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Fluid Mechanics

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CLASS TEST 2019-2020

CIVIL ENGINEERING

Date of Test : 10/06/2019

ANSWER KEY ➤ Fluid Mechanics

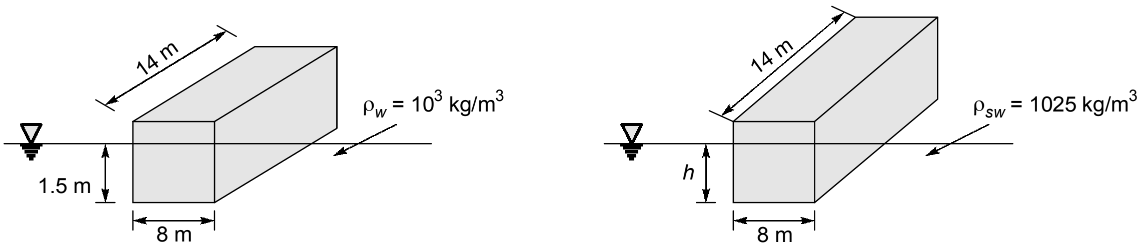
1.	(c)	7.	(c)	13.	(c)	19.	(c)	25.	(d)
2.	(b)	8.	(a)	14.	(d)	20.	(d)	26.	(d)
3.	(b)	9.	(d)	15.	(d)	21.	(c)	27.	(d)
4.	(a)	10.	(b)	16.	(a)	22.	(a)	28.	(a)
5.	(d)	11.	(b)	17.	(d)	23.	(b)	29.	(a)
6.	(b)	12.	(b)	18.	(b)	24.	(c)	30.	(c)

DETAILED EXPLANATIONS

2. (b)

$$P_A + \rho_w \cdot g\,(0.5) = \rho_{Hg} \cdot g\,(0.43)$$
$$P_A = (13.6 \times 10^3) \times g \times (0.43) - (10^3) \times g\,(0.5) \text{ Pa}$$
$$\frac{P_A}{P_w . g} = \frac{(13.6 \times 10^3).g.(0.43) - (10^3).g.(0.5)}{(10^3).g}$$
$$= (13.6 \times 0.43) - 0.5 = 5.35 \text{ m of } H_2O$$

5. (d)



In both the cases the weight of rectangular portion remains same and balanced by Buoyancy force. So,

$$Mg = F_{B\,\text{water}} \quad \text{...(i)}$$
$$Mg = F_{B\,\text{sea water}} \quad \text{...(i)}$$

By equation (i) and (ii)

$$F_{B\,\text{water}} = F_{B\,\text{sea water}}$$
$$\rho_w\,(14 \times 8 \times 1.5) \,.\, g = \rho_{sw}\,(14 \times 8 \times h) \,.\, g$$
$$(10^3)\,(14 \times 8 \times 1.5) = (1025)\,(14 \times 8 \times h)$$
$$h = 1.46 \text{ m}$$

7. (c)

$$\text{Given stream function } (\Psi) = 2xy$$
$$u = -\frac{\partial \Psi}{\partial y} = (-2x)$$
$$V = \frac{\partial \Psi}{\partial x} = 2y$$

at (1, 2) $\quad u = -2$ ms, $V = 4$ ms

$$V = \sqrt{u^2 + V^2} = \sqrt{(-2)^2 + (4)^2} = \sqrt{20}$$

8. (a)

Bernoulli equation used in pipe flow, each term represent energy per unit weight (Head form).

10. (b)

Shear velocity is fictitious quantity having dimension of velocity

$$V^* = \sqrt{\frac{\tau_0}{\rho}}, \qquad \tau_0 = \text{boundary shear stress}$$

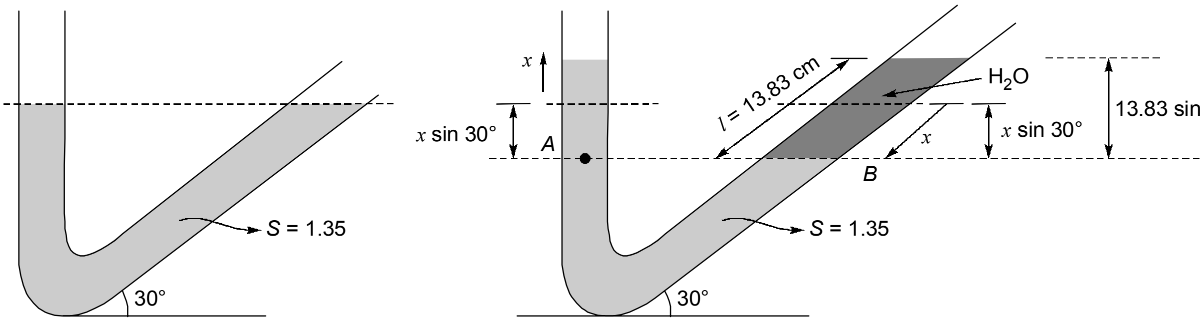
11. (b)

