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FLUID MECHANICS

CIVIL ENGINEERING

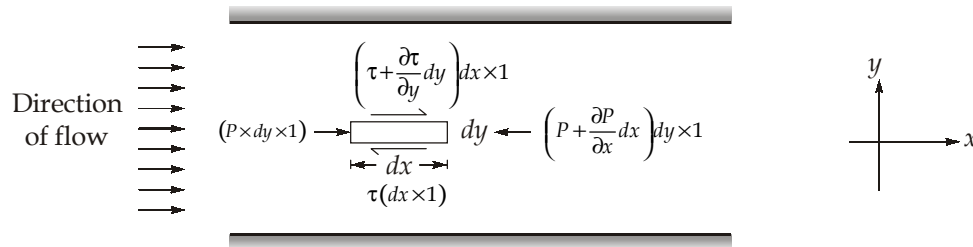
Date of Test : 15/10/2026

ANSWER KEY ➤

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

DETAILED EXPLANATIONS

1. (b)



For steady and uniform flow, there is no acceleration and hence resultant force in the direction of flow is zero

$$P \times (dy \times 1) - \left(P + \frac{\partial P}{\partial x} dx \right) dy \times 1 - \tau(dx \times 1) + \left(\tau + \frac{\partial \tau}{\partial y} dy \right) dx \times 1 = 0$$

$$\frac{\partial P}{\partial x} = \frac{\partial \tau}{\partial y}$$

The pressure gradient in the direction of flow is equal to the shear gradient normal to the direction of flow.

2. (d)

Since $\overline{GM}_{\text{rolling}} \ll \overline{GM}_{\text{pitching}}$

Hence the stability of ship in rolling is more critical compared to pitching.

Higher the period of oscillation, more comfort the passengers will feel.

3. (a)

$$dQ = |d\psi| = |\psi_2 - \psi_1|$$

At (1, 1); $\psi_1 = 3 \times 1^2 \times 1 - 1^3 = 2 \text{ units}$

At $(\sqrt{3}, 1)$; $\psi_2 = 3 \times (\sqrt{3})^2 \times 1 - 1^3 = 8 \text{ units}$

So, $dQ = |8 - 2|$
 $= 6 \text{ units}$

4. (b)

In spherical water droplet,

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

In water jet,

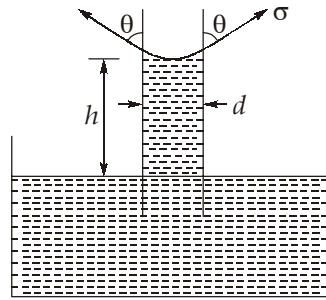
$$\Delta P = \frac{\sigma}{R_{\text{jet}}}$$

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

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

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

5. (b)



Capillary rise,
$$h = \frac{4\sigma \cos \theta}{(\rho g \cdot d)}$$

σ = Surface tension
 d = Diameter of tube
 (ρg) = Specific weight or weight density of fluid

6. (b)

Pipe flow is a case of application of Reynold's model law and Weber model law is applicable in capillary rise in narrow passages.

8. (d)

A submerged body becomes unstable if the centre of gravity is above the centre of buoyancy. While a floating body may remain stable even if centre of gravity is above the centre of buoyancy so statement 2 is wrong.

For a submerged body, if the centre of gravity coincides with the centre of buoyancy, the equilibrium is said to be neutral stability so statement 4 is wrong.

9. (d)

10. (a)

The dimension of dynamic viscosity is $ML^{-1}T^{-1}$ and that of kinematic viscosity is $L^2 T^{-1}$.

11. (a)

Friction factor, $f = 4f' = 4 \times 0.02 = 0.08$

Head loss in pipeline due to friction,

$$h_f = \frac{8Q^2}{\pi^2 g} \frac{fL}{D^5} = \frac{8Q^2}{\pi^2 g} \frac{0.08 \times 1500}{(0.3)^5} \text{ m}$$

Applying Bernoulli's theorem between reservoirs A and B,

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + h_f - E_{\text{pump}}$$

$$\therefore \quad \begin{aligned} V_A &= V_B = 0, & P_A &= P_B = P_{\text{atm}} \\ z_A &= 200 \text{ m}, & z_B &= 185 \text{ m}, & E_{\text{pump}} &= 20 \text{ m} \end{aligned}$$

$$\frac{P_{\text{atm}}}{\rho g} + 200 = \frac{P_{\text{atm}}}{\rho g} + 185 + \frac{8Q^2}{\pi^2 g} \frac{fL}{D^5} - 20$$

$$\Rightarrow 200 - 185 + 20 = \frac{8Q^2 \times 0.08 \times 1500}{\pi^2 \times 9.81 \times (0.3)^5}$$

$$\Rightarrow Q = 0.0926 \text{ m}^3/\text{s}$$

12. (a)

