ACE Engineering Academy

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ESE- 2019 (Prelims) - Offline Test Series Test- 9

CIVIL ENGINEERING

SUBJECT: FLUID MECHANICS & OPEN CHANNEL FLOW, HYDRAULIC MACHINES AND HYDRO POWER AND SURVEYING GEOLOGY

SOLUTIONS

01. Ans: (d)

Sol: $S = 1000\,cm = 10\,m$

$$\ell = \frac{Sr}{40\sqrt{2}} = \frac{10\times 25}{40\sqrt{2}} = 4.42\,m$$

02. Ans: (a)

Sol:

Line	F.B	B.B	
AB	75°35′	255° 35′	+1°15′@ B
BC	116°35′	296°35′	
CD	165°35′	345°35′	
DE	224°50′	44°50′	+45′@E
EA	305°50′	125°35′	+30′@A

03. Ans: (b)

04. Ans: (c)

Sol: $V_1 = 1$ m/s, $Q = 3.0\ m^3/s$

$b = 3$ m

$Q_1 = A_1V_1$

$= by_1.V_1$

$\therefore\ y_1 = \dfrac{3.0}{3\times1} = 1$

Given, $\dfrac{y_2}{y_1} = 1.5$,

$y_2 = 1.5 \times 1.0$

$= 1.5$ m

For positive surge moving down stream,

$$V_w - V_1 = \sqrt{\frac{gy_2}{2y_1}(y_1+y_2)}$$

$$(V_w - V_1)^2 = \frac{gy_2}{2y_1}(y_1+y_2)$$

$$(V_w - V_1)^2 = \frac{10}{2}\times1.5(1.0+1.5)$$

$$= \frac{15}{2}(2.5) = 18.75$$

$V_w - V_1 = 4.33$ m/s

$V_w = 4.33 + 1$

$= 5.33$ m/s

05. Ans: (b)

Sol:

- Load factor = $\dfrac{\text{Average load}}{\text{Maximum load}}$
- Capacity factor = $\dfrac{\text{Average load}}{\text{Plant capacity}}$
- Utilization factor = $\dfrac{\text{Maximum load}}{\text{Plant capacity}}$
- Diversity factor

$$= \frac{(\text{Sum of peak load of each unit})}{(\text{Maximum load on entire plant})}$$

06. Ans: (a)

Sol: The power developed by Pelton wheel is given by

Rotor power = $\rho aV\,(V - u)\,(1 + K\cos\beta_2) \times u$

For maximum power $u = \dfrac{V}{2}$

& for hemispherical bucket = $\beta_2 = 0$

$$\therefore \text{ Rotor power } = \rho Q\left(V - \frac{V}{2}\right)(1 + 1\times 1)\times\frac{V}{2}$$

$$= \frac{\rho Q V^2}{2}$$

07. Ans: (c)

Sol:

- Depth of focus ranges up to 70 km it is shallow focus earth quake.
- Depth of focus between 70- 300 km it is intermediate focus earth quake.
- Depth of focus grater then 300 km then it is deep focus earth quake.

08. Ans: (a)

Sol: For laminar flow through pipe,

$$\Delta P = \frac{32\mu VL}{D^2}$$

$$\therefore\ h_f = \frac{\Delta P}{\rho g} = \frac{32\mu VL}{\rho g D^2} \propto V$$

$$\therefore\ \frac{h_{f_2}}{h_{f_1}} = \frac{V_2}{V_1} = 2$$

Note: If $h_f = \dfrac{fLV^2}{2gD}$ is used then for laminar flow $f = \dfrac{64}{Re}$ must be considered.