$$\frac{p_1}{\rho g} + y + \frac{hS_2}{S_1} = \frac{p_2}{\rho g} + h + y$$

$$\therefore \quad \frac{p_2 - p_1}{\rho g} = h\left(\frac{S_2}{S_1} - 1\right) = \frac{V_1^2}{2g}$$

$$\therefore \quad V_1 = \sqrt{2gh\left(\frac{S_2}{S_1} - 1\right)}$$

12. (b)



$$l = \frac{V}{a} = \frac{8.3}{0.6} = 13.83 \text{ cm}$$

According to Pascal Law

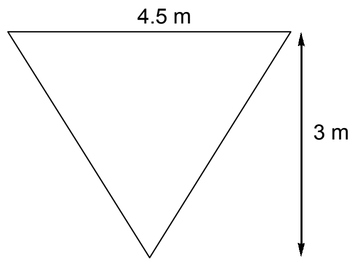
$$P_A = P_B$$

$$(1.35 \times 10^3) \,.\, g \,.\, (x + x \sin 30°) = (10^3) \,.\, g \,.\, (13.83 \sin 30°)$$

$$(1.35)\left(\frac{3x}{2}\right) = \frac{13.83}{2}$$

$$x = 3.41 \text{ cm}$$

13. (c)



$$\text{centre of pressure } (h_P) = h_c + \frac{I_{GG}}{Ah_c}$$

$$A = \left(\frac{1}{2} \times 4.5 \times 3\right) = 6.75 \text{ m}^2$$

$$I = \frac{bh^3}{36} = 3.375 \text{ m}^4$$

$$h_c = \frac{3}{3} = 1 \text{ m}$$

$$h_p = 1 + \frac{3.375}{(6.75 \times 1)} = 1.5 \text{ m}$$

14. (d)

$\forall_b \Rightarrow$ Volume of body

$\forall_w \Rightarrow$ Displaced volume of water

$\forall_{Hg} \Rightarrow$ Displaced volume of Hg

$$\text{weight} = \text{Buoyance force}$$

$$\text{weight} = F_{B_w} + F_{B_{Hg}}$$

$$\rho_b . \forall_b . g = \rho_w . \forall_w . g + \rho_{Hg} . \forall_{Hg} . g$$

Divide by $\rho_w . g$

$$\frac{\rho_b}{\rho_w} . \forall_b = \forall_w + \frac{\rho_{Hg}}{\rho_w} . \forall_{Hg} \qquad \{\forall_b = \forall_w + \forall_{Hg}\}$$

$$8.6 \forall_b = \forall_w + 13.6(\forall_b - \forall_w)$$

$$12.6 \forall_w = 5 \forall_b$$

$$\frac{\forall_w}{\forall_b} \times 100 = \frac{5}{12.6} \times 100 = 39.68$$

15. (d)

For steady and incompressible flow continuity equation must be satisfied

$$\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y} + \frac{\partial w}{\partial z} = 0$$

$$\lambda y^3 - 2xy + 2xy - 3y^3 + 0 = 0$$

$$y3(\lambda - 3) = 0$$

$$\lambda = 3$$

16. (a)

$$\Gamma = \text{Vorticity} \times \text{Area}$$

Given: $x^2 + y^2 - 2ay = 0$

$$(x - 0)^2 + (y - a)^2 = a^2$$

So, the given area is circle of radius $R = a$

$$\text{Area} = \pi a^2$$

$$\text{Vorticity} = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = \frac{\partial}{\partial x}\left(-6x^2 y\right) - \frac{\partial}{\partial y}\left(2x^3\right) = -12xy - 0 = -12xy$$

So, $\Gamma = -12xy(\pi a^2)$

17. (d)

Discharge through venturimeter

$$Q = \frac{C_d a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

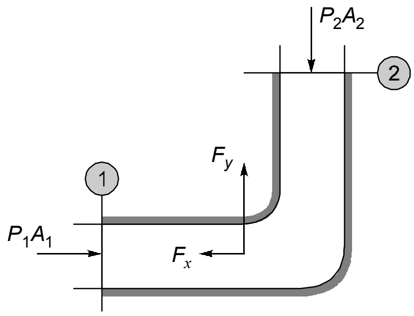
a_1 = cross sectional area of pipe

a_2 = cross sectional area of venturimeter

h = Difference in piezometric heads

$$\therefore \quad Q = \frac{1 \times \left(\frac{\pi}{4} \times (4)^2\right) \times \left(\frac{\pi}{4} \times (0.2)^2\right) \times \sqrt{2 \times 9.81 \times 3}}{\sqrt{\left(\frac{\pi}{4} \times 0.4^2\right)^2 - \left(\frac{\pi}{4} \times 0.2^2\right)^2}} = 0.25 \text{ m}^3/\text{s}$$

