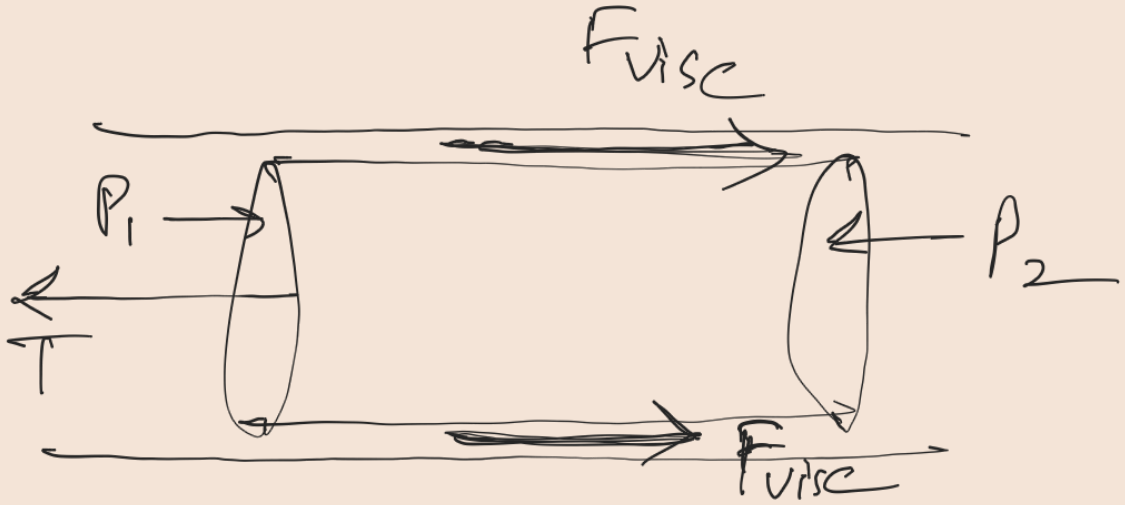
Let's draw the situation of 1st part :→



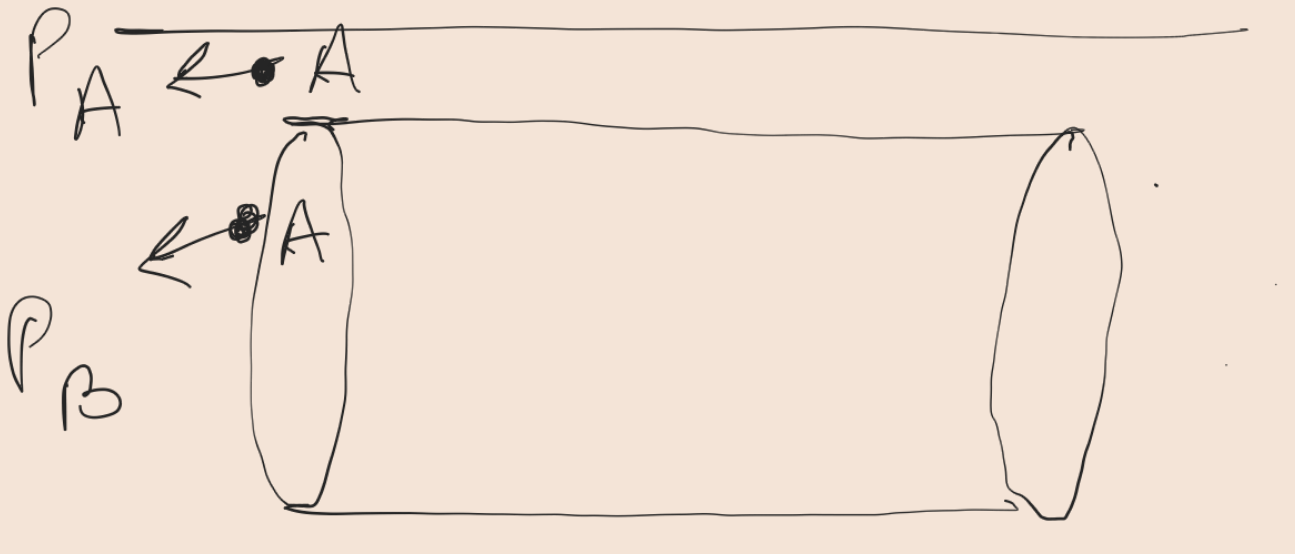
Under steady state condition, the fluid will ONLY be flowing in the annular clearance region in the entire pipe.

Hence, the volume flow rate is $(2\pi r h)(v)$.

