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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 20/05/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

Dimensions of dynamic viscosity is $M^1L^{-1}T^{-1}$.

2. (d)

3. (d)

4. (d)

As per Manning's formula,

$$v = \frac{1}{n} \cdot R^{2/3} S^{1/2}$$

We know that,
$$\frac{v_m}{v_p} = \sqrt{L_r}$$

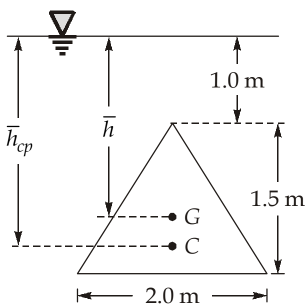
$$\text{The dimension of } R = [L]$$
$$\text{The dimension of } S = M^\circ L^\circ T^\circ$$

$$\therefore \quad n_r = \frac{n_m}{n_p} = \frac{R_r^{2/3}}{v_r}$$

$$\Rightarrow \quad \frac{n_m}{n_p} = \frac{(L_r)^{2/3}}{\sqrt{L_r}}$$

$$\Rightarrow \quad n_p = \frac{n_m}{L_r^{1/6}} = \frac{0.012}{\left(\frac{1}{80}\right)^{1/6}} = 0.025$$

5. (b)



Centre of pressure,
$$\bar{h}_{cp} = \bar{h} + \frac{I_{GG}}{A \cdot \bar{h}}$$

Here,
$$\bar{h} = 1 + \frac{2}{3} \times 1.5 = 2 \text{ m}$$

$$I_{GG} = \frac{bh^3}{36} = \frac{1}{36} \times 2 \times (1.5)^3$$
$$= 0.19 \text{ m}^4$$

and
$$A = \frac{1}{2} \times bh = \frac{1}{2} \times 2 \times 1.5 = 1.5 \text{ m}^2$$

$$\therefore \quad \bar{h}_{cp} = 2 + \frac{0.19}{1.5 \times 2} = 2.06 \text{ m}$$

6. (d)

In case of parallel connection, head loss remains same for all the pipes.

$$\therefore \quad h_{f1} = h_{f2}$$

$$\Rightarrow \quad \frac{8Q_1^2}{\pi^2 g} \times \frac{fL}{D_1^5} = \frac{8Q_2^2}{\pi^2 g} \times \frac{fL}{D_1^5}$$

where Q_1 and Q_2 are discharges in smaller and larger diameter pipe respectively

Since, f and L are equal for both the pipes,

$$\therefore \quad \frac{Q_1^2}{D_1^5} = \frac{Q_2^2}{D_2^5}$$

Here, $D_1 = 20$ cm

and $D_2 = 35$ cm

$$\therefore \quad \frac{Q_1}{Q_2} = \sqrt{\left(\frac{D_1}{D_2}\right)^5} = \sqrt{\left(\frac{20}{35}\right)^5} = 0.2468 \approx 0.25$$

7. (a)

8. (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

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

$$\Rightarrow \quad P_A = 12090.825 \text{ N/m}^2 = 12.09 \text{ kN/m}^2$$

9. (a)

Hydraulic gradient line gives the sum of datum head and the pressure head.

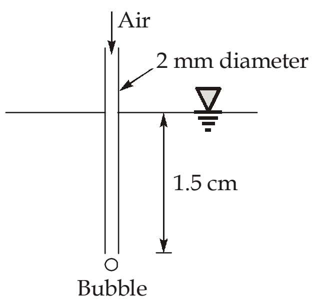
In a gradual contraction, the velocity of flow increases and the pressure decreases. The flow is from higher to lower pressure, which eliminates the causes of turbulence following formation of eddies. The loss of energy in a gradual contraction (also called as reducer) is due to friction mainly, and the resistance (energy loss) offered by a reducer is always less than that of a similar diffuser.

