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ESE- 2019 (Prelims) - Offline Test Series Test-1

MECHANICAL ENGINEERING

SUBJECT: FLUID MECHANICS AND TURBO MACHINERY

SOLUTIONS

01. Ans: (a)

Sol: From Newton's Law of viscosity:

$$\tau = \mu \frac{du}{dy}$$

$$= -\mu \frac{du}{dr} \text{ for a pipe}$$

$$= -\mu \frac{d}{dr}\left[u_{max}\left(1-\frac{r^2}{R^2}\right)\right]$$

$$= u_{max} \times \mu \times \frac{2r}{R^2} = \frac{2\mu u_{max}}{R^2} \times r$$

⇒ Straight line variation passing through origin.

Thus, $\tau = 0$ at $r = 0$

and $\tau = \frac{2\mu u_{max}}{R}$ for $r = R$

Hence, figure given in option (a) is correct.

02. Ans: (b)

Sol:

1. In reaction turbines the pressure drop occurs in both fixed and moving blades. Therefore, both fixed and moving blades act as nozzle.
2. The use of initial Curtis stage reduces the number of stages required. Thus, the length of the rotor is reduced.
3. In Rateau staging pressure drop is divided equally among stages. Pressure drop occurs only in nozzles. There is no pressure drop while the steam flows through blades.

Shortcut: Statement 1 is wrong. Inspecting the options given one can eliminate all options containing 1. Thus, option (b) is correct.

03. Ans: (c)

Sol:

- $(F_V)_{water}$ and $(F_V)_{oil}$ act in opposite directions.
- The point of application of $(F_V)_{oil}$ is the centroid of the volume of oil being supported by the curved surface. This is found to be at a distance $\frac{4R}{3\pi}$ from the vertical line passing through O.
- $(F_v)_{oil} = \gamma_{oil} \times \frac{\pi}{4} R^2 \times 1 = 8 \times 10^3 \times \frac{\pi}{4} \times 1 \times 1$

$= 2\pi$ kN per meter width of the gate.

04. Ans: (b)

Sol: $NPSH = H_a - H_s - H_v - h_{fs}$

$= 10.3 - 5 - 0.35 - 0.65$

$= 4.3$ m

05. Ans: (d)

Sol: Let $H_1 = a_1 - b_1Q_1^2$ ------------(1) be the characteristic curve of the pump at $N_1 = 2N$ rpm.

By similarity laws

$$u = \frac{\pi DN}{60} \propto \sqrt{H}$$

$\therefore \quad H \propto N^2$

Or, $\frac{H_1}{H} = \left(\frac{N_1}{N}\right)^2 = 4$ -----------(2)

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

$\propto ND^3 \quad (\because ND \propto \sqrt{H})$

$\propto N$

$\therefore \quad \frac{Q_1}{Q} = \frac{N_1}{N} = 2$ ----------------------(3)

Substituting values of H_1 & Q_1 from (2) and (3) into equation (1)

$$4H = a_1 - b_1(2Q)^2$$

i.e. $H = \frac{a_1}{4} - b_1Q^2$ ---------(4)

But, $H = a - bQ^2$ ------------(5) (Given)

Comparing (4) and (5)

$a_1 = 4a$

and $b_1 = b$

$\therefore \quad H = 4a - bQ^2$

06. Ans: (c)

Sol: $\Delta P \times \frac{\pi}{4}d^2 = \sigma(\pi d)$

Or, $\sigma = \Delta P \times \frac{d}{4}$

$= 28 \times 10^3 \times \frac{0.01 \times 10^{-3}}{4}$

$= 0.07$ N/m

07. Ans: (c)

Sol: It is known that

$$GM = \frac{W_1 z \ell}{W.d}$$

where, $W_1 = 100$ kN,

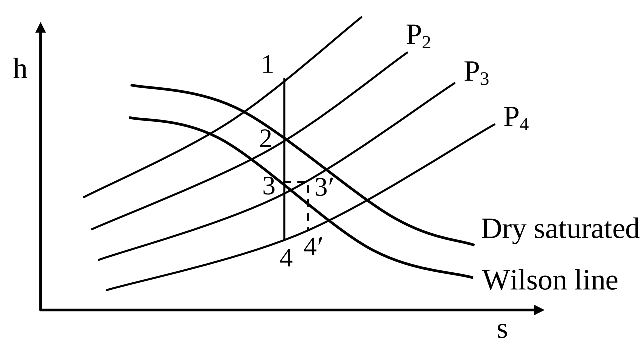
$W = 7200$ kN, $\ell = 2.8$ m

$d = 0.14$ m & $z = 9$ m

$$GM = \frac{100 \times 9 \times 2.8}{7200 \times 0.14} = 2.5\,m$$

08. Ans: (d)

Sol: The effect of supersaturation is to reduce the enthalpy drop slightly during the expansion.



- The final dryness fraction and entropy are also increased.
- The mass flow rate with supersaturated is greater than mass flow with isentropic flow.

09. Ans: (b)

Sol: When the tank partially filled with water is accelerated with constant acceleration in horizontal direction, the water level surface will move up at the rear and move down at the front.

10. Ans: (a)

Sol: When an array of arrows indicating the magnitude and direction of a vector property at an instant is plotted, it is called vector plot.

