1 PROPERTIES OF FLUIDS

4. Ans : (a)

Sol: Newton is the force required to produce unit acceleration in unit mass of a body

Given the body is subjected to gravitational force

Hence,

$a = g \Rightarrow 10\ m/s^2$

$\Rightarrow$ Force $= 0.1$ kg

22.Ans : (d)

Sol: $\mu = 1.2\times10^{-4}\ N-s/m^2$

$\frac{du}{dy} = 1000/s$

$\tau = \mu.\frac{du}{dy} = 0.12\ N/m^2$

28. Ans : (d)

Sol: Specific gravity, S = 2

Fluid density, $\rho = S\times\rho_{water}$

$= 2\times1000 = 2000\ kg/m^3$

Kinematic viscosity,

ν = 6 stokes = 6 cm^2 / sec

$= 6\times10^{-4}\ m^2/sec$

$\nu = \frac{\mu}{\rho}$

$\mu = \nu\times\rho$

$= (6\times10^{-4}\ m^2/s)\times(2000\ kg/m^3)$

$= 1.2\ Ns/m^2$ or Pa.s

29. Ans : (b)

Sol: 1 kg(f) = 9.81 N

$\mu = 0.139\ kg(f) - s/m^2$

$= 0.139\times9.81$

$= 1.364\ N.s/m^2$

Specific gravity, S = 0.95

Density, $\rho = 950\ kg/m^3$

Kinematic viscosity, $\nu = \frac{\mu}{\rho} = \frac{1.364}{950}$

$= 0.001435\ m^2/s$

33. Ans : (d)

Sol: bulk modulus of water is around 20000 times more than that of air.

Air is about 20,000 times more compressible than water.

Water is about 100 times more compressible than mild steel.

47. Ans : (a)

Sol: Surface tension is the surface energy per unit area.

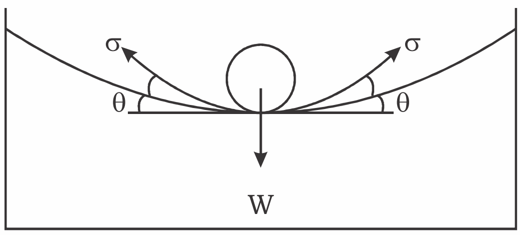
$\sigma = \frac{\text{surface energy}}{\text{surface area}} = \frac{F\times L}{L^2} = \frac{F}{L}$

Hence, it is also the tangential force per unit length.

It has a unit of N/m (or) kN/m (or) Joule /m^2

52. Ans : (d)

Sol:



Upward force due to surface tension

$= 2\sigma \sin\theta$

Downward force due to self weight of needle = W

Note : In the second line of the question, the word weight shall be understood as weight density. A printing mistake in the question framed.

53. Ans : (c)

Sol: $dp = \frac{4\sigma}{d} = \frac{4\times 0.0075}{6\times 10^{-3}\times 10^{-3}}$

$= 5000\ kg/m^2 = 0.5\ kg/cm^2$

Note: In the given material the numerical value for option **'c'** is incorrect.The correct value is 0.5

54. Ans : (d)

Sol: An air bubble has only one surface.

Hence

$$dP = \frac{4\sigma}{d} = \frac{4\times 0.073}{0.01} = 29.2\ kN/m^2$$

59. Ans : (b)

Sol: Mercury has more cohesion compared to the adhesion between the glass and mercury.

60. Ans : (c)

Sol: $h = \frac{4\sigma\cos\theta}{\gamma d}$

For pure water and clean glass $\theta = 0$

$$h = \frac{4\sigma}{\gamma d}$$

62. Ans : (b)

Sol: Rise or depression of liquid due to surface tension, $h = \frac{4\sigma\cos\theta}{\gamma d}$

As size of tube increases, rise or depression of liquid decreases.

64. Ans : (a)

Sol: d = 2 mm = 0.2 cm

$\sigma = 0.075$ g/cm $= 0.0075$ kg/m

$$h = \frac{4\sigma}{\gamma d} = \frac{4\times 0.0075}{9810\times 2\times 10^{-3}} = 1.5\ cm$$

71. Ans : (a)

Sol: $\nu = \frac{\mu}{\rho}$

$$3\times 10^{-4}\ cm^2/sec = \frac{\mu}{0.8\frac{g}{cm^3}}$$

$$\mu = 2.4\times 10^{-4}\frac{g}{cm-sec} \quad = 2.4\times 10^{-6}\frac{ms\ell}{m-s}$$

76. Ans : (a)

Sol: $\rho_{oil} = 959.42\ kg/m^3$

$\tau = 0.216\ N/m^2$

$\frac{du}{dy} = 0.21\ sec^{-1}$

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

$\mu = 1.0286$ Pa. sec

$\nu = \mu/\rho$

$$= \frac{1.0286}{959.42} = 1.072\times 10^{-3}\ m^2/s$$

Note: In the given material the numerical value for option **'a'** is incorrect.The correct value is 1.072×10^{-3}

86. (b)

Sol: Ball pen function on the principle of surface tension. Pen is fitted with a tiny ball bearing in its tip. As the pen moves along the paper, the ball rotates picking up ink from the ink cartridge and leaving it on the paper.

A sticky ink goes down a riffle obstructed at the bottom end by a tiny little ball. There is a narrow clearance between the riffle and the ball so that when the ball is rolled across a piece of paper it entrains a thin film of sticky ink from the other side and deposits it onto the paper. Because the ink is sticky, it feels like the ink is instantaneously dry. Another advantage is consistent deposition (Due to clearance between riffle and ball) regardless of how much pressure is applied by the writing hand.

99. Ans : (a)

Sol: $S_{oil} = \frac{\gamma_{oil}}{\gamma_{water}} = \frac{7.85\times10^3}{9810} = 0.8$

101. Ans : (a)

Sol: Weight = m × g

$500 = m\times 9.81$

$m = 50.97$ kg

102. Ans : (a)

Sol: $v = \frac{\mu}{\rho} = \frac{2\times10^{-3}}{800}$

$= 0.0000025 \frac{m^2}{Sec}$

$= 0.025 \frac{cm^2}{Sec}$ (or) stoke

= 0.025×100centistoke

= 2.5 centistoke

105. Ans : (d)

Sol: S = 0.96

$\rho = 960\ kg/m^3$

$\mu = 0.00109\ Ns/m^2$

$v = \frac{\mu}{\rho}$

$= \frac{0.00109}{960} = 1.135\times10^{-6}\ m^2/sec$

111. Ans : (a)

Note: In the given material the given option 'b' was incorrect.

115. Ans : (a)

Note: In the given material the given option 'd' was incorrect.

125. Ans : (b)

Sol: $dy = 14\ mm = 14\times10^{-3} m$

$\mu = 14\ \text{poise} = 1.4\frac{N-S}{m^2}$

du = 2.5 m/s

$\tau = \mu\frac{du}{dy} = 1.4\times\frac{2.5}{14\times10^{-3}} = 250\ N/m^2$

129. Ans : (b)

Sol: $\Delta P = 2\times10^4 \frac{kN}{m^2} = 2\times10^7 \frac{N}{m^2}$

$K = \frac{\Delta P}{\frac{\Delta V}{V}}$

$= \frac{2\times10^7}{\frac{0.50}{50}} = 2\times10^7\times10^2 = 2\times10^9\ N/m^2$

132. (c)

Sol : $\mu = 1\frac{N-S}{m^2}$

$u = 0.9y - y^2$

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

$= 1\times\frac{d}{dy}(0.9y - y^2)$

$\tau = 0.9 - 2y$

$\tau_{0.45} = 0.9 - 2\times0.45$

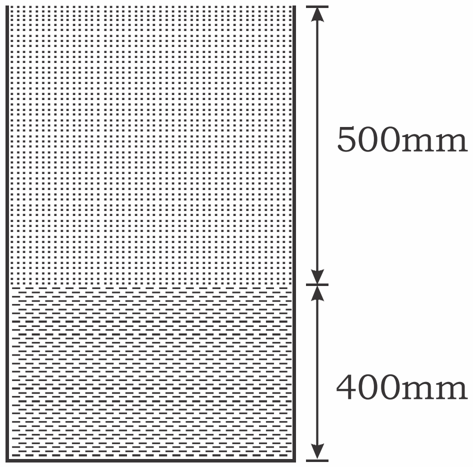
$= 0.9 - 0.9$

$= 0$

2 PRESSURE AND IT'S MEASUREMENTS

1. (a)

Sol:



γ_{water} = 9810N/m^3

h_{water} = 400 mm = 0.4m

γ_{oil} = 8.8kN/m^3=8800N/m^3

h_{oil} = 500mm = 0.5m

Pressure at bottom of the vessel

$= \gamma_{water} \times h_{water} + \gamma_{oil} \times h_{oil}$

= 9810×0.4+8800×0.5

= 8324 N/m^2

= 8.324kN/m^2

2. (d) P = 4.8 kgf/cm^2

$$= \frac{4.8 \times 9.81\text{N}}{(10^{-4})\text{m}^2}$$

= 470880 N/m^2

S_{oil} = 0.8

$\rho_{oil} = S_{oil} \times \rho_{water}$

= 0.8×1000

= 800kg/m^3

$\gamma_{oil} = \rho_{oil} \times g = 800 \times 9.81 = 7848\text{N/m}^3$

$\rho = \gamma_{oil} \times h$

$$h = \frac{P}{\gamma_{oil}} = \frac{470880}{7848} = 60\text{m}$$

h= 60m

3. (d)

Sol: P= γ h

= 9810×1

= 9810Pa

4. Ans : (c)

Sol: P = $= \rho g H$

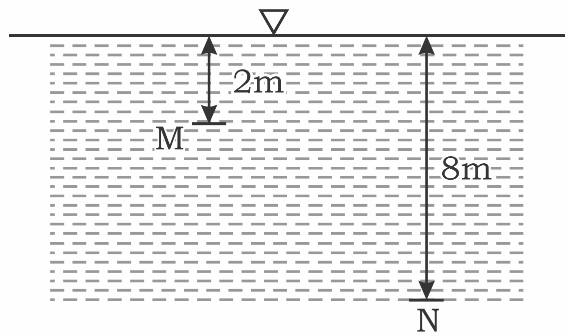
$= 1000 \times 10 \times 10$

$= 100\,000$ N/m^2

$= 100$ kN/m^2

9. Ans : (d)

Sol:



$$\frac{P_M}{P_N} = \frac{\gamma_W h_M}{\gamma_W h_N} = \frac{h_M}{h_N} = \frac{2}{8} = \frac{1}{4} = 1:4$$

$$= \frac{2}{8} = \frac{1}{4} = 1:4$$

10. Ans : (c)

Sol: $P_{Abs} = P_{Atm} + P_{gauge}$

= 100 + 200 = 300 kPa (Abs)

11. Ans : (c)

Sol: $P = \rho g H$

$= 1000 \times 9.81 \times 25$

$= 245250\ \text{N/m}^2$

$= 245.25\ \text{kN/m}^2$

13. Ans : (a)

Sol: $P = \rho g H$

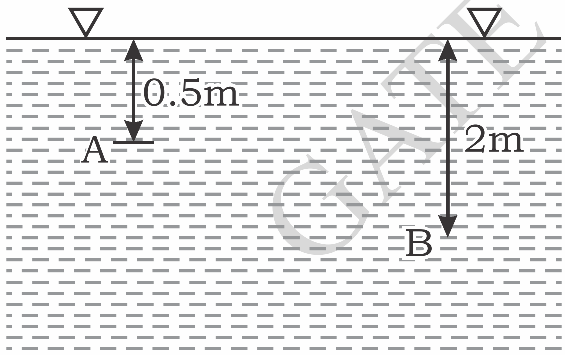
$= 1000 \times 10 \times 10$

$= 100\,000\ \text{N/m}^2$

$= 100\ \text{kN/m}^2$

17. Ans : (b)

Sol:



$$\frac{P_A}{P_B} = \frac{\gamma_W h_A}{\gamma_W h_B} = \frac{h_A}{h_B} = \frac{0.5}{2} = \frac{1}{4} = 1:4$$

18. Ans : (d)

Sol: $P_{Atm} = \rho_{Hg}.g.H_{Hg}$

$= 13600 \times 9.81 \times 0.74$

$= 98.73 \times 10^3\ \text{N/m}^2$

$= 1.05\ \text{kgf/cm}^2$

$P_{Abs} = 5.05\ \text{kgf/cm}^2 \text{(given)}$

$P_{Abs} = P_{Atm} + P_{gauge}$

$5.05 = 1.05 + P_{gauge}$

$P_{gauge} = 4\ \text{kg f/cm}^2$

20. Ans : (c)

Sol: $P = 50\,N/cm^2 = 50 \times 10^4 N/m^2$

$\rho_{oil} = S_{oil} \times \rho_w = 0.9 \times 1000 = 900 kg/m^3$

$P = \rho g h$

$50 \times 10^4 = (900)(9.81) \times h$

$h = 56.63\ \text{m}$

21. Ans : (c)

Sol: $S_{oil} = 0.8$

$\rho_{oil} = 800 kg/m^3$

$\gamma_{oil} = 800 \times 9.81 = 7848 N/m^3$

$h_{water} = 80m$

$P_{water} = \gamma_{water} \times h_{water}$

$= 9810 \times 80$

$= 784800\ \text{N/m}^2$

$P_{oil} = P_{water}$

$\gamma_{oil} \times h_{oil} = 784800$

$7848 \times h_{oil} = 784800$

$h_{oil} = 100m$

25. Ans : (d)

Sol: $\frac{P_x}{P_y} = \frac{\rho g h_x}{\rho g H_y}$

$= \frac{0.5}{8} = \frac{1}{16}$

$P_x : P_y = 1:16$

28. Ans : (b)

Sol: $P = \rho_{oil} . g . h_{oil}$

$0.14 \times 9.81 \times 10^4 = (0.7 \times 1000)(9.81) \times h_{Oil}$

$\therefore h_{Oil} = 2\text{m of oil}$

32. Ans : (a)

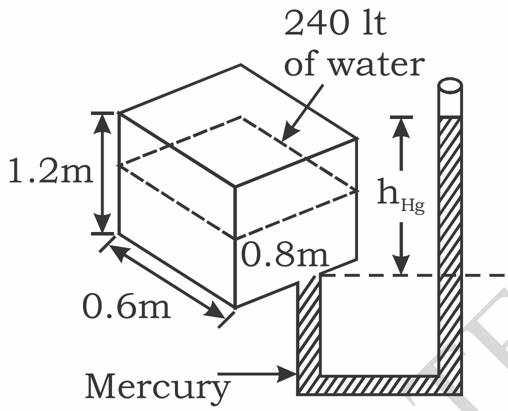
Sol: $P_{Abs} = P_{Atm} - P_{Vac}$

$= 10.33 - 4.5$ interms of water head

= 5.83m of head

35. Ans : (d)

Sol:



$V_{water} = A_{c/s} \times h$

$240 \times 10^{-3} = (0.6 \times 0.8) h_{water}$

$h_{water} = 0.5\text{m}$

By principle of manometers, $P_x = P_y$

$\rho_w . g . h_w = \rho_{Hg} . g . h_{Hg}$

$1000 \times 9.81 \times 0.5 = 13600 \times 9.81 \times h_{Hg}$

h_{Hg}=36.76mm

39. Ans : (b)

Sol: $h_w = x\left(\frac{S_{mercury}}{S_{water}} - 1\right)$

$= 0.5\left(\frac{13.6}{1.0} - 1\right)$

$= 0.5 \times 12.6 = 6.3\text{ m}$

40. Ans : (b)

$h_w = x\left[\frac{S_{Hg}}{S_w} - 1\right]$

$= 0.6\left[\frac{13.6}{1} - 1\right]$

= 7.56m

43. Ans : (c)

Sol: To avoid effect of capillarity rise due to surface tension of fluids

1. Manometer tube diameter should be more than 6 mm
2. Minimum angle of inclination of it is 4°

46. Ans : (b)

Sol: $h_{water} = x\left(\frac{S_{mercury}}{S_{water}} - 1\right)$

$= 0.2\left(\frac{13.6}{1.0} - 1\right)$

$= 0.2 \times 12.6 = 2.52\text{m of water}$

48. Ans : (b)

Sol: $h_{water} = x\left(\frac{S_{mercury}}{S_{water}} - 1\right)$

$= 0.2\left(\frac{13.6}{1.0} - 1\right)$

$= 0.2 \times 12.6 = 2.52\text{m of water}$

50. Ans : (c)

Sol:

(a) 33 inch Hg = $33 \times 2.54 \times 10$

= 838.2 mm of Hg

= 1.1028 bar (760 mm of Hg =1 bar)

(b) 31.6 ft water $= 31.6\times12\times2.54\times10$

= 9631.68mm of water

= 9.63 m water

= 0.935 bar (10.3 m water = 1 bar)

(c) $1.1013\ \text{kg f/cm}^2 = \frac{1.1013\times10}{10^{-4}} = 1.1013\ \text{bar}$

$\left(10^5\ \text{N/m}^2 = 1\ \text{bar}\right)$

(d) 75.6 cm of Hg = 756 mm of Hg

= 0.99 bar

62. Ans : (d)

Sol: $P = \rho_{OIL}.g.h_{OIL}$

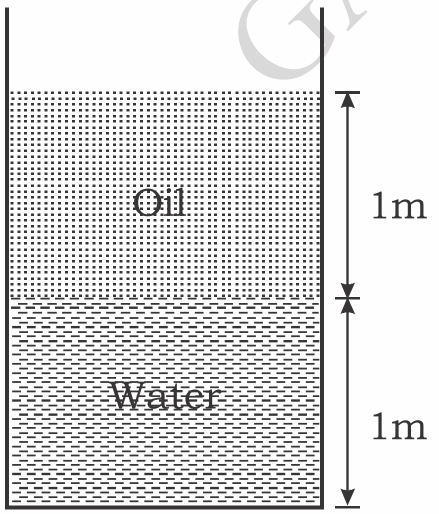
$4.8\times9.81\times10^4 = (1000\times0.8)\times9.81\times h_{oil}$

$h_{oil} = 60\text{m}$

Note: In the given material for this question the given options are in 'cm' but they should in 'm'.

67. Ans : (a)

Sol:



S_{oil} = 0.8

γ_{oil} = 800

$\gamma_{oil} = 800\times9.81 = 7848\ \text{N/m}^3$

h_{oil} = 1m

$\gamma_{water} = 9810\ \text{N/m}^3$

h_{water} = 1m

$P_{bottom} = \gamma_w h_w + \gamma_{oil} h_{oil}$

= (9810×1)+(7848×1)

= 17658Pa

68. Ans : (d)

Sol: $P = \rho gh$

$= 1000\times9.81\times1$

$= 9810\ \text{N/m}^2 = 9810\ \text{Pa}$

75. Ans : (d)

Note: In the given material the given option 'c' was incorrect.

87. Ans : (a)

Sol: h = 30mm of mercury

$P = \rho gh$

= 13600×9.81×0.03 = 4002.48 = 4kPa

80. Ans : (a)

Sol: P = 0.15 MPa= 0.15×10^6Pa

$P = \rho gh$

$0.15\times10^6 = 1000\times9.81\times h$

h = 15.3 m

91. Ans (b)

Sol :

$D = 2m$

$H = 100\ m$

$\therefore P = \rho gh\left(N/m^2\right)$

$t = 7.5mm = 0.0075\ m$

$\therefore \sigma_1 = \frac{PD}{2t} = \frac{(1000\times9.81\times100)(2)}{2\times0.0075}$

$= 130.8\times10^6\ \text{N}/\text{m}^2$

$= 130.8\text{MPa}$

94. Ans : (b)

Sol: $P_{abs} = P_{atm} + \rho g$

$360 = 710 + \rho g$

$\rho g = -350mm$

$= 350mm$ of vacuum

95. Ans : (d)

Sol: $P = \rho g L \sin\theta$

$= k\sin\theta$

$dp = k\cos\theta d\theta$

$$\frac{dp}{P} = \frac{\text{Cos}\theta d\theta}{\sin\theta}$$

$$= \frac{1}{\text{Tan}\theta} \times d\theta$$

$$= \frac{1}{\theta} \times d\theta$$

$$= \frac{1}{30^0} \times 1^0 \times 100$$

$= 3.33\%$

96. Ans : (c)

Sol: $P_{abs} = P_{atm} - P_{vac}$

$13600 \times 9.81 - 10 \times 10^3 \times 0.74$

$= 88.72kPa$

97. Ans : (b)

Sol: h = 5 cm

S = 0.75

relative density

$$(S) = \frac{\text{density of given fluid}}{\text{density of std.fluid}}$$

$$0.75 = \frac{\rho_{oil}}{\rho_{water}}$$

$1000 \times 0.75 = \rho_{oil}$

$\rho_{oil} = 750$

then

$P = \rho g h$

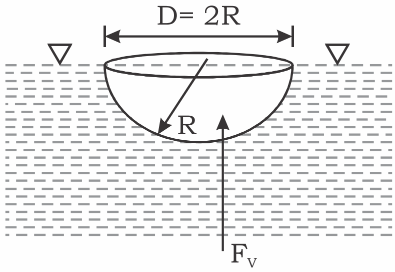
$= 750 \times 9.81 \times 5$

$= 367.87 N/m^2$

3 HYDROSTATIC FORCES

2. Ans : (b)

Sol:

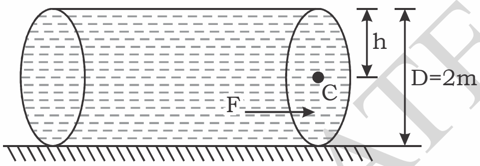


F_V = Vertical component of hydrostatic force = weight of the fluid displaced by the body $= \gamma v$

$$= \gamma\left(\frac{\frac{4}{3}\pi R^3}{2}\right) = \gamma.\frac{4}{6}.\pi\left(\frac{D}{2}\right)^3 = \frac{1}{12}\gamma\pi D^3$$

3. Ans : (c)

Sol:



$$F_{\text{End plate}} = \rho.g.\bar{h}.A$$

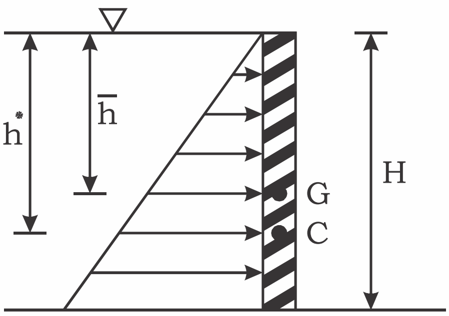
$$= 1000 \times 9.81 \times \frac{D}{2} \times \frac{\pi}{4} D^2$$

$$= 1000 \times 9.81 \times \frac{2}{2} \times \frac{\pi}{4}(2)^2$$

$$= 30800 \text{ N} = 30.8 \text{ kN}$$

4. Ans : (b)

Sol:



Depth of centre of pressure,

h* = centroid of pressure prism

$$= \frac{2}{3} \times H = 0.67H$$

5. Ans : (d)

Sol: $F_{\text{Bottom surface}} = F_{\text{vertical curved surface}}$

$$\rho g A h = \rho g A\bar{h}$$

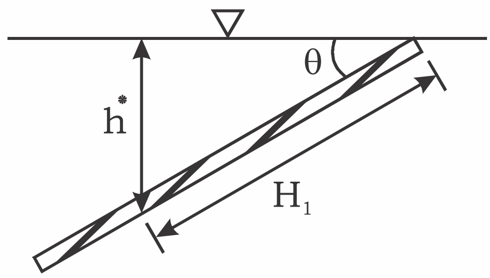
$$\rho g \frac{\pi}{4} d^2 H = \rho.g.\,d \times H \times \frac{H}{2}$$

$$\frac{\pi d}{4} = \frac{H}{2}$$

$$H = \frac{\pi}{2} d = \frac{3.14}{2} d = 1.57d$$

7. Ans : (a)

Sol:



$$\sin\theta = \frac{h^*}{H_1}$$

$$\therefore h^* = H_1.\sin\theta$$

11. Ans : (b) or (c)

Note: In the given material for this question both the options 'b' and 'c' are same.

