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FLUID MECHANICS & TURBOMACHINERY

Volume - I : Study Material with Classroom Practice Questions

Fluid Mechanics & Turbomachinery

Solutions for Vol – I _ Classroom Practice Questions

Chapter- 1
Properties of Fluids

01. Ans: (d)

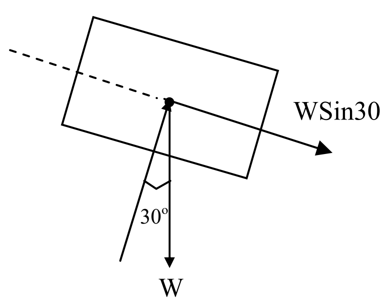
02. Ans: (c)

03. Ans: 100

Sol: $\tau = \frac{\mu V}{h} = \frac{0.2 \times 1.5}{3 \times 10^{-3}} = 100 \text{ N/m}^2$

04. Ans: 1

Sol:



$$F = \tau \times A$$

$$W \sin 30 = \frac{\mu A V}{h}$$

$$\frac{100}{2} = \frac{1 \times 0.1 \times V}{2 \times 10^{-3}}$$

$$V = 1 \text{m/s}$$

Common data Q. 05 & 06

05. Ans: (c)

Sol: $D_1 = 100\text{mm}$, $D_2 = 106\text{mm}$

Radial clearance,

$$h = \frac{D_2 - D_1}{2}$$

$$= \frac{106 - 100}{2} = 3\text{mm}$$

$L = 2\text{m}$

$\mu = 0.2$ pa.s

$N = 240$ rpm

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 240}{60}$$

$$\omega = 8\pi$$

$$\tau = \frac{\mu \omega r}{h} = \frac{0.2 \times 8\pi \times 50 \times 10^{-3}}{3 \times 10^{-3}}$$

$$= 83.77 \text{N/m}^2$$

06. Ans: (b)

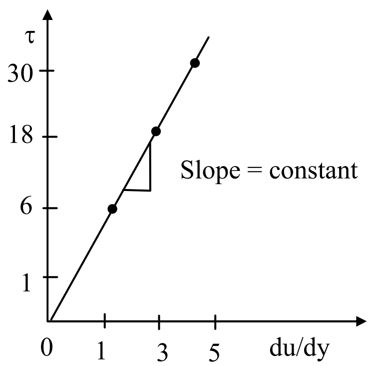
Sol: $\text{Power}, P = \frac{2\pi\omega^2 \mu L r^3}{h}$

$$= \frac{2\pi \times (8\pi)^2 \times 0.2 \times 2 \times (0.05)^3}{3 \times 10^{-3}}$$

$$= 66 \text{ Watt}$$

07. Ans: (c)

Sol:



∴ Newtonian fluid

08. Ans: (d)

Sol: $\tau = \mu \dfrac{du}{dy}$

$u = 3\sin(5\pi y)$

$$\frac{du}{dy} = 3\cos(5\pi y) \times 5\pi = 15\pi\cos(5\pi y)$$

$$\tau\big|_{y=0.05} = \mu \frac{du}{dy}\bigg|_{y=0.05}$$

$$= 0.5 \times 15\pi\cos(5\pi \times 0.05)$$

$$= 0.5 \times 15\pi \times \cos\left(\frac{\pi}{4}\right) = 0.5 \times 15\pi \times \frac{1}{\sqrt{2}}$$

$$= 7.5 \times 3.14 \times 0.707 \approx 16.6 \text{ N/m}^2$$

$$\tau\big|_{y=0.12} = 0.5 \times 15\pi\cos(5\pi \times 0.12)$$

$$= 7.5 \times \pi\cos\left(5\pi \times \frac{3}{25}\right)$$

$$= 7.5 \times \pi\cos\left(\frac{3\pi}{5}\right)$$

Which is negative, so zero shear stress

09. Ans: (c)

10. Ans: (d)

11. Ans: (a)

12. Ans: (d)

Ans: Viscosity in liquids decreases and in gases it increases with rise in temperature.

13. Ans: (d)

Ans: Blood is a pseudo plastic fluid. So statement I is wrong.

14. Ans: (b)

15. Ans: (b)

Sol: $V = 0.01 \text{ m}^3$

$\beta = 0.75 \times 10^{-9} \text{ m}^2/\text{N}$

$dp = 2 \times 10^7 \text{ N/m}^2$

$$K = \frac{1}{\beta} = \frac{1}{0.75 \times 10^{-9}} = \frac{4}{3} \times 10^9$$

$$K = \frac{-dp}{dV/V}$$

$$dV = \frac{-2 \times 10^7 \times 10^{-2} \times 3}{4 \times 10^9} = -1.5 \times 10^{-4}$$

16. Ans: 320 Pa

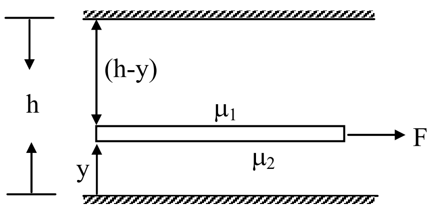
Sol: $\Delta P = \dfrac{8\sigma}{D} = \dfrac{8 \times 0.04}{1 \times 10^{-3}} = \dfrac{32 \times 10^{-2}}{10^{-3}}$

$\Delta P = 320 \text{ N/m}^2$

Conventional Questions which can be asked as objective Questions

01.

Sol:



Assumptions:

- Thin plate has negligible thickness.
- Velocity profile is linear because of narrow gap.
- Given fluid is a Newtonian fluid which obeys Newton's law of viscosity.

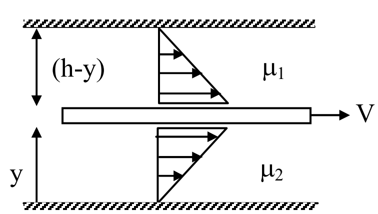
The force required to pull it is proportional to the total shear stress imposed by the two oil layers.

$$F = F_1 + F_2,$$

Where F_1 = Force on top sides of plate,

F_2 = Force on bottom side of plate

The plate moves with velocity V



From Newton's law of viscosity,

$$\tau = \frac{\mu du}{dy} \qquad \text{Let A be area of plate}$$

$$\therefore F_1 = \tau_1 \times \text{Area of plate}$$

$$F_1 = \mu_1 \times \frac{V}{h-y} \times A$$

$$F_2 = \mu_2 \times \frac{V}{y} \times A$$

(i) Shear force on two sides of the plate are equal:

$$F_1 = F_2$$

$$\frac{\mu_1 \times VA}{h-y} = \frac{\mu_2 VA}{y}$$

$$\frac{\mu_1}{\mu_2} = \frac{h-y}{y}$$

$$\frac{h}{y} = \frac{\mu_1}{\mu_2} + 1$$

$$\frac{h}{y} = \frac{\mu_1 + \mu_2}{\mu_2}$$

$$y = \frac{\mu_2 h}{\mu_1 + \mu_2}$$

(ii) The position of plate so that pull required to drag the plate is minimum.

$F = \dfrac{\mu_1 VA}{h-y} + \dfrac{\mu_2 VA}{y}$, V, A, μ_1 & μ_2 , h are constant

For minimum force, $\dfrac{dF}{dy} = 0$

$$-\mu_1 VA(h-y)^{-2}(-1) - \mu_2 VAy^{-2} = 0$$

$$\frac{\mu_2 VA}{y^2} = \frac{\mu_1 VA}{(h-y)^2}$$

$$\frac{(h-y)^2}{y^2} = \frac{\mu_1}{\mu_2}$$

$$\frac{h-y}{y} = \sqrt{\frac{\mu_1}{\mu_2}}$$

$\frac{h}{y} = 1 + \sqrt{\frac{\mu_1}{\mu_2}}$ where y is the distance of the thin flat plate from the bottom flat surface.

$$y = \frac{h}{1+\sqrt{\frac{\mu_1}{\mu_2}}}$$

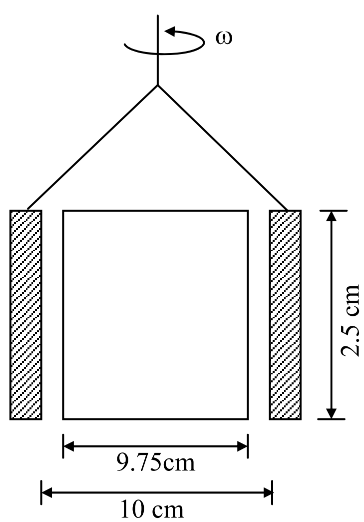
02. Ans: 8.105 Pa. S

Sol: Torque = 1.2N-m

Speed, N = 90 rpm

Diameter, D_1 = 10 cm , D_2 = 9.75 cm

H = 2.5cm



Assumptions:

- The gap between two cylinders is narrow and hence velocity profile in the gap is assumed linear.
- No change in properties

Torque = Tangential force × radius

Force = shear stress×Area

$$= \frac{\mu \times VA}{h}$$

Where h is the clearance (radial)

$$h = \frac{10-9.75}{2}$$

$$= 0.125\text{cm} = 1.25\times10^{-3}\text{m}$$

Area = πDL

$$= \pi\times0.1\times2.5\times10^{-2}$$

$$= 7.8539\times10^{-3}\text{m}^2$$

$$F_s = \frac{\mu\times\omega r\times A}{h}$$

$$\omega = \frac{2\pi N}{60} = \frac{2\pi\times90}{60} = 3\pi \text{ rad/s}$$

Torque = $F_s\times r$

$$= \frac{\mu\omega r A}{h}\times r$$

$$= \frac{\mu\omega r^2}{h}\times A$$

$$1.2 = \frac{\mu\times3\pi\times(0.05)^2\times7.8539\times10^{-3}}{1.25\times10^{-3}}$$

$$\mu = 8.105 \text{ Pa.s}$$

Chapter- 2
Pressure Measurement & Fluid Statics

01. Ans: (a)

Sol: 1 millibar = $10^{-3}\times10^{5}$

$= 100\ N/m^2$

One mm of Hg = $13.6\times10^{3}\times9.81\times1\times10^{-3}$

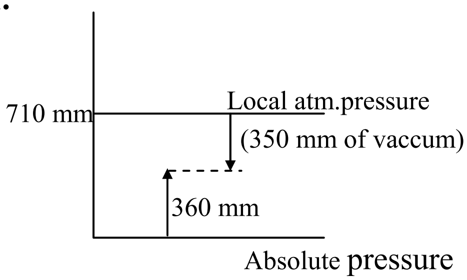
$= 133.416\ N/m^2$

$1\ N/mm^2 = 1\times10^{6}\ N/m^2$

$1\ kgf/cm^2 = 9.81\times10^{4}\ N/m^2$

02. Ans: (b)

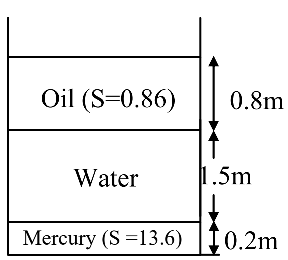
Sol:



03. Ans: (c)

04. Ans: 48.147

Sol:



$P_{bottom} = \rho_{oil}gh_{oil} + \rho_w gh_{water} + \rho_{Hg}gh_{Hg}$

$= (860\times9.81\times0.8)+(9810\times1.5)+(13600\times9.81\times0.2)$

$= 48147.48$ Pa

$P_{bottom} = 48.147$ kPa

05. Ans: (b)

06. Ans: 2.2

Sol: h_p in terms of oil

$s_o h_o = s_m h_m$

$0.85\times h_0 = 13.6\times0.1$

$h_0 = 1.6m$

$h_p = 0.6+1.6 \Rightarrow h_p = 2.2m$ of oil

(or)

$P_p - \gamma_{oil}\times0.6 - \gamma_{Hg}\times0.1 = P_{atm}$

$$\frac{P_p - P_{atm}}{\gamma_{oil}} = \left(\frac{\gamma_{Hg}}{\gamma_{oil}}\times0.1+0.6\right)$$

$$= \frac{13.6}{0.85}\times0.1+0.6 = 2.2 \text{ m of oil}$$

Gauge pressure of P in terms of m of oil

$= 2.2$ m of oil

07. Ans: 750

Sol: $P_{atm}+\rho_w gh_w = P_{atm}+\rho_0 gh_0$

$1000\times6\times10^{-2} = \rho_0\times8\times10^{-2}$

$\rho_0 = 750\ kg/m^3$

08. Ans: (b)

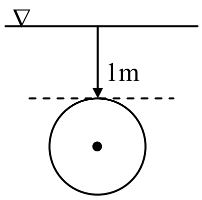
Sol: $$h_M - \frac{s_w}{s_0}h_{w_1} = h_N - \frac{s_w h_{w_2}}{s_0} - h_0$$

$$h_M - h_N = \frac{9}{0.83} - \frac{18}{0.83} - 3$$

$$h_M - h_N = -13.843 \text{ cm of oil}$$

09. Ans: 2.125

Sol:



$$h_P = \bar{h} + \frac{I}{A\bar{h}}$$

$$= 2 + \frac{\pi D^4 \times 4}{64 \times D^2 \times 2 \times \pi}$$

$$= 2 + \frac{2^2 \times 4}{64 \times 2} = 2.125\text{m}$$

10. Ans: 61.6

Sol: $F = P \times A$

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

$$= 9810 \times 2 \times \frac{\pi}{4} \times 2^2 = 61.6 \text{ kN}$$

11. Ans: 10

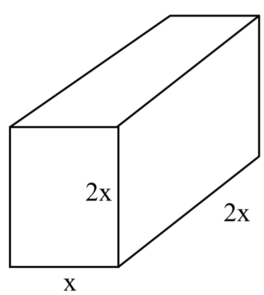
Sol: $F = \rho g \bar{h} A$

$$= 9810 \times 1.625 \times \frac{\pi}{4}\left(1.2^2 - 0.8^2\right)$$

$$F = 10\text{kN}$$

12. Ans: 1

Sol:



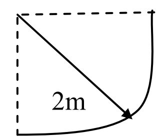
$$F_{bottom} = \rho g \times 2x \times 2x \times x$$

$$F_V = \rho g x \times 2x \times 2x$$

$$\frac{F_B}{F_V} = 1$$

13. Ans: 10

Sol:



$$F_V = x \times \pi$$

$$F_V = \rho g V = 1000 \times 10 \times \frac{\pi \times 2^2}{4}$$

$$F_V = 10\pi \text{ kN}$$

$$\therefore\ x = 10$$

14. Ans: (d)

Sol: $F_{net} = F_{H1} - F_{H2}$

$$F_{H1} = \gamma \times \frac{D}{2} \times D \times 1 = \frac{\gamma D^2}{2}$$

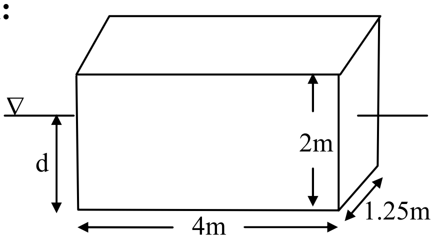
$$F_{H2} = \gamma \times \frac{D}{4} \times \frac{D}{2} \times 1 = \frac{\gamma D^2}{8}$$

$$= \gamma D^2\left(\frac{1}{2} - \frac{1}{8}\right) = \frac{3\gamma D^2}{8}$$

Chapter- 3
Buoyancy and Metacentric Height

01. Ans: (d)

Sol:



$$F_B = \text{weight of body}$$

$$\rho_b g V_b = \rho_f g V_f d$$

$$640\times4\times2\times1.25 = 1025\times(4\times1.25\times d)$$

$$d = 1.248\text{m}$$

$$V_{fd} = 1.248\times4\times1.25$$

$$V_{fd} = 6.24\text{m}^3$$

02. Ans: (c)

Sol: Surface area of cube $= 6a^2$

Surface area of sphere $= 4\pi r^2$

$4\pi r^2 = 6a^2$

$$\frac{2\pi}{3} = \left(\frac{a}{r}\right)^2$$

$F_{b,s} \propto V_s$

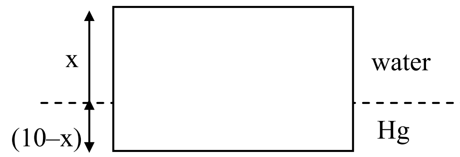
$$= \frac{\frac{4}{3}\pi r^3}{a^3} = \frac{4}{3}\frac{\pi r^3}{\left(r\sqrt{\frac{2\pi}{3}}\right)^3}$$

$$= \frac{4}{3}\frac{\pi r^3}{\left(\sqrt{\frac{2\pi}{3}}\times\sqrt{\frac{2\pi}{3}}r^3\right)} = \sqrt{\frac{6}{\pi}}$$

03. Ans: 4.76

Sol: $F_B = F_{B,Hg} + F_{B,W}$

$W_B = F_B$



$$\rho_b g V_b = \rho_{Hg} g \forall_{Hg} + \rho_w g \forall_w$$

$$\rho_b V_b = \rho_{Hg} \forall_{Hg} + \rho_w \forall_w$$

$$S\times V_b = S_{Hg}\forall_{Hg} + S_w \forall_w$$

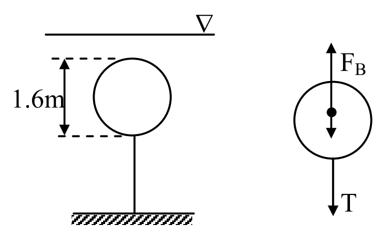
$$7.6\times10^3 = 13.6\times10^2(10-x)+10^2\times x$$

$$-6000 = -1260x$$

$$x = 4.76 \text{ cm}$$

04. Ans: 11

Sol:



$$F_B = W + T$$

$$W = F_B - T$$

$$= \rho_f g V_{fd} - T$$

$$= 10^3\times9.81\times\frac{4}{3}\pi(0.8)^3 - \left(10\times10^3\right)$$

$$= 21 - 10$$

$$W = 11 \text{ kN}$$

05. Ans: 1.375

Sol: $W_{water} = 5N$

$W_{oil} = 7N$

$S = 0.85$

W – Weight in air

$F_{B1} = W - 5$

$F_{B2} = W - 7$

$W - 5 = \rho_1 g V_{fd}$.....(1)

$W - 7 = \rho_2 g V_{fd}$.....(2)

$V_{fd} = V_b$

$$W - 5 = \rho_1 g V_b$$
$$W - 7 = \rho_2 g V_b$$
$$2 = (\rho_1 - \rho_2) g V_b$$

$$V_b = \frac{2}{(1000 - 850)9.81}$$

$V_b = 1.3591\times10^{-3} m^3$

$W = 5 + (9810\times1.3591\times10^{-3})$

$W = 18.33N$

$W = \rho_b g V_b$

$$\frac{18.33}{9.81\times1.3591\times10^{-3}} = \rho_b$$

$\rho_b = 1375.05\ kg/m^3$

$S_b = 1.375$

06. Ans: (d)

07. Ans: –14

Sol: GM = BM – BG

$$BM = \frac{I}{V} = \frac{3\times(1)^3}{12\times3\times1\times0.75}$$

$$BM = \frac{4}{12\times3}, BG = \frac{1}{2} - \frac{3}{8} = \frac{1}{8}$$

$$BM = \frac{1}{9}$$

$$GM = \frac{1}{9} - \frac{1}{8}$$

GM = – 13.8 mm ≈ – 14 mm

08. Ans: (b)

Sol: $W = F_B$

$\rho_b g V_b = \rho_f g V_{fd}$

$\rho_b V_b = \rho_f V_{fd}$

$$0.6\times\frac{\pi}{4}d^2\times2d = 1\times\frac{\pi}{4}d^2\times x$$

$x = 1.2d$

GM = BM – BG

$$BM = \frac{I}{V} = \frac{\pi d^4}{64\times\frac{\pi}{4}d^2\times1.2d} = \frac{d}{19.2}$$

BG = d–0.6d = 0.4d

GM < 0 unstable

09. Ans: 20s

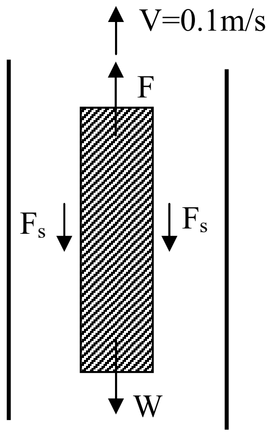
Sol: $$T = 2\pi\sqrt{\frac{k^2}{g(GM)}}$$

$$= 2\pi\sqrt{\frac{(7.72)^2}{9.81\times0.6}}$$

T = 20s

10. Ans:

Sol:



The thickness of the oil layer is same on either side of plate

y = thickness of oil layer

$$= \frac{23.5 - 1.5}{2} = 11\text{mm}$$

Shear stress on one side of the plate

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

F_s = total shear force (considering both sides of the plate)

$$= 2A \times \tau = \frac{2A\mu V}{y}$$

$$= \frac{2 \times 1.5 \times 1.5 \times 2.5 \times 0.1}{11 \times 10^{-3}}$$

= 102.2727 N

Weight of plate, W = 50 N

Upward force on submerged plate,

$F_v = \rho g V = 900 \times 9.81 \times 1.5 \times 1.5 \times 10^{-3}$

= 29.7978 N

Total force required to lift the plate

$= F_s + W - F_V$

= 102.2727 + 50 – 29.7978

= 122.4749 N

Chapter- 4
Fluid Kinematics

01. Ans: (b)

02. Ans: (a)

Sol: Given, $u = -x$,

$v = 2y$

Stream line equation in 2 – D

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

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

On integration

$$\int \frac{dx}{-x} = \int \frac{dy}{2y}$$

$$-\int \frac{1}{x} dx = \frac{1}{2}\int \frac{1}{y} dy$$

$$-\log x = \frac{1}{2}\log y + \log c$$

$$\log\left(\frac{1}{x}\right) = \log\sqrt{y} + \log c$$

$$\log\left(\frac{1}{x}\right) = \log\left(\sqrt{y}.c\right)$$

$$\frac{1}{x} = \sqrt{y}.c$$

At (1,1) point $= \frac{1}{1} = \sqrt{1}.c$

$c = 1$

$$x\sqrt{y} = 1$$

03. Ans: (a)

Sol: $\vec{V} = 2x\hat{i} + y\hat{j}$

Compare $\vec{V} = u\hat{i} + v\hat{j}$

Where, $u = 2x$, $v = y$

Velocity, $|\vec{v}| = \sqrt{u^2 + v^2}$

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

$$V = \sqrt{4x^2 + y^2}$$

$$V_{(1,1)} = \sqrt{4(1)^2 + (1)} = \sqrt{5}\,m/s$$

Acceleration, $\vec{a} = a_x\hat{i} + a_y\hat{j}$

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

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

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

$= 2x\,(2) + y(0)$

$= 4x$

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

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

$= 2x\,(0) + y\,(1)$

$= y$

$$|\vec{a}| = \sqrt{{a_x}^2 + {a_y}^2} = \sqrt{(4x)^2 + y^2}$$

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

$$= |\vec{a}|_{(1,1)} = \sqrt{16(1)^2 + (1)^2}$$

$$= \sqrt{17}\,m/sec^2$$

Common Data for Questions 04 & 05

04. Ans: 0.94

Sol:
$$a_{Local} = \frac{\partial V}{\partial t}$$
$$= \frac{\partial}{\partial t}\left(2t\left(1-\frac{x}{2L}\right)^2\right)$$
$$= \left(1-\frac{x}{2L}\right)^2 \times 2$$
$$(a_{Local})_{at\ x=0.5,\ L=0.8} = 2\left(1-\frac{0.5}{2\times 0.8}\right)^2$$
$$= 2(1-0.3125)^2 = 0.945 \text{ m/sec}^2$$

05. Ans: –13.68

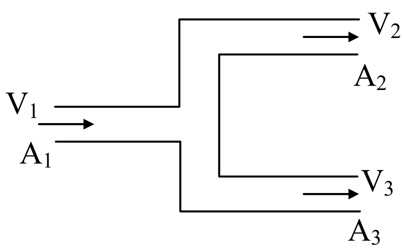
Sol:
$$a_{convective} = v.\frac{\partial v}{\partial x} = \left[2t\left[1-\frac{x}{2L}\right]^2\right]\frac{\partial}{\partial x}\left[2t\left(1-\frac{x}{2L}\right)^2\right]$$
$$= \left[2t\left[1-\frac{x}{2L}\right]^2\right]2t\left[2\left(1-\frac{x}{2L}\right)\left(-\frac{1}{2L}\right)\right]$$

At t = 3 sec; x = 0.5 m; L = 0.8 m

$$a_{convective} = 2\times 3\left[1-\frac{0.5}{2\times 0.8}\right]^2 \times 2\times 3\left[2\left(1-\frac{0.5}{2\times 0.8}\right)\right]\left[\frac{-1}{2\times 0.8}\right]$$
$$a_{convective} = -14.62 \text{ m/sec}^2$$
$$a_{total} = a_{local} + a_{convective} = 0.94 - 14.62$$
$$= -13.68 \text{ m/sec}^2$$

06. Ans: 8 m/s

Sol:



According to the conservation of mass

Total inward flow = Total outward flow
$$Q_1 = Q_2 + Q_3$$
$$A_1V_1 = A_2V_2 + A_3V_3$$
$$A_2 = A_3$$
$V_1 = 2$ m/s ; $V_2 = 3$ m/s ; $V_3 = 5$ m/s
$$A_1 \times 2 = A_2 \times 3 + A_2 \times 5$$
$$A_1 = 4A_2$$
At another instant $V_1 = 3$ m/s
$$V_2 = 4 \text{ m/s}$$
$$V_3 = ?$$
$$A_1V_1 = A_2V_2 + A_3V_3$$
$$4A_2 \times 3 = A_2 \times 4 + A_2 \times V_3$$
$$12 A_2 = 4A_2 + A_2V_3$$
$$V_3 = 8 \text{ m/s}$$

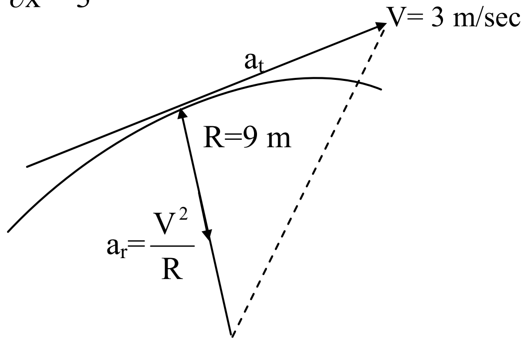
07. Ans: (d)

Sol: $u = 6xy - 2x^2$

continuity equation for 2D flow
$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$
$$\frac{\partial u}{\partial x} = 6y - 4x$$
$$(6y-4x) + \frac{\partial v}{\partial y} = 0$$
$$\frac{\partial v}{\partial y} = (4x-6y) = 0$$
$$\partial v = (4x-6y)\,dy$$
$$v = \int 4x\,dy - \int 6y\,dy$$
$$= 4xy - 3y^2 + c$$
$$= 4xy - 3y^2 + f(x)$$

08. Ans: $\sqrt{2}$

Sol: $\dfrac{\partial V}{\partial x} = \dfrac{1}{3}(m/sec/m)$



$$a_r = \frac{V^2}{R} = \frac{(3)^2}{9} = \frac{9}{9} = 1\ m/s^2$$

$$a_t = V\frac{\partial V}{\partial x} = 3\times\frac{1}{3} = 1\ m/s^2$$

$$a = \sqrt{(a_r)^2+(a_t)^2} = \sqrt{(1)^2+(1)^2} = \sqrt{2}\ m/sec^2$$

09. Ans: 13.75

Sol: $a_{t\,(conv)} = V_{avg}\times\dfrac{dV}{dx}$

$$a_{t\,(conv)} = \left(\frac{2.5+3}{2}\right)\left(\frac{3-2.5}{0.1}\right) = 2.75\times 5$$

$$a_{t\,(conv)} = 13.75\ m/s^2$$

10. Ans: 1.5

Sol: $a_r = \dfrac{\partial V}{\partial \theta}\times\dfrac{\partial \theta}{\partial t}$

$$= \frac{\partial V}{\partial \theta}\times\omega \quad (\because V = r\omega)$$

$$= \frac{\partial V}{\partial \theta}\times\frac{V}{r}$$

$$= \frac{\partial}{\partial \theta}(3\sin\theta)\times\frac{3\sin\theta}{3} = 3\cos\theta\times\sin\theta$$

$$(a_r)_{(\theta=45)} = 3\times\cos45^0\times\sin45^0$$

$$= 3\times\frac{1}{\sqrt{2}}\times\frac{1}{\sqrt{2}} = \frac{3}{2} = 1.5\ m/sec^2$$

11. Ans: 0.3

Sol: $Q = Au$

$$a_{Local} = \frac{\partial u}{\partial t} = \frac{\partial}{\partial t}\left(\frac{Q}{A}\right)$$

$$a_{local} = \frac{1}{A}\frac{\partial Q}{\partial t}$$

$$a_{Local} = \left(\frac{1}{0.4-0.1x}\right)\frac{\partial Q}{\partial t}$$

$$(a_{Local})_{at\ x=0} = \frac{1}{0.4}\times 0.12 \quad \left(\because \frac{\partial Q}{\partial t} = 0.12\right)$$

$$= 0.3\ m/sec^2$$

12. Ans: (b)

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

$$a_{Total} = (a_x)\hat{i} + (a_y)\hat{j}$$

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

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

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

$$= (2y)(0) + (2x)(2)$$

$$\therefore a_x = 4x$$

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

$$= (2y)\times(2) + (2x)\times(0)$$

$$a_y = 4y$$

$$\therefore a = (4x)\hat{i} + (4y)\hat{j}$$

13. Ans: (b)

Sol: Given, The stream function for a potential flow field is $\psi = x^2 - y^2$

$\phi = ?$

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

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

$u = 2y$

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

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

$\phi = -2\,xy + c_1$

Given, ϕ is zero at (0,0)

