

CLASS TEST

S.No. : 02 SK1_CE_C_100619

Fluid Mechanics



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CLASS TEST 2019-2020

CIVIL ENGINEERING

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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)

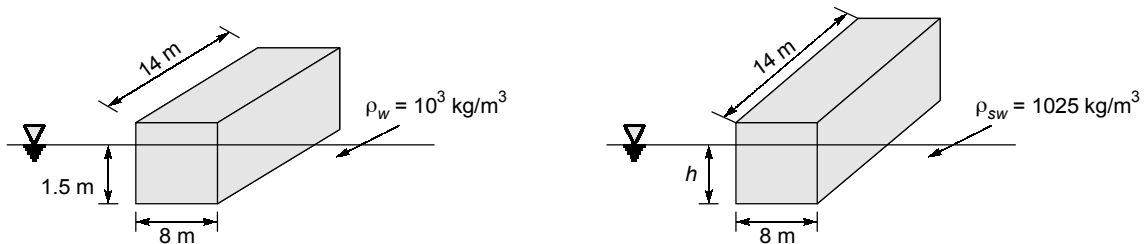
$$P_A + \rho_w \cdot g(0.5) = \rho_{\text{Hg}} \cdot g(0.43)$$

$$P_A = (13.6 \times 10^3) \times g \times (0.43) - (10^3) \times g(0.5) \text{ Pa}$$

$$\frac{P_A}{\rho_w \cdot g} = \frac{(13.6 \times 10^3) \cdot g(0.43) - (10^3) \cdot g(0.5)}{(10^3) \cdot g}$$

$$= (13.6 \times 0.43) - 0.5 = 5.35 \text{ m of H}_2\text{O}$$

5. (d)



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

$$Mg = F_{B \text{ water}} \quad \dots(i)$$

$$Mg = F_{B \text{ sea water}} \quad \dots(ii)$$

By equation (i) and (ii)

$$F_{B \text{ water}} = F_{B \text{ sea water}}$$

$$\rho_w (14 \times 8 \times 1.5) \cdot g = \rho_{sw} (14 \times 8 \times h) \cdot g$$

$$(10^3) (14 \times 8 \times 1.5) = (1025) (14 \times 8 \times h)$$

$$h = 1.46 \text{ m}$$

7. (c)

Given stream function (Ψ) = $2xy$

$$u = -\frac{\partial \Psi}{\partial y} = (-2x)$$

$$v = \frac{\partial \Psi}{\partial x} = 2y$$

at (1, 2)

$$u = -2 \text{ ms}, v = 4 \text{ ms}$$

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

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

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

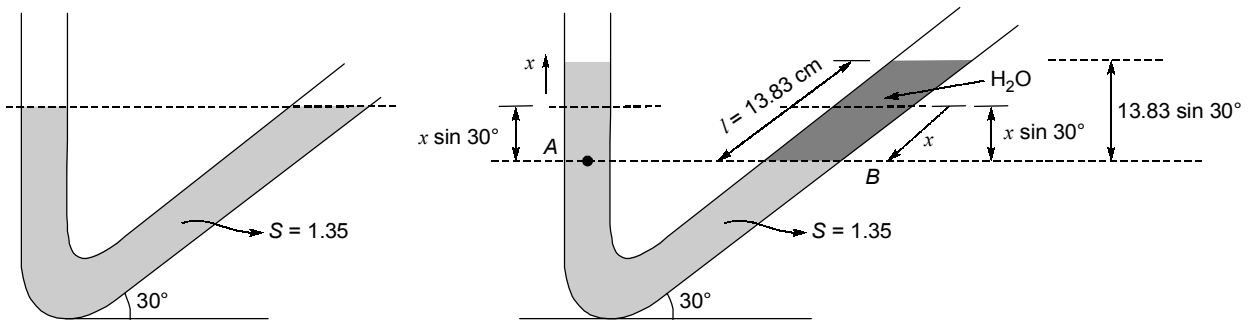
11. (b)

$$\frac{\rho_1}{\rho g} + y + \frac{h.S_2}{S_1} = \frac{\rho_2}{\rho g} + h + y$$

$$\therefore \frac{\rho_2 - \rho_1}{\rho g} = h \left(\frac{S_2}{S_1} - 1 \right) = \frac{V_1^2}{2g}$$

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

12. (b)



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

According to Pascal Law

$$P_A = P_B$$

$$(1.35 \times 10^3) \cdot g \cdot (x + x \sin 30^\circ) = (10^3) \cdot g \cdot (13.83 \sin 30^\circ)$$

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

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

13. (c)

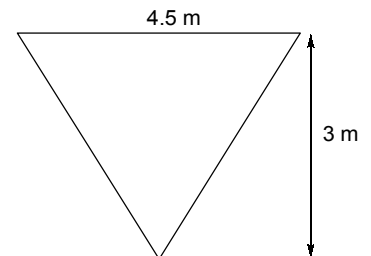
$$\text{centre of pressure } (h_p) = h_c + \frac{I_{GG}}{Ah_c}$$

