CLASS TEST

S.No. : 02_SK_CE_S+G_210922

MADE EASY

India's Best Institute for IES, GATE & PSUs

Delhi | Bhopal | Hyderabad | Jaipur | Lucknow | Pune | Bhubaneswar | Kolkata | Patna

Web: www.madeeasy.in | **E-mail:** info@madeeasy.in | **Ph:** 011-45124612

FLUID MECHANICS

CIVIL ENGINEERING

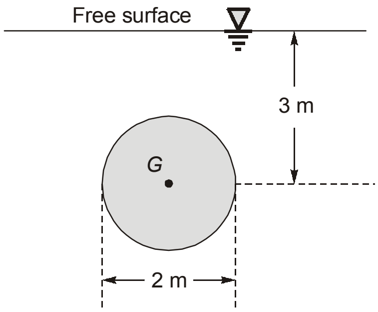
Date of Test : 21/09/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

2. (d)



$$d = 2 \text{ m}$$

$$A = \frac{\pi}{4} \times 2^2 = 3.14 \text{ m}^2$$

$$\bar{h} = 3.0 \text{ m}$$

$$\text{Total pressure, } F = \rho g A \bar{h}$$

$$= 1000 \times 9.81 \times 3.14 \times 3 = 92.41 \text{ kN}$$

4. (b)

For laminar boundary layer over a flat plate

$$\tau = C_f \frac{\rho V^2}{2}$$

where $$C_f = \frac{0.664}{\sqrt{R_{ex}}}$$

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

$$\Rightarrow \quad \frac{\tau_1}{\tau_2} = \sqrt{15}$$

5. (c)

For pipes in series

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

$$\Rightarrow \quad \frac{6000}{d^5} = \frac{1000}{(0.2)^5} + \frac{2000}{(0.4)^5} + \frac{3000}{(0.6)^5}$$

$$\Rightarrow \quad d = 0.282 \text{ m} \quad \text{or} \quad d = 282 \text{ mm}$$

6. (b)

In this case Froude model law is applicable

Given: $$L_r = \frac{1}{15}$$

$$\because \quad V_r = \sqrt{L_r}$$

$\therefore$ Force ratio, $F_r = L_r^3$

$\therefore$ Force on prototype $= 0.8 \times (15)^3 = 2700$ Newton

7. (b)

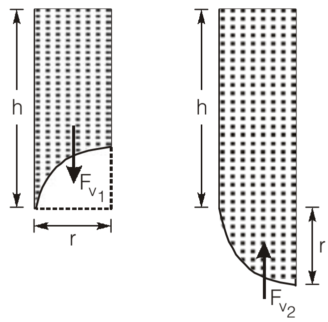
$$a = \frac{\pi}{4}d^2 = \frac{\pi}{4} \times (0.070)^2 = 0.00385 \text{ m}^2$$

Velocity of jet, $V = 10$ m/s

The force exerted by the jet of water on a stationary vertical plate is given as,

$$F = \rho a V^2 = 1000 \times 0.00385 \times 10^2$$
$$= 385 \text{ N}$$

12. (d)



Horizontal component $(F_x) = \rho g \bar{h} A$

where A is projected area of gate

$$F_x = \rho gh \times 2rw = 2\rho ghrw$$

$$F_H = \text{Pressure} \times \text{Projector arc of gate}$$
$$= \rho gh \times (2r \times w) = 2\rho ghrw$$

$$F_{v_1} = \rho g \forall = \rho g\left(h \times r - \frac{\pi r^2}{4}\right)w \quad \text{(downwards)}$$

$$F_{v_2} = \rho g \forall = \rho g\left(h \times r + \frac{\pi r^2}{4}\right)w \quad \text{(upwards)}$$

Vertical component,

$$(F_y) = \left(F_{v_2} - F_{v_1}\right)$$
$$= \rho g w\left[2 \times \frac{\pi r^2}{4}\right]$$
$$= \frac{\pi \rho g w r^2}{2}$$

Positive sign indicates that net vertical component of hydrostatic force is in upward direction.

