UNIT - I -

LAMINAR FLOW & BOUNDARY LAYER THEORY

[13 MARKS]

THEORIES :- 06 Marks
NUMERICALS :- 07 Marks

THEORY :-

01. Define boundary layer thickness, displacement thickness, momentum thickness, and energy thickness.
(Compulsary)

ANS> (a) Boundary layer thickness :-

It is defined as the distance from the boundary of the solid body measured in the y-direction to the point, where the velocity of the fluid is approximately equal to 0.99 times the free stream (U) velocity of the fluid.
It is denoted by the symbol δ.

(b) Displacement thickness :-

It is defined as the distance, measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for the reduction in flow rate on account of boundary layer formation.
It is denoted by the symbol δ^*.

(c) Momentum thickness :-

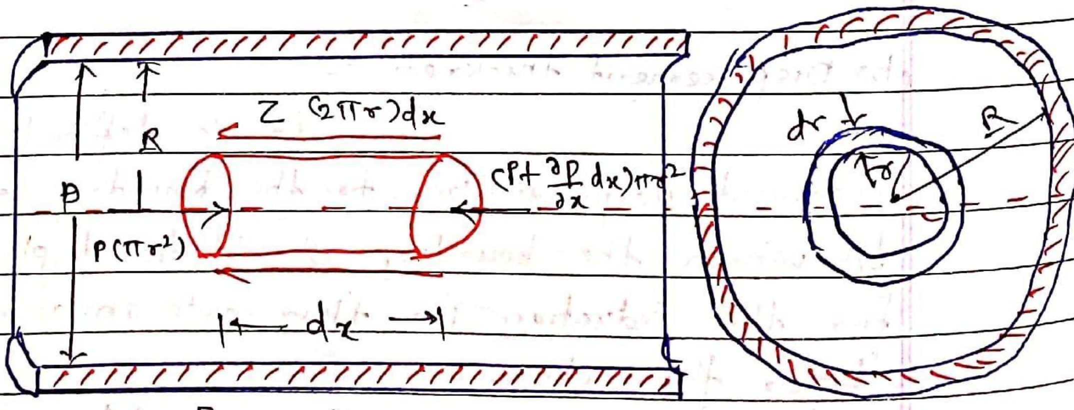
Momentum thickness is defined as the distance measured perpendicular to the boundary of the solid body, by which the boundary should be

displaced to compensate for the reduction in momentum of the flowing fluid on account of boundary layer formation.
It is denoted by θ.

(d) Energy thickness :-
It is defined as the distance, measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for the reduction in kinetic energy of the flowing fluid on account of boundary layer formation.
It is denoted by δ^{**}.

Q2. Derive Hagen-Poiseuille equation and write the assumptions made in it. [Compulsory]

ANS→ Hagen-Poiseuille Equation :-



(Fig. Laminar flow through a circular pipe)

Fig. shows a horizontal circular pipe having laminar flow of fluid through it.
Now, By Bernoulli's eqn

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

where h_f is the loss of head due to resistance

P_1 and P_2 be the average intensities

v_1 and v_2 be the mean velocity

$$\text{loss of head} = h_f = \left(\frac{P_1}{w} - \frac{P_2}{w}\right)$$

A small concentric cylindrical fluid element of radius r and length dx.

Now, Summation of all these forces in the x-direction must equal zero.

$$p(\pi r^2) - \left(p + \frac{\partial p}{\partial x} dx\right) \pi r^2 - \tau (2\pi r) dx = 0$$

$$\text{Or} \quad \left(-\frac{\partial p}{\partial x} dx\right) \pi r^2 - \tau (2\pi r) dx = 0$$

Dividing the above equation by the volume of the element $(\pi r^2) dx$

$$\tau = -\frac{\partial p}{\partial x} \frac{r}{2}$$

$$\tau_0 = \left(-\frac{\partial p}{\partial x}\right) \frac{R}{2}$$

Since the pipe is uniform the pressure gradient will be constant and hence

$$\left(-\frac{\partial p}{\partial x}\right) = \left(\frac{P_1 - P_2}{L}\right) = \frac{w h_f}{L}$$

$$\tau = \frac{w h_f}{2L} r$$

Now, using Newton's law of viscosity,

$$\tau = \mu \left(\frac{dv}{dy}\right) \qquad \text{--- } y = R - r, \quad dy = -dr$$

$$\tau = -\mu \left(\frac{dv}{dy}\right) \quad \text{--- (i)}$$

Substituting the value of τ from equations (i)

$$-\mu \frac{\partial v}{\partial r} = -\frac{\partial p}{\partial x} \cdot \frac{r}{2}$$

