CLASS TEST

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 13/07/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

Kinetic energy correction factor is given by

$$\alpha = \frac{1}{AV^3}\int u^3 dA$$

2. (a)

Equating pressure at interface level,

$$P_A + \rho_0 g(0.15) = \rho_{Hg} g(0.1)$$

where ρ_0 is density of oil and ρ_{Hg} is density of mercury

$$\Rightarrow \quad P_A + (0.85 \times 10^3) \times g \times 0.15 = (13.6 \times 10^3) \times g \times 0.10$$

$$\Rightarrow \quad P_A = 12090.825 \text{ N/m}^2$$

$$= 12.09 \text{ kN/m}^2$$

3. (a)

Dynamic viscosity of gases decrease with decrease in fluid temperature as the momentum transfer between the fluid particles decreases.

4. (b)

$$u = \frac{1}{4\mu}\left(-\frac{dP}{dx}\right)\left(R^2 - r^2\right)$$

5. (b)

Statement 1 is false. If streamlines are straight and diverging then only convective tangential **retardation i.e. negative** acceleration exists.

6. (d)

Weight of pontoon, $W = 20000$ kN

Movable weight, $w = 400$ kN

Metacentric height GM is given by,

$$\text{GM} = \frac{wx}{W\tan\theta}$$

$$\Rightarrow \quad 2.5 = \frac{(400)x}{20000\tan 30^o}$$

$$\Rightarrow \quad x = 72.17 \text{ m}$$

7. (c)

Buoyant force, $B = W_{air} - W_{water}$

$$B = 200 - 153 = 47 \text{ kN}$$

$$\Rightarrow \quad \rho_{fluid} V_{immersed} g_{eff} = 47000 \text{ N}$$

$$\Rightarrow \quad 1000 V_{immersed}(10) = 47000 \text{ N}$$

$$\Rightarrow \quad V_{immersed} = 4.7 \text{ m}^3$$

$\because$ Metal piece is completely immersed in water and thus volume of metal is 4.7 m^3.

8. (b)

$$\frac{\delta}{x} = \frac{5}{\sqrt{R_{ex}}}$$

$$\therefore \quad \frac{\delta_1}{\delta_2} = \sqrt{\frac{x_1}{x_2}}$$

$$\Rightarrow \quad \frac{3}{\delta_2} = \sqrt{\frac{1}{5}}$$

$$\delta_2 = 3\sqrt{5} \text{ mm}$$

9. (a)

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

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

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

So, $dQ = |8-2|$

$= 6$ units

10. (d)

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

Hence the stability of ship in rolling is more critical compared to pitching.
Higher the period of oscillation, more comfort the passengers will feel.

11. (c)

From the given velocity field,

$$u = \lambda xy^3 - x^2y$$

$$v = xy^2 - \frac{3}{4}y^4$$

For possible, steady and incompressible flow, continuity equation should be satisfied

$$\therefore \quad \left(\frac{\partial u}{\partial x}\right)+\left(\frac{\partial v}{\partial y}\right)+\left(\frac{\partial w}{\partial z}\right) = 0$$

$$\Rightarrow \quad \left(\lambda y^3 - 2xy\right) + 2xy - 3y^3 + 0 = 0$$

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

$$\therefore \quad \lambda = 3$$

12. (d)

Given, $\theta = 60°$

Distance, $AC = \dfrac{h}{\sin 60°} = \dfrac{2h}{\sqrt{3}}$

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,

$$h^* = (h - 3) \text{ m} \qquad \text{...(i)}$$

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

Taking width of gate unity, then

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

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

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

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

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

From (i) and (ii)

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

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

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

13. (d)

Let the weight of man is W_2

Then, Total weight = Weight of man + Weight of parachute

$$= W_2 + W_1$$

$$= (W_2 + 9.81) \text{ N}$$

Total drag force, $F_D = (W_2 + 9.81)$ N

Also, $F_D = \dfrac{1}{2} C_D \rho A U^2$

$$\therefore \quad (W_2 + 9.81) = \frac{1}{2} \times 0.6 \times 1.25 \times \frac{\pi}{4} \times 4^2 \times 25^2$$

$$\Rightarrow \quad W_2 = 2943.75 - 9.81$$

$$\Rightarrow \quad W_2 = 2933.9 \text{ N}$$

14. (a)

