ACE Engineering Academy

Hyderabad | Delhi | Bhopal |Pune | Bhubaneswar | Bengaluru |Lucknow | Patna | Chennai | Vijayawada | Visakhapatnam | Tirupati | Kukatpally| Kolkata

H.O: 204, II Floor, Rahman Plaza, Opp. Methodist School, Abids, Hyderabad-500001,

Ph: 040-23234418, 040-23234419, 040-23234420, 040 - 24750437

ESE- 2018 (Prelims) - Offline Test Series Test-1

MECHANICAL ENGINEERING

SUBJECT: FLUID MECHANICS & TURBO MACHINERY - SOLUTIONS

01. Ans: (b)

Sol: From the top tube containing alcohol,

11 kPa + (0.9)(10)(3.3)

$= 40.7\text{ kPa} = (P_B)_{abs} = (P_A)_{abs}$

So,

$(P_A)_{gauge} = (P_A)_{abs} - (P_{atm})$

$= 40.7 - 93 = -52.3\text{ kPa}$

Again,

From the U-tube, we can write

$(P_B)_{abs} + 0.9\times10(y + h) - 13.6\times10\times h = 0$

$(P_B)_{abs} + 9y + 9h - 136h = 0$

Or, $127\, h = 40.7 + 9\times1.6$

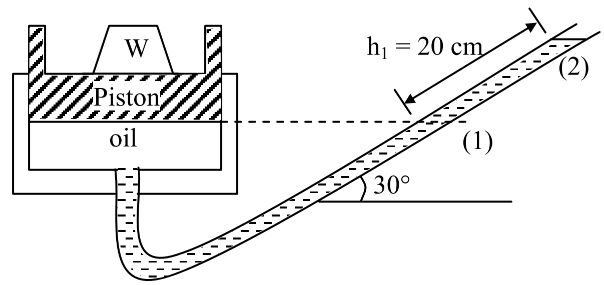
$= 40.7 + 14.4$

$= 55.1$

or, $h = \dfrac{55.1}{127}\text{ m} = 0.434\text{ m} = 43.4\text{ cm}$

02. Ans: (b)

Sol:



With piston alone, let pressure on the piston $= P_P$

The manometric equation gives,

$P_P - \gamma_{oil}h_1\sin30° = 0$ -----------(1)

With weight added, pressure P_P increases to

P'_P where $P'_P = P_P + \dfrac{W}{A_P}$

where, A_P is piston area and manometric equation becomes

$P'_P - \gamma_{oil}(h_1 + 0.20)\sin 30° = 0$ ----------(2)

Subtract equation (1) from equation (2)

$P'_P - P_P - \gamma_{oil}[h_1 + 0.20 - h_1]\sin 30° = 0$

or, $\frac{W}{A_P} = \gamma_{oil} \times 0.2 \times \sin 30^o$

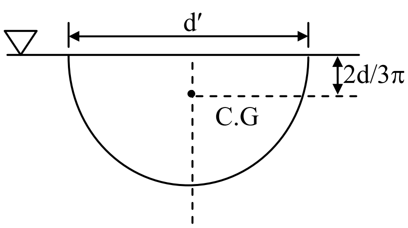
or,

$$W = A_P \times \gamma_{oil} \times 0.2 \times \frac{1}{2} = \frac{\pi}{4} \times 0.2^2 \times 9.5 \times 0.2 \times \frac{1}{2}$$

$$= 9.5\,\pi \text{ N}$$

03. Ans: (a)

Sol:



The depth of centre of pressure

$$h_{CP} = \bar{h} + \frac{I_{xx,\,c}}{A.\bar{h}}$$

But $\frac{I_{xx,\,c}}{A}$ = radius of gyration of plate about centroid $= \frac{0.22d^2}{4\pi}$ (given)

$$\bar{h} = \frac{2d}{3\pi}$$

Then, $h_{CP} = \frac{2d}{3\pi} + \frac{0.22d^2 \times 3\pi}{4\pi \times 2d}$

$$= \frac{2d}{3\pi} + \frac{0.66d}{8}$$

$$= d\left[\frac{2}{3\pi} + 0.0825\right]$$

$$= 0.295\text{ d}$$

≈ 0.3d (approximately)

04. Ans: (b)

Sol: The capillary rise in a glass tube is given by,

$$h = \frac{4\sigma_s}{\gamma \times d}$$

$$= \frac{4 \times 0.073}{10^4 \times 0.4 \times 10^{-3}} = 0.073 \text{ m} = 7.3 \text{ cm}$$

05. Ans: (a)

Sol: For an ideal gas, P = ρRT

$$\left(\frac{\partial P}{\partial \rho}\right)_T = RT = \frac{P}{\rho}$$

or, $\rho\left(\frac{\partial P}{\partial \rho}\right)_T = P$

or, coefficient of compressibility for an ideal gas, β = P.

