CLASS TEST

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 24/07/2023

ANSWER KEY

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

Detailed Explanations

1. (c)

2. (d)

3. (b)

$$v = \frac{\partial\psi}{\partial x} = \frac{\partial(6x^2 - y^3)}{\partial x} = 12x$$

$$u = \frac{-\partial\psi}{\partial y} = \frac{-\partial(6x^2 - y^3)}{\partial y} = 3y^2$$

At point (2, 1),

$$v = 24 \text{ units}$$

$$u = 3 \text{ units}$$

$\therefore$ The total velocity is the vector sum of two components i.e.,

$$\Rightarrow \quad V = \sqrt{u^2 + v^2} = \sqrt{3^2 + 24^2} = 24.19 \text{ units}$$

4. (d)

For a laminar boundary layer

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

$$\Rightarrow \quad \frac{\delta}{x} = \frac{5}{\sqrt{\frac{\rho v x}{\mu}}}$$

$$\therefore \quad \delta \propto \sqrt{x}$$

$$\therefore \quad \frac{\delta_2}{\delta_1} = \sqrt{\frac{2x_1}{x_1}} \Rightarrow \delta_2 = \sqrt{2}\,\delta_1$$

5. (a)

Ideal fluid has zero viscosity.

6. (b)

Let V be the volume of fluid

$$\therefore \quad dV = \frac{-6}{100} \times V$$

$$\Rightarrow \quad \frac{-dV}{V} = 0.06$$

$\therefore$ Increase in pressure $\Delta P = \dfrac{-\Delta V}{V} \times K$

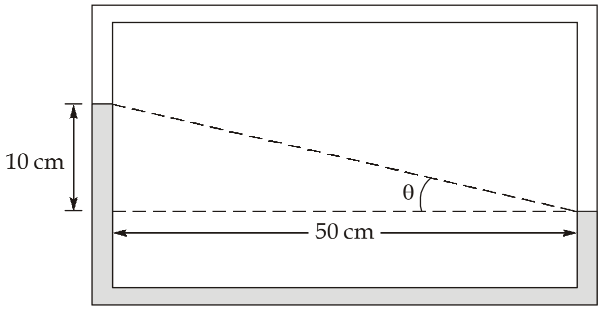
Where 'K' is bulk modulus.

$$= 1.5 \times 10^9 \times 0.06 \text{ Pa}$$

$$= 0.090 \text{ GPa}$$

7. (b)

8. (c)



$$\tan\theta = \frac{a_x}{g} = \frac{10}{50}$$

$$\frac{a_x}{g} = \frac{10}{50}$$

$$a_x = 1.962 \text{ m/s}^2$$

9. (c)

We know that Chezy's constant,

$$C = \sqrt{\frac{8g}{f}}$$

As given R_e i.e. is 320 is less than 2000, the flow would be laminar.

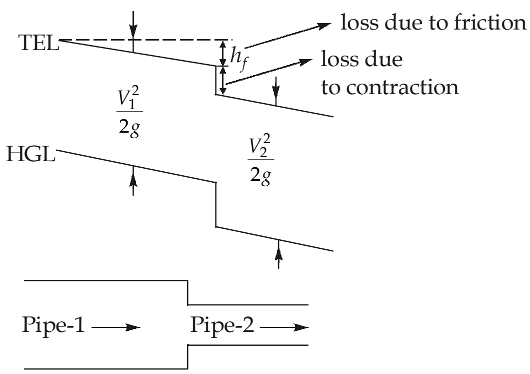
For laminar flow, $$f = \frac{64}{R_e}$$

$$f = \frac{64}{320} = \frac{1}{5}$$

$$C = \sqrt{\frac{8 \times 9.81}{\frac{1}{5}}}$$

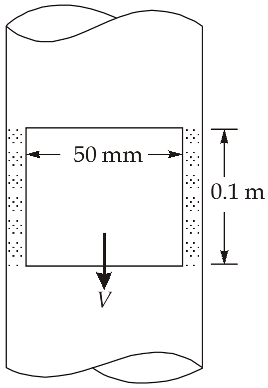
$$C = 19.80 \text{ m}^{1/2} \text{ s}^{-1}$$

10. (b)



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

11. (a)



Let V be its terminal velocity of fall

Shear stress τ will be

$$\tau = \mu \frac{dv}{dy} = 1.9 \times \frac{V}{1 \times 10^{-3}}$$

$$= 1.9 \times 10^3 \; V \text{ N/mm}^2$$

The shear stress will act on the surface of the cylinder.

Hence, Total force, $F = \tau \times A$

$$= 1.9 \times 10^3 \times V \times 3.142 \times 50 \times 10^{-3} \times 0.1$$

$$= 29.849 \text{ V}$$

Under equilibrium condition, the weight will be balanced by total shear force.