16. Ans : (c)

Sol: Hydrostatic total pressure on one side of circular surface.

$$= \rho.g.\bar{h}.A$$

$=1000\times9.81\times1\times1$

$=9810\text{ N}$

$=\dfrac{9810}{9.81}\text{kgf}=1000\text{ kgf}$

18. Ans : (a)

Sol: $F=\rho g\,\bar{h}A=1000\times9.81\times4\times\pi\left(2^2-1^2\right)$

$=1000\times9.81\times4\times\pi\times3$

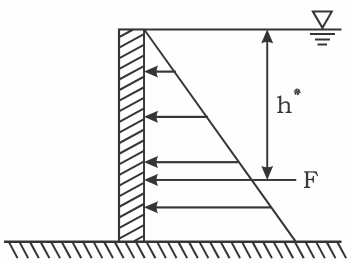
$=12\,\pi\times9810\text{ N}$

$=\dfrac{12\pi\times9810}{9.81}(\text{kgf})$

$=12000\;\pi\text{ kgf}$

19. Ans : (a)

Sol:



Moment of hydrostatic force about top edge of the gate

$=F\times h^*$

$=\rho g\,h\,A\times h^*$

$=1000\times9.81\times\dfrac{3}{2}\times(3\times3)\times\left(\dfrac{2}{3}\times3\right)$

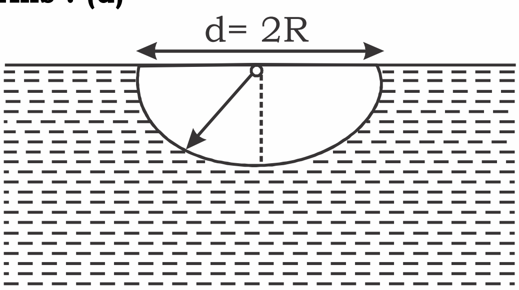
$=1000\times9.81\times\dfrac{3}{2}\times9\times2$

=26,487 N-m

$=2700\text{ kgf}-\text{m}$

21. Ans : (d)

Sol:



Center of pressure of a vertical semi circular plane

$$h^*=\bar{h}+\frac{I}{A\bar{h}}$$

$$=\frac{4r}{3\pi}+\frac{0.011r^4}{\frac{\pi r^2}{2}\times\frac{4r}{3\pi}}$$

$$=\frac{2d}{3\pi}+\frac{0.011(d/2)^4}{\frac{\pi d^2}{8}\times\frac{2d}{3\pi}}$$

After simplification $h^*=\dfrac{3\pi d}{32}$

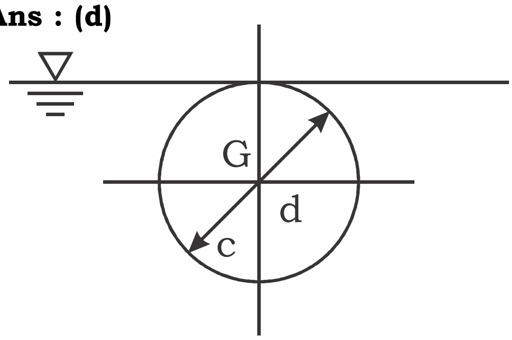
22. Ans : (b)

Note: In the given material the given option 'a' was incorrect.

24. Ans : (b)

Sol: $h^*=\dfrac{2}{3}\times H=\dfrac{2}{3}\times3=2\text{m}$

26. Ans : (d)



Sol: $h^*=\bar{h}+\dfrac{I_G}{A\bar{h}}\rightarrow(1)$

Where $\bar{h}=d/2$, $A=\dfrac{\pi}{4}d^2$

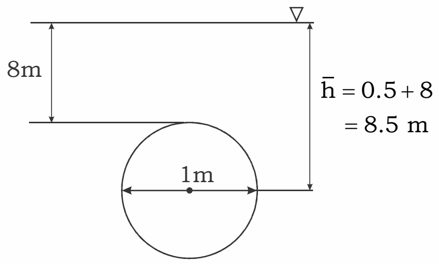
$I_G=\dfrac{\pi}{64}d^4$

Substitute $\bar{h}$, A and I_G in Eq (1)

$h^*=\dfrac{5}{8}d$

28. (b)

Sol :



$$F = \rho g A \bar{h}$$

$$= 9810 \times \frac{\pi}{4}(1)^2 \times 8.5$$

= 65490 N

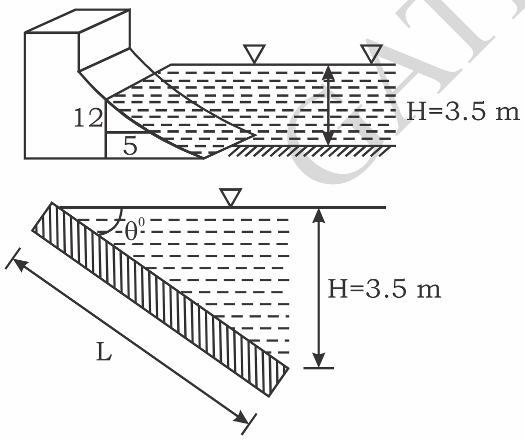
= 65.49kN

29. Ans : (b)

Sol: $h^* = \frac{2}{3}H = \frac{2}{3} \times 3 = 2\text{m}$

30. Ans : (b)

Sol: $\theta^o = \tan^{-1}(12/5) = 67.38^o$



$$L = \left(\frac{H}{\sin\theta}\right) = \left(\frac{3.5}{\sin 67.38^o}\right) = 3.8\text{m}$$

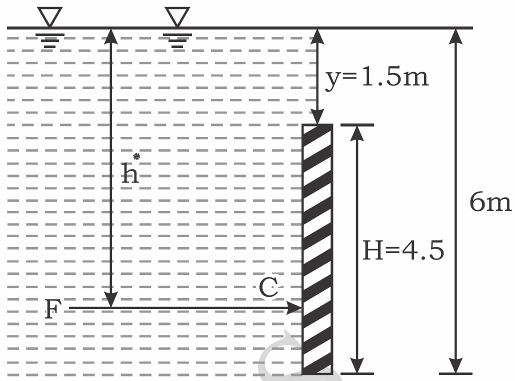
$$F_N = \rho.g.\bar{h}.A = 1000 \times 9.81 \times \frac{3.5}{2} \times (3.8 \times 1)$$

= 65240 N/m

= 65.24 kN/m

31. Ans : (d)

Sol:



$$h^* = \bar{h} + \frac{I}{A\bar{h}}$$

Where,

$$\bar{h} = y + \frac{H}{2} = 1.5 + \frac{4.5}{2}$$

$$1.5 + 2.25 = 3.75 \text{ m}$$

$$A = B \times H = B \times 4.5 \left(m^2\right)$$

$$I = \frac{BH^3}{12} = \frac{B \times (4.5)^3}{12}$$

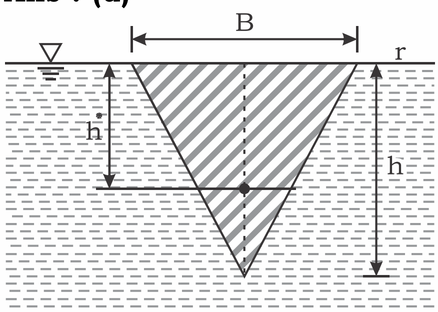
$$\therefore h^* = \bar{h} + \frac{I}{A\bar{h}}$$

$$= 3.75 + \frac{\frac{B \times (4.5)^3}{12}}{(B \times 4.5)(3.75)}$$

= 3.75 + 0.45 = 4.2 m

33. Ans : (d)

Sol:



$$h^* = \bar{h} + \frac{I_G}{A\bar{h}}$$

$$\bar{h} = \frac{h}{3} \qquad I_G = \frac{bh^3}{36}$$

$$A = \frac{bh}{2}$$

$$\therefore h^* = \frac{h}{2}$$

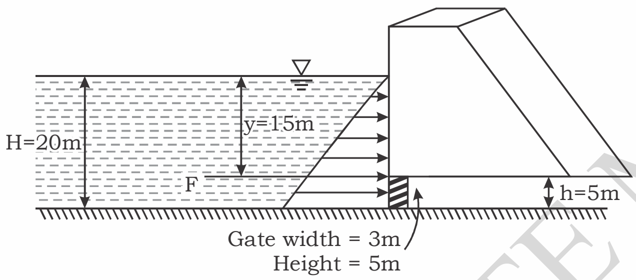
34. Ans : (b)

Sol: h = 5 m
b = 3 m

$$P = \gamma.H$$

$$196.2\times10^3 = 9810\times H$$

H = 20 m



$$F = \rho.g.\bar{h}.A$$

$$= \rho.g\left(y+\frac{h}{2}\right)(b\times h)$$

$$= 1000\times9.81\times\left(15+\frac{5}{2}\right)(3\times5)$$

$$= 2.575\times10^6\,N$$

$$= 2.575\text{ MN}$$

36. Ans : (d)

Sol: $\sin\theta = \frac{0.85}{1.2}$

$$\theta = 45.099^o$$

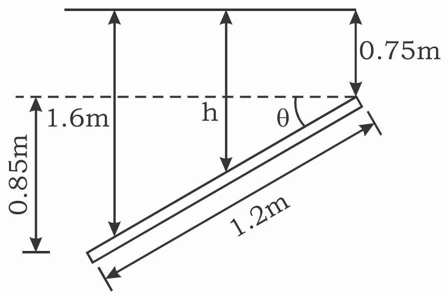
$$\bar{h} = 0.75 + 0.6\sin(45.099)$$

= 1.175 m

Hydraulic force, $F = \rho g\bar{h}A$

$$= 1000\times10\times1.175\times(1.2\times0.6)$$

= 8.46 kN



37. Ans : (c)

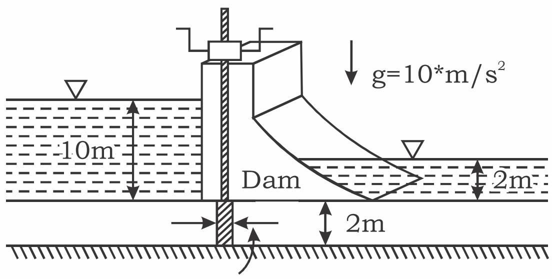
Sol: $H_{bottom} = 1.5\,H_{middle}$

$$H + 10 = 1.5\left(\frac{H}{2}+10\right)$$

$$\therefore H = 20\text{ m}$$

39. Ans : (d)

Sol: B = 3 m
H = 2m



Gate (3m wide x 2m high)

$$F_{Net} = F_{Left} - F_{Right}$$

$$= \rho.g.\bar{h}_1.A - \rho.g.\bar{h}_2.A$$

$$= 1000\times10\times\left(10+\frac{2}{2}\right)\times(3\times2) - 1000\times10\times\left(2+\frac{2}{2}\right)(3\times2)$$

$$= 660000 - 180000$$

$$= 480000\text{ N} = 480\text{ kN}$$

42. Ans : (b)

Sol: $F = \rho . g . \bar{h} . A$

$$= \rho . g\left(y + \frac{d}{2}\right) . \frac{\pi}{4} d^2$$

$$= 1000 \times 9.81\left(8 + \frac{1}{2}\right) \times \frac{\pi}{4}(1)^2$$

$$= 65.49 \times 10^3 \text{ N} = 65.49 \text{ kN}$$

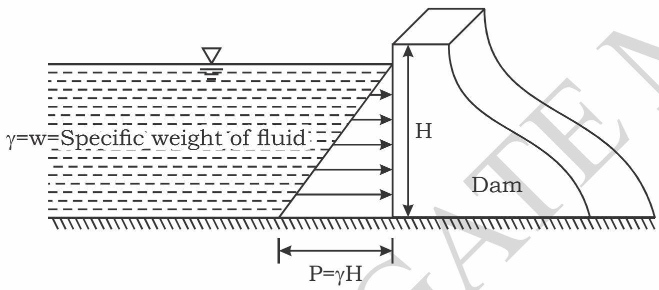
45. Ans : (d)

Sol: Average pressure on a submerged plane surface.

= Pressure at the centroid of the that surface = $\rho . g . \bar{h}$

50. Ans : (b)

Sol:



Total pressure on the vertical surface wetted per unit length = Area of the pressure diagram

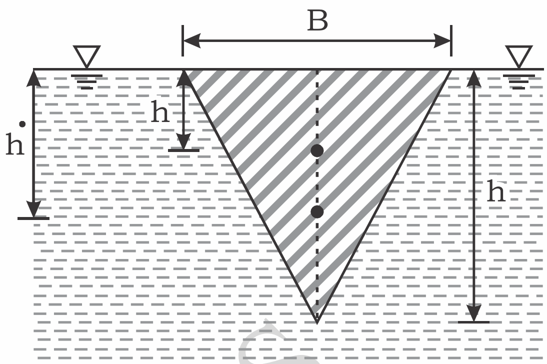
$$= \frac{1}{2} \times \text{Base} \times \text{height}$$

$$= \frac{1}{2} \times P \times H = \frac{1}{2} \times \gamma H \times H$$

$$= \frac{1}{2} \gamma H^2 = \frac{1}{2} wH^2$$

52. Ans : (c)

Sol:



$$h^* = \bar{h} + \frac{I_G}{A\bar{h}}$$

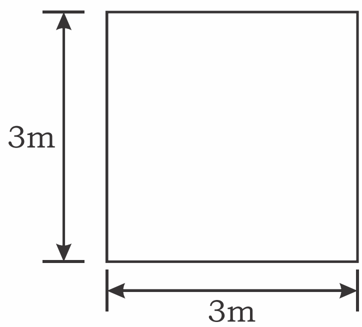
$$\bar{h} = \frac{h}{3} \qquad I_G = \frac{bh^3}{36}$$

$$A = \frac{bh}{2}$$

$$\therefore h^* = \frac{h}{2}$$

54. Ans : (c)

Sol:



Total pressure on one face $= \rho g \bar{h} A$

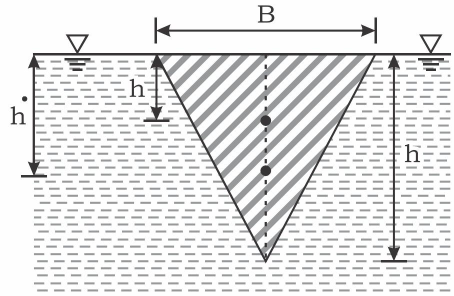
$$= 1000 \times 9.81 \times 1.5 \times 9$$

= 132 kN

57. Note : (Data Insufficient)

59. Ans : (d)

Sol:



$$h^* = \bar{h} + \frac{I_G}{A\bar{h}}$$

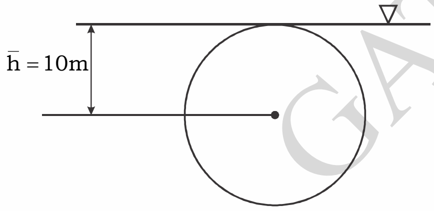
$$\bar{h} = \frac{h}{3} \qquad I_G = \frac{bh^3}{36}$$

$$A = \frac{bh}{2}$$

$$\therefore h^* = \frac{h}{2}$$

61. Ans (b)

Sol :



$$A = 1m$$

$$F = \rho g\bar{h}A$$

$$= \rho g(10)\times(1)$$

$$= 10\rho g$$

63. Ans : (b)

Sol: Intensity of pressure

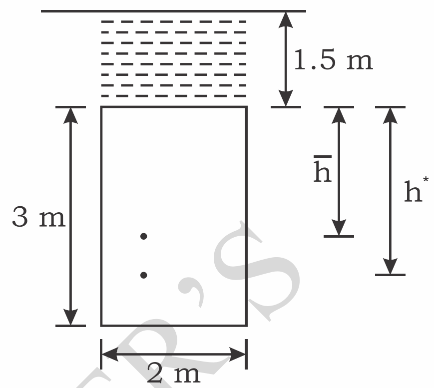
$$= \rho g\,\bar{h}A$$

$$= 9810\times\frac{1.3}{2}\times[1.3\times1]$$

$$= 8.29\times10^3 N$$

$$= 8.29 \text{ kN}$$

74. Ans : (b)



Centre of pressure $h^* = \bar{h} + \frac{I_G}{A\bar{h}}$

$$= 1.5 + \frac{\frac{2\times3^3}{12}}{(2\times3)(3)}$$

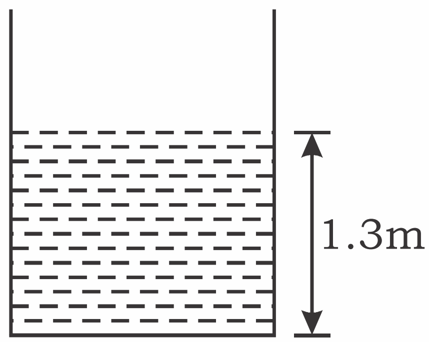
$$= 1.75 \text{ m}$$

Centre of pressure at a depth of below the water surface = 1.5 + 1.75 = 3.25 m

75. Ans : (b)

Sol: Pressure exerted by the water per metre length of the bank

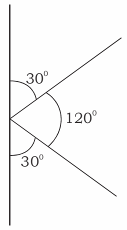
$$F = \rho g\bar{h}A$$



$$=1000\times 9.81\times \frac{1.3}{2}\times (1.3\times 1)=8.3\text{ kN}$$

80. Ans : (d)

Sol.



$$\theta = 30^0$$

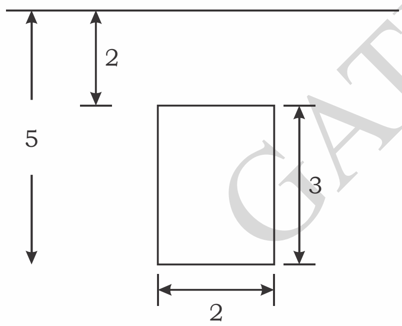
$$F=\frac{P}{2\times \sin\theta}$$

$$=\frac{P}{2\times \sin 30^0}$$

$$= P$$

81. Ans : (c)

Sol:



$$F=\gamma A\bar{h}$$

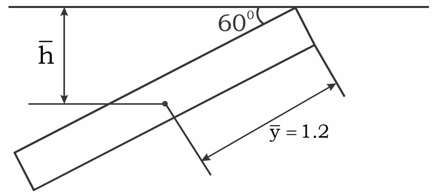
$$=9.81\times 3\times 2\times [2+1.5]$$

$$=9.81\times 6\times 3.5$$

$$=206.01\text{ kN}$$

84. Ans (a)

Sol



$$\bar{h}=\bar{y}\ \sin 60^0$$

$$= 1.2\times \sin 60^0$$

$$= 1.039\text{m}$$

$$F = \rho g A\bar{h}$$

$$= 850\times 9.81\times (0.75\times 2.4)\times 1.039$$

$$= 15598\text{ N}$$

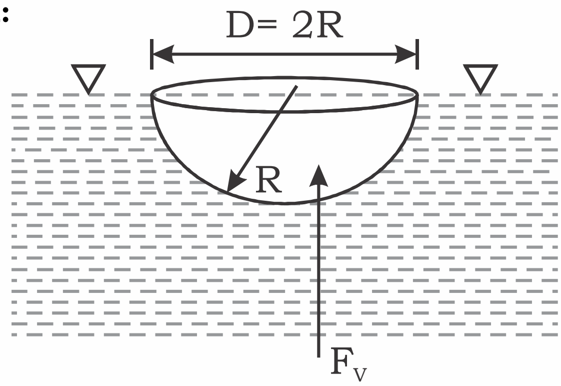
$$= 15.59\text{kN}$$

85. Ans: (c)

Sol: $\bar{h}$ is the distance from free surface to centroid of the submerged surface. When $\bar{h}$ is changed, hydrastatic free also not changed. By tilting plane 90^0, about centroidal line, $\bar{h}$ is remains same.

86. Ans : (b)

Sol:



F_V = Vertical component of hydrostatic force = weight of the fluid displaced by the body $=\gamma v$

$$=\gamma\left(\frac{\frac{4}{3}\pi R^3}{2}\right)=\gamma.\frac{4}{6}.\pi\left(\frac{D}{2}\right)^3=\frac{1}{12}\gamma\pi D^3$$

88. Ans (d)

Sol : Here the vertical component of force = weight of water on curved surface

$$W = \gamma \times V$$

$$= \gamma \times A \times \ell$$

$$\frac{W}{\ell} = \gamma \times A$$

$$= 9.81 \times \frac{\pi}{16} \times d^2$$

$$= 9.81 \times \frac{\pi}{16} \times (2r)^2$$

$$= 9.81 \times \frac{\pi}{16} \times (2 \times 2)^2$$

$$= \frac{W}{\ell} = 9.81\pi \text{ kN}$$

02.Ans : (b)

Note: In the given material for this question the given data was incorrect and the numerical value of option '**b**' is also incorrect and the actual question is as follows:

Q. A rectangular body of 20m long , 5m wide and 2m height is floating in water. The water line is 1.5m above the bottom, then the metacentre height will be approximately

a) 3.3m b) 1.13 m
c) 0.34 m d) 0.30 m

03. Ans : (a)

Sol. $S_{body} \times V_{body} = S_{water} \times \bar{V}$

$0.5 \times (2\times2\times2) = 1 \times \bar{V}$

$\bar{V} = 4m^3$

$\bar{V}$ = volume of water displaced or volume of cube submerged

11. Ans : (d)

Sol. $S_b H = S_{sw} h$

$0.64 \times 2 = 1.025 \times h$

$\therefore h = 1.25m$

14. Ans : (c)

Sol. $S_{body} \times V_{body} = S_{mercury} \times \bar{V}$

$3.4 \times 1 = 1 \times x$

$x = 0.25$

$\bar{V}$ = volume of submerged body

27.Ans : (c)

Sol. $S_{solid} = \left(\frac{W_{AIR}}{W_{AIR} - W_{LIQUID}}\right).S_{Liquid}$

$S_{solid} = \left(\frac{45}{45-20}\right).\frac{\gamma_{Liquid}}{\gamma_{water}}$

$S_{solid} = \left(\frac{45}{25}\right)\times\left(\frac{10}{10}\right)$

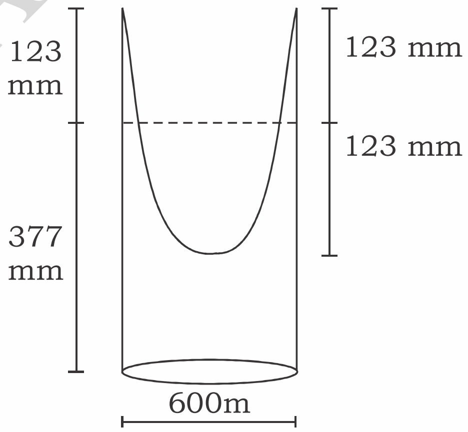
$= 1.8$

28. NOTE : Data Missing

A cylindrical vessel of radius 300 mm and height 500 mm storing the water to a **377 mm** starts rotating with constant angular acceleration. Water will start to spill when the speed is ______ r.p.m.

Ans : (b)

Sol.



r=300mm = 0.3m

h = 246mm = 0.246m

$h = \frac{\omega^2 r^2}{2g}$

$\omega = \sqrt{\frac{2gh}{r^2}}$

$= \sqrt{\frac{2\times9.81\times0.246}{(0.3)^2}}$

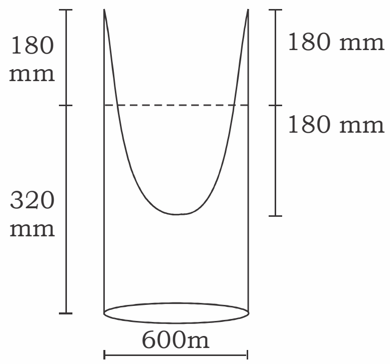
$\omega = 7.32 \text{ rad/sec}$

$$\omega = \frac{2\pi N}{60}$$

$$N = \frac{60 \times 7.32}{2\pi}$$

N = 70 rpm

29. Ans : 84.68 rpm



Sol. r=300mm = 0.3m

h = 360mm = 0.36m

$$h = \frac{\omega^2 r^2}{2g}$$

$$\omega = \sqrt{\frac{2gh}{r^2}}$$

$$= \sqrt{\frac{2 \times 9.81 \times 0.36}{(0.3)^2}}$$

$\omega = 8.85 \text{ rad/sec}$

$$\omega = \frac{2\pi N}{60}$$

$$N = \frac{60 \times 8.85}{2\pi}$$

N = 84.68 rpm

35. Ans (d)

Sol. given data

$S_{body} = 2.4$

$\rho_{A\ell} = 2.4 \times 1000 = 2400$

$\gamma_{body} = 2400 \times 10$

$$S_{fluid} = 0.8 = \frac{\rho_{fluid}}{\rho_{water}}$$

$\rho_{fluid} = 0.8 \times \rho_{water} = 0.8 \times 1000 = 800$

$\gamma_{fluid} = 800 \times 10$

Buoyant force

F_B = Weight of the body – Tension in the wire

$F_B = W_{body} - T$

$T = W_{body} - F_B$

= (m×g) – weight of fluid displaced

= m×g – γ_{fluid} × volume of fluid displaced .... (i)

But we know

volume of fluid displaced = volume of submerged body

we know, the weight of body $W_b = \gamma_b \times v_b$

volume of submerged body,

$$V_b = \frac{W_b}{\gamma_b}$$

$$= \frac{12 \times 10}{2400 \times 10}$$

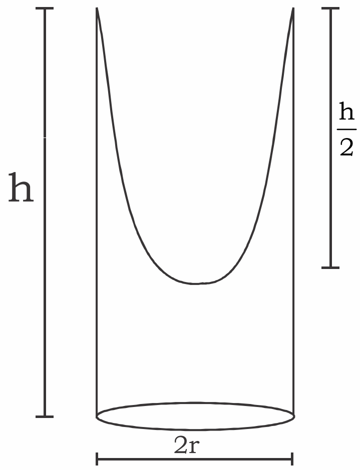
substitute all the respective values in equation (i)

$$\text{then } T = 12 \times 10 - 800 \times 10 \times \frac{12 \times 10}{2400 \times 10}$$

= 80N

38. Ans (a)

Sol.