10. (d)

Kinetic energy correction factor is given by

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

11. (d)



$$\text{Pressure inside the bubble } (P_1) = 200 \text{ N/m}^2$$

$$\text{Pressure outside the bubble } (P_2) = \rho g h$$

$$= 0.92 \times 10^3 \times 9.81 \times \frac{1.5}{100}$$

$$= 135.378 \text{ N/m}^2$$

$$\Delta P = P_1 - P_2 = 200 - 135.378$$

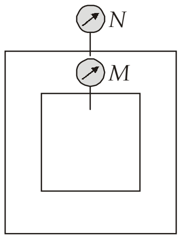
$$= 64.622 \text{ N/m}^2$$

Now, $\Delta P = \frac{2\sigma}{r}$ [where 'r' is internal radius of tube]

$$\Rightarrow \quad 64.622 = \frac{2\sigma}{0.0011}$$

$$\Rightarrow \quad \sigma = 0.0355 \text{ N/m}$$

12. (c)



A bourdon gauge records the gauge pressure relative to the pressure of medium surrounding the tube. Local atmospheric pressure is measured by the aneroid barometer.

In the present case, local atmospheric pressure outside the gauge N = 750 mm of mercury.

Hence absolute pressure at N,

$$(P_N)_{abs.} = 750 + \left(\frac{35 \times 10^3 \times 1000}{13.6 \times 1000 \times 9.81}\right) = 1012.34 \text{ mm of mercury}$$

The gauge M reads relative to its surrounding pressure of 1012.34 mm of mercury (abs.)

Hence, $$(P_M)_{abs} = 1012.34 + \left(\frac{20 \times 10^3 \times 1000}{13.6 \times 1000 \times 9.81}\right) = 1162.25 \text{ mm of mercury}$$

$\therefore$ difference in magnitude of absolute pressure

$$= (P_M)_{abs} - (P_N)_{abs} = 1162.25 - 1012.34 = 149.91 \text{ (mm of mercury)}$$

13. (a)

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

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

Similarly, $$a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = 4 + (t^2 + 3y)(5) + (4t + 5x)(0)$$

$$= 4 + 5t^2 + 15y$$

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

$$a_x = 14 \times 2 + 15 \times 5 = 103 \text{ unit}$$

$$a_y = 4 + (5 \times 2^2) + (15 \times 3) = 69 \text{ unit}$$

$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{(103)^2 + (69)^2} = 123.975 \text{ units} \simeq 123.98 \text{ units}$$

14. (d)

Velocity, $$V_0 = 30 \text{ km/hr} = \frac{30 \times 10^3}{60 \times 60} = 8.33 \text{ m/s}$$

Drag force, $$F_D = C_D \cdot \frac{1}{2}\rho \cdot AV_0^2 = 0.2 \times \frac{1}{2} \times 10^3 \times (2 \times 1.5) \times (8.33)^2$$

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

Lift force, $$F_L = C_L \times \frac{1}{2} \times \rho \times AV_0^2 = 0.6 \times \frac{1}{2} \times 10^3 \times (2 \times 1.5) \times 8.33^2$$

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

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

15. (a)

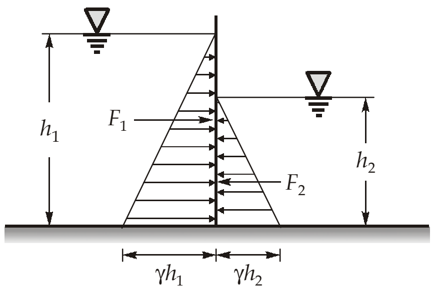
Volume of sea water displaced, $V = \dfrac{\text{Weight}}{\text{Specific weight of sea water}} = \dfrac{40000}{10.1} = 3960.396 \text{ m}^3$

Using the relation, $BM = \dfrac{I}{V} = \dfrac{9000}{3960.396} = 2.2725 \text{ m}$

Also, Metacentric height, $GM = BM - BG = 2.2725 - 1.5 = 0.7725 \text{ m}$

Now, $T = 2\pi\sqrt{\dfrac{K^2}{GM \times g}} = 2\pi\sqrt{\dfrac{(4)^2}{0.7725 \times 9.81}} = 9.1297 \approx 9.13 \text{ sec}$

16. (b)