Hence,

$$16 = 29.849 \text{ V}$$

or $V = 0.536$ m/s

12. (d)

	u	v	$\frac{\partial v}{\partial x}$	$\frac{\partial u}{\partial y}$
A	$x + y$	$2x - y$	2	1
B	$2x + 3y$	$-2y^2 + x$	1	3
C	x^2	$-2xy$	$-2y$	0
D	$-2x$	$2y$	0	0

For irrotational flow $\frac{\partial v}{\partial x} = \frac{\partial u}{\partial y}$

13. (a)

Reynold number at the trailing end,

$$Re_L = \frac{UL}{\nu} = \frac{1 \times 3}{10^{-5}} = 3 \times 10^5 < 5 \times 10^5$$

$\Rightarrow$ Boundary layer is laminar over the entire length of plate.

Thus, thickness of boundary layer at the end of the plate from Blasius's solution is,

$$\delta = \frac{5 \times L}{\sqrt{Re_L}} = \frac{5 \times 3}{\sqrt{3 \times 10^5}} = 0.0274 \text{ m}$$

$$\simeq 27.4 \text{ mm}$$

14. (b)

The mean velocity of flow V is given by, $V = \dfrac{Q}{A}$

where,
$$Q = \int_0^R 2\pi r V_{max}\left(1-\frac{r}{R}\right)^n dr$$

$$Q = \frac{2\pi R^2 V_{max}}{(n+1)(n+2)}$$

$$V = \frac{2V_{max}}{(n+1)(n+2)} \qquad [\because A = \pi R^2]$$

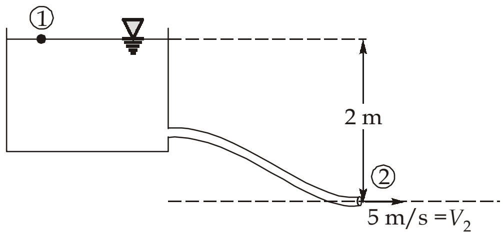
15. (d)

16. (a)

$$h_p = \bar{x} + \frac{I_{xx}}{A\bar{x}} = \bar{x} + \frac{d^2}{12\bar{x}}$$

as $\left(I_{xx} = \dfrac{bd^3}{12}\right.$ and $\left.A = bd\right)$

17. (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,
$V_1 = 0$
$P_1 = P_2 = 0$ (Gauge Pressure)
$z_1 = 2$ m (given)

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

$$h_f = 0.75 \text{ m}$$

From Darcy-Weisbach equation,

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

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

$$L = 3 \text{ m}$$

18. (a)

Given $\tau_{wall} = 0.3\text{kPa}$

$\mu = 9 \text{ Poise} = 0.9 \text{ Pa-s}$

$R = 15 \text{ cm} = 0.15 \text{ m}$

We know that, $$\tau_{wall} = \frac{R}{2}\left(\frac{\partial P}{\partial x}\right)$$

$$0.3 \times 10^3 \text{ Pa} = \frac{0.15 \text{ m}}{2}\left(\frac{\partial P}{\partial x}\right)$$

$$\left(\frac{\partial P}{\partial x}\right) = 4 \text{ kPa/m}$$

For laminar flow in pipe,

$$u_{max} = \frac{1}{4\mu}\left(\frac{\partial P}{\partial x}\right)\left(R^2\right)$$

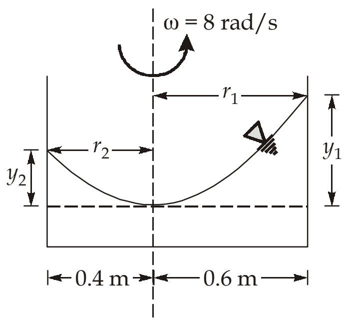
$$u_{max} = \frac{1}{4 \times 0.9 \text{ Pa-s}} \times \left(4 \times 10^3 \text{ Pa/m}\right) \times (0.15)^2 \text{ m}^2$$

$$u_{max} = 25 \text{ m/s}$$

We know, $$u_{mean} = \frac{u_{max}}{2} \qquad \text{(For laminar flow in pipe)}$$

$$u_{mean} = 12.5 \text{ m/s}$$

19. (b)



Difference in level of water,

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

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

$$y_1 - y_2 = \frac{64 \times 10^{-2} \times (36 - 16)}{20} = 0.64 \text{ m}$$

20. (b)

- Cavitation can be prevented by reducing the velocity head as pressure head increases.
- When the flow contracts, it becomes rotational due to Eddie formation and pressure decreased after contraction instead of increase.

21. (b)

We know that Kinetic energy correction factor for laminar flow between stationary plates is 1.54 and for laminar flow through pipe is 2.0 .

$$\text{Ratio} = \frac{1.54}{2} = 0.77$$

22. (d)

Given: $D_1 = 200$ mm, $D_2 = 400$ mm

Velocity in smaller diameter pipe,

$$V_1 = \frac{Q}{A_1} = \frac{0.250 \text{ m}^3/\text{s}}{\frac{\pi}{4}\times(0.2)^2} = 7.96 \text{ m/s}$$

Velocity in larger diameter pipe,

$$V_2 = \frac{Q}{A_2} = \frac{0.250 \text{ m}^3/\text{s}}{\frac{\pi}{4}\times(0.4)^2} = 1.99 \text{ m/s}$$