Volume of water spilled out of the cylinder = Volume of paraboloid = $\frac{1}{2}\pi r^2\left(\frac{h}{2}\right)$

Original Volume = $\pi r^2 h$

$$= \frac{\frac{1}{2}\pi r^2\left(\frac{h}{2}\right)}{\pi r^2 h}$$

$$= \frac{1}{4} = 0.25 = 25\%$$

40. Ans : (d)

Sol. $S_{water}.h^2_w = S_{wood}.H^2$

$1.0 \times h^2_w = 0.64 \times (0.6)^2$

$h_w = 0.48$ m

$$OB = \frac{2}{3}h = \frac{2}{3}\times 0.48 = 0.32 \text{ m}$$

$$OG = \frac{2}{3}H = \frac{2}{3}\times 0.6 = 0.4 \text{ m}$$

Distance between centre of buoyancy to C.G of wooden log = BG = OG – OB

= 0.4 – 0.32

= 0.08 m = 80 mm

41. Ans : (b)

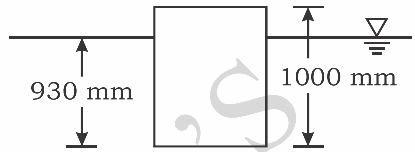
$S_{water}\times h_{water} = S_{body} \times H$

$1.0 \times (1 - 0.19) = S_{body} \times 1$

$\therefore S_{body} = 0.81$

43. Ans : (d)

Sol.



$S_b h_b^3 = S_w h_w^3$

$S_b \times (1000)^3 = 1 \times (930)^3$

$= 0.8$

46.Ans : (c)

Sol. $S_b V_b = S_w V_w$

$0.75 \times 5 \times 2 \times 3 = 1 \times V_w$

$\Rightarrow V_w = 22.5 \text{ m}^3$

51.Ans: (c)

Sol. Weight of the body = F_B

= $\gamma\times$volume of water displaced

$= 9.81 \times 3 \times 2 \times 0.6$

$= 35.3$ kN

53.Ans : (c)

Sol. $S_{body} = \left(\frac{W_{air}}{W_{air} - W_{water}}\right)\times S_{water}$

$$= \left(\frac{3}{3-2.5}\right)\times 1$$

$= 6$

57. Ans : (c)

Sol. Weight of the body = F_B

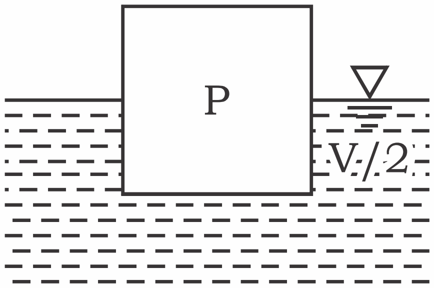
= $\gamma\times$volume of water displaced

$= 9.81 \times 3 \times 2 \times 0.6$

$= 35.3$ kN

60. Ans : (c)

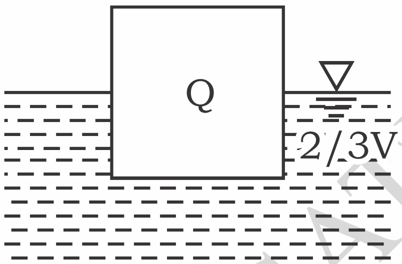
Sol.



$$F_B = \rho g\left(\frac{V}{2}\right) = \rho_P g \times V$$

$$\rho_P = \frac{\rho}{2}$$

$$F_B = \rho g\left(\frac{2}{3}V\right) = \rho_Q g \times V$$

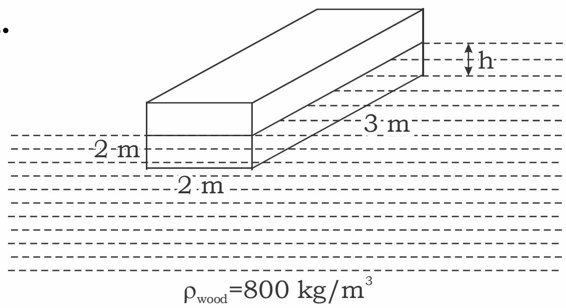


$$\rho_Q = \frac{2}{3}\rho$$

$$\frac{\rho_P}{\rho_Q} = \frac{\frac{\rho}{2}}{\frac{2\rho}{3}} = \frac{3}{4}$$

65. Ans : (a)

Sol.



$$S_{wood} \times V_{wood} = S_{water} \times \bar{V}$$

$$0.8 \times (3 \times 2 \times 2) = 1 \times \bar{V}$$

$$\bar{V} = 9.6$$

68. Ans : (c)

Sol. If meta centric height is more stability is more

70. Ans : (c)

Sol. $T = 2\pi\sqrt{\frac{k^2}{gGM}}$

$$= 2\pi\sqrt{\frac{4^2}{9.81 \times 0.6}} = 10.4\text{s}$$

87. Ans : (a)

Sol. Weight of abody in air = 40 N

Weight of a body in water = 35 kN

Specific gravity of body = ?

Under equilibrium, weight in air – weight of stone in water = weight of water displaced.

$40 - 35 = 1000 \times 9.81 \times V_{water}$

Volume of water displaced = $\frac{5}{1000 \times 9.81}$

$= 5.09 \times 10^{-4}\ m^3$

Mass of body = $\frac{\text{weight in air}}{g} = \frac{40}{9.81}$

$= 4.08$ kg

Density of body = $\frac{\text{mass of body}}{\text{volume}}$

$$= \frac{4.08}{5.09 \times 10^{-4}}$$

$= 8010.7\ kg/m^3$

Specific gravity of body

$$= \frac{\text{density of body}}{\text{density of water}}$$

$$= \frac{8010.7}{1000} = 8.0$$

88. Ans : (d)

Sol. $T = 2\pi\sqrt{\frac{K^2}{g.GM}}$

$$T \propto \sqrt{\frac{1}{GM}}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{GM_2}{GM_1}}$$

$$= \sqrt{\frac{3.6}{2.7}}$$

$$= \sqrt{\frac{4}{3}}$$

90.Ans : (c)

Sol. By the principle of flotation (i.e. Archimedes principle), the weight of body immersed in water is equals to an upward force exerted by the fluid i.e. buoyant force.

So buoyant force = weight of body = 5N

91.Ans : (a)

Sol. $S_{ice} = 0.9$

$$= \frac{\gamma_{ice}}{\gamma_{water}} = \frac{\rho_{ice}}{\rho_{water}}$$

then $\rho_{ice} = 0.9 \times 1000 = 900$

$S_{sea\ water} = 1.03$

$$= \frac{\gamma_{sea\ water}}{\gamma_{water}} = \frac{\rho_{sea\ water}}{\rho_{water}}$$

then $\rho_{sea\ water} = 1.03 \times 1000$

then the ratio of volume of iceberg to sea water equals to ratio of their respective densities i.e.

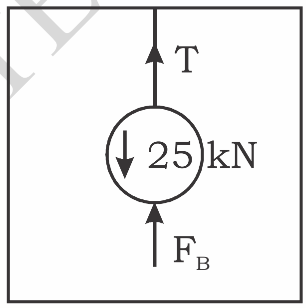
$$\frac{V_{ice}}{V_{seawater}} = \frac{\rho_{ice}}{\rho_{seawater}} = \frac{0.9}{1.03}$$

=0.8737

In percentage = 0.8737×100 =87.37%

92.Ans : (a)

Sol.



$T + F_B = W$

$W = 25$ kN

$F_B = \gamma.V = 10 \times 1 = 10$ kN

$T = W - F_B = 25 - 10 = 15$ kN

5 FLUID KINEMATICS

05. Ans : (c)

Sol. To satisfy conservation of mass i.e. flow to be taken place, continuity equaiton must satisfy.

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

u = 2x, v = 2y

$$\frac{\partial(2x)}{\partial x}+\frac{\partial(2y)}{\partial y}=0$$

2+2 = 0

$4 \neq 0$

14. Ans : (c)

Note: In the given material the given option 'b' was incorrect.

23. Ans : (a)

Sol. ψ = 2xy

$$u=\frac{\partial\psi}{\partial y}=\frac{\partial(2xy)}{\partial y}=2x$$

$$v=\frac{-\partial\psi}{\partial x}=\frac{-\partial(2xy)}{\partial x}=-2y$$

Velocity at (2, 2) = $\sqrt{u^2+v^2}$

$$=\sqrt{(2x)^2+(-2y)^2}$$

$$=\sqrt{(2\times2)^2+(-2\times2)^2}$$

$$=4\sqrt{2}$$

27. Ans : (c)

Sol. ψ = 2xy

$$u=\frac{\partial\psi}{\partial y}=\frac{\partial(2xy)}{\partial y}=2x$$

$$v=\frac{-\partial\psi}{\partial x}=\frac{-\partial(2xy)}{\partial x}=-2y$$

Velocity at (2, 2) = $\sqrt{u^2+v^2}$

$$=\sqrt{(2x)^2+(-2y)^2}$$

$$=\sqrt{(2\times2)^2+(-2\times2)^2}$$

$$=\sqrt{32}$$

= 5.66m/sec

30. Ans : (d)

Note: In the given material the given option 'b' was incorrect.

31. Ans : (d)

Sol. $V\propto\frac{1}{r}$ (in flow net)

$V_1r_1 = V_2r_2$

$1 \times 10 = V_2 \times 5$

V_2 = 2m/s

38. Ans : (d)

Sol. $V = 4x^2ti - 5y^2j + 6ztk$

$u = 4x^2t$

$v = -5y^2$

$w = 6zt$

$$a_{x_{Local}} = \frac{du}{dt} = \frac{d}{dt}(4x^2t) = 4x^2$$

$$a_{y_{Local}} = \frac{dv}{dt} = \frac{d}{dt}(5y^2) = 0$$

$$a_{z_{Local}} = \frac{dw}{dt} = \frac{d}{dt}(6zt) = 6z$$

Resultant local acceleration,

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

$$a = \sqrt{(4x^2)^2 + (0)^2 + (6z)^2}$$

$$a = \sqrt{(16)^2 + (12)^2}$$

$$a = \sqrt{256+144} = \sqrt{400} = 20 m/s^2$$

40. Ans : (c)

Sol. Stream function must satisfy Laplace equation

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} = 0$$

$\psi = ax^2y - 2y^3$

$$\frac{\partial\psi}{\partial x} = 2axy - 0 \qquad \frac{\partial\psi}{\partial y} = ax^2 - 6y^2$$

$$\frac{\partial^2\psi}{\partial x^2} = 2ay \qquad \frac{\partial^2\psi}{\partial y^2} = -12y$$

Substitute in laplace equation

$2ay - 12y = 0$

$\Rightarrow a = 6$

41. Ans : (c)

Sol. $V=6x^3i-8x^2yj$

$u = 6x^3$

$v = -8x^2y$

Vorticity (ζ) $= 2\omega$

$$= 2 \times \frac{1}{2}\left[\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right]$$

$$= \left[\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right]$$

$= [-16xy - 0]$

$= -16xy$

60. Ans : (c)

Sol. Total head = Pressure head + Kinetic head + Potential head.

$$= \frac{P}{\rho g} + \frac{v^2}{2g} + h$$

Total energy = weight × Total head

$$= mg\left(\frac{P}{\rho g} + \frac{v^2}{2g} + h\right)$$

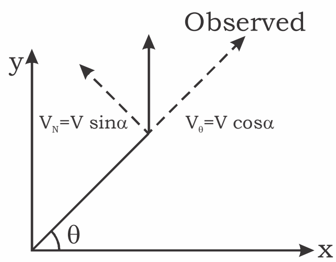
Then substitute the values

$$\text{Total energy} = 3\times9.81\left(\frac{4\times10^5}{9810} + \frac{5^2}{2\times9.81} + 10\right)$$

$= 1530Nm$

68. Ans : (d)

Sol.



Velocity V has two components

$V_\theta = V \cos\alpha$

$V_N = V \sin\alpha$

78. Ans : (c)

Sol. $u = 2(1+t)$

$$a_L = \frac{du}{dt} = 2$$

91. Ans : (c)

Sol. $\phi = x^2 - y^2$

Magnitude of velocity of point P(1, 1)=?

$$U = -\frac{\partial\phi}{\partial x} = -2x$$

$$V = -\frac{\partial \phi}{\partial y} = 2y$$

$$\text{Velocity} = \sqrt{u^2 + v^2}$$

$$= \sqrt{(-2x)^2 + (2y)^2}$$

$$= \sqrt{(-2\times1)^2 + (2\times1)^2} = 2\sqrt{2}$$

92. Ans : (b)

Sol. A fluid flow is to be taken place for which continuity equation must be satisfied i.e

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$u = -x$

$v = y$

$$\frac{\partial u}{\partial x} = -1$$

$$\frac{\partial v}{\partial y} = 1$$

$-1 + 1 = 0$

95. Ans : (c)

Sol. $u = a, v = a$

$(x, y) = (2, 6)$

Equation of stream line

$$\frac{dx}{u} = \frac{dy}{v}$$

$$\frac{dx}{a} = \frac{dy}{a}$$

$dx = dy$

Integrating both sides

$x = y + c$

$2 = 6 + c$

$c = -4$

$\therefore x = y - 4$

$\therefore y = x + 4$

96. Ans : (b)

Sol. A fluid flow is to be irrotational for which

$$\omega_z = 0$$

$$\frac{1}{2}\left[\frac{\partial V}{\partial x} - \frac{\partial u}{\partial y}\right] = 0$$

$$\therefore \frac{\partial V}{\partial x} = \frac{\partial u}{\partial y}$$

109. Ans : (a)

Sol. Impingement of a jet on a flat plate is idealized, if given stream function (ψ) satisfies Laplace equation

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = 0$$

120. Ans : (a)

Note: In the given material the given option 'd' was incorrect.

121. Ans : (b)

Sol. $U = 3x + 4y$

$V = 2x - 3y$

$\text{Vorticity, } \zeta = 2\omega_z$

$$\zeta = 2\times\frac{1}{2}\left[\frac{\partial V}{\partial x} - \frac{\partial u}{\partial y}\right]$$

$= 2 - 4$

$= -2$ units

122. Ans : (d)

Sol. $u = 3x - 2xy$

$v = 1 - 2y^2$

Velocity in z-direction = ?

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0$$

$$(3 - 2y) + (-4y) + \frac{dw}{dz} = 0$$

$$\int dw = \int (6y-3)dz$$

$w = -3z + 6zy$

125. Ans : (b)

Note: In the given material the given option 'a' was incorrect.

129. Ans : (d)

Sol. If any given field is said to be as a possible fluid flow then it should be satisfy the continuity equation from continuity equation

$$\frac{du}{dx}+\frac{dv}{dy}=0$$

check the given options

i) $u=x;\ v=y$

apply the continuity equation

i.e. $\frac{du}{dx}+\frac{dv}{dy}=0$

$1+1\neq 0$

$\because$ Flow is not possible

ii) $u=x^2;\ v=y^2$

apply the continuity equation

i.e. $\frac{du}{dx}+\frac{dv}{dy}=0$

$2x+2y=0$

$x+y\neq 0$

$\because$ Flow is not possible

iii) $u=xy;\ v=x^2y^2$

apply the continuity equation

i.e. $\frac{du}{dx}+\frac{dv}{dy}=0$

$y+2xy^2=0$

$1+2xy\neq 0$

$\because$ Flow is not possible

iv) $u=x,\ v=-y$

apply the continuity equation

i.e. $\frac{du}{dx}+\frac{dv}{dy}=0$

$1-1=0$

$\because$ Flow is possible

131. Ans : (d)

Sol. $v = 6xy - 2x^2$

y = component of the flow

$$\frac{du}{dx}+\frac{dv}{dy}=0$$

$$(6y-4x)+\frac{dv}{dy}=0$$

$$\int dv = \int (4x-6y)dy$$

$v = 4xy - 3y^2$

137. Ans : (b)

Sol. $u = 2x$

$v = -2y$

Discharge between the point (1, 1) & (2, 2) is $\frac{\partial\psi}{\partial x} = -v$

$$\int \partial\psi = \int -v\partial x$$

$$\int -(-2y)\partial x$$

$\psi = 2xy$

$\psi_1 = 2(1)(1)=2$

$\psi_2 = 2(2)(2)=8$

$|\psi_2-\psi_1| = |2-8| = 6$ units

138. Ans : (b)

Sol. $\psi = x^2 - y^2$

$$v = -\frac{\partial\psi}{\partial x} = -2x$$

$$u = \frac{\partial\psi}{\partial y} = -2y$$

$$\frac{\partial\phi}{\partial x} = -u = 2y$$

$$\frac{\partial\phi}{\partial y} = -V = 2x$$

$$\int \partial\phi = \int 2x\partial y$$

$$\phi = 2xy$$

139. Ans : (c)

Sol. $\psi = 3x^2y - y^3$

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

$$v = \frac{-\partial\psi}{\partial x} = -6xy$$

145. Ans : (c)

Sol. $V = (5x + 6y + 7z)i + (6x+5y+9z)j + (3x+2y+\lambda z)k$

$\rho = \rho_0 e^{-2t}$

$\lambda = ?$

$$\frac{\partial\rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

$$\frac{\partial}{\partial t}\left(\rho_0 e^{-2t}\right) + \frac{\partial}{\partial x}\left[\left(\rho_0 e^{-2t}\right)(5x + 6y + 7z)\right] + \frac{\partial}{\partial y}$$

$$\left[\left(\rho_0 e^{-2t}\right)(6x + 5y + 9z)\right] + \frac{\partial}{\partial z}\left[\left(\rho_0 e^{-2t}\right)(3x + 2y + \lambda z)\right] = 0$$

$$-2\rho_0 e^{-2t} + \rho_0 e^{-2t}(5 + 5 + \lambda) = 0$$

$$\rho_0 e^{-2t}(-2 + 5 + 5 + \lambda) = 0$$

$$\lambda = -8$$

147. Ans : (c)

Sol. $u = 1.5x$

From continuity equation

$$\frac{du}{dx} + \frac{dv}{dy} = 0$$

$$\frac{d}{dx}(1.5x) + \frac{dv}{dy} = 0$$

$$1.5 + \frac{dV}{dy} = 0$$

$$dv = -1.5dy$$

Integrating on both sides

$$\int dv = \int -1.5\, dy$$

$$V = -1.5\, y$$

148. Ans : (c)

Sol. The given velocity potential function

$$\phi = \log_e\left(x^2 + y^2\right)$$

We know from the relation between velocity potential function and stream function

$$\frac{d\psi}{dy} = u = \frac{d\phi}{dx}$$

$$\frac{d\psi}{dy} = \frac{d}{dx}\log_e(x^2 + y^2)$$

$$\frac{d\psi}{dy} = \left(\frac{1}{x^2 + y^2}\right)2x$$

$$d\psi = \left(\frac{1}{x^2 + y^2}\right)2xdy$$

Integrating on both sides the stream functon equation is as follows

$$\psi = 2\tan^{-1}\left(\frac{y}{x}\right)$$

149. Ans : (no option is matched)

Sol. The given velocity function,

$V = 2yi + 3xj$

$u = 2y;\ v = 3x$

From the equation of stream line

$$\frac{dx}{u} = \frac{dy}{v}$$

$$\frac{dx}{2y} = \frac{dy}{3x}$$

$3xdx - 2ydy = 0$

150. Ans : (a)

Sol. $\psi = 2xy$

$$u = \frac{\partial\psi}{\partial y} = \frac{\partial(2xy)}{\partial y} = 2x$$

$$v = \frac{-\partial\psi}{\partial x} = \frac{-\partial(2xy)}{\partial x} = -2y$$

Velocity at (2, 2) = $\sqrt{u^2 + v^2}$

$= \sqrt{(2x)^2 + (-2y)^2}$

$= \sqrt{(2\times 2)^2 + (-2\times 2)^2}$

$= 4\sqrt{2}$

6 FLUID DYNAMICS

02. Ans : (a)

Note: In the given material the given option 'c' was incorrect.

13. Ans : (c)

Note: In the given material the given option 'b' was incorrect.

16. Ans : (b)

Sol. Total head = Pressure head + Datum head + Velocity head

$$= \frac{196.2\times10^3}{1000\times9.81}+5+0.5$$

$= 20 + 5 + 0.5$

$= 25.5$ m

35. Ans : (d)

Sol. $V = C_v \times \sqrt{2gh}$

$3 = C_v \times \sqrt{2\times9.81\times0.475}$

$$\therefore C_v = \frac{3}{\sqrt{2\times9.81\times0.475}} = 0.983$$

49. Ans : (a)

Note: In the given material the given option 'd' was incorrect.

50. Ans : (a)

Sol. $C_d = 0.95$

Differential pressure head, h = 2.8 m

Loss of head between inlet and throat of differential manometer.

$h_L = h\left(1-C_d^2\right)$

$= 2.8\ (1 - 0.95^2)$

$= 0.273$ m

Note: In the given material the given option 'd' was incorrect.

51. Ans : (b)

Sol. $V = C_v\sqrt{2gh}$

$$h = x\left(\frac{S_h}{S_L}-1\right) = x\left(\frac{\rho_h}{\rho_L}-1\right)$$

$$V = 1.0\sqrt{2\times9.81\times0.012\left(\frac{1000}{1.2}-1\right)}$$

V = 13.998 m/s

Say 14 m/s

90. Ans : (d)

Sol. Minimum pressure occurs at down side of orifice plate at 50% of minimum size of orifice plate

$= 0.5\ d_2$

$= 0.5 \times 40 = 20$ mm

108. Ans : (a)

Sol. $$Q = C_d\frac{A_1A_2}{\sqrt{A_1^2-A_2^2}}\sqrt{2gh}$$

$A_1 = \frac{\pi}{4}(0.1)^2 = 0.00785\ m^2$

$A_2 = \frac{\pi}{4}(0.05)^2 = 0.00196\ m^2$

$C_d = 0.95$

h = 7 m

$$Q = 0.95\times\frac{0.00785\times0.00196}{\sqrt{(0.00785)^2-(0.00196)^2}}\times\sqrt{2\times9.81\times7}$$

$$Q = 0.00192\times\sqrt{2\times9.81\times7} = 0.0225\ m^3/sec$$

123. Ans : (b)

Sol. $V = C_v\sqrt{2g\left(h_{stag} - h_{static}\right)}$

$V = 1.0\sqrt{2\times 9.81(0.3 - 0.24)}$

$= 1.0\sqrt{2\times 9.81\times 0.06}$

= 1.085 m/s × 60 = 65 m/min

135. Ans : (d)

Sol. Velocity, $V = \sqrt{2gh}$

$h = x\left[1 - \frac{S_L}{S_h}\right]$

$V = \sqrt{2gx\left[1 - \frac{S_L}{S_h}\right]}$

$= \sqrt{2\times 9.81\times 0.25\left[1 - \frac{0.6}{1}\right]}$

V = 1.4 m/s

Velocity head = $\frac{V^2}{2g} = \frac{(1.4)^2}{2\times 9.81} = 0.1$ m

137. Ans : (b)

Sol. $V = C_V\sqrt{2g(h_{stag} - h_{static})}$

$= 0.98\sqrt{2\times 9.81\times(3-2)}$

= 4.341 m/s

Note: In the given material the given option 'a' was incorrect.

143. Ans (a)

Sol : $h_L = h_m(1 - C_d^2)$

= 2.8 (1-(0.95)²)

= 0.273

147. Ans (d)

$V = C_V\sqrt{2gh}$

$= 0.99\sqrt{2\times 9.81\times 0.75} = 3.8 m/s$

7 VORTEX MOTION

2. Ans : (c)

Sol. Free cylindrical vortex

Radius = 12 cm

Velocity = 7.2 m/s

Intensity of pressure = 2.5 kg/cm^2

Velocity at a radius of 24 cm = ?

For free vortex flow = v.r = const

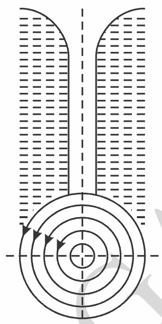
$v_1 r_1 = v_2 r_2$

$7.2 \times 12 = v_2 \times 24$

$v_2 = 3.6$ m/s

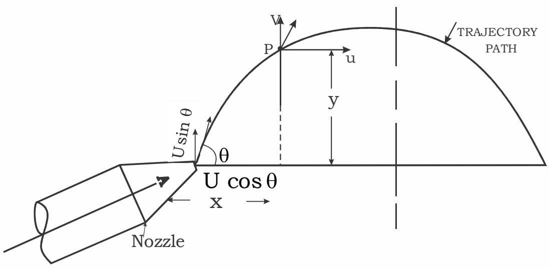
7. Ans : (d)

Sol. In vortex flow of fluid mass represented by concentric circles is known as free cylindrical vortex flow.



8. Ans : (a or b)

18. Ans (b)



Sol: The total horizontal distance travelled by the fluid particle is called horizontal range of the jet, i.e. the horizontal distance AB in above Figure is called horizontal range of the jet. Let this range is denoted by x*

Then,

x*= velocity component in x-direction

× time taken by the particle to reach from A to B

= U cos θ ×Time of flight

$$= U\cos\theta \times \frac{2U\sin\theta}{g}$$

$$= \frac{U^2}{g}\, 2\cos\theta \times \sin\theta \qquad \left\{\because T = \frac{2U\sin\theta}{g}\right\}$$

$$= \frac{U^2}{g}\sin 2\theta$$

$$\sin\theta = 1 \text{(or)} \sin 2\theta = \sin 90^0 = 1$$

$$2\theta = 90^0 \text{ (or) } \theta = 45^0$$

then maximum range $\theta = 45^0$

21. Ans : (b)

Sol. Constant pressure surface in forced vertex is a paraboloid of revolution. A circle drawn on the surface such that its centre is on the axis of parabolid has a constant elevation. As the pressure is already same on the parabolic surface the piezometric head is constant along the circle.

