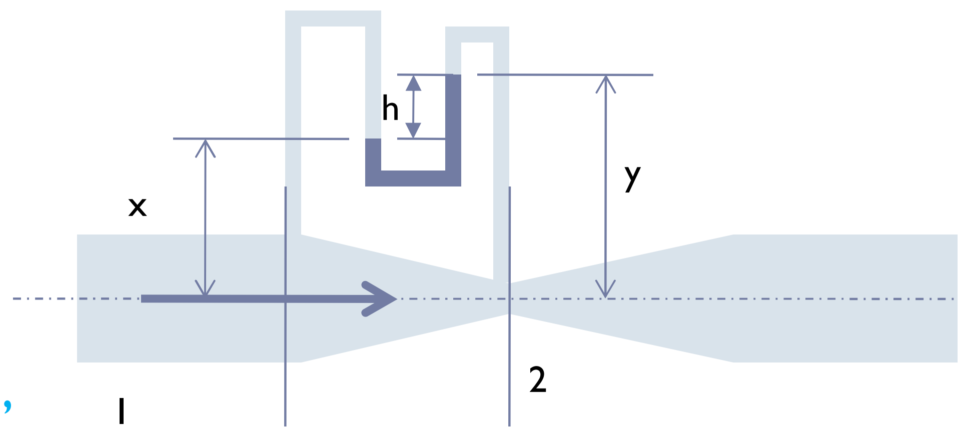
Flow Measurements in Pipes

- Types of Venturimeter
- *a. Horizontal Venturimeter*
- *b. Vertical Venturimeter*

$$Q_{act} = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g\left(\frac{P_1}{\gamma} - \frac{P_2}{\gamma}\right)}$$

- **a. Horizontal Venturimeter**
- Figure shows a venturimeter connected with a differential manometer.
- At section 1, diameter of pipe is D_1, and pressure is P_1 and similar D_2 and P_2 are respective values at section 2.



According to gauge pressure equation

$$\frac{P_1}{\gamma} - x - S_m h + y = \frac{P_2}{\gamma}$$

$$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = S_m h - (y - x) = S_m h - (h)$$

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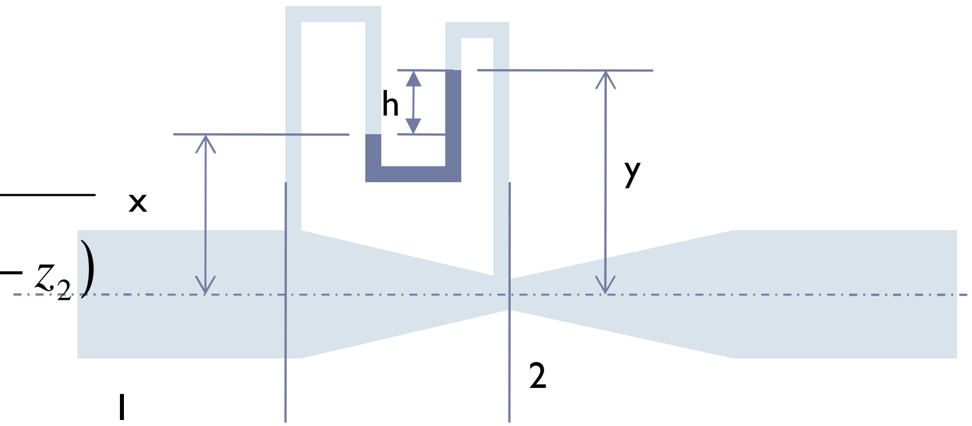
- **a. Horizontal Venturimeter**



$$Q_{act} = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g\left(\frac{P_1}{\gamma} - \frac{P_2}{\gamma}\right) + 2g(z_1 - z_2)}$$

For horizontal venturimeter, $(z_1 - z_2) = 0$

$$Q_{act} = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g\left(\frac{P_1}{\gamma} - \frac{P_2}{\gamma}\right)}$$

$$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = S_m h - (y - x) = S_m h - (h)$$