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

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

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

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

$$= \bar{h}_1 + \frac{I_{gg}}{A_1\bar{h}_1} = \frac{3.5}{2} + \frac{\dfrac{1\times 3.5^3}{12}}{(3.5\times 1)\times\left(\dfrac{3.5}{2}\right)} = 2.333 \text{ m}$$

∴ Lever arm, $a_1 = 3.5 - 2.333 = 1.167 \text{ m}$

F_2 = Force due to fresh water

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

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

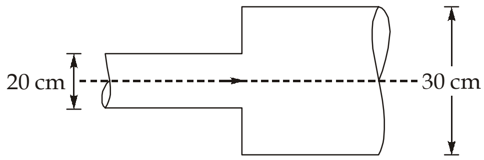
$$= \bar{h}_2 + \frac{I_{gg}}{A_2 \cdot \bar{h}_2} = \frac{2.5}{2} + \left(\frac{\dfrac{1\times 2.5^3}{12}}{(2.5\times 1)\times\left(\dfrac{2.5}{2}\right)}\right) = 1.667 \text{ m}$$

∴ Lever arm, $a_2 = 2.5 - 1.667 = 0.833 \text{ m}$

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

$= 62.2\times1.167 - 30.7\times0.833 = 72.59 - 25.57 = 47.02 \text{ kN-m} \approx 47 \text{ kN-m}$

17. (d)



Head loss due to sudden expansion,

$$h_L = \frac{(V_1 - V_2)^2}{2g}$$

Also, $$Q = A_1 V_1 = A_2 V_2$$

$$\Rightarrow \quad 0.5 = \frac{\pi d_1^2}{4} \cdot V_1 = \frac{\pi d_2^2}{4} \cdot V_2$$

$$\Rightarrow \quad V_1 \cdot d_1^2 = V_2 \cdot d_2^2 = \frac{0.5 \times 4}{\pi} \qquad [\because d_1 = 0.2 \text{ m}, d_2 = 0.3 \text{ m}]$$

$$\Rightarrow \quad V_1 = 15.92 \text{ m/s}$$

and $$V_2 = 7.07 \text{ m/s}$$

$$\therefore \quad h_L = \frac{(15.92 - 7.07)^2}{2 \times 9.81} = 3.99 \text{ m}$$

18. (b)

Let 'n' be the number of parachutes needed

Now, Drag force, $$F_D = \frac{1}{2} C_D A \rho V^2$$

$$= \frac{1}{2} \times 1.3 \times \frac{\pi}{4} \times 8^2 \times 1.25 \times 4^2 = 653.45 \text{ N}$$

Number of parachutes required, $n = \dfrac{1500}{653.45} = 2.296 \simeq 3$

19. (b)

In venturimeter,

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

Here, $$H = 18\left(\frac{\rho_{Hg}}{\rho_w} - 1\right) = 18\left(\frac{13.6 \times 10^3}{10^3} - 1\right) = 226.8 \text{ cm}$$

$$\therefore \quad Q = \frac{0.98 \times \frac{\pi}{4} \times 35^2 \times \frac{\pi}{4} \times 20^2}{\sqrt{\left(\frac{\pi}{4} \times 35^2\right)^2 - \left(\frac{\pi}{4} \times 20^2\right)^2}} \times \sqrt{2 \times 9.81 \times 10^2 \times 226.8}$$

$$= 217284.83 \text{ cm}^3/\text{s} = 217.28 \ l/\text{s} \approx 217.3 \ l/\text{s}$$

20. (a)

Given, H = 6 m, x = 2 m and y = 0.18 m

$$\text{Now, Coefficient of velocity, } C_V = \frac{x}{2\sqrt{y.H}}$$

$$= \frac{2}{2\sqrt{0.18 \times 6}} = 0.962$$

$$\text{Now, Discharge, } Q = C_d \times A \times \sqrt{2gH}$$

where 'Q' is 4×10^{-3} m^3/s

$$\Rightarrow \quad 4 \times 10^{-3} = C_d \times \frac{\pi \times 0.03^2}{4} \times \sqrt{2 \times 9.81 \times 6}$$

$$\Rightarrow \quad C_d = 0.522$$

$$\text{Now, } C_d = C_V \times C_C$$

where C_C is coefficient of contraction

$$\Rightarrow \quad C_C = \frac{C_d}{C_v} = \frac{0.522}{0.962} = 0.543$$

21. (a)