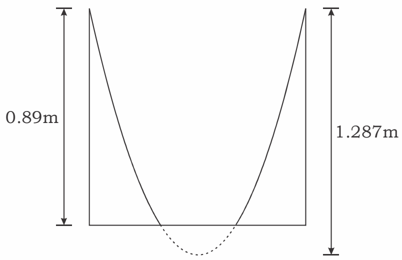
22. Ans : (b)

Sol. $h = \frac{\omega^2 R^2}{2g} = \left(\frac{2\pi \times 120}{60}\right)^2 \times \frac{0.4^2}{2 \times 9.81}$

i.e. h = 1.29 m >0.89 m

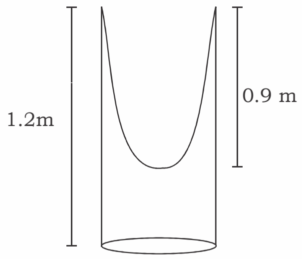
$\therefore$ Surface at the centre of base exposed to atmosphere.

$\therefore P_{gauge} = 0$



23. Ans : (a)

Sol.



$V_{\text{spilled out}} = V_{\text{paraboloid}}$

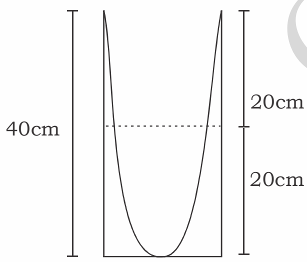
$$= \frac{1}{2}\pi R^2 \times 0.9$$

$V_{\text{original}} = \pi R^2 \times 1.2$

$$\frac{V_{\text{spilled out}}}{V_{\text{original}}} = \frac{\frac{1}{2}\pi R^2 \times 0.9}{\pi R^2 \times 1.2} = \frac{9}{24} = \frac{3}{8}$$

24.Ans : (b)

Sol.



h = 40cm = 0.4m

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

$$0.4 = \frac{\omega^2 \times 0.1^2}{2 \times 9.81}$$

$\omega = 28.01$ rad /sec

$$N = \frac{\omega \times 60}{2\pi}$$

$= 267.5$ rpm

25.Ans : (c)

Sol. Whirlpool is example of free vortex motion

In free vertex motion

vr = constant

$v_1 r_1 = v_2 r_2$

$5 \times 10 = v_2 \times 30$

$v_2 = 5/3$ m/s

As the free vortex is an irrotation vortex flow the Bernouli's equation can be applied between any two points. Considering undisturbed free surface as a reference level application of Bernouli's equation between the given point & far away point from the centre gives.

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

$$\frac{P_{atm}}{\rho g} + \frac{V_2^2}{2g} + Z_2 = \frac{P_{atm}}{\rho g} + 0 + Z_3$$

$$\left[\therefore r_3 \to \infty V_3 = \frac{K}{r_3} = 0\right]$$

$$Z_3 - Z_2 = \frac{V_2^2}{2g} = \frac{\left(\frac{5}{3}\right)^2}{2 \times 9.81}$$

$= 0.1416$m

$= 14.16$ cm

8 ORIFICE AND MOUTHPIECES

01. Ans : (d)

Sol. $V = \sqrt{2gH} = \sqrt{2\times 9.81\times 50}$

$= 31.3$ m/s

02. Ans : (c)

Sol. $h_L = H\,(1-C_v^2)$

$= 3.0\,(1-(0.96)^2 = 0.235$ m

03. Ans : (a)

Sol. Time of empting tank (T)

$$T \propto \left(\sqrt{H_1}-\sqrt{H_2}\right)$$

$$\frac{T_1}{T_2} = \frac{\sqrt{H_1}-\sqrt{H_2}}{\sqrt{H_1^{1}}-\sqrt{H_2^{1}}}$$

$$\frac{25}{T_2} = \frac{\sqrt{49}-\sqrt{25}}{\sqrt{36}-\sqrt{16}}$$

$$\frac{25}{T_2} = \frac{7-5}{6-4} = \frac{2}{2} = 1$$

$\therefore T_2 = 25$ sec

04. Ans : (c)

Sol. Pressure head at Vena contracta in absolute

$H_c = H_a - 0.89H$

$= 10.3 - 0.89\times 10$

$= 1.4$m (absolute)

05. Ans : (c)

Sol. $$\frac{a}{a_c} = \sqrt{1+\frac{H_a-H_c}{H}}$$

a = area at outlet

a_c = area at venacontracta

$$\frac{\frac{\pi}{4}d_0^2}{\frac{\pi}{4}(4)^2} = \sqrt{1+\frac{9}{3}} = \sqrt{1+3} = 2$$

$d_0 = 4\sqrt{2}$

09. Ans : (d)

NOTE : In the given material the given option 'b' was incorrect.

11. Ans : (d)

Sol. $V = \sqrt{2gH}$

$= \sqrt{2\times 9.81\times 1} = 4.43$m/sec

12. Ans : (c)

Sol. $$T = \frac{2A}{C_d.a.\sqrt{2g}}.\sqrt{H}$$

$$T = \frac{2\times(1\times 1)}{0.9\times 2000\times 10^{-6}\times\sqrt{2\times 9.81}}\times\sqrt{2}$$

$= 355$ sec

17. Ans : (a)

Sol. $$C_c = \frac{a_c}{a} = \frac{\pi}{4}\times 16^2 \Big/ \frac{\pi}{4}\times 20^2$$

$= 0.64$

20. Ans : (d)

Sol. $$C_c = \frac{a_c}{a} = \frac{\pi}{4}\times 30^2 \Big/ \frac{\pi}{4}\times 40^2$$

$= 0.56$

28. Ans : (a)

Sol. Vena-contracta is occurs at a distance of 0.5 times the orifice diameter

41.Ans : (a)

NOTE : In the given material the given option 'c' was incorrect.

42. Ans : (c)

Sol :

Type of Mouth Piece	Discharge Expression
1) Cylinder	$Q = 0.855a\sqrt{2gH}$
2) Convergent	$Q = 0.975a\sqrt{2gH}$
3) Convergent & Divergent	$Q = a\sqrt{2gH}$
4) Running full	$Q = 0.707a\sqrt{2gH}$
5) Running free	$Q = 0.5a\sqrt{2gH}$

43. Ans : (a)

Sol. Stream of water discharge by an orifice is called "Jet".

44. Ans : (a)

Sol. Area of vena contracta = 94% of orifice opening area.

46. Ans : (c)

Sol. $V = \sqrt{2gH}$

$V = \sqrt{2 \times 9.81 \times 1.3} = 5 \text{ m/s}$

47. Ans : (c)

Sol. Discharge through the mouthpiece is more than that of an orifice due to more pressure across mouth piece causing maximum possible velocity there by discharge is more through mouthpiece.

48. Ans : (b)

Sol. $T \propto \sqrt{H}$

$\therefore \quad T \propto H^{\frac{1}{2}}$

49. Ans : (b)

Sol. $C_d < C_c < C_v$

54.Ans : (d)

NOTE : In the given material the given option 'a' was incorrect.

57.Ans : (b)

Sol. $C_c = \frac{a_c}{a} = \frac{\pi}{4} \times 32^2 \Big/ \frac{\pi}{4} \times 40^2$

$= 0.64$

60. Ans : (b)

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

Where H = head

But $V = \sqrt{2gh}$

Where h = head measured by pitot tube

$\therefore C_v\sqrt{2gH} = \sqrt{2gh}$

$C_v = \sqrt{\frac{h}{H}} = \sqrt{\frac{1.2}{1.25}} = 0.98$

61. Ans (b)

Sol : Coefficient contraction (C_c)

$= \left(\frac{\text{Area at vena contracta}}{\text{Area of orifice}}\right)$

$= \frac{\frac{\pi}{4} \times 15.75^2}{\frac{\pi}{4} \times 20^2} = 0.62$

62. Ans : (b)

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

Where H = head

But $V = \sqrt{2gh}$

Where h = head measured by pitot tube

$\therefore C_v\sqrt{2gH} = \sqrt{2gh}$

$C_v = \sqrt{\frac{h}{H}} = \sqrt{\frac{1.2}{1.25}} = 0.98$

9 FLOW OVER NOTCHES AND WEIRS

01. Ans : (c)

Sol. Discharge in V-notch (or) Triangular notch

$$Q = \frac{8}{15}.C_d.\tan\frac{\theta}{2}\sqrt{2g}H^{5/2}$$

$Q \propto H^{5/2}$

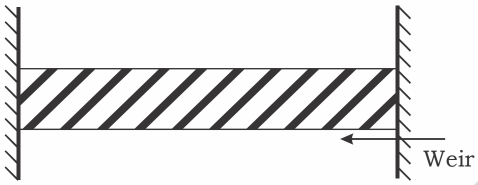
02. Ans : (c)

Sol. $$\frac{dQ}{Q} = \frac{3}{2}.\left(\frac{dH}{H}\right)$$

$$= \frac{3}{2}\times 1\% = 1.5\%$$

03. Ans : (c)

Sol.



This type of weir is called suppressed weir. End contractions are not accounted.

04. Ans : (c)

Sol. **Sharp Crested Weir :** It is type of weir in which the water merely touches a line of weir.

05. Ans : (b)

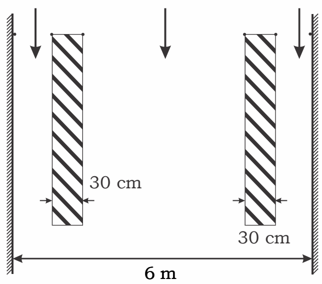
Sol. $$Q = \frac{8}{15}\times C_d.\tan\frac{\theta}{2}.\sqrt{2g}.H^{5/2}$$

$$Q = \frac{8}{15}\times 0.62\times \tan 60°\times\sqrt{2\times 9.81}\times(0.25)^{5/2}$$

$= 0.079\ m^3/sec$

06. Ans : (b)

Sol.



Francis formula :

$$Q = \frac{2}{3}.C_d.(L - n\times 0.1H)\times\sqrt{2g}\times H^{3/2}$$

L = Effective Length

= Total length of weir – 2× width of Piers.

= 6 – 2 × 0.3 = 5.4 m

$$= \frac{2}{3}\times 0.623\ (5.4 - 6\times 0.1\times 0.45)\times\sqrt{2\times 9.81}(0.45)^{\frac{3}{2}}$$

$= 2.85 m^3/s$

07. Ans : (b)

Sol. For rectangular notch, error in measurement of head gives error in discharge

$$\frac{dQ}{Q} = \frac{3}{2}\frac{dH}{H}$$

11. Ans : (d)

Sol. $Q \propto H^{5/2}$

$$\left(\frac{Q_2}{Q_1}\right) = \left(\frac{H_2}{H_1}\right)^{5/2}$$

$$\therefore \frac{Q_2}{Q_1} = \left(\frac{0.3}{0.15}\right)^{2.5} = 5.657$$

13. Ans : (b)

Sol. L = 9 m

Q_1 = 0.9 m^3/unit time

Q_2 = 0.6 m^3/unit time

$$\frac{dL}{L} = ?$$

$Q \propto L\ H^{3/2}$

$Q = k.\ L.\ H^{3/2}$ .... (1)

Keeping H constant and L is varies

$dQ = k.\ dL.\ H^{3/2}$ .... (2)

(2) ÷ (1)

$$\frac{dQ}{Q} = \frac{dL}{L}$$

$$\frac{300}{900} = \frac{dL}{L}$$

$$\frac{dL}{L} = 33.33\%$$

15. Ans : 10%

Sol. $\left(\frac{dQ}{Q}\right) = 2.5\frac{dH}{H}$

= 2.5 × 4

= 10%

16. Ans : 3490

Sol. $Q = \frac{2}{3}.C_d.\sqrt{2g}.L.H^{3/2}$

$= \frac{2}{3} \times 0.623 \times \sqrt{2 \times 9.81} \times 1 \times (0.1)^{1.5}$

= 0.058 m^3/sec

= 3490 *lit*/min

17. Ans : (b)

Sol. $\left(\frac{dQ}{Q}\right) = 2.5\frac{dH}{H}$

= 2.5 × 5

= 12.5%

23. Ans : (c)

Sol. Shape of fire hose of the nozzle is convergent.

24. Ans : (d)

Sol. For maximum discharge the angle of triangular notch is 120°

33. Ans : (b)

Sol. $Q = \frac{2}{3}.C_d\sqrt{2g}.LH^{3/2}$

$= \frac{2}{3} \times 0.6 \times \sqrt{2 \times 9.81} \times 2 \times (0.64)^{\frac{3}{2}}$

= 1.8143 m^3/sec

= 1814 *l*it/sec

37. Ans : (b)

Sol. $V_a = \sqrt{2gh_a} = \sqrt{2 \times 9.81 \times 0.041}$

= 0.898 = 0.9 m/s

38. Ans : (b)

Sol. $\frac{dQ}{Q} = \frac{5}{2}\frac{dH}{H}$ for triangular notch

$= \frac{5}{2} \times 5 = 12.5\%$

42. Ans : (a)

Sol. $Q_{V\text{-Notch}} = \frac{8}{15}.C_d.\sqrt{2g}\tan\frac{\theta}{2}.H^{5/2}$

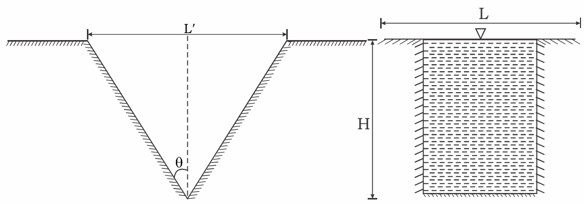
$= \frac{8}{15} \times 0.58 \times \sqrt{2 \times 9.81} \times \tan 45°.(0.1)^{5/2}$

= 4.333 × 10^{-3} [1000 × 60]

= 260 lit/min

47. Ans : (b)

Sol.



In suppressed weir, end contractions are not counted for discharge. Measurement i.e., (length of channel level to length of weir)

$Q_{V\text{-notch}} = Q_{Rectangular}$

$$\frac{8}{15}.C_d.\sqrt{2g}.\tan\frac{\theta}{2}H^{5/2} = \frac{2}{3}.C_d.\sqrt{2g}.L.H^{3/2}$$

$$\frac{8}{15} \times \tan\frac{\theta}{2}H^{5/2} = \frac{2}{3}.L.H^{3/2}$$

$$\frac{8}{15}\frac{(L'/2)}{H}H^{5/2} = \frac{2}{3}.L.H^{3/2}$$

$$\frac{8}{15} \times \left(\frac{L'}{2}\right)H^{3/2} = \frac{2}{3}.L.H^{3/2}$$

$$\frac{4}{15}.L' = \frac{2}{3}.L$$

$$\frac{L'}{L} = \frac{2}{3} \times \frac{15}{4} = \frac{5}{2} = 2.5$$

52. Ans : (d)

Sol. Q α $H^{5/2}$ for V-notch

$$\frac{Q_2}{Q_1} = \left(\frac{H_2}{H_1}\right)^{5/2} = \left(\frac{0.2}{0.1}\right)^{2.5} = 5.66$$

54. Ans : (b)

Sol. $Q_a = \frac{8}{15} \times 0.6\sqrt{2 \times 9.81} \times 1 \times H^{5/2}$

$= 1.417H^{5/2}$

73. Ans : (a)

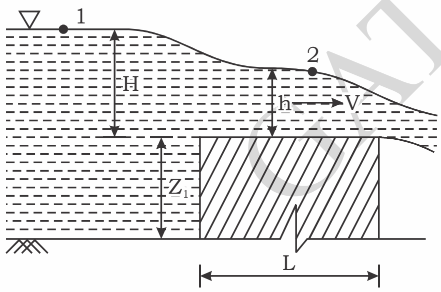
Sol. $L_1 H_1^{3/2} = L_2 H_2^{3/2}$

$1 \times (8)^{3/2} = 8 \times H_2^{3/2}$

$\Rightarrow H_2 = 2$ cm

78. Ans : (d)

Sol. In broad crested weir,



$Q = C_d \times$ Area of flow $\times$ Velocity

$= C_d \times (L \times h) \times \sqrt{2g(H-h)}$

$= C_d \times L \times \sqrt{2gh^2(H-h)}$

$= C_d \times L \times \sqrt{2g(Hh^2 - h^3)}$

The discharge will be maximum,

$\frac{d}{dh}(Hh^2 - h^3) = 0$

$H \times 2h - 3h^2 = 0$

$2H = 3h$

$h = \frac{2}{3}H$

86. Ans : (c)

Sol. Effective length of Notch

$L' = (L - 0.1\ H \times n)$

Where n = Number end contractions

$n = 2$

$L' = L - 0.1H \times 2$

$= L' - 0.2H$

91. Ans : (c)

Sol. $Q \propto H^{5/2}$

$$\frac{Q_2}{Q_1} = \left(\frac{H_2}{H_1}\right)^{5/2} = \left(\frac{0.3}{0.15}\right)^{5/2} = 5.66$$

93.Ans : (d)

Sol. For triangular notch

$$Q = \frac{8}{15} C_d \sqrt{2g} \tan\frac{\theta}{2} \times H^{5/2}$$

Assuming only θ to be variable

$$Q = K \tan\frac{\theta}{2}$$

$$dQ = \sec^2\frac{\theta}{2}.\frac{d\theta}{2}$$

i.e. $$\frac{dQ}{Q} = \frac{\sec^2\frac{\theta}{2}}{\tan\frac{\theta}{2}} \times \frac{d\theta}{2}$$

$$= \frac{1}{2}\left(\frac{\sec^2\theta/2}{\tan\theta/2}\right) \times \frac{d\theta}{\theta} \times \theta$$

Taking $\theta = \frac{\pi}{2}$

$$\frac{dQ}{Q} = \frac{1}{2} \times \frac{\sec^2\left(\frac{\pi}{4}\right)}{\tan\left(\frac{\pi}{4}\right)} \times 0.02 \times \frac{\pi}{2}$$

$= 0.01\pi$

$= \pi\%$

101 Ans : (b)

Sol. Inflow = Outflow

Applying continuity equation

$A_pV_p = A_QV_Q + A_RV_R$

$$\frac{\pi}{4}d_p^2v_p = \frac{\pi}{4}d_Q^2V_Q + \frac{\pi}{4}d_R^2V_R$$

$$\frac{\pi}{4}d_p^2v_p = \frac{\pi}{4}\left[d_Q^2V_Q + d_R^2V_R\right]$$

$$d_p^2v_p = d_Q^2V_Q + d_R^2V_R$$

$(4)^2\times6=(4)^2\times5+(2)^2\times V_R$

$96 = 80+4V_R$

$4V_R=96-80$

$4V_R= 16$

$$V_R = \frac{16}{4} = 4\text{m/s}$$

105. Ans : (b)

Sol. $$\left(\frac{dQ}{Q}\right) = 2.5\frac{dH}{H}$$

$= 2.5 \times 4$

$= 10\%$

106. Ans : (a)

Sol. For triangular notch

$$Q = \frac{8}{15}C_d\sqrt{2g}\tan\frac{\theta}{2}\times H^{5/2}$$

Assuming only θ to be variable

$$Q = K\tan\frac{\theta}{2}$$

$$dQ = \sec^2\frac{\theta}{2}.\frac{d\theta}{2}$$

i.e. $$\frac{dQ}{Q} = \frac{\sec^2\frac{\theta}{2}}{\tan\frac{\theta}{2}}\times\frac{d\theta}{2}$$

$$= \frac{1}{2}\left(\frac{\sec^2\theta/2}{\tan\theta/2}\right)\times\frac{d\theta}{\theta}\times\theta$$

Taking $\theta = \frac{\pi}{2}$

$$\frac{dQ}{Q} = \frac{1}{2}\times\frac{\sec^2\left(\frac{\pi}{4}\right)}{\tan\left(\frac{\pi}{4}\right)}\times0.02\times\frac{\pi}{2}$$

$= 0.01\pi$

$= \pi\%$

107. Ans : (b)

Sol. For triangular notch

$$Q = \frac{8}{15}C_d\sqrt{2g}\tan\frac{\theta}{2}H^{5/2}$$

But $Q = 1.37H^{5/2}$

$$\therefore\frac{8}{15}C_d\sqrt{2g}.\tan\frac{\theta}{2} = 1.37$$

i.e.. $$\therefore\frac{8}{15}C_d\sqrt{2\times9.81}\times\tan\left(\frac{\pi}{4}\right) = 1.37$$

$C_d = 0.58$

112. Ans : (a)

Sol. $$\left(\frac{dQ}{Q}\right) = 2.5\frac{dH}{H}$$

$= 2.5 \times 4$

$= 10\%$

10 FLOW THROUGH PIPES

01. Ans : (d)

Sol. $R_e = \frac{v.d}{\nu}$

$R_e \propto \frac{1}{\nu}$ [v & d kept constant]

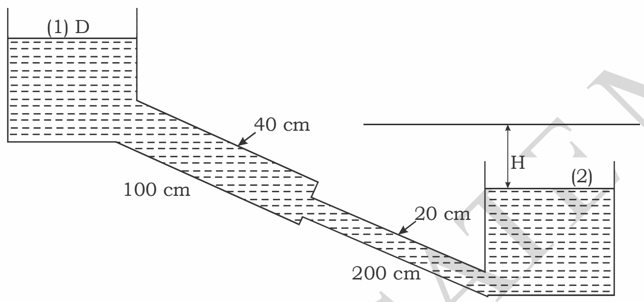
02. Ans : (b)

Sol. Loss of head at exit of pipe = $\frac{v^2}{2g}$

(velocity head)

03. Ans : (a)

Sol. $\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_f$



$0+2+0 = 0+0+0+h_f$

$h_f = 2m$

04. Ans : (c)

Sol. Flow in siphon pipe ceases if pressure at summit point falls below the vapour pressure of the fluid flow in that.

06. Ans : (c)

Sol. $h_f = \frac{1}{3}$ H = KH

Where K = $\frac{1}{3}$

09. Ans : (d)

Sol. $R_e = \frac{\text{Inertia force}}{\text{Viscous force}}$

11. Ans : (c)

Sol. $h_f = \frac{f.l.Q^2}{12.1d^5}$

$h_f \propto Q^2$ [f, l, d unaltered]

12. Ans : (a)

Sol. Loss of head in a pump foot valve=

Head loss at entry of pipe = $0.5\frac{V^2}{2g}$

(i.e. foot valve)

13. Ans : (b)

Sol. A siphon pipe is that part of pipe above the H.G.L of the flow with respect to datum

14. Ans : (c)

Sol. $A_2 = 2A_1$

$$h_L = \frac{V_1^2}{2g}\left[1 - \frac{A_1}{A_2}\right]^2$$

$$= \frac{V_1^2}{2g}\left[1 - \frac{1}{2}\right]^2$$

$$= \frac{V_1^2}{2g} \times \frac{1}{4}$$

$$= 2 \times \frac{1}{4}$$

$$= \frac{1}{2} = 0.5 \text{ m}$$

15. Ans : (c)

Sol. $h_f = \frac{H}{3} = \frac{15}{3} = 5m$

16. Ans : (b)

Sol. $f = \frac{16}{R_e} = \frac{16}{1600} = 0.01$ = 0.04

24. Ans : (b)

Sol. When pipes are connected end to end, then pipes are said to be series for which discharge is same in all the pipes.

26. Ans : (b)

Sol. $h_e = \frac{(V_1 - V_2)^2}{2g}$

27. Ans : (b)

Sol. $h_f = \frac{4.f^1.l.v^2}{2g.d}$

$$0.4 = \frac{4 \times f^1 \times 39.25 \times (0.5)^2}{2 \times 9.81 \times 0.3}$$

$f^1 = 0.05988 \cong 0.06$

28. Ans : (a)

Sol. $h_f = \frac{4.f^1.l.v^2}{2g.d}$

$$0.84 = \frac{(4 \times 0.1) \times 10 \times v^2}{2 \times 9.81 \times 0.12}$$

$\therefore$ v = 0.7 m/sec

29. Ans : (a)

Sol. $h_e = \frac{V_1^2}{2g}\left[1 - \left(\frac{d_1}{d_2}\right)^2\right]^2$

$$= \frac{(0.9)^2}{2 \times 9.81}\left[1 - \left(\frac{40}{60}\right)^2\right]^2 = 0.012 \text{ m}$$

= 12 mm

30. Ans : (c)

Sol. $h_{L_{head}} = K_{Bend} \cdot \frac{V^2}{2g}$

$$0.36 = 12 \times \frac{V^2}{2 \times 9.81}$$

V = 0.77 m/s

$Q = AV = \frac{\pi}{4}(0.05)^2 \times 0.77$

$Q = 1.5 \times 10^{-3}$ m³/sec = 1.5 *lt*/sec

33. Ans : (a)

Sol. $R_e = \frac{v.d}{\nu} = \frac{1.2 \times 0.06}{2 \times 10^{-5}}$

= 3600

34. Ans : (c)

Sol. Water power (P) = ρgQH

$= 1000 \times 9.81 \times 1 \times 37.5$

P = 367875 watts

1 metric Horse power (MHP) = 736 watts

$P = \frac{367875}{736}$

P = 499.83 H.P $\approx$ 500 HP

35. Ans : (c)

Sol. $\frac{df}{f} = -2.\frac{dQ}{Q}$

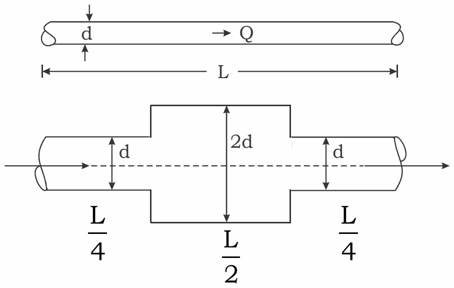
$\frac{df}{f} = -2(1\%) = -2\%$

36. Ans : (c)

Sol. Two pipes are said to be equivalent means same head loss and same discharge in both systems.