11. Ans: (a)

Sol: Given: $u = 2xy + 1$ and $v = -y^2 - 0.6$

The shear strain rate is given by:

$$\in_{xy} = \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right) = (2x + 0) = 2x$$

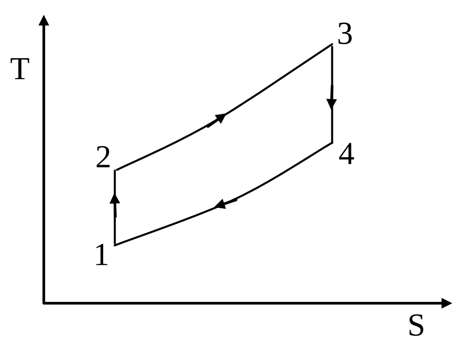
$$\in_{xy}|_{2,1} = 2 \times 2 = 4\ s^{-1}$$

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

$$\omega_z|_{2,1} = 2 \text{ rad/s}$$

12. Ans: (b)

Sol:



$T_1 = 300$ K, $T_2 = 500$ K

$T_3 = 1000$ K, $T_4 = ?$

$$\Rightarrow \frac{T_2}{T_1} = \frac{T_3}{T_4}$$

$$\Rightarrow \frac{500}{300} = \frac{1000}{T_4}$$

$$T_4 = \frac{1000 \times 300}{500} = 600 \text{ k}$$

$$\text{Back work ratio} = \frac{W_T - W_C}{W_T}$$

$$= \frac{(h_3 - h_4) - (h_2 - h_1)}{(h_3 - h_4)}$$

$$= \frac{(1200 - 600) - (500 - 300)}{(1200 - 720)} = 0.67$$

13. Ans: (b)

Sol: The velocity profile (given) is linear, i.e.,

$$V = V_{max}\frac{y}{h}$$

K.E. Correction factor is given by,

$$\alpha = \frac{\text{Kinetic energy of flow per second based on actual velocity}}{\text{Kinetic energy of flow per second based on average velocity}}$$

$$\text{Thus,} \quad \alpha = \frac{\int \frac{1}{2}(\rho dAV) \times V^2}{\frac{1}{2}(\rho A\overline{V})\overline{V}^2} = \frac{\int V^3 dA}{A\overline{V}^3}$$

$$= \frac{1}{A}\int_A \left(\frac{V}{\overline{V}}\right)^3 dA = \frac{1}{h \times 1}\int_0^h \left(\frac{V_{max} y/h}{V_{max}/2}\right)^3 (dy \times 1)$$

$$= \frac{8}{h^4}\int_0^h y^3 dy = \frac{8}{h^4} \times \frac{h^4}{4} = 2$$

14. Ans: (b)

Sol: $Q_{annulus} = Q_{pipe}$

$$\frac{\pi}{4}\left(D_0^2 - D_i^2\right)V = \frac{\pi}{4}D_i^2 \times V$$

Or, $D_0^2 - D_i^2 = D_i^2$

Or, $D_0^2 = 2D_i^2$

Or, $\left(\frac{D_0}{D_i}\right)^2 = 2$

$\Rightarrow \quad \frac{D_0}{D_i} = \sqrt{2}$

15. Ans: (a)

Sol:

- Ramjet engine cannot operate under static conditions as there will be no pressure rise in the diffuser.
- Ramjet consists of both supersonic and subsonic diffuser. Air enter the engine with supersonic speed which must be reduced to subsonic value. This is necessary to prevent blow out of the flame in the combustion chamber.
- They are most efficient at high velocities of about 2400 - 6000 km/h and at very high altitudes.
- Due to the fact that a turbine is not used to drive the mechanical compressor, the maximum temperature which can be allowed in ramjet is very high, about 2000°C as compared to about 900°C in turbojets.

16. Ans: (a)

Sol: $Q_{in} - Q_{out} = A_{tank}\frac{dh}{dt}$

$$A_{in}V_{in} - A_{out} \times V_{out} = A_{tank}\frac{dh}{dt}$$

$$0.0025 \times V_{in} - 0.0025\sqrt{2 \times 10 \times 0.1} = 0.1 \times 0.1 \times 10^{-2}$$

Or, $0.0025 \times V_{in} - 0.0025 \times 1.4 = 10^{-4}$

$$V_{in} - 1.4 = \frac{10^{-4}}{0.0025} = 0.04$$

$\Rightarrow \quad V_{in} = 1.44$ m/s

17. Ans: (b)

Sol: Applying Bernoulli's equation to inside the balloon and the nozzle exit, we get

$$\frac{P_{inside}}{\rho} = \frac{V^2}{2}$$

where V is the velocity of fluid jet leaving the nozzle.

Or, $V^2 = \frac{2 \times P_{inside}}{\rho} = \frac{2 \times 2400}{1.2} = 4000$

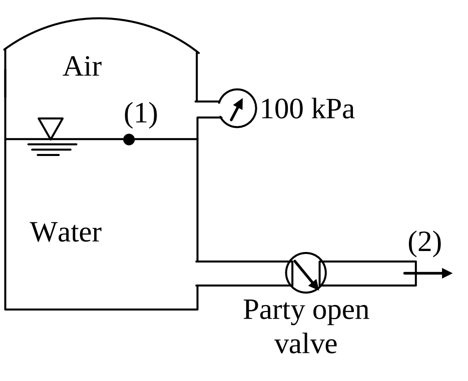
Applying momentum equation in x-direction

$F = \rho A V^2 = 1.2 \times 80 \times 10^{-6} \times 4000$

$= 4.8 \times 8 \times 10^{-2} = 0.384$ N

18. Ans: (c)

Sol:



Applying energy equation for points (1) and (2), we write

$$\frac{P_1}{\gamma}+\frac{V_1^2}{2g}+Z_1=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}+Z_2+K_L\frac{V_2^2}{2g}$$

where, $V_1 = 0$,

$P_2 = P_{atm} = 0$,

$V_2 = 10$ m/s

$Z_1 = 8$ m,

$Z_2 = 0$

$$\frac{100\times10^3}{10^3\times10}+0+8=0+\frac{10^2}{2\times10}+0+K_L\times\frac{10^2}{2\times10}$$

Or, $18 = 5\,(1 + K_L)$

Or, $K_L=\frac{18}{5}-1=3.6-1=2.6$

19. Ans: (c)

Sol: Lift is the sum of the components of the pressure and wall shear forces in the direction normal to the flow.