09. Ans: (c)

Sol: Poise is CGS unit of dynamic viscosity,

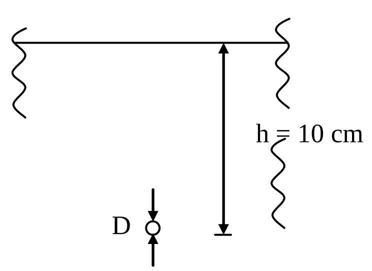
$$\therefore\ 1 \text{ poise} = 1.\frac{\text{dyne.s}}{\text{cm}^2}$$

$$= 1\frac{g}{\text{cm.s}} = \frac{10^{-3}\text{kg}}{10^{-2}\text{m}\times 1\text{s}}$$

= 0.1 Pa.s

10. Ans: (d)

Sol:



Air bubble in water has only one surface (similar to liquid drop)

Hence, $\Delta P = \dfrac{4\sigma}{D}$

$$P_{in} - P_{out} = \frac{4\times 0.072}{10^{-3}}$$

$\therefore$ $P_{in} = P_{out} + 288$

(0 gauge)

$= P_{atm} + \rho gh + 288$

$= P_{atm} + \rho gh + 288$

$= 1000 \times 10 \times 0.1 + 288 = 1288$ Pa

11. Ans: (c)

Sol: Semi-circular shape has the minimum perimeter and hence minimum lining cost.

12. Ans: (d)

Sol: $E_c = y_c + \dfrac{V_c^2}{2g}$

$= y_c + \dfrac{D}{2}$

$= y_c + \dfrac{1}{2}\left(\dfrac{3}{4}y_c\right)$

$= y_c + \dfrac{3y_c}{8}$

$= y_c\left(1 + \dfrac{3}{8}\right) = 1.375\, y_c$

Note: For channel which is half of a regular hexagon hydraulic depth,

$$D = \frac{3}{4}y$$

Shortcut:

Average of rectangle and triangle

$$= \frac{1.5+1.25}{2} = 1.375$$

13. Ans: (b)

14. Ans: (d)

Sol: For completely submerged object

B above G $\rightarrow$ Stable

B below G $\rightarrow$ Unstable

15. Ans: (b)

Sol: $V = \dfrac{Q}{a}$

$= \dfrac{10^{-3}}{2\times 10^{-4}} = 5$ m/s

$F = \rho a V^2$

$= 1000 \times 2 \times 10^{-4} \times 5^2$

$= 5$ N

16. Ans: (b)

Sol: $(n+1) = 61 \quad \rightarrow n = 60$

$L.C = \dfrac{S}{n} = \dfrac{15'}{60}$

$= \dfrac{(15\times 60)''}{60} = 15''$

17. Ans: (c)

Sol: $e = \dfrac{-1}{2}[(2.16-3.510)-(0.91-2.35)]$

$= -\dfrac{1}{2}[-1.35-(-1.44)] = -0.045\,m'$

$e = e_{col} + 0.06735\times 1.2^2$

$-0.045 = e_{col} + 0.0969$

$\therefore$ $e_{col} = (-)\ 0.1419 \simeq (-)\ 0.142$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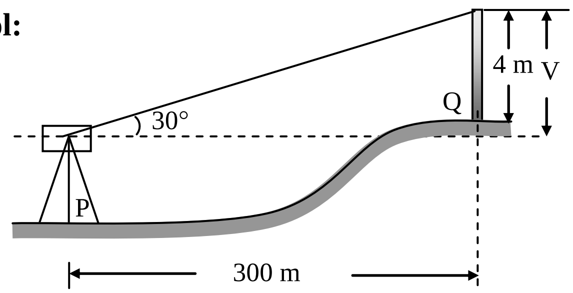
18. Ans: (b)

Sol:



$V = 300 \tan 30° = 173.20$ m

Corr 'V' $= 173.20 + 0.06735\times0.3^2$

$= 173.20$ m

RL of Q $= 420.500 + 173.20 - 4 = 589.85$ m

$\simeq 590$ m

19. Ans: (b)

20. Ans: (c)

Sol: In super critical flow upstream sections are preferred as control sections, as disturbances are present on down stream only. Hence, control sections are chosen away from downstream disturbances, and hence chosen on upstream reaches. Hence, statement (2) is wrong.

21. Ans: (b)

22. Ans: (c)

23. Ans: (d)

24. Ans: (c)

25. Ans: (c)

Sol: Left end of the manometer senses static pressure and right end senses stagnation pressure.

Applying Bernoulli's equation along the nozzle.