Also, $\beta = \frac{\Delta P}{\Delta\rho/\rho}$ Or, $P = \frac{\Delta P}{\Delta\rho/\rho}$

Thus, $\frac{\Delta\rho}{\rho} = \frac{\Delta P}{P}$

At 10 atm: $\frac{\Delta\rho}{\rho} = \frac{(11-10)}{10} = 10\%$

At 1000 atm : $\frac{\Delta\rho}{\rho} = \frac{1001-1000}{1000} = 0.1\%$

06. Ans: (d)

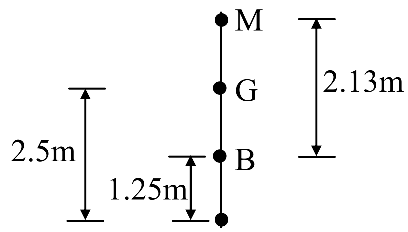
Sol: $F_H = \gamma_w \times \frac{3}{2} \times 3 \times 1 = 4.5\,\gamma_w$

$$F_V = \gamma_w \times \frac{\pi}{4} \times 3^2 = 2.25\pi\,\gamma_w$$

Ratio $\frac{F_H}{F_V} = \frac{4.5}{2.25\pi} = \frac{2}{\pi}$

07. Ans: (c)

Sol:



Total weight of the arrangement

$= (1200 + 800)\text{ kN} = 2000\text{ kN}$

Volume of sea water displaced,

$$\forall = \frac{2000}{10} = 200\text{ m}^3$$

and, depth of immersion, $d = \dfrac{200}{8\times10} = 2.5\text{m}$

Distance of centre of buoyancy (B) from the base point O,

$$OB = \frac{d}{2} = 1.25\text{m}$$

Let M be the metacentre, then

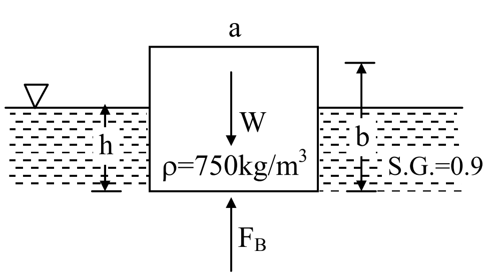
$$BM = \frac{I}{\forall} = \frac{1}{12}\times\frac{10\times8^3}{200} = \frac{32}{15} = 2.13\text{ m}$$

The metacentric height,

$$GM = BM - BG = BM - (OG - OB)$$
$$= 2.13 - (2.5 - 1.25)$$
$$= 2.13 - 1.25$$
$$= 0.88\text{ m} \approx 0.9\text{ m}$$

08. Ans: (a)

Sol:



Let the dimension of the block be 'a' and 'b' and, its width be *l*.

Weight of the block = Buoyant force

Or $a\times b\times l\times750\times9.81 = a\times h\times l\times0.9\times10^3\times9.81$,

where h is depth of immersion.

$$h = \frac{750b}{900}$$

Volume of block which is submerged,

$$V_s = a\times h\times l$$

Total volume of the block = $a\times b\times l$

Volume of block which is not submerged

$$= a\times b\times l - a\times h\times l$$
$$= a\times b\times 1 - \frac{750\,ab\ell}{900} = \frac{150}{900}ab\ell$$

% of volume of block which is not submerged, is

$$= \frac{ab\ell\times150/900}{ab\ell}\times100 = \frac{150}{9} = 16.67\%$$

09. Ans: (b)

Sol: Weight of filled up balloon + weight of equipment + weight of maximum allowable load = Buoyant force

$$\frac{4}{3}\pi R^3\times0.6\times g + 50\times g + \text{Load}\times g = \frac{4}{3}\pi R^3\times1.2\times g$$

Or, $\text{Load} = \frac{4}{3}\pi R^3(1.2 - 06) - 50$

$$= \frac{4}{3}\pi\times3^3\times0.6 - 50$$
$$= 67.86 - 50 = 17.86\text{ kg}$$

10. Ans: (d)

Sol:

- Buoyant force, $F_B = \gamma \forall$

  For completely immersed objected $F_B \propto \gamma$

  So, statement 1 is FALSE.

- $F_R = \gamma \bar{h} A$

  First case:

  $$\bar{h}_1 = \frac{L}{2} \quad \text{and} \quad A = L \times L$$

  $$F_{R_1} = \gamma\left(\frac{L}{2}\right)(L \times L) = \frac{\gamma L^3}{2}$$

  Second case:

  $$\bar{h}_2 = L + \frac{L}{2} = \frac{3L}{2} \quad \text{and} \quad A = L \times L$$

  $$F_{R_2} = \gamma\left(\frac{3L}{2}\right)(L \times L) = \frac{3\gamma L^3}{2}$$

  Thus, $F_{R2} = 3\,F_{R1}$

  So, statement 2 is CORRECT.

- $\frac{\partial p}{\partial r} = -\rho\omega^2 r$

  So, statement 3 is FALSE

- $\frac{dp}{dz} = -\rho g \rightarrow$ valid for both incompressible and so statement 4 is CORRECT.

11. Ans: (a)

Sol: The soap bubble will have the greater pressure because there are two surfaces (two surface tension forces) creating the pressure within the bubble. The correct choice is (a).

12. Ans: (b)

Sol: From the given stream function

$$\psi = -2x^2 + y$$

$$u = \frac{-\partial\psi}{\partial y} = -1 \quad \text{and} \quad v = \frac{\partial\psi}{\partial x} = -4x$$

So, $V = \sqrt{u^2 + v^2} = \sqrt{(1)^2 + (-4x)^2}$

$$V\big|_{\substack{x=1\\y=2}} = \sqrt{1+16} = \sqrt{17}\ \text{m/s} = 4.12\ \text{m/s}$$

Statement (1) is correct.

$$\omega_z = \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = (-4, -0) = -4 \neq 0$$

Flow is rotational.

Statement (2), is wrong.

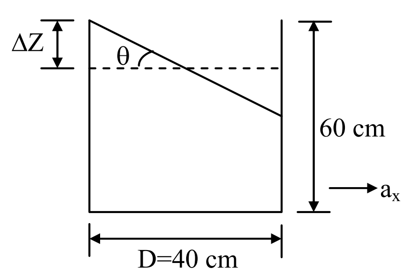
Since, $u = -1 \neq 0$. So, there is no stagnation point

$\Rightarrow$ Statement (3) is correct.

