Name: Salman Abdullah Khan

ID: 7772

Subj: Advance fluid Mechanics

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Submitted to Sir Abdul Waheed

Question1 part(a)

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

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

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

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

Aided by the above relation

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

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 = at r = D/2

(on Solid boundry)

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

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

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

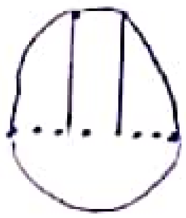
$\therefore u_{max} = 0 + c$
$c = u_{max}$

Thus

$$u = u_{max} = \frac{hL_v}{2\mu L}\cdot\frac{r}{2}$$ velocity at any point

⇒ Assume $K = \frac{hL_v}{4\mu L}$. $(u = u_{max} - kr^2)$

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

$dr_0 \rightarrow$ 

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

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

It is also known as critical velocity

Now

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

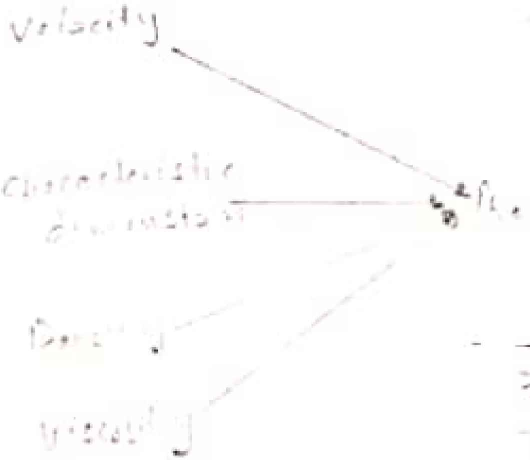
Q1 part b

Critical Reynolds Number

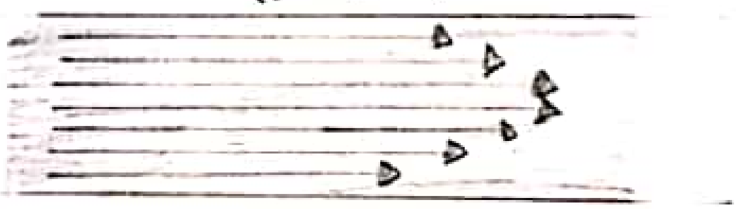
A critical Reynold number is determined as a limit where the laminar flow changes to turbulent flow. If the calculated NRe is greater than the critical Reynold number NRec, the flow regime is turbulent, otherwise the flow regime is laminar.

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

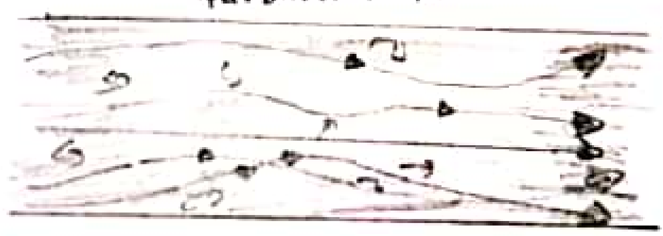
$$Re = \frac{\text{Inertia forces}}{\text{viscous forces}} = \frac{\rho \cdot V \cdot D}{\mu}$$

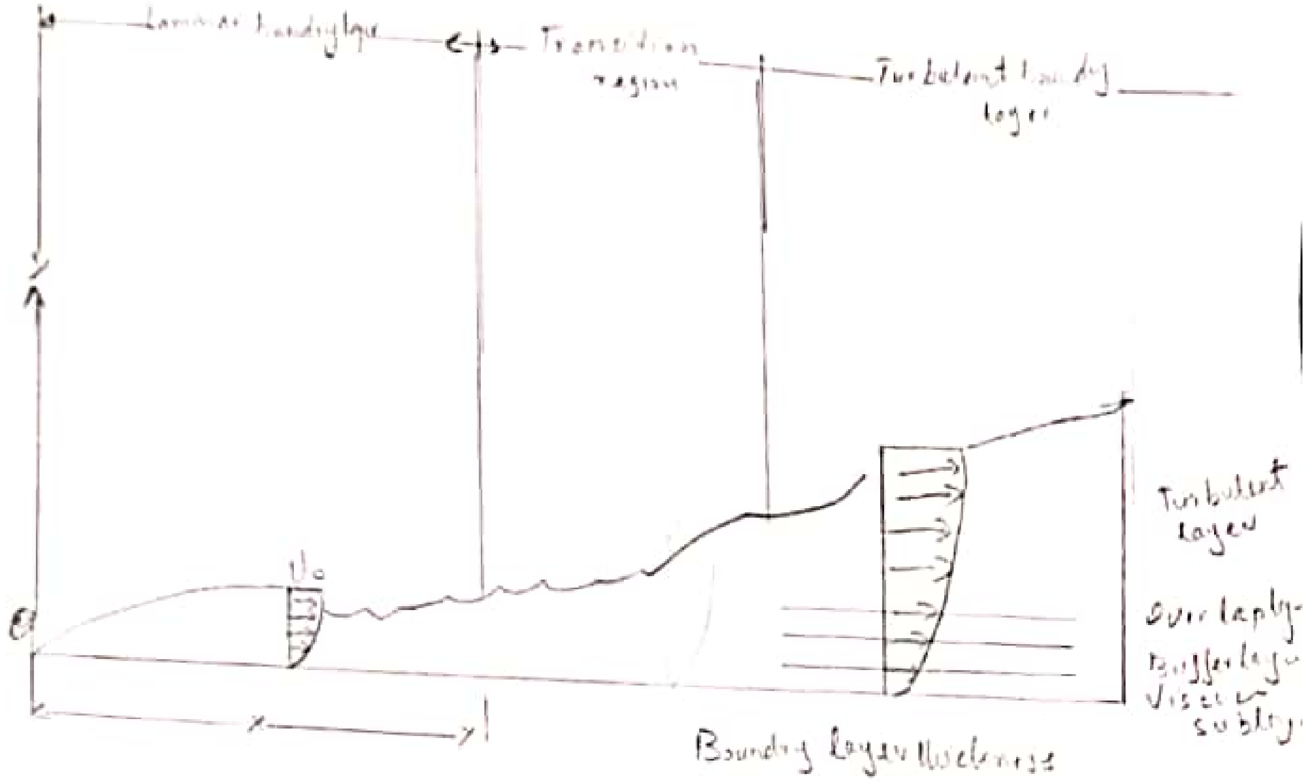


laminar flow



turbulent flow





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

$$N_{rec} = 3470 - 1370n$$

Where n is power Law fluid index

Question 2

(5)

Given data

Oil having S = 0.7

Kinematic Viscosity = 1.8×10^{-5} m^2/sec

Dia of pipe = 150 mm = 0.15 m

Flow = 0.5 L/sec = 0.0005 m^3/sec

Req

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

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

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

$$V = 0.028 \ m/sec$$

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

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

$V_{av} = 2V = 2 \times 0.028$

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

As

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

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:

$u = 0.056 - 996(r^2) \longrightarrow (*)$

velocity at 10mm from edge

$r = 0.065\text{ m}$

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

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

velocity at edge

$r = 0.075\text{ m}$

$V = 0.056 - 996(0.075)$

$V = -0.00002 \text{ m/se}$ Say $V = 0$

Similarly:

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

$f = 0.27$

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Shear stress at wall

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

$$= \frac{0.27}{4 *} \times (0.7 \times 1000)$$

$$\tau = 0.074 \ N/m^2$$

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