2. A lubricating oil of viscosity 1 poise and sp. gravity 0.9 is pumped through a 30 mm diameter. If the pressure drop per meter length of pipe is 20 kN/m², determine (11)

(a) The mass flow rate in kg/min

(b) The shear stress at the pipe wall.

(c) The Reynold's number of flow.

Soln

$\mu = 1 \text{ poise} = .1 \text{ Ns/m}^2$,

$P_1 - P_2 = 20 \text{ kN/m}^2 = 20\times10^3 \text{ N/m}^2$

(a) $P_1 - P_2 = \dfrac{32\mu\bar{u}L}{D^2} \Rightarrow 20\times10^3 = \dfrac{32\times.1\times u\times1}{(.03)^2}$

$u = \dfrac{20\times10^3\times(.03)^2}{32\times.1\times1} = 5.625 \text{ m/s}.$

$Q = A\times\bar{u} = \frac{\pi}{4}\times(.03)^2\times5.625 = .003975 \text{ m}^3/\text{s}.$

mass flow rate $= \rho\times A\times V = \rho\times Q.$

$= (.9\times1000)\times.003975\times60$

$= 214.65$ kg/min.

(b)

$\tau = -\left(\dfrac{\partial p}{\partial x}\right)\times\dfrac{R}{2} \Rightarrow \dfrac{20\times10^3\times(.03/2)}{2} = 150 \text{ N/m}^2$

(c)

$Re = \dfrac{\rho V D}{\mu} = \dfrac{.9\times1000\times5.625\times.03}{.1} = 1518.7.$

$Re < 2000$ (hence flow is laminar)

Q. An oil (μ = 20 centpoise, ρ = 1200 kg/m³) flows through a 2.5 cm diameter pipe of 250 m long.

(a) what is the max^m flow in m³/s that will ensure laminar flow

(b) what would be the pressure drop for this flow.

Sol^n

$$\mu = 20 \text{ centpoise} = \frac{20 \times 10^{-2}}{10} = .02 \ NS/m^2$$

flow is Laminar

$$Re = 2000$$

$$2000 = \frac{1200 \times V \times .025 \times V}{.02} = 1.33 \ m/s.$$

(a) max^m flow

$$= A \times V = \frac{\pi}{4} \times (.025)^2 \times 1.33$$

$$= 6.528 \times 10^{-4} \ m^3/s.$$

(b) $f = \frac{16}{Re}$, $h_f = \frac{4 f L V^2}{2 d g}$

$$= \frac{16}{2000} = .008.$$

$$= \frac{4 \times .008 \times 250 \times 1.33^2}{2 \times .025 \times 9.81}$$

$$= 28.85 \ m.$$

Pressure drop = $w h_f$ = $\rho g \times h_f$

$$= 1200 \times 9.81 \times 28.85$$

$$= 339622.2 \ N/m^2$$

$$= 3.396 \text{ bar.}$$

(13)

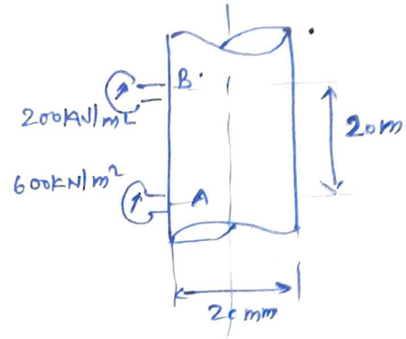
Q. Crude oil of $\mu = 1.5$ poise and relative density 0.9 flows through a 20mm diameter vertical pipe. The pressure gauges fixed 20m apart read 600 kN/m² and 200 kN/m², as shown in fig. Find the direction and discharge through the pipe

Sol

(A) $\mu = 1.5$ poise $= 0.15\ Ns/m^2$, rel. density $= 0.9$

$D = 20\ mm = .02\ m$, $l = 20m$.

$w = .9 \times 1000 \times 9.81 = 8.829\ \frac{kN}{m^3}$



Piezometric head at

$$A = \frac{P_A}{\rho g} + Z_A = \frac{600}{8.829} + 0 = 67.96\,m.$$

$$\text{at } B - \quad \frac{P_B}{\rho g} + Z_B = \frac{200}{8.829} + 20 = 42.65\,m.$$

Piezometric head at A > B.

flow takes place from A to B.

(B). Loss of piezometric head $= 67.96 - 42.65$

$= 25.31m$

$$h_f = \frac{32 \mu u L}{\rho g D^2} \Rightarrow$$

$$25.31 = \frac{32 \times .15 \times \bar{u} \times 20}{8.829 \times 10^3 \times (.02)^2}$$

$$\bar{u} = .931 m/s$$

$$Re = \frac{\rho \bar{u} D}{\mu} = \frac{.9 \times 1000 \times .931 \times .02}{.15} = 111.72. \text{ (Laminar)}.$$

Flow rate $Q = A \cdot V$

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

$$= \frac{\pi}{4} \times (.02)^2 \times .931$$

$$= 2.925 \times 10^{-4}\ m^3/s.$$

$Q = .2925$ lit/s.

Q. Oil of sp gravity 0.82 is pumped through a horizontal (4) pipe line 150mm in diameter and 3 km long at a rate of 0.015 m^3/s. The pump has an efficiency of 68% and requires 7.5 KW to pump the oil.

(1) what is the dynamic viscosity of the oil?

(2) is the flow laminar?

Sol^n-

$$\bar{u} = \frac{Q}{A} = \frac{.015}{\frac{\pi}{4} \times (.15)^2} = 0.849 \text{ m/s}$$, input = 7.5 KW. $\eta = 68\%$

$$\eta = \frac{\text{output}}{\text{input}} \Rightarrow \text{output} = .68 \times 7.5 \times 10^3 \text{ W}$$

$$\text{output} = \rho g \times Q \times h_f$$

$$\rho g Q h_f = .68 \times 7.5 \times 10^3$$

$$h_f = \frac{.68 \times 7.5 \times 10^3}{.82 \times 1000 \times 9.81 \times .015} = 42.26 \text{m}$$

$$h_f = \frac{P_1 - P_2}{\rho g} = \frac{32 \mu \bar{u} L}{\rho g \times D^2} \Rightarrow 42.26 = \frac{32 \times \mu \times .849 \times 3000}{.82 \times 1000 \times 9.81 \times (.15)^2}$$

$$\mu = .0938 \text{ NS/m}^2$$

$$Re = \frac{\rho V D}{\mu} = \frac{.82 \times 1000 \times .849 \times .15}{.0938}$$

$$= 1113.3 \quad (\text{laminar}).$$