13. Ans: (c)

Sol: We know that

$$\tan\theta = \frac{a_x}{g + a_z} = \frac{4}{10 + 0} = 0.4$$



The maximum vertical rise of the free surface occurs at the back of the tank.

$$\Delta Z_{max} = \frac{D}{2}\tan\theta = \frac{0.4}{2} \times 0.4 = 0.08\,\text{m} = 8\,\text{cm}$$

Therefore, the maximum initial water height in the tank to avoid spilling is

$$h_{max} = 60 - 8 = 52 \text{ cm}$$

14. Ans: (b)

Sol: Normal acceleration,

$$a_N = \frac{V^2}{R} = g \quad \text{(given)}$$

So, $V = \sqrt{gR} = \sqrt{9.81 \times 0.6} = 2.42$ m/s

15. Ans: (b)

Sol: It is known for the trajectory of the jet that $x = V_o \times t$ where V_o is the velocity of jet at the orifice

And $\quad y = \frac{1}{2}gt^2 = \frac{1}{2}g\left(\frac{x}{V_o}\right)^2$

From the given coordinates, i.e., x = 1m and y = 1m,

$$V_o = 1\left(\frac{10}{2 \times 1}\right)^{1/2} = 5^{1/2} = 2.21 \text{ m/s}$$

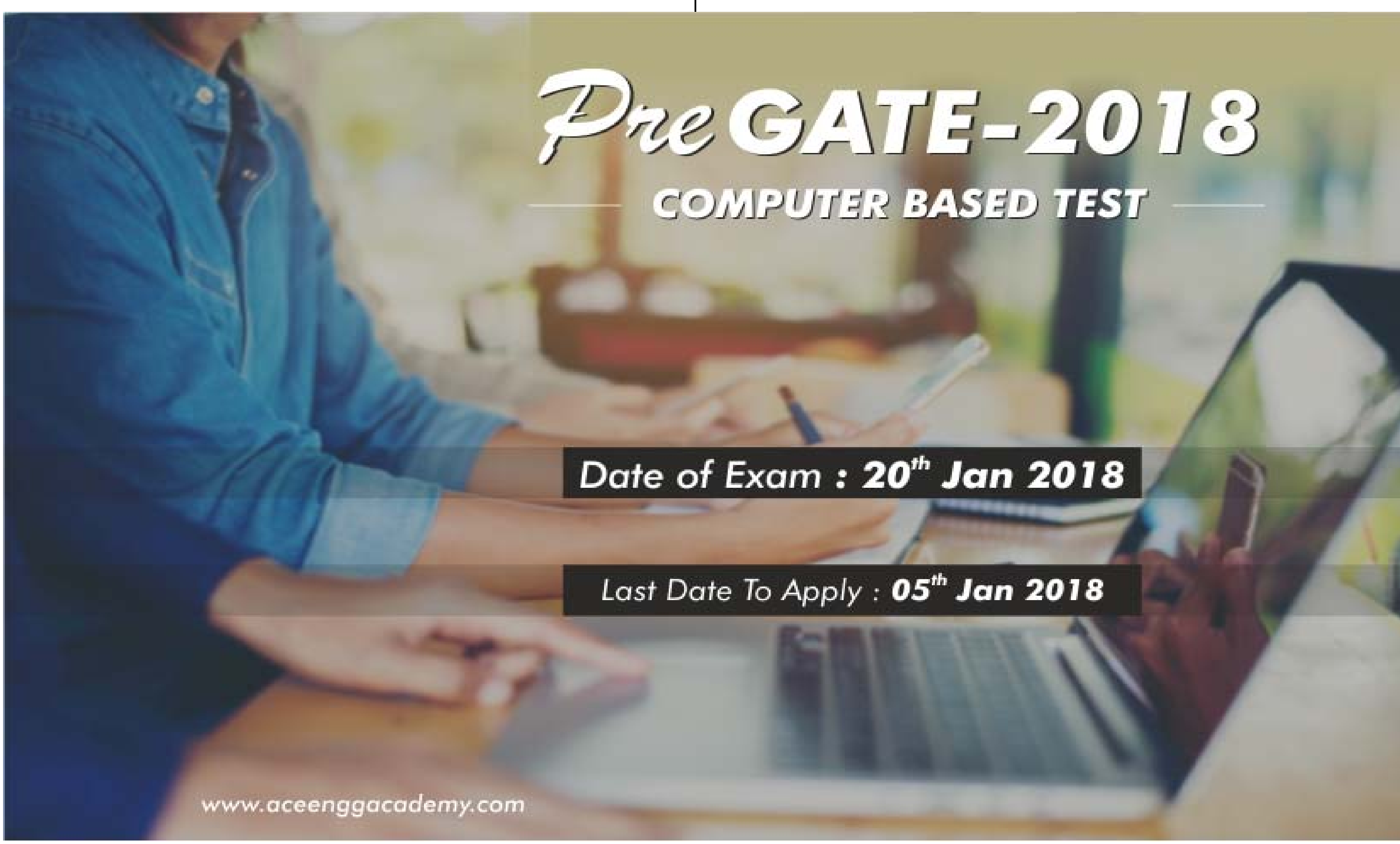
16. Ans: (a)

Sol: In the x-y plane, the rate of rotation of a fluid particle is given by

$$\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = \frac{1}{2}\left(0 - \frac{v_0}{h}\right)$$

$$= -\frac{v_0}{2h}$$

The other components will be zero.