According to gauge pressure equation

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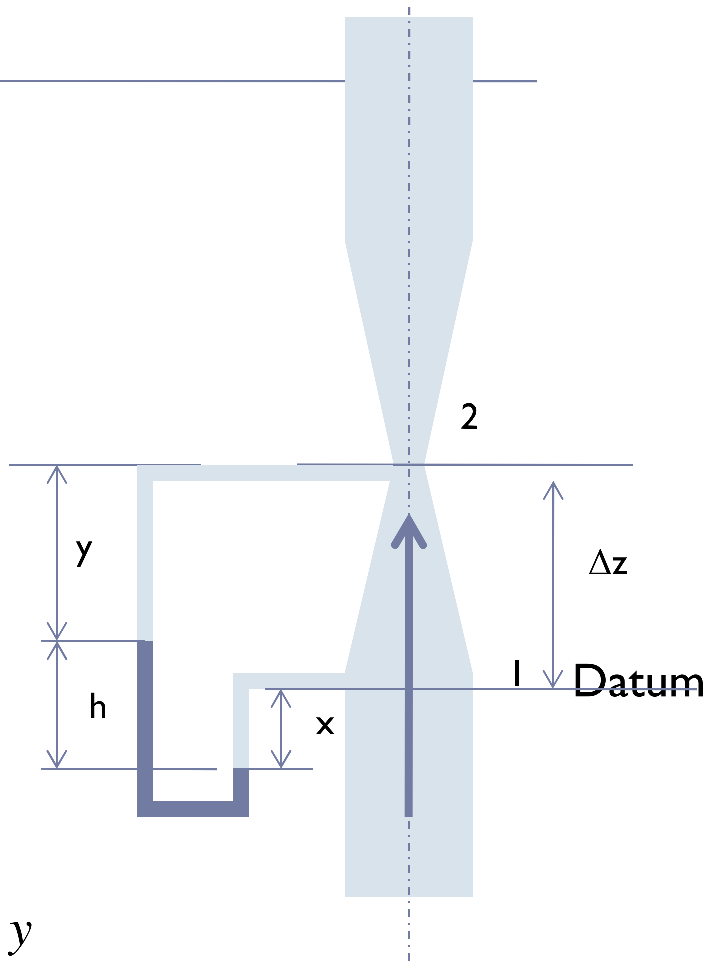
- **b. Vertical Venturimeter**
- Figure shows a venturimeter connected with a differential manometer.

According to gauge pressure equation

$$\frac{P_1}{\gamma} + x - S_m h - y = \frac{P_2}{\gamma}$$

$$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = S_m h + y - x$$

$$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = S_m h + \Delta z - h \qquad \because x + \Delta z = h + y$$



Flow Measurements in Pipes

- Types of Venturimeter
- *a. Horizontal Venturimeter*
- *b. Vertical Venturimeter*

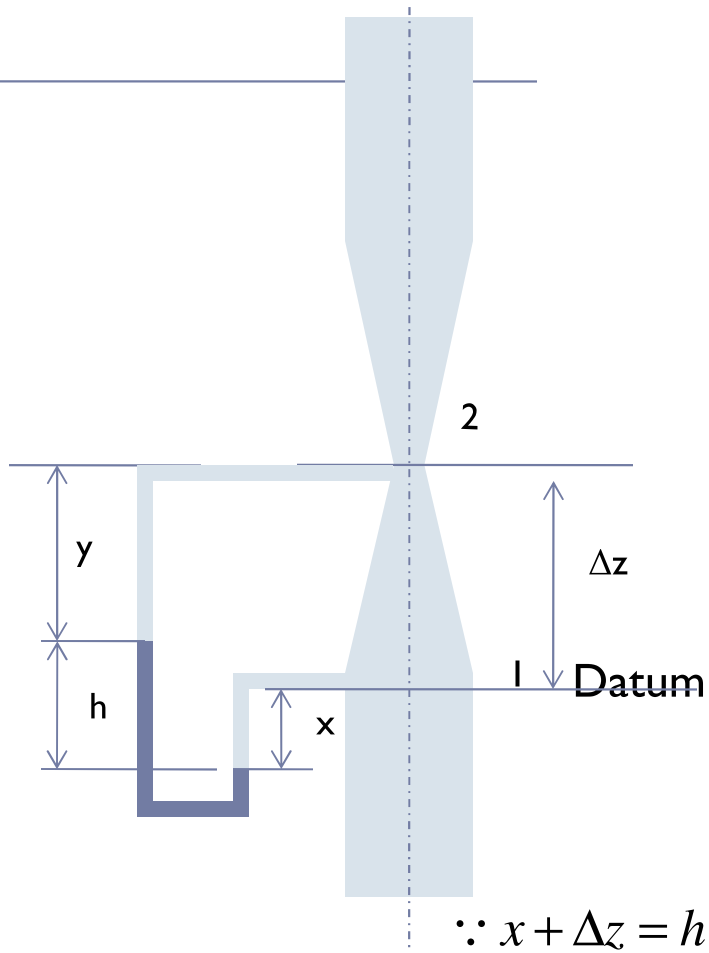
$$Q_{act} = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g\left(\frac{P_1}{\gamma} - \frac{P_2}{\gamma}\right) + 2g(z_1 - z_2)}$$