Since the pipes are connected in series

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

$$\Rightarrow \quad \frac{1700}{d^5} = \frac{800}{0.500^5} + \frac{500}{0.4^5} + \frac{400}{0.3^5}$$

$$\Rightarrow \quad d^5 = \frac{1700}{239037.18}$$

$\Rightarrow$ $d = 0.3719$ m

$= 371.9$ mm $\simeq 372$ mm

15. (b)

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

Tangential velocity of shaft, $u = \dfrac{\pi DN}{60} = \dfrac{\pi \times 0.5 \times 200}{60} = 5.236$ m/s

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

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

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

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

$= 411.23$ N

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

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

$= 2153.25$ W $= 2.15$ kW

16. (c)

Given, Time period $= 12$ sec

Distance between the centre of buoyancy and centre of gravity,

BG $= 1.6$ m

Moment of inertia, $I = 11250$ m^4

Weight, $W = 30{,}000$ kN

Metacentric height, $GM = \dfrac{I}{V_{dis}} - BG$

$$V_{disp} = \frac{\text{Weight of ship}}{\text{Specific weight of sea water}}$$

$\Rightarrow$ $V_{disp} = \dfrac{30000 \times 10^3}{10000}$

$\Rightarrow$ $V_{disp} = 3000$ m^3

$\therefore$ $GM = \dfrac{11250}{3000} - 1.6 = 3.75 - 1.6$

$\Rightarrow$ $GM = 2.15$ m

Now, $T = 2\pi\sqrt{\dfrac{k^2}{g \times GM}}$

$\Rightarrow$ $12 = 2\pi\sqrt{\dfrac{k^2}{9.81 \times 2.15}}$

$\Rightarrow$ $k = \dfrac{12 \times \sqrt{9.81 \times 2.15}}{2 \times \pi}$

$\Rightarrow$ $k = 8.77$ m

17. (b)

Given, $\phi = x(2y-1)$

The velocity components, u and v are

$$u = -\frac{\partial \phi}{\partial x} = -\frac{\partial}{\partial x}\left[x(2y-1)\right] = 1-2y$$

$$v = -\frac{\partial \phi}{\partial y} = -\frac{\partial}{\partial y}\left[x(2y-1)\right] = -2x$$

We know that, $\dfrac{\partial \psi}{\partial y} = -u = -(1-2y) = 2y-1$

and, $\dfrac{\partial \psi}{\partial x} = v = -2x$

Now, $\int d\psi = \int (2y-1)\,dy$

$\Rightarrow \quad \psi = \dfrac{2y^2}{2} - y + C$

$\Rightarrow \quad \psi = y^2 - y + C \quad \ldots(i)$

Differentiating eq. (i) w.r.t. x,

$$\frac{\partial \psi}{\partial x} = \frac{\partial C}{\partial x}$$

But, $\dfrac{\partial \psi}{\partial x} = -2x$

Hence, $\dfrac{\partial \psi}{\partial x} = \dfrac{\partial C}{\partial x} = -2x$

On integrating, $C = -x^2 + C_1$

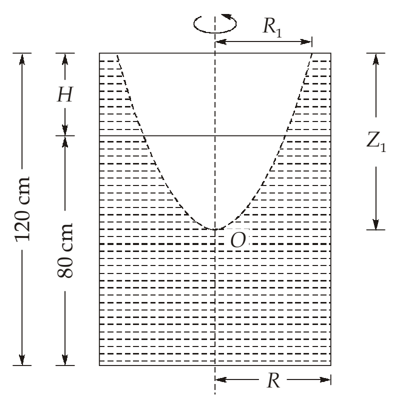
Hence, $\psi = y^2 - y - x^2 + C_1$

ψ at $(0, 0) = 0 = C_1$

Hence, $\psi = y^2 - y - x^2$

$\therefore$ Value of ψ at point P (4, 5) is, $\psi = 5^2 - 5 - 4^2 = 4$ units

18. (a)



Let, Z_1 = Height of paraboloid

R_1 = Radius made by water surface at top of container

Given, N = 400 rpm

$$\therefore \quad \omega = \frac{2\pi N}{60} = 41.89 \text{ rad/sec}$$

$$Z_1 = \frac{\omega^2 R_1^2}{2g} = \frac{41.89^2 \times (R_1)^2}{2 \times 9.81} = 89.438 R_1^2 \quad \text{...(i)}$$