From the FBD of cylinder,

$$T = (\Delta p)\pi R^2 + F_{visc.}$$

Now here comes a confusing part. It is written clearly in question that 'Δp' is pressure diff at flat faces of the cylinder. Pressure is a point function



Let point 'A' be a

point in fluid in clearance region. Pressure at 'A' is dynamic & at point 'B' is static. However, to arrive at question answer, we assume pressure at both points to be same & apply equilibrium equation for the flowing fluid.

$$(\Delta p)(2\pi R)(h) = 2F_v$$

The factor of half is because the viscous force on fluid will act

from both cylinder & pipe surface. Hence,

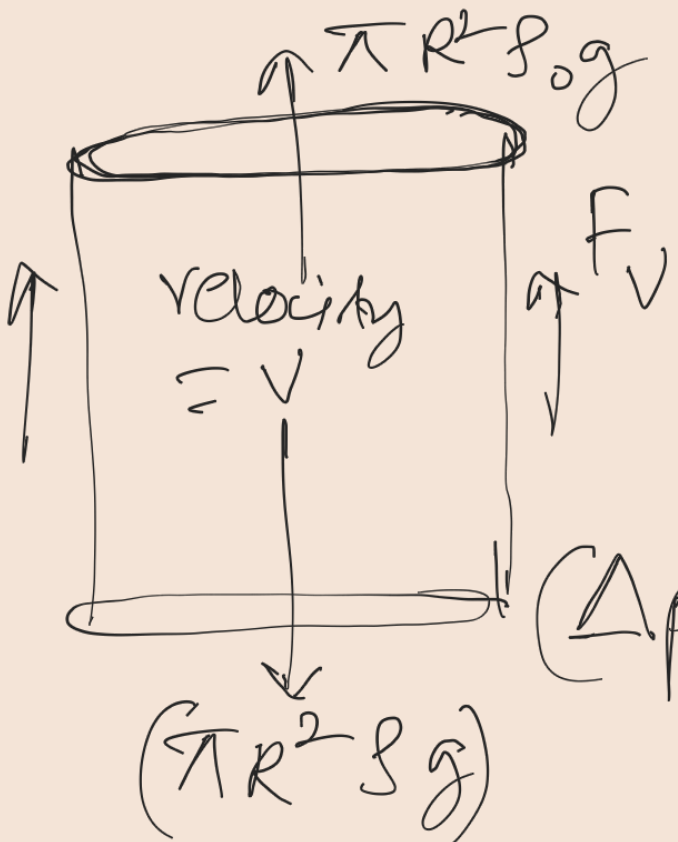
$$T = (\Delta p)\pi R^2 + (\Delta p)\pi R h$$

$$= (\Delta p)\pi R^2\left[1 + \frac{h}{R}\right].$$ Using

$$Q = 2\pi R v \quad \& \quad F_v = \eta\frac{(2\pi R \ell)v}{\ell},$$

we get 'Q' also.

2nd Part



Since cylinder is falling down, Water must

flow up to accommodate space. $(\pi R^2) v = (2\pi R) h v_w$

v_w = velocity of $H_2O = \frac{Rv}{2h}$.

Viscous force

$$= \eta v \frac{\left\{1 + \frac{R}{2h}\right\}}{h} (2\pi R)(l)$$

Pressure force

$$= (\Delta p) 2\pi R h = F_v$$

$$\Delta p = \frac{\eta v \left(1 + \frac{R}{2h}\right)}{h} \frac{(2\pi R) l}{\pi R h}$$

$$= \frac{2\eta v l \left(1 + \frac{R}{2h}\right)}{h^2}$$

Net force acting on cylinder will be 0.

$$\rho \pi R^2 l g - \rho_0 \pi R^2 l g$$

$$- \frac{\eta v}{h} (2\pi R l) \left(1 + \frac{R}{2h}\right)$$

$$- \frac{2\eta v l}{h^2} \left(1 + \frac{R}{2h}\right) \pi R^2$$

$$= 0$$

$$(\rho - \rho_0)(Rg)$$

$$= \frac{2\eta v}{h} \left[1 + \frac{R}{2h} + \frac{R}{h}\left(1 + \frac{R}{2h}\right)\right]$$

$$= \frac{2\pi}{h} V \left[\frac{2h^2 + Rh + 2Rh + R^2}{2h^2} \right]$$

Assuming $h \ll R$, we can neglect h^2 in front of R^2

$$v = \frac{(\rho - \rho_0) R g h^3}{\eta (3Rh + R^2)}$$

$$= \boxed{\frac{(\rho - \rho_0) g h^3}{\eta (R + 3h)}}$$

On assuming approximations midway as given in side solution, we arrive at book answer.