13. (d)

As the pipe is rigid, velocity of pressure wave,

$$C = \sqrt{\frac{K}{\rho}} = \left(\frac{2.2 \times 10^9}{998}\right)^{1/2} = 1484.7 \text{ m/s}$$

Critical time $\quad T_o = \frac{2L}{C} = \frac{2 \times 3500}{1484.7} = 4.715$ s

As T = time of closure = 4.0s, the closure is rapid

Hence the water hammer pressure,

$$P_h = \rho C V_0 = 998 \times 1484.7 \times 0.8 = 1.185 \text{ MPa}$$

14. (a)

Reynold number at the trailing end,

$$Re_L = \frac{UL}{\nu} = \frac{1 \times 3}{10^{-5}} = 3 \times 10^5 < 5 \times 10^5$$

⇒ Boundary layer is laminar over the entire length of plate.

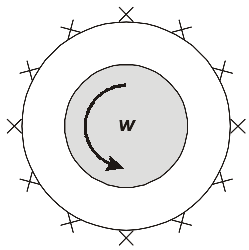
Thus, thickness of boundary layer at the end of the plate from Blasius's solution is,

$$\delta = \frac{5 \times L}{\sqrt{Re_L}} = \frac{5 \times 3}{\sqrt{3 \times 10^5}} = 0.0274 \text{ m}$$

$$\simeq 27.4 \text{ mm}$$

15. (a)

The torque is transmitted through the fluid layers to the outer cylinder.



Tangential velocity of the inner cylinder

$$= \omega r = \frac{2\pi n}{60} \times r = 0.2 \times \frac{2\pi 60}{60} = 1.257 \text{ m/s}$$

For small space between the cylinders, the velocity profile may be assumed to be linear, and thus

$$\frac{du}{dy} = \frac{1.257}{(205 - 200) \times 10^{-3}} = 251.4 \text{ per sec}$$

Torque applied = Torque resisted

⇒ 0.98 = τ × Area × Lever arm

⇒ 0.98 = τ × (2π × 0.20 × 0.30) × 0.20

⇒ $\tau = 12.998 \simeq 13 \text{ N/m}^2$

∴ $$\mu = \frac{\tau}{du/dy} = \frac{13}{251.4} = 0.052 \text{ N-s/m}^2$$

16. (b)

$$v = \frac{\partial \psi}{\partial x} = \frac{\partial(6x^2 - y^3)}{\partial x} = 12x$$

$$u = \frac{-\partial \psi}{\partial y} = \frac{-\partial(6x^2 - y^3)}{\partial y} = 3y^2$$

At point (2, 1),

v = 24 units

u = 3 units

∴ The total velocity is the vector sum of two components i.e.,

⇒ $$V = \sqrt{u^2 + v^2} = \sqrt{3^2 + 24^2} = 24.19 \text{ units}$$

17. (b)

Circulation,
$$\Gamma = \text{Vorticity} \times \text{Area}$$
$$= \left(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial y}\right) \times \text{Area}$$
$$= (2-5) \times \pi \times 1^2$$
$$= -3\pi \text{ units}$$

18. (b)

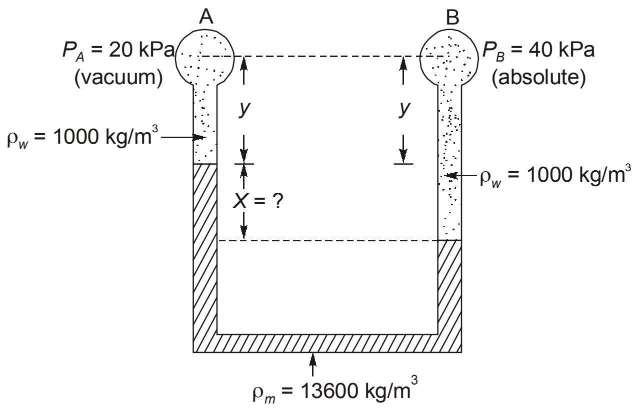
From Bernoulli's equation, we have
$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + h_c$$
$$\Rightarrow \quad \frac{14 \times 10^4}{1000 \times 9.81} + \frac{1.6^2}{2 \times 9.81} = \frac{12 \times 10^4}{1000 \times 9.81} + \frac{6.4^2}{2 \times 9.81} + h_c$$
$$\Rightarrow \quad h_c = 0.0816 \text{ m}$$