- **b. Vertical Venturimeter**

$$Q_{act} = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g\left(\frac{P_1}{\gamma} - \frac{P_2}{\gamma}\right) + 2g(z_1 - z_2)}$$

$$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = S_m h + \Delta z - h$$

$$(z_1 - z_2) = \Delta z$$



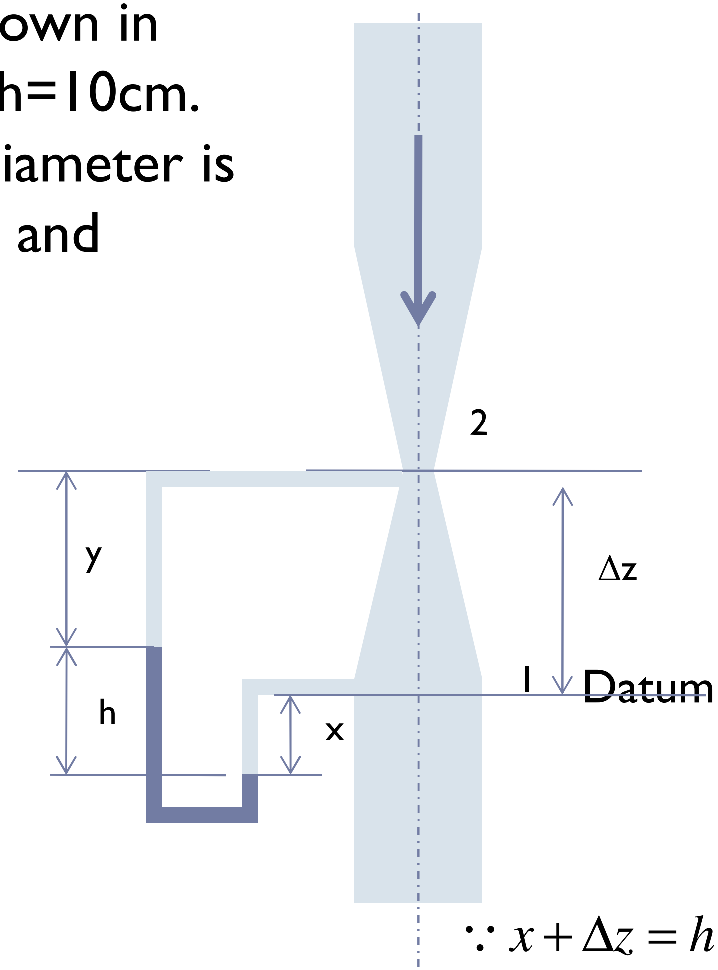
$$\because x + \Delta z = h + y$$

Numerical Problem

- Find the flow rate in venturimeter as shown in figure if the mercury manometer reads h=10cm. The pipe diameter is 20cm and throat diameter is 10 cm and Δz =0.45m. Assume C_d=0.98 and direction of flow is downward.

$$Q_{act} = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g\left(\frac{P_1}{\gamma} - \frac{P_2}{\gamma}\right) + 2g(z_1 - z_2)}$$

$$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = S_m h + \Delta z - h$$



$$\because x + \Delta z = h + y$$

Classification of Orifice

- **According to size**
- **1. Small orifice**
- **2. Large orifice**

- An orifice is termed as small when its size is small compared to head causing flow. The velocity does not vary appreciably from top to bottom edge of the orifice and is assumed to be uniform.

