ kg/ms}$$

Reynolds number: $Re = \frac{\rho V d}{\mu}$

From continuity equation, $\dot{m} = \rho A V$

or $V = \frac{\dot{m}}{\rho A} = \frac{\dot{m}}{\frac{\rho \pi d^2}{4}} = \frac{4\dot{m}}{\rho \pi d^2}$

$$\therefore \quad Re = \frac{\rho d}{\mu} \times \frac{4\dot{m}}{\rho \pi d^2} = \frac{4\dot{m}}{\pi \mu d}$$

$$= \frac{4 \times 0.01}{3.14 \times 0.001 \times 0.02} = \mathbf{637}$$

22. (c)

Instantaneous velocity : $u = \bar{u} + u'$

The time-average of the fluctuating velocity

$$\bar{u}' = \frac{1}{T}\int_0^T u'dt = \frac{1}{T}\int_0^T (u - \bar{u})dt$$

$$= \frac{1}{T}\int_0^T udT - \frac{1}{T}\bar{u}\int_0^T dt = \bar{u} - \frac{\bar{u}}{T}T$$

$$= \bar{u} - \bar{u} = \mathbf{0}$$

24. (a)

Shear stress on wall,

$$\tau_w = -\frac{\partial p}{\partial x}\frac{R}{2}$$

where $-\frac{\partial p}{\partial x} = \frac{\Delta p}{L}$

Δp = Pressure drop

and $R = \frac{D}{2}$

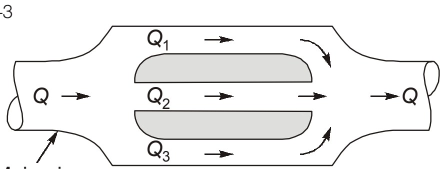
$$\therefore \quad \tau_w = \frac{\Delta p}{L} \times \frac{D}{2 \times 2} = \frac{\Delta pD}{4L}$$

25. (b)

Total discharge,

$$Q = Q_1 + Q_2 + Q_2$$

Head loss: $h_L = h_{L_1} = h_{L_2} = h_{L3}$



Three pipes in parallel

For the pipe connected in series,

Total discharge,

$$Q = Q_1 = Q_2 = Q_3$$

Head loss; $h_L = h_{L_1} + h_{L_2} + h_{L_3}$

26. (c)

Head loss: $h_f = \frac{32\mu\bar{u}L}{\rho g D^2}$

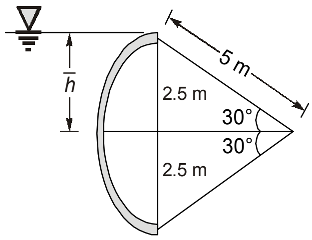
$$h_1 = \frac{32\mu\bar{u}L}{\rho g D^2}$$

and $$h_2 = \frac{32\mu \times 2\bar{u}L}{\rho g (D/2)^2}$$

$$= \frac{32\mu 2\bar{u}L \times 4}{\rho g D^2} = \frac{8 \times 32\mu\bar{u}L}{\rho g D^2}$$

$$\frac{h_2}{h_1} = \frac{8 \times 32\mu\bar{u}L}{\rho g D^2} \times \frac{\rho g D^2}{32\mu\bar{u}L} = 8$$

27. (d)



$$F_x = \rho g \bar{h} A_V = (10^3)(10)\left(\frac{5}{2}\right)(5 \times 1)$$

$$= 125 \text{ kN per unit width}$$

$$F_y = \rho g \forall$$

where $$\forall = \frac{\pi(5)^2}{6} - \left(\frac{1}{2} \times 5 \times 5 \cos 30°\right) = 2.264 \text{m}^3$$

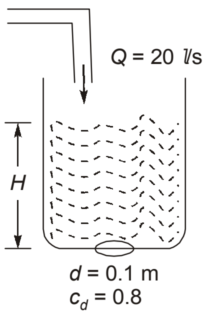
$$F_y = (10)^3 (10)(2.264) = 22.64 \text{ kN}$$

Resultant force per unit width,

$$F_R = \sqrt{F_x^2 + F_y^2} = \sqrt{125^2 + 22.64^2}$$

$$= 127.03 \text{ kN}$$

28. (a)



Assume H is the level of water in the tank in steady condition.

For steady water level in the tank

Discharge through orifice

= Water enters in the tank

$$c_d \cdot a \cdot \sqrt{2gH} = 20 \times 10^{-3}$$

$$0.8 \times \frac{\pi}{4}(0.1)^2 \sqrt{2gH} = 0.02$$

$$H = 0.52 \text{ m}$$

29. (b)

$$Q = 0.21 \text{ m}^3/\text{s}$$

Allowable velocity = 0.75 m/s

$$f = 0.01$$

$$g = 9.81 \text{ m/s}^2$$

$$Q = A\,V$$

$$0.21 = \left(\frac{\pi}{4}d^2\right)(0.75)$$

$$\Rightarrow \quad d = 0.597 \text{ m}$$

$$\Rightarrow \quad h_f = \frac{flV^2}{2gd} = \frac{0.01\times 100\times (0.75)^2}{2\times 9.81\times 0.597}\text{m}$$

$$= 4.8 \text{ cm}$$

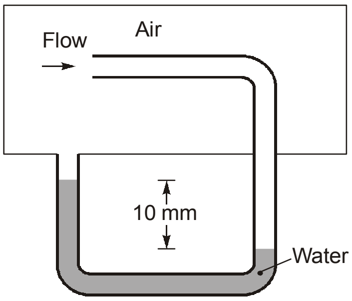
$$= 0.048 \text{ m}$$

$$\Rightarrow \text{Min. gradient} = \frac{h_f}{l} = \frac{4.8\text{cm}}{100\text{m}}$$

Hence, **answer is 4.8.**

30. (c)

Given data:



Density of air,

$$\rho_a = 1.2 \text{ kg/m}^3$$

Density of water,

$$\rho_w = 1000 \text{ kg/m}^3$$

Differential head in manometer,

$$h = 10 \text{ mm of water} = 0.01 \text{ m of water}$$

This reading is the dynamic pressure head. Hence dynamic pressure,

$$p_{dyn} = (\rho g h)_{water} = \rho_w g h$$

$$= 1000 \times 9.81 \times 0.01 = 98.1 \text{ N/m}^2$$

also $p_{dyn} = \left(\frac{1}{2}\rho V^2\right)_{air} = \frac{1}{2}\rho_a V^2$

$$\therefore \quad 98.1 = \frac{1}{2}\times 1.2\times V^2$$

or $V^2 = 163.5$

$$V = \mathbf{12.78 \text{ m/s}}$$

Alternatively

$$V = \sqrt{2gh}$$

$$h = x\left(\frac{\rho_m}{\rho} - 1\right)$$

where

x = Reading of differential manometer
= 10×10^{-3} m

ρ_m = Density of manometric fluid
= 1000 kg/m^3

ρ = Density of following fluid = 1.2 kg/m^3

$$\therefore \; V = \sqrt{2 \times 9.81 \times 10 \times 10^{-3}\left(\frac{1000}{1.2} - 1\right)}$$

V = 12.779 m/s ≈ **12.8 m/s**

■■■■