17. Ans: (c)

Sol: The equation of the streamlines for the given flow field is given by

$$\frac{dy}{dx} = -\frac{2Cxy}{C(x^2 - y^2)} = \frac{-2xy}{x^2 - y^2} = \frac{v}{u}$$

For flow to be parallel to y-axis, u = 0

Or, $\frac{dy}{dx} = \frac{-2xy}{x^2 - y^2} = \infty$

This is possible when $x = \pm y$

18. Ans: (b)

Sol: The two dimensional continuity equation in cylindrical polar coordinates is

$$\frac{1}{r}\frac{\partial}{\partial r}(rv_r) + \frac{1}{r}\frac{\partial v_\theta}{\partial \theta} = 0$$

Or, $\frac{\partial v_\theta}{\partial \theta} = -\frac{\partial}{\partial r}(rv_r)$

For $v_r = \frac{r}{2} + \frac{r^2}{3}\sin\theta$

$$\frac{\partial v_\theta}{\partial \theta} = \frac{-\partial}{\partial r}\left(\frac{r^2}{2} + \frac{r^3}{3}\sin\theta\right) = -r - r^2\sin\theta$$

Integrating the above equation with respect to θ,

we get, $v_\theta = -r(\theta - r\cos\theta) + f(r)$

19. Ans: (c)

Sol: The velocity of water in the pipe is given by,

$$V = \sqrt{\frac{2(P_0 - P)}{\rho}} = \sqrt{2g(h_0 - h)}$$

where $P = \rho g h$

$$= \sqrt{2\times 10(0.35 - 0.2375)}$$

$$= \sqrt{20\times 0.1125} = \sqrt{2.25} = 1.5 \text{ m/s}$$

20. Ans: (a)

Sol: $P + \gamma Z + \frac{\rho V^2}{2} \rightarrow$ This is the Bernoulli equation per unit volume of the fluid flowing.

$\frac{P}{\rho} + gZ + \frac{V^2}{2} \rightarrow$ This is Bernoulli equation per unit mass of the fluid flowing.

$\frac{P}{\gamma} + Z + \frac{V^2}{2g} \rightarrow$ This is the Bernoulli equation

21. Ans: (a)

Sol: Efficiency of transmission

$$= \frac{\text{Power delivered at the pipe outlet}}{\text{Power available at the pipe inlet}}$$

$$= \frac{50\times 10^3}{10^4 \times 12\times 10^{-3}\times 500}\times 100$$

$$= \frac{1000}{12} = 83.3\%$$

22. Ans: (d)

Sol: We know that $\Delta P = \rho L\frac{\Delta V}{\Delta t}$

$$250\times 10^3 = 10^3\times 2500\times \frac{2}{\Delta t}$$

$$\Delta t = \frac{10^3\times 2500\times 2}{250\times 10^3} = 20\,\text{s}$$

23. Ans: (c)

Sol: The jet is deflected by 180°. So, the force exerted by the jet on the vane is

$$F = 2\rho A_{jet}V^2 + \rho\, A_{vane}\, L \times g$$

$$= 2\times10^3 \times \frac{\pi}{4}\times 4\times10^{-4}\times10^2 + 10^3 \times \frac{\pi}{4}\times\left(2\times10^{-2}\right)^2 \times 1\times 10$$

$$= 21\,\pi\text{ N}$$

24. Ans: (c)

Sol: For incompressible flow, ρ = constant. So, $\frac{\partial\rho}{\partial t} = 0$ even for unsteady flow. So, statement (i) is correct. The second statement is also correct.

25. Ans: (b)

Sol: If there is no hole in the vane then the force acting on the vane is

$$F = \rho A V^2(1+\cos\theta)$$

Due to hole effective area of the deflected jet reduces to (A–a)

$$\therefore\ F = \rho(A-a)V^2(1+\cos\theta)$$

$$= \rho(A-a)V^2\left(1+\frac{1}{2}\right) \qquad [\text{as } \theta = 60°]$$

$$= \frac{3}{2}\rho(A-a)V^2$$

26. Ans: (c)

Sol: Considering force F (towards right) to be force exerted on the fluid by contraction, the linear moment equation may be written as:

$$F_{on\ fluid} - P_1A_1 + P_2A_2 = \rho A_1V_1(-V_2+V_1)$$

$$F_{on\ fluid} = (P_1A_1 - P_2A_2) - \rho A_1V_1^2\left(\frac{V_2}{V_1}-1\right)$$

$$F_{on\ fluid} = (P_1A_1 - P_2A_2) - \rho A_1V_1^2\left(\frac{A_1}{A_2}-1\right)$$

Thus, $F_{on\ contraction} = F_{on\ fluid}$ but acting towards left.