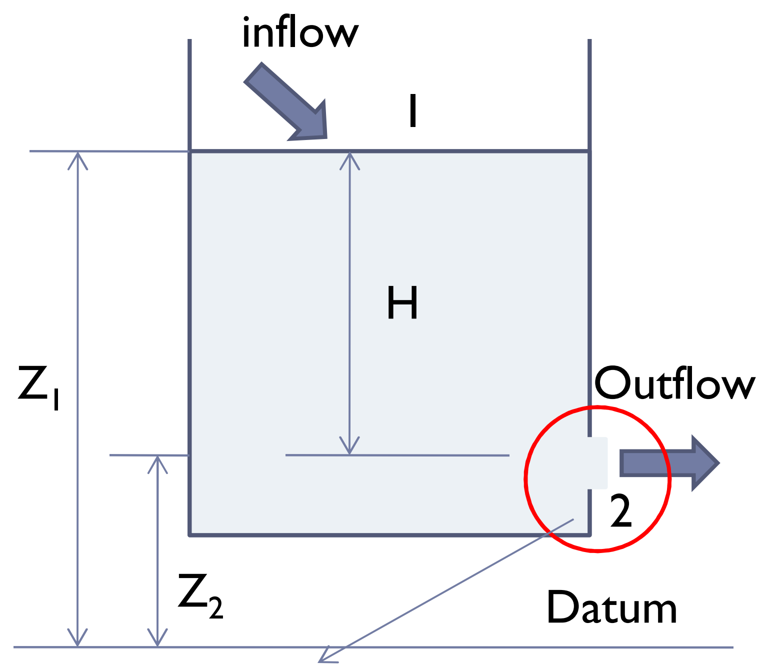
- The orifice is large if the dimensions are comparable with the head causing flow. The variation in the velocity from top to bottom edge is considerable.

- **According to shape**
- 1. Circular orifice
- 2. Rectangular orifice
- 3. Square orifice
- 4. Triangular orifice

- **According to shape of upstream edge**
- 1. Sharp-edged orifice
- 2. bell-mouthed orifice
- **According to discharge condition**
- 1. Free discharge orifice
- 2. Submerged orifice

Orifice

- **Small orifice**
- Figure shows a tank having small orifice at it bottom. Let the flow in tanks is steady.
- Let's take section 1 (at the surface) and 2 just outside of tank near orifice.



- According to Bernoulli's equation

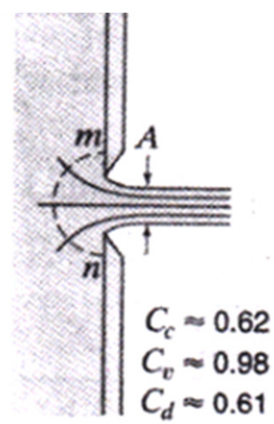
$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$0 + z_1 + 0 = 0 + z_2 + \frac{v_2^2}{2g}$$