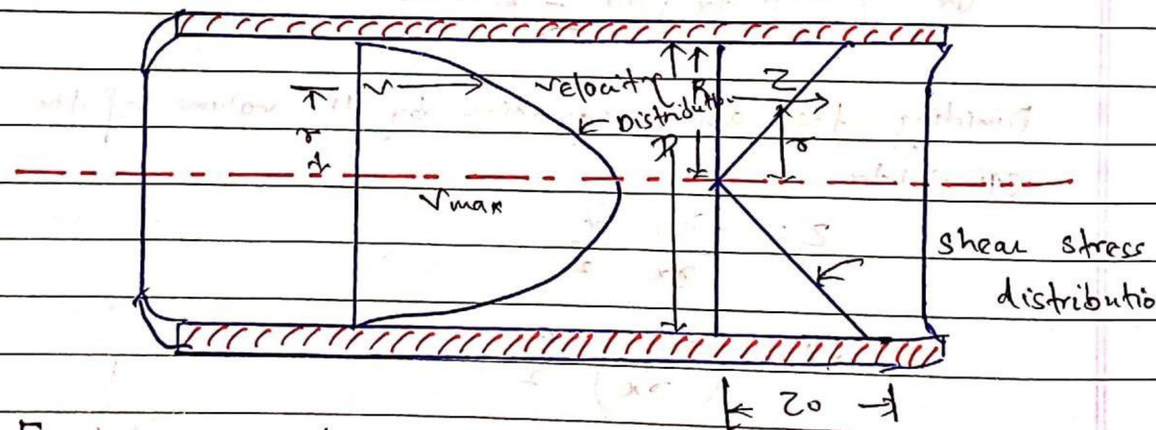
$$\text{or} \quad \frac{\partial v}{\partial r} = \frac{1}{\mu} \frac{\partial p}{\partial x} \cdot \frac{r}{2} \quad \text{—— (ii)}$$

Integrating eq^n (ii) w.r.t r

$$v = \frac{1}{4\mu}\left(\frac{\partial p}{\partial x}\right) r^2 + C$$

$$\therefore C = -\frac{1}{4\mu}\left(\frac{\partial p}{\partial x}\right) R^2 \quad \text{----} \quad r = R$$

$$v = \frac{1}{4\mu}\left(-\frac{\partial p}{\partial x}\right)\left(R^2 - r^2\right)$$



(fig: velocity and shear-stress distribution for laminar flow in a circular pipe)

$$v_{max} = \frac{1}{4\mu}\left(-\frac{\partial p}{\partial x}\right) R^2$$

$$\boxed{\therefore v = v_{max}\left[1 - \left(\frac{r}{R}\right)^2\right]}$$

Assumptions :-

03. Derive an expression for shear stress distribution and velocity distribution for laminar flow in a circular pipe.

Ans→ QUE No. 2 Hagen - Poiseuille Eq^n derivation

NUMERICALS :-

TYPE-I- (Compulsary)

[Based On Oil viscosity, Det. the average velocity, rate of flow]

[7 MARKS]

S 2015 Q1. Fluid of viscosity 8 poise and specific gravity 1.2 is flowing through a circular pipe of diameter 100 mm, The maximum shear stress at the pipe wall is 210 N/m2

Find: (a) Pressure gradient
(b) Average velocity
(c) Reynold's no. of the flow

Solⁿ→ Given data,

$$\mu = 8 \text{ poise} = \frac{8}{10} = 0.8 \text{ N-s/m}^2$$

$$\text{Specific gravity} = 1.2$$

$$D = 100\text{mm} = 0.1\text{m}$$

$$\tau_0 = 210 \text{ N/m}^2$$

$$\rho = 1.2 \times 1000 = 1200 \text{ kg/m}^3$$

To find:- (a) Pressure gradient, $\frac{\partial p}{\partial x}$
(b) Average velocity, v
(c) Reynold's no., Re