27. Ans: (c)

Sol: Re = 1600

So, the flow is laminar and

$$f = \frac{64}{Re} = \frac{64}{1600} = 0.04$$

Head loss, $h_f = \frac{fLV^2}{2gD}$

Hence, $V = \sqrt{\frac{h_f \times 2gD}{fL}}$

$$= \sqrt{\frac{2\times2\times10\times0.25\times10^{-2}}{0.04\times5}}$$

$$= \sqrt{0.5} = 0.707\text{ m/s}$$

28. Ans: (a)

Sol: The energy equation gives :

$$\Delta z = \frac{f\,L\,V^2}{2gd}$$

$$d = \frac{f\,L\,V^2}{2g\,\Delta z}$$

$$= \frac{0.04\times180\times2.5^2}{2\times10\times90}$$

$$= 0.025\text{ m} = 2.5\text{ cm}$$

29. Ans: (b)

Sol: Blower power = $\rho g\, Q\, h_f$

$$1200 = 1.2 \times 10 \times 800 Q^3$$

$$Q^3 = \frac{1200}{1.2 \times 10 \times 800}$$

$$\Rightarrow Q = \frac{1}{2} m^3/s$$

30. Ans: (c)

Sol: $C_1 = \sqrt{\frac{K_1}{\rho_1}}$, $C_2 = \sqrt{\frac{K_2}{\rho_2}}$

$$\frac{C_1}{C_2} = \sqrt{\frac{K_1}{K_2}}\sqrt{\frac{\rho_2}{\rho_1}}$$

$$= \sqrt{\frac{2.16 \times 10^9}{1.296 \times 10^9}} \times \sqrt{0.6} = 1$$

31. Ans: (d)

Sol: Losses for flow through valves and fittings are expressed in terms of loss coefficient K_s. It is expressed in terms of equivalent length of a straight pipe

32. Ans: (c)

Sol: $C = \sqrt{\frac{K}{\rho}}$

$$\Delta P = \rho\, C\, V$$

$$\rho g H = \rho \times \sqrt{\frac{K}{\rho}} \times V$$

$$H = \frac{V}{g} \times \sqrt{\frac{K}{\rho}}$$

33. Ans: (b)

Sol: $h = \frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{1}{10^3 \times 10}(30-10)\times 10^4$

$$= 20 \text{ m}$$

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

$$= 0.6 \times \frac{250 \times 150 \times 10^{-4}}{\sqrt{(250)^2 - (150)^2}} \times \sqrt{2 \times 10 \times 20}$$

$$= 0.6 \times \frac{250 \times 150 \times 10^{-4}}{200} \times 20$$

Q = 225 lit/sec

34. Ans: (c)

Sol: $V = \frac{1}{A}\int_0^{r_o} u_{max}\left(1 - \frac{r}{r_o}\right)^m 2\pi r\, dr$

$$= 2\pi \times \frac{u_{max}}{\pi r_o^2}\int_0^{r_o}\left(1 - \frac{r}{r_o}\right)^m r\, dr$$

$$= \frac{2u_{max}}{r_o}\int_0^{r_o}\left(1 - \frac{r}{r_o}\right)^m \left(\frac{r}{r_o}\right) dr$$

$$\left(\text{taking } \left(1 - \frac{r}{r_o}\right) = z\right)$$

$$= \frac{2u_{max}}{r_o}\int_0^1 (z)^m (1-z) r_o\, dz$$

$$= \frac{2u_{max}}{r_o} \times \frac{r_o}{(m+1)(m+2)}$$

$$= 2u_{max}\frac{1}{(m+1)(m+2)}$$

35. Ans: (b)

Sol: In Pipe flow, shear stress is zero at the centre and increases linearly from centre to the pipe wall.

$$\Delta P = \frac{128\mu QL}{\pi d^4}$$

$$Q \propto \frac{1}{\mu}$$

In a constant diameter pipe pressure decreases linearly. $\left(\frac{P}{\rho g} + Z\right)$ also decreases linearly.

36. Ans: (b)

Sol: μ_{water} at 40^{o} C is 0.6531 mPa-s

37. Ans: (a)

Sol: $h_{L_1} = \frac{32\mu V(2L)}{\rho g D^2}$

$$h_{L_2} = 12 \times \frac{\mu VL}{\rho g B^2}$$

$$\frac{h_{L_1}}{h_{L_2}} = \frac{32}{12} \times \frac{2}{1} \times \frac{B^2}{D^2}$$

$$\frac{32}{12} \times 2 \times \frac{3^2}{12^2} = \frac{1}{3}$$

38. Ans: (b)

Sol: Let z_1 and z_2 be the elevation of reservoir and nozzle

Let 'D' diameter of pipe and 'd' be diameter of nozzle.

Net head = $(z_1 - z_2)$ = H

$$z_1 + 0 + 0 = z_2 + \frac{V_2^2}{2g} + h_L$$

$$h_L = 0.5\frac{V^2}{2g} + f.\frac{L}{D}.\frac{V^2}{2g}$$

(entrance loss + pipe loss)

$$V_2 = \left(\frac{D}{d}\right)^2 V$$

$$z_1 - z_2 = \left(\frac{D}{d}\right)^4 .\frac{V^2}{2g} + 0.5\frac{V^2}{2g} + f.\frac{L}{D}.\frac{V^2}{2g}$$

f = 0.07, D = 2 cm, d = 1 cm

$$H = \left[0.5 + f.\frac{L}{D} + \left(\frac{D}{d}\right)^4\right].\frac{V^2}{2g}$$

$$= \left[0.5 + 7\times10^{-2}\frac{1}{2\times10^{-2}} + 16\right].\frac{V^2}{2g}$$

$$= [0.5 + 3.5 + 16]\times\frac{16}{20}$$

H = 16

39. Ans: (a)

Sol: The specific speed values given actually refer to the non-dimensional specific speed (in rad/s^{-1}). Here, again the minimum value (0.1) is for Pelton wheel, followed by Francis turbine (1.0). The propeller turbine will have the value of 3.0. Kaplan turbine will have the highest value of 4.0.