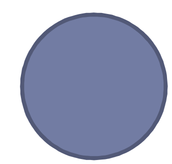
$$\frac{v_2^2}{2g} = z_1 - z_2 = H$$

$$v_{th} = \sqrt{2gH}$$

Where, H is depth of water above orifice



(a) Sharp-edge



Cross-sectional area

Orifice

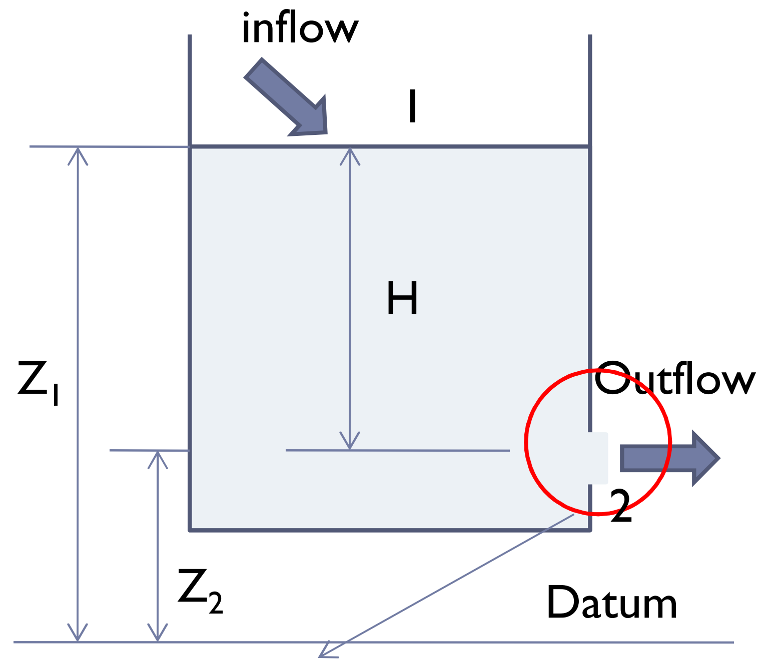
- **Small orifice**

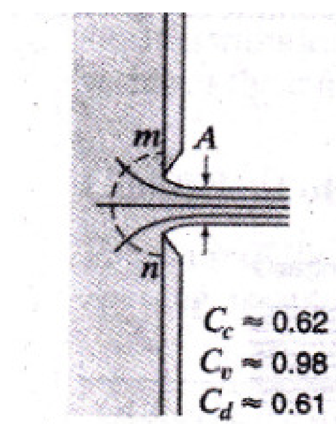
$$Q_{th} = Av_{th} = A\sqrt{2gH}$$

$$Q_{act} = C_d A v_{th} = C_d A\sqrt{2gH}$$

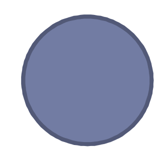
$$\because v_{th} = \sqrt{2gH}$$

Where, A is cross-sectional are of orifice and C_d is coefficient of discharge.





(a) Sharp-edge



Cross-sectional area, A

Numerical Problem

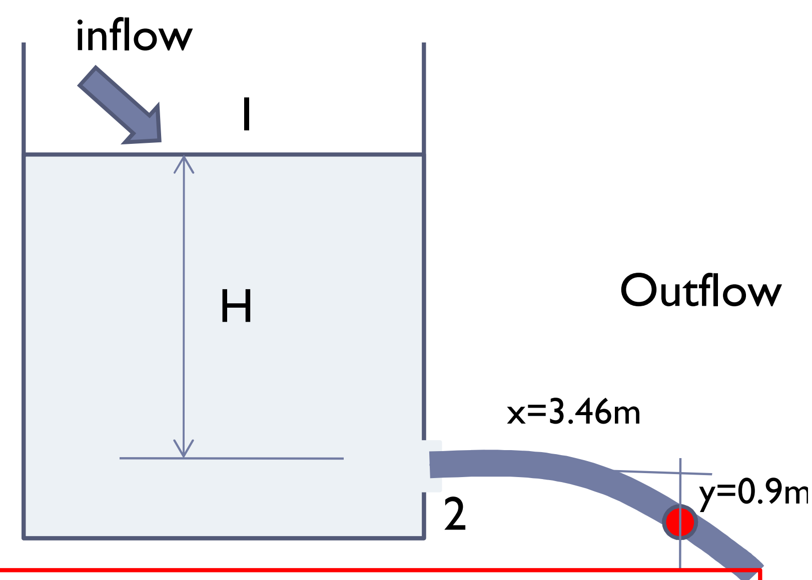
- A jet discharges from an orifice in a vertical plane under a head of 3.65m. The diameter of orifice is 3.75 cm and measured discharge is 6m^3/s. The co-ordinates of centerline of jet are 3.46m horizontally from the vena-contracta and 0.9m below the center of orifice.
- Find the coefficient of discharge, velocity and contraction.

$$Q_{act} = C_d A v_{th} = C_d A\sqrt{2gH}$$

$$C_d = Q_{act} / \left(A\sqrt{2gH}\right)$$

$$C_v = \frac{v_{act}}{v_{th}} = \frac{\sqrt{gx^2/2y}}{\sqrt{2gH}}$$

$$C_c = C_d / C_v$$



$$x = v_{act} t$$

$$y = \frac{1}{2} g t^2 \Rightarrow V_{act} = \sqrt{gx^2 / 2y}$$