18. (b)



In *y*-direction

$$F_y - P_2A_2 = \dot{m}(V_2 - 0)$$
$$F_y - P_2A_2 = \rho \,.\, A_2 \,.\, V_2 \,.\, V_2$$
$$F_y = \rho \,.\, A_2 \,.\, V_2^2 + P_2A_2 = \left[(10^3).(7)^2 + 6000\right]\left[\frac{\pi}{4}(0.4)^2\right] = 6.91 \text{ kN}$$

19. (c)

Given data

$$\text{diameter of pipe} = 120 \text{ mm}$$
$$\text{velocity through pipe} = 0.018 \text{ m/s}$$
$$\text{kinematic viscosity} = 1.13 \times 10^{-6} \text{ m}^2\text{/s}$$
$$\text{Reynold number} = \left(\frac{vd}{\nu}\right) = \frac{0.018 \times 0.12}{(1.13 \times 10^{-6})} = 1911.5$$

as $\text{Re} < 2000$ (Flow is laminar)

$$\text{friction factor} = \frac{64}{\text{Re}} = 0.033$$

20. (d)

For laminar pipe flow flow (circular cross-section)

- Statement 1 is correct

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

For centreline $r = 0$, so shear stress is zero.

- According to Hagen-poiseuille equation

$$h_f = \frac{128}{\pi} \cdot \frac{\mu . Q . L}{\rho . g . D^4}$$

So, statement 2 is incorrect.

- Velocity distribution equation

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

So, velocity is maximum at centre of pipe.
Statement 3 is correct.

- According to Hagen-poiseuille equation

$$h_f = \frac{32 \mu . V . L}{\rho . g . D^4}$$

Hydraulic gradient

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

$$\frac{h_f}{L} \propto V$$

So, statement 4 is incorrect.

21. (c)

$$\delta' = \text{Laminar sublayer}$$
$$V^* = \text{Shear velocity}$$
$$\nu = \text{Kinematic viscosity}$$

$$\delta' = \frac{11.6\,\nu}{V^*}$$

$$V^* = \sqrt{\frac{\tau_0}{\rho}}$$

$$\delta' = \frac{11.6 \times 10^{-6}}{\sqrt{\frac{800}{1000}}} = 12.97 \times 10^{-6} \text{ m}$$

$$\frac{k_s}{\delta'} = \frac{0.12 \times 10^{-3}}{12.97 \times 10^{-6}} = 9.25$$

22. (a)

Given data,

$$L_r = \left(\frac{1}{100}\right)$$
$$\rho_m = 900 \text{ kg/m}^3$$
$$Q_p = 10000 \text{ m}^3\text{/s}$$
$$Q_m = ??$$

According to Froude's Law

$$(\text{Fr})_m = (\text{Fr})_p$$

$$\left(\frac{V}{\sqrt{Lg}}\right)_m = \left(\frac{V}{\sqrt{Lg}}\right)_p \qquad \because g_m = g_p$$

$$V_r = \sqrt{L_r} \qquad \text{...(i)}$$

Now,

$$Q_r = A_r \,.\, V_r = (L_r)^2\left(\sqrt{L_r}\right)$$

$$Q_r = (L_r)^{2.5}$$

$$\frac{Q_m}{Q_p} = \left(\frac{1}{100}\right)^{2.5}$$

$$\frac{Q_m}{10000} = \left(\frac{1}{100}\right)^{2.5}$$

$$Q_m = 0.1 \text{ m}^3\text{/s}$$

23. (b)

Given data,

$$L_r = \left(\frac{1}{100}\right)$$

$$f_m = 0.12\text{ N}$$

The resistance offered is at free surface and is significant.