Since,volume of paraboloid so formed = Initial volume of air

$$\Rightarrow \quad \frac{\pi R_1^2 Z_1}{2} = \pi \times R^2 H$$

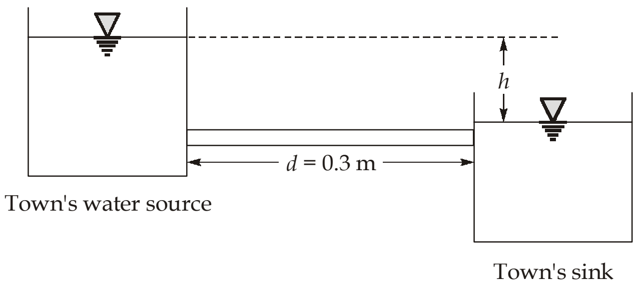
$$\Rightarrow \quad \frac{\pi \times Z_1}{2 \times 89.438} \times Z_1 = \pi \times 0.1^2 \times 0.4 \text{ [From eq. (i)]}$$

$$\Rightarrow \quad Z_1 = 0.8458 \text{ m}$$

$$Z_1 = 84.58 \text{ cm}$$

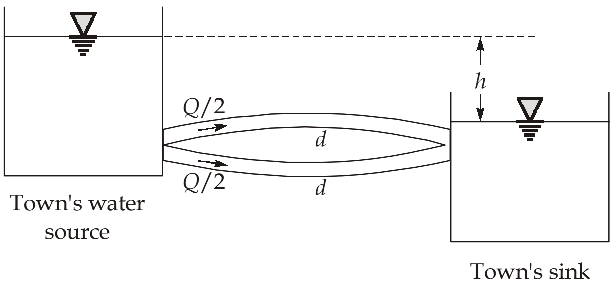
19. (d)

Case 1: Single pipe connection



$$h = \frac{flQ^2}{12(0.3)^5} \quad \text{... (i)}$$

Case 2: Dual pipe connection



$$h = \frac{fl(Q/2)^2}{12d^5} \quad \text{... (ii)}$$

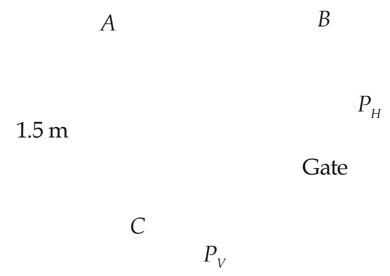
Using (i) and (ii)

$$\frac{flQ^2}{12(0.3)^5} = \frac{fl(Q/2)^2}{12d^5}$$

$$\Rightarrow \quad d = 0.2274 \text{ m} = 22.74 \text{ cm}$$

$$\Rightarrow \quad \text{d} = 227.4 \text{ mm} \simeq 227 \text{ mm}$$

20. **(c)**



$$P_H = \text{Force on the projected area of the curved surface on vertical plane}$$
$$= \text{Force on AC}$$
$$= \text{Pressure at CG of plate} \times \text{Projected area of plate}$$
$$= \gamma_w \times \frac{1.50}{2} \times 1.5 \times 3 = 3.375\ \gamma_w\ \text{kN}$$

Vertical force, P_V = Weight of water supported by BC

$$= \gamma_w \times \frac{\pi r^2}{4} \times \text{width} = \gamma_w \times \frac{\pi \times 1.5^2}{4} \times 3$$
$$= 5.301\ \gamma_w\ \text{kN}$$

Resultant force $= \sqrt{(3.375\gamma_w)^2 + (5.301\gamma_w)^2}$

$$= 6.284\ \gamma_w$$
$$= 61.65\ \text{kN}$$

21. **(a)**

Now, $a_x = \dfrac{\partial u}{\partial t} + u\dfrac{\partial u}{\partial x} + v\dfrac{\partial u}{\partial y}$

$$= 2t + (t^2 + 3y) \times 0 + (4t + 5x) \times 3$$
$$= 14t + 15x$$

Similarly, $a_y = \dfrac{\partial v}{\partial t} + u\dfrac{\partial v}{\partial x} + v\dfrac{\partial v}{\partial y}$

