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Subject	Advanced fluid Mechanics
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Mid term summer Exam

Q1

Write down expressions for velocity profile in laminar flow inside the pipe.

Velocity Profile for Laminar flow:-

As $h_L = \frac{\tau \cdot 2 \cdot L}{\varepsilon r}$

From Viscosity $\rightarrow$ $\tau = \mu \frac{du}{dy}$

where "μ" is velocity at distance "y" from the boundary

Thus,

$$y = \varepsilon_0 - \varepsilon$$

$$dy = d\cancel{\varepsilon_0} - d\varepsilon$$

$$dy = -d\varepsilon$$

Putting values in (x)

$$\tau = -\frac{\mu du}{d\varepsilon}$$

Now,

$$h_L = \frac{\tau \cdot 2 \cdot L}{\varepsilon \cdot r} = -\frac{\mu du \cdot 2L}{\varepsilon \cdot r \cdot d\varepsilon}$$

or

$$du = \frac{-h_L r}{2\mu L} \cdot \varepsilon d\varepsilon$$

Integrating b/s

$$\int du = \int -\frac{hLr}{2\mu L} \cdot \varepsilon \cdot d\varepsilon$$

$$u = -\frac{hLr}{2\mu L} \cdot \frac{\varepsilon^2}{2} + c$$

$\Rightarrow$ Now for $\varepsilon = 0$, $u = u_{max}$

Putting values

$$u = \frac{-hLr}{2\mu L} \cdot \frac{\varepsilon^2}{2} + c$$

$\therefore$ $u_{max} = 0 + c \Rightarrow c = u_{max}$

Thus $u = u_{max} - \frac{hLr}{2\mu L} \cdot \frac{\varepsilon^2}{2} \rightarrow$ Velocity at any point

$\Rightarrow$ Assume $k = \frac{hL.r}{4.\mu L}$ $\therefore u = u_{max} - k\varepsilon^2$

As for $\varepsilon = \varepsilon_0$, $u = 0$

$0 = u_{max} - K\varepsilon_0^2$ or $u_{max} = k\varepsilon_0^2 = \frac{hLr}{4\mu L} \cdot \varepsilon_0^2$

It is also known as critical Velocity

Now $V_{av} = \frac{V_{cr} + 0}{2} = 0.5 V_{cr}$

$\downarrow$

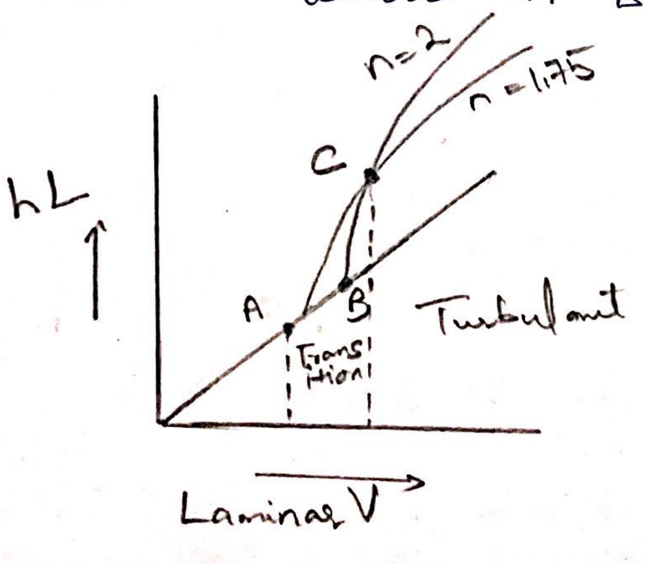
average velocity

Q 1
b) Define critical Reynold number. Write down its equation.

Ans Critical Reynolds Number:-

If head loss in given length of uniform pipe is measured at different values of velocity, It will be found that as long as velocity is low enough to secure laminar flow, The head loss due to friction will be directly proportional to velocity, but increase in velocity, change flow from laminar to turbulant because change in head loss. Thus if values are plotted, lines obtained with slope ranging about 1.75 to 2

Thus for Laminar, drop of energy varies as V and for turbulant, friction varies as V^n where n is 1.75 to 2



The upper critical reynolds number corresponding to point B is indeterminate and depend upon case taken to prevent initial disturbance. its value is 4000. But normally, its impossible for flow to be in straight line after R is at 2000. Thus lower value is much more definite than higher one and is dividing point. Thus lower value is true critical Reynold's Number.