Therefore froude law is applicable in this case

$$F = \frac{V_m}{\sqrt{gL_m}} = \frac{V_P}{\sqrt{gV_p}}$$

$$V_r = \sqrt{L_r}$$

$$\frac{f_m}{f_p} = \rho L_r^2 V_r^2 = \rho_r L_r^3 \qquad [V_r = \sqrt{L_r}]$$

$$\frac{f_m}{f_p} = (L_r)^3 = \left(\frac{1}{100}\right)^3$$

$$f_p = 120\text{ kN}$$

24. (c)

Neglecting Minor losses

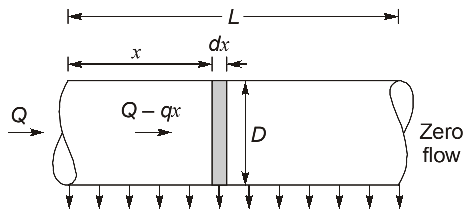
$$h_f = \frac{8Q^2}{\pi^2 g}\frac{f.L}{D^5}$$

$$25 = \frac{8Q^2}{\pi^2 g}\frac{(0.03)(25+180)}{(0.12)^5}$$

$$Q = 34.99 \times 10^{-3}\text{ m}^3/\text{s} = 34.99\ l/s$$

25. (d)

Assume q = uniform discharge per unit length $Q = qL$)



$$dh_f = \frac{8(Q-qx)^2}{\pi^2 g}\frac{fdx}{D^5}$$

Int. it

$$h_f = \frac{8}{\pi^2 g}\frac{f}{D^5}\int_0^L (Q-qx)^2 dx = \frac{8}{\pi^2 g}\frac{f}{D^5}\int_0^L \left[Q^2 + q^2x^2 + 2qQx\right]dx$$

$$= \frac{8}{\pi^2 g}\frac{f}{D^5}\left[Q^2x + \frac{q^2x^3}{3} - \frac{2qQx^2}{2}\right]_0^L$$

$$= \frac{8}{\pi^2 g}\frac{f}{D^5}\left[Q^2L + \frac{q^2L^3}{3} - qQL^2\right] \qquad (\text{Since } Q = qL)$$

$$= \frac{8}{\pi^2 g}\frac{f}{D^5}\left[Q^2L + \frac{Q^2L}{3} - Q^2L\right] = \frac{8Q^2}{\pi^2 g}\frac{fL}{D^5} = \frac{1}{3}$$

26. (d)

$$\text{Velocity of pressure wave} = \sqrt{\frac{k}{\rho}} = c$$

$$\Rightarrow \quad c = \sqrt{\frac{20\times 10^8}{1000}} = 1414.21\text{ m/s}$$

$$\text{Critical time } (t_c) = \frac{2L}{c} = \frac{2\times 3000}{1414.21} = 4.24\text{ sec}$$

$$\text{Given time of closure, } t = 3.5\text{ sec} < t_c$$

$\therefore$ Sudden closure

$$\frac{P}{\rho g} = \frac{V}{g}\sqrt{\frac{k}{\rho}} = \frac{1.5}{9.81}\sqrt{\frac{20\times10^8}{1000}} = 216.21 \text{ m of water}$$

27. (d)

Hardy cross method is used to find out discharge in various pipe is pipe network and not applicable to open channel flow.

28. (a)

Let n number of parachute are needed

given data,
$$\rho_{air} = 1.25 \text{ kg/m}^3,\ c_p = 1.3$$
$$D = 8 \text{ m},\ V_0 = 4 \text{ m/sec}$$

$$\text{Drag force } (F_n) = \frac{1}{2}C_D A\rho V^2 = \frac{1}{2}\times1.3\times\frac{\pi}{4}\times8^2\times1.25\times4^2 = 653.45 \text{ N}$$

$$\text{No. of parachute required} = \left(\frac{1500}{653.45}\right) = 2.29 \simeq 3$$

29. (a)

Laminar Boundary layer thickness

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

$\Rightarrow$ δ increase in flow direction

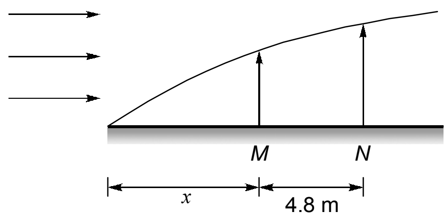
Shear stress at plate,
$$\tau = \frac{1}{2}\rho v^2 ef_x = \frac{1}{2}\rho v^2\frac{0.664}{\sqrt{R_{ex}}}$$
$$\tau \propto \frac{1}{\sqrt{x}}$$

Shear stress decrease in flow direction and pressure gradient $\frac{dP}{dx} = 0$ along flow direction.

30. (c)

We know that,
$$\frac{\delta}{x} = \frac{5}{\sqrt{R_x}}$$

$\Rightarrow$
$$\delta \propto \sqrt{x}$$



Let section m is x_m downstream of loading edge

$$\delta_M = 1.2 \text{ cm},\quad \delta_N = 3.6 \text{ cm}$$
$$x_M = x,\quad x_N = (x + 4.8)$$

$$\frac{1.2}{3.6} = \left(\frac{x}{x+4.8}\right)^{1/2}$$

$$x + 4.8 = 9x$$
$$x = 0.6 \text{ m}$$

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