$\therefore\ c_1 = 0$

$\therefore\ \phi = -2xy$

14. Ans: 4

Sol: Given, 2D – flow field

Velocity, $V = 3xi + 4xyj$

$u = 3x$, $v = 4xy$

$$\omega_z = \frac{1}{2}\left(\frac{dv}{dx} - \frac{du}{dy}\right)$$

$$\omega_z = \frac{1}{2}(4y - 0)$$

$$(\omega_Z)_{at(2,2)} = \frac{1}{2}\times 4(2) = 4\ \text{rad/sec}$$

Chapter- 5
Energy Equation and its Applications

01. Ans: (c)

Sol: Applying Bernoulli's equation for ideal fluid

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

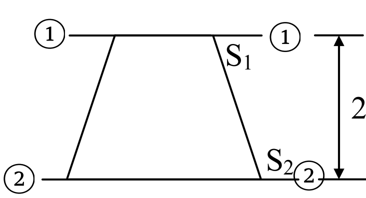
$$\frac{P_1}{\rho g} + \frac{(2)^2}{2g} = \frac{P_2}{\rho g} + \frac{(1)^2}{2g}$$

$$\frac{P_2}{\rho g} - \frac{P_1}{\rho g} = \frac{4}{2g} - \frac{1}{2g}$$

$$\frac{P_2 - P_1}{\rho g} = \frac{3}{2g} = \frac{1.5}{g}$$

02. Ans: (c)

Sol:



$$\frac{V_1^2}{2g} = 1.27\text{m}\ , \qquad \frac{P_1}{\rho g} = 2.5\text{m}$$

$$\frac{V_2^2}{2g} = 0.203\text{m}\ , \qquad \frac{P_2}{\rho g} = 5.407\text{m}$$

$Z_1 = 2$ m , $\quad Z_2 = 0$ m

Total head at (1) – (1)

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

$= 1.27 + 2.5 + 2 = 5.77$ m

Total head at (2) – (2)

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

$= 0.203 + 5.407 + 0 = 5.61$ m

Loss of head = 5.77 – 5.61 = 0.16 m

∴ Energy at (1) – (1) > Energy at (2)– (2)

∴ Flow takes from higher energy to lower energy

i.e. from (S_1) to (S_2)

Flow takes place from top to bottom.

03. Ans: 1.5

Sol: $A_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4}(0.1)^2 = 7.85 \times 10^{-3}\ \text{mm}^2$

$$A_2 = \frac{\pi}{4} d_2^2 = \frac{\pi}{4}(0.05)^2 = 1.96 \times 10^{-3}\ \text{mm}^2$$

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

$Z_1 = Z_2$, it is in horizontal position

Since, at outlet, pressure is atmospheric

$P_2 = 0$

Q = 100 lit/sec = 0.1 m^3/sec

$$V_1 = \frac{Q}{A_1} = \frac{0.1}{7.85 \times 10^{-3}} = 12.73\ \text{m/sec}$$

$$V_2 = \frac{Q}{A_2} = \frac{0.1}{1.96 \times 10^{-3}} = 51.02\ \text{m/sec}$$

$$\frac{P_{1gauge}}{\rho_{air} \times g} + \frac{(12.73)^2}{2 \times 10} = 0 + \frac{(51.02)^2}{2 \times 10}$$

$$\frac{P_1}{\rho_{air}.g} = 121.53$$

$$P_1 = 121.53 \times \rho_{air} \times g$$

= 1.51 kPa

04. Ans: 395

Sol: Q = 100 litre/sec = 0.1 m^3/sec

$V_1 = 100$ m/sec; $P_1 = 3 \times 10^5$ N/m^2

$V_2 = 50$ m/sec; $P_2 = 1 \times 10^5$ N/m^2

Power (P) = ?

Bernoulli's equation

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

$$\frac{3 \times 10^5}{1000 \times 10} + \frac{100^2}{2 \times 10} + 0 = \frac{1 \times 10^5}{1000 \times 10} + \frac{50^2}{2 \times 10} + 0 + h_L$$

$\Rightarrow h_L = 395$ m

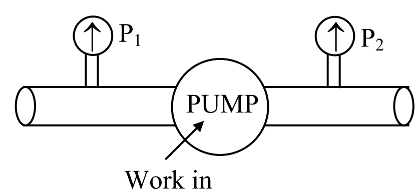
$P = \rho g Q.h_L$

$P = 1000 \times 10 \times 0.10 \times 395$

P = 395 kW

05. Ans: 51.33

Sol: Apply Bernoulli's equation to pump



$$\frac{P_1}{\rho g} + Z_1 + \frac{V_1^2}{2g} + \text{Work in}$$

$$= \frac{P_2}{\rho g} + Z_2 + \frac{V_2^2}{2g} + H_{Loss}$$

Where work in = Head raised = 10 m

Since pipes are same size

$V_1 = V_2$ and $Z_1 = Z_2$

$$\frac{P_1}{\rho g} + 0 + 0 + 10 = \frac{120 \times 10^3}{1000 \times 9.81} + 0 + 0 + 3$$

$P_1 = (12.2324 + 3 - 10) \times \rho g$

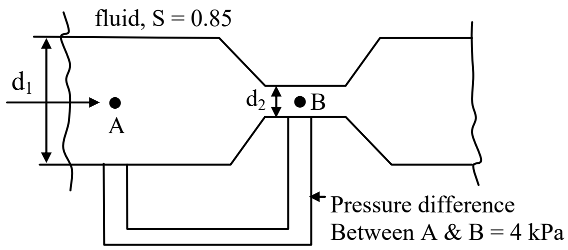
$P_1 = (5.2324)(1000\times9.81)$

$= 51.33\times10^3\ N/m^2$

$= 51.33\ kPa$

06. Ans: 35

Sol:



$d_1 = 300$ mm, $d_2 = 120$ mm

$$Q_{Th} = \frac{A_1A_2}{\sqrt{A_1^2 - A_2^2}}\sqrt{2gh}$$

$$= \frac{A_1A_2}{\sqrt{A_1^2 - A_2^2}}\sqrt{2g\left(\frac{\Delta P}{w}\right)}$$

$$A_1 = \frac{\pi}{4}d_1^2 = \frac{\pi}{4}(0.30)^2 = 0.07\,m^2$$

$$A_2 = \frac{\pi}{4}d_2^2 = \frac{\pi}{4}(0.12)^2 = 0.011\,m^2$$

$\Delta P = 4$ kPa,

$$h = \frac{\Delta P}{w} = \frac{\Delta P}{\rho_f . g}$$

$$= \frac{\Delta P}{s_f \rho_w g} = \frac{4\times10^3}{0.85\times1000\times9.81}$$

$$Q_{Th} = \frac{0.07\times0.011}{\sqrt{(0.07)^2 - (0.011)^2}}\sqrt{\frac{2\times9.81\times4\times10^3}{0.85\times1000\times9.81}}$$

$= 0.035\ m^3/sec$

$= 35.15$ ltr/sec

07. Ans: 65

Sol: $h_{stag} = 0.30$ m

$h_{stat} = 0.24$ m

$$V = c\sqrt{2gh_{dyna}}$$

$$V = 1\sqrt{2g(h_{stag} - h_{stat})}$$

$$= \sqrt{2(9.81)(0.30 - 0.24)} = 1.085\ m/s$$

$= 1.085 \times 60 = 65.1$ m/min

08. Ans: 81.5

Sol: $x = 30$ mm

$g = 10\ m/s^2$

$\rho_{air} = 1.23\ kg/m^3$; $\rho_{Hg} = 13600\ kg/m^3$

$C = 1$

$$V = \sqrt{2gh_D}$$

$$h_D = x\left(\frac{S_m}{S} - 1\right)$$

$$h_D = 30\times10^{-3}\left(\frac{13600}{1.23} - 1\right)$$

$h_D = 331.67$ m

$$V = 1\times\sqrt{2\times10\times331.67}$$

$V = 81.5$ m/sec

09. Ans: 140

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

$$C_d \propto \frac{1}{\sqrt{h}}$$

$$\frac{C_{d_{venturi}}}{C_{d_{orifice}}} = \frac{0.95}{0.65} = \sqrt{\frac{h_{orifice}}{h_{venturi}}}$$

$h_{venturi} = 140$ mm

Chapter- 6
Momentum equation and its Applications

01. Ans: 720

Sol: $P = \rho(g + a)h = \rho(g + 5g)h = 6\rho gh$

$= 6 \times 1200 \times 10 \times 10 = 720$ kPa

02. Ans: 1600

Sol: $S = 0.80$

$A = 0.02\ m^2$

$V = 10$ m/sec

$F = \rho.A.V^2$

$F = 0.80 \times 1000 \times 0.02 \times 10^2$

$F = 1600$ N

03. Ans: 6000

Sol: $A = 0.015\ m^2$

$V = 15$ m/sec (Jet velocity)

$U = 5$ m/sec (Plate velocity)

$F = \rho A\ (V + U)^2$

$F = 1000 \times 0.015\ (15 + 5)^2$

$F = 6000$ N

04. Ans: 19.6

Sol: $V = 100$ m/sec (Jet velocity)

$U = 50$ m/sec (Plate velocity)

$d = 0.1$ m

$F = \rho A\ (V – U)^2$

$$F = 1000 \times \frac{\pi}{4} \times 0.1^2 \times (100 - 50)^2$$

$F = 19.6$ kN

05. Ans: (b)

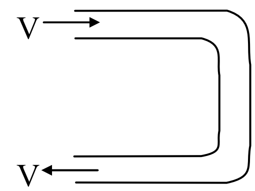
Sol: $F_x = \rho aV(\ V – 0)$

$= \rho a\ V^2$

$= 1000 \times 1 \times 10^{-4} \times 10^2 = 10$ N

06. Ans: (c)

Sol:



$F_x = \rho aV(\ V_{1x} – V_{2x})$

$= \rho aV(\ V – (–V))$

$= 2\ \rho a\ V^2$

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

07. Ans: (d)

Sol: $F_1 = \rho A(V–u)^2$

Power $(P_1) = F_1 \times u = \rho A(V–u)^2 \times u$

$F_2 = \rho.A.V \times V_r$

$= \rho.A(V).(V–u)$

Power $(P_2) = F_2 \times u = \rho AV(V–u)u$

$$\frac{P_1}{P_2} = \frac{\rho A(V-u)^2 \times u}{\rho AV(V-u) \times u}$$

$$= 1 - \frac{5}{20} = 0.75$$

Chapter- 7
Laminar Flow

01. Ans: (d)

02. Ans: (d)

03. Ans: (d)

Sol: $Q = A.V_{avg}$

$$Q = A.\frac{V_{max}}{2} \quad (\because V_{max} = 2\,V_{avg})$$

$$Q = \frac{\pi}{4}\left(\frac{40}{1000}\right)^2 \times \frac{1.5}{2}$$

$$= \frac{\pi}{4} \times (0.04)^2 \times 0.75$$

$$= \frac{\pi}{4} \times \frac{4}{100} \times \frac{4}{100} \times \frac{3}{4} = \frac{3\pi}{10000}\ \text{m}^3/\text{sec}$$

