CHAPTER (13)

FLOW MEASUREMENTS

SOLVED PROBLEMS

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