20. Ans: (d)

Sol: Turbulent boundary layer consists of laminar sub-layer, overlap layer and outer turbulent layer.

21. Ans: (d)

Sol: For creeping flow over a sphere, $F_D = 3\pi\mu VD$ (as sphere is considered as one of the three dimensional objects)

Hence, the density is not the factor on which the aerodynamic drag on such a body depends in creeping flow.

22. Ans: (c)

Sol:

- Loss in pressure rise due to flow separation on blade is called stalling.
- Unsteady periodic flow reversal when compressor is operated on positive slope region of characteristic curve.
- When velocity of flow becomes equal to sonic speed, mass flow rate cannot be increased in converging portion. This phenomenon is called choking.
- Decrease in whirl velocity at exit of centrifugal compressor due to relative eddy is called slip.

23. Ans: (a)

Sol: Head loss at entry to the pipe = $0.5\frac{V^2}{2g}$

$= 0.5\times0.8 = 0.4$ m

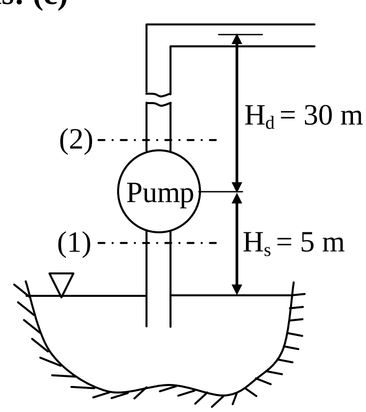
Head loss due to friction = $\frac{fL}{D}\times\frac{V^2}{2g}$

$$=\frac{0.012\times10}{0.2}\times0.8=0.48\,\text{m}$$

Thus, figure given in option (a) is correct.

24. Ans: (c)

Sol:



The manometric head represents net output of a pump.
i.e. energy added by the pump to fluid.

$$\therefore\ H_m = \left(\frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2\right) - \left(\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1\right)$$

$$= 42 - 4 = 38 \text{ m}$$

25. Ans: (c)

Sol: Entrance length for fully developed laminar flow in a pipe is given by

$$\frac{L_e}{D} \cong 0.05\,\text{Re}$$

Or, $L_e = 0.05 \times 200 \times 0.6$ m

$= 0.6$ m $= 60$ cm

26. Ans: (c)

Sol: Given L = 2.828 km, V = 1 m/s,

$T_{actual} = 20$ s, C = 1414 m/s

Critical time, $T_c = \frac{2L}{C} = \frac{2 \times 2828}{1414} = 4\,\text{s}$

Since, $T_C < T_{actual}$, the valve is gradually closed.

Hence, Pressure rise, $\Delta P_{gradual} = \frac{\rho L V}{T_{actual}}$

$$= \frac{10^3 \times 2828 \times 1}{20} = 141.4\,\text{kPa}$$

27. Ans: (a)

Sol:

- The pressure gradient, $\frac{dP}{dx}$ in the direction of flow for a horizontal pipe is negative.
- The lower critical Re for a flow in pipe is same for different fluids.

28. Ans: (a)

Sol:

- Sometimes actual discharge in a reciprocating pump is more than theoretical discharge $(ALN/60)$.
- This happens when acceleration head in suction pipe is high as compared to acceleration head in delivery pipe. This causes delivery valve to open before completion of suction stroke.

29. Ans: (d)

Sol:

- Pitot-static tube is used to measure the fluid velocity using a differential manometer.
- Rotameter is used to measure flow rate of liquids.
- Hot wire anemometer is used to measure the fluctuating components of velocity in turbulent flow.
- Nozzle meter is used to measure flow rate of fluids.

30. Ans: (c)

Sol: Power required, P = F × V

Or, $F = \frac{P}{V} = \frac{30}{0.15} = 200\,\text{N}$

Thus, statement (1) is correct.