(a)
$$\tau_0 = \frac{-\partial p}{\partial x} \times \frac{R}{2}$$

$$210 = \frac{-\partial p}{\partial x} \times \left(\frac{0.1/2}{2}\right)$$

$$\frac{\partial p}{\partial x} = -\frac{210 \times 4}{0.1}$$

$$\boxed{\frac{\partial p}{\partial x} = +8400 \text{ N/m}^3 \text{ per m}}$$

(b) Average velocity, v

$$v = \frac{1}{2} u_{max}$$

$$v = \frac{1}{2}\left[-\frac{1}{4\mu} \cdot \frac{\partial p}{\partial x} \cdot R^2\right]$$

$$v = \frac{1}{2}\left[-\frac{1}{4 \times 0.8} \times (-8400) \times (0.1/2)^2\right]$$

$$\boxed{v = 3.28 \text{ m/sec}}$$

(c) Reynold No., Re

$$Re = \frac{\rho . v . D}{\mu}$$

$$Re = \frac{1200 \times 3.28 \times 0.1}{0.8}$$

$$\boxed{\therefore Re = 492}$$

Q2 Oil having viscosity of 1.5 Pa-sec, $\rho = 1260$ kg/m3 flows at average velocity of 2 m/sec in a pipe of 10cm diameter.

Determine

(i) Boundary shear stress

(ii) head loss in length of 12m

(iii) Power exerted by the flow in distance of 12m.

Soln → Given data, $\mu = 1.5$ Pa-sec $= 1.5$ Ns/m2

$\rho = 1260$ kg/m3

$$\text{spr gr} = \frac{1260}{1000} = 1.26$$

$w = 9810 \times 1.26 = 12360.6$ N/m2

$v = 2$ m/sec

$D = 10$ cm $= 0.1$ m

$L = 12$ m

To find (a) τ_o
(b) h_f
(c) P

$$h_f = \frac{32 \mu L v}{w D^2}$$

$$h_f = \frac{32 \times 1.5 \times 12 \times 2}{12360.6 \times (0.1)^2}$$

$$\boxed{\therefore h_f = 9.31\,m}$$

$$\tau_o = -\frac{dp}{dx} \times \frac{R}{2}$$

$$\frac{-dp}{dx} = \left(\frac{P_1 - P_2}{L}\right)$$

$$h_f = \frac{P_1 - P_2}{w}$$

$$P_1 - P_2 = 9.31 \times 12360.6$$

$$\boxed{\therefore P_1 - P_2 = 115.07 \times 10^3\ N/m^2}$$

$$\frac{-dp}{dx} = \frac{115.07 \times 10^3}{12}$$

$$\frac{-dp}{dx} = 9589.76\ N/m^2$$

$$\tau_o = 9589.76 \times \frac{0.1/2}{2}$$

$$\boxed{\tau_o = 239.74\ N/m^2}$$

$$P = \frac{Q(P_1 - P_2) \times Dist^{n} \cdot 12}{\text{cu}\ w}$$

Power; $$P = \frac{w Q h_f}{1000}$$

$$P = \frac{12360.6 \times \frac{\pi}{4} \times (0.1)^2 \times 2 \times 9.31}{1000} \quad (\because Q = Av)$$

$$\boxed{\therefore P = 1.81\,kW}$$

03. A 20cm diameter having 20km length carries oil of rate of $0.01 m^3/sec$. Calculate the power required to maintain the flow. If $\mu = 0.08$ Pa-sec
$\rho = 900 \; kg/m^3$

Sol^n → Given data,

$D = 20cm = 0.20 m$

$L = 20km = 20\times10^3 m$

$Q = 0.01 \; m^3/sec$

$\mu = 0.08 \; N\text{-}s/m^2$

$\rho = 900 \; kg/m^3$

Specific gravity $= \frac{900}{1000} = 0.9$

$w = 0.9\times9810 = 8829 \; N/m^3$

$P = \frac{wQh_f}{1000}$

$Q = AV$

$\Rightarrow 0.01 = \frac{\pi}{4}\times 0.20^2 \times V$

$\boxed{\therefore V = 0.3184 \; m/sec}$

$h_f = \frac{32\mu L V}{wD^2}$

$h_f = \frac{32\times0.08\times20\times10^3\times0.3184}{8829\times0.20^2}$

$\boxed{h_f = 46.160 m}$

$P = \frac{8829\times0.01\times46.160}{1000}$

$\boxed{\therefore P = 4.075 \; kW}$

04. Oil of viscosity $0.168 \; Ns/m^2$, sp. gr $= 0.9$, flows through a 2cm diameter pipe 300mm long. If Reynold's No. 400 - determine:-