40. Ans: (a)

Sol: $$H_m = \frac{P_d - P_s}{\rho g} + \frac{V_d^2 - V_s^2}{2g} + Z_d - Z_s$$

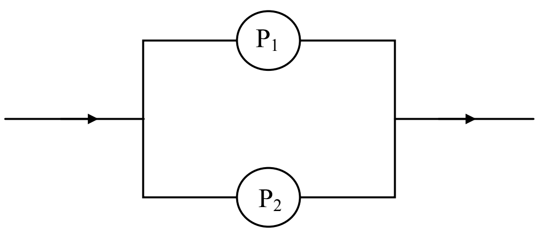
Assuming suction and delivery pipes of same diameter and neglecting elevation changes between inlet and exit.

$$H_m = \frac{P_d - P_s}{\rho g}$$

$$= \frac{300 \times 10^3 - \left(-25 \times 10^3\right)}{1000 \times 10} = 32.5 \text{ m}$$

41. Ans: (c)

Sol:



For parallel combination, head remains same but discharge becomes twice.

i.e., $H_P = H$ & $Q_P = 2Q$

let $H_p = a - b\,Q_p^2$

i.e., $H = a - b\,(2Q)^2$

$$40 - 60\,Q^2 = a - 4b\,Q^2$$

Comparing both sides

$$a = 40 \;\;\&\;\; b = 15$$

$$\therefore \quad H_p = 40 - 15\,Q^2$$

42. Ans: (a)

Sol: $$\frac{D_m}{D_p} = \frac{1}{5}, \; \frac{H_m}{H_p} = \frac{4}{1}$$

$$P \propto QH$$

$$Q \propto D^2\sqrt{H}$$

$$\therefore \; P \propto D^2 H^{3/2}$$

$$\frac{P_p}{P_m} = \left(\frac{D_p}{D_m}\right)^2 \times \left(\frac{H_p}{H_m}\right)^{3/2}$$

$$= \left(\frac{5}{1}\right)^2 \times \left(\frac{1}{4}\right)^{3/2} = \frac{25}{8} = 3.125$$

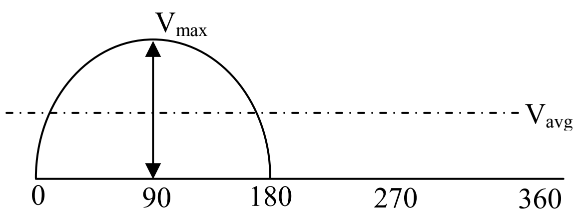
43. Ans: (d)

Sol: Velocity head in delivery pipe is maximum at the middle of delivery stroke

i.e., $\theta = 270°$

44. Ans: (d)

Sol: The velocity variation in suction pipe of a single acting reciprocating pump is



$$V = V_{max} \sin\theta$$

$$V_{avg} = \frac{1}{2\pi}\int_0^{\pi} V_{max} \sin\theta \, d\theta$$

$$= \frac{1}{2\pi}\left[-\cos\theta\right]_0^{\pi} V_{max}$$

$$V_{avg} = \frac{V_{max}}{\pi}$$

i.e., $\frac{V_{max}}{V_{avg}} = \pi$

45. Ans: (d)

Sol: $Q = \frac{ALN}{60}$, $L = 2r$

$\therefore Q \propto r$

$\propto N$

$$\frac{Q_2}{Q_1} = \left(\frac{r_2}{r_1}\right)\times\left(\frac{N_2}{N_1}\right) = \left(\frac{1}{2}\right)\times\left(\frac{2}{1}\right) = 1$$

$$\frac{Q_2 - Q_1}{Q_1}\times 100 = 0\%$$

46. Ans: (c)

Sol: Air vessel on delivery side does not have any effect on suction side. It reduces velocity fluctuations in delivery side. Hence, acceleration head is reduced only on delivery side.

Static delivery head is the elevation difference between delivery pipe exit and pump exit. It is independent of any other parameter.

47. Ans: (b)

Sol: $\eta_{max} = \frac{1+\cos\theta}{2} = \frac{1+\cos(180-120)}{2} = 0.75$

Applying energy balance to the rotor

$$\frac{V_1^2}{2g} = H_e + \frac{V_2^2}{2g}$$

$$= \eta_{max}\times\frac{V_1^2}{2g} + \frac{V_2^2}{2g}$$

$$\frac{V_2^2}{2g} = (1-\eta_{max})\frac{V_1^2}{2g}$$

$$\frac{V_2^2/2g}{V_1^2/2g} = (1-\eta_{max}) = 0.25$$

48. Ans: (b)

Sol: $F = \rho a V (V - u)(1 + \cos\theta)$

At the starting $u = 0$

$\therefore\ F = \rho\, a\, V^2\,(1 + \cos\theta)$

$$T = F \times R = \rho\, a\, V^2\,(1 + \cos\theta) \times \frac{D}{2}$$

$$= 1000 \times (0.1) \times 50 \times (1 + \cos 60) \times \frac{2}{2}$$

$= 7.5$ kN.m

49. Ans: (a)

Sol: $T = F \times R$

$$\frac{T_2}{T_1} = \frac{F_2}{F_1}$$

i.e., $$\frac{1}{2} = \frac{\rho a V_2 (V_2 - u_2)(1 + k\cos\theta)}{\rho a V_1 (V_1 - u_1)(1 + k\cos\theta)}$$

The jet speed only depends on net head. hence $V_1 = V_2 = V$

For maximum efficiency $\frac{u}{V} = \frac{1}{2}$

The initial condition corresponds to maximum efficiency

$$u_1 = \frac{V}{2}$$

$$\frac{1}{2} = \frac{V - u_2}{\left(V - \frac{V}{2}\right)}$$

i.e., $$\frac{V}{4} = V - u_2$$

$$u_2 = \frac{3V}{4}$$

$$\frac{u_2 - u_1}{u_1} = \frac{\frac{3V}{4} - \frac{V}{2}}{\frac{V}{2}} \times 100 = 50\%$$

50. Ans: (d)

Sol: Whether, the Francis turbine has radial vanes or not, the velocity of flow is always radial. If the rotor blade at inlet is radial then the relative velocity (which is tangential to the blade) is also radial.