For equilibrium condition in vertical direction

$$F = W + F_{shear}$$

Or, $F_{shear} = F - W = 200 - 50 = 150$ N

Thus, Statement (2) is also correct.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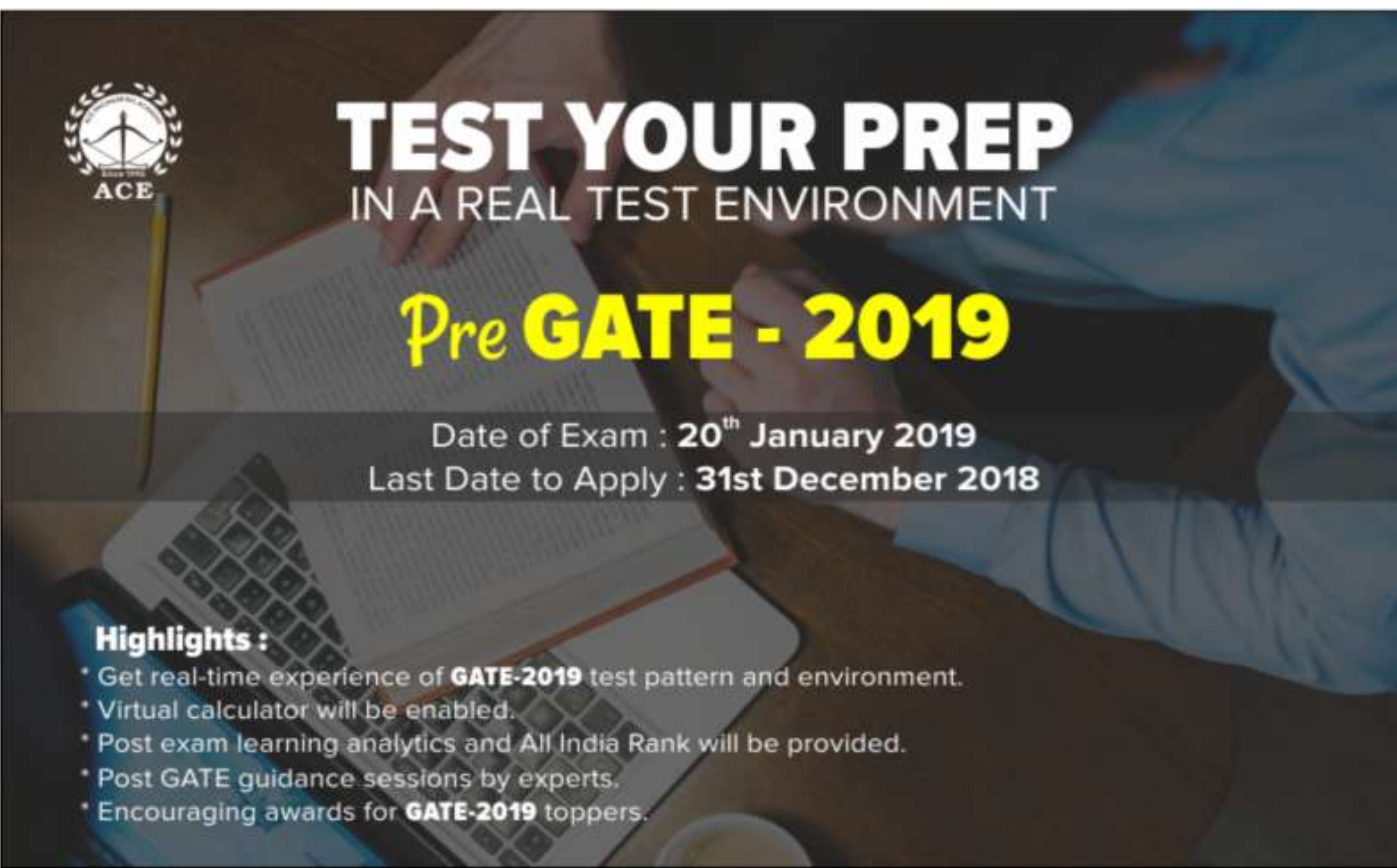
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31. Ans: (d)

Sol: For radial blade, $\beta_2 = 90°$

$\therefore \quad u_2 = V_{w2} = 300$ m/s

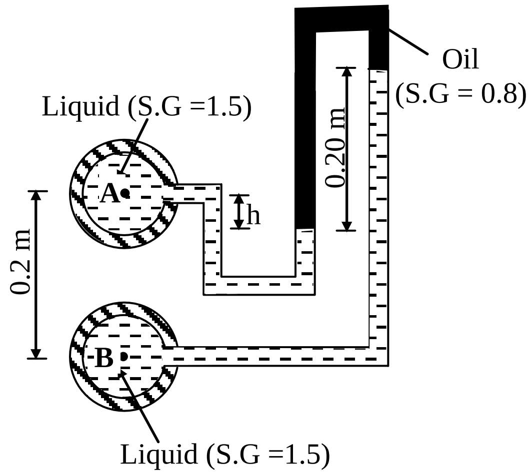
$\Delta h = P_{in} \times u_2 V_{w2}$

$90 \times 10^3 = P_{in} \times 0.9 \times 300 \times 300$

$P_{in} = \frac{1}{0.9} = 1.11$

32. Ans: (b)

Sol:



Starting from point A using manometric equation:

$P_A + 1.5\,\gamma_w \times h - 0.8\,\gamma_w \times 0.20 + 1.5\,\gamma_w\,(0.2 + 0.2 - h) = P_B$

Or, $P_B - P_A = 1.5\gamma_w \times h - 0.8\,\gamma_w \times 0.2 + 1.5\,\gamma_w \times 0.4 - 1.5\,\gamma_w \times h$

$= \gamma_w\,(-0.8 \times 0.2 + 1.5 \times 0.4)$

$= \gamma_w\,(-0.16 + 0.6)$

$= 0.44\,\gamma_w$

$\Rightarrow \frac{P_B - P_A}{\gamma_w} = 0.44\,\text{m}$

33. Ans: (c)

Sol:

- U-Tube manometer is used to measure pressure differential.
- Bourd on gauge is used to measure gauge pressure.
- Hydrometer is used to measure relative density.
- Barometer is used to measure local atmospheric pressure.

34. Ans: (d)

Sol:

- The region outside the boundary layer is called inviscid region. Thus, in this region boundary layer approximation does not arise as there is no velocity variation in different layers in this region.
- The boundary layer approximation is appropriate for wake and jet also. These flows have a predominant flow direction, and for high Reynolds numbers, the shear layer is very thin causing the viscous terms to be much smaller than the inertial terms, just as in the case of a boundary layer along a wall.

35. Ans: (c)

Sol: For minimum work input, the optimum pressure ratio is given by,

$$r_p = \left(\frac{P_o}{P_i}\right)^{\frac{1}{n}}$$

n = number of stages

$\therefore \quad r_p = \left(\frac{16}{1}\right)^{\frac{1}{4}} = 2$

$\therefore \quad P_i = P_1 = 1$ bar,

$P_2 = 2$ bar,

$P_3 = 4$ bar,

$P_4 = 8$ bar and

$P_5 = P_0 = 16$ bar

$\therefore$ The pressure difference for last stage is

$P_5 - P_4 = 16 - 8 = 8$ bar.