Given, $U_0 = V_A = 30 \text{ m/s}$, $\delta^* = 1 \text{ mm}$, $A_A = 100 \times 100 \text{ mm}^2$
 $A_B = (100 - \delta^*)(100 - \delta^*) \text{ mm}^2$

Using continuity equation

$$A_A V_A = A_B V_B$$

$$\Rightarrow V_B = \frac{A_A V_A}{A_B} = \frac{100 \times 100 \times 30}{(100 - 2)(100 - 2)}$$

$$\Rightarrow V_B = 31.237 \text{ m/s}$$

13. (d)

Given, $\theta = 60^\circ$

Distance, $AC = \frac{h}{\sin 60^\circ} = \frac{2h}{\sqrt{3}}$

The gate will start tipping about hinge B if the resultant pressure force acts at B. If the resultant pressure force passes through a point which is lying from B to C anywhere on the gate, the gate will tip over the hinge. Hence for the given position, point B becomes the centre of pressure.

Depth of centre of pressure,

$$h^* = (h - 3) \text{ m} \quad \dots(i)$$

But h^* is also given by, $h^* = \frac{I_G \sin^2 \theta}{A \bar{h}} + \bar{h}$

Taking width of gate unity, then

Area, $A = AC \times 1 = \frac{2h}{\sqrt{3}} \times 1$; $\bar{h} = \frac{h}{2}$

$$I_G = \frac{bd^3}{12} = \frac{1 \times AC^3}{12} = \frac{1 \times \left(\frac{2h}{\sqrt{3}}\right)^3}{12}$$

$$= \frac{8h^3}{12 \times 3 \times \sqrt{3}} = \frac{2h^3}{9 \times \sqrt{3}}$$

$$h^* = \frac{2h^3}{9\sqrt{3}} \times \frac{\sin^2 60}{\frac{2h}{\sqrt{3}} \times \frac{h}{2}} + \frac{h}{2}$$

$$\Rightarrow h^* = \frac{2h^3 \times \frac{3}{4}}{9h^2} + \frac{h}{2} = \frac{2h}{3} \quad \dots(ii)$$

From (i) and (ii)

$$h - 3 = \frac{2h}{3}$$

$$\Rightarrow h = 9 \text{ m}$$

 $\therefore$ Height of water required for tipping the gate = 9 m

14. (b)

Reynolds number upto which laminar boundary exists = 2×10^5

Kinematic viscosity for air

$$\nu = 0.15 \text{ stokes} = 0.15 \times 10^{-4} \text{ m}^2/\text{s}$$

$$\text{Reynold's number, } Re = \frac{\rho Vx}{\mu} = \frac{Vx}{\nu}$$

If $Re_x = 2 \times 10^5$, then x denotes the distance from the leading edge upto which laminar boundary layer exists

$$\therefore 2 \times 10^5 = \frac{10 \times x}{0.15 \times 10^{-4}}$$

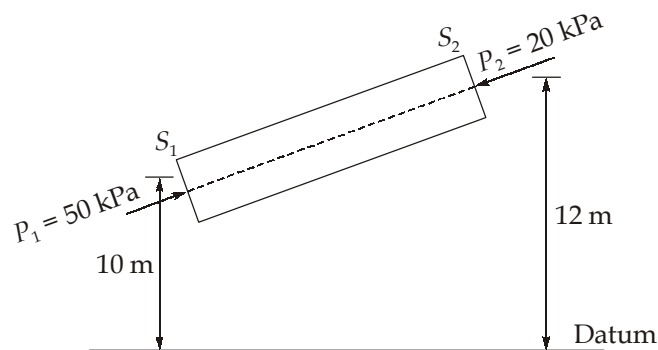
$$\Rightarrow x = 0.30 \text{ m} = 300 \text{ mm}$$

For thickness of laminar boundary layer,

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

$$\begin{aligned} \Rightarrow \delta &= \frac{5 \times x}{\sqrt{Re_x}} = \frac{5 \times 0.30}{\sqrt{2 \times 10^5}} \\ &= 3.354 \times 10^{-3} \text{ m} = 3.354 \text{ mm} \end{aligned}$$