(a) discharge through pipe in Lit/min

(b) head loss in m

(c) Power required

Solⁿ → Given data, $\mu = 0.168\ Ns/m^2$, $D = 2cm = 0.02m$

$L = 300mm = 0.30m$

Sp. gr. $= 0.9$

$w = 0.9 \times 9810 = 8829\ N/m^3$

$\rho = 0.9 \times 1000 = 900\ kg/m^3$

$Re = 400$

To find:- (a) $Q = ?$

(b) $hf = ?$

(c) $P = ?$

$$Re = \frac{\rho . v . D}{\mu}$$

$$\Rightarrow 400 = \frac{900 \times v \times 0.02}{0.168}$$

$\therefore v = 3.73\ m/sec$

$Q = A \times v$

$$Q = \frac{\pi}{4} \times (0.02)^2 \times 3.73$$

$Q = 0.0012\ m^3/sec$

$Q = 0.0012 \times 1000 \times 60$

$\boxed{\therefore Q = 72\ L/min}$

$$hf = \frac{32 \mu L v}{w D^2}$$

$$hf = \frac{32 \times 0.168 \times 0.30 \times 3.73}{8829 \times (0.02)^2}$$

$\boxed{\therefore hf = 1.7034\ m}$

$$P = \frac{w Q hf}{1000}$$

$$P = \frac{8829 \times 0.0012 \times 1.7034}{1000}$$

$\boxed{\therefore P = 0.0180\ kW}$

Q5. Oil of viscosity 1.5 poise and density 843.3 kg/m³ flows through a 30cm I.D. pipe. If the head loss in 3000m Length of pipe is 20cm, assuming a laminar flow, determine –

(a) Velocity

(b) Reynolds no.

(c) Friction factor (fannings)

Soln → Given data,

$\mu = 1.5$ poise $= 0.15$ N-s/m²

$\rho = 843.3$ kg/m³

$D = 30$ cm $= 0.30$ m

$h_f = 20$ cm $= 0.20$ m

$L = 3000$ m

(a) Velocity, $\Delta p = \dfrac{32\mu VL}{D^2}$

or $\Delta p = \rho g \times h_f = \dfrac{32\mu VL}{D^2}$

$$V = \frac{\rho g \times h_f \times D^2}{32\mu L}$$

$$V = \frac{843.3 \times 9.81 \times 0.20 \times 0.3^2}{32 \times 0.15 \times 3000}$$

$$\boxed{\therefore V = 0.010 \text{ m/sec}}$$

(b) $Re = \dfrac{\rho V D}{\mu}$

$$Re = \frac{843.3 \times 0.010 \times 0.30}{0.15} = 16.866 \simeq 17.$$

(c) $f = \dfrac{64}{Re} = \dfrac{64}{17}$

$$\boxed{\therefore f = 3.764}$$

S/2016 06. An oil with density 9000 N/m3 and viscosity 0.18 N-s/m2 flows through a 10cm diameter horizontal pipe. The pressure drop over a 10m length of pipe is 10kPa. Determine the average velocity and the rate of flow.

Soln → Given data;

$\mu = 0.18\ Ns/m^2$, $L = 10m$

$\rho = 9000\ N/m^3$

$D = 10cm = 0.10m$

$P_1 - P_2 = 10kPa = 10\times10^3\ Pa$

To find : (a) average velocity $v = ?$

(b) $Q = ?$

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

$$A = \frac{3.14}{4}\times(0.10)^2 = 7.85\times10^{-3}\ m^2$$

$$\Delta p = \frac{32\mu vL}{D^2}$$

$$P_1 - P_2 = \frac{32\mu vL}{D^2}$$

$$\Rightarrow 10\times10^3 = \frac{32\times0.18\times v\times10}{(0.10)^2}$$

$$\boxed{\therefore v = 1.736\ m/sec}$$

$Q = A\times v$

$Q = 7.85\times10^{-3}\times1.736$

$$\boxed{\therefore Q = 0.0136\ m^3/sec}$$

W 2015 07. Determine the pressure gradient, average velocity and Reynold's number if the fluid of viscosity 8.40 Ns/m2 considering specific gravity 1.0 which is flowing through a pipe having diameter 1.00 meter. Assume maximum shear stress as 210 N/m2.