36. Ans: (c)

Sol: Von-Karman momentum integral equation for flow over a flate plate $\left(\frac{dP}{dx} = 0\right)$ for steady, laminar or turbulent incompressible flow is $\frac{d\theta}{dx} = \frac{\tau_w}{\rho U^2}$

Thus, only statement (iii) is correct.

37. Ans: (c)

Sol:

- Air vessels make the velocity in pipe nearly equal to average velocity. Hence, acceleration head is reduced, which helps in reducing cavitation chances.
- As flow velocity is constant the head loss due to friction is also reduced.

38. Ans: (a)

Sol: Weight of the cubic ice block = Buoyant force

Or, $\gamma_{ice}\, A\, (h + 0.22) = \gamma_{seawater}\, A\, h$

where A is the cross-section area of ice block and h is the height of the ice block below the seawater surface.

$$h\,(\gamma_{seawater} - \gamma_{ice}) = \gamma_{ice} \times 0.22$$

Or, $h\left(\frac{\gamma_{seawater}}{\gamma_{ice}} - 1\right) = 0.22$

Or, $h\,(1.11 - 1) = 0.22$

Or, $h = \frac{0.22}{0.11} = 2\,m$

39. Ans: (d)

Sol: Pathline is define as the actual path by an individual fluid particle over some period of time.

40. Ans: (a)

Sol: For critical flow in a pipe, Re = 2000

$$2000 = \frac{Vd}{\nu} = \frac{V \times 1 \times 10^{-2}}{1 \times 10^{-6}}$$

Or, $V = \frac{2000}{10^4} = 0.2\ m/s$

Thus, discharge $= \frac{\pi}{4} \times 1^2 \times 10^{-4} \times 0.2\ m^3/s$

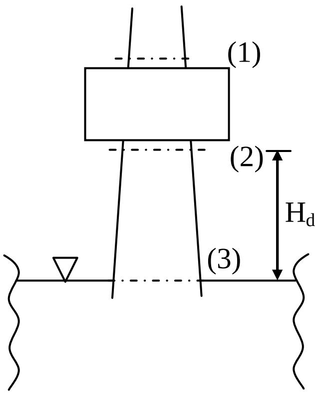
$$= \frac{\pi}{200}\ lit/s$$

41. Ans: (b)

Sol:

- Draft tube converts a part of residual kinetic energy into useful work.
- Draft tube extracts the lost potential head equal to draft tube height H_d by reducing pressure at the turbine exit proportional to

draft tube height H_d. As pressure difference across turbine is increased, input energy is increased.



By Bernoulli's equation,

$$\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+Z_2=\frac{P_3}{\rho g}+\frac{V_3^2}{2g}+Z_3+h_{fd}$$

$P_3 = P_{atm}$; $Z_2 – Z_3 = H_d$

$$\frac{P_2}{\rho g}=\frac{P_{atm}}{\rho g}-\left[H_d+\frac{V_2^2-V_3^2}{2g}-h_{fd}\right]$$

- Draft increases chances of cavitation as pressure at turbine exit is reduced.

42. Ans: (a)

Sol: Shear velocity, $V^*=\sqrt{\frac{\tau_o}{\rho}}$

where, τ_0 = Wall or boundary shear stress

- Shear velocity is a fictious (imaginary) quantity. It is used in the analysis of laminar sub layer, and in classification of turbulent flow as hydro dynamically smooth, transition, rough, etc.

43. Ans: (c)

Sol: For turbulent flow through rough pipes, the required relation is given as:

$$\frac{V_{max}}{\overline{V}}=1+1.43\sqrt{f}$$

$$= 1+1.43\sqrt{0.04}$$

$$= 1 + 1.43 \times 0.2 = 1.286$$

44. Ans: (c)

Sol:

- $N_u=\frac{N}{\sqrt{H}}$
- $Q_u=\frac{Q}{\sqrt{H}}$
- $P_u=\frac{P}{H^{\frac{3}{2}}}$

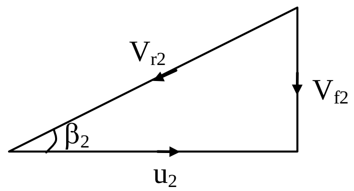
45. Ans: (c)

Sol:

- Boundary layer thickness δ is the normal distance from the boundary where velocity is 99% of free stream velocity.
- Displacement thickness is the distance from the boundary by which the main flow can be assumed to be shifted so that potential flow theory can be used to analyze the flow.
- Laminar sublayer is the region near the boundary where viscous stress is also present. The velocity profile in this region is linear.

46. Ans: (a)

Sol:



The velocity triangle of Kaplan turbine at exit is given by

$$\tan\beta_2 = \frac{V_{f2}}{u_2}$$

$$V_{f2} = \frac{Q}{\frac{\pi}{4}\left(D_{tip}^2 - D_{hub}^2\right)} = \text{constant everywhere.}$$

But $u_2 = r\omega \propto r$

$\therefore$ u_2 is highest at tip and lowest at hub.

$\Rightarrow$ β_2 highest at hub and lowest at tip.

47. Ans: (c)

Sol: Applying linear momentum equation in x-direction:

$$F_{\text{on water}} + (P_{\text{inlet}})_{\text{guage}} \times A = \dot{m}(V\cos 60° - V)$$

$$F_{\text{on water}} = \rho AV \times V(\cos 60° - 1) - (P_{\text{inlet}})_{\text{gauge}} \times A$$

$= 10^3 \times 0.07 \times 36 \times (-0.5) - 4\times10^3 \times 0.07$

$= -1260 - 280 = -1540$ N $= -1.54$ kN

From Newton's third law of motion,

$F_{\text{on bend}} = 1.54$ kN

48. Ans: (a)

Sol:

- Since atmospheric pressure acts on the control volume, the pressure forces are evaluated using gauge pressure at inlet and exit sections when linear momentum equation is applied.
- To analyse flow through a lawn sprinkler, moment of momentum principle is applied.
- Using energy equation, one can find out pressure at a point in a pipeline if required data are given.