15. (b)



Velocity of flow, $V_1 = V_2 = 2 \text{ m/s}$ (uniform diameter)

Net head at section 1 (S_1)

$$H_1 = \frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{50 \times 10^3}{1000 \times 9.81} + \frac{(2)^2}{2 \times 9.81} + 10 = 15.3 \text{ m}$$

Net head at section 2 (S_2)

$$H_2 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 = \frac{20 \times 10^3}{1000 \times 9.81} + \frac{(2)^2}{2 \times 9.81} + 12 = 14.24 \text{ m}$$

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

$$\begin{aligned} \therefore \text{Head loss, } H_L &= H_1 - H_2 \\ &= 15.3 - 14.24 = 1.06 \text{ m} \end{aligned}$$

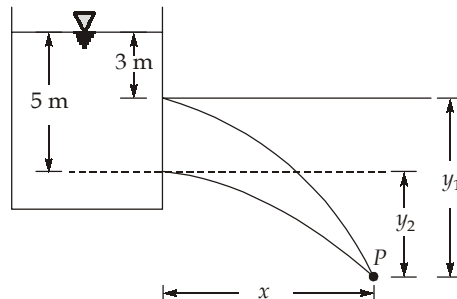
16. (a)

Let P is the point of intersection of the two jets coming from orifice (1) and (2), such that

x = Horizontal distance of P

y_1 = Vertical distance of P from orifice (1)

y = Vertical distance of P from orifice (2)



Then,

$$y_1 = y_2 + (5 - 3) = (y_2 + 2) \text{ m}$$

...(1)

The equation of C_V is given by

$$\text{For orifice (1), } C_{V1} = \frac{x}{\sqrt{4y_1H_1}} = \frac{x}{\sqrt{4y_1 \times 3}}$$

$$\text{For orifice (2), } C_{V2} = \frac{x}{\sqrt{4y_2H_2}} = \frac{x}{\sqrt{4 \times y_2 \times 5}}$$

$$\text{Since, } C_{V1} = C_{V2}$$

$$\text{Hence, } \frac{x}{\sqrt{4y_1 \times 3}} = \frac{x}{\sqrt{4y_2 \times 5}}$$

$\Rightarrow$

$$3y_1 = 5y_2$$

...(2)

From (1) and (2),

$$y_2 = 3.0 \text{ m}$$

So,

$$C_{V2} = \frac{x}{\sqrt{4y_2 \times 5}}$$

$\Rightarrow$

$$x = 0.96 \times \sqrt{4 \times 3 \times 5} \\ = 7.436 \text{ m}$$

17. (a)

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

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

By substitution, we get

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

$\therefore$

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

18. (a)

Since the pipes are connected in series

$$\begin{aligned}\therefore \frac{L}{d^5} &= \frac{L_1}{d_1^5} + \frac{L_2}{d_2^5} + \frac{L_3}{d_3^5} \\ \Rightarrow \frac{1700}{d^5} &= \frac{800}{0.500^5} + \frac{500}{0.4^5} + \frac{400}{0.3^5} \\ \Rightarrow d^5 &= \frac{1700}{239037.18} \\ \Rightarrow d &= 0.3719 \text{ m} \\ &= 371.9 \text{ mm} \simeq 372 \text{ mm}\end{aligned}$$

19. (c)

Using Bernoulli's equation

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_L \dots (i)$$

$$V_1 = \frac{Q}{A_1} = \frac{4.0}{\frac{\pi}{4} \times 1.0^2} = 5.093 \text{ m/s}$$

$$V_2 = \frac{Q}{A_2} = \frac{4.0}{\frac{\pi}{4} \times 2.0^2} = 1.273 \text{ m/s}$$

$$h_L = 0 \text{ (Frictionless flow)}$$

From eq. (i)

$$\begin{aligned}\frac{8.0}{9.81} + \frac{5.093^2}{2 \times 9.81} + 0 &= \frac{P_2}{9.81} + \frac{1.273^2}{2 \times 9.81} + 0 + 0 \\ P_2 &= 20.16 \text{ kPa}\end{aligned}$$

20. (b)

For the free vortex motion,

$$V \times r = \text{Constant}$$

Hence, $V_1 r_1 = V_2 r_2$

$$\Rightarrow V_2 = \frac{V_1 r_1}{r_2} = \frac{10 \times 0.2}{0.4} = 5 \text{ m/s}$$