Now,
$$h_c = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$
$$\Rightarrow \quad 0.0816 = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$
$$\Rightarrow \quad 0.0816 = \frac{6.4^2}{2 \times 9.81}\left[\frac{1}{C_c} - 1\right]^2$$
$$\Rightarrow \quad C_c = 0.835 \simeq 0.84$$

19. (b)

$$C_D = \frac{24}{Re}$$
$$Re = \frac{1000 \times 0.1 \times 0.1 \times 10^{-2}}{1} = 0.1$$
$$C_D = \frac{24}{0.1} = 240$$

22. (a)

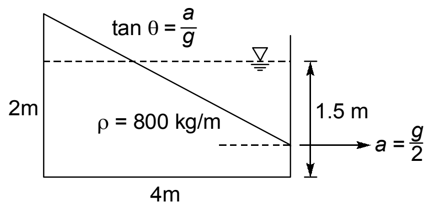


Equating pressure in two limbs.

$\Rightarrow$ $$P_A + P_w gy + P_m gx = P_B + P_w gy + P_w gx$$

$$P_A = -20 \text{ kPa} \quad \text{(given)}$$
$$P_B = 40 \text{ kPa} \quad \text{(given)}$$
$$(\rho_m - \rho_w) \times g \times x = (40 + 20) \text{ kPa}$$
$$x = \frac{60 \times 1000}{12600 \times 9.81} = 0.485 \text{ m}$$

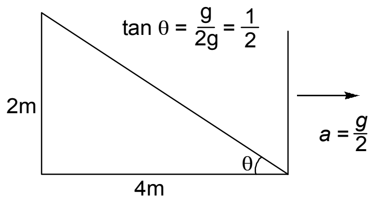
23. (c)



$\Rightarrow$ Surface of liquid will make angle with horizontal = a/g

$\Rightarrow$ $$\tan\theta = \frac{a}{g} = \frac{g/2}{g} = \frac{1}{2}$$

$\Rightarrow$ $$\frac{y}{4} = \frac{1}{2}$$



$\Rightarrow$ $$y = 2 \text{ m}$$

$\Rightarrow$ $$\text{Initial volume} = 1.5 \times 4 \times 2.5 = 15 \text{ m}^3$$

$\Rightarrow$ $$\text{Finally retained volume} = \frac{1}{2} \times 2 \times 4 \times 2.5 = 10 \text{ m}^3$$

$\Rightarrow$ $$\text{Spilled out volume} = 15 - 10 = 5 \text{ m}^3$$

24. (c)

$$\tau_r = -\frac{\partial p}{\partial x}\frac{r}{2}$$
$$\tau_{wall} = -\frac{\partial p}{\partial x}\frac{R}{2}$$

Since flow is taking place under same pressure gradient, therefore

$$\frac{\tau_r}{\tau_w} = \frac{r}{R} \Rightarrow \tau_r = \tau_w \frac{r}{R} = 72 \times \frac{50}{90} = 40 \text{ N/m}^2$$

25. (b)