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

$$\frac{P_1}{2g}+\frac{V_1^2}{2g}=\frac{P_{o2}}{\rho g}$$

$$\frac{V_1^2}{2g}=\frac{P_{o2}-P_1}{\rho g}=x\left(\frac{\rho_m}{\rho}-1\right)$$

$$V_1^2=2g\times x\times\left(\frac{\rho_m}{\rho}-1\right)$$

$= 2 \times 10 \times 0.1 \times (13.6 - 1) = 25.2$

$\therefore\ V_1 = 5.02$ m/s

$$V_2=\frac{A_1}{A_2}\times V_1=\left(\frac{d_1}{d_2}\right)^2\times V_1$$

$$=\left(\frac{10}{5}\right)^2\times 5.02 = 20.08 \text{ m/s}$$

26. Ans: (a)

Sol:

- Drag coefficient of a car depends on Reynolds number
- Froude number is used model wave drag of a car
- Flow over rocket is supersonic and Mach number is used model supersonic flow
- Weber number is used model capillary flows

27. Ans: (a)

Sol: The flow through water tank takes place due to gravity, hence the flow is modeled using Froude number.

$(Fr)_m = (Fr)_p$

i.e $\left(\frac{V}{\sqrt{gL}}\right)_m = \left(\frac{V}{\sqrt{gL}}\right)_p$

or $\frac{V_m}{V_p} = \sqrt{\left(\frac{L_m}{L_p}\right)}$

i.e $V_r = \sqrt{L_r}$

$T_r = \frac{L_r}{V_r} = \sqrt{L_r}$

$\frac{T_p}{T_m} = \sqrt{\frac{L_p}{L_m}}$

$T_p = \sqrt{\frac{25}{1}} \times 5 = 25$ min

28. Ans: (c)

Sol: For laminar flow through circular pipe.

- $\frac{U_{max}}{V} = 2$
- $\alpha = \frac{\int u^3 dA}{V^3 A} = 2$

Note: Both the above results are standard and students are expected to know these results.

29. Ans: (b)

30. Ans: (a)

Sol: Wt of $\frac{A}{4} = 5 \times 4^2 = 80$

Wt of $6A = \frac{5}{6^2} = \frac{5}{36}$

Ratio $= \frac{80}{\left(\frac{5}{36}\right)} = \frac{80 \times 36}{5} = \frac{288}{5}$

31. Ans: (d)

Sol: Double Meridian Method:

Double Meridian distance of a line

= Double Meridian distance of preceding line + Departure of preceding line + Departure of present line

Line	L	D	M	$\frac{1}{2}$ML
AB	1	2	2	1
BC	–3	4	8	–12
CA	5	–6	6	15
				$\sum \frac{1}{2}ML = 4m^2$

$A = \frac{1}{2}ML = 4m^2$

32. Ans: (b)

Sol: $d = \frac{r_2 h_2}{(H - h_1)} = \frac{60 \times 100}{(2500 - 500)} = 3\,mm$

33. Ans: (a)

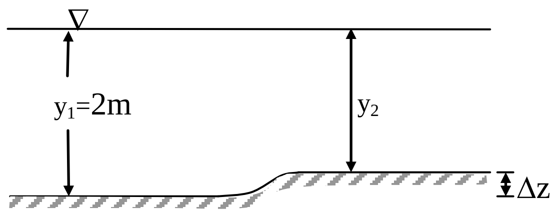
Sol: $\tau_{avg} = \gamma.\ R.\ S_0 = \rho g.R.S_0$

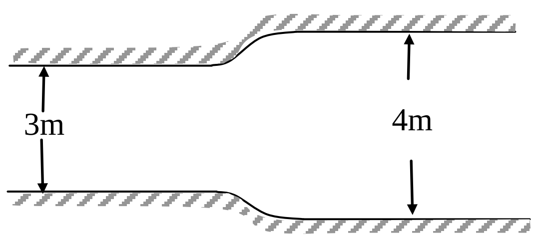
$$= 1000\times10\times\frac{4}{2}\times\frac{1}{1000} = 20\ \text{N/m}^2$$

Note: For efficient trapezoidal channel, hydraulic radius, R = $\frac{y}{2}$.