51. Ans: (a)

Sol: $$\eta_h = \frac{u_1 V_{w1}}{gH}$$

i.e., $0.8 = \dfrac{10 \times V_{w1}}{10 \times 12}$ [as $g = 10\ m/s^2$]

$V_{w1} = 9.6$ m/s

$$\tan\alpha_1 = \frac{V_{f1}}{V_{w1}} = \frac{5}{9.6} = 0.52$$

$$\tan 30^\circ = \frac{1}{\sqrt{3}} = \frac{\sqrt{3}}{3} = \frac{1.732}{3} = 0.577$$

$$0.52 < 0.577 \Rightarrow \alpha_1 < 30$$

$\therefore\ \alpha_1 = 28°$

The exact value of α_1 is

$$\alpha_1 = \tan^{-1}\left(\frac{5}{9.6}\right) = 27.5^\circ$$

52. Ans: (b)

Sol: $$Q = A_f V_f = \frac{\pi}{4}\left(D_t^2 - D_h^2\right) \times V_f$$

$$= \frac{\pi}{4}\left(3^2 - \left(\frac{1}{3} \times 3\right)^2\right) \times 5$$

$$= \frac{\pi}{4} \times (9 - 1) \times 5$$

$= 10\,\pi\ m^3/s = 31.4\ m^3/s$

53. Ans: (a)

Sol: $\tan\alpha_1 = \dfrac{V_{f1}}{V_{w1}}$

In Kaplan turbine V_{w1} follows free vortex distribution

$$V_{w1} = \frac{k}{r}$$

Thus V_{w1} decreases from hub towards tip. As V_f is constant α_1 increases from hub towards tip.

54. Ans: (c)

Sol: $N_s = \dfrac{N\sqrt{P}}{H^{5/4}}$

$$P = F \times V = F\times\frac{L}{T} = F\,L\,T^{-1}$$

$$N = T^{-1}$$

$$N_s = \frac{T^{-1}\sqrt{F\,L\,T^{-1}}}{L^{5/4}}$$

$$= F^{1/2}\,L^{-3/4}\,T^{-3/2}$$

55. Ans: (a)

Sol: $F_D = \dfrac{C_D}{2}\rho U_\infty^2$

$$\therefore \frac{F_{D2}}{F_{D1}} = \frac{C_{D2}}{C_{D1}}\times\frac{\rho_2}{\rho_1}\left\{\because U_{\infty_1} = U_{\infty_2}\right\}$$

$$= \sqrt{\frac{Re_1}{Re_2}}\times\frac{\rho_2}{\rho_1}\left\{\because C_D = \frac{1.328}{\sqrt{Re}}\right\}$$

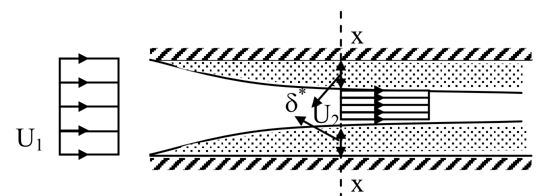
$$= \sqrt{\frac{\rho_1}{\rho_2}}\times\sqrt{\frac{\mu_2}{\mu_1}}\times\frac{\rho_2}{\rho_1}$$

$$= \sqrt{\frac{\mu_2}{\mu_1}}\times\sqrt{\frac{\rho_2}{\rho_1}}$$

i.e. $F_{Dr} = \sqrt{\mu_r}\times\sqrt{\rho_r}$

56. Ans: (c)

Sol: The displacement thickness (δ^*) can be considered as an imaginary growth in the thickness of the wall so that the outside flow can be considered as uniform flow.



Using continuity equation

$$U_1\pi R^2 = U_2\pi\left(R-\delta^*\right)^2$$

$$\frac{U_2}{U_1} = \left(\frac{R}{R-\delta^*}\right)^2$$

57. Ans: (b)

Sol: $u = U_\infty\left[\dfrac{3}{2}\dfrac{y}{\delta} - \dfrac{1}{2}\left(\dfrac{y}{\delta}\right)^3\right]$

$$\frac{du}{dy} = U_\infty\left[\frac{3}{2}\frac{1}{\delta} - \frac{3}{2}\left(\frac{y}{\delta}\right)^2\times\frac{1}{\delta}\right]$$

$$\left.\frac{du}{dy}\right|_{y=\frac{\delta}{2}} = \frac{U_\infty}{\delta}\left[\frac{3}{2} - \frac{3}{2}\left(\frac{1}{2}\right)^2\right] = \frac{9}{8}\frac{U_\infty}{\delta}$$

$$\tau = \mu\frac{du}{dy} = \frac{9}{8}\frac{\mu U_\infty}{\delta}$$

$$\therefore\ k = \frac{9}{8}$$

58. Ans: (d)

Sol: Velocity gradient normal to the surface is very high as compared to streamwise velocity gradient.

i.e., $\frac{\partial u}{\partial y} >> \frac{\partial u}{\partial x}$

Continuity equation must be satisfied at each point in a flow

i.e., $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

or $\frac{\partial u}{\partial x} = -\frac{\partial v}{\partial y}$

$\therefore \left|\frac{\partial u}{\partial x}\right| = \left|\frac{\partial v}{\partial y}\right|$

59. Ans: (d)

Sol: All of the above methods will reduce the chances of separation. Rough surface makes the boundary layer turbulent and the turbulent boundary layer is comparatively less susceptible to separation.