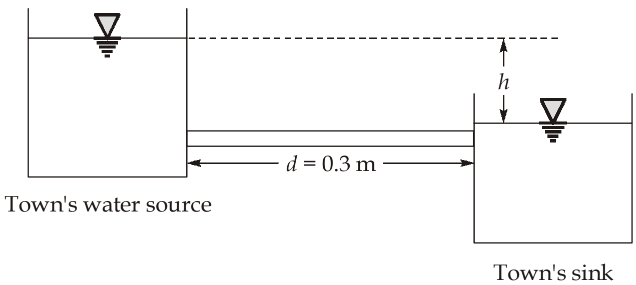
For two dimensional laminar flow between paralllel plates,

$$\text{Pressure gradient, } \left(-\frac{\partial p}{\partial x}\right) = \frac{12\mu V}{B^2}$$

$$= \frac{12 \times 1.05 \times 10^{-1} \times 1.4}{(0.012)^4} = 12250 \text{ Pa/m}$$

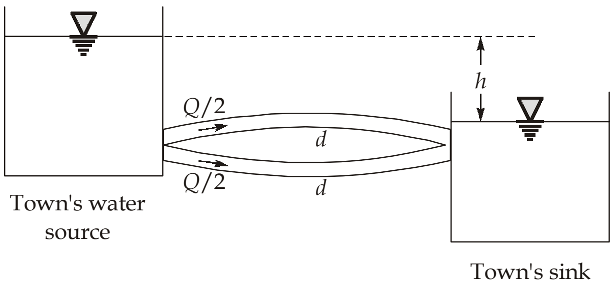
22. (d)

Case 1: Single pipe connection



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

Case 2: Dual pipe connection



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

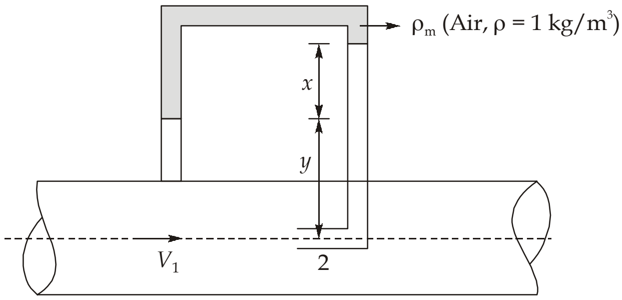
Using (i) and (ii)

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

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

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

23. (a)



$$V_1 = \sqrt{2gh}$$

$$h = \frac{P_2 - P_1}{\rho g}$$

Applying pressure balance equation between (1) and (2)

$$P_1 - \rho g y - \rho_m g x + \rho g(y + x) = P_2$$

$$\frac{P_2 - P_1}{\rho g} = x\left(1 - \frac{\rho_m}{\rho}\right)$$

$$h = x\left(1 - \frac{\rho_m}{\rho}\right) = 0.15\left(1 - \frac{1}{1000}\right)$$

$$h = 0.149 \text{ m}$$

$$V_1 = \sqrt{2 \times 9.81 \times 0.149} = 1.714 \text{ m/s}$$

24. (c)

$$u = V_0 \sin\frac{\pi}{2}\left(\frac{y}{\delta}\right)$$

$\therefore$ $$\frac{du}{dy} = V_0 \cos\frac{\pi}{2}\left(\frac{y}{\delta}\right)\times\frac{\pi}{2\delta}$$

Local shear stress, $$\tau_0 = \mu\left(\frac{du}{dy}\right)_{y=0}$$

$$= \mu\times\frac{V_0\pi}{2\delta}$$

$$= 1.02\times10^{-3}\times\frac{0.20\times\pi}{2\times8\times10^{-3}}$$

$$= 0.04 \text{ N/m}^2$$

25. **(a)**

Consider an annular ring with thickness *dr* at radius *r*. Velocity variation in the gap is given as linear.

