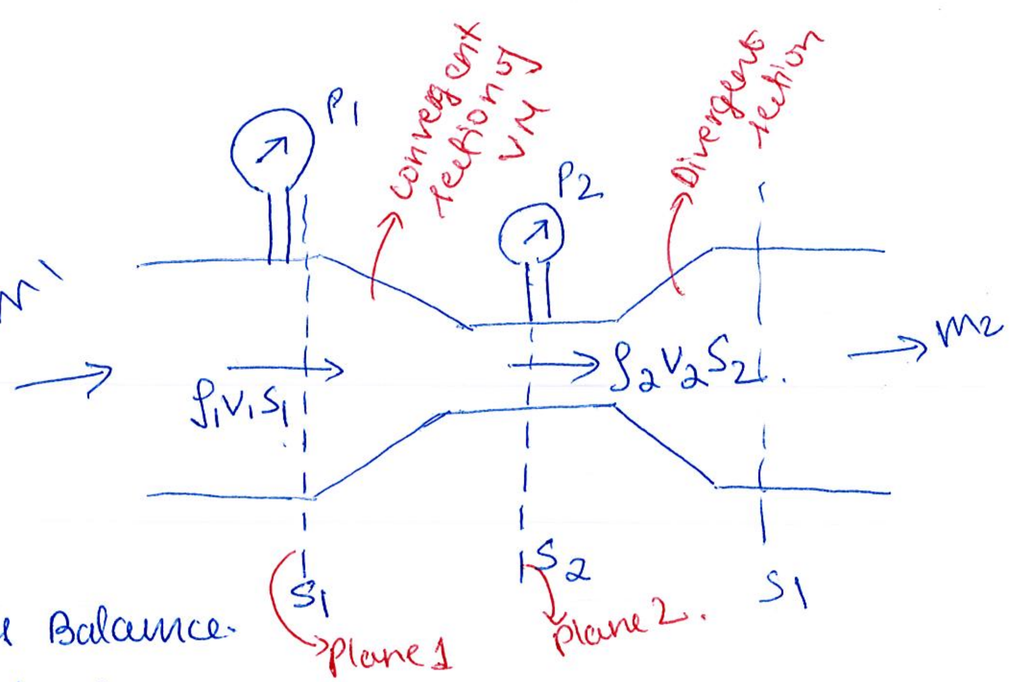
2a.
Venturimeter
Problem



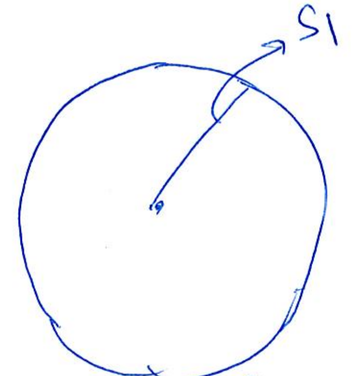
Macroscopic Mass Balance.

→ For any control volume

$$\frac{dm_{total}}{dt} = \text{mass in} - \text{mass out}$$

For steady state → $\frac{dm}{dt} = 0$

$\Rightarrow$ mass in = mass out.



$S_1 = \pi R_1^2$.

V_1

Volumetric flow rate $= V_1 S_1$

$= \frac{m}{s} \times m^2$

$= m^3/s$.

Mass flow rate $= \rho_1 V_1 S_1$

→ Macroscopic Mass Balance

$$\rho_1 V_1 S_1 = \rho_2 V_2 S_2$$

If we assume incompressible flow

$\rho_1 = \rho_2$

$\Rightarrow V_1 S_1 = V_2 S_2$

$$\boxed{V_2 = \frac{V_1 S_1}{S_2}}$$

$\frac{S_1}{S_2} > 1$

$V_2 > V_1$

Macroscopic Energy Balance

$$\Delta\left[\frac{1}{2}\frac{\langle v^3\rangle}{\langle v\rangle}+\phi+\frac{P}{\rho}\right] = \hat{W}_m - \hat{E}_v.$$

$$\boxed{\hat{F}_c = 0}$$

incompressible flow.

$$\frac{1}{2}(v_2^2-v_1^2)+\cancel{g\Delta h}^{\,0}+\frac{(P_2-P_1)}{\rho} = \cancel{\hat{W}_m}^{\,0} - \cancel{\hat{E}_v}^{\,0}$$

Assumption → $\hat{E}_v = 0$
ie. no viscous loss in the instrument.

$\hat{W}_m = 0$
(no moving parts in control volume)
No. PE change.

$$\frac{1}{2}(v_2^2-v_1^2)\rho + (P_2-P_1) = 0.$$

$$(v_2^2-v_1^2) = \frac{2(P_1-P_2)}{\rho}.$$

From mass balance, $v_2 = \dfrac{v_1 S_1}{S_2}$

$$\frac{v_1^2 S_1^2}{S_2^2} - v_1^2 = \frac{2(P_1-P_2)}{\rho}$$

$$\boxed{v_1 = \sqrt{\frac{2(P_1-P_2)}{\rho\left[\frac{S_1^2}{S_2^2}-1\right]}}}$$

→ Theoretical velocity in terms of no viscosity assumption.

$$w = \rho v_1 S_1$$

$$= \rho S_1\sqrt{\frac{2(P_1-P_2)}{\rho\left[\frac{S_1^2}{S_2^2}-1\right]}}$$

$$w_{actual} = \rho C_D S_1\sqrt{\frac{2(P_1-P_2)}{\rho\left[\frac{S_1^2}{S_2^2}-1\right]}}$$

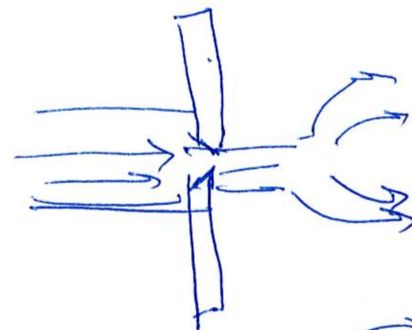
$$C_d = \frac{\text{Actual flow rate}}{\text{Theoretical flow rate}}$$

$C_d \approx 0.90$

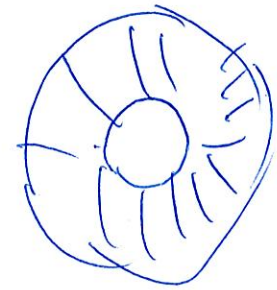
→ Callibration of instruments are done by relating a known flow rate with theoretical flow rate calculation

Flow rate | theorectical

Know plnt.



$C_d \approx 0.6$



C_d

R