34. Ans: (d)

Sol:





$Q_1 = Q_2$

$A_1V_1 = A_2V_2$

For horizontal water surface, flow is uniform.

$\Rightarrow V_1 = V_2$

$\therefore A_1 = A_2$

$3\times2 = 4y_2$

$\therefore y_2 = \frac{6}{4} = 1.5\,m$

$\Delta z = y_1 - y_2 = 2 - 1.5 = 0.5$ m

$\Rightarrow$ Rise of 0.5 m

35. Ans: (a)

Sol: $\frac{u_{max}}{v} = 1 + 1.33\sqrt{f}$

$1.266 = 1 + 1.33\sqrt{f}$

$\sqrt{f} = \frac{0.266}{1.33} = 0.2$

f = 0.04

36. Ans: (c)

Sol: Let P_{atm} = 100 kPa & g = 10 m/s^2

$$h = \frac{1.5P_{atm}}{\rho g} = \frac{150\times10^3}{1000\times10} = 15\ \text{m}$$

37. Ans: (b)

Sol: Roughness introduces turbulent. The turbulent boundary layer separates late hence the separation point will shift downstream.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38. Ans: (c)

Sol: The absolute velocity at turbine exit represents loss. To minimize this loss the turbine is designed in such a way that under normal working conditions velocity of whirl is zero at exit.

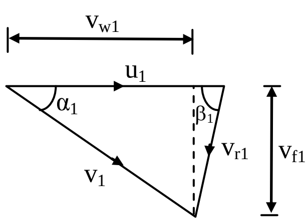
i.e. $V_2 = \sqrt{V_{w_2}^2 + V_{f_2}^2}$

To minimize V_2, $V_{w2} = 0$

V_{f2} cannot be made zero otherwise discharge through the turbine will be zero.

39. Ans: (d)

Sol:



Velocity triangle should satisfy vector relation $\vec{V} = \vec{u} + \vec{V}_r$.

Hence (b) and (c) are wrong.

For fast runner of Francis turbine

$u_1 > v_{w1}$

or $\beta_1 < 90^o$

40. Ans: (c)

Sol:

- For Kaplan turbine flow area is same at inlet and exit hence velocity flow remains constant.

$$V_{f1} = V_{f2} = \frac{Q}{\frac{\pi}{4}(D_o^2 - D_i^2)}$$

- In the analysis of Kaplan turbine the velocity triangle is drawn at a particular section along the radius, such as mean blade radius or tip. Hence blade velocity remains same at inlet and exit.

i.e. $u_1 = u_2 = r\omega$ $(\because r_1 = r_2 = r)$

41. Ans: (b)

Sol: $u = \frac{-\partial\psi}{\partial y} = -4x$

$v = \frac{\partial\psi}{\partial x} = 4y$

$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = (-4x)(-4) + 4y(0)$

$= 16x$

$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = (-4x)(0) + 4y(4)$

$= 16y$

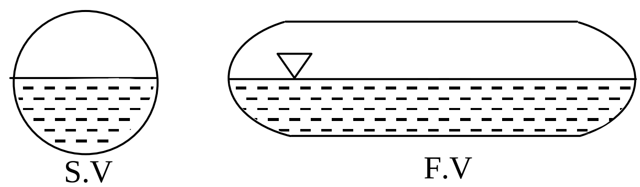
$\vec{a} = 16x\hat{i} + 16y\hat{j}$

$|\vec{a}| = \sqrt{(16x)^2 + (16y)^2}$

$= 16\sqrt{x^2 + y^2} = 16\sqrt{1^2 + 1^2} = 16\sqrt{2}$

42. Ans: (c)

Sol:

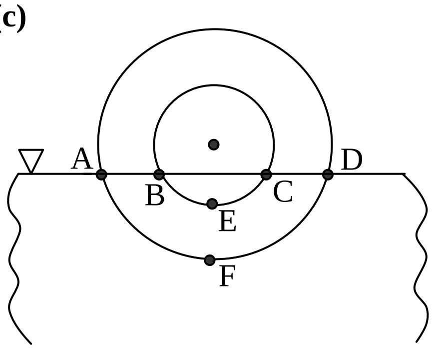


$F_H = \rho g\bar{h}A = 1000 \times 10 \times \frac{4\times 1}{3\times\pi} \times \frac{\pi\times 1^2}{2}$

