**Solved problems in fluid flow measurements**

**Ex.1**
A pitot static tube is used to measure the velocity of air flowing through a duct. The manometer shows a difference in head of 5 cm of water. If the density of air and water are 1.13 kg/m\(^3\) and 1000 kg/m\(^3\) determine the velocity of air. Assume the coefficient of the pitot tube as 0.98.

\[
V = C_v \sqrt{2gh_m \left[ \frac{\rho_a}{\rho_w} - 1 \right]}
\]

\[
= 0.98 \sqrt{2 \times 9.81 \times \left( \frac{1000}{113} - 1 \right) \frac{5}{100}} = 28.86 \text{ m/s}
\]

**Ex.2**
A pitot static tube is mounted on an aircraft travelling at a speed 300 kmph against a wind velocity of 20 kmph. If the specific weight of air is 12 N/m\(^3\) determine the pressure difference the instrument will register.

<table>
<thead>
<tr>
<th>Aircraft velocity</th>
<th>Wind velocity</th>
<th>Relative velocity of plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{300 \times 1000}{3600})</td>
<td>(\frac{20 \times 1000}{3600})</td>
<td>(83.33 + 5.56 = 88.89 \text{ m/s})</td>
</tr>
</tbody>
</table>

Velocity recorded by pitot tube,

\[
V = C_v \sqrt{2gh}
\]

\[88.89 = 0.98 \sqrt{2 \times 9.81 \times h}, \text{ Solving for, } h \text{ which is head of air,}
\]

\[h_{air} = 419.32 \text{ m, } \Delta P = 419.32 \times 12 = 5032 \text{ N/m}^2\]

**Pr.3**
A pitot static tube is used to measure the velocity of air in a duct. The water manometer shows a reading of 8 cm. The static pressure in the duct is 9 kN/m\(^2\) and the air temperature is 320 K. The local barometer reads 740 mm of mercury. Calculate the air velocity if \(C_v = 0.98\). Assume the gas constant for air as 287 J/kg K.

**Ex. 4**
A venturimeter of 150 mm × 75 mm size is used to measure the flow rate of oil having specific gravity of 0.9. The reading shown by the U tube manometer connected to the venturimeter is 150 mm of mercury column. Calculate the coefficient of discharge for the venturimeter if the flow rate is 1.7 m\(^3\)/min. (Note: The size of venturimeter generally specified in terms of inlet and throat diameters)
A venturimeter is used to measure liquid flow rate of 7500 litres per minute. The difference in pressure across the venturimeter is equivalent to 8 m of the flowing liquid. The pipe diameter is 19 cm. Calculate the throat diameter of the venturimeter. Assume the coefficient of discharge for the venturimeter as 0.96.

\[ Q = C_d \frac{A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}. \]

\[ A_1 = \frac{\pi}{4} \times 0.19^2 = 0.0284 \text{ m}^2 \]

\[ \frac{7500 \times 10^{-3}}{60} = \frac{0.96 \times 0.0284 \times A_2}{\sqrt{0.0284^2 - A_2^2}} \sqrt{2 \times 9.81 \times 8}, \text{ Solving } A_2 = 0.0098 \text{ m}^2 \]

Let the diameter be \( d \), \[ \frac{\pi}{4} \times d^2 = 0.0098 \]

\[ \therefore \quad d = \sqrt{\frac{4 \times 0.0098}{\pi}} = 9.9 \text{ cm} \]
Ex.6
A venturimeter is fitted in a pipe of 30 cm diameter inclined at 40° to the horizontal to measure the flow rate of petrol having a specific gravity of 0.8. The ratio of areas of main pipe and throat is 5 and the throat is at 1 m from the inlet along its length. The difference in manometer head is 40 mm of mercury. Assuming the coefficient of discharge as 0.96. Calculate the discharge through the venturimeter and the pressure difference between the throat and the entry point of the venturimeter.