$$= 4 + (t^2 + 3y)(5) + (4t + 5x)(0)$$
$$= 4 + 5t^2 + 15y$$

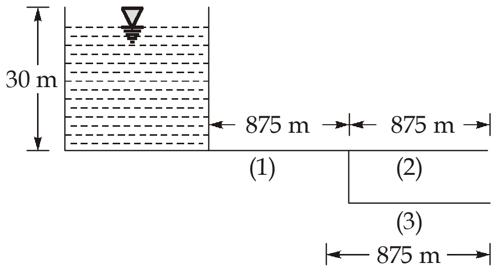
At point (5, 3) and t = 2 units,

$$a_x = 14 \times 2 + 15 \times 5 = 103\ \text{unit}$$
$$a_y = 4 + (5 \times 2^2) + (15 \times 3) = 69\ \text{unit}$$
$$a = \sqrt{{a_x}^2 + {a_y}^2} = \sqrt{(103)^2 + (69)^2} = 123.975\ \text{units} \simeq 123.98\ \text{units}$$

22. **(b)**

Let Q be the initial discharge.

Diameter, d = 0.55 m, Length, l = 1.75 km = 1750 m



Before addition of pipe, $h_f = \dfrac{8fLQ^2}{\pi^2 gD^5}$ ... (i)

$$\Rightarrow \quad 30 = \frac{8(0.04)\times(1750)Q^2}{\pi^2(9.81)\times(0.55)^5}$$

Solving, $Q = 0.51\ \text{m}^3/\text{sec}$

After addition of pipe, $h_f = h_{f1} + h_{f2}$ ... (ii)

Where, h_{f2} is Head loss in pipe 2, h_{f3} is Head loss in pipe 3

Also, $h_{f2} = h_{f3}$

$$\therefore \quad \frac{f\,l_2 v_2^2}{2gD_2} = \frac{f\,l_3 v_3^2}{2gD_3}$$

$$v_2 = v_3$$

Also, let Q' be the final discharge

Now, $Q' = Q_2 + Q_3$ [$\because$ Continuity equation]

$\because \quad Q_2 = Q_3$ [$\because V_2 = V_3, A_2 = A_3$]

$$\Rightarrow \quad Q_2 = Q_3 = \frac{Q'}{2}$$

Substituting values in (ii)

$$h_f = \frac{8fl_1Q'^2}{\pi^2 gD_1^5} + \frac{8fl_2(Q'/2)^2}{\pi^2 gD_2^5}$$

$$30 = \frac{8\times0.04\times875}{\pi^2\times9.81\times0.55^5}\left(Q'^2 + \frac{Q'^2}{4}\right)$$

Solving, $Q' = 0.65\ \text{m}^3/\text{s}$

$$\%\ \text{increase} = \frac{Q'-Q}{Q}\times100 = \frac{0.65-0.51}{0.51}\times100 = 27.45\%$$

23. (d)

$$\text{Velocity, } V_0 = 30\ \text{km/hr} = \frac{30\times10^3}{60\times60} = 8.33\ \text{m/s}$$

$$\text{Drag force, } F_D = C_D\cdot\frac{1}{2}\rho\cdot AV_0^2 = 0.2\times\frac{1}{2}\times10^3\times(2\times1.5)\times(8.33)^2$$

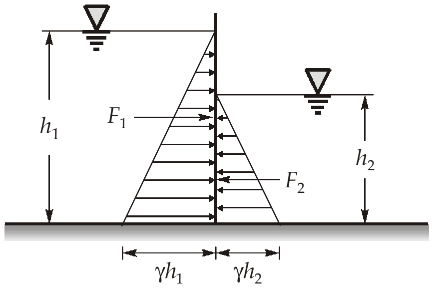
$$= 20816.67\ \text{N} = 20.82\ \text{kN}$$

$$\text{Lift force, } F_L = C_L\times\frac{1}{2}\times\rho\times AV_0^2 = 0.6\times\frac{1}{2}\times10^3\times(2\times1.5)\times8.33^2$$

$$= 62450\ \text{N} = 62.45\ \text{kN}$$

$$\text{Resultant force, } F_R = \sqrt{F_D^2+F_L^2} = \sqrt{(20.82)^2+(62.45)^2} = 65.83\ \text{kN}$$

24. (b)