60. Ans: (c)

Sol: $\delta(x) = \frac{5x}{\sqrt{Re_x}} = \frac{5x}{\sqrt{\frac{\rho U_\infty x}{\mu}}} \propto \sqrt{x}$

$C_{fx} = \frac{0.664}{\sqrt{Re_x}} = \frac{0.664}{\sqrt{\frac{\rho U_\infty x}{\mu}}} \propto \frac{1}{\sqrt{x}}$

$\therefore \frac{\delta(x)}{C_{fx}} \propto \frac{\sqrt{x}}{\left(\frac{1}{\sqrt{x}}\right)} \propto x$

61. Ans: (c)

Sol: Normally a specific property of a substance is defined per unit mass. But for a fluid its specific weight is defined as weight per unit volume. It is an intensive property. So, statement (II) is wrong.

62. Ans: (d)

Sol: The coefficient of volume expansion of a fluid differs from its bulk modulus of compressibility. So, statement (I) is wrong. However, statement (II) is correct.

63. Ans: (b)

Sol: Reynolds number is the ratio of inertia forces to the viscous forces in the fluid flow. These inertia forces generate due to the change in momentum of the fluid. At higher Reynolds number, flow is turbulent and the velocity profile is logarithmic.

64. Ans: (a)

Sol: For irrotational flow, Bernoulli equation can be applied at any two points in the flow. Centrifugal forces will cause the increase in pressure from inside to outside edge. Application of Bernoulli equation will show the decrease of velocity from inside to outside edge.

65. Ans: (a)

Sol: For stability of floating bodies, GM > 0. So, if a body with wide rectangular cross section is tilted slightly, its B (centre of buoyancy) shifts more towards the tilted end resulting in larger BM. So, GM will be positive. Also it provides a righting couple. Therefore, the body will be in the stable condition.

66. Ans: (a)

Sol: C_d of venture meter lies between 0.97 to 0.99. This is mainly due to smooth gradual variation of cross-sectional area down to throat and then back to the full pipe area. This results in less friction losses. However, in the case of orifice meter there is an abrupt constriction at the orifice plate. This causes the formation of eddies which leads to higher friction losses. The C_d of orifice meter varies from 0.58 to 0.65.

67. Ans: (c)

Sol: The resultant hydrostatic force is given by $F_R = \gamma\bar{h}A$.

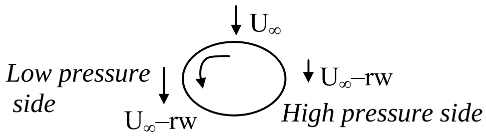
So, F_R can be determined if $\bar{h}$ and A are known. So, statement (I) is correct. However, F_R depends on specific weight of the liquid in which it is submerged. So, statement (II) is wrong.

68. Ans: (d)

Sol: In steady flow, local acceleration is zero but convective acceleration may not be zero.

69. Ans: (c)

Sol: The unsymmetric pressure distribution on the football surface is due to Magnus effect. Spinning of football generates low velocity on one side and high velocity on other side.



70. Ans: (c)

Sol: At separation point shear stress is zero because velocity gradient becomes zero. Pressure gradient is positive when flow is about to separate.

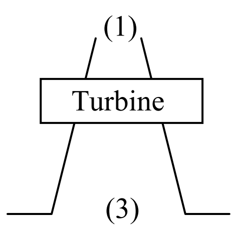
71. Ans: (c)

Sol: For blunt object pressure drag is major contributor to the overall drag. Streamlining avoids the flow separation hence pressure drag is reduced. Therefore, overall drag is also reduced.

Streamlining in fact increases the skin friction drag as the contact area is increased. Hence, Statement (II) is false.

72. Ans: (a)

Sol:



Without draft tube, kinetic energy head loss would have been $\frac{V_2^2}{2g}$. When draft tube is used, kinetic energy head loss is $\frac{V_3^2}{2g}$.

Hence kinetic energy head loss is reduced by $\frac{V_2^2 - V_3^2}{2g}$

73. Ans: (b)

Sol: Kaplan turbine has higher efficiency as compared to propeller turbine at part load condition because Kaplan turbine has adjustable rotor blades where as propeller turbine has fixed rotor blades. Due to adjustable rotor blades, the Kaplan turbine can adjust to different flow condition with minimum separation loss.

74. Ans: (d)

Sol: Statement (II) is the definition of NPSH. Hence, it is correct statement.

$$\text{NPSH} = \frac{P_i}{\rho g} + \frac{V_i^2}{2g} - \frac{P_v}{2g}$$
$$= H_a - H_s - H_v - h_{fs}$$

From above equation it is clear that as suction head increases, NPSH decreases. Hence, statement I is wrong.

75. Ans: (d)

Sol: Theoretical head developed by the pump is

$$H_e = \frac{u_2 V_{w2}}{g}$$

Head developed only depends on exit velocity triangle. Thus statement (I) is wrong.

The theoretical pressure rise across the pump is $\rho g H_e = \rho u_2 V_{w2}$.

Hence, statement (II) is correct.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