37.Ans : (c)

Sol.



$$h_{f_1} = h_{f_2}$$

$$\frac{f.L.Q^2}{12.1d^5} = \frac{f.L.Q^2}{4\times 12.1d^5} + \frac{f.L.Q^2}{2\times 12.1(2d)^5} + \frac{f.L.Q^2}{4\times 12.1d^5}$$

$$= \frac{f.LQ^2}{12.1d^5}\left[\frac{1}{4}+\frac{1}{64}+\frac{1}{4}\right]$$

$$= \left(\frac{fLQ^2}{12.1d^5}\right)0.516$$

i.e. $h_{f_2} = 0.516 h_{f_1}$

Loss of head reduced to 51.6% in second case.

38. Ans : (d)

Sol. $\frac{L_e}{d_e^5} = \frac{L_1}{d_1^5} + \frac{L_2}{d_2^5} + \frac{L_3}{d_3^5}$

39. Ans : (a)

Sol. $R_e = \frac{\rho.V.d}{\mu} = \frac{850\times 0.05\times 0.15}{0.186}$

= 34.27 < 2000 (laminar flow)

40. Ans : (b)

Sol. Loss of head due to enlargement

$$h_e = \frac{(V_1 - V_2)^2}{2g}$$

41. Ans : (d)

Sol. For solving pipe flow network problems, the following equations must be satisfied.

(i) Continuity equation

(ii) Bernoulli's energy equation

(iii) Head loss equation (Darcy's equation)

48. Ans : (a)

Sol. Pressure at submit of siphon point

$$\frac{P_s}{\rho g} = -h_f - z_{siphon} - \frac{V^2_{siphon}}{2g}$$

= –2–4–0.5

= –6.5 meters of water

$P_s = \rho.g.h$

= 1000×9.81×(–6.5)

= –63600 N/m²

= –63.6 KN/m²

= –63.6 KPa

50. Ans : (d)

Sol. $\frac{df}{f} = -2\frac{dQ}{Q}$

$$+25 = -2\frac{dQ}{Q}$$

$$\frac{dQ}{Q} = -12.5\%$$

55. Ans : (b)

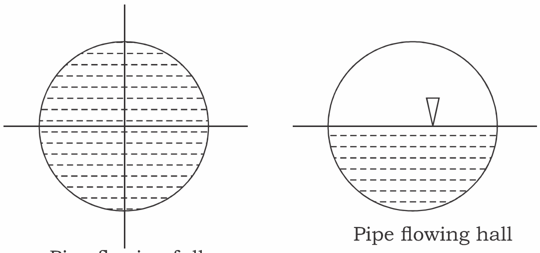
Sol. Loss of head at exit of pipe = $\frac{V^2}{2g}$

56. Ans : (a)

Sol. Minor head loss in pipe flow implies insignificant when compared to frictional loss.

57. Ans : (c)

Sol.



$h_f \propto \frac{1}{d_h}$ (for same velocity)

Where d_h is hydraulic diameter.

For pipe flowing full of half full

$d_h = 4R$

where R is hydraulic radius

$\Rightarrow h_r$ is same

$\Rightarrow \frac{h_{f_1}}{h_{f_2}} = 1$

58. Ans : (c)

Sol. Fluid flow in pipe becomes fully turbulent when Reynolds number exceeds upper critical Reynolds number value.

i.e. 2300

59. Ans : (c)

Sol. Condition for maximum power transmission through pipe.

Loss of frictional head $(h_f) = \frac{H}{3}$

60. Ans : (c)

Sol. Hydraulic diameter = $\frac{4A}{m}$

Where, A = c/s area of pipe

m = perimeter of pipe

61. Ans : (d)

Sol. Maximum head loss occurs if bend is 90° orientation

62. Ans : (c)

Sol. Function of air vessel attached to siphon pipe at summit point :

(i) To maintain continuous flow i.e. avoid interruption of the flow.

(ii To avoid flow separation i.e. cavitation effect.

63. Ans : (a)

Sol. If 'n' no. of pipes of same size (d) connected in parallel, replaced by a single pipe.

$D = (n)^{2/5}.d$

$d = \frac{D}{(n)^{\frac{2}{5}}}$

64. Ans : (d)

Sol. Hydraulic mean depth, $R = \frac{A}{p}$

$= \frac{\pi d^2/4}{\pi d} = d/4$

65. Ans : (c)

Sol. Water Hammer pressure $\Delta P = \rho.c.V$

$\Delta P = \rho\sqrt{k/\rho}.V$

$\Delta P = \sqrt{\rho}.\sqrt{k}.V$

$\Delta P \propto \sqrt{\rho}$

66. Ans : (d)

Sol. Loss of head due to friction interms of coefficient of friction = $\frac{4f.l.v^2}{2g.d}$

67. Ans : (a)

Sol. Upper critical value of Reynold's number at which flow changes from laminar to turbulent flow.

68. Ans : (c)

Sol. Flow in pipe said to be turbulent if $R_e > 2800$ (upper critical Reynolds number)

69. Ans : (a)

Sol. $R_e = \frac{\rho.v.L}{\mu} = \frac{v.L}{\upsilon}$

Reynolds number is directly proportional to velocity and length of system.

70. Ans : (d)

NOTE : In the given material the given option 'c' was incorrect.

74. Ans : (c)

Sol. Fluid Particles can move in straight lines (parallel lines) as well as concentric circles path curves.

75. Ans : (d)

Sol. In pipe flow, after entrance length, the velocity profile is remains same i.e. fully developed flow.

76. Ans : (a)

Sol. Velocity head = $\frac{v^2}{2g}$

$= \frac{(3.6)^2}{2\times 9.81}$

= 0.66m

78. Ans : (a)

Sol. Darcy's head loss due to friction in pipe flow in terms of friction factor = $\frac{f.l.v^2}{2g.d}$

79. Ans : (c)

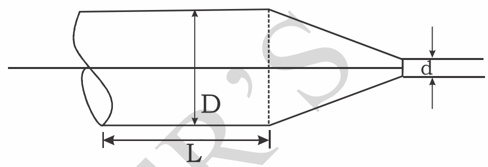
Sol. Head loss at entry of pipe = $0.5\ v^2/2g$

Head loss at exit of pipe = $v^2/2g$

% of head increase = $\frac{v^2/2g - 0.5v^2/2g}{0.5v^2/2g} = 1$ = 100%

80. Ans : (a)

Sol.



For maximum power transmission through a nozzle fitted at end of pipe

$\frac{A}{a} = \sqrt{\frac{2fL}{D}} = \sqrt{\frac{8f'L}{D}}$

$\frac{D^2}{d^2} = \sqrt{\frac{2f.L}{D}}$

$= \sqrt{\frac{8fL}{D}}$

$\left[\text{coefficient of friction } f' = \frac{f}{4}\right]$

$\frac{D}{d} = \sqrt[4]{\frac{8f'L}{D}}$

81. Ans : (b)

Sol. With respect to water hammer analysis, it can be treated that fluid and penstock pipe is perfectly elastic.

82. Ans : (a)

Sol. In pipe flow, fluid always flow from higher energy to lower energy.

85. Ans : (c)

Sol. A pipe is said to be syphon if pressure at summit point is below atmospheric pressure.

87.Ans : (d)

Sol. Friction factor (f) in pipe flow is direct measure frictional resistance for which variables connected to it is Reynold's number (R_e) and roughness height. Reynold's number is function of velocity of flow, diameter of pipe and kinematic viscosity of fluid.

88.Ans : (d)

Sol. Maximum power transmission through pipe, loss of head due to friction

$$= \frac{1}{3} \times \text{Head at inlet of pipe}$$

89. Ans : (d)

Sol. Steady minor flow means laminar flow for which shear stress is zero at centre line, velocity is maximum at centre and hydraulic gradient varies proportional to mean velocity of flow.

91. Ans : (c)

Sol. Energy loss in pipe flow is due to major loss and minor losses.

Major loss is called frictional loss minor losses are many reasons like bend in pipe, enlargement pipe fittings etc.

92. Ans : (c)

Sol. $$\frac{dp}{dr} = \frac{\rho.v^2}{r}$$

94. Ans : (d)

Sol. To maintain continuous flow in siphon pipe, pressure at syphon pipe should not fluid vapour pressure. As the case in practice, if the pressure is reduced to about 2.6 m of water absolute (or) 7.8 m of water vacuum, the dissolved air (or) other gases would come out causing the flow obstruction.

97. Ans : (a)

Sol. V = 3m/s

d = 0.1m

ρ = 1260 kg/m^3

$$\mu = 0.9\frac{N-S}{m^2}$$

$$V_{avg} = \frac{V_{max}}{2}$$

$$= \frac{3}{2} = 1.5 \text{ m/s}$$

$$R_e = \frac{\rho vd}{\mu}$$

$$= \frac{1260 \times 1.5 \times 0.1}{0.9} = 210$$

104. Ans : (c)

Sol. Hazen Williams formulae used to measure velocity of water flow in supply main pipe line.

105. Ans : (b)

Sol. Reynolds number = 2000

Which is lower critical velocity for laminar flow.

106. Ans : (d)

Sol. In turbulent flow, frictional resistance is proportional to square of the velocity (approximately)

107. Ans : (a)

Sol. The syphon should be laid such a way that no section of pipe will be more than 7.8 m above the H.G.L at the section

124. Ans : (c)

Sol. HGL line = Pressure head + datum head

= 4 + 5

= 9 m

132. Ans : (b)

Sol. $$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2$$

$$\frac{P_1-P_2}{\rho g}=\frac{V_2^2-V_1^2}{2g}$$

$$P_1-P_2=\frac{\rho}{2}\left(V_2^2-V_1^2\right)$$

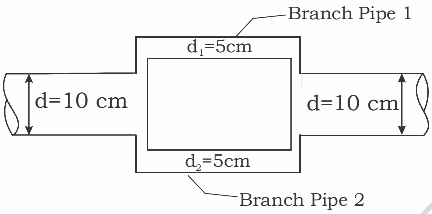
$(V_1 = V,\ V_2 = 2V)$

$$=\frac{\rho}{2}\left(4V^2-V^2\right)=\frac{3\rho V^2}{2}=\frac{3}{2}\rho V^2$$

$$P_1-P_2=\frac{3}{2}\rho V^2$$

133. Ans : (d)

Sol.



$Q = Q_1+Q_2$

$AV=A_1V_1+A_2V_2$

$$\frac{\pi}{4}\times d^2\times V=\frac{\pi}{4}\times d_1^2\times V_1+\frac{\pi}{4}\times d_2^2\times V_2$$

$$\frac{\pi}{4}\times 10^2\times 1=\frac{\pi}{4}\times 5^2\times V+\frac{\pi}{4}\times 5^2\times V$$

$V = 2\text{m/s}$

138. Ans : (d)

Sol. $$(h_L)_{S.C}=\frac{V_2^2}{2g}\left(\frac{1}{C_C}-1\right)^2$$

$$=1.25\left[\frac{1}{0.66}-1\right]^2$$

$= 0.332\text{m}$

11 LAMINAR FLOW

02. Ans : (d)

Sol. Pressure drop in laminar flow

$$\Delta p = \frac{32\mu.v.l}{d^2} = \frac{128\mu Q l}{\pi d^4}$$

$\mu.Q$ = constant

(keeping other parameters unaltered)

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

More the viscosity, lesser the discharge.

03. Ans : (b)

Sol. Q = A.V

$$Q = A\frac{V_{max}}{2}$$

$$Q = 1\ (cm^2) \times \frac{2}{2}\ (cm/s)$$

$= 1\ cm^3/sec$

04. Ans : (a)

Sol. In laminar pipe flow,

friction factor (f) $= \frac{64}{R_e}$

05. Ans : (d)

Sol. $Q = A.V = A\frac{V_{max}}{2}$

$$Q = \frac{\pi}{4}(0.04)^2 \times \frac{1.5}{2}$$

$$Q = \frac{3\pi}{10000} m^3/sec$$

7.Ans : (a)

Sol: $u = \frac{-1}{4\mu}\frac{\partial P}{\partial x}\left(R^2 - r^2\right)$

$$u = \frac{P_1 - P_2}{4\mu\ell}\left(R^2 - r^2\right)$$

8. Ans : (c)

Sol. The equation for viscous flow was first formulated by Newton.

13.Ans : (a)

Sol: $h_f = \frac{4f^1lv^2}{2gd}$ $\quad \left\{\because f^1 = \frac{16}{R_e}\right\}$

$$h_f = \frac{16}{R_e}\frac{4L}{d}\frac{V^2}{2g}$$

16. Ans : (a)

Sol. $R_e = \frac{\rho Vd}{\mu}$

$$2000 = \frac{1000 \times V \times 6 \times 10^{-3}}{0.01 \times 10^{-1}}$$

$$V = \frac{100}{3} cm/s$$

Note : In the question 0.1 poise is given but the value is 0.01 poise

21.Ans : (c)

Sol: $f = \frac{64}{R_e}$

$$f = \frac{64\mu}{\rho vd}$$

$$f \propto \mu$$

$$f \propto \frac{\tau}{\left(\frac{du}{dy}\right)}$$

$$f \propto \tau$$

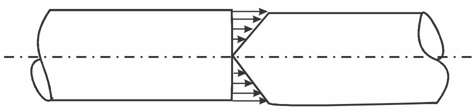
NOTE : In the given material the given option 'a' was incorrect.

22.Ans : (c)

Sol: $\frac{L_e}{D} = 0.06\ R_e$ to $0.07\ R_e$

30.Ans : (b)

Sol.



Shear stress of viscous fluid flow in a pipe varies linearly zero at centre and maximum at surface.

38.Ans : (d)

Sol: $dp = \frac{32\mu vL}{D^2}$

39.Ans : (b)

Sol. $f = \frac{16}{R_e}$ for laminar flow

$$f = \frac{16}{2000} = 0.008$$

40. Ans : (a)

Sol. $\tau \propto r$

$$\frac{\tau}{r} = \text{constant}$$

$$\frac{\tau}{r} = \frac{\tau_o}{R}$$

$$\tau = \frac{28 \times 3}{4} = 21 \text{ Pa}$$

42.Ans : (a)

Sol. Average velocity of flow in laminar flow through a pipe of radius at a distance measured from centre line of pipe is at

$$\frac{R}{\sqrt{2}} = 0.707R = 0.71R$$

Proof :

$$V_r = \frac{1}{4\mu}\left(\frac{-dp}{dx}\right)\left(R^2 - r^2\right)$$

$r = \bar{r}$ = Radial distance at which mean velocity occurs.

Mean velocity $\bar{V} = \frac{1}{4\mu}\left(\frac{-dp}{dx}\right)(R^2 - \bar{r}^2)$

$$\frac{V_{max}}{2} = \frac{1}{4\mu}\left(\frac{-dp}{dx}\right)(R^2 - \bar{r}^2)$$

$$\frac{\frac{1}{4\mu}\left(\frac{-dp}{dx}\right)R^2}{2} = \frac{1}{4\mu}\left(\frac{-dp}{dx}\right)(R^2 - \bar{r}^2)$$

$$\frac{R^2}{2} = R^2 - \bar{r}^2$$

$$\therefore\ \bar{r}^2 = R^2 - \frac{R^2}{2} = \frac{R^2}{2}$$

$$\bar{r} = \sqrt{\frac{R^2}{2}} = \frac{R}{\sqrt{2}} = 0.707R$$

45.Ans : (a)

Sol: $R_e < 1$ (in Laminar flow)

52.Ans : (c)

Sol: $Q = \frac{\pi d^4 \Delta p}{128\mu L}$

55. Ans : (d)

Sol. Navier-Stoke's equations are used for viscous (Real) fluids motion equations.

56. Ans : (b)

Sol. For laminar flow, friction factor (f) = $\frac{64}{R_e}$

$$0.1 = \frac{64}{R_e}$$

$$\therefore\ R_e = \frac{64}{0.1} = 640$$

57.Ans : (b)

Sol: $\frac{R}{\sqrt{2}}$ = 0.707R = 0.71R

Proof :

$$V_r = \frac{1}{4\mu}\left(\frac{-dp}{dx}\right)(R^2 - r^2)$$

$r = \bar{r}$ = Radial distance at which mean velocity occurs.

Mean velocity $\bar{V} = \frac{1}{4\mu}\left(\frac{-dp}{dx}\right)(R^2 - \bar{r}^2)$

$$\frac{V_{max}}{2} = \frac{1}{4\mu}\left(\frac{-dp}{dx}\right)(R^2 - \bar{r}^2)$$

$$\frac{\frac{1}{4\mu}\left(\frac{-dp}{dx}\right)R^2}{2} = \frac{1}{4\mu}\left(\frac{-dp}{dx}\right)(R^2 - \bar{r}^2)$$

$$\frac{R^2}{2} = R^2 - \bar{r}^2$$

$$\therefore \ \bar{r}^2 = R^2 - \frac{R^2}{2} = \frac{R^2}{2}$$

$$\bar{r} = \sqrt{\frac{R^2}{2}} = \frac{R}{\sqrt{2}}$$

59. Ans : (b)

Sol. In laminar flow, coeff of drag $\propto \frac{1}{R_e}$

60. Ans : (a)

Sol. In laminar flow, loss of pressure

$$\Delta p = \frac{32\mu.v.l}{d^2}$$

$$\Delta p \propto v$$

61. Ans : (b)

Sol. For laminar flow through pipe.

$$V_{max} = 2V$$

62. Ans : (c)

Sol. Shear stress over cross section varies linearly, zero at central axis to maximum at outer surface.

63. Ans : (d)

Sol. In laminar flow, coefficient of friction

$$(f') = \frac{f}{4} = \frac{64}{4Re} = \frac{16}{Re}$$

64. Ans : (b)

Sol. For laminar pipe flow, $V_{max} = 2V$

65. Ans : (a)

Sol. Friction factor (f) is function of Reynolds number in laminar flow.

$$f \propto \frac{1}{R_e}$$

$$f = \frac{64}{R_e}$$

- Lower the Reynolds number, higher the friction factor.

66. Ans : (b)

Sol. $V_r = V_{max}\left(1 - \frac{r^2}{R^2}\right)$

$$= 1\left(1 - \left(\frac{50}{100}\right)^2\right)$$

$$= 1\left(1 - \frac{1}{4}\right) = 1\left(\frac{3}{4}\right) = 0.75 \text{ m/s}$$

67. Ans : (c)

Sol. Experimental studies of laminar flow through pipe was contributed by Hagen and Poiseuille

69. Ans : (d)

Sol. Lower limit of Reynolds number for laminar flow is 2000.

70. Ans : (b)

Sol. Shear stress distribution in pipe flow

$$\tau = \frac{-dp}{dx}.\frac{r}{2}$$

71.Ans : (a)

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

$Q = \frac{\pi d^4 \Delta p}{128\mu L}$

72. Ans : (c)

Sol. Pressure drop per unit length of pipe in laminar flow

$$\frac{\Delta p}{l} = \frac{32\mu.v}{d^2}$$

75.Ans : (d)

Sol. For same discharge through a pipe

$$\Delta p = \frac{128\mu Ql}{\pi d^4} \Rightarrow \frac{\Delta p}{l} = \frac{128\mu.Q}{\pi d^4}$$

$$\frac{\Delta p}{l} \propto \frac{1}{d^4}$$

$$\frac{h_{L_2}}{h_{L_1}} = \left(\frac{d_2}{d_1}\right)^4$$

$$h_{L_2} = h_{L_1} \times (2)^4 = 16h_{L_1}$$

76. Ans : (b)

Sol. $h_L = \frac{32\mu.v.l}{\rho g.d^2} \Rightarrow h_L \propto V$

80.Ans : (d)

Sol. ρ = 900 kg/m^3

μ = 1.2 pa-sec

B = 3cm = 0.03 m

Q = 600 cm^3/ sec/cm

Q = 600 × 10^{-4} m^3/sec/meter width of plates

$\tau_{surfaces}$ = ? (N/m^2)

$$\tau = \left(\frac{dp}{dx}\right)\frac{h}{2}$$

Q = AV = B × w × v

600 = 3 × 1 × v

V = 200 cm/sec = 2 m/sec

$$V_{max} = \frac{3}{2}V = \frac{3}{2} \times 2 = 3 \text{ m/s}$$

$$V_{max} = \frac{1}{8\mu}\left(\frac{-dp}{dx}\right)B^2$$

$$3 = \frac{1}{8 \times 1.2}\left(\frac{-dp}{dx}\right)(0.03)^2$$

$$\therefore \frac{-dp}{dx} = 32000 \text{ pa/m}$$

$$\tau_{wall} = \frac{-dp}{dx}.\frac{B}{2} = 32000 \times \frac{0.03}{2}$$

= 480 N/m^2

81. Ans : (a)

Sol. Velocity distribution in between two fixed parallel plate

$$V_{max} = \frac{V_y}{4}\left(\frac{B^2}{By - y^2}\right)$$

$$V_y = 4V_{max}\left(\frac{By - y^2}{B^2}\right)$$

$$V_y = 4 \times 1.8\left(\frac{6 \times 1 - 1}{(6)^2}\right)$$

$$= 4 \times 1.8\left(\frac{5}{36}\right)$$

= 1 m/s

84.Ans : (d)

Sol: $T.H = \frac{P}{\gamma} + \frac{V^2}{2g} + Z$

$\frac{P}{\gamma} = \frac{-0.02 \times 136}{7.5}$

$= -0.362$m of oil

$Q = AV$

$V = \frac{Q}{A} = \frac{70 \times 10^{-3}}{\frac{\pi}{4} \times (0.15)^2}$

V= 3.96m/sec

$\alpha \times \frac{V^2}{2g} = \frac{1.1 \times (3.96)^2}{2 \times 9.81}$

= 0.879m of oil

Z = 0.12m of oil

Total Head = –0.362+0.879+0.12

= 0.636m of oil

91.Ans : (a)

Sol: $V_{avg} = \frac{2}{3} V_{max}$

$= \frac{2}{3} \times 30 = 20$cm/sec

96.Ans : (a)

Sol: $\tau = \frac{-dp}{dx} \times \frac{R}{2}$

$= \frac{75 \times 10^3}{15} \times \frac{0.04}{2}$

=100pa = 0.1 kPa

97.Ans : (c)

Sol: $\Delta P \propto \frac{1}{r^4}$

$\frac{\Delta P_2}{\Delta P_1} = \left(\frac{r_1}{r_2}\right)^4$

$\frac{\Delta P_2}{\Delta P_1} = \left(\frac{r}{\frac{r}{2}}\right)^4$

$\Delta P_2 = 2^4 \times \Delta P_1$

$\Delta P_2 = 16 \times \Delta P_1$

95.Ans : (c)

Sol. $V = V_{max}\left(1 - \frac{r^2}{R^2}\right)$

$= 1\left(1 - \frac{5^2}{10^2}\right)$

$= 0.75$ m/s

12 TURBULENT FLOW

01. Ans : (d)

Sol. Laminar flow occurs for the following cases

(i) very slow motion i.e. low velocities.

(ii) very viscous fluids i.e. high viscous fluids

(iii) very narrow passage, size of passage is less

All variables are contributed low Reynolds number

$$R_e = \frac{V.d}{\gamma}$$

Turbulent flow to occur, the above cases in opposite sense

02. Ans : (d)

Sol. $h_L \propto V^n$

where

$n = 1 \rightarrow$ Laminar flow

$n = 1.75 \rightarrow$ Turbulent flow in smooth pipe

$n = 2.0 \rightarrow$ Turbulent flow in rough pipes

03. Ans : (a)

Sol. Moody diagram is a graphical method showing the variation of friction factor (f) is function of Reynold's number (R_e) and $\frac{k_s}{D}$ ratio.

Where D = dia. of pipe

k_s = uniform sand grain diameter called equivalent sand grain roughness.

05. Ans : (a)

Sol. $$\tau_{wall} = \frac{-dp}{dx}\frac{R}{2} = \frac{0.16\times10^6}{30}\times\frac{37.5\times10^{-3}}{2}$$

$= 100\ N/m^2$

10. Ans : (c)

Sol. In turbulent flow, rough & smooth conditions decided by comparing roughness projections with thickness of laminar sub layer.

13. Ans : (d)

Sol. For high Reynolds number values friction factor is independent upon the Reynolds number. Friction factor is function of relative roughness.

14. Ans : (d)

Sol. Moody diagram refers to design of commerical pipes w.r.t roughness, Reynolds number and friction factor values.

19. Ans : (b)

Sol. Entrance length of a pipe for turbulent flow

= 50 to 60 times dia. of pipe

= 50 × 0.8 = 40 m

Note : Entrance length of a pipe for laminar flow

= 100 to 120 times dia. of pipe

20. Ans : (a)

Sol. In turbulent flow relation between maximum velocity and mean velocity of pipe flow.

$$V_{max} = V\left[1+1.43\sqrt{f}\right]$$

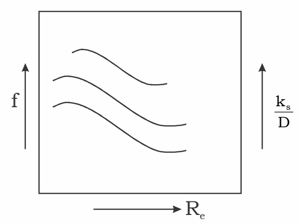
for f = Friction factor generally 0.018

$\therefore V_{max} = 1.2\ V$

$$\therefore \frac{V}{V_{max}} \simeq 0.82$$

21. Ans : (d)

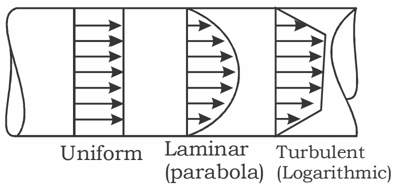
Sol.