Consider 1 m length of pile, F_1 =Force due to salt water

$$= \gamma_1 A_1 \bar{h}_1$$

$$= (1.035 \times 9.81) \times (3.5 \times 1.0)\left(\frac{3.5}{2}\right) = 62.2 \text{ kN}$$

h_{c1} = Depth of centre of pressure from free surface of force F_1

$$= \bar{h}_1 + \frac{I_{gg}}{A_1 \bar{h}_1}$$

$$= \frac{3.5}{2} + \frac{\frac{1 \times 3.5^3}{12}}{(3.5 \times 1) \times \left(\frac{3.5}{2}\right)} = 2.333 \text{ m}$$

$\therefore$ Lever arm, a_1 = 3.5 – 2.333 = 1.167 m

F_2 = Force due to fresh water

$$= \gamma_2 A_2 \bar{h}_2 = 9.81 \times (2.5 \times 1) \times \left(\frac{2.5}{2}\right) = 30.7 \text{ kN}$$

$\bar{h}_{c2}$ = Depth of centre of pressure from free surface of force F_2

$$= \bar{h}_2 + \frac{I_{gg}}{A_2 \cdot \bar{h}_2} = \frac{2.5}{2} + \left(\frac{\frac{1 \times 2.5^3}{12}}{(2.5 \times 1) \times \left(\frac{2.5}{2}\right)}\right) = 1.667 \text{ m}$$

$\therefore$ Lever arm, a_2 = 2.5 – 1.667 = 0.833 m

$\therefore$ Net moment about base, M = $F_1 a_1 - F_2 a_2$

= 62.2 × 1.167 – 30.7 × 0.833

= 72.59 – 25.57

= 47.02 kN-m ≈ 47 kN-m

25. (b)

The Reynold's number must be the same in the model and the prototype for similar pipe flows

$$\frac{V_p \cdot D_p}{\nu_p} = \frac{V_m D_m}{\nu_m}$$

$$V_m = \frac{V_p \cdot D_p}{D_m} \cdot \frac{\nu_m}{\nu_p}$$

Here, $V_p = \dfrac{Q}{\frac{\pi}{4}\times D^2} = \dfrac{3}{\frac{\pi}{4}\times(1.5)^2} = 1.7\text{ m/s}$

$\therefore$ $V_m = 1.7\times\dfrac{1.5}{0.15}\times\dfrac{0.01}{0.03} = 5.67\text{ m/s}$

$\therefore$
$$\begin{aligned} Q_m &= \text{Discharge in model} \\ &= V_m\cdot A_m \\ &= V_m\times\frac{\pi}{4}\times D_m^2 \\ &= 5.7\times\frac{\pi}{4}\times 0.15^2 = 0.1\text{ m}^3/\text{sec} \end{aligned}$$

26. (b)

Given,
$$\begin{aligned} H &= 5.5\text{ m} \\ x &= 1.5\text{ m} \\ y &= 0.12\text{ m} \\ d_0 &= 25\text{ mm} \\ C_v &= \frac{x}{2\sqrt{yH}} = \frac{1.5}{2\sqrt{0.12\times5.5}} = 0.923 \end{aligned}$$

Now, $Q = C_d\cdot a\sqrt{2gH}$

$\Rightarrow$ $3\times10^{-3} = C_d\left(\dfrac{\pi}{4}\times0.025^2\right)\times\sqrt{2\times9.81\times5.5}$

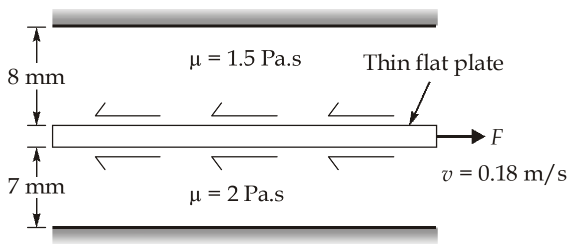
$\Rightarrow$ $C_d = 0.588$

Since $C_d = C_v\cdot C_c$

$\Rightarrow$ $C_c = \dfrac{0.588}{0.923} = 0.637$

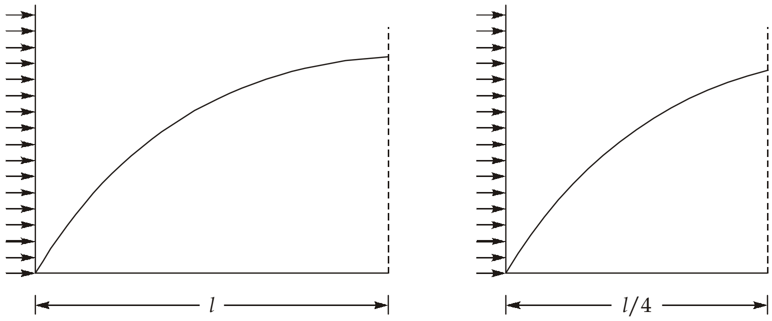
27. (a)