Hence the velocity at radius *r* from centre = $v = wr$

$\therefore$ Shear stress on the ring,

$$\tau = \mu\frac{du}{dy} = \mu\left(\frac{wr}{h}\right)$$

Force on the ring, $$dF = \tau \times dA$$

$$= \left(\frac{\mu wr}{h}\right)\times 2\pi r dr = \left(\frac{2\pi\mu w}{h}\right)r^2 dr$$

Torque on the ring, $$dT = F \times r$$

$$= r\tau dA$$

$$= \left(\frac{2\pi\mu w}{h}\right)r^2\cdot rdr$$

$$= \left(\frac{2\pi\mu w}{h}\right)r^3 dr$$

$\therefore$ Total torque on disc $$= \int_0^R dT = \frac{2\pi\mu w}{h}\int_0^R r^3 dr$$

$\Rightarrow$ $$T = \frac{2\pi\mu w}{h}\left[\frac{r^4}{4}\right]_0^R$$

$$= \frac{\pi\mu w R^4}{2h}$$

26. **(a)**

Equation of stream line is given as,

$$\frac{dx}{u} = \frac{dy}{v}$$

$$\Rightarrow \quad \frac{dx}{\cos\theta} = \frac{dy}{\sin\theta}$$

$$\Rightarrow \quad dx = \frac{\cos\theta}{\sin\theta}dy$$

Integrating both sides, we get

$$\int dx = \int \frac{\cos\theta}{\sin\theta}dy$$

$$\Rightarrow \quad x = y\cot\theta + C$$

As the line is passing through origin, therefore, $C = 0$.

27. (b)

$$\text{Central velocity} = C_v\sqrt{2gh}$$

$$= 0.98 \times \sqrt{2 \times 9.81 \times 0.06}$$

$$= 1.06 \text{ m/s}$$

$$\text{Mean velocity} = 0.85 \times 1.06 = 0.9 \text{ m/s}$$

$$\therefore \quad \text{Discharge, } Q = \frac{\pi}{4} \times 0.3^2 \times 0.9$$

$$= 0.064 \text{ m}^3\text{/s}$$

28. (a)

As we know, $Q = |d\psi| = |\psi_2 - \psi_1|$

At (2, 1): $\psi_1 = 8 \times 2 \times 1^2 - 2(2)$

$= 12$ units

At $(2\sqrt{2}, 1)$; $\psi_2 = 8 \times 2\sqrt{2} \times 1^2 - 2(2\sqrt{2}) = 12\sqrt{2}$

So, $Q = |12\sqrt{2} - 12| = 4.97$ units

29. (d)

Given, $\theta = 60°$

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

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,

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

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

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

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

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

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

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

30. (d)

Momentum thickness, θ is given by

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

$\Rightarrow$ $$\theta = \int_0^\delta \left\{\left(\frac{2y}{\delta}\right) - \frac{y^2}{\delta^2}\right\}\left\{1 - \frac{2y}{\delta} + \frac{y^2}{\delta^2}\right\} dy$$

$$= \int_0^\delta \left[\frac{2y}{\delta} - \frac{4y^2}{\delta^2} + \frac{2y^3}{\delta^3} - \frac{y^2}{\delta^2} + \frac{2y^3}{\delta^3} - \frac{y^4}{\delta^4}\right] dy$$

$$= \int_0^\delta \left[\frac{2y}{\delta} - \frac{5y^2}{\delta^2} + \frac{4y^3}{\delta^3} - \frac{y^4}{\delta^4}\right] dy$$

$$= \left[\frac{2y^2}{2\delta} - \frac{5y^3}{3\delta^2} + \frac{4y^4}{4\delta^3} - \frac{y^5}{5\delta^4}\right]_0^\delta = \left[\delta - \frac{5\delta}{3} + \delta - \frac{\delta}{5}\right] = \frac{2\delta}{15}$$

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