04. Ans: 100000

Sol: $\tau = \frac{-dP}{dx} \times \frac{r}{2}$

$$250 = -\frac{dP}{10} \times \frac{0.1\cancel{/2}}{2}$$

$\therefore P_1 - P_2 = 1 \times 10^5\ \text{N/m}^2$

05. Ans: 1.92

Sol: $\rho = 1000\ \text{kg/m}^3$

$Q = 800\ \text{mm}^3/\text{sec} = 800 \times (10^{-3})^3\ \text{m}^3/\text{sec}$

$L = 2$ m

$D = 0.5$ mm

$\Delta P = 2$ MPa $= 2 \times 10^6$ Pa

$\mu = ?$

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

$$2 \times 10^6 = \frac{128 \times \mu \times 800 \times (10^{-3})^3 \times 2}{\pi(0.5 \times 10^{-3})^4}$$

$\mu = 1.917$ Milli Pa – sec

06. Ans: 0.75

Sol: $U_r = U_{max}\left(1 - \left(\frac{r}{R}\right)^2\right)$

$$\left[\because \frac{U}{U_{max}} = 1 - \left(\frac{r}{R}\right)^2\right]$$

$$= 1\left(1 - \left(\frac{50}{200}\right)^2\right)$$

$$= 1\left(1 - \frac{1}{4}\right) = \frac{3}{4} = 0.75\ \text{m/s}$$

07. Ans: 0.08

Sol: Given, $\rho = 0.8 \times 1000 = 800\ \text{kg/m}^3$

$\mu = 1$ Poise $= 10^{-1}$ N-s/m

$d = 50$ mm $= 0.05$ m

velocity = 2 m/s

Reynold's Number , $Re = \frac{\rho VD}{\mu}$

$$= \frac{800 \times 2 \times 0.05}{10^{-1}} = 800$$

$(\because Re < 2000)$ $\therefore$ Flow is laminar,

For laminar, Darcy friction factor

$$f = \frac{64}{Re} = \frac{64}{800} = 0.08$$

08. Ans: (c)

09. Ans: 0.32

Sol: Given:

$\mu = 0.01\text{Poise} = 0.01\times10^{-1}$ N-s/m^2

$D = 10$ mm $= 10 \times 10^{-3}$ m

$V = 10$ mm/s $= 10\times10^{-3}$ m/sec

$L = 1$ km $= 1000$ m

$\rho = 1000$ kg/m^3

Reynolds Number, $Re = \dfrac{\rho VD}{\mu}$

$$= \frac{1000\times10\times10^{-3}\times10\times10^{-3}}{0.01\times10^{-1}}$$

Re = 100 < 2000

$\therefore$ Re < 2000, hence flow is laminar

For laminar flow, $h_f = \dfrac{32\mu VL}{\rho g D^2}$

$$= \frac{32\times0.01\times10^{-1}\times10\times10^{-3}\times10^{3}}{10^{3}\times10\times\left(10\times10^{-3}\right)^2}$$

= 0.32 m

10. Ans: 16

Sol: For fully developed laminar flow,

$$h_f = \frac{32\mu VL}{\rho g D^2} \quad (\therefore Q = AV)$$

$$h_f = \frac{32\mu\left(\frac{Q}{A}\right)L}{\rho g D^2} = \frac{32\mu QL}{AD^2\times\rho g}$$

$$h_f = \frac{32\mu QL}{\frac{\pi}{4}D^2\times D^2\times\rho g}$$

$$h_f \propto \frac{1}{D^4}$$

$$h_{f1} D_1^4 = h_{f_2} D_2^4$$

Given, $D_2 = \dfrac{D_1}{2}$

$$h_{f1}\times D_1^4 = h_{f2}\times\left(\frac{D_1}{2}\right)^4$$

$$h_{f_2} = 16 h_{f_1}$$

$\therefore$ Head loss, increase by 16 times if diameter halved.

11. Ans: 5.2

Sol: Oil viscosity, $\mu = 10$ poise $= 10\times0.1$

$= 1$ N-s/m^2

$y = 50 \times 10^{-3}$m

$L = 120$ cm $= 1.20$ m

$\Delta P = 3 \times 10^3$Pa

Width of plate = 0.2 m

Q = ?

$Q = A.V_{avg} = (\text{width of plate}\times y)V$

$$\Delta P = \frac{12\mu VL}{B^2}$$

$$3\times10^3 = \frac{12\times1\times V\times1.20}{\left(50\times10^{-3}\right)^2}$$

V = 0.52 m/sec

$Q = AV_{avg} = (0.2\times50\times10^{-3})\ (0.52)$

$= 5.2$ lit/sec

Chapter- 8
Flow Through Pipes

01. Ans: (d)

Sol: $\nu = 0.4\ cm^2/sec = 0.4\times10^{-4}\ m^2/sec$

$d = 8\ cm = 8\times10^{-2}\ m.$

Lower critical Reynolds number for laminar flow is 2000

$$Re = \frac{V.D}{\nu}$$

$$2000 = \frac{V\times8\times10^{-2}}{0.4\times10^{-4}}$$

Average (or) Mean velocity (V) = 1 m/sec

For Laminar pipe flow; $V_{max} = 2V_{avg}$

$= 2 \times 1 = 2$ m/s

02. Ans: (a)

Sol: $\nu = 8\times10^{-4}\ m^2/sec$; $d = 0.08$ m

$Q = 3200\ \pi\times10^{-6}\ m^3/sec$

Type of flow = ?

$$Q = AV$$

$$3200\ \pi\times10^{-6} = \frac{\pi}{4}\left(0.08^2\right)\times V$$

Mean (or) Average velocity = 2 m/sec

$$Re = \frac{V.D}{\nu}$$

$$\therefore Re = \frac{2\times0.08}{8\times10^{-4}}$$

Re = 200 < 2000 (Critical Reynolds's number for laminar flow)

$\therefore$ Type of flow is "Laminar"

03. Ans: (a)

Sol: In pipes Net work, series arrangement

$$\therefore\ h_f = \frac{f.lV^2}{2gd} = \frac{f.lQ^2}{12.1\times d^5}$$

$$\frac{h_{f_A}}{h_{f_B}} = \frac{f_A.l_A.Q_a^2}{12.1\times d_A^2}\times\frac{12.1\times d_B^5}{f_B.l_B.Q_B^2}$$

Given $l_A = l_B$, $f_A = f_B$, $Q_A = Q_B$

$$\frac{h_{f_A}}{h_{f_B}} = \left(\frac{d_B}{d_A}\right)^5 = \left(\frac{d_B}{1.2d_B}\right)^5$$

$$= \left(\frac{1}{1.2}\right)^5 = 0.4018 \approx 0.402$$

04. Ans: (a)

Sol: Given, $d_1 = 10$ cm; $d_2 = 20$ cm

$f_1 = f_2$; $\quad l_1 = l_2 = l$

$l_e = l_1 + l_2 = 2l$

$$\frac{l_e}{d_e^5} = \frac{l_1}{d_1^5} + \frac{l_2}{d_2^5} \Rightarrow \frac{2l}{d_e^5} = \frac{l}{10^5} + \frac{l}{20^5}$$

$\therefore\ d_e = 11.4$ cm

05. Ans: (b)

Sol: In parallel pipe arrangement;

$$h_{f_A} = h_{f_B}$$

$$\frac{f_A.l_A.Q_A^2}{12.1\times d_A^5} = \frac{f_B l_B.Q_B^2}{12.1\times d_B^5}$$

Given $d_A = d_B$; $l_A = l_B$, $f_A = 4f_B$

$$\left(\frac{Q_A}{Q_B}\right)^2 = \frac{f_B}{f_A}$$

$$\frac{Q_A}{Q_B} = \sqrt{\frac{f_B}{f_A}} = \sqrt{\frac{f_B}{4f_B}} = \sqrt{\frac{1}{4}} = \frac{1}{2} = 0.5$$

06. Ans: (d)

Sol: For parallel pipes

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

$$\frac{f_1 \times l_1 \times Q_1^2}{12.1 \times d_1^5} = \frac{f_2 \times l_2 \times Q_2^2}{12.1 \times d_2^5}$$

For given data

$$\frac{Q_1^2}{Q_2^2} = \left(\frac{d_1}{d_2}\right)^5$$

$$\left(\frac{Q_1}{Q_2}\right)^2 = \left(\frac{2d}{d}\right)^5 = (2)^5 = 32$$

$$\frac{Q_1}{Q_2} = \sqrt{32} = 4\sqrt{2}$$

07. Ans: (c)

Sol: $d_e = (n)^{2/5}.d$

$30 = (2)^{2/5}\,d$

$\therefore$ d = 22.73 cm

Select near higher size i.e. 25 cm

08. Ans: (b)

Sol: Power transmitted by the pipe,

$P = \rho gQ(H - h_f)$

For maximum power transmission, the condition is $h_f = \dfrac{H}{3}$

$$P = \rho gQ \left(H - \frac{H}{3}\right)$$

$$= \rho gQ \frac{2H}{3}$$

$$= 1000 \times 10 \times 1 \times \left(2 \times \frac{99}{3}\right)$$

$= 660 \times 10^3$ Watt = 660 kW

09. Ans: (b)

Sol: Q = 100 m^3/sec

H = 75 m

$$1 \text{ HP} = 75 \frac{\text{kgf} - \text{m}}{\text{sec}} \approx 750 \frac{\text{Nm}}{\text{sec}}$$

1 HP = 750 Watt = 0.75 kW

Power (Theoretical) = ρgQH

$\approx 1000 \times 10 \times 100 \times 75$

= 75000000 W

= 75000 kW

0.75 kW = 1 MHP

75000 kW = – ?

