Q. In a laminar flow through a pipe of diameter 'D' the average velocity is indicated as local velocity at a radial distance measured from the centre of pipe is

(a) .707D

(b) 0.223D

(c) 0.5D

(D) 0.354D

Soln:

Given:

Average velocity (V) is equal to fluid velocity (u) at a radial distance (r) from centre of the pipe

$$u = u_{max}\left(1 - \frac{r^2}{R^2}\right)$$

$$V = \frac{u_{max}}{2}$$

Given, $u = V$

2) $\cancel{\frac{u_{max}}{2}} = u_{max}\left(1-\frac{r^2}{R^2}\right)$

$= \frac{1}{2} = 1 - \frac{r^2}{R^2}$

$r^2 = \left(1-\frac{1}{2}\right)R^2 = \frac{1}{2}\cdot\frac{D^2}{4}$

$= r = \frac{D}{2\sqrt{2}} = 0.354D$

Q $h_L = \frac{4f'Lv^2}{\rho g D}$

if $\frac{f'}{\rho} = \frac{f_c}{2}$ then:

$h_L = \frac{4f}{2}\cdot\frac{Lv^2}{gD}$

$h_L = \frac{4f_c Lv^2}{2gD}$ where f = coefficient of friction.

Sometimes h_L is written as

$\boxed{h_L = \frac{fLv^2}{2gD}}$ where

f = friction factor.

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A crud oil of viscosity 0.97 poise and relative density 0.9 is flowing through a horizontal circular pipe of diametre 100 millimetre and of length 10m. calculate the difference of pressure at the two ends of the pipe, if 100kg of oil is collected in a tank in 30sec.

Solⁿ:

$\rho = \frac{0.9 \times 100\cancel{0}}{1\cancel{0}} = 900$

~~0.9 × 1000~~

$\rho = \frac{m}{V}$

$900 = \frac{100}{V}$

$V \times 900 = 100$

$V = \frac{100}{900} = \frac{1}{9}\ m^3$

$R_e = \frac{\rho V L}{\mu} = 900 \times \frac{1}{9} \times$

$\mu = 0.97\ \text{poise} = 0.97 \times 0.1$

Relative density $\rho = 0.9$

$D = 100\,mm = 100 \times 10^{-3}\,m = 0.1\,m$

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length = $L = 10m$

$P_1 - P_2 = ?$

$m = 100 kg$

$t = 30 sec$

Now as we know

$$S_0 = \frac{\rho_0}{\rho_{H_2O}}$$

$$0.9 = \frac{\rho_0}{1000}$$

$$\rho_0 = 0.9 \times 1000 = 900 \, kg/m^3$$

$$vol = \frac{m}{\rho} = \frac{100}{900} m^3$$

$$Q = \frac{volume}{time} = \frac{100}{900 \times 30} = 0.0037 \, m^3/s$$

Now, mean velocity of oil is given by

$$V = \frac{Q}{A} = \frac{0.0037}{\frac{\pi}{4} D^2}$$

$$= \frac{4 \times 0.0037}{\pi \times (0.1)^2} = 0.471 \, m/s$$

Now for circular pipe

$$Re = \frac{\rho V D}{\mu}$$

$$= \frac{900 \times 0.471 \times 0.1}{0.97 \times 0.1}$$

$$= 436.91$$

since Re < 2000 so flow of oil will be laminar.

∴ pressure drop is given by:

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

$$= \frac{32 \times 0.97 \times 0.1 \times 0.471 \times 10}{(0.1)^2}$$

$$= 1461.984 \ N/m^2 \ \text{Ans}$$

Q2: An oil of viscosity 0.1 N.sec/m² and relative density 0.9 is flowing through a circular pipe of diametre 50 mm and of length 300m. The rate of flow of fluid through the pipe is 3.5 liters/sec. find the pressure drop in a length of 300m and also the shear stress at the pipe wall.

$\boxed{1 \text{ litre} = 10^{-3} m^3/sec}$

Sol^n:

$\mu = 0.1$

$$S_o = \frac{\rho}{\rho_{H_2O}}$$

$$0.9 = \frac{\rho}{1000}$$

$$\rho = \frac{0.9 \times 1000}{1} = 900 \ Kg/m^3$$

$$Q = 3.5 \times 10^{-3} = \frac{3.5}{1000} = 0.0035 \ m^3/sec$$

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

$$V = \frac{Q}{A}$$

$$= \frac{0.0035}{\frac{\pi}{4} \times (0.05)^2}$$

$$= 1.78 \text{ m/sec}$$

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

$$= \frac{32 \times 0.1 \times 1.78 \times 300}{(0.05)^2}$$

$$= 683520 \text{ N/m}^2$$

$$= 68.35 \text{ N/cm}^2.$$

Now,
Shear stress is given by

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

at the wall $r = R$ (radius)

$$= \frac{D}{2} = \frac{0.05}{2} = 0.025$$

$$\tau_{wall} = -\frac{(P_2 - P_1)}{(x_2 - x_1)} \cdot \frac{0.025}{2}$$

$$= \cancel{68.35 \times 0.025}$$

$$= \frac{684480}{300} \times \frac{0.025}{2} = 28.52 \text{ N/m}^2$$

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Ans. 0.75 m/sec

70.7 millim...

0.96 m/sec

Q3 A laminar flow is taking place in a pipe of diametre 200 millimetre. The maximum velocity is 1.5 m/sec. Find the mean velocity and radius at which this occurs. Also calculate the velocity at 4 cm from the wall of the pipe.

Soln:

$D = 200mm$

$V_{max} = 1.5 m/sec$

$\bar{V} = ?$

$r = ?$

velocity at 4 cm, $u = ?$

mean velocity $= \frac{U_{max}}{2}$

$= \frac{1.5}{2} = 0.75 m/s$

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

$= 0.75 = 1.5\left(1 - \frac{r^2}{\left(\frac{0.2}{2}\right)^2}\right]$

$= 0.75 = 1.5\left[1 - \frac{r^2}{(0.1)^2}\right)$

$= \frac{0.75}{1.5} = 1 - \frac{r^2}{(0.1)^2}$

$= 0.5 = 1 - \frac{r^2}{0.01}$

$$\frac{r^2}{0.01} = 1 - 0.5$$

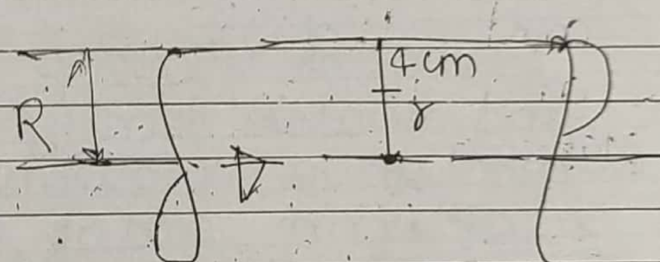
$$\frac{r^2}{0.01} = 0.5$$

$$r^2 = 0.5 \times 0.01$$

$$r = \sqrt{0.5 \times 0.01}$$

$$r = 0.070\,m$$

$$r = \underline{70.71\ mm}$$



$$4\,cm + r = R$$

$$\cancel{4\,cm} + \cancel{70.71}\ r = 0.1$$
$$0.04$$

$$r = 0.1 - 0.04$$

$$r = \underline{0.06}$$

$$u = u_{max}\left(1 - \frac{r^2}{R^2}\right)$$

$$165 = \cancel{2.06}\ 1.5\left(1 - \frac{(0.06)^2}{(0.1)^2}\right)$$

$$= 0.96\ m/s$$