Soln → Given data :

$\mu = 8.40\ Ns/m^2$

Spe. gr. = 1.0

$w = 1.0 \times 9810 = 9810\ N/m^3$

~~$R = \left(\frac{1.0}{1000}\right) = 1\times10^{-3}$~~

$\rho = 1.0 \times 1000 = 1000\ kg/m^3$

$\tau_0 = 210\ N/m^2$

$D = 1m$

To Find :- (a) ~~$P_1 - P_2$~~ = ? $\frac{dp}{dx}$ = ?

(b) v = ?

(c) Re = ?

(a) $\tau_0 = \frac{-dp}{dx} \times \frac{R}{2} = \frac{-dp}{dx} \times \frac{R}{2}$

$\Rightarrow 210 = \frac{-dp}{dx} \times \frac{(1/2)}{2}$

$\boxed{+\frac{dp}{dx} = -840\ N/m^3 \text{ per m}}$

(b) $v = \frac{1}{2}\left[-\frac{1}{4\mu} \cdot \frac{dp}{dx} \cdot R^2\right]$

$v = \frac{1}{2}\left(-\frac{1}{4 \times 8.40} \cdot -840 \times (0.5)^2\right)$

$\boxed{\therefore v = 3.125\ m/sec}$

(c) $Re = \frac{\rho v D}{\mu} = \frac{1000 \times 3.125 \times 1}{8.40}$

$\boxed{\therefore Re = 372.023.}$

W 2014

08. An oil of specific gravity 0.85 is flowing through a circular pipe of 30 cm diameter. Determine the shear stress at the pipe wall if the viscosity of oil is 0.15 Ns/m² and head loss is 20 m in 3000 m length of pipe.

Soln → Given data,

$Spr\ gr = 0.85$

$w = 0.85 \times 9810 = 8338.5\ N/m^3$

$\rho = 0.85 \times 1000 = 850\ kg/m^3$

$D = 30\,cm = 0.3\,m$

$\mu = 0.15\ Ns/m^2$

$hf = 20\,m$

$L = 3000\,m$

To find :- (a) $\tau_0 = ?$

$$hf = \frac{32\mu v L}{D^2}$$

$$\Rightarrow 20 = \frac{32 \times 0.15 \times v \times 3000}{(0.30)^2}$$

$$\boxed{\therefore v = 1.25 \times 10^{-4}\ m/sec}$$

$$v = \frac{1}{2}\left[-\frac{1}{4\mu} \cdot \frac{dp}{dx} \cdot R^2\right]$$

$$\Rightarrow 1.25 \times 10^{-4} = \frac{1}{2}\left[-\frac{1}{4 \times 0.15} \cdot \frac{dp}{dx} \cdot (0.3/2)^2\right]$$

$$\boxed{\therefore \frac{dp}{dx} = -6.67 \times 10^{-3}\ N/m^3 \text{ per m}}$$

$$\tau_0 = \frac{-dp}{dx} \times \frac{R}{2}$$

$$\tau_0 = -(-6.67 \times 10^{-3}) \times \frac{(0.3/2)}{2}$$

$$\boxed{\therefore \tau_0 = 5.0025 \times 10^{-4}\ N/m^2}$$

W 2013 Q9. Oil of viscosity 9 poise and specific gravity 0.9 is flowing through an horizontal pipe of 60 mm diameter. If pressure drop in 100 m length of pipe is 1800 kN/m².

Determine:

(a) The rate of flow of oil

(b) The centre line velocity

(c) Total fractional drag over 100 m length.

(d) State whether flow is laminar.