$= 6.67$ kN

43. Ans: (c)

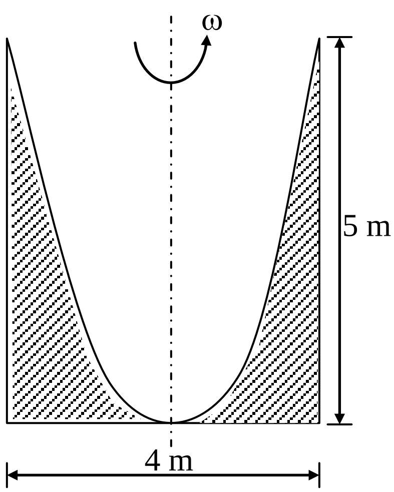
Sol:



- Option A refers to volume ABECDFA and option B refers to volume.
- BCEB both of which are not correct.
- The centre of buoyancy is located at centroid of displaced volume ABCDFA.

44. Ans: (d)

Sol:



Volume of a paraboloid of revolution is half of volume of cylinder which inscribes the paraboliod. Hence vertex of the paraboloid must touch the base of the cylinder.

$$z = \frac{\omega^2 R^2}{2g}$$

$$\omega = \frac{\sqrt{2gz}}{R} = \frac{\sqrt{2\times 9.81\times 5}}{2}$$

$$= 4.95 \text{ rad/sec}$$

45. Ans: (b)

Sol: Shear forces at the top and bottom surfaces of the thin plate are same

$$(F_{shear})_{upper} = (F_{shear})_{lower}$$

$$\mu_{upper} \times \left(\frac{du}{dy}\right)_{upper} \times A = \mu_{lower}\left(\frac{du}{dy}\right)_{lower} \times A$$

or, $$2\mu\frac{V - V_1}{b - cb} \times A = \mu\frac{V_1}{cb}A$$

or, $$\frac{V}{V_1} - 1 = \frac{1 - c}{2c}$$

$$\frac{V_1}{V} = \frac{2c}{1 + c}$$

46. Ans: (a)

Sol: For flow at constant rate, the local acceleration will be zero. Since it passes through a bend, there will be convective acceleration. But when it passes through a straight duct, its convective acceleration will also be zero, i.e., in this case acceleration is zero.

For gradually changing flow through a bend, there will be local and convective acceleration both. But for this type of flow through a straight pipe, there will be only local acceleration.

47. Ans: (b)

Sol: The volumetric flow rate, $Q = V \times (a \times b)$

where, a and b are the sides of the rectangular duct

$Q = 7 \times (0.15 \times 0.2) = 0.21\ m^3/s$

The required pumping power,

$P = Q.\ \Delta P = 0.21 \times 33.3 = 6.993\ W \approx 7.0\ W$

48. Ans: (a) **49. Ans: (c)**

50. Ans: (d) **51. Ans: (c)**

52. Ans: (d)

Sol: Cavitation starts when

$P_{min} < P_r$

or NPSH < NPSHR

$\sigma < \sigma_c$

53. Ans: (a)

Sol:

- Only Kaplan turbine has adjustable runner blades.
- Both Kaplan and Pelton turbine have high efficiency at part load.
- Both Kaplan and Francis turbine have adjustable guide vanes.
- Francis turbine, Kaplan turbine and centrifugal pump all have spiral casing.