Moody's chart is graphical representation between Reynolds number, relative roughness and friction factor.

23. Ans : (c)

Sol.



Across the section of a pipe flow, the velocity profile distribution for turbulent flow is exponential (or) logarithmic profile

25. Ans : (b)

Sol. In turbulent pipe flow, entrance length

= 50 D

= 50 × 0.8 = 40 m

26. Ans : (c)

Sol. R_e > 2300 treated as turbulent flow (upper critical)

Flow based on Reynolds number :

$R_e \le 2000 \rightarrow$ Laminar

$2000 < R_e < 4000 \rightarrow$ Transitional flow

$R_e > 4000 \rightarrow$ Turbulent flow

29.Ans : (c)

Sol. Most essential feature of a turbulent flow is that flow exhibits fluctuations in velocity and pressures

30.Ans : (c)

Sol.

Laminar flow through a pipe	**Turbulent flow through a pipe**
1. V_{max} = 2V	V_{max} = 1.2 V
2. Shear stress at wall $= \frac{dp}{dx}.\frac{d}{4}$ in laminar flow Laminar flow $\tau = \mu \frac{dv}{dy}$	Shear stress at wall is more in addition to pressure gradient and turbulent shear stress $\tau = \mu \frac{dv}{dy} + \eta \left(\frac{dv}{dy}\right)$
3. Pressure drop $\frac{32\mu vl}{d^2}$	Pressure drop is more by experimental values

31. Ans : (c)

Sol. In turbulent flow through a rough pipe, friction factor is function or Reynolds number and relative roughness.

32. Ans : (c)

Sol. Classification of boundary surfaces in turbulent flow through a pipe

S.No.	**Type of boundary**	**(k/δ') Ratio of roughness height to laminar sublayer thickness**
1	Hydrodynamically smooth pipe surface	$\frac{k}{\delta'} \le 0.25$
2	Hydro dynamically transition surface	$0.25 < \frac{k}{\delta'}$
3	Hydro dynamically rough surface	$\frac{k}{\delta'} < 6$

33. Ans : (c)

Sol. In hydro dynamic smooth pipe $\frac{k}{\delta'} \le 0.25$,

i.e. laminar sub-layer thickness greater than roughness height.

42.Ans : (a)

Sol.

Type of boundary	$\frac{k}{\delta'}$
Hydrodynamically smooth	$\le$ 0.25

05. Ans : (c)

Sol. v_1 = 1 lit = 1000 cm^3

v_2 = 995 cm^3

$p_2 = 2 \times 10^6$ N/m^2

$p_1 = 1 \times 10^6$ N/m^2

k = ?

$$\therefore k = \frac{dp}{-\frac{dv}{v_1}}$$

$$k = \frac{(2-1)}{-\left(\frac{995-1000}{1000}\right)} = 200 \text{ MN/m}^2$$

08. Ans : (c)

Sol. An isentropic flow is that thermodynamic flow which is reversible adiabatic flow.

09. Ans : (c)

Sol. Mach angle in a compressible fluid flow is formed for super sonic flows (M > 1)

10. Ans : (d)

NOTE : In the material the option 'd' is printing mistake i.e. rise in temperature and rise in pressure.

11. Ans : (c)

Sol. Normal shock wave is a steep finite pressure wave

It is similar to hydraulic jump.

12. Ans : (c)

Sol. As per 1st Law of thermodynamics

Heat supplied = Increase in internal energy + work done

$$dQ = dE + dW$$

$$\therefore dE = dQ - dW$$

13. Ans : (c)

Sol. In isentropic the of compressible fluids,

$$\frac{T_0}{T} = \left[1+\left(\frac{K-1}{2}\right)M^2\right]$$

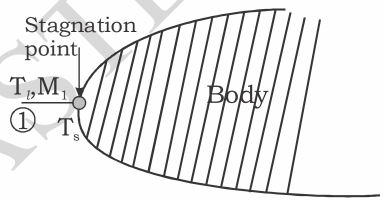
Where

T_0 = stagnation temperature (Abs)

T = Absolute temperature

K = 1.4

M = Match number



$$\therefore T_0 = T\left[1+\left(\frac{1.4-1}{2}\right)M^2\right]$$

$$T_0 = T\left[1+0.2\,M^2\right]$$

14. Ans : (b)

Sol. Area ratio =

$$\left(\frac{\text{Area of throat}}{\text{Area of throat under sonic conditions}}\right)$$

$$\frac{A}{A^*} = \frac{1}{M}\left[\frac{2+(K-1)M^2}{K+1}\right]^{\frac{K+1}{2(K-1)}}$$

Where,

K = 1.4 for air

$$\frac{A}{A^*} = \frac{1}{M}\left[\frac{2+(1.4-1)M^2}{1.4+1}\right]^{\frac{1.4+1}{2(1.4-1)}}$$

$$= \frac{1}{M}\left[\frac{2+0.4M^2}{2.4}\right]^3$$

$$= \frac{1}{M}\left[\frac{0.4\left[\frac{2}{0.4}+M^2\right]}{2.4}\right]^3 = \frac{1}{M}\left[\frac{5+M^2}{6}\right]^3$$

$$\frac{A}{A^*} = \frac{1}{M}\left[\frac{5+M^2}{6}\right]^3$$

NOTE : In the material the option 'd' is printing mistake i.e. $\frac{A}{A_1} = \frac{1}{M}\left[\frac{5+M^2}{6}\right]^3$

20. Ans : (d)

Sol. Mach angle (α) = 30°

Velocity of sound (C) = 330 m/s

Velocity of bullet (V) = ?

$\alpha = \sin^{-1}\left(\frac{1}{M}\right)$

$\sin\alpha = \frac{1}{M}$

$\sin 30° = \frac{1}{M}$

$0.5 = \frac{1}{M}$

M = 2

$M = \frac{V}{C}$

$2 = \frac{V}{330}$

∴ V = 660 m/s

21. Ans : (b)

Sol. Compressible fluid flow through C-D tube (converging-Diverging) without shock, mach number at exit of C-D tube is sub-sonic

(i.e. M < 1).

22. Ans : (b)

Sol. Speed of sound (c) in an ideal gas flow is function of absolute temperture.

$C = \sqrt{KRT}$

$\therefore C \propto \sqrt{T}$

24.Ans : (d)

Sol. C = 300 m/s

$V = 1620 \times \frac{5}{18} = 450$ m/sec

$\alpha = \sin^{-1}\left(\frac{1}{M}\right) = \sin^{-1}\left(\frac{C}{V}\right)$

$\alpha = \sin^{-1}\left(\frac{300}{450}\right) = 41.8°$

26. Ans : (d)

Sol. If mach number (M) is less than 0.3, then compressibility effect ignored.

30. Ans : (c)

Sol. For sub sonic flow, if the area of the flow increase. (M < 1) velocity decreases (as per continuity equation)

31. Ans : (a)

Sol. Sonic velocity (c) = $\sqrt{KRT}$

$= \sqrt{1.4 \times 287 \times (15 \times 273}$

= 340.17 m/s

32. Ans : (b)

Sol. Isentropic thermodynamic process follows

$\frac{P}{\rho^k}$ = const

Where,

$K = \frac{C_p}{C_v}$ = ratio of specific heat at constant pressure to that of constant volume.

34. Ans : (a)

Sol. A nozzle is fitted to a gas stored reservoir. The gas gets choked when the velocity of flow is sonic in the nozzle (M=1). A passage where sonic velocity reached and maximum flow rate occurs.

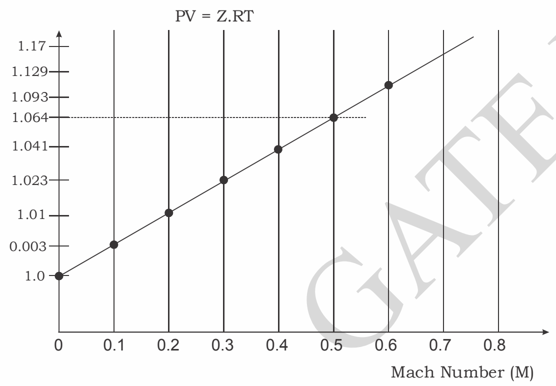
36. Ans : (b)

Sol. For sonic flow, Mach number (M) = 1

37. Ans : (d)

Sol. If Mach number (M) = 0.5, then compressibility correction factor is slightly more than unity.

'Z' is the ratio of the molar volume of a gas to the molar volume of an ideal gas at pressure and temperature. It is used to modify ideal gas law to account for the real gas behavior.



If M increases, Z also increases form initial value M = 1.

46. Ans : (d)

Sol. Effect of compressibility of a fluid can be neglected if mach number (M) is less than 0.3

47. Ans : (b)

Sol. In supersonic flow condition, flow through divergent passage, increase in area (dA >0) causes flow velocity to increase (dV > 0) and pressure, density & temperature decreases.

NOTE : In the given material the given option 'b' was printing mistake i.e. means in velocity and density decrease.

49.Ans : (a)

Sol. Sonic velocity = velocity of sound in air

$C = \sqrt{KRT}$

$C = \sqrt{1.4 \times 287 \times (15+273)}$

C = 340.3 m/s

[Note: Standard atmospheric temperature = 15°C]

50. Ans : (b)

Sol. For supersonic flow, if area of flow increases, velocity also increases.

$\frac{dA}{A} > 0; \frac{dV}{V} > 0$

$\frac{dP}{P} < 0, \frac{dP}{P} < 0$

52. Ans : (b)

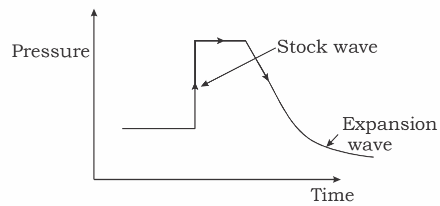
Sol. Measure of effect of compressibility in compressibility fluids studies and classified compressible fluids by dimensionless number "MACH NUMBER".

53. Ans : (c)

Sol. If Mach number (M) is less than 0.3, then compressibility effect is ignored.

55. Ans : (b)

Sol. Shock wave is characterized by an abrupt change in pressure, temperature and density of the fluid medium.



56. Ans : (b)

Sol. Sonic velocity, $C = \sqrt{KRT}$

$C \propto \sqrt{T}$

61.Ans : (b)

Sol. $K = 2\times10^9 N/m^2$

$$\rho = 8000 kg/m^3$$

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

$$= \sqrt{\frac{2\times10^9}{8000}}$$

= 500m/s

65. Ans : (c)

Sol : $R = C_P - C_V$

$$C_p = C_v + R$$

$$k = \frac{C_P}{C_V} = \frac{C_V + R}{C_V} = 1 + \frac{R}{C_V}$$

68. Ans : (d)

Sol : $\sin\alpha = \frac{1}{M} = \frac{1}{\frac{V}{C}} = \frac{C}{V}$

$$\alpha = \sin^{-1}\left(\frac{C}{V}\right)$$

$$= \sin^{-1}\left(\frac{300}{1620\times\frac{5}{18}}\right)$$

$$= \sin^{-1}\left(\frac{300}{450}\right)$$

$$= \sin^{-1}(0.667) = 41.8^0$$

69. Ans : (d)

$$T_1 = 15^0C = 15 + 273 = 288^0K$$

$$T_2 = -56^0C = -56 + 273 = 217^0K$$

$$M_1 = 1.5$$

$$M_2 = ?$$

$$M_1 = \frac{V}{C_1} = \frac{V}{\sqrt{KRT_1}}$$

$$M_2 = \frac{V}{C_2} = \frac{V}{\sqrt{KRT_2}}$$

$$\therefore \frac{M_2}{M_1} = \sqrt{\frac{T_1}{T_2}}$$

$$M_2 = 1.5\sqrt{\frac{288}{217}} = 1.73$$

70. **Ans : (d)**

Critical pressure in nozzle flow

$$\frac{P_2}{P_1} = \left(\frac{2}{K+1}\right)^{k/k-1}$$

Given

$K = 1.4$

$$\therefore \frac{P_2}{P_1} = \left(\frac{2.0}{1.4+1}\right)^{\frac{1.4}{1.4-1}} = 0.528$$

71. **Ans : (a)**

Sol. Normal shock wave is characterised by upstream super soinic flow and down stream is sub- sonic flow

72. **Ans : (a)**

Between two points of isentropic flow, stagnation pressure and stagnation temperature varied.

73. Ans : (b)

Mach number relations is normal shock wave Pattern

Given

$M_1 = 3.52$

K= 1.4

$$M_2 = \sqrt{\frac{2+(K-1)M_1^2}{2KM_1^2-(K-1)}}$$

$$M_2 = \sqrt{\frac{2+(1.4-1)(3.52)^2}{2\times1.4\times(3.52)^2-(1.4-1)}}$$

= 0.45

74. **Ans : (a)**

K= 1.4

M_2 = 0.5

$$M_1 = \sqrt{\frac{2+(K-1)M_2^2}{2KM_2^2-(K-1)}}$$

$$M_1 = \sqrt{\frac{2+(1.4-1)(0.5)^2}{2\times1.4\times(0.5)^2-(1.4-1)}}$$

= 2.65

75. Ans : (b)

Sol: V= 1580 km/h

$$=1580\times\frac{5}{18}\text{ m/sec} = 438.88 \text{ m/s}$$

T= –60^{0}C = –60^0+273 = 213^{0}k

K = 1.4

R = 287 J/Kg ^{0}K

$$C=\sqrt{KRT}=\sqrt{1.4\times287\times213}$$

$$=292.54 \text{ m/s}$$

$$M=\frac{V}{C}=\frac{438.88}{292.54}=1.5$$

15 BOUNDARY LAYER THEORY

15.Ans : (d)

Sol. $\delta^* = \int_0^{\delta}\left(1-\frac{U}{U_\alpha}\right)dy = \int_0^{\delta}\left(1-\frac{y}{\delta}\right)dy$

$= y - \frac{y^2}{2\delta}\Big|_0^{\delta} = \delta - \frac{\delta^2}{2\delta}$

$= \frac{\delta}{2}$

16 DIMENSIONAL ANALYSIS

08. Ans : (b)

Sol. $\sqrt{\dfrac{M\times L^2}{L^3\times F}}\times\dfrac{L^3}{T}\times\dfrac{1}{L^2}$

$\sqrt{\dfrac{M}{MLT^{-2}\times L}}\times\dfrac{L}{T}$ = dimensionless

12. Ans : (c)

Sol. $\dfrac{\partial P}{\partial x}\dfrac{D^4}{\mu Q}=\dfrac{N}{m^3}\dfrac{m^4}{\dfrac{N.S}{m^2}.\dfrac{m^3}{S}}$

18. Ans : (c)

Sol. $\dfrac{\rho F}{\mu^2}=\dfrac{\dfrac{Kg}{m^3}.N}{\dfrac{N.s}{m^2}.\dfrac{N.s}{m^2}}$

$=\dfrac{\dfrac{Kg}{m^3}.N}{\dfrac{N.s}{m^2}.\dfrac{Kg.m}{s^2}.\dfrac{s}{m^2}}$

= 1

22. Ans : (d)

Sol. Scale ratio in model spillway, L_r = 1:9

Discharge in the prototype,

Q_P = 2430 cumecs

Discharge in the model, Q_m = ?

$$Q_r=\frac{Q_m}{Q_p}=\left(\frac{1}{9}\right)^{5/2}$$

$$Q_m=2430\times\left(\frac{1}{9}\right)^{5/2}$$

= 10 cumecs

23. Ans : (c)

Sol. Force ratio (F_r) = $(\text{mass}\times\text{ acceleration})_r$

$$=\left(\rho\times v\times\frac{L}{T^2}\right)_r=\left(\rho L^3\frac{L}{T^2}\right)_r=\left(\rho\frac{L^4}{T^2}\right)_r$$

$$=\frac{\rho_r L_{r^4}}{T_{r^2}}=\frac{\rho_r L_{r^4}}{L_r}$$

$$F_r=\rho_r L_{r^3}$$

26. Ans : (a)

Sol. $Q_r=A_rV_r$

$$=L_{r^2}\frac{\mu_r}{\rho_r L_r}$$

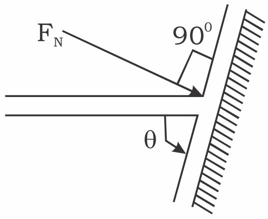
$$=\frac{\mu_r L_r}{\rho_r}$$

17 IMPACT OF JETS

01. Ans : (a)

Sol. $F_N = \rho A V^2 \sin\theta$

F_N will be maximum when $\theta = 90^0$



02. Ans : (d)

Sol. d= 5cm = 0.05m

$F_x = \rho a(v-u)^2$

$= 1000 \times \frac{\pi}{4}(0.05)^2 \times (18-12)^2$

$= 70.7$ N

03. Ans : (b)

Sol. Water Power

$$= \rho gQH = \rho gav \times \left(\frac{v^2}{2g}\right) = \frac{1}{2}\rho av^3$$

$$= \frac{1}{2} \times 1000 \times 0.1962 \times (15)^3$$

$= 331087.5$W [1HP=736W]

$$= \frac{331087.5}{736} \text{ HP} = 450 \text{ HP}$$

04. Ans : (c)

Sol. Total head = 37.5 m

Discharge = 1 cumec= $1 m^3/sec$

Power generated = ?

$P = \rho gQH$

$= 1000 \times 9.81 \times 1 \times 37.5$

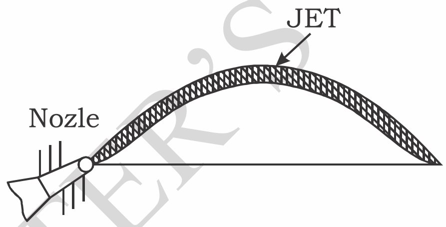
$= 367875$W

$$= \frac{367875}{736} \text{HP}$$

$= 499.83\text{HP} \simeq 500$ HP

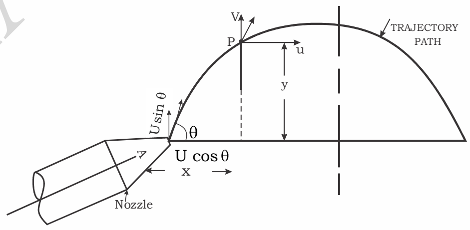
05. Ans : (c)

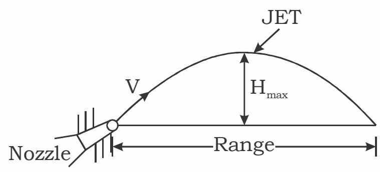
Sol. Path of fluid Jet from Nozzle exposed in atmosphere is trajectory parabolic are



06. Ans : (c)

Sol.





$$\frac{H_{max}}{\text{Range}} = \frac{V^2 \sin^2\theta / 2g}{\frac{V^2 \sin 2\theta}{g}}$$

$$= \frac{\sin^2\theta}{2 \times 2\sin\theta\cos\theta} = \frac{1}{4}\tan\theta$$

$= 0.25 \tan\theta$

7. Ans : (b)

Sol. $F_x = \rho a v^2 = \dfrac{w a v^2}{g}$ (specific weight $w = \rho g$)

8. Ans : (b)

Sol. $F_x = \rho a\ (V-U)^2$

$= \dfrac{w}{g} a (V-U)^2$

10. Ans : (a)

Sol. $F = \rho a v^2 = 1000 \times 1200 \times 10^{-4} \times (5)^2$

$= 3000 N = 3 KN$

11. Ans : (a)

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

$= 1000 \times 2000 \times 10^{-6} \times 10^2\ (1+\cos 120°)$

$= 100\ N$

12. Ans : (d)

Sol. $\eta = \dfrac{W.D/sec}{KE/sec} = \dfrac{\rho AV(V-U).U}{\frac{1}{2}\rho AV^3}$

$= \dfrac{2(V-U)U}{V^2}$

$= \dfrac{2(25-10)\times 10}{(25)^2} = 0.48$

$= 48\%$

13. Ans : (a)

Sol. $u = 36 km/hr = 10 m/s$

$v = 30\ m/s$

Propulsive force $= \rho.A.V_r.V$

$= \rho.A.\ (V+U)\ V$

$= 1000 \times 20000 \times 10^{-6}\ (30+10) \times 30$

$= 24000\ N = 24\ kN$

14. Ans : (b)

Sol. $\eta = \dfrac{W.D/sec}{\frac{1}{2} m V_r^2} = \dfrac{2V.U}{V_r^2}$

$= \dfrac{2 \times 30 \times 10}{(30+10)^2} = \dfrac{600}{(40)^2}$

$= \dfrac{600}{1600} = 0.375 = 37.5\%$

15.Ans : (b)

Sol. $F_N = \rho a v^2 \sin\theta = \dfrac{\gamma}{g} a v^2 \sin\theta$

18. Ans : (b)

Sol. $F = \rho a v^2$

$= 1000 \times \dfrac{\pi}{4}\left(50 \times 10^{-3}\right)^2 \times (30)^2$

$= 1767.14 N = 1.767 KN$

NOTE : In the given material the given option 'b' was printing mistake.Ans is 1.767KN

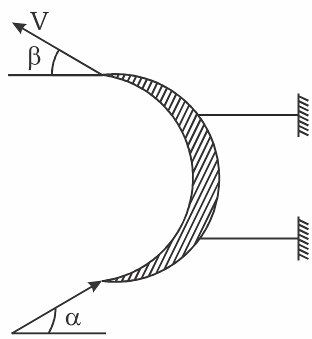
19. Ans : (d)

Sol. $F = \rho a v^2 = \dfrac{w a v^2}{g}$

20.Ans : (a)

Sol. $F = \rho a v^2\ (\cos\alpha + \cos\beta)$

$= \dfrac{w a v^2}{g}\ (\cos\alpha + \cos\beta)$

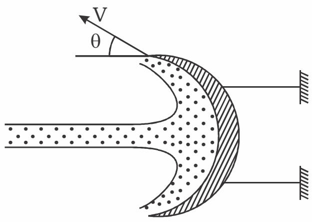


21. Ans : (b)

Sol. $\dfrac{F_{N_1}}{F_{N_2}} = \dfrac{\rho AV^2 . \sin\theta}{\rho AV^2} = \sin\theta = \sin 30° = \dfrac{1}{2}$

23. Ans : (d)

Sol.



$F = \rho a v^2 (1 + \cos\theta)$

24.Ans : (d)

Sol. No. of series of curved vanes mounted or wheel shape is

Semi–circular (θ = 180°)

η_{max} = 100%

25. Ans : (c)

Sol. $W.D/sec = \rho a v \left(v_{w_1} u_1 \pm v_{w_2} u_2\right)$

$$\frac{WD/sec}{Mass/sec} = \left(v_{w_1} u_1 \pm v_{w_2} u_2\right)$$

28.Ans : (b)

Sol. η of series plates

$$= \frac{W.D/sec}{K.E/sec} = \frac{\rho a(v\text{-}u)v.u}{\frac{1}{2}\rho a v^3}$$

$$= \frac{2u(v-u)}{v^2}$$

29.Ans : (d)

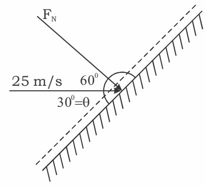
Sol. $F = \rho a (v–u)^2$

$= 1000 \times 0.002 \times (15–5)^2 = 200$ N

$= 0.2$KN

30. Ans : (a)

Sol. d = 0.05 m



V = 25 m/s

θ = 60°

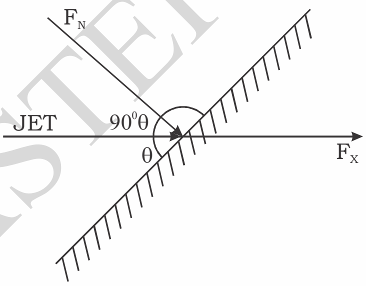
$F_N = \rho A\ V^2 \sin\theta$

$= 1000 \times \frac{\pi}{4}(0.05)^2 \times 25^2 \times \sin 30°$

= 613.5 N

35. Ans : (c)

Sol.



F_N = 600 N

$F_X = F_N \sin\theta = 600 \times \sin 30°$

= 300 N

36. Ans : (d)

Sol. $F = \rho a (v–u)^2$

$$= \rho a \left(v - \frac{1}{3}v\right)^2$$

$$= \rho a \left(\frac{2}{3}v\right)^2$$

$$= \frac{4}{9} \rho a v^2 = K\rho a v^2$$

Where $K = \dfrac{4}{9}$

39. Ans : (c)

Sol. Impulse momentum equation is independent upon viscous effects

41. Ans : (b)

Sol. m = mass flow rate = $\rho.Q$

m = $\rho a v_r$ = ρa (v-u)

45. Ans : (d)

Sol. Impulse momentum Equation for control volume considered gravity force, pressure force and boundary resistance forces.

46. Ans : (d)

Sol. $F = \rho a\,(v-u)^2$

$= 1000 \times 0.015\,(15-5)^2$

= 1500 N

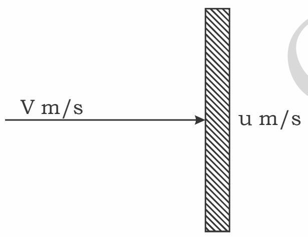
47.Ans : (d)

Sol. For maximum efficiency

$$u = \frac{v}{3} = \frac{30}{3} = 10\,\text{m/sec}$$

48. Ans : (c)

Sol.