Using Bernoulli's equation,

$$\begin{aligned}\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 &= \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 \\ \Rightarrow \frac{117.72 \times 10^3}{1.24 \times 9.810} + \frac{10^2}{2 \times 9.81} + 0.1 &= \frac{P_2}{\rho g} + \frac{5^2}{2 \times 9.81} + 0.2 \\ \Rightarrow \frac{P_2}{\rho g} &= 9677.4 + 5.097 + 0.1 - 1.274 - 0.2 = 9681.12 \text{ m} \\ \Rightarrow P_2 &= 117.765 \text{ kN/m}^2 \simeq 117.8 \text{ kN/m}^2\end{aligned}$$

21. (b)

The pressure gradient, $\frac{\partial P}{\partial x}$

$$\therefore \tau = -\frac{r}{2} \frac{\partial P}{\partial x} = -\frac{D}{4} \left(\frac{\partial P}{\partial x} \right)$$

$$\Rightarrow 196.2 = -\frac{0.1}{4} \times \frac{\partial P}{\partial x}$$

$$\Rightarrow \frac{\partial P}{\partial x} = -7848 \text{ N/m}^2$$

Hence statement [1] is incorrect.

$$\begin{aligned} \text{Average velocity, } \bar{u} &= \frac{1}{8\mu} \times \left(-\frac{\partial P}{\partial x} \right) \times r^2 \\ &= \frac{1}{8 \times 0.7} \times 7848 \times 0.05^2 = 3.5 \text{ m/s} \end{aligned}$$

Hence statement [2] is correct.

$$\text{Reynold's number, } Re = \frac{\rho V D}{\mu} = \frac{1300 \times 3.5 \times 0.1}{0.7} = 650$$

Hence statement [3] is correct.

22. (d)

Momentum thickness, θ is given by

$$\theta = \int_0^\delta \frac{u}{U} \left(1 - \frac{u}{U} \right) dy$$

$$\begin{aligned} \Rightarrow \theta &= \int_0^\delta \left\{ \left(\frac{2y}{\delta} \right) - \frac{y^2}{\delta^2} \right\} \left\{ 1 - \frac{2y}{\delta} + \frac{y^2}{\delta^2} \right\} dy \\ &= \int_0^\delta \left[\frac{2y}{\delta} - \frac{4y^2}{\delta^2} + \frac{2y^3}{\delta^3} - \frac{y^2}{\delta^2} + \frac{2y^3}{\delta^3} - \frac{y^4}{\delta^4} \right] dy \\ &= \int_0^\delta \left[\frac{2y}{\delta} - \frac{5y^2}{\delta^2} + \frac{4y^3}{\delta^3} - \frac{y^4}{\delta^4} \right] dy \\ &= \left[\frac{2y^2}{2\delta} - \frac{5y^3}{3\delta^2} + \frac{4y^4}{4\delta^3} - \frac{y^5}{5\delta^4} \right]_0^\delta \\ &= \left[\delta - \frac{5\delta}{3} + \delta - \frac{\delta}{5} \right] = \frac{2\delta}{15} \end{aligned}$$

23. (d)

For maximum power transmission, $h_f = \frac{H}{3} = \frac{500}{3} = 166.7 \text{ m}$

Now, $h_f = \frac{f L V^2}{d \times 2g} = \frac{0.06 \times 3500 \times V^2}{0.3 \times 2 \times 9.81}$

$$\Rightarrow 166.7 = 35.68 V^2$$

$$\Rightarrow V = 2.162 \text{ m/s}$$

$$\text{Head available at the end of the pipe} = \frac{2H}{3} = 333.33 \text{ m}$$

$$\therefore \text{Maximum power available} = \rho Q g H = \rho (AV) g H$$

$$\Rightarrow P_{max} = 1000 \times \frac{\pi}{4} \times 0.3^2 \times 2.162 \times 9.81 \times 333.33 \text{ W}$$

$$\Rightarrow P_{max} = 499.7 \text{ kW} \simeq 500 \text{ kW}$$

24. (a)