54. Ans: (b)

Sol: For double acting pump

$$Q_{th} = \frac{(2A_P - A_r)LN}{60}$$

$$= \left(2 \times \frac{\pi}{4} \times 0.3^2 - \frac{\pi}{4} \times 0.06^2\right) \times (2 \times 0.15) \times \frac{30}{60}$$

$(\because L = 2r)$

$= 20.78\ lps$

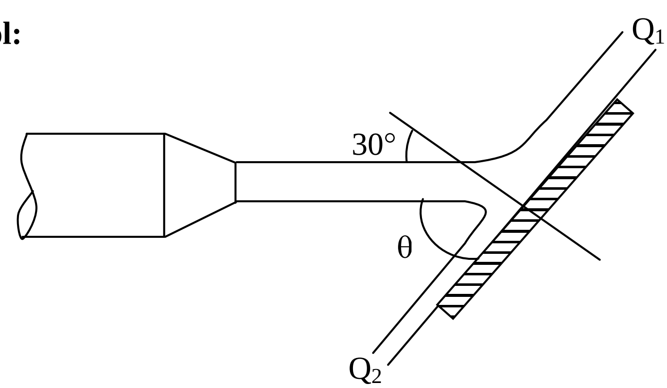
$Q_{act} = (1 - S) \times Q_{th} = (1 - 0.06) \times 20.78$

$= 19.53\ lps$

Note: Such calculations are difficult to perform without calculator. In ESE exam such questions are purposefully asked to trap the students. Students are advised not spend much time on such question in the beginning.

55. Ans: (b)

Sol:



If 'θ' is the angle between the jet and plate as shown in the figure, then

$$Q_1 = \frac{Q}{2}(1 + \cos\theta)$$

$$Q_2 = \frac{Q}{2}(1-\cos\theta)$$

$$\therefore \frac{Q_1}{Q_2} = \frac{1+\cos\theta}{1-\cos\theta} = \frac{1+\cos 60}{1-\cos 60} = 3$$

56. Ans: (a)

Sol: $V = \frac{1}{n}.R^{\frac{2}{3}}.S^{\frac{1}{2}}$

$$n_r = \frac{R^{\frac{2}{3}}.S^{\frac{1}{2}}}{V}$$

$$n_r = \frac{L_V^{\frac{2}{3}}}{\sqrt{L_V}}.\sqrt{\frac{L_V}{L_H}} = \frac{L_V^{\frac{2}{3}}}{\sqrt{L_H}}$$

57. Ans: (c)

Sol: The pressure rise due to water hammer is given by,

$$\Delta P = \rho CV = \rho\sqrt{\frac{k}{\rho}}\ V$$

$$= \sqrt{\rho k}\ V$$

$$= \sqrt{\frac{\rho}{\alpha}}\ V \qquad \{\because \alpha = 1/k\}$$

58. Ans: (c)

Sol: $\frac{L}{D^5} = \frac{L_1}{D_1^5} + \frac{L_2}{D_2^5}$ for pipes in series

$$\therefore \frac{200}{D^5} = \frac{100}{50^5} + \frac{100}{25^5}$$

D = 28.5 cm

Note:

Such calculations are very difficult to perform without calculator but if one knows the fact that the diameter of equivalent pipe must be between 25 cm and 50 cm and its value is near to the smaller diameter then all options except 'c' can be eliminated.

59. Ans: (c)

Sol: $h_f = \frac{fLQ^2}{12.1D^5}$

$$P = \rho g Q h_f = \rho g Q \times \frac{fLQ^2}{12.1D^5}$$

$$P \propto Q^3$$

$$\therefore \frac{P_2}{P_1} = \left(\frac{Q_2}{Q_1}\right)^3 = 1.05^3 = 1.157$$

$\Rightarrow$ 15.7% increase in pumping power

60. Ans: (b)

Sol: Cruising speed, $V = 1080 \times \frac{5}{18} = 300\text{m/s}$

Weight of the airplane, W = 32500 × 10 N

Lift coefficient,

$$C_L = \frac{W}{\frac{1}{2}\rho AV^2} = \frac{32500 \times 10 \times 2}{0.5 \times 65 \times 300 \times 300}$$

$$= 0.22$$

61. Ans: (b)

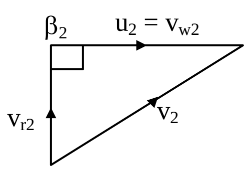
Sol:

- At free delivery point discharge is maximum and head developed is zero.
- Hence, $\eta_o = \dfrac{\rho g Q H}{\text{Shaft power}} = 0$
- Pump will consume some of the power at shut off head to overcome the mechanical frictional resistance even though discharge zero at shut off head.
- If cavitation bubble form in large quantity the average density of the fluid inside the pump reduces. Hence head developed by the pump also reduces.