If Reynolds Number is below 2000 (critical Reynolds Number) flow would be laminar and it is above 4000 flow would be treated as turbulant, region from Reynolds Number 2000 - 4000 is transition.

Equation:-

Ratio of interial force to viscous force is called Reynold's number

$$R = \frac{FI}{FV} \Rightarrow FI = ma = \rho V^3 \cdot \frac{L}{T^2}$$

$$= \rho L^4 T^2 = \rho \left(\frac{L}{T}\right)\left(\frac{L}{T}\right)$$

$$= \rho V^2 L^2$$

$$FV = \mu \left(\frac{du}{dy}\right) A = \mu \left(\frac{V}{L}\right) L^2 = \mu V L$$

$\because \; R = \frac{L^2 V^2 \rho}{L V \mu} = \frac{L V \rho}{\mu} = \frac{L V}{\nu}$

ν = kinematic Viscosity

for Circular pipe

$$\boxed{R = \frac{D V \rho}{\mu} = \frac{D V}{\nu}}$$

equation to determine Critical Reynold's Number

The lower value (2000) is known as critical Reynold's Number.

$N_{REC} = 3470 - 1370n$

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Q2 An oil of $(S = 0.7)$ and kinematic viscosity of 1.8×10^{-5} m^2/s flows in 150mm Pipe at $0.5 m^3/s$. Find the centreline Velocity. Velocity at 10mm from edges and velocity at edge of the pipe. Also Find max shear stress at wall of the pipe?

Given :-

Specific Gravity $(S) = 0.7$

Kinematic Viscosity $(\nu) = 1.8 \times 10^{-5} m^2/sec$

Dia of Pipe $(d) = 150mm = 0.15m$

Discharge $(Q) = 0.5 L/sec$

$$= \frac{0.5}{1000} = 5 \times 10^{-4} m^3/sec$$

Solution :-

$$\text{Area} = \frac{\pi}{4}(0.15)^2 = 0.0176 m^2$$

$$\Rightarrow Q = AV \Rightarrow V = Q/A$$

$$= \frac{5 \times 10^{-4}}{0.0176}$$

$$V = 0.028 \; m/sec$$

Reynold Numbes $(R) = DV/\gamma$

$$= \frac{0.15 \times 0.028}{1.8 \times 10^{-5}}$$

$$= 233 < 2000$$

So it means laminar flow

Now centerline Velocity,

$$V_{cr} = 2V_{av}$$

$$= 2(0.028)$$

$$= 0.056 m/sec$$

$$u = u_{max} - K\mathcal{E}_o^2$$

for $\mathcal{E} = \mathcal{E}_o = \frac{0.15}{2} = 0.075m$, $u = 0$

Thus

$$= u_{max} - Kr^2$$

$$u_{max} = Kr^2$$

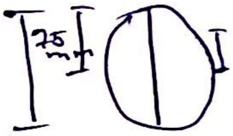
$$K = \frac{U_{max}}{r^2} = \frac{0.056}{(0.075)^2}$$

$$K = 9.96$$

We get an equation ;

$$u = 0.056 - 9.96(r^2) \rightarrow 1$$

Velocity at 10mm from edge/150mm



$r = 0.065m$

$V = 0.056 - 9.96(0.065)^2$

$V = 0.14$ m/sec

Velocity at edge;

$r = 0.075m$

$V = 0.056 - 9.96(0.075)$

$V = -0.0002$ m/sec say $V = 0$

Similarly

$f = \frac{64}{R} = \frac{64}{233.33}$

$f = 0.27$

Shear stress at wall;

$\tau = \frac{f}{4}\rho\frac{V^2}{2}$

$= \frac{0.27}{4} \times (0.7 \times 1000) \times \frac{(0.056)^2}{2}$

$\boxed{\tau = 0.074 \ N/m^2}$

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