$$\text{Horizontal force at curved gate, } F_H = \rho g A_v \times \bar{h}$$

$$\Rightarrow F_H = 9.81 \times 3 \times 4 \times (1.5)$$

$$\Rightarrow F_H = 176.58 \text{ kN}$$

$$\text{Vertical force at curved gate, } F_V = \rho g \nabla$$

$$= \text{Wt. of fluid above curved surface upto free surface}$$

$$\Rightarrow F_V = 9.81 \times \left(9 - \frac{\pi}{4} (3)^2 \right) \times 4$$

$$\Rightarrow F_V = 75.929 \text{ kN}$$

Resultant force acting at the centroid of curved gate,

$$F_R = \sqrt{F_H^2 + F_V^2} = \sqrt{176.58^2 + 75.929^2}$$

$$\Rightarrow F_R = 192.212 \text{ kN}$$

25. (c)

$$\text{Given, } \mu = 5 \text{ poise} = 0.5 \text{ Ns/m}^2$$

$$\text{Tangential velocity of shaft, } u = \frac{\pi D N}{60} = \frac{\pi \times 0.5 \times 200}{60} = 5.236 \text{ m/s}$$

$$\text{Shear stress, } \tau = \mu \frac{du}{dy} = 0.5 \times \frac{5.236}{1 \times 10^{-3}} = 2618 \text{ N/m}^2$$

$$\text{Shear force on the shaft, } F = \tau \times A$$

$$\Rightarrow F = \tau \times \pi D \times L$$

$$\Rightarrow F = 2618 \times \pi \times 0.5 \times 0.1$$

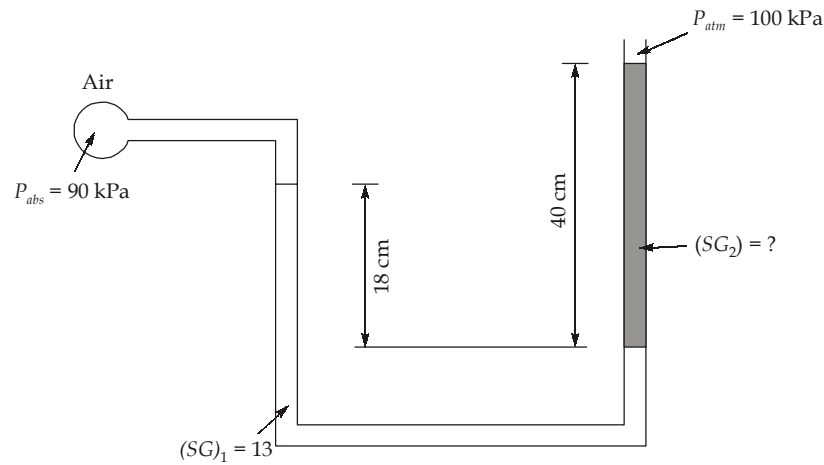
$$= 411.23 \text{ N}$$

$$\text{Torque on the shaft, } T = F \times \frac{D}{2} = 411.23 \times \frac{0.5}{2} = 102.81 \text{ Nm}$$

$$\text{Power lost, } P = T \times \omega = 102.81 \times \frac{2 \times \pi \times 200}{60}$$

$$= 2153.25 \text{ W} = 2.15 \text{ kW}$$

26. (c)



$$10^3 \times 90 + 13 \times 9.81 \times 10^3 \times 0.18 = 100 \times 10^3 + (SG_2) \times 9.81 \times 10^3 \times 0.4$$

$$\Rightarrow (SG_2) = 3.3$$

27. (c)

Reynold's similarity law is applicable (pipe flow).

$$(Re)_m = \frac{V_m d_m}{\nu_m} = (Re)_p = \frac{V_p d_p}{\nu_p}$$

$$V_r = \frac{V_m}{V_p} = \frac{d_p \nu_m}{d_m \nu_p} = \frac{d_p \mu_m}{\rho_m} \times \frac{\rho_p}{d_m \mu_p}$$

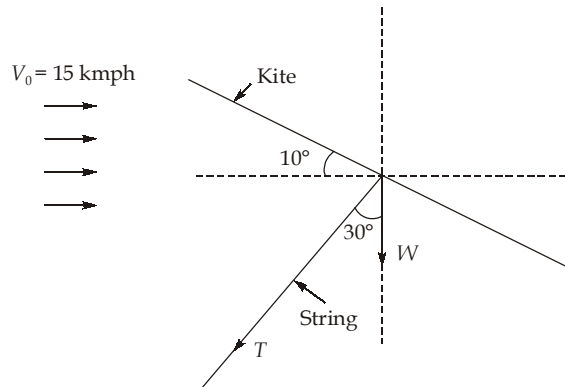
$$\Rightarrow \frac{V_m}{V_p} = \frac{\mu_m}{\mu_p} \times \frac{1}{\left(\frac{L_m}{L_p}\right) \left(\frac{\rho_m}{\rho_p}\right)}$$