62. Ans: (a)

Sol: For radial blade at exit

$\beta_2 = 90^o$ or $u_2 = v_{w2}$



$$\therefore \eta_{mano} = \frac{gH_m}{u_2 v_{w2}} = \frac{gH_m}{u_2^2}$$

$$\therefore H_m = \eta_{mano} \cdot \frac{u_2^2}{g}$$

$$\text{Shaft power} = \frac{\rho g Q H_m}{\eta_o}$$

$$= \frac{\rho g Q}{n_o} \times \frac{u_2^2}{g} \times \eta_{mano}$$

$$= \frac{1000 \times 0.01 \times 20^2 \times 0.9}{0.8}$$

= 4.5 kw

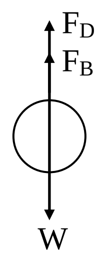
63. Ans: (a)

Sol:

- Magnus effect causes curling of football.
- Circulation is the reason behind lift on aeroplane wing as well as magnus effect.
- Singing of cables is caused by von karman vortex shedding.
- Swing of a cricket ball is result of laminar boundary layer on one side & turbulent boundary layer on other side.

64. Ans: (b)

Sol:



At terminal velocity

$W = F_B + F_D$

$$\rho \times \frac{1}{6}\pi D^3 \times g = \rho_\ell \times \frac{1}{6}\pi D^3 \times g + 3\pi\mu VD$$

$$V = \frac{(\rho - \rho_\ell) g D^2}{18\mu}$$

65. Ans: (d)

Sol: For turbulent boundary layer over flat plate

$$\delta(x) = \frac{0.37x}{Re_x^{1/5}} = \frac{0.37x}{\left(\dfrac{\rho V_\infty x}{\mu}\right)^{1/5}} \propto x^{4/5}$$

66. Ans: (d)

67. Ans: (c)

Sol: von – Karman M.I. equation is expressed as

$$\frac{d\theta}{dx} = \frac{\tau_0}{\rho U_\infty^2}$$

68. Ans: (c)

Sol:

- Relative efficiency = $\frac{\Delta E}{E_1}$

$$E_1 = \frac{(V_1 - V_2)^3}{2g(V_1 + V_2)}$$

V_1 and V_2 will be horizontal components of velocity. On sloping glacis, horizontal component of velocity = V cos θ at any section.

As bed slope θ increases, cos θ decreases.

⇒ Statement (I) is correct.

- On a sloping glacis, the location of the jump is almost fixed for fluctuating discharges. Hence, the design is easy. It is more safe compared to horizontal apron.

69. Ans: (b)

Sol:

- The statement I is related to variation of velocity gradient in streamwise direction (i.e variation of $\frac{du}{dy}$ with respect to x)
- Statement II is related to variation of velocity gradient in normal direction (i.e variation of $\frac{du}{dy}$ with respect to y)
- The boundary layer thickness increases along the plate hence velocity gradient at surface decreases. The highest velocity gradient is at leading edge.

70. Ans: (c)

Sol: For turbulent flow through smooth pipe the friction factor is given by

$$f = \frac{0.3164}{Re^{0.25}} \propto \frac{1}{V^{0.25}}$$

71. Ans: (a)

Sol: Equation of streamlines in $\frac{dx}{u} = \frac{dy}{v}$

$\therefore \frac{dy}{dx} = \frac{v}{u}$ for streamline.

as stream lines and equipotential line are perpendicular to each other,

$\frac{dy}{dx} = \frac{-u}{v}$ for equi-potential line

i.e $\frac{dx}{v} = -\frac{dy}{u}$

72. Ans: (a)

Sol: Draft tube recovers kinetic energy at exit by reducing pressure at the exit of turbine by equivalent amount. The reaction turbines work on pressure difference hence reducing pressure at exit of turbine helps to increase output of reaction turbine. This is not possible in Pelton turbine as it works at constant pressure.

73. Ans: (a)

74. Ans: (b)

75. Ans: (b)