$$= \frac{75000}{0.75} = 100000 \text{ MHP}$$

10. Ans: (c)

Sol: $$\eta_{pump} = \frac{\text{Fluid power}}{\text{Shaft power}}$$

$$\eta_{pump} = \frac{\rho gQ(H + h_f)}{P_{shaft}}$$

Given H = 10 m

Q = 0.1 m^3/sec

h_f = 5 m

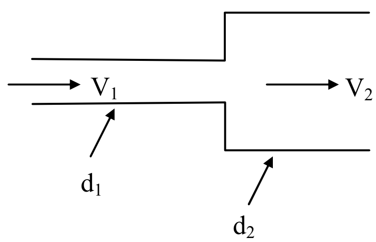
$$1 = \frac{1000 \times 10 \times 0.1 \times (10 + 5)}{P_{Shaft}}$$

$\therefore$ P_{Shaft} = 15000 W

= 15 kW

11. Ans: (c)

Sol:



Given $d_2 = 2d_1$

Losses due to sudden expansion,

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

$$= \frac{V_1^2}{2g}\left(1 - \frac{V_2}{V_1}\right)^2$$

By continuity equation,

$Q = A_1V_1 = A_2V_2$

$$\therefore \frac{V_2}{V_1} = \frac{A_1}{A_2} = \left(\frac{d_1}{d_2}\right)^2 = \left(\frac{1}{2}\right)^2$$

$$h_L = \frac{V_1^2}{2g}\left(1 - \frac{1}{4}\right)^2$$

$$h_L = \frac{9}{16} \times \frac{V_1^2}{2g}$$

$$\frac{h_L}{\frac{V_1^2}{2g}} = \frac{9}{16}$$

12. Ans: (b)

Sol: $K = 2 \times 10^9$ N/m^2

Given $\rho = 965$ kg/m^3

$$C = \sqrt{\frac{k}{\rho}} = \sqrt{\frac{2\times10^9}{965}} \simeq 1440 \text{ m/sec}$$

13. Ans: (b)

Sol: Pipes are in parallel

$Q_e = Q_A + Q_B$ ------- (i)

$h_{Le} = h_{L_A} = h_{L_B}$

$L_e = 175$ m

$f_e = 0.015$

$$\frac{f_eL_eQ_e^2}{12.1D_e^5} = \frac{f_A.L_AQ_A^2}{12.1D_A^5} = \frac{f_BL_BQ_B^2}{12.1D_B^5}$$

$$\frac{0.020\times150\times Q_A^2}{12.1\times(0.1)^5} = \frac{0.015\times200\times Q_B^2}{12.1\times(0.08)^5}$$

$Q_A = 1.747\ Q_B$ -------(ii)

From (i) $Q_e = 1.747\ Q_B + Q_B$

$Q_e = 2.747\ Q_B$ --------(iii)

$$\frac{0.015\times175(2.747Q_B)^2}{12.1\times D_e^5} = \frac{0.015\times200\times Q_B^2}{12.1\times(0.08)^5}$$

D_e= 116.6 mm $\simeq$ 117 mm

Chapter- 9
Elementary Turbulent Flow

01. Ans: (b)

02. Ans: (d)

03. Ans: 2.4

Sol: Given: V = 2 m/s

f = 0.02

V_{max} = ?

$V_{max} = V(1 + 1.43\sqrt{f})$

$= 2\left(1+1.43\sqrt{0.02}\right)$

$= 2 \times 1.2 = 2.4$ m/s

04. Ans: (c)

Sol: Given data:

D = 30 cm = 0.3 m

Re = 10^6

f = 0.025

Thickness of laminar sub layer, δ' = ?

$$\delta' = \frac{11.6\nu}{V^*}$$

Where V^* = shear velocity = $V\sqrt{\frac{f}{8}}$

ν = Kinematic viscosity

$$Re = \frac{V.D}{\nu}$$

$$\therefore \nu = \frac{V.D}{Re}$$

$$\delta' = \frac{11.6\times\frac{VD}{Re}}{V\sqrt{\frac{f}{8}}}$$

$$\delta' = \frac{11.6\times D}{Re\sqrt{\frac{f}{8}}}$$

$$= \frac{11.6\times 0.3}{10^6\times\sqrt{\frac{0.025}{8}}}$$

$= 6.22\times10^{-5}$ m $= 0.0622$ mm

05. Ans: 25

Sol: Given:

L = 100 m

D = 0.1 m

h_L = 10 m

τ = ?

For any type of flow, the shear stress at wall/surface $\tau = \frac{-dP}{dx}\times\frac{R}{2}$

$$\tau = \frac{\rho g h_L}{L}\times\frac{R}{2}$$

$$\tau = \frac{\rho g h_L}{L}\times\frac{D}{4}$$

$$= \frac{1000\times9.81\times10}{100}\times\frac{0.1}{4}$$

$= 24.525$ N/m^2 = 25 Pa

06. Ans: 0.905

Sol: k = 0.15 mm

τ = 4.9 N/m^2

ν = 1 centi-stoke

$$V^* = \sqrt{\frac{\tau_o}{\rho}} = \sqrt{\frac{4.9}{1000}} = 0.07 \text{ m/sec}$$

ν = 1 centi-stoke

$$= \frac{1}{100}\text{stoke} = \frac{10^{-4}}{100} = 10^{-6}\,m^2/sec$$

$$\frac{k}{\delta'} = \frac{0.15\times10^{-3}}{\left(\dfrac{11.6\times\nu}{V^*}\right)}$$

$$= \frac{0.15\times10^{-3}}{\dfrac{11.6\times10^{-6}}{0.07}} = 0.905$$

07. Ans: 480

Sol: Given: d = 5 cm = 0.05 m

Flow rate $\dot{m} = \pi$ kg/sec

$\mu = 0.001$ N-s/m^2

$\rho = 1000$ kg/m^3

$f_D = \dfrac{64}{Re_d}$ …………. for laminar

$f_D = 0.316\ Re_d^{-0.25}$ …. for turbulent

g = 10 m/sec^2

$$\dot{m} = \rho AV = \rho\times\frac{\pi}{4}\times d^2\times V$$

$$\pi = 1000\times\frac{\pi}{4}(0.05)^2\times V$$

V = 1.6 m/sec

$$Re = \frac{\rho VD}{\mu} = \frac{1000\times1.6\times0.05}{0.001}$$

$= 80000 > 2000\ (R_{eD})$

$\therefore$ Flow is turbulent

$\therefore f_D = 0.316\ R_{eD}^{-0.25}$

$= 0.316\ (80000)^{-0.25} = 0.0187$

Pressure drop $(P_1 - P_2) = h_f \times \rho g$

$$= \frac{fLV^2}{2gD}\times\rho g = \frac{fLV^2\rho}{2D}$$

$$= \frac{0.0187\times1\times(1.6)^2\times1000}{2\times0.05}$$

$= 478$ Pa / m $\approx$ 480 Pa/m

08. Ans: 20%

Sol: Since, Discharge decrease is associated with increase in friction.

$$\frac{df}{f} = -2\times\frac{dQ}{Q} = 2\left[-\frac{dQ}{Q}\right]$$

$$= 2\times10 = 20\%$$

09. Ans: 68.35

Sol: Power lost per one km length = $\gamma_w Q h_f$

$$h_f = \frac{f\ell Q^2}{12.1d^5}$$

$$Q = \frac{36}{60} = 0.6\,m^3/sec$$

$$\frac{1}{\sqrt{4f'}} = 2\log_{10}\left(\frac{R}{K}\right)+1.74$$

$$\frac{1}{\sqrt{4f'}} = 2\log_{10}\left(\frac{300}{3}\right)+1.74$$

4f′ = 0.03

f = 4f′ = 0.03

$$h_f = \frac{0.03\times1000\times0.6^2}{12.1\times0.6^5} = 11.61 \text{ m}$$

Power = $\gamma_w Q h_f$

$= 9.81 \times 0.6 \times 11.61 = 68.35$ kW

Chapter- 10
Boundary Layer Theory

01. Ans: (c)

Sol: $\text{Re}_{\text{Critical}} = \dfrac{U_\infty x_{\text{critical}}}{\nu}$

Assume water properties

$5\times10^5 = \dfrac{6\times x_{\text{critical}}}{1\times10^{-6}}$

$x_{\text{critical}} = 0.08333$ m = 83.33 mm

02. Ans: 1.6

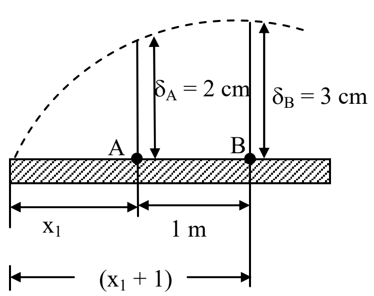
Sol: $\delta \propto \dfrac{1}{\sqrt{\text{Re}}}$ (At given distance 'x')

$\dfrac{\delta_1}{\delta_2} = \sqrt{\dfrac{\text{Re}_2}{\text{Re}_1}}$

$\dfrac{\delta_1}{\delta_2} = \sqrt{\dfrac{256}{100}} = \dfrac{16}{10} = 1.6$

03. Ans: 80

Sol:



$\delta \propto \sqrt{x}$

$\dfrac{\delta_A}{\delta_B} = \sqrt{\dfrac{x_1}{(x_1+1)}}$

$x = \dfrac{2}{3} = \sqrt{\dfrac{x_1}{x_1+1}}$

$\dfrac{4}{9} = \dfrac{x_1}{x_1+1}$

$5x_1 = 4 \Rightarrow x_1 = 80$ cm

04. Ans: 1.5

Sol: $\tau = \mu\dfrac{du}{dy}$

(Newton's law of viscosity)