49. Ans: (c)

Sol: The gauge would read the stagnation pressure.

Or, $$P_0 = P + \rho\frac{V_0^2}{2}.$$

where, P is the static pressure far upstream of the disk where velocity is V_0.

Thus, the gauge would read a pressure greater than $\rho\frac{V_0^2}{2}$.

50. Ans: (a)

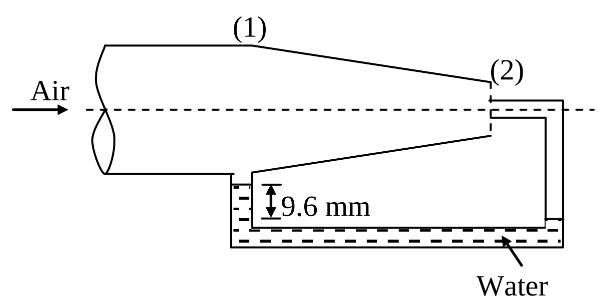
Sol: $$\eta_m = \frac{gH_m}{u_2 V_{w2}}$$

$$0.9 = \frac{10 \times H_m}{50 \times 30}$$

$$H_m = 135 \text{ m}$$

51. Ans: (b)

Sol:



Given data: $\Delta h_w = 9.6 \times 10^{-3}$ m ;

$V_2 = 1.5\ V_1$;

$\rho_{air} = 1.2\ kg/m^3$

It is known that

$$P_0 = P_1 + \frac{1}{2}\rho_{air} V_1^2$$

$$(P_0 - P_1) = \frac{1}{2}\rho_{air} V_1^2$$

$$\rho_w g \Delta h_w = \frac{1}{2}\rho_{air} V_1^2$$

Or, $$V_1 = \sqrt{\frac{2\rho_w g \Delta h_w}{\rho_{air}}}$$

$$= \sqrt{\frac{2\times 10^3 \times 10 \times 9.6 \times 10^{-2}}{1.2}}$$

= 40 m/s

Thus, $V_2 = 1.5 \times 40 = 60$ m/s

52. Ans: (c)

Sol: The resultant hydrostatic force acting on the gate (width = unity) is

$$F_R = \gamma_{oil} \times \frac{2}{2} \times (2\times 1) + \left(\gamma_{oil} \times 2 + \gamma_{water} \times \frac{2}{2}\right)(2\times 1)$$

$$= 2\gamma_{oil} + 4\gamma_{oil} + 2\gamma_{water}$$

$$= 6\gamma_{oil} + 2\gamma_{water} = 6\times 8 + 2\times 10$$

= 68 kN

53. Ans: (a)

Sol: The velocity components u and v are related to stream function, ψ as:

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

Thus, $$\frac{\partial\psi}{\partial y} = -u = -\frac{\log x}{y},$$

Integrating w.r.t. y, we have

$$\psi = -\log x \log y + f(x)$$

Differentiating w.r.t. x,

$$\frac{\partial\psi}{\partial x} = -\frac{\log y}{x} + f'(x) = v = -\frac{\log y}{x} \text{ (Given)}$$

Or, $f'(x) = 0$

Integrating the above equation,

$f(x) = c$

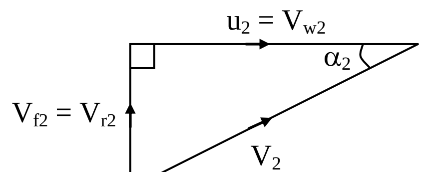
Thus, $\psi = -\log x \log y + c$

where c is constant of integration.

The correct option is (a).

54. Ans: (b)

Sol:



For radial blades at exit $\beta_2 = 90°$

$\therefore\ u_2 = V_{w2}$

$$\eta_h = \frac{u_2 V_{w2}}{gH} = \frac{u_2^2}{gH}$$

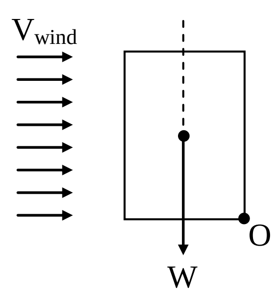
$$= \frac{\left(k_u\sqrt{2gH}\right)^2}{gH}$$

$$= 2k_u^2 = 2 \times 0.65^2$$

= 84.5%

55. Ans: (b)

Sol:



Drag force, $F_D = C_D A \dfrac{\rho V_{wind}^2}{2}$

$$= C_D (H \times D) \rho \frac{V_{wind}^2}{2}$$

Taking ΣM_o, we write

$$F_D \times \frac{H}{2} = W \times \frac{D}{2}$$

Or, $$C_D (H \times D) \rho \frac{V_{wind}^2}{2} \times \frac{H}{2} = mg \times \frac{D}{2}$$

Or, $$V_{wind} = \sqrt{\frac{2mg}{H^2 \rho C_D}}$$

$$= \sqrt{\frac{2 \times 20 \times 10}{0.8^2 \times 1.2 \times 1.2}}$$

$$= \frac{20}{0.8 \times 1.2} = 20.8 \text{ m/s}$$

56. Ans: (a)

Sol: Given data:

$D_{piston} = 80$ mm,

$D_{cylinder} = 80.4$ mm,

$\mu = 76.5$ mPa.s $= 76.5 \times 10^{-3}$ Pa.s

$F_{axial} = 27\pi$ N,

$L = 200$ mm

Oil thickness, $h = (80.4 - 80)/2 = 0.2$ mm

Let V be the piston velocity. Then

$$\tau = \mu \times \frac{V}{h}$$

$$F_{sheer} = \tau \times \text{Area}$$

$$= \mu \frac{V}{h} \times \pi \times D_{piston} \times L$$

Equating the axial load, F_{axial} to shear force, F_{shear},

Or, $F_{shear} = F_{axial}$

Or, $$\mu \frac{V}{h} \pi D_{piston} \times L = 27\pi$$

Or, $$V = \frac{27 \times h}{\mu \times D_{piston} \times L}$$

$$= \frac{27 \times 0.2 \times 10^{-3}}{67.5 \times 10^{-3} \times 0.08 \times 0.2} = 5 \text{ m/s}$$

57. Ans: (b)

Sol: $V = c_v \sqrt{2gH} = 1 \times \sqrt{2 \times 10 \times 180} = 60$ m/s

For maximum efficiency

$$u = \frac{V}{2} = 30 \text{ m/s}$$

$$u = \frac{\pi D N}{60}$$

$$30 = \frac{\pi \times \frac{6}{\pi} \times N}{60} \Rightarrow N = 300 \text{ rpm}$$

58. Ans: (d)

Sol: At normal temperature (20°C)

$\nu_{air} = 1.516 \times 10^{-5}$ m²/s

$\nu_{water} = 1.004 \times 10^{-6}$ m²/s

$\therefore \quad \nu_{air} > \nu_{water}$

Similarly,

$\mu_{air} = 1.825 \times 10^{-5}$ Pa.s

$\mu_{water} = 1.002 \times 10^{-3}$ Pa.s

$\therefore \quad \mu_{air} < \mu_{water}$

Therefore, both the statements are correct.

Note: As the density of water is much more than that of air, the denominator causing kinematic viscosity is higher for water.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59. Ans: (a)

Sol: Inside diffuser of a centrifugal compressor kinetic energy is converted into static pressure. Hence, static pressure increases along the direction of flow. However, the stagnation pressure $\left(P_o = P + \frac{\rho V^2}{2}\right)$ remains constant.

60. Ans: (c)

Sol: Torque convertor is a device which modifies torque. It acts like a gear box.

$$\therefore \quad \frac{T_2}{T_1} \neq 1 \quad \text{and} \quad \frac{N_2}{N_1} \neq 1$$

Fluid coupling transfers torque from one shaft to other.

$$\therefore \quad \frac{T_2}{T_1} = 1$$

$$\eta_{coupling} = \frac{T_2 N_2}{T_1 N_1} < 1 \Rightarrow \frac{N_2}{N_1} < 1$$

61. Ans: (c)

Sol:

- The given expression for shear stress is indeed valid for both laminar and turbulent steady incompressible flow in a pipe.
- Pressure gradient does depend on the nature of flow.

For Laminar flow : $\frac{\Delta P}{L} = \frac{32\mu V}{d^2}$

For turbulent flow: $\Delta P = \rho g h_f = \frac{\rho f L V^2}{2d}$

Or, $\frac{\Delta P}{L} = \frac{\rho f V^2}{2d}$

62. Ans: (d)

Sol:

- Velocity profile in Couette flow is affected by the pressure gradient imposed which can be concluded from

$$u = \frac{Vy}{h} + \frac{1}{2\mu}\left(\frac{\partial P}{\partial x}\right)\left(y^2 - hy\right)$$

where h is the vertical distance between the two plates and V is the velocity of the top plate.

- Statement (II) is correct.

63. Ans: (a)

Sol: Turbine and generator are connected to each other through gear box or they are mounted on same shaft. Frequency of A.C. voltage produced depends upon generator speed.

$$f = \frac{NP}{60}$$

where, P = Pairs of poles in generator,

N = Generator shaft speed

Variation in A.C. frequency can damage electronic components hence it is undesirable. Therefore, to maintain constant A.C. frequency the turbine speed must be kept constant.

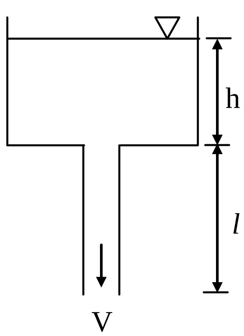
64. Ans: (b)

Sol:

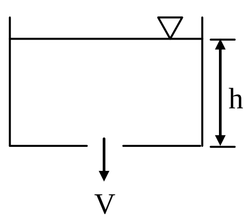
- Statement (I) is correct. This may be further explained with the example of a Golf ball.
- A smooth golf ball (imaginary ball) would maintain a laminar boundary layer on its surface and the boundary layer would separate fairly easily, leading to large aerodynamic drag.
- Golf balls have dimples (a type of surface roughness) in order to create an early transition to a turbulent boundary layer. Flow will separate from the golf ball surface further downstream in the boundary layer resulting in significantly reduced aerodynamic drag.
- Statement (II) is also correct but it is not the correct explanation of statement (I). The turbulent boundary layer has high energy. Hence, it has better ability to overcome adverse pressure gradients.

65. Ans: (c)

Sol:



Drain with long pipe



Drain through orifice

Velocity of flow at Outlet of pipe $= \sqrt{2g(h+\ell)}$

Velocity of flow through orifice $= \sqrt{2gh}$

As seen above the velocity with the long pipe being more, it takes less time for draining reservoir compared to that of flow through orifice. Statement (I) is correct. However, Statement (II) is wrong as seen from the above equations.

Note: However, as length of drain pipe is large, frictional losses are more along with minor losses (entry and exist loss). Hence, the actual velocity through the long drain pipe may be less and hence may take more time, practically.