Soln → Given data, $\mu = 9 \text{ poise} = \frac{9}{10} = 0.9 \text{ Ns/m}^2$

Specific gravity $= 0.9$

$w = 0.9 \times 9810 = 8829 \text{ N/m}^3$

$\rho = 0.9 \times 1000 = 900 \text{ kg/m}^3$

$D = 60 \text{ mm} = 60/1000 = 0.06 \text{ m}$

$L = 100 \text{ m}$

$\Delta p = P_1 - P_2 = 1800 \text{ kN/m}^2 = 1800 \times 10^3 \text{ N/m}^2$

(a) $\Delta p = P_1 - P_2 = \frac{32 \mu V L}{D^2}$

$\Rightarrow 1800 \times 10^3 = \frac{32 \times 0.9 \times V \times 100}{0.06^2}$

$\boxed{\therefore V = 2.25 \text{ m/sec}}$

$Q = A \times V$

$Q = \frac{\pi}{4} \times (0.06)^2 \times 2.25$

$\boxed{\therefore Q = 6.3585 \times 10^{-3} \text{ m}^3/\text{sec}}$

(b) The centre line velocity, u_{max}

$u_{max} = 2 \times V = 2 \times 2.25$

$\boxed{u_{max} = 4.5 \text{ m/sec}}$

(c) The total frictional drag over 100m length,

F_D

Wall shear stress,

$$\tau_0 = \frac{-\partial p}{\partial x} \times \frac{R}{2}$$

$$V = \frac{1}{2}\left[-\frac{1}{4\mu} \times \frac{\partial p}{\partial x} \times R^2\right]$$

$$\Rightarrow 2.25 = \frac{1}{2}\left[-\frac{1}{4 \times 0.9} \times \frac{\partial p}{\partial x} \times (0.06/2)^2\right]$$

$$\boxed{\therefore \frac{\partial p}{\partial x} = -18000 \text{ N/m}^3 \text{ per m}}$$

$$\tau_0 = \frac{-\partial p}{\partial x} \times \frac{R}{2}$$

$$\tau_0 = -(-18000) \times \frac{(0.06/2)}{2}$$

$$\boxed{\therefore \tau_0 = 270 \text{ N/m}^2}$$

$F_D = \tau_0 \times \pi D \times L$

$F_D = 270 \times 3.14 \times 0.06 \times 100$

$F_D = 5089 N$

$\boxed{\therefore F_D = 5.089 \text{ kN}}$

(d) $Re = \frac{\rho V D}{\mu}$

$Re = \frac{900 \times 2.25 \times 0.06}{0.9}$

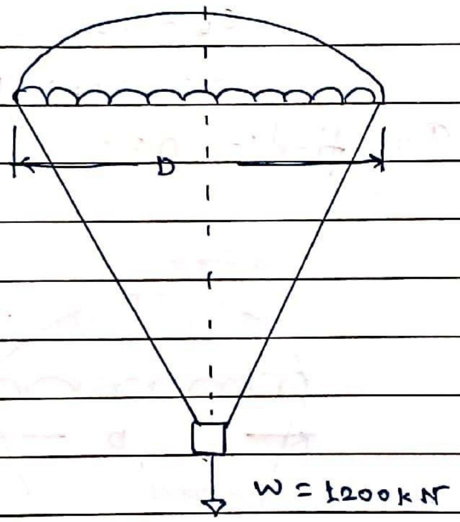
$\boxed{\therefore Re = 135}$

As Re is less than 2000, the flow is laminar.

TYPE-II (Compulsary)

[Based on parachute Problems] [7 MARKS]

Q1. The vertical component of the landing speed of a parachute is 6 m/s. Treat the parachute as an open hemisphere and determine its diameter if the total weight to be carried is 1200 N. Take $\rho = 1.208\ kg/m^3$ and $C_D = 1.33$.



Soln → Given data:

Speed of parachute, $U = 6\ m/sec$

Weight to be carried $= W = 1200\ N = F_D$

Density of air, $\rho = 1.205\ kg/m^3$

Coefficient of drag, $C_D = 1.33$

To find :- Diameter $(D) = ?$

Drag force

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

$$\Rightarrow 1200 = \frac{1.33 \times 1.205 \times 6^2}{2} \times \frac{\pi}{4} \times D^2$$

$$\boxed{\therefore D = 7.27\ m}$$

W 2016

02. Calculate the diameter of a prachute to be use for dropping an object weighting 980N so that the maximum terminal velocity of dropping is 5m/sec. The drag coefficient for the parachute which may be treated as hemispherical is 1.3. The density of air is 1.22kg/m³.