Referring to oil with a subscript p and water with a suffix m .

$$\frac{V_m}{V_p} = \frac{1.31 \times 10^{-3}}{0.3} \times \frac{1}{\frac{1}{15} \times \frac{998}{920}} = 0.0604$$

$$\therefore V_m = \text{Velocity of water} = V_p \times 0.0604 = 2 \times 0.06 = 0.12 \text{ m/s}$$

28. (a)



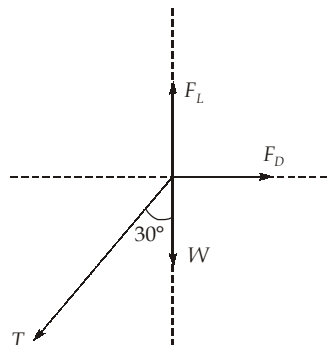
$$V_0 = 15 \text{ kmph} = 4.167 \text{ m/s}$$

Drag force,
$$F_D = C_D A \frac{\rho V_0^2}{2}$$

Lift force,
$$F_L = C_L A \frac{\rho V_0^2}{2}$$

Let weight of kite = W

Resolving the tension T into components in horizontal and vertical directions.



$$T \cos 30^\circ + W = F_L \text{ and } T \sin 30^\circ = F_D$$

$$\therefore T = \frac{F_D}{\sin 30^\circ} = \frac{0.25 \times (0.8 \times 0.5) \times 1.2 \times (4.167)^2}{\sin 30^\circ \times 2}$$

$$\Rightarrow T = \frac{0.25 \times 0.4 \times 1.2 \times 17.36}{\frac{1}{2} \times 2} = 2.083 \text{ N}$$

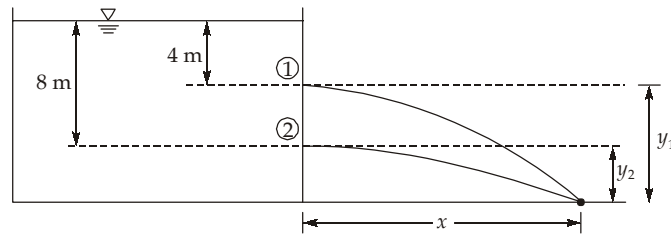
Now $T \cos 30^\circ + W = F_L$

$$\Rightarrow 2.083 \cos 30^\circ + 1 = C_L \times (0.8 \times 0.5) \times \frac{1.2 \times (4.167)^2}{2}$$

$$\Rightarrow 2.804 = C_L \times 4.167$$

$$\Rightarrow C_L = 0.673$$

29. (c)



As both the orifices are identical

$$\therefore C_{V1} = C_{V2}$$

$$\Rightarrow \frac{x}{2\sqrt{y_1 h_1}} = \frac{x}{2\sqrt{y_2 h_2}}$$

$$\Rightarrow y_1 h_1 = y_2 h_2$$

$$\Rightarrow y_1 \times 4 = y_2 \times 8$$

$$\Rightarrow y_1 = 2y_2$$

$$\text{Also, } y_1 - y_2 = 4$$

$$\Rightarrow 2y_2 - y_2 = 4$$

$$\Rightarrow y_2 = 4 \text{ m}$$

$$\therefore y_1 = 2y_2 = 8 \text{ m}$$

$$\text{As } C_{v1} = \frac{x}{2\sqrt{y_1 h_1}}$$

$$\Rightarrow 0.95 = \frac{x}{2\sqrt{8 \times 4}}$$

$$\Rightarrow x = 0.95 \times 2 \times \sqrt{32}$$

$$\Rightarrow x = 10.75 \text{ m}$$

30. (b)

$$\text{Since } \frac{P_{stag}}{\gamma} - \frac{P_{static}}{\gamma} = \frac{V^2}{2g}$$

$$\begin{aligned} \Rightarrow V_{\text{actual}} &= c_v \sqrt{2g(h_{\text{stag}} - h_{\text{static}})} \\ &= 0.98 \sqrt{29.81 \times (3 - 0.5)} \\ &= 6.86 \text{ m/s} \end{aligned}$$

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