$F = \rho a\,(v-u)^2$

m = $\rho Q = \rho a v$

Actual mass striking is $\rho a v$

NOTE : In the given material the given option 'a' was incorrect.

49. Ans : (a)

Sol. Number of Jets = 2

S.P = 15450 KW

d = 200mm = 0.2 m

H = 400m

$c_v = 1$

$v = \sqrt{2gH}$

$= \sqrt{2 \times 9.81 \times 400}$

= 88.58 m/s

Power at the inlet of turbine

= No. of Jets×water power

$= 2 \times \frac{1}{2} \rho a v^3$

$= \rho a v^3$

$= 1000 \times \frac{\pi}{4}(0.2)^2 \times (88.58)^3$

=21835186.24W

= 21835.18 KW

50.Ans : (d)

Sol. a= $0.03 m^2$

F =1KN=1000N

$F = \rho a v^2$

$1000 = 1000 \times 0.03 \times v^2$

v = 5.78 m/s

18 HYDRAULIC TURBINES

01. Ans : (a & d)

Sol.
- Hydraulic machine is a device which converts fluid energy into mechanical energy is called turbine.
- Hydraulic machine is a device which converts mechanical energy into fluid energy is called pump.

02. Ans : (a)

Sol. **Turbine :** It is machine for producing continuous power in which a wheel (or) rotor fitted with vanes (blades), is made to revolve by a flow of moving fluid (i.e. water, steam, gas, air (or) other fluid of working substance). Hence a turbine is a machine that transforms rotational energy from a fluid is picked up by a rotor into usable energy (or) work.

Ex : Water turbines, steam turbines, Gas turbines, wind mill etc.

Water (or) hydraulic turbine

03. Ans : (c)

Sol. **Hydraulic turbine (or) Water turbine :** It is a rotary machine that converts hydraulic energy (potential and kinetic energy) of water into mechanical energy (or) work.

Ex : Impulse turbines (Pelton wheel Turgo, Banki). Reaction turbines (Francis, Kaplan and Propeller turbine).

Note :

i) Electric generator :
It converts mechanical energy into electrical energy.

ii) Hydraulic energy means potential energy (or) kinetic energy (or) combination of both.

iii) Pump is also a hydraulic machine which converts mechanical energy into hydraulic energy.

06. Ans : (a)

Sol. Pump is a mechanical device that moves fluids (liquids (or) gases) by mechanical action. Pump consume mechanical energy (by means of electric motor, heat engines, wind power (or) manual), operates by rotary (or) reciprocating mechanism.

S.No.	Name of machine (or) device	Function
1	Pump	Mechanical energy into hydraulic energy
2	Hydraulic Turbine	Hydraulic energy into mechanical energy
3	Electric motor	Electrical energy into mechanical energy
4	Electric generator	Mechanical energy into electrical energy

8. Ans : (d)

Sol. Methods of avoid cavitation in reaction turbines :

1. Special materials (or) coatings such as aluminium-bronze and strainless steel, which are cavitation resistant materials should be used.
2. Install reaction turbine below the tail race water level.
3. Provide blades with smooth surfaces
4. Pressure of flowing liquid in any part of the turbine should not be allowed to fall below the vapour pressure.
   Ex : For water flow in turbine, absolute pressure head should not be below 2.5 m of water.

10. Ans : (c)

Sol. Penstock is the long pipe that carries the water flowing from the reservoir towards the power generation unit.

The water in penstock possesses kinetic energy due to its motion and potential energy due to height. It transports water under pressure forebay to turbines.

11. Ans : (d)

Sol. Penstock is a high pressure steel pipe line that carries water from storage reservoir to the turbine.

Steel material is sued for the following **Reasons:** Limited water hammer effect durability, easy joining / fabrication/ weld methods; pressure (static &

dynamic) of passing water limitations since penstocks are required to withstand high pressure because of high heads.

Steel penstock pipes withstands hydrodynamic pressure (Water hammer pressure). Steel provides more strength against bursting of pipe under dynamic pressure.

12. Ans : (d)

Sol. **Surge tank :** It is a hydraulic structure used to control pressure and flow fluctuations in a penstock.

Functions : It Reduces water flow transient pressures in penstock (i.e. reduces water hammer effect).

14. Ans : (c)

Sol. Surge tank connected to penstock before turbine for the follows :

1. To reduce water hammer for penstock pipe U/S of flow control value.
2. acts as storage of water
3. Absorb oscillations etc.

16. Ans : (b)

Sol. Surge tank in a penstock pipe should be provided to relieve the dynamic pressure due to water hammer influence. It should be located as close to the turbine.

17. Ans : (d)

Sol. **Tailrace :** The water from penstock pass through turbine, draft tube and has to pass itno main river stream through tail race.

19. Ans : (c)

Sol. Susceptible part of a water turbine to cavitation is

(i) at exit of reaction turbine

(ii) at inlet of the draft tube

20. Ans : (a)

Sol. **Gross Head :** Difference in vertical height between the water intake and tailrace levels. The difference in elevation between the free water surface of dam above and tail water surface below a hydel power plant (i.e. head race and tail race)

21. Ans : (d)

Sol. **Effective head (or) Net head :** It is the head available at the inlet of the turbine.

Net head = Gross head – Head loss due to friction.

$H = H_g - h_f$

28. Ans : (c)

Sol. Tangential flow → Pelton wheel

Radial flow → Francis

Axial fow → Kaplan turbine

Mixed flow → Modern Francis

30. Ans : (c)

Sol. Cavitation is observed in reaction turbines like Francis turbine, Kaplan turbine, propeller turbine and centrifugal pumps. Cavitation is not occur in Impulse turbine (Pelton wheel) and reciprocating pump.

32. Ans : (b)

Sol. **Avoiding cavitation in reaction turbines:**

1. Turbine parameters should be set such that at any point of flow static pressure may not fall below the vapour pressure of the liquid.
2. Flow separation at exit of turbine in the draft tube entrance causes vibrations. To stabilize this, inject air in the draft tube. Draft tube is to be submerged below the level of the water in tailrace

33. Ans : (d)

Sol. **Impulse turbine :** (Ex : Pelton wheel, Turgo, Banki turbines)

It is classified based on type of energy of water at inlet, direction of flow, head available, specific speed range etc.

i. Initially water from reservoir (P.E), fully converted into kinetic energy at end of nozzle (i.e. Impulse action)

ii. Flow is tangential

iii. High head of water required

iv. Works in open atmosphere (No pressure change according to turbine).
v. During flow across the pelton wheel, there is change in velocity only.
vi. It works on Impulse-momentum principle (i.e. impact of jet causes force exertion).
vii. Pelton wheel is a tangential flow impulse turbine.
viii. Turgo wheel is an axial flow impulse turbine
ix. Banki turbine is a radial flow impulse turbine
x. Jonval turbine is an axial flow type impulse turbine.

46. Ans : (b)

Sol. Cavitation occurs when the static pressure of the liquid falls below its vapour pressure of that liquid.

47. Ans : (b)

Sol. Force exerted by a water jet on a bucket of pelton wheel (or) series of vanes mounted on fixed axis wheel is determined by "**Impulse-momentum**" Principle.

48. Ans : (c)

Sol. Casing has no hydraulic function. In impulse turbines, it is necessary to prevent the splashing of water to lead the water towards tail race and to safeguard against any accident. It is made strong enough to resist reaction of jet.

Note : To convert P.E to K.E, nozzle is used.

49. Ans : (c)

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

$40 = 0.985 \times \sqrt{2\times 9.81\times H}$

$\Rightarrow H = 84.05$ m

Approximate answer is 'C'

50. Ans : (a)

Sol. Speed ratio (ϕ) of pelton wheel varies from 0.4 to 0.5

Practical range of ϕ is 0.44 to 0.46

S.No.	Turbine	Speed ratio	Flow ratio
1	Pelton wheel	0.4 to 0.5	0.98 – 0.99
2	Francis Turbine	0.6 to 0.9	0.15 – 0.30
3.	Kaplan & Propeller turbine	1.8 to 2.5	0.7

52. Ans : (a)

Sol. $\phi = \frac{U}{\sqrt{2gH}} = \frac{\pi DN/60}{\sqrt{2gH}}$

$0.4 = \frac{\pi \times D \times 250/60}{\sqrt{2\times 9.81\times 50}}$

$\Rightarrow D = 0.95$ m

53. Ans : (d)

Sol. JET RATIO : It is defined as the ratio of the pitch diameter (D) of the pelton wheel to the diameter of the jet (d). It is denoted by "m"

$$m = \frac{D}{d}$$

The range of jet ratio: 10 to 20

56. Ans : (c)

Sol. No. of buckets on the periphery of a pelton wheel (or) on a runner is given by

$$Z = \frac{D}{2d} + 15 = 0.5m + 15$$

[Tygun's emperical formula]

Gibson's formula (Z) = constant $\sqrt{\frac{m}{2}}$

When constants are between 7 to 8

Jet ratio (m) is between 10 to 20

58. Ans : (d)

Sol. $Z = \frac{m}{2} + 15 = \frac{24}{2} + 15 = 12 + 15 = 27$

59. Ans : (b)

Sol. In practice, the number of nozzles provided is generally not allowed to exceed six.

60. Ans : (b)

Sol. Force on the pelton wheel bucket is obtained by using impulse momentum equation

61. Ans : (b)

Sol. **Breaking jet in a pelton wheel :**
To stop the runner of a pelton wheel in a short interval of time, a small nozzle is provided, which directs the jet on the back of the buckets. This jet of water is called breaking jet.

62. Ans : (b)

Sol. Breaking jet is used in pelton wheel to reduce the speed of the wheel (or) bring the runner to rest in short time.

63. Ans : (b)

Sol. **Dimension of Bucket :**
Depth of the bucket = 0.8 d to 1.2 d
Radial height = 2d to 3d
Axial width = 3d to 5d

64. Ans : (c)

Sol. Ratio of width of bucket to jet diameter is 3 to 5

67. Ans : (b)

Sol. H = Head available = 37.5 m

Q = Discharge of water = 1 m^3/sec

Power (in watt) = ρgQH

$= 1000 \times 9.81 \times 1 \times 37.5$

= 367875 Watt

= 367.875 kW

[1 HP $\simeq$ 0.736 kW]

$= \frac{367.875}{0.736} \simeq 500$ HP

68. Ans : (c)

Sol. Power obtained from the turbine shaft
– Frictional losses (or) Mechanical loss
– Hydraulic loss in runner
= Power supplied by water at entry of turbine
i.e. $P_{shaft} - P_{water}$ = Hydraulic losses in runner + mechanical losses

69. Ans : (a)

Sol.

$$\eta_{hyd} = \frac{\text{Power from runner of turbine}}{\text{Hydraulic power at entry of runner wheel}}$$

72. Ans : (a)

Sol. $\eta_m = \frac{\text{Shaft power}}{\text{Power produced by turbine}}$

73. Ans : (a)

Sol. η_h = Hydraulic efficiency

$$= \frac{\text{Power developed by the runner}}{\text{Power supplied by the water at entrance of wheel}}$$

$$\eta_m = \frac{\text{Power of the runner shaft}}{\text{Power supplied by the water to runner}}$$

Similarly other efficiencies in case of pelton wheel are

$$\eta_{vol} = \frac{\text{volume of water actually strike the runner}}{\text{volume of water supplied to the runner}}$$

$$\eta_o = \eta_h \times \eta_m = \frac{\text{Shaft power}}{\text{Water power}}$$

75. Ans : (c)

Sol. Overall efficiency of a pelton wheel varies from 85% to 90%

77. Ans : (b)

Sol.

$$\eta_{Transmission} = \frac{\text{Power available at the end of penstock}}{\text{Power supplied at entry of penstock}}$$

78. Ans : (a)

Sol. Maximum hydraulic efficiency of a pelton wheel

$$\eta_h = \frac{W.D/sec}{K.E \text{ of Jet/sec}} = \frac{F \times U}{\frac{1}{2} m V_1^2}$$

$$= \frac{m(\Delta V)_w U}{\frac{1}{2} m V_1^2} = \frac{m\left(V_{w_1} + V_{w_2}\right)U}{\frac{1}{2} m V_1^2}$$

$$= \frac{2\left(V_{w_1} + V_{w_2}\right)U}{V_1^2}$$

From velocity diagrams of a pelton wheel bucket.

$$V_{w_1} = V_1$$

$$V_{w_2} = V_{r_2} \cos\phi - U$$

Where,

$$V_{r_2} = V_1 - U$$

$$\therefore \eta_h = \frac{2\left[V_1 + (V_1 - U)\cos\phi - U\right]U}{V_1^2}$$

$$= \frac{2(V_1 - U)[1 + \cos\phi]U}{V_1^2}$$

Differentiate with respect to U for maximum efficiency $\frac{d(\eta_h)}{d(U)} = 0$

i.e. $U = \frac{V_1}{2}$ & $\frac{1 + \cos\phi}{V_1^2} \neq 0$

$$\eta_{hydmax} = \frac{2\left(V_1 - \frac{V_1}{2}\right)(1 + \cos\phi)\frac{V_1}{2}}{V_1^2}$$

$$\eta_{hydmax} = \frac{1 + \cos\phi}{2}$$

79. Ans : (b)

Sol. Condition for maximum efficiency of a pelton wheel is $U = \frac{V}{2}$

Where,

U = Tangential velocity of wheel

V = Velocity of water jet at inlet of turbine

$$\eta = \frac{O/P}{I/P} = \frac{W.D/sec}{K.E/sec} = \frac{F \times U}{\frac{1}{2} m v^2}$$

$$= \frac{m.V_r \times U}{\frac{1}{2} m V^2} = \frac{2V_r.U}{V^2}$$

$$\eta = \frac{2(V - U)U}{V^2}$$

Differentiate with respect to U for maximum hydraulic efficiency $\frac{d(\eta)}{d(U)} = 0$

$$\Rightarrow \frac{2(V - 2U)}{V^2} = 0$$

$\therefore$ V = 2U

$$\therefore U = \frac{V}{2}$$

Note : For maximum Hydraulic efficiency, wheel velocity should be half of the jet velocity.

85. Ans : (a)

Sol.
- Francis water turbine is classified as medium head, radial inward flow, medium specific speed, medium discharge and reaction type turbine.
- Kaplan & Propeller turbines are classified as low head, axial flow, high specific speed, high discharge and reaction type turbines.

Note :

1. Modern Francis turbine is mixed flow turbine i.e radial inward and axial out flow turbine.
2. In inward flow reaction turbine water enters at outer periphery of runner and flows out from the centre of the runner.
3. In reaction turbine (Francis turbine) part of head is converted into velocity before enters the runner

94. Ans : (d)

Sol. Water enters the turbine at high pressure and low velocity is a type of reaction turbine [Ex: Francis & Kaplan, propeller type]

Water enters at atmosphere and high velocity is a type of impulse turbine (Ex : Pelton wheel)

Note :

1. Francis turbine is radial flow type turbine
2. Kaplan & Propeller turbine areaxial flow type turbines.

105. Ans : (d)

Sol. Euler's equation of energy transfer in hydraulic turbines gives theoretical power developed by it.

Power developed by turbine = F × U

= Tangential force × Tangential velocity of runner

= ma × U

$= m\ (\Delta V)_{whirl} \times U$

$= m\left(V_{w_1} \pm V_{w_2}\right)U$

$= m\left(V_{w_1}U_1 \pm V_{w_2}U_2\right)$

106. Ans : (c)

Sol. Power developed by a reaction turbine

$= \eta_o \times \rho.g.Q.H$ (Watt)

= 0.8 × 1000 × 9.81 × 50 × 7.5

= 2943×10^3 Watt

= 2943 kW [1 HP = 0.736 kW]

$\simeq \dfrac{2943}{0.736}$ = 4000 HP

107. Ans : (c)

Sol. $P - \dfrac{2\pi NT}{60} = \dfrac{2 \times \pi \times 240 \times 100}{60}$

= 2513.27 kW

$\simeq$ 2515 kW

108. Ans : (d)

Sol. $\eta = 0.85$

H = 36 m

Q = 10 m^3/s

γ = 10 kN/m^3

Shaft power, P = ?

$P = \eta \times \gamma.Q.H$

$= 0.85 \times 10 \times 10 \times 36 = 3.06MW$

109. Ans : (b)

Sol. Reaction turbines (Francis, Kaplan, & Propeller type) are mounted vertically and coupled with electric generator in order to take advantage of head available maximum. Bottom most portion is turbine and above it is generator and both are coupled in vertical position. Impulse turbine shaft is generally horizontal arranged since flow of jet is tangential.

110. Ans : (b)

Sol. Speed ratio of a Francis turbine range is 0.6 to 0.9

Speed ratio of pelton wheel range is 0.4 – 0.5

S.No.	Type of Turbine	Speed of ratio(ϕ) $\phi = \dfrac{U}{\sqrt{2gh}}$
1.	Pelton wheel	0.4 – 0.5
2.	Francis turbine	0.6 – 0.9
3.	Kaplan & Propeller	1.8 – 2.5

112. Ans : (a)

Sol. Given data :

Flow ratio (ψ) = 0.4

Value of $\sqrt{2gH}$ = 100 m/s

Area of flow (A_f) = 6m^2

Discharge (Q) through turbine =?(m^2/sec)

Flow Ratio, $\psi = \dfrac{V_f}{\sqrt{2gH}}$

$$0.4 = \frac{V_f}{100}$$

$$\therefore V_f = 40 \text{ m/sec}$$

$$Q = A_f V_f = 6 \times 40$$

$$= 240 \text{ m}^3/\text{sec}$$

113. Ans : (b)

Sol. Number of blades on runner of a kaplan turbine = 3 to 6

Note: Francis turbine runner has 16 to 24 blades

114. Ans : (b)

Sol. Theoretical discharge through Francis turbine (Q) = $A_{f_1}.V_{f_1} = A_{f_2}.V_{f_2}$

Actual discharge = K.W

$$= K.A_{f_1}.v_{f_1} = K.A_{f_2}.v_{f_2}$$

$$= k\pi DBv_f$$

Where,

K = vane factor

115. Ans : (d)

Sol. Discharge through Kaplan turbine is given by

$$Q = A_f \times V_f = \frac{\pi}{4}\left(D_o^2 - D_b^2\right)V_f$$

Where,

D_o = Outer diameter of the runner

D_f = Diameter of hub portion of runner

116. Ans : (a)

Sol. Low head & Low power turbine is a Kaplan turbine.

117. Ans : (c)

Sol. Power generated = $\eta_o \gamma QH$

$$= 0.8 \times 10 \times 12 \times 25$$

$$= 2400 \text{ kW}$$

129. Ans : (a)

Sol. **Draft tube :** It is a vertical tube which connects outlet of reaction turbines (Francis, Kaplan & propeller) with the tail race crosssectional area gradually increases towards the tail race i.e. outlet of it. (maximum divergent cone angle of tube is 8°)

It is required to perform the following :

(i) It allows to install the reaction turbines above the tail race without loss of head.

This makes the inspection and maintenance of turbine easy (safety aspects also)

(ii) Outlet of reaction K.E is converted to pressure head, there by head on turbine increases.

Efficiency of draft tube :

$$\eta_{\text{Draft tube}} = \frac{\text{Actual regain of pressure head}}{\text{Velocity head at entrance}}$$

$$= \frac{\frac{V_1^2 - V_2^2}{2g} - h_f}{\frac{V_1^2}{2g}}$$

If h_f is neglected

$$\eta_{\text{Draft tube}} = \frac{V_1^2 - V_2^2}{V_1^2}$$

Note : Draft tube is not required for an Impulse turbine (Pelton wheel) as this turbine works in open atmosphere.

123. Ans : (d)

Sol. Draft is used for reaction turbine i.e. Francis & Kaplan turbines.

135. Ans : (d)

Sol. Degree of Reaction (D.O.R) of a turbine is defined as the ratio of pressure energy change to total energy change inside the turbine runner.

$$\text{D.O.R} = \frac{H_P}{H_r} = \frac{\text{P.E change inside runner}}{\text{T.E change inside runner}}$$

For Pelton wheel : ($U_1 = U_2$)

$$\therefore \text{D.O.R} = 0$$

$$H_P = 0$$

136. Ans : (d)

Sol. Governing of a turbine :

The governor varies the water flow through the water turbine to control is speed according to load of electrical generator.

137. Ans : (c)

Sol. Functions of governor :

It can automatically adjust the rotating speed of hydroelectric generator, keeping them running with in the allowable deviation rated speed, so as to meet the requirements of power grid frequency quality.

- It quickly makes hydroelectric generating set automatically or manually starting to adapt to the power grid load's increase and decrease, and the needs of the normal downtime or emergency stop.

When it runs in parallel with hydroelectric generating set in the power system, the governor can be automatically scheduled for the load distribution, and make each unit to achieve economic operation.

138. Ans : (d)

Sol. Types of Governors :

Governors are classified into : Impact governor, monotone, dual regulating. The impact governor applies to the impulse turbine (Pelton wheel) unit; the drab applies to the mixed-flow turbines or axial flow turbine (Reaction type); the dual governor applies to the movable propeller turbine and bulb tubular turbine with the adjustment of wheel blade.

All types of water turbines use "oil pressure governor"

139. Ans : (c)

Sol. The runaway sped of a water turbine is its speed at full flow, and no shaft load (Electric generator not coupled). The turbine is to be designed to survive the high mechanical forces of this speed. The manufacturer will supply the runway speed rating.

146. Ans : (a)

Sol. $N_{synchronous} = \frac{60f}{p} = \frac{60 \times 50}{10} = 300$

148. Ans : (c)

Sol. Specific speed (N_s) of a turbine :

It is defined as the rotational speed at which a water turbine would operate at best efficiency under unit head (1 m) and which is sized to produce unit power (1k W).

N_s is given by $= \frac{N\sqrt{P}}{(H)^{5/4}}$

Where

N → turbine runner wheel (rpm)

P → shaft power (kW)

H → Head on turbine (m)

Classification of water turbines based on : Specific Speed range :

S.No.	Turbine type	Specific Speed	Head (m)
1	Turgo	20 – 80	30 m to 300 m
2	Cross flow (Bank)	20 – 70	5 m to 200m
3	Pelton Wheel	10 – 60	300 m to 2000 m
4	Francis	60 – 300	30 m to 300 m
5	Kaplan	300 – 1000	4 m to 30 m

157. Ans : (c)

Sol. H = 10 m (low head turbine)

i.e. Kaplan turbine

164. Ans : (b)

Sol. 0 – 4.5 → Impulse type

10 – 100 → Reaction type

80 – 200 → Axial type

175. Ans : (a)

Sol. Given data :

P = 1600 kW

N = 360 rpm

H = 8 m

$$N_s = \frac{N\sqrt{P}}{(H)^{\frac{5}{4}}} = \frac{360\sqrt{1600}}{(8)^{\frac{5}{4}}} = 1070$$

The range is valid for "Kaplan turbine"

176. Ans : (a)

Sol. P = 10140 HP

= 10140 × 0.736 kW

= 7463 kW

H = 24.7 m

N = 180 rpm

$$N_s = \frac{N\sqrt{P}}{(H)^{\frac{5}{4}}} = \frac{180\sqrt{7463}}{(24.7)^{\frac{5}{4}}} = 282$$

The range is valid for "Francis turbine".

177. Ans : (b)

Sol. P = 1024

P = 1024 × 0.736 kW

= 753.7 kW

H = 16 m

N = 100 rpm

$$N_s = \frac{N\sqrt{P}}{(H)^{\frac{5}{4}}} = \frac{100\sqrt{753.7}}{(16)^{\frac{5}{4}}} = 86$$

The range is valid for "Francis turbine".

178. Ans : (d)

Sol. P = 7360 kW

H = 81 m

N = 500 rpm

$$N_s = \frac{N\sqrt{P}}{(H)^{\frac{5}{4}}} = \frac{500\sqrt{7360}}{(81)^{\frac{5}{4}}} = 177$$

The range is valid for "Francis turbine".

179. Ans : (a)

Sol. P = 1500 kW

N = 300 rpm

H = 150 m

$$N_s = \frac{300\sqrt{1500}}{(150)^{\frac{5}{4}}} = 22$$

N_s < 30, Hence Pelton wheel with one nozzle used.

180. Ans : (b)

Sol. $$N_s = \frac{400\sqrt{15000}}{(30)^{\frac{5}{4}}} = 698$$

The range is valid for "Kaplan turbine"

181. Ans : (b)

Sol. H = 20 m

N = 375 rpm

P = 400 kW

$$N_s = \frac{N\sqrt{P}}{(H)^{\frac{5}{4}}} = \frac{375\sqrt{400}}{(20)^{\frac{5}{4}}} = 177$$

The range is valid for "Francis turbine".

182. Ans : (d)

Sol. P = 1000 HP = 736 kW

H = 81 m

N = 500 rpm

$$N_{s_T} = \frac{500\sqrt{736}}{(81)^{\frac{5}{4}}} = 56$$

The range is valid for "Francis turbine".

