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SUMMER MID PAPER= ADVANCE FLUID

Questions part (a)

①

Velocity profile in laminar flow inside the pipe

For a circular pipe:- The laminar flow is defined to have the flow Reynold number < 2000
Reynold number

$$Re = \frac{\rho V D}{\mu} = \frac{V D}{\nu} < 2000 \text{ for laminar flow}$$

Laminar pipe flow: The shear stress for laminar flow is linearly related to fluid viscosity

$$\text{as } \tau = \mu \frac{du}{dr}$$

Aided by the above relation

$$\mu \frac{du}{dr} = - r/2 \frac{dp}{dx}$$

To integrate the above yields

$$u = \frac{1}{\mu} \frac{dp}{dx} \frac{r^2}{2} + C$$

The integration constant C can be determined by $u = 0$ at $r = D/2$

(on solid boundary)

(2)

$$0 = \frac{1}{\mu} \cdot \frac{dp}{dx} \cdot \frac{r^2}{2} + c$$

Now for $r=0$, $u = u_{max}$

$$u = -\frac{hLv}{2\mu L} \cdot \frac{r^2}{2} + c$$

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

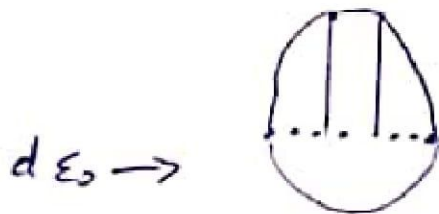
$$c = u_{max}$$

Thus

$$u = u_{max} = \frac{hLv}{2\mu L} \cdot \frac{r^2}{2} \quad \text{velocity at any point}$$