Soln → Given data:

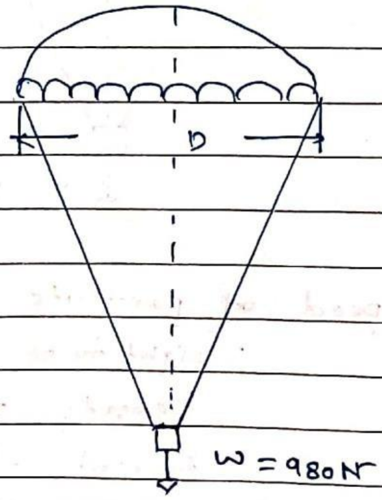
$$F_D = W = 980N$$

$$U = 5 m/sec$$

$$C_D = 1.3$$

$$\rho = 1.22 kg/m^3$$

To find:- $D = ?$



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

$$\Rightarrow 980 = \frac{1.3 \times 1.22 \times 5^2}{2} \times \frac{\pi}{4} \times D^2$$

$$\boxed{\therefore D = 5.61 m}$$

FORMULA

FOR TYPE-I-

(1) Maximum shear stress, τ_0

$$\boxed{\tau_0 = \frac{-\partial p}{\partial x} \times \frac{R}{2}}$$

where; τ_0 = Max^m shear stress in N/m^2

$\frac{\partial p}{\partial x}$ = pressure gradient in N/m^3 per m

R = radius of the circular pipe in m

(2) Average velocity, v

$$\boxed{v = \frac{1}{2}\left[-\frac{1}{4\mu} \cdot \frac{\partial p}{\partial x} \cdot R^2\right]}$$

where, v = Average velocity in m/sec

μ = Viscosity of fluid in N·s/m^2

$\frac{\partial p}{\partial x}$ = Pressure gradient in N/m^3 per m

R = Radius of the circular pipe in m

(3) Reynold's Number, Re

$$\boxed{Re = \frac{\rho v D}{\mu}}$$

where; Re = Reynold's number

ρ = Density in kg/m^3

v = velocity in m/sec

D = Diameter of the pipe in m

μ = Viscosity of fluid N-s/m^2

(4) Head loss, H_f

$$\boxed{h_f = \frac{32 \mu v L}{w D^2}}$$

where, h_f = head loss in m.

μ = viscosity of fluid in $N\text{-}s/m^2$

v = velocity in m/sec

L = Length of the pipe in m.

w = 9810 × Specific gravity in N/m^2

Specific gravity = $\frac{\rho}{1000}$ in const.

D = Diameter of pipe in m.

(5) Power, $\boxed{P = \frac{wQh_f}{1000}}$ $\boxed{\therefore P = \frac{wQh_f}{75}}$ metric horsepower

where, P = power in kw

w = 9810 × specific gravity in N/m^2

h_f = head loss in m

Q = Discharge in m^3/sec

$Q = Av$

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

(6) friction factor (fanning's), f

$$\boxed{f = \frac{64}{Re}}$$

where, f = friction factor

Re = Reynold's no.

(7) Pressure drop, Δp

$$\Delta p = \frac{32 \mu v L}{D^2}$$

$$\boxed{\therefore P_1 - P_2 = \frac{32 \mu v L}{D^2}}$$

Where; $\Delta p = p_1 - p_2 =$ Pressure drop in Pa N/m2

(8) Centre line velocity, u_{max}

$$\boxed{u_{max} = 2 \times v}$$

where, u_{max} = Centre line velocity in m/s
v = velocity in m/sec

(9) Frictional Drag, F_D

$$\boxed{F_D = \tau_0 \times \pi \times D \times L}$$

where; F_D = Frictional Drag in kN or N.
τ_0 = Max^m shear stress in N/m2
D = Diameter in m.
L = Length in m.

TYPE-II -

(1) Drag force; F_D

$$\boxed{F_D = W = C_D \times \frac{\rho U^2}{2} \times A}$$

where, F_D = Drag force in N.
C_D = Coefficient drag in const.
ρ = Air density kg/m3
A = Area in m2
$A = \frac{\pi}{4} \times D^2$
D = Diameter in m.