For the given condition,



Force on both sides of plate,
$$\begin{aligned} F &= A[\tau_1+\tau_2] \\ &= 2.5\left[1.5\left(\frac{0.18-0}{8\times10^{-3}}\right)+2\left(\frac{0.18-0}{7\times10^{-3}}\right)\right] \qquad \left[\because \tau = \mu\frac{du}{dy}\right] \\ &= 212.95\text{ N} \end{aligned}$$

28. (d)



For laminar flow, $$C_D = \frac{0.664}{\sqrt{Re}}$$

where, $$Re = \frac{Ul}{\nu}$$

$$C_D = \frac{0.664}{\sqrt{\frac{Ul}{\nu}}}$$

$$C_D \propto \frac{1}{\sqrt{l}}$$

$$C_D\sqrt{l} = \text{Constant}$$

$$C_{D,1}\sqrt{l_1} = C_{D,2}\sqrt{l_2}$$

$$\frac{C_{D,1}}{C_{D,2}} = \sqrt{\frac{l_2}{l_1}}$$

$$\frac{C_{D,1}}{C_{D,2}} = \sqrt{\frac{l/4}{l}}$$

$$\frac{C_{D,1}}{C_{D,2}} = \sqrt{\frac{l}{4}} = 0.5$$

29. (c)

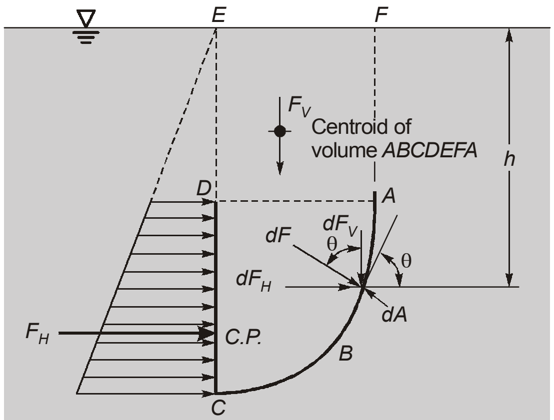
$\because$ $$\bar{h}_p = \bar{h} + \frac{I_G}{A\bar{h}}$$

Also, $$\frac{I_G}{A\bar{h}} > 0$$

Therefore, $\bar{h}_p > \bar{h}$, i.e. centre of pressure or point of action of total hydrostatic force is always below the centroid of the area.

$$F_H = \int dF_H = \gamma \int h dA \sin\theta$$

$$F_V = \int dF_V = \gamma \int h dA \cos\theta$$



where,
$(dA)\sin\theta$ = vertical projection of elementary area dA
$(dA)\cos\theta$ = horizontal projection of elementary area dA
Thus, F_H is the total hydrostatic force on the projected area of the curved surface on the vertical plane and will act at the centre of pressure of the plane surface.
F_V is the weight of the liquid contained in the portion extending vertically above the curved surface up to the free surface of the liquid.

30. (b)

Velocity before expansion, V_1 =2.65 m/s
Velocity after expansion V_2= 1.18 m/s
Loss of load at sudden expansion

$$H_L = \frac{(V_1 - V_2)^2}{2 \times g} = \frac{(2.65 - 1.18)^2}{2 \times 9.81} = 0.11$$

By energy equation

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z + H_L$$

$$\Rightarrow \quad \frac{p_2}{\rho g} = \frac{p_1}{\rho g} + \frac{V_1^2}{2g} - \frac{V_2^2}{2g} - H_L$$

$$\Rightarrow \quad \frac{p_2}{1000 \times 9.81} = \frac{20 \times 1000}{9.81 \times 1000} + \frac{2.65^2}{2 \times 9.81} - \frac{1.18^2}{2 \times 9.81} - 0.11$$

$$p_2 = 21.735 \text{ kN/m}^2$$
$$\simeq 21.74 \text{ kN/m}^2$$

Increase in pressure $= (21.74 - 20)$ kN/m^2
$= 1.74$ kN/m^2

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