66. Ans: (a)

Sol: For gas turbine intended for use in vehicles, it is desirable to operate near the compressor pressure ratio that yields maximum net work per unit mass so as to keep engine weight small. If compressor pressure ratio for the maximum thermal efficiency is used then to develop the same net power output a larger mass flow rate would be required and thus might dictate a larger system.

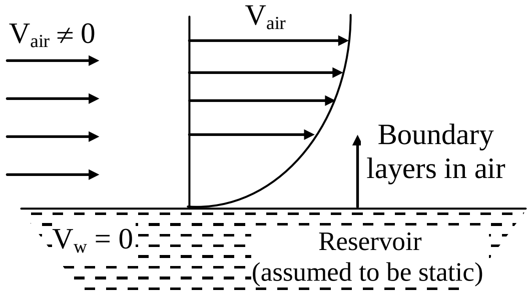
67. Ans: (b)

Sol:

- At the point of separation the value of $\left.\frac{du}{dy}\right|_{y=0}$ is zero. Therefore $\tau = \mu.\frac{du}{dy} \Rightarrow \tau = 0$.
- But the zone of forward flow & reverse flow doesn't imply that the shear stress is zero.

68. Ans: (a)

Sol: In the present problem, Air is blowing over the reservoir. Hence, there is an interface between the two fluids. The velocity of water in the reservoir can be assumed to zero. We know, At the interface of two different fluids, the velocities of two fluids are equal. Hence the velocity of air at the interface also becomes zero. As the flowing air has certain free stream velocity, this velocity can be achieved in a certain narrow region above the reservoir called boundary layer. Hence the boundary layer forms in the air only, as reservoir is assumed to the static.



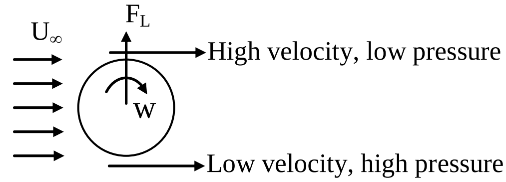
69. Ans: (d)

Sol:

- Hydraulic ram is used in hilly region where it takes water from upstream of river, discards some water at downstream of river and remaining water is sent at higher elevation.
- In hydraulic ram high pressure is generated in downstream chamber due to water hammer effect.

70. Ans: (a)

Sol:



Because of rotation of cylinder unsymmetric velocity distribution is present around the surface of cylinder, which leads to unsymmetric pressure distribution causing lifting force.

71. Ans: (a)

Sol: Wake is indeed unsteady due to vortex shedding and this creates oscillatory forces. These forces cause structural vibration which can lead to failure when the structure's natural frequency is closely matched to the vortex shedding frequency. Thus, both statements are correct and statement (II) is the correct explanation of statement (I).

72. Ans: (a)

Sol: Under homologous condition, geometry and velocity triangles are similar. The efficiency of Francis turbine after neglecting frictional effects is given by

$$\eta = \frac{u_2 V_{w2}}{gH}$$

$$\frac{\eta_m}{\eta_p} = \frac{(u_2)_m}{(u_2)_p} \times \frac{(V_{w2})_m}{(V_{w2})_p} \times \left(\frac{H_p}{H_m}\right)$$

By similarity laws:

All velocities $\propto \sqrt{H}$

u_2 and $V_{w2} \propto \sqrt{H}$

$$(u_2)_m = c_1\sqrt{H_m}$$

$$(V_{w2})_m = c_2\sqrt{H_m}$$

$$(u_2)_p = c_1\sqrt{H_p}$$

$$(V_{w2})_p = c_2\sqrt{H_p}$$

$$\therefore \frac{\eta_m}{\eta_p} = \frac{c_1\sqrt{H_m}}{c_1\sqrt{H_p}} \times \frac{c_2\sqrt{H_m}}{c_2\sqrt{H_p}} \times \frac{H_p}{H_m} = 1$$

73. Ans: (a)

Sol:

- In laminar flow through a pipe head loss is given by $h_f = \frac{32\mu VL}{\gamma D^2} = \frac{128\mu QL}{\gamma\pi D^4}$

  $h_f \propto Q$, keeping other parameters constant.

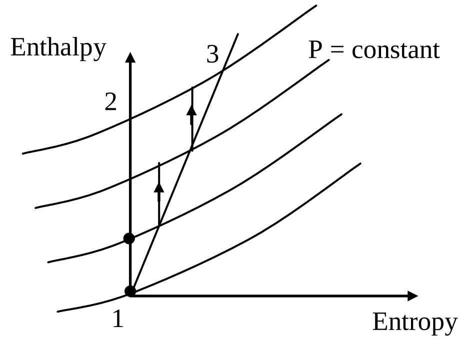
  P = Power consumption = γ Q h_f

  $$P \propto Q^2$$

- If discharge is doubled, then the power consumption increases to four times.

74. Ans: (d)

Sol: Polytropic efficiency of compression process is more than overall efficiency and for expansion process is less than overall efficiency. As constant pressure lines diverge from each other, sum of isentropic work of each successive small stage is more than isentropic work in overall stage. Hence, small stage efficiency for compression process is more than isentropic efficiency.



$$\eta_{ci} = \frac{T_2 - T_1}{T_3 - T_1}$$

$$\eta_{cp} = \frac{\sum \Delta T_i}{T_3 - T_1}$$

$\Sigma\Delta T_i > T_2 - T_i$

$\Rightarrow \eta_{cp} > \eta_{ci}$

75. Ans: (b)

Sol:

- Capillary depression for Hg is given by

  $$h = \frac{4\sigma\cos\theta}{\rho_{Hg} g \times d}$$

  From the above relation, h depends on σ and ρ. Thus, statement(I) is correct.

- For Hg, θ varies between 130° to 150°. Thus, statement (II) is also correct. However, statement (II) is not the correct explanation of statement (I).