183. Ans : (b)

Sol. $$N_{s_T} = \frac{320\sqrt{2500}}{16^{5/4}} = 500$$

185. Ans : (c)

Sol. Homologous and similar geometrical turbines should have same Specific speed.

$$N_{S_{Model}} = N_{S_{Prototype}}$$

$$\frac{N_m\sqrt{P_m}}{(H_m)^{5/4}} = \frac{N_p\sqrt{P_p}}{(H_p)^{5/4}}$$

187. Ans : (b)

Sol. $$N_s = \frac{N\sqrt{P}}{(H)^{5/4}} = 8.1$$

$$= \frac{N\sqrt{\frac{P}{6}}}{(H)^{5/4}} = 8.1 \qquad \left[\because \frac{N\sqrt{P}}{(H)^{5/4}} = 8.1\right]$$

$$N_s = \sqrt{\frac{1}{6}} \times 8.1$$

N_s =3.30

188. Ans : (a)

Sol. $$N_s = \frac{N\sqrt{P}}{(H)^{5/4}} = 9.3$$

$$= \frac{N\sqrt{\frac{P}{9}}}{(H)^{5/4}} = 9.3 \qquad \left[\because \frac{N\sqrt{P}}{(H)^{5/4}} = 9.3\right]$$

$$N_s = \sqrt{\frac{1}{9}} \times 9.3$$

N_s =3.10

189. Ans : (d)

Sol. Kaplan turbine is to be superior to other turbines from consideration of high power generation on account of better overall efficiency.

191. Ans : (b)

Sol. More efficiency under part load operation is observed in case of Kaplan turbine only.

192. Ans : (a)

Sol. Kaplan turbine → High – part load efficiency

Pelton wheel → Works in open atmosphere

Axial flow machine → High Sp. Speeds

Draft tube → Pressure head recovery

193. Ans : (b)

Sol. **Unit speed (N_U) :** It is defined as the speed of a water turbine working under a unit head

$$N_u = \frac{N}{\sqrt{H}} \qquad \therefore \frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$$

194. Ans : (b)

Sol. **Unit Discharge (Q) :** It is defined as the discharge passing through a turbine, which is working under a unit head.

$$Q_U = \frac{Q}{\sqrt{H}}$$

$$\therefore \frac{Q_1}{\sqrt{H_1}} = \frac{Q_2}{\sqrt{H_2}}$$

196. Ans : (c)

Sol. **Unit Power (P_u) :** It is defined as the power developed by a turbine, working under a unit head.

$$P_u = \frac{P}{H^{\frac{3}{2}}}$$

$$\therefore \frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}}$$

199. Ans : (c)

Sol. $P \propto H^{\frac{3}{2}}$

200. Ans : (c)

Sol. P = 1750 kW

H = 100 m

Unit power,

$$P_u = \frac{P}{H^{\frac{3}{2}}} = \frac{1750}{(100)^{\frac{3}{2}}} = 1.75 \text{ kW}$$

201. Ans : (c)

Sol. $P_u = \frac{10}{(25)^{3/2}} = 0.08 \text{ kW}$

202. Ans : (d)

Sol. $P_u = \frac{P}{H^{3/2}} = \frac{540}{(36)^{3/2}} = 2.5 \text{ kW}$

203. Ans : (a)

Sol. Q = 400 m^3/sec

H = 120 m

$$Q_u = \frac{Q}{\sqrt{H}} = \frac{400}{\sqrt{120}} = 36.5 \ \ m^3/\text{sec}$$

204. Ans : (a)

Sol. $N.D \propto \sqrt{H}$

$A \propto D^2\sqrt{H} \propto D^3N \qquad \therefore Q \propto N$

205. Ans : (b)

Sol. $N_u = \frac{N}{\sqrt{H}}$

206. Ans : (a)

Sol. $N_u = \frac{N}{\sqrt{H}}$

207. Ans : (b)

Sol. P = 600 kW, H = 30 m, N = 450 rpm

$$N_u = \frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$$

$$\frac{450}{\sqrt{30}} = \frac{N_2}{\sqrt{24}}$$

N_2 = 403 rpm

$$P_u = \frac{P_1}{(H_1)^{3/2}} = \frac{P_2}{(H_2)^{3/2}}$$

$$\frac{600}{(30)^{3/2}} = \frac{P_2}{(24)^{3/2}}$$

P_2 = 429 kW

208. Ans : (b)

Sol. $P_u = \frac{P}{H^n}$

Where, $n = \frac{3}{2} = 1.5$

209. Ans : (d)

Sol. Turbine constants like N_u, Q_u and P_u are used to plot performance curves.

210. Ans : (a)

Sol. Curved vanes are preferred over flat vanes in hydraulic machines due to advantage of more energy transfer possible between working fluid and contact surface.

211. Ans : (a)

Sol. Operating characteristic curves of a turbine are plotted when the speed on the turbine is constant; N and H are constant and variation of power (P) and efficiency η() with respect to discharge (Q) are plotted.

213. Ans : (b)

Sol. Characteristic curves of a turbine means main characteristic curves only. These curves are plotted by maintaining a constant head. Speed of the turbine varies by changing load on the turbine.

214. Ans : (c)

Sol. In impulse turbine, water impinges on the bucket with K.E. Pressure of flowing fluid remains unchanged (i.e. in open atmosphere). In reaction turbine, water glids over the moving vanes with P.E. Pressure of flowing fluid decreases after gliding over the vanes.

216. Ans : (a)

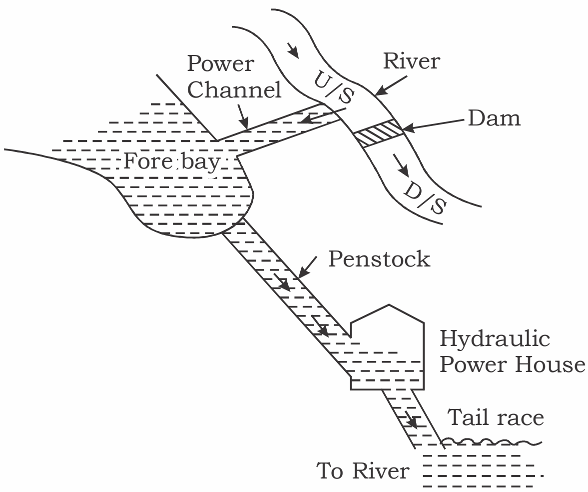
Sol. Cavitation in a hydraulic machine like water turbine causes erosion on the surface of runner, high frequency waves produces noise & vibrations.

220. Ans : (c)

Sol. Forebay tank (or) reservoir forms the connection between the power channel and the penstock. It also serve as a reservoir to store water. When hydel plant is located at base of the dam, no forebay is required because reservoir acts as forebay.

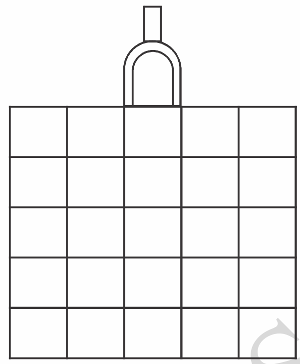
Ex : Nagarjuna sagar project does not have fore bay.

When plants are located away form the storage reservoir forebay is needed. Forebay provides steady and continuous water flow into the penstock/ turbine



221. Ans : (a)

Sol.



Trash rack : Is a metal frame provide in front portion of sluice gate of penstock to keep out debris and not to allow floating and suspended materials into penstock.

222. Ans : (b)

Sol. **Pondage :** Small water storage behind weir of run-of-river hydel plants. It is less storage than reservoir less dams.

Weir : Weir is necessary for surplus water to pass over it.

Dam : Dam is necessary for build the head of water.

223. Ans : (a)

Sol. Pumbp storage plant turbine is used during peak terms of electrical power demand and later same turbine is used as pump to lift water from tail race to reservoir with help of power from other source i.e. thermal energy generated electrical power.

224. Ans : (b & c)

Sol. **Base power :** It is power consistently generate the electric power needed to satisfy minimum demand. This is the minimum level of demand on an electrical grid over 24 hours. For India, base power is thermal power.

Firm Power (or) Primary power :

This power is always available and corresponds tot he minimum water stream flow and adverse hydrologic conditions in a river. Firm power can be defined as **the minimum power which can be generated throughout the year.** By providing storage of water the firm power can be increased considerably.

Installed capacity : It is the maximum power generation can produce under available specific conditions at site. Installed capacity is the amount of electric energy that a hydel power station is able to produce under specific conditions.

225. Ans : (a)

Sol. A common fault that arises in a hydraulic system is air lock.

229. Ans : (a)

Sol. Load factor is the ratio of average load on the hydal plant during the period considered.

232. Ans : (b)

Sol. t_a= 4.5 sec

v = 1500 m/s

l = 3000 m

$$t_c = \frac{2L}{C} = \frac{2\times3000}{1500} = 4\,\text{sec}$$

$t_a > t_c$ Slow closure

233. Ans : (No answer)

Sol. $P = \eta_0 \times \rho g Q H$

$P = 0.91\times9810\times35\times9$

P = 2812.03 kW

234. Ans : (a)

Sol. $\eta_d = \dfrac{V_1^2 - V_2^2}{V_1^2}$

V_2= 5 m/sec

$$0.75 = \frac{(10)^2 - V_2^2}{(10)^2}$$

$$\boxed{\frac{P_1}{\rho g} = \frac{P_a}{\rho g} - H_S - \left(\frac{V_1^2 - V_2^2}{2g} - h_f\right)}$$

$$= 10.3 - 1.82 - \left[\frac{(10)^2 - (5)^2}{2\times9.81} - 0\right]$$

= 4.65 –10.30

= – 5.65 m

235. Ans : (a)

Sol. In a pelton wheel,

The component of absolute velocities,

$V_{w_1} = V_1$

$V_1 = C_v\sqrt{2gh}$

C_v = 0.98

h = 30 m

$V_1 = 0.98\sqrt{2\times9.81\times30}$

= 23.78 m/s

= 2378 cm/s

19 CENTRIFUGAL PUMPS

01. Ans : (c)

Sol. → Centrifugal pump adds energy to fluid.

→ Turbine extracts energy from fluid

→ Reciprocating pump works on reciprocating action to lift liquid

06. Ans : (a)

Sol. It is the method of removing air and any gases entrapped in suction pipe & casing of pump.

07. Ans : (b)

Sol. Priming of a centrifugal pump :

"Priming" is the process of filling the suction pipe, casing and the delivery pipe upto the delivery valve by the liquid which is to be pumped. Priming is required in order to drive out the air voids present, which otherwise would make the operation of the pump imparted by the centrifugal pump is proportional to the density of the liquid and if any air pocket exist in the casing, then only negligible amount of pressure would be generated. This pressure might not be sufficient for lifting of the liquid. Hence priming becomes essential in case of centrifugal pump does not create suction at the start without filling of impeller with water. This is especially required where there is first start up. Reciprocating pump is a self primed pump.

08. Ans : (c)

Sol. The centrifugal force induced due to forced vortex and this centrifugal force increases the pressure energy of the liquid in the casing.

09. Ans : (b)

Sol. The liquid enters the centrifugal pump impeller radially at inlet for best efficiency of the pump which means the absolute velocity of water at inlet makes an angle of 90° with the direction of motion of the impeller at inlet. Hence $\alpha = 90°$, and $V_{w1} = 0$

13. Ans : (b)

Sol. In centrifugal pump, regulating valve i.e. discharge valve is provided on delivery pipe

14. Ans : (c)

Sol. A centrifugal pump can be used to work on a fluid which is to be compressed to increase pressure of it is called compressor

Ex : Air compressor

15. Ans : (b)

Sol. In a centrifugal pump, the water enters the impeller radially and leaves the vanes radially ($\alpha = 90°$, $V_{w1} = 0$, $V_{f1} = V_1$)

21. Ans : (c)

Sol. $$\eta_o = \frac{\text{Output power}}{\text{Input power}} = \frac{\rho.g.Q.H \text{ (watt)}}{P \text{ (watt)}}$$

$$\eta_o = \frac{w.Q.H}{P}$$

In metric units (1HP = 75 kgf-m/sec)

$$\eta_o = \frac{wQH}{75.(HP)}$$

23. Ans : (c)

Sol. $\eta_o = \frac{\text{Output power of pump}}{\text{Input power of pump}}$

$= \frac{\text{water power}}{\text{shaft power}}$

35. Ans : (c)

Sol. It is defined as the sum of the actual lift+the friction losses in the pipes + the discharge velocity head

$$H_m = H + h_f + \frac{V_d^2}{2g}$$

$$= \frac{p_2 - p_1}{\rho g} + \frac{V_2^2 - V_1^2}{2g}$$

Manometric head is defined as its head against which a centrifugal pump has to work. If suction pipe & delivery pipe velocities neglected, $H_m = \frac{p_2 - p_1}{\rho g}$

37. Ans : (a)

Sol. H = 40 m

h_f = 4 m

η = 100%

W.D by pump = $H + h_f$

= 40 + 4 = 44 m

Note : In case of turbine, W.D = H – h_f

38. Ans : (b)

Sol. Work done by pump impeller

= Manometric head + Losses

39. Ans : (b)

Sol. Head developed by a centrifugal pump is functioning impeller size and its speed

$$H_m = \frac{V_{w_2} U_2}{g} = \frac{V_{w_2} \frac{\pi DN}{60}}{g}$$

40. Ans : (a)

Sol. Water power of a centrifugal Pump

= Impeller power + Power lost in pump

41. Ans : (b)

Sol. W.D by impeller of Centrifugal pump/ Newton weight of fluid/sec

$\frac{v_{w_2} u_2}{g}$ (meters)

(for shock less flow at inlet)

42. Ans : (b)

Sol. Power of pump (P) = ρg Q (H + h_f)

P = $\rho g Q$ (H + h_f)

= 1000×9.81 × 0.1 × (10 + 5)

=1500×9.81N-m/sec

= 1500 kg-m/sec

43. Ans : (b)

Sol. P = $\rho g Q$ (H + h_f)

$= 1000 \times 10 \times \frac{6}{60} \times (12+5)$

= 1000 × 10 × 0.1 × 17

= 17000W

= 17 KW

44. Ans : (d)

Sol. $\eta = \frac{\text{Water Power}}{\text{Shaft Power}}$

$$\eta = \frac{\rho g Q H}{P_{shaft}}$$

$$0.64 = \frac{1000 \times 9.81 \times 32.6 \times 10^{-3} \times 25}{P_{shaft}}$$

P_{shaft} = 12.49 kW

$\simeq$ 12.5 kW

45. Ans : (d)

Sol. Power, $P = \rho g Q.H$

$7.5 \times 1000 = 1000 \times 9.81 \times (50\times10^{-3}) \times H$

$\therefore H = 15.29$ m

46. Ans : (a)

Sol. Power, $P = \rho g\ QH$

$$4.9 \times 10^3 = 1000 \times 9.81 \times \left(\frac{3}{60}\right) \times H$$

$$H = 9.98 \simeq 10 \text{ m}$$

47. Ans : (a)

Sol. $P = \rho g\ Q\ (H + h_f)$

$14.72 \times 10^3 = 1000 \times 9.81 \times 0.1\ (10 + h_f)$

$h_f = 5$ m

48. Ans : (c)

Sol. Specific speed, $N_s = \dfrac{N\sqrt{P}}{H^{3/4}}$

$$30 = \frac{1450\sqrt{0.2}}{H^{3/4}}$$

H = 60 m

Number of pumps required

$$\frac{\text{Total head}}{\text{Head Developed by each pump}} = \frac{180}{60} = 3$$

49. Ans : (c)

Sol. $Q = A_f \cdot V_f$

= flow area × flow velocity

$Q = \pi D_1 . B_1 . V_{f_1} = \pi D_2 B_2 V_{f_2}$

51. Ans : (a)

Sol. $$\eta_{mano} = \frac{\text{Manometric head}}{\text{Head imparted by impeller}}$$

$$= \frac{H_m}{\frac{V_{w_2}.U_2}{g}} = \frac{g.H_m}{V_{w_2}.U_2}$$

52. Ans : (d)

Sol. Manometric head in case of a centrifugal pump (H_m) :

In different form : -

Manometric head is defined as the head against which a centrifugal pump has to work :

1. H_m = Head Imparted by the impeller to the liquid – Loss of head in the pump

$\dfrac{V_{w_2}.U_2}{g}$ – [Loss of head in impeller and casing]

2. H_m = Total head at outlet of the pump – Total head at the inlet of the pump

$$H_m = \left(\frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2\right) - \left(\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1\right)$$

Suffix 1 & 2 denotes inlet and outlet of pump

3. $H_m = (h_f + h_{fs}) + (h_d + h_{fd}) + \dfrac{V_d^2}{2g}$

= Static head + Frictional head loss in Suction pipe + Delivery head + Frictional head loss in delivery pipe + Velocity head in the delivery pipe

53. Ans : (a)

Sol. Static head is the sum of suction height and delivery lift.

55. Ans : (c)

Sol. A centrifugal pump starts deliver liquid when pressure head rise by impeller ≥ manometric head.

56. Ans : (a)

Sol. Power required to drive pump

$$= \frac{\rho.Q.H}{\eta} \quad \text{(metric Units)}$$

57. Ans : (d)

Sol. For best efficiency, the vane exit angle is about 25° to 30°

58. Ans : (d)

Sol. P = 15 HP

H_1 = 36 m

N_1 = 1500 rpm

N_2 = 1000 rpm

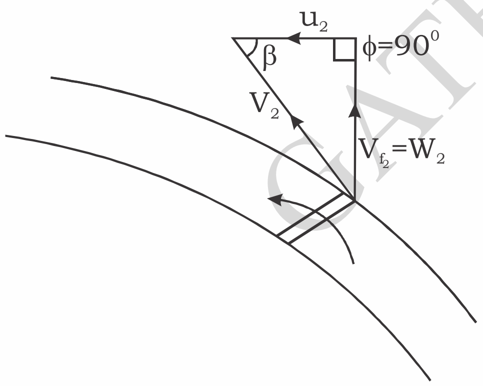
H_2 = ?

Head coefficient $\frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$

$$H_2 = H_1 \times \left(\frac{N_2}{N_1}\right)^2 = 36\left(\frac{1000}{1500}\right)^2 = 16 \text{ m}$$

59. Ans : (d)

Sol. Radial flow pump



NOTE : In the given material the given option 'c' was incorrect.

60. Ans : (c)

Sol. Specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver one cubic metre of liquid per second against a head of one meter

$$N_S = \frac{N\sqrt{Q}}{(H)^{3/4}}$$

Where N = speed of the impeller in rpm

Q = Discharge through pump (in m^3/sec)

H = Head developed by pump (in meters)

63. Ans : (b)

Sol. $N_S = \frac{N\sqrt{Q}}{H^{0.75}}$

65. Ans : (d)

Sol. $N_S = \frac{N\sqrt{Q}}{H^{3/4}}$

67. Ans : (c)

Sol. Q = 750 *l*t/sec

= 0.75 m^3/sec

H = 15 m

N = 725 rpm

$$N_S = \frac{N\sqrt{Q}}{(H)^{3/4}} = \frac{725\sqrt{0.75}}{(15)^{3/4}} = 82.4 \text{ rpm}$$

68. Ans : (d)

Sol.

Pump	**Speed (N)**	**Sp – speed(N_{sp})**
Radial flow	Slow	10 – 30
	Medium	30 – 50
	High	50 – 80
Mixed flow		80 – 160
Axial flow		160 – 500

73. Ans : (b)

Sol. Q = 100 lit/sec

= 0.1 m^3/sec

H = 25 m

N = 1450 rpm

$$N_S = \frac{N\sqrt{Q}}{(H)^{3/4}} = \frac{1450 \times \sqrt{0.1}}{(25)^{3/4}} = 41$$

Specific speed is same for homologous pumps

74. Ans : (a)

Sol. Q = 40 m^3/sec; N = 1500 rpm; H = 25 m

$$N_S = \frac{N\sqrt{Q}}{(H)^{3/4}} = \frac{1500\sqrt{40}}{(25)^{3/4}} = 848.5$$

75. Ans : (a)

Sol. $$N_S = \frac{1440\sqrt{0.04}}{(16)^{3/4}} = 36$$

76. Ans : (a)

Sol. $$N_S = \frac{1450\sqrt{44}}{(36)^{3/4}} = 654$$

80. Ans : (b)

Sol. Q = 150 lit/sec = 0.15 m^3/sec

H = 45 m

N = 1750 rpm

$$N_S = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1750\sqrt{0.15}}{(45)^{3/4}} = 39$$

83. Ans : (b)

Sol. For pumps

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{T^{-1}\sqrt{L^3T^{-1}}}{L^{3/4}}$$

$$= M^0L^{3/4}T^{-3/2}$$

89. Ans : (c)

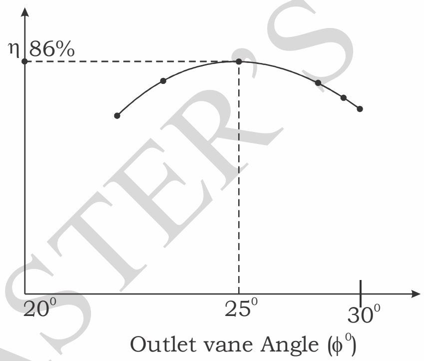
Sol. Overall efficiency of a centrifugal pump usually fall into the 50 – 70% range.

93. Ans : (b)

Sol. Inlet angle of Centrifugal pump impeller is designed such that no shock entry of water for which absolute velocity in radial direction ($V_1 = V_{f1}$) ($\alpha = 90°$)

94. Ans : (b)

Sol. Optimum vane angle at exit of a centrifugal pump



Maximum performance, efficiency at the outlet vane angle 20° – 25°, with six Vanes

95. Ans : (c)

Sol. Suddenly failure of delivering the liquid by a centrifugal pump means possibility of air entered into suction pipe.

96. Ans : (b)

Sol. From speed coefficient of centrifugal pump

$$N \propto \sqrt{H} \qquad \left[\text{speed} \propto \sqrt{\text{Head}}\right]$$

97. Ans : (b)

Sol. Different coefficient in case of centrifugal pump

1. Head coefficient = $\frac{N.D}{\sqrt{H}}$

2. Discharge coefficient = $\frac{Q}{D^2.\sqrt{H}} = \frac{Q}{D^3.N}$

3. Power coefficient $= \frac{p}{D^2.H^{3/2}} = \frac{p}{D^5N^3}$

From above, for given size of impeller

$Q \propto N$

$Q \propto D^3$

$H \propto N^2$

$H \propto D^2$

$P \propto N^3$ $\therefore$ Option (b) is wrong

100. Ans : (c)

Sol. Water flow leaves the impeller inside closing is forced vortex, where in casing free vortex.

101. Ans : (c)

Sol. $\frac{P}{D^5N^3} =$ Constant

$P \propto N^3$

Power $\propto$ (Impeller speed)^3

104. Ans : (c)

Sol. Mechanical defects like coupling broken, coupling bolts loose (or) Bearing damage, misalignment pump shaft causes noise in operation of a pump

105. Ans : (c)

Sol. Manometric head of a Centrifugal pump running at speed (N) and giving a discharge (Q) may be written as

$H = AN^2+BNQ+CQ^2$

Where A,B and C are constants.

106. Ans : (d)

Sol. $\frac{P}{D^5N^3} =$ Constant

$P \propto D^5$

$$\frac{P_{prototype}}{P_{model}} = \left(\frac{D_{prototype}}{D_{model}}\right)^5$$

$P_{prototype} = 20 \times (2)^5 = 640$ kW

107. Ans : (b)

Sol. (At sea level the suction head of C.P is 10.3 meter head of water)

In really the suction head of C.P is limited to about 8m.

108. Ans : (a)

Sol. $NPSH = H_{atm} - H_{vapour} - H_s - h_f$

$= 9.8 - 0.4 - 5 - 0.6$

$= 9.8 - 6 = 3.8$ m

110. Ans : (a)

Sol. Methods to avoid cavitation in centrifugal pump

1. Increase the pressure at the suction of the pump.
2. Increase NPSH by decreasing the temperature of the liquid being pumped.
3. Head losses in the suction pipe should be reduced. (increasing suction pipe diameter, reduces no of elbows, valves and fittings in pipe, decrease length of pipe)
4. Reduce flow rate through a pump by throttling a discharge valve decreases NPSH
5. Reduce the speed of impeller for limited applications
6. Increase diameter of the eye of the impeller
7. Use two low capacity pumps in parallel.
8. Use booster pump to feed the principle pump.

112. Ans : (a)

Sol. Cavitation factor of a centrifugal pump (σ_c): It is the ratio of NPSH to H (Manometric head)

$$\therefore \sigma_c = \frac{NPSH}{H} = \frac{H_1}{H}$$

113. Ans : (a)

Sol. An axial flow pump (a type of centrifugal pump) is useful in flood dewatering applications where large quantities of water need to be moved and irrigation purpose.

115. Ans : (b)

Sol. Semi-open impeller is used for trash and debris laden liquids pumping.

116. Ans : (a)

Sol. Cavitation parameter,

$$\sigma = \frac{NPSH}{H}$$

$$\sigma = \frac{5}{20} = \frac{1}{4} = 0.25$$

125. Ans : (b)

Sol. $U_1 = \frac{\pi D_1 N}{60} = 12.56$

$$U_2 = \frac{\pi D_2 N}{60} = 25.13$$

126. Ans : (c)

Sol. $Q = \pi D_2 B_2 V_{f2}$

$= \pi \times 0.5 \times 0.05 \times 2.5$

$= 0.1963 \text{ m}^3/\text{sec}$