$\tau = \mu\dfrac{d}{dy}\left(u_m \times 1.5\dfrac{y}{\delta}\right)$

$\tau = \mu \times u_m \times 1.5 \times \dfrac{1}{\delta}$

$\tau = 1.5\dfrac{\mu u_m}{\delta}$

$\tau = K\dfrac{\mu u_m}{\delta}$

By comparing, K = 1.5

05. Ans: 2

Sol: $\tau \propto \dfrac{1}{\delta}$

$\tau \propto \dfrac{1}{\sqrt{x}} \quad \because \delta \propto \sqrt{x}$

$\dfrac{\tau_1}{\tau_2} = \sqrt{\dfrac{x_2}{x_1}}$

$\dfrac{\tau_1}{\tau_2} = \sqrt{4} = 2$

06. Ans: 3

Sol: $\dfrac{U}{U_\infty} = \dfrac{y}{\delta}$

$\dfrac{\delta^*}{\theta} = \text{Shape factor} = ?$

$$\delta^* = \int_0^\delta \left(1 - \frac{u}{u_\infty}\right) dy$$

$$= \int_0^\delta \left(1 - \frac{y}{8}\right) dy$$

$$= y - \frac{y^2}{2\delta}\Bigg|_0^\delta$$

$$= \delta - \frac{\delta}{2} = \frac{\delta}{2}$$

$$\theta = \int_0^\delta \frac{u}{u_\infty}\left(1 - \frac{u}{u_\infty}\right) dy$$

$$= \int_0^\delta \frac{y}{8}\left(1 - \frac{y}{\delta}\right) dy$$

$$= \frac{y^2}{2\delta} - \frac{y^3}{3\delta}\Bigg|_0^\delta$$

$$= \frac{\delta}{2} - \frac{\delta}{3} = \frac{\delta}{6}$$

Shape factor $= \dfrac{\delta^*}{\theta} = \dfrac{\delta/2}{\delta/6} = 3$

07. Ans: 7.33

Sol: $\text{Re}_{(x=L)} = \dfrac{U_\infty L}{\nu}$

$$\text{Re}_{(x=L)} = \frac{U_\infty L}{\nu} = \frac{6\times 1}{0.15\times 10^{-4}} = 4\times 10^5$$

Since, $\text{Re}_{(x=L)} < 5\times 10^5$

Hence,

$$\delta_{x=L} = \frac{Kx}{\sqrt{\text{Re}}} = \frac{4.64L}{\sqrt{\text{Re}}} = \frac{4.64\times 1}{\sqrt{4\times 10^5}} = 7.33\,\text{mm}$$

08. Ans: 21

Sol: $\tau = \mu\left(\dfrac{du}{dy}\right)$

We know that $\dfrac{U_\infty}{\delta} = \dfrac{U}{y}$

On differentiating

$$\tau = \frac{\mu.U_\infty}{\delta}$$

$$\tau_{x=L} = \frac{(\rho.v)U_\infty}{\delta_{\text{at } x=L}} \;(\because \mu = \rho v)$$

$$= \frac{1.226\times 0.15\times 10^{-4}\times 6}{7.33\times 10^{-3}} = 0.015\ \text{N/m}^2$$

$$\frac{\tau_1}{\tau_2} = \sqrt{\frac{x_2}{x_1}} = \frac{\tau_{x=L}}{\tau_{X=L/2}} = \sqrt{\frac{(L/2)}{L}}$$

$$\tau_{x=L/2} = \sqrt{2}\,\tau_{x=L}$$

$$= \sqrt{2}\times 0.015\,\text{N/m}^2 = 21\ \text{milli Pa}$$

09. Ans: 22.6

Sol: Drag force,

$$F_D = \frac{1}{2} C_D.\rho.A_{Proj}.U_\infty^2$$

$B = 1.5$ m, $\rho = 1.2$ kg/m^3

$L = 3.0$ m, $\nu = 0.15$ stokes

$U_\infty = 2$ m/sec

$$\text{Re} = \frac{U_\infty L}{\nu} = \frac{2\times 3}{0.15\times 10^{-4}} = 4\times 10^5$$

$$C_D = \frac{1.328}{\sqrt{\text{Re}}} = \frac{1.328}{\sqrt{4\times 10^5}} = 2.09\times 10^{-3}$$

Drag force,

$$F_D = \frac{1}{2} \times 2.09 \times 10^{-3} \times 1.2 \times (1.5 \times 3) \times 2^2$$

$= 22.57$ milli-Newton

10. Ans: 1.62

Sol: $\dot{m} = \rho A U_\infty = \rho(B \times \delta)U_\infty \quad (\because \delta = L)$

$$\dot{m}_{ab} = \dot{m}_{bc} + \dot{m}_{cd}$$

$$\dot{m}_{bc} = \frac{1}{2}\dot{m}_{ab} = \frac{1}{2}\rho(B \times \delta).U_\infty$$

$$= \frac{1}{2} \times 1.2 \times 1 \times 1.5 \times 10^{-3} \times 30$$

$= 1.62$ kg/minute

Chapter- 11
Force on Submerged Bodies

01. Ans: 8

Sol: Drag power = Drag Force × Velocity

$$P = F_D \times V$$

$$P = C_D \times \frac{\rho A V^2}{2} \times V$$

$$P \propto V^3$$

$$\frac{P_1}{P_2} = \left(\frac{V_1}{V_2}\right)^3$$

$$\frac{P_1}{P_2} = \left(\frac{V}{2V}\right)^3$$

$$P_2 = 8P_1$$

Comparing the above relation with XP,

We get, X = 8

02. Ans: 4.56 m

Sol: $F_D = C_D.\dfrac{\rho A V^2}{2}$

$$W = 0.8 \times 1.2 \times \frac{\frac{\pi}{4}(D)^2 \times V^2}{2}$$

(Note: A = Normal (or)

projected Area = $\frac{\pi}{4}D^2$)

$$784.8 = 0.8 \times 1.2 \times \frac{\pi}{4}(D)^2 \times \frac{10^2}{2}$$

$\therefore$ D = 4.56 m

03. Ans: 0.054

Sol: Given data:

$V = 8$ m/s

$D = 0.06$ m

$\rho = 1.2$ kg/m^3

$\nu = 1.6\times10^{-4}$ m^2/sec

$W = ?$

$$Re = \frac{V.D}{\nu} = \frac{8\times0.06}{1.6\times10^{-4}} = 3000$$

For flow over sphere; $C_D = 0.5$

$1000 < Re < 1\times10^5$

$W = F_D$

$$W = C_D\times\frac{\rho A V^2}{2}$$

$$W = 0.5\times\frac{1.2\times\frac{\pi}{4}(0.06)^2\times(8)^2}{2}$$

$W = 0.5\times0.108 = 0.054$ N

04. Ans: 4

Sol: Given data:

$l = 0.5$ km $= 500$ m

$d = 1.25$ cm

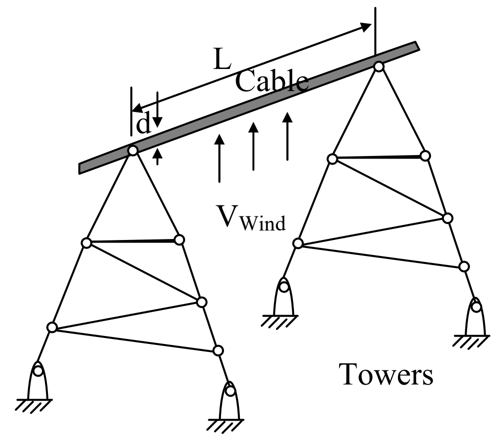
$V_{Wind} = 100$ km/hr

$\gamma_{Air} = 1.36\times9.81 = 13.4$ N/m^3

$\nu = 1.4\times10^{-5}$ m^2/s

$C_D = 1.2$ for $R_e > 10000$

$C_D = 1.3$ for $R_e < 10000$



$$Re = \frac{V.L}{\nu} = \frac{\left(\frac{100\times5}{18}\right)(500)}{1.4\times10^{-5}}$$

Note: The characteristic dimension for electric power transmission tower wire is "L"

$Re = 992\times10^6 > 10{,}000$

$\therefore\ C_D = 1.2$

$$F_D = C_D\times\frac{\rho A V^2}{2}$$

$$= 1.2\times\frac{\left(\frac{13.4}{9.81}\right)(L\times d)V^2}{2}$$

$$= \frac{1.2\times\left(\frac{13.4}{9.81}\right)(500\times0.0125)\left(100\times\frac{5}{18}\right)^2}{2}$$

$= 3952.4$ N

$= 4$ kN

05. Ans: 0.144 & 0.126

Sol: Given data:

$W_{Kite} = 2.5$ N

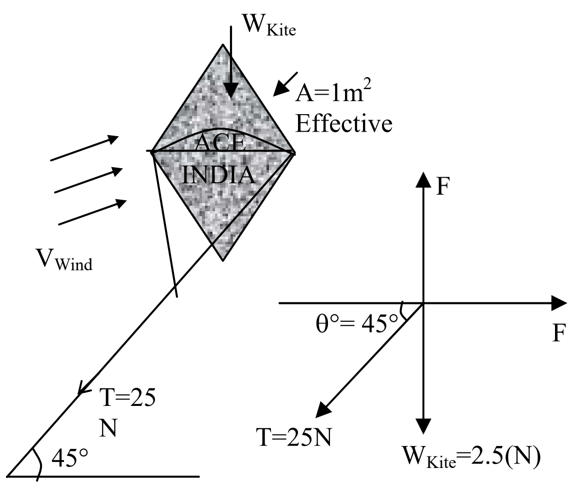
$A = 1$ m^2

$\theta = 45^o$

T = 25 N

V_{Wind} = 54 km/hr

$= 54 \times \frac{5}{18} = 15$ m/s



Resolving forces horizontally

$$F_D = T\cos 45^o$$

$$C_D \times \frac{\rho A V^2}{2} = 25 \times \cos 45^o$$

$$\frac{C_D \times \left(\frac{12.2}{9.81}\right)(1)(15)^2}{2} = 25 \times \frac{1}{\sqrt{2}}$$

$$\therefore C_D = 0.126$$

Resolving forces vertically

$$F_L = W_{Kite} + T\sin 45^o$$

$$\frac{C_L \rho A V^2}{2} = 2.5 + 25\sin 45^o$$

$$\frac{C_L\left(\frac{12.2}{9.81}\right)(1)(15)^2}{2} = 2.5 + \frac{25}{\sqrt{2}}$$

$$\therefore C_L = 0.144$$

06. Ans: (a)

Sol: Given data:

$C_{D_2} = 0.75\, C_{D_1}$ (25% reduced)

Drag power = Drag force × Velocity

$$P = F_D \times V = \frac{C_D \rho A V^2}{2} \times V$$

$$P = C_D \times \frac{\rho A V^3}{2}$$

Keeping ρ, A and power constant

$C_D V^3$ = constant = C

$$\frac{C_{D_1}}{C_{D_2}} = \left(\frac{V_2}{V_1}\right)^3$$

$$\left(\frac{C_{D_1}}{0.75 C_{D_1}}\right)^{1/3} = \frac{V_2}{V_1}$$

$$\therefore V_2 = 1.10064 V_1$$

% Increase in speed = 10.064%

07. Ans: 0.1875

Sol: Given:

F_D = 300N

ρ = 0.8 × 1000 = 800 kg/m³

L = 2 m

D = 80 mm = 0.08 m

V = 5 m/s

C_D = coefficient of drag

$$F_D = C_D \cdot \frac{\rho V^2}{2} \times A$$

$$300 = C_D \times \frac{800 \times 5^2}{2} \times (0.08) \times (2)$$

$\Rightarrow C_D = 0.1875$

08. Ans: (c)

09. Ans: 61.3

Sol: Area = 45 m^2

Velocity = 5.6 kmph = 1.56 m/s

$\rho_{sea\ water} = 1025\ kg/m^3$

$\nu = 1.67 \times 10^{-6}\ m^2/s$

$C_D = 0.7$

Power required =?