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

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

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

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



14. (d)

$V_b \Rightarrow$ Volume of body

$V_w \Rightarrow$ Displaced volume of water

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

weight = Buoyance force

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

$$\rho_b \cdot V_b \cdot g = \rho_w \cdot V_w \cdot g + \rho_{Hg} \cdot V_{Hg} \cdot g$$

Divide by $\rho_w \cdot g$

$$\frac{\rho_b}{\rho_w} \cdot V_b = V_w + \frac{\rho_{Hg}}{\rho_w} \cdot V_{Hg} \quad \{V_b = V_w + V_{Hg}\}$$

$$8.6 V_b = V_w + 13.6(V_b - V_w)$$

$$12.6 V_w = 5 V_b$$

$$\frac{V_w}{V_b} \times 100 = \frac{5}{12.6} \times 100 = 39.68$$

15. (d)

For steady and incompressible flow continuity equation must be satisfied

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

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

$$y^3(\lambda - 3) = 0$$

$$\lambda = 3$$

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 $R = a$

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

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

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

17. (d)

Discharge through venturimeter

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

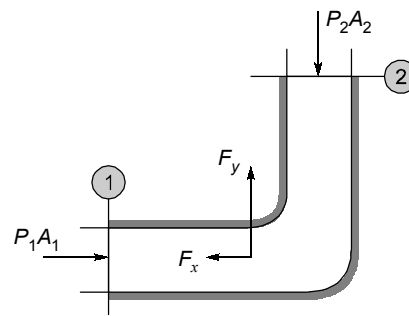
a_1 = cross sectional area of pipe

a_2 = cross sectional area of venturimeter

h = Difference in piezometric heads

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

18. (b)



In y-direction

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

$$F_y - P_2A_2 = \rho \cdot A_2 \cdot V_2 \cdot V_2$$

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

19. (c)

Given data

- diameter of pipe = 120 mm
- velocity through pipe = 0.018 m/s
- 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

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

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

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

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

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

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

Hydraulic gradient

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

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

So, statement 4 is incorrect.

21. (c)

δ' = Laminar sublayer

V^* = Shear velocity

ν = 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

$$(Fr)_m = (Fr)_p$$

$$\left(\frac{V}{\sqrt{Lg}} \right)_m = \left(\frac{V}{\sqrt{Lg}} \right)_p$$

$$\therefore g_m = g_p$$

$$V_r = \sqrt{L_r} \quad \dots(i)$$

Now,

$$Q_r = A_r \cdot V_r = (L_r)^2 (\sqrt{L_r})$$

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

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

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

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

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

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

$$V_r = \sqrt{L_r}$$

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

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

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

24. (c)

Neglecting Minor losses

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

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

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

25. (d)

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

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

Int. it

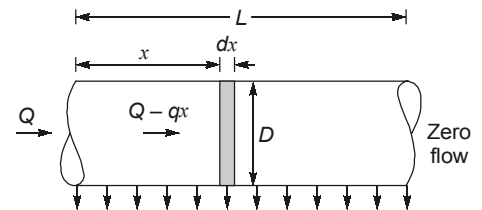
$$h_f = \frac{8 f}{\pi^2 g D^5} \int_0^L (Q-qx)^2 dx = \frac{8 f}{\pi^2 g D^5} \int_0^L [Q^2 + q^2 x^2 + 2qQx] dx$$

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

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

(Since $Q = qL$)

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



26. (d)

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

⇒

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

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

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

∴ Sudden closure

$$\frac{P}{\rho g} = \frac{V}{g} \sqrt{\frac{k}{\rho}} = \frac{1.5}{9.81} \sqrt{\frac{20 \times 10^8}{1000}} = 216.21 \text{ m of water}$$

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,

$$\rho_{\text{air}} = 1.25 \text{ kg/m}^3, c_p = 1.3$$

$$D = 8 \text{ m}, V_0 = 4 \text{ m/sec}$$

$$\text{Drag force } (F_n) = \frac{1}{2} C_D A \rho V^2 = \frac{1}{2} \times 1.3 \times \frac{\pi}{4} \times 8^2 \times 1.25 \times 4^2 = 653.45 \text{ N}$$

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

29. (a)

Laminar Boundary layer thickness

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

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

⇒ δ increase in flow direction

$$\text{Shear stress at plate, } \tau = \frac{1}{2} \rho v^2 e_{f_x} = \frac{1}{2} \rho v^2 \frac{0.664}{\sqrt{Re_x}}$$

$$\tau \propto \frac{1}{\sqrt{x}}$$

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

30. (c)

We know that,

$$\frac{\delta}{x} = \frac{5}{\sqrt{R_x}}$$

⇒

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

Let section m is x_m downstream of leading edge

$$\delta_M = 1.2 \text{ cm}, \delta_N = 3.6 \text{ cm}$$

$$x_M = x, x_N = (x + 4.8)$$

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

$$x + 4.8 = 9x$$

$$x = 0.6 \text{ m}$$