Loss of head due to sudden enlargement is given by,

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

23. (a)

In spherical water droplet,

$$\Delta P = \frac{2\sigma}{R_{drop}}$$

In water jet, $$\Delta P = \frac{\sigma}{R_{jet}}$$

$$\Delta P_{jet} = \frac{\Delta P_{drop}}{2} \times \frac{R_{drop}}{R_{jet}}$$

$$= \frac{5}{2} \times \frac{R}{2R}$$

$$\Delta P_{\text{jet}} = 1.25 \text{ kPa}$$

24. (a)

Remember, if $$\frac{u}{U} = \left(\frac{y}{\delta}\right)^{1/m}$$

$$\delta^* = \frac{\delta}{m+1}$$

$$\theta = \frac{m\delta}{(m+2)(m+1)}$$

$$\Rightarrow \qquad \frac{\delta^*}{\theta} = \frac{m+2}{m} = \frac{8}{6}$$
$$= 1.33$$

25. (a)

Local velocity at a point = Average velocity

$$u = \bar{U}$$

For a smooth or rough pipe,

$$\frac{u-\bar{U}}{V_*} = 5.75\log\left(\frac{y}{R}\right)+3.75$$

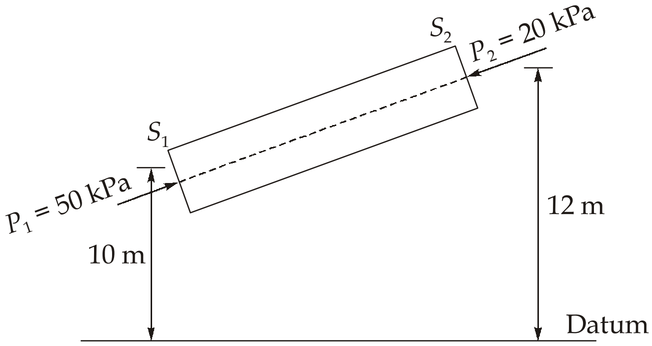
$$\frac{\bar{U}-\bar{U}}{V_*} = 5.75\log\left(\frac{y}{R}\right)+3.75$$

$$\log\left(\frac{y}{R}\right) = -\frac{3.75}{5.75} = -0.6521$$

$$\frac{y}{R} = 10^{-0.6521} = 0.2228$$

$$y = 0.223\,R$$

26. (d)



Velocity of flow, $V_1 = V_2 = 2$ m/s

Net head at section 1 (S_1)

$$H_1 = \frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1 = \frac{50\times10^3}{1000\times9.81}+\frac{(2)^2}{2\times9.81}+10 = 15.3\text{ m}$$

Net head at section 2 (S_2)

$$H_2 = \frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2 = \frac{20\times10^3}{1000\times9.81}+\frac{(2)^2}{2\times9.81}+12 = 14.24\text{ m}$$

Since, net head at section 1 is greater than at section 2, so the flow direction is from section S_1 to S_2.

$\therefore$ Head loss, $H_L = H_1 - H_2$

$= 15.3 - 14.24 = 1.06$ m

27. (a)

For pipes in series

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

$$\Rightarrow \quad \frac{6000}{d^5} = \frac{1000}{(0.2)^5} + \frac{2000}{(0.4)^5} + \frac{3000}{(0.6)^5}$$

$$\Rightarrow \quad d = 0.282 \text{ m} \quad \text{or} \quad d = 282 \text{ mm}$$

28. (a)

Since for flow of fluids through pipes only viscous and inertia forces predominant, Reynolds model law is the criterion for similarity. Thus

$$\left(\frac{Vd}{\upsilon}\right)_m = \left(\frac{Vd}{\upsilon}\right)_p$$

By substitution, we get

$$\frac{4 \times 150 \times 10^{-3}}{1.145 \times 10^{-6}} = \frac{V \times 75 \times 10^{-3}}{3.0 \times 10^{-6}}$$

$$\therefore \quad V = 20.96 \text{ m/s}$$

29. (c)

In Venturimeter,

Rate of flow, $$Q = \frac{C_d A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh}$$

Here, $$h = 20\left(\frac{\rho_{Hg}}{\rho_w} - 1\right) = 20\left(\frac{13.6 \times 10^3}{10^3} - 1\right) = 20(13.6 - 1) = 252 \text{ cm}$$

$$\therefore \quad Q = \frac{0.98 \times \frac{\pi}{4} \times 30^2 \times \frac{\pi}{4} \times 15^2}{\sqrt{\left[\frac{\pi}{4} \times 30^2\right]^2 - \left[\frac{\pi}{4} \times 15^2\right]^2}} \times \sqrt{2 \times 981 \times 252}$$

$$= \frac{0.98 \times 30^2 \times \frac{\pi}{4} \times 15^2}{\sqrt{30^4 - 15^4}} \times \sqrt{2 \times 981 \times 252}$$

$$= 125.76 \times 10^3 \text{ cm}^3/\text{s}$$

$$= 125.76 \; l/\text{s}$$

30. (a)

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