$$\Rightarrow \text{Assume } k = \frac{hLv}{4\mu L} \quad (u = u_{max} - kr^2)$$

As for $r = r_0$, $u = 0$



$$0 = u_{max} - k r_0^2$$

$$\text{or } u_{max} = k r_0^2 = \frac{hLv}{4\mu L} = \epsilon_0$$

It is also known as critical velocity

Now

$$V_{av} = \frac{V_{eq} + 0}{2} = 0.5 V_{eq} \quad (\text{average velocity})$$

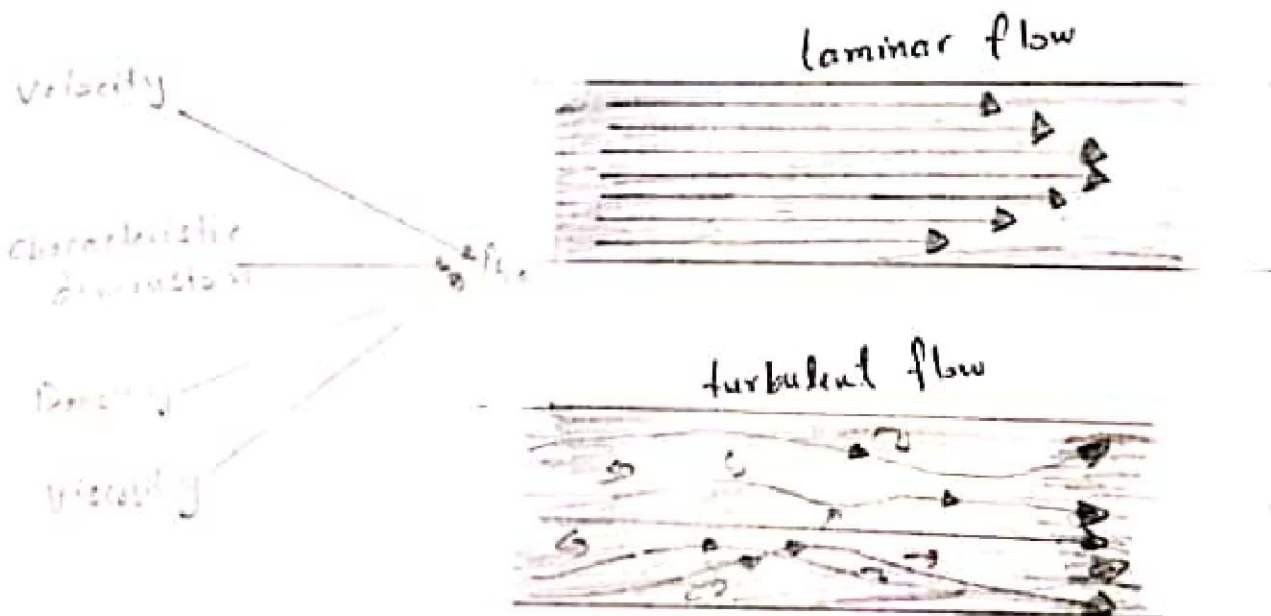
Q1 part b

Critical Reynolds Number

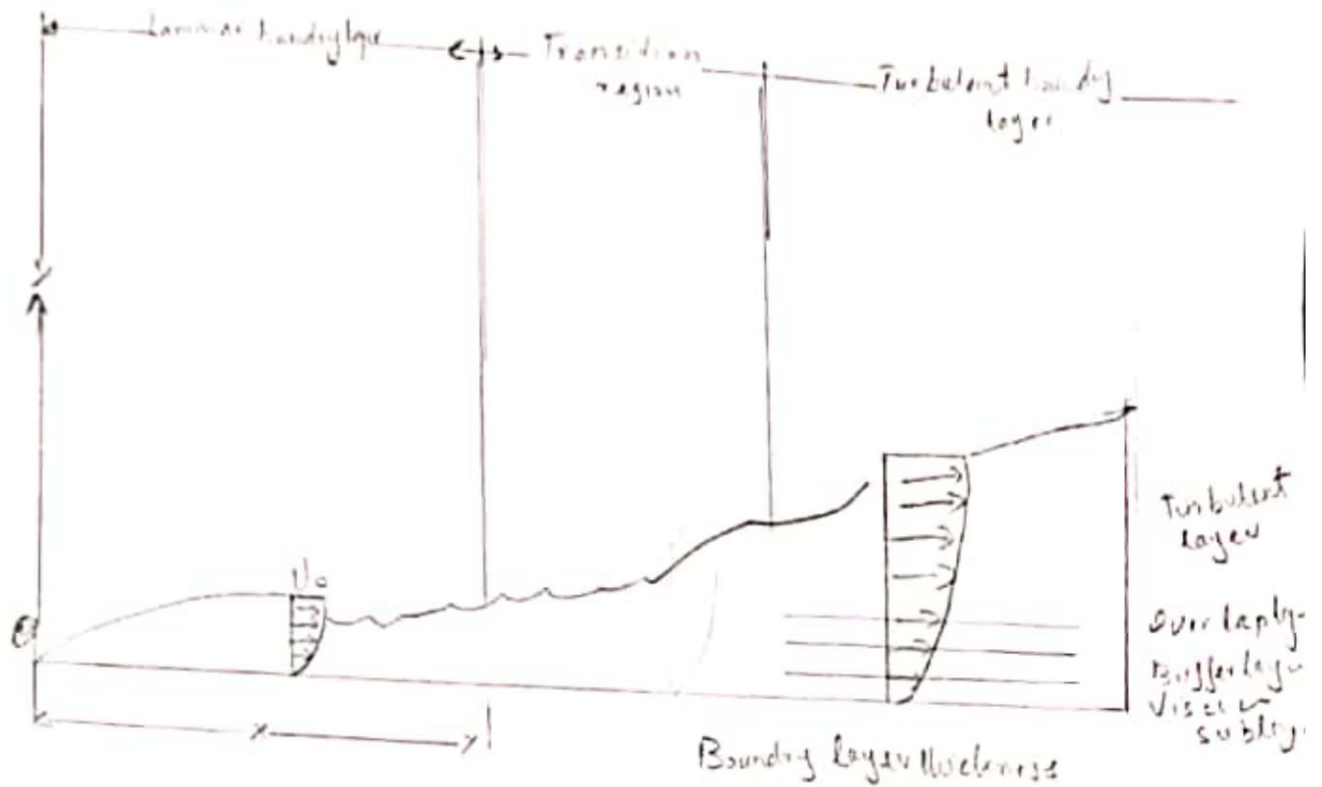
A critical Reynolds number is determined as a limit where the laminar flow changes to turbulent flow. If the calculated Re is greater than the critical Reynolds number Re_{crit} , the flow regime is turbulent; otherwise the flow regime is laminar.

Critical Reynolds number is the number which decides whether flow is laminar or turbulent flow.

$$Re = \frac{\text{Inertia forces}}{\text{viscous forces}} = \frac{\rho \cdot V \cdot D}{\mu}$$



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In case of ~~is~~ internal flow, if Reynolds number is below 2000 (Critical Reynolds number) flow would be Laminar and if it is above 4000 flow would be treated as turbulent region from Reynolds number 2000-4000 is Transition

$$N_{rec} = 3470 - 13724$$

Where n is power ^{Law} fluid index

Question 2

(5)

Given data

Oil having $S = 0.7$

Kinematic viscosity $= 1.8 \times 10^{-5} \text{ m}^2/\text{sec}$

Dia of pipe $= 150 \text{ mm} = 0.15 \text{ m}$

Flow $= 0.5 \text{ L}/\text{sec} = 0.0005 \text{ m}^3/\text{sec}$

Reqd

Centerline velocity = ?

Velocity at 10mm from edge = ?

Velocity at edge of pipe = ?

Max shear stress at wall = ?

Solution

First we check flow is laminar or turbulent

$$R = \frac{DV}{\nu} \quad \text{--- (1)}$$

$$V = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} d^2} = \frac{0.0005}{\frac{\pi}{4} (0.15)^2}$$

$$V = 0.028 \text{ m/sec}$$

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

$$R = 233.37 < 2000 \text{ (laminar)}$$

(6)

$$V_{cr} = 2V = 2 \times 0.028 = 0.056$$

$$V_{cr} = 0.056 \text{ m/sec}$$

As

$$u = U_{max} - ky^2$$

at

$$r = r_0 = 0.075 \text{ m}, u = 0$$

Thus

$$0 = U_{max} - kr^2$$

$$U_{max} = kr^2$$

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

we get a equation,

$$u = 0.056 - 996 \left(\frac{r}{0.075}\right)^2 \rightarrow (*)$$

velocity at 10mm from edge

$$r = 0.065 \text{ m}$$

$$V = 0.056 - 996 (0.065)^2$$

$$V = 0.014 \text{ m/sec}$$

velocity at edge

$$r = 0.075 \text{ m}$$

$$V = 0.056 - 996 (0.075)^2$$

$$V = -0.00002 \text{ m/sec} \text{ say } V = 0$$

Similarly:

$$f = \frac{64}{R} = \frac{64}{233.37}$$

$$f = 0.27$$



Shear stress at wall (7)

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

$$= \frac{0.27}{4} \times (0.72 \times 1000)$$

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

