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ESE- 2020 (Prelims) - Offline Test Series Test- 19

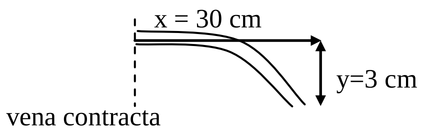
CIVIL ENGINEERING

SUBJECT : FLUID MECHANICS & OPEN CHANNEL FLOW, HYDRAULIC MACHINES AND HYDRO POWER + HYDROLOGY & WATER RESOURCES ENGINEERING AND SURVEYING & GEOLOGY

SOLUTIONS

01. Ans: (b)

Sol:



H = 750 mm

= 75 cm

$$C_v = \sqrt{\frac{x^2}{4Hy}}$$

$$= \sqrt{\frac{30^2}{4\times3\times75}} = 1$$

$\therefore$ $C_v = 1$

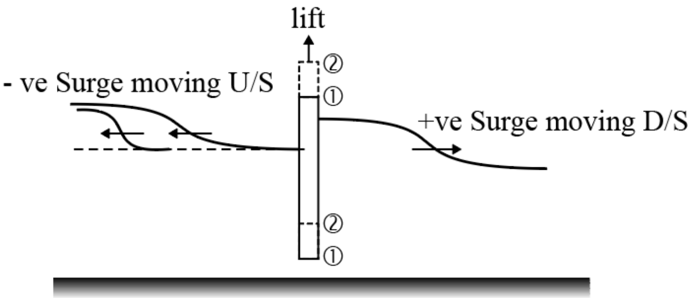
02. Ans: (a)

Sol:

Due to negative pressure, Nappe pulls down more flow rate.

03. Ans: (b)

Sol: By sudden lifting of gates



By lifting of gate, more discharge travel towards d/s. Hence +ve surge moving d/s and water levels falls on u/s, so –ve surge moving u/s.

04. Ans: (d)

Sol: For efficient trapezoidal: Half of regular Hexagon

$$m = \frac{1}{\sqrt{3}}$$

$$B + 2my = 2y\sqrt{1+m^2}$$

$$B = \frac{2y}{\sqrt{3}}$$

$$\therefore \frac{B}{y} = \frac{2}{1.73} = 1.155$$

05. Ans: (c)

Sol: Hydraulically efficient rectangle:

Semi circular section:

$B = 2y$

$R = \frac{d}{4}$

$R = \frac{y}{2}$

$\therefore\ y = \frac{d}{2}$

If discharge passing through both are same

$Q_1 = Q_2$

Slope → same

'n' → same

$$\frac{1}{n}A_1R_1^{2/3}.s_1^{1/2} = \frac{1}{n_2}.A_2R_2^{2/3}.S_2^{1/2}$$

$$A_1R_1^{2/3} = A_2.R_2^{2/3}$$

$$2y_1^2.\left(\frac{y_1}{2}\right)^{2/3} = \frac{\pi}{4}d^2.\left(\frac{d}{4}\right)^{2/3}$$

$$\frac{2y_1^{8/3}}{2^{2/3}} = \frac{\pi}{4}\times(2y_2)^2.\left(\frac{2y_2}{4}\right)^{2/3}$$

$$\frac{2y_1^{8/3}}{2^{2/3}} = \frac{\pi}{4}\times 4y_2^2\times\frac{y_2^{2/3}}{2^{2/3}}$$

$$\left(\frac{y_1}{y_2}\right)^{8/3} = \frac{\pi}{2}$$

$$\frac{y_1}{y_2} = \left(\frac{\pi}{2}\right)^{\frac{3}{8}}$$

06. Ans: (b)

Sol:

If frictional resistance is neglected, total energy remain constant as it depends on arbitrary down for non-uniform flow. But when channel bottom transition occur, specific energy will not remain constant at all section for non-uniform flow.