\[
Q = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g h_m \left(\frac{p_m}{\rho} - 1\right)} \quad A_1 = \frac{\pi}{4} \times 0.3^2 = 0.0707 \text{ m}^2
\]

\[
A_1/A_2 = 5
\]

\[
\therefore A_2 = 0.0707/5 = 0.0141 \text{ m}^2, \text{ Substituting,}
\]

\[
Q = \frac{0.96 \times 0.0141 \times 0.0707}{\sqrt{0.0707^2 - 0.0141^2}} \sqrt{2 \times 9.81 \times 0.04 \times \left(\frac{136}{0.8} - 1\right)}
\]

\[
= 0.0486 \text{ m}^3/\text{s}
\]

Considering points A and B and level at A as datum

\[
P_A + \rho gy + \rho g(0.04) = P_B + \rho gx + \rho gy + \rho mg(0.04)
\]

\[
P_A - P_B = \rho gx + 0.04 \times g \times (\rho_m - \rho)
\]

\[
= \rho g (1 \times \sin 40) + 0.04 \times 9.81 \times (13600 - 800)
\]

\[
= 800 \times 9.81 (1 \times \sin 40) + 0.04 \times 9.81 \times (13600 - 800)
\]

\[
= 10067.32 \text{ N/m}^2 \text{ or } 10.07 \text{ kN/m}^2
\]
Pr. 7
A venturimeter of 20 cm × 10 cm size is calibrated in a laboratory using a right angled V notch. When a steady head of 0.187 m is maintained over the notch with a coefficient of discharge 0.6, the difference of head between he entrance and throat section of the Venturimeter is found to be 39 cm head of the fluid measured using notch as actual flow,determine the discharge coefficient of venturimeter.

Ex. 8
The actual velocity of a liquid issuing through a 7 cm diameter orifice fitted in an open tank is 6 m/s under a head of 3 m. If the discharge measured in a collecting tank is 0.020 m³/s, calculate the coefficient of velocity, coefficient of contraction and the theoretical discharge through the orifice.

Flow velocity in orifice \[ V = C_v \sqrt{2gh} \]

Coefficient of velocity \( C_v = 0.9124 \) \[ \therefore \] Actual discharge \( Q = C_d \sqrt{2gh} \)

\[ 0.020 = C_d \frac{\pi}{4} \left( \frac{7}{100} \right)^2 \times \sqrt{2 \times 9.81 \times 3} \]

Coefficient of discharge
\[ C_d = 0.6774 \]

Coefficient of contraction
\[ C_c = \frac{C_d}{C_v} = \frac{0.6774}{0.9124} = 0.7424 \]

Ex. 9
Water is discharged through a 15 cm diameter orifice in the vertical side of an open tank at the rate of 190 litres per second. Water stands 15 m above the centerline of the orifice. A point on the jet measured from the vena contracta has co-ordinates 5 m horizontal and 0.5 m vertical. Find the hydraulic coefficients \( C_v \), \( C_c \) and \( C_d \) of the orifice.

Actual discharge \[ Q = C_d A \sqrt{2gh} \]

\[ 190 \times 10^{-3} = C_d \frac{\pi}{4} \times 0.15^2 \times \sqrt{2 \times 9.81 \times 15} \]

\[ C_d = 0.627 \]

Let the jet travel during time \( t \) horizontally through a distance \( x \) and the jet fall by distance \( y \) during this time.
An orifice of 8 cm diameter is fitted in a 20 cm diameter pipe that carries oil of specific gravity 0.8. The mercury manometer attached to the orifice shows a reading of 0.75 m. Calculate the oil flow rate through the pipe. Assume coefficient of discharge for orifice as 0.6.

\[
\begin{align*}
   x &= V \times t = C_v \sqrt{2gh_t} \text{ or } x^2 = C_v^2 2ght^2 \\
   y &= (1/2)gt^2 \\
   \therefore \quad \frac{x^2}{y} &= 4C_v^2 h \\
   \therefore \quad C_v &= \sqrt{\frac{x^2}{4yh}} \text{,}
\end{align*}
\]

Here \( x = 5 \text{ m} \), and \( y = 0.5 \text{ m} \)

\[
\therefore \quad C_v = \sqrt{\frac{5^2}{4 \times 0.5 \times 15}} = 0.913
\]