Reynold's number must be same for model and prototype

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

$$\Rightarrow \quad \frac{\rho_p V_p D_p}{\mu_p} = \frac{\rho_m V_m D_m}{\mu_m}$$

$$\Rightarrow \quad V_m = V_p \cdot \frac{D_p}{D_m} \cdot \frac{\rho_p}{\rho_m} \frac{\mu_m}{\mu_p}$$

$$= 1.7099 \times \frac{2.2}{0.20} \times \frac{0.9}{1} \times \frac{0.01}{0.03} = 5.64 \text{ m/s}$$

$$\left[\because \quad V_p = \frac{Q_p}{A_p} = \frac{6.5}{\frac{\pi}{4}(2.2)^2} = 1.7099 \text{m/s}\right]$$

$$\therefore \quad \text{Discharge in the model} = 5.64 \times \frac{\pi}{4} \times 0.20^2 = 0.18 \text{ m}^3/\text{s}$$

26. (c)

$$F = \rho A\ V^2$$

$$V = C_v \sqrt{2gH}$$

$$= 0.98\ \sqrt{2 \times 10 \times 50} = 30.99 \text{ m/s}$$

$$F = 1000 \times \frac{\pi}{4} \times (0.030)^2 \times 30.99^2$$

$$= 678.87 \text{ N} \simeq 0.68 \text{ kN}$$

27. (a)

Maximum head available at the outlet of the pipe $= H - h_f$

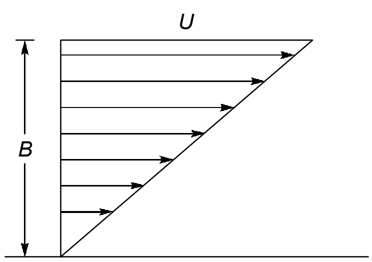
$$= H - \frac{H}{3} = \frac{2H}{3} = \frac{2 \times 400}{3} = 266.67 \text{ m}$$

$$\therefore \text{ Maximum power available} = \rho Qg(H - h_f)$$

$$= \frac{1000 \times 9.81 \times 0.2 \times 266.67}{1000} \text{ kW}$$

$$= 523.2 \text{ kW}$$

28. (b)



$$\Rightarrow \quad q = \frac{U \times B}{2}$$

29. (d)

$$\text{Mean velocity, } V = \frac{Q}{A} = \frac{300 \times 10^{-3}}{\left(\frac{\pi}{4}\right) \times (0.3)^2} = 4.244 \text{ m/s}$$

$$\text{Shear velocity, } u_* = V\sqrt{\frac{f}{8}} = 4.244 \times \sqrt{\frac{0.0097}{8}} = 0.1478 \text{ m/s}$$

Maximum velocity u_m is related to the mean velocity in both smooth and rough turbulent flows as

$$\frac{u_m - V}{u_*} = 3.75$$

$$\Rightarrow \quad u_m = 3.75\, u_* + V = 3.75 \times 0.1478 + 4.244$$

$$= 4.798 \text{ m/s} \simeq 4.8 \text{ m/s}$$

30. (b)

Discharge through a venturimeter is given by

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

where, $a_2 = \frac{\pi}{4} \times 0.3^2 = 0.0707 \text{ m}^2$

$a_1 = \frac{\pi}{4} \times 0.15^2 = 0.0177 \text{ m}^2$

and $Q = 120\ l\text{/s} = 0.12 \text{ m}^3\text{/s}$

$$\Rightarrow \quad 0.12 = \frac{0.0177 \times 0.0707 \times \sqrt{2 \times 9.81 \times h}}{\sqrt{(0.0707)^2 - (0.0177)^2}}$$

$\Rightarrow \quad h = 2.196$ m

Also, head, $h = x\left(\frac{S_h}{S_l} - 1\right)$

where, S_h and S_l are specific gravities of heavier and lighter manometric fluids.

$\Rightarrow \quad S_h = S_{Hg} = 13.6$

$S_l = S_{water} = 1$

$\Rightarrow \quad 2.196 = x(13.6 - 1)$

$\Rightarrow \quad x = 0.1743 \text{ m} = 17.43 \text{ cm}$

■■■■