Drag power = Drag force × Velocity

$$= \frac{C_D \rho A V^2}{2} \times V$$

$$= \frac{0.7 \times 1025 \times (1.56)^3}{2} \times 45$$

= 61.3 kW

10. Ans: 318

Sol: Width = 3 m

Height = 0.8 m

Velocity = 50 kmph = 13.89 m/s

$\rho = 1.25\ kg/m^3$

$C_D = 1.1$

$$\text{Drag force } F = \frac{C_D \rho A V^2}{2}$$

$$= \frac{1.1 \times 1.25 \times 3 \times 0.8 \times 13.89^2}{2}$$

= 318.33 N

Chapter- 12
Dimensional Analysis

01. Ans: (c)

02. Ans: (b)

03. Ans: (b)

04. Ans: (c)

05. Ans: (c)

06. Ans: (a)

Sol: $L_r = \frac{1}{16}$

$Q_P = 1024$; $Q_m = ?$

$$Q_r = L_r^{5/2} = \frac{Q_m}{Q_P} = \left(\frac{1}{16}\right)^{5/2}$$

$$\frac{Q_m}{Q_p} = \left(\frac{1}{16}\right)^{5/2}$$

$Q_m = 1\ m^3/sec$

07. Ans: (b)

Sol: According to Froude's law

$$T_r = \sqrt{L_r}$$

$$\frac{t_m}{t_p} = \sqrt{L_r}$$

$$t_p = \frac{t_m}{\sqrt{L_r}} = \frac{10}{\sqrt{1/25}}$$

$t_p = 50$ min

08. Ans: (a)

Sol: $V_P = 10$ m/s, dia = 3m

$V_m = 5$ m/s

$F_m = 50$ N

$F_p = ?$

According to Froude's law: $F_r = L_r^3$

(But L_r is not given)

$$P \propto \rho V^2 = \frac{F}{A}$$

$\boxed{\rho A V^2 = F}$ Reynolds law

Now scale ratio:

$$\frac{F_m}{F_P} = \frac{V_m^2}{V_P^2} \times \frac{A_m}{A_p} \times \frac{\rho_m}{\rho_p}$$

$$\frac{50}{F_P} = \left(\frac{1}{10}\right)^2 \times \left(\frac{5}{10}\right)^2 \left(A = L_r^2\right)$$

($\because$same fluid)

$F_P = 20000$ N

09. Ans: (a)

Sol: L = 100 m

$V_P = 10\,m/s$,

$$L_r = \frac{1}{25}$$

As viscous parameters are not discussed follow Froude's law

Acc to Froude

$$V_r = \sqrt{L_r}$$

$$\frac{V_m}{V_p} = \sqrt{\frac{1}{25}}$$

$$V_m = \frac{1}{5} \times 10 = 2 \text{ m/s}$$

10. Ans: (c)

Sol: $L_r = 1 : 25$,

$F_m = 5$ N,

$F_p = ?$

$$\frac{F_m}{F_p} = L_r^3$$

$F_p = 78.125$ kN

11. Ans: (a)

Sol: $L_r = \frac{1}{100}$

$a_m = 0.013$

$$\frac{a_m}{a_p} = (L_r)^{\frac{1}{6}}$$

$$a_p = \frac{a_m}{(L_r)^{\frac{1}{6}}} = \frac{0.013}{\left(\frac{1}{100}\right)^{1/6}}$$

$a_p = 0.028$

12. Ans: (a)

Sol: $L_r = \frac{1}{9}$

$y_{p1} = 0.5$ m, $y_{p2} = 1.5$ m

$q_m = ?$, $q_p = ?$

$$\frac{2q_P^2}{g} = y_{1p}.y_{2p}\left(y_{1p} + y_{2p}\right)$$

$$\frac{2q_P^2}{9.81} = 0.5 \times 1.5 \times (0.5 + 1.5)$$

$$\frac{2q_P^2}{9.81} = (0.5)(1.5)(2)$$

$$q_p = 2.71$$

$$q_r = \frac{q_m}{q_p} = L_r^{3/2}$$

$$q_m = \left(\frac{1}{9}\right)^{3/2} \times q_p = 0.1 \text{ m}^3\text{/s/m}$$

13. Ans: (c)

Sol: For distorted model according to Froude's law

$$Q_r = L_H L_V^{3/2}$$

$L_H = 1:1000$,

$L_V = 1:100$

$Q_m = 0.1 \text{ m}^3\text{/s}$

$$Qr = \frac{1}{1000} \times \left(\frac{1}{100}\right)^{3/2} = \frac{0.1}{Q_p}$$

$Q_P = 10^5 \text{ m}^3\text{/s}$

14. Ans: (a)

Sol: $L_H = 1:1000$, $L_V = 1:100$

$q_m = 0.1 \text{ m}^3\text{/sec}$

$q_P = ?$

$q_r = (L_V)^{3/2}$

$$\frac{q_m}{q_P} = \left(\frac{1}{100}\right)^{3/2}$$

$$\left[\begin{aligned} q_r &= \frac{Q_r}{L_H} \\ &= \frac{L_H . L_V^{3/2}}{L_H} \\ &= L_V^{3/2} \end{aligned}\right]$$

$q_P = q_m \times 100$

$= 0.1 \times 1000 = 10^2$

15. Ans: (b)

Sol: $L_H = \frac{1}{150}$, $T_r = \frac{L_H}{\sqrt{L_V}}$

$$L_V = \frac{1}{60}$$

$$\frac{T_m}{T_P} = \frac{1}{150} \times \frac{\sqrt{60}}{1}$$

$T_m = 0.0516 \times T_P$

The actual time interval between two successful high tides in a sea $\rightarrow$ 12 hour 24 min

$T_P = (12 \times 60) + 24$

$= 744$ min

$T_m = 0.0516 \times 744 \simeq 40$ min

16. Ans: (d)

Sol: Froude number = Reynolds number.

$\nu_r = 0.0894$

If both gravity & viscous forces are important then

$$\nu_r = (L_r)^{3/2}$$

$$\sqrt[3]{\frac{\nu_m}{\nu_p}} = L_r$$

$L_r = 1:5$

Chapter - 13
Turbomachinery

01. Ans: 1000

Sol: T = Moment of momentum of water in a turbine = Torque developed = 15915 N-m

Speed (N) = 600 rpm

Power developed = $\frac{2\pi NT}{60}$

$= \frac{2\times\pi\times 600\times 15915}{60}$

$= 1000 \times 10^3$ W = 1000 kW

02. Ans: 4000

Sol: Q = 50 m^3/sec

H = 7.5 m

$\eta_{Turbine} = 0.8$

$\eta_{Turbine} = \frac{P_{shaft}}{P_{water}} = \frac{P_{shaft}}{\rho g Q(H - h_f)}$

$0.8 = \frac{P_{shaft}}{1000\times 9.81\times 50(7.5-0)}$

$P_{shaft} = 2943\times 10^3$ W = 2943 kW

$= \frac{2943}{0.736}$ HP = 4000 HP

03. Ans: 1

Sol: We know that

$$U = \frac{\pi DN}{60} = k_u \cdot \sqrt{2gH}$$

Where D = diameter of wheel

N = speed of turbine = 600 rpm

H = Head available of pelton wheel turbine = 300 m

$$\therefore \frac{\pi\times D\times 600}{60} = 0.41\sqrt{2\times 9.81\times 300}$$

D = 1.0 m

04. Ans: (b)

05. Ans: (b)

Sol: P = 8.1 MW = 8100 kW

H = 81 m

N = 540 rpm

Specific speed $N_S = \frac{N\sqrt{P}}{(H)^{5/4}}$

$= \frac{540\times\sqrt{8100}}{(81)^{5/4}}$

$= \frac{540\times 90}{243} = 200$

$60 < N_S < 300$ (Francis Turbine)

06. Ans: (a)

07. Ans: (b)

08. Ans: (a)

09. Ans: (d)

10. Ans: (d)

11. Ans: 1000

Sol: Given $N_p = 500$ rpm

$$\frac{D_m}{D_p} = \frac{1}{2}$$

We know that

$$\left(\frac{ND}{\sqrt{H}}\right)_m = \left(\frac{ND}{\sqrt{H}}\right)_P$$

Given H is constant

$$\therefore \frac{N_m}{N_p} = \frac{D_p}{D_m}$$

$$\therefore \frac{N_m}{500} = 2$$

$$\Rightarrow N_m = 1000 \text{ rpm}$$

12. Ans: 72

Sol: Given $P_1 = 100$ kW

$H_1 = 100$ m and $H_2 = 81$ m

We know that

$$\left(\frac{P}{(H)^{3/2}}\right)_1 = \left(\frac{P}{(H)^{3/2}}\right)_2$$

$$\therefore \frac{100}{(100)^{3/2}} = \frac{P_2}{(80)^{3/2}}$$

$P_2 = 71.55 \text{ kW} \simeq 72 \text{ kW}$

$\therefore$ New power developed by same turbine

= 72 kW