07. Ans: (d)

Sol: Applying principle of linear momentum in the direction along the inclined plate,

$$F_t = \rho\alpha QV - \rho(1-\alpha)QV - \rho QV\cos\theta$$

$= 0$ [No friction]

Thus, simplifying

$\rho\alpha QV - \rho QV + \rho\alpha QV - \rho QV\cos\theta = 0$

$2\rho\alpha QV = \rho QV(1+\cos\theta)$

$$\Rightarrow \alpha = \frac{1}{2}(1+\cos\theta)$$

08. Ans: (b)

Sol: $u = x-4y$; $v = -(y+4x)$

$\frac{\partial u}{\partial x} = 1$; $\frac{\partial v}{\partial y} = -1$

$\frac{\partial u}{\partial y} = -4$; $\frac{\partial v}{\partial x} = -4$

Now, $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 1-1 = 0;$

$\Rightarrow$ Continuity equation for incompressible flow is satisfied.

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

$\Rightarrow$ Irrotational condition is also satisfied.

09. Ans: (b)

Sol: Piezometric head $= \frac{P}{\rho g} + z$

$$= \frac{29.43}{10^{-4}} \times \frac{1}{10^3 \times 9.81} + 5 = 30 + 5 = 35\,\text{m}$$

10. Ans: (d)

Sol: Given data:

$Q = 0.2\ m^3/s$, $A_A = 0.05\ m^2$

$A_B = 0.1 m^2$, $P_A = 100\times10^3\ N/m^2$

$P_B = 60\times10^3\ N/m^2$, $\gamma_w = 10^4\ N/m^3$

$$V_A = \frac{0.2}{0.05} = 4\,m/s^2$$

$$V_B = \frac{0.2}{0.1} = 2\,m/s^2$$

Total energy at A:

$$E_A = \frac{P_A}{\gamma_w} + \frac{V_A^2}{2g} + Z_A = \frac{100\times10^3}{10^4} + \frac{16}{2\times10} + 0$$

$= 10 + 0.8 = 10.8$

Total energy at B:

$$\frac{P_B}{\gamma_w} + \frac{V^2}{2g} + z_B = \frac{60\times10^3}{10^4} + \frac{4}{2\times10} + 5$$

$= 6 + 0.2 + 5 = 11.2$ m

Since $E_B > E_A$, the flow is from B to A and energy loss $= 11.2 - 10.8 = 0.4$ m

11. Ans: (b)

Sol: Velocity of sound in a medium,

$C = \sqrt{kRT}$

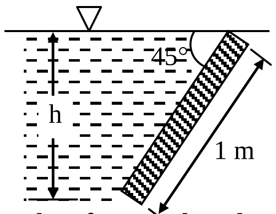
$C \propto \sqrt{T}$

$$\frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{600}{400}} = \sqrt{1.5}$$

$\Rightarrow C_2 = 400 \times \sqrt{1.5} = 490$ m/s

12. Ans: (c)

Sol:



From the figure, height of liquid from the lower edge of the door,

$$h = 1 \times \sin 45^o = \frac{1}{\sqrt{2}} \text{ m}$$

The resultant hydrostatic force on the submerged door due to the liquid of density ρ, is

$$F_R = P_c A = \rho g \bar{h}(1\times 1)$$

$$= \rho g \times \frac{h}{2} = \rho g \times \frac{1}{2\sqrt{2}}$$

13. Ans: (d)

Sol: Applying Bernoulli's equation between sections (1) and (2), we write

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

But $P_1 = P_2$ (Given), $V_1 = V_2$ (as $d_1 = d_2$)

Thus, $h_L = Z_1 - Z_2$

$$\frac{f\,L\,V^2}{2gd} = (Z_1 - Z_2) = 3 \times \sin 30^o = 1.5$$

$$\frac{f\,L\,V^2}{2gd} = 1.5$$

$$\frac{8f\,L\,Q^2}{\pi^2 g\,d^5} = 1.5$$

$$\frac{Q^2}{\pi^2} = \frac{1.5 \times g \times d^5}{8\text{ f L}}$$

$$= \frac{1.5 \times 10 \times 2^5 \times 10^{-10}}{8 \times 0.02 \times 3}$$

$$= \frac{20}{0.02} \times 10^{-10}$$

$$= 1000 \times 10^{-10}$$

$$= 10^{-7} = \frac{10^{-6}}{10}$$

$$\frac{Q}{\pi} = \frac{10^{-3}}{\sqrt{10}}$$

$$Q = \frac{\pi}{\sqrt{10}} \times 10^{-3} \text{ m}^3/\text{s}$$

$$= \frac{\pi}{\sqrt{10}} \text{lit/s} \cong 1 \text{ lit/s}$$

14. Ans: (a)

Sol: The volume displaced,

$$\forall = \frac{500 \times 10^6}{10^3 \times 10} = 50000 \text{ m}^3$$

$$I = \frac{1}{12} \times 200 \times 25^3 \times 0.6 = 156{,}250 \text{ m}^4$$

$$\overline{BM} = \frac{I}{\forall} = \frac{156{,}250}{50{,}000} = 3.125 \text{ m}$$

The metacentric height,

$$\overline{GM} = \overline{BM} - \overline{BG}$$

$$= 3.125 - 2.5 = 0.625 \text{ M}$$

The metacentre is 0.625 m above the centre of gravity and the ocean liner is stable.

15. Ans: (c)

16. Ans: (a)

Sol:

$$\delta_t = \frac{0.38x}{(Re_x)^{1/5}} \propto x^{4/5}$$

$$\delta_\ell = \frac{5x}{\sqrt{Re_x}} \propto x^{1/2}$$

$$\frac{\delta_t}{\delta_\ell} \propto \frac{x^{4/5}}{x^{1/2}} \propto x^{0.3}$$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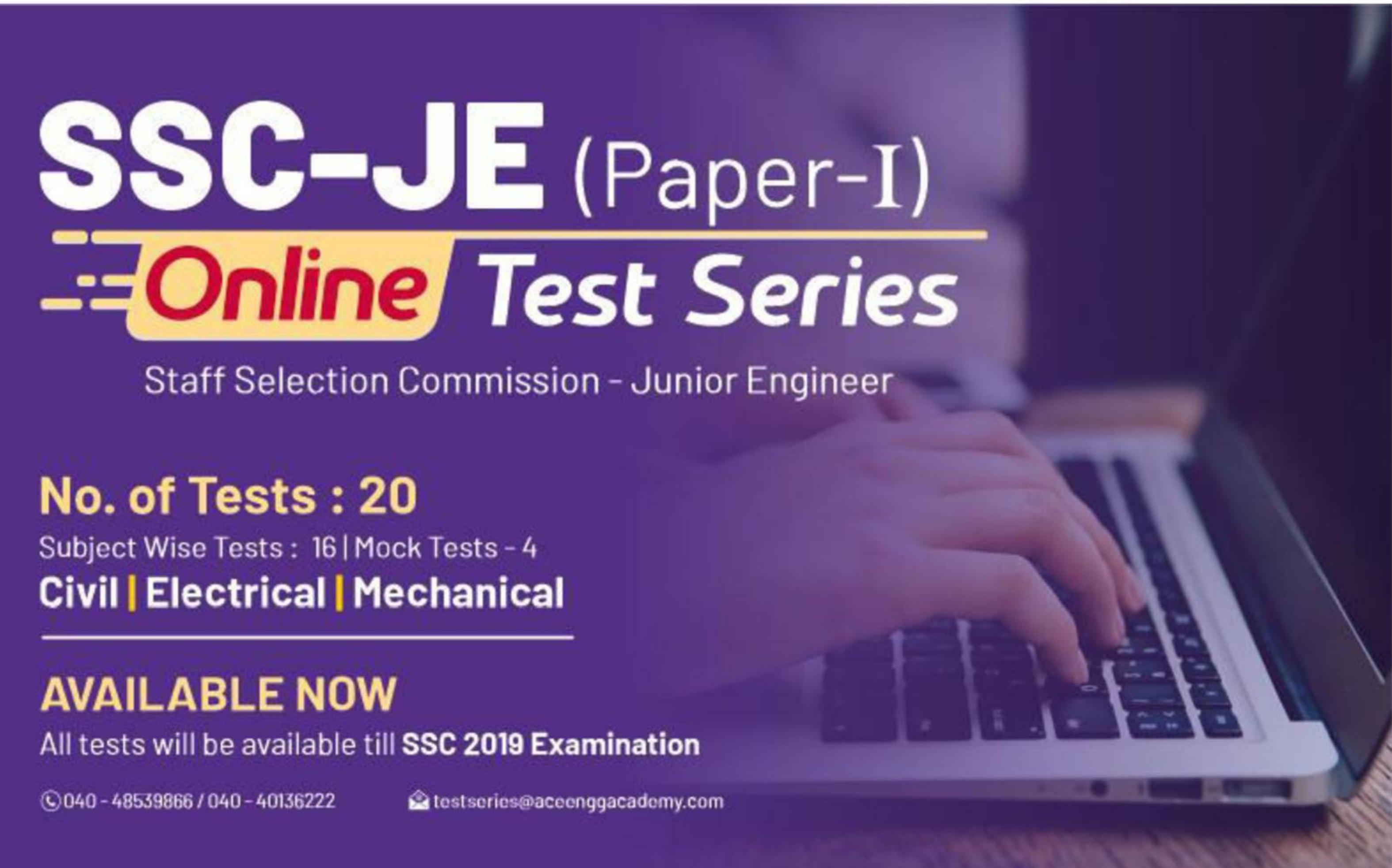
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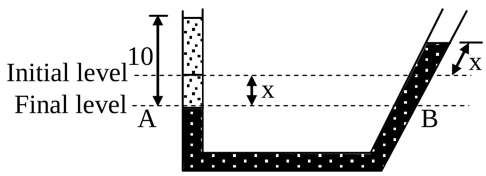
17. Ans: (b)

Sol:



$P_A = P_B$

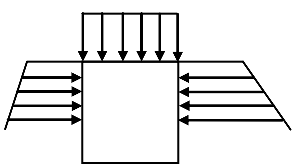
$800 \times g \times 10 = 1000 \times (x + x\sin\theta) \times g$

$$x + \frac{x}{2} = 8 \quad \Rightarrow \quad \frac{3}{2}x = 8$$

$$x = \frac{16}{3} = 5.33 \text{ cm}$$

18. Ans: (d)

Sol:



The force exerted by water will be due to the pressure on upper face as shown in the figure.

$F = P\,A = 1000 \times 10 \times 5 \times 10^{-2} \times 10 \times 10^{-4}$

$= 0.5$ N (downward)

19. Ans: (a)

Sol: Irrotational flow is not a necessary assumption for Bernoulli's equation. In fact if flow is irrotational, Bernoulli's equation can be applied between any two points even though they are not on the same streamline.

20. Ans: (a)

Sol: The curve $(x-1)^2 + (y+2)^2 = 16$ represents a circle with centre (1, –2) and radius '4'.

$$\Gamma = \oint \vec{V}.\vec{ds} = \iint \vec{\Omega}.\vec{dA} = \iint \Omega_z \, dA$$

$[\because \Omega_x = \Omega_y = 0$ for flow in xy plane$]$

$$\Omega_z = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = 5 - 3 = 2 \text{ rad/s}$$

$$\Gamma = 2 \times \iint dA$$

$= 2 \times \pi \times 4^2$

$= 32\,\pi$

21. Ans: (d)

Sol: The capillary depression is given by:

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

$\Rightarrow h \,\alpha\, \frac{1}{d}$ if σ, θ remain same

Thus, $\frac{h_2}{h_1} = \frac{d_1}{d_2} = \frac{3}{2} = 1.5$

Percentage increases in capillary depression is

$$= \left(\frac{h_2}{h_1} - 1\right) \times 100$$

$= (1.5–1)\times 100 = 50\ \%$

22. Ans: (a)

Sol: Stone weight in air = 392.4 N

Stone weight in water = Stone weight in air – Buoyancy force

$196.2 = 392.4 - \rho_w \forall_{stone} \times g$

or,

$$\forall_{stone} = \frac{392.4 - 196.2}{10^3 \times 9.81} = \frac{196.2}{10^3 \times 9.81} = 0.02\,m^3$$

$$\rho_{stone} = \left(\frac{mass}{\forall}\right)_{stone} = \frac{392.4}{9.81 \times 0.02}$$

$= 2000 \ \ kg/m^3$

Thus, $(S.G)_{stone} = \frac{2000}{10^3} = 2$

23. Ans: (c)

Sol: $N_S = \frac{N.\sqrt{P}}{(H)^{5/4}}$

$$325 = \frac{1040\sqrt{P}}{(16)^{1.25}}$$

$$325 = \frac{1040\sqrt{P}}{32}$$

$$325 = 32.5\ \sqrt{P}$$

$$\sqrt{P} = 10$$

$\therefore$ P = 100 kW/runner

No. of units required = $\frac{400}{100}$

= 4

24. Ans: (b)

Sol: Speed ratio $(\phi) = \frac{U}{\sqrt{2gH}}$

$$0.41 = \frac{\frac{\pi \times D \times 420}{60}}{\sqrt{2 \times 10 \times 320}}$$

$$0.41 \times \sqrt{6400} = \frac{\pi \times D \times 420}{60}$$

0.41 × 80 = 7 π D

D = 1.5 m

25. Ans: (a)

Sol: N.P.S.H = $\frac{P}{\rho.g} + \frac{V^2}{2g} - \frac{P_v}{\rho g}$

$$= \frac{20000}{1000 \times 9.81} + \frac{\left(\frac{0.15}{\frac{\pi}{4}(0.25)^2}\right)^2}{2 \times 9.81} - \frac{12.5 \times 1000}{1000 \times 9.81}$$

= 2.04 + 0.48 – 1.27 = 1.25 m

26. Ans: (a)

Sol: Deriaz turbine is adjustable blade diagonal flow reaction turbine. The flow of water against the turbine blades is neither axial nor radial, but at an angle.

27. Ans: (d)

Sol: Power of the runner of Impulse turbine = $\dot{m}\left(V_{w_1}U_1 + V_{w_2}U_2\right)$

Absolute velocity (V_2) of jet Angle (= 90°)

i.e radial discharge $\therefore\ V_{w_2} = 0$

$P_{RUNNER} = \dot{m}V_{w_1}U_1$

Head Extracted by runner = $\frac{\dot{m}V_{w_1}U_1}{\dot{m}g}$

$$= \frac{V_{w_1}U_1}{g}$$

$$= \frac{100 \times 40}{10}$$

= 400 m

28. Ans: (d)

29. Ans: (d)

Sol: $N_S = \frac{N\sqrt{P}}{(H)^{5/4}} = \frac{N\sqrt{3600}}{(81)^{5/4}}$

$$60 = \frac{N \times 60}{243}$$

$\therefore$ N = 243 rpm

$$N_{sym} = \frac{120f}{P}$$

$$243 = \frac{120 \times 50}{P}$$

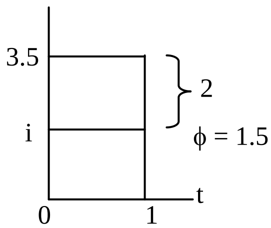
$\therefore$ P = 25

30. Ans: (c)

Sol: Convective Rainfall - short duration heavy rainfall.

31. Ans: (d)

Sol: 2cm/hr = 20 mm/hr



32. Ans: (a)

Sol:

$E_L \propto (e_w - e_a)$

$E_L = k\,(e_w - e_a)$

33. Ans: (d)

Sol:

$$F = \frac{f_o - f_c}{k} \times f_{ct}$$

$$36 = \frac{(15-1)}{k} + (1\times 8)$$

K = 0.5/hr

34. Ans: (b)

Sol:

i = 2.5 cm/hr

t = 4 hr

p = i × t = 10 cm

C.A = 100 ha

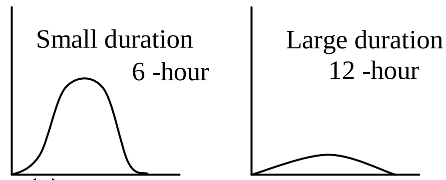
R.V = 0.03×10^6 m^3

$$R = \frac{R.V}{C.A} = \frac{0.03\times10^6}{100\times10^4} = 0.03\,m = 3\,cm$$

F = P – R = 10 – 3 = 7 cm

35. Ans: (b)

Sol:



36. Ans: (c)

Sol:

Time	1-hr VH	S- curve addition Lag 1 hr	S_1- curve
0	0	-	0
1	3	0	3
2	8	3	11
3	12	11	23
4	6	23	29
5	3	29	32
6	0	32	32

37. Ans: (c)

Sol: Peak of $UH = \frac{(\text{Peak of FH} - \text{BF})}{R\,cm} \times 1cm$

$$= \frac{(180-30)}{3} \times 1cm$$

$= 50\ m^3/s$

38. Ans: (b)

Sol: $S_y = \frac{V_{wy}}{AxZ}$

$$0.2 = \frac{V_{wy}}{100\times10^4\times5}$$

$V_{wy} = 1\times 10^6\ m^3$

$V_{wy} = 1\ Mm^3$

39. Ans: (a)

Sol: Definition of tortuosity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40. Ans: (a)

Sol: $\forall_{plant} = A\Delta$

$$\forall_{reservoir} = \frac{A\Delta}{\eta_a \eta_c \eta_r}$$

$$= \frac{\frac{60}{100}(20{,}000)\times 10^4\left(\frac{120}{100}\right)\times 10^{-6}}{0.8\times 0.9\times 0.82}$$

$$= \frac{6\times 2\times 12}{0.8\times 0.9\times 0.82} = 243.9\ \text{Mm}^3$$

41. Ans: (c)

Sol: At B, $x = \frac{-b}{4}$

$$\phi_B = \frac{100}{\pi}\cos^{-1}\left(\frac{2x}{b}\right)$$

$$= \frac{100}{\pi}\cos^{-1}\left(\frac{2}{b}\left(\frac{-b}{4}\right)\right)$$

= 66.66%

42. Ans: (c)

Sol: $\alpha = \frac{40}{10} = 4$

$$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2} = 2.56$$

$$G_E = \frac{H}{d}\frac{1}{\pi\sqrt{\lambda}} = \frac{8}{10}\frac{1}{\pi\sqrt{2.56}} = 0.16 = \frac{1}{6}$$

43. Ans: (d)

Sol: Options (a) ,(b) & (c) are valid essentially for Lacey's theory for silt of any size

44. Ans: (c)

Sol: $V = \frac{Q}{A} = \frac{Q}{y^2(\theta + \cot\theta)} = 2.3\ \text{m/s}$

$P = 2y\,(\theta + \cot\theta) = 10.44$ m

45. Ans: (b)

Sol: $P_s = \frac{1}{2}k_a\gamma_{sub}H_s^2$

$P_w = 2\,w\,h_w^2$ $\quad P_s > P_w$

But lever arm of P_w is $H_1 + \frac{3}{8}h_w$

$\therefore M_s << M_w$

46. Ans: (d)

Sol:

- Upstream face is equipotential line.
- Top most flow line is phreatic line so, phreatic line is a streamline.
- Streamline & equipotential lines are always mutually perpendicular

47. Ans: (c)

Sol: By concept of contour irrigation answer is 'c' obviously

48. Ans: (c)

Sol: Most sedimentary rocks are deposited under conditions which favour development of distinct layers piled up one above another, from bottom to top. These layers also called beds or strata.

49. Ans: (c)

Sol: The key words in the definition are fracture and movement. The exact significance of these key words must be clearly understood.

50. Ans: (a)

Sol: Dams are constructed for achieving any one or more of the following objectives: generation of hydropower energy; providing water for irrigation facilities; providing water supply for domestic and industrial purposes; fighting droughts and controlling of floods; providing navigational facilities.

51. Ans: (b) **52. Ans: (d)**

53. Ans: (a) **54. Ans: (b)**

55. Ans: (c) **56. Ans: (c)**

57. Ans: (d)

58. Ans: (d)

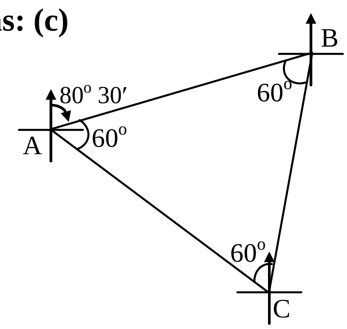
Sol: Planimeter constant $\mu = 2\pi rL$

$\mu = 2\pi \times 1.06 \times 15 = 100\ cm^2$

59. Ans: (c) **60. Ans: (a)**

61. Ans: (c)

Sol:



FB of AB = 80° 30′

FB of BC = BB of AB - ∠ B

$= (80^o\ 30' + 180^o\ 0') - 60^o\ 0'$

$= 260^o\ 30' - 60^o\ 0' = 200^o\ 30'$

FB of CA = BB of BC + exterior ∠ C

$= (200^o\ 30' - 180^o\ 0') + (360^o\ 0' - 60^o\ 0')$

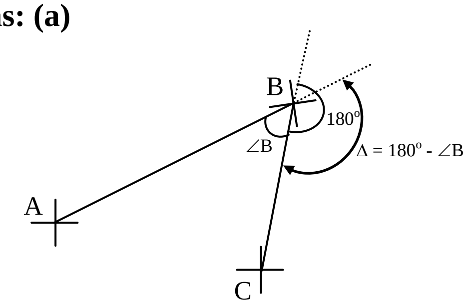
$= 20^o\ 30' + 300^o\ 0' = 320^o\ 30'$

62. Ans: (b) **63. Ans: (b)**

64. Ans: (b)

65. Ans: (a)

Sol:



66. Ans: (d)

67. Ans: (d)

Sol: When 'm' is integer, then method of super position is used other wise S-curve technique is used.

68. Ans: (c)

Sol: Statement (1) True

Statement (2) False

69. Ans: (a)

Sol: If $(q_m)_{incoming} \neq (q_m)_{out\ going}$, aggradation & degradation takes place

⇒ Regime condition is not possible

70. Ans: (c)

Sol: $C_d = C_c \times C_v$

$$\left[\because\ C_d = \frac{Q}{Q_{th}} = \frac{A.V}{A_{th}V_{th}} = C_c \times C_v\right]$$

71. Ans: (d)

Sol: Even though turbulence created by rough surface has high friction drag overall drag will be less due to reduction in pressure drag. Turbulence delays flow separation and reduces size of wake due to which pressure drag reduces.

72. Ans: (d)

Sol: Angular velocity (ω_z) in polar coordinate system is given by

$$\omega_z = \frac{1}{2r}\left[\frac{\partial}{\partial r}(ru_\theta) - \frac{\partial u_r}{\partial \theta}\right]$$

$$= \frac{1}{2r}\left[\frac{\partial}{\partial r}\left(r\times\frac{k}{r}\right) - \frac{\partial}{\partial \theta}(0)\right]$$

$$= 0$$

$\Rightarrow$ Free vortex is irrotational.

In irrotational flow Bernoulli's equation can be applied between any two points even though they are not on same streamline.

73. Ans: (a)

Sol: In turbulent flow effective viscosity is sum of dynamic viscosity and eddy viscosity. The eddy viscosity is present due to Reynolds stresses.

74. Ans: (d)

Sol: For turbulent flow through smooth pipe,

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

Hence statement (II) is correct.

$$h_f = \frac{f\,L\,V^2}{2gD} = \frac{0.3164}{Re^{0.25}} \times \frac{LV^2}{2gD} \propto V^{1.75}$$

Hence, statement (I) is wrong.

75. Ans: (a)

Sol: Air vessels maintain constant velocity in the pipe. As acceleration of the fluid in pipe is zero the acceleration head is eliminated. Therefore, the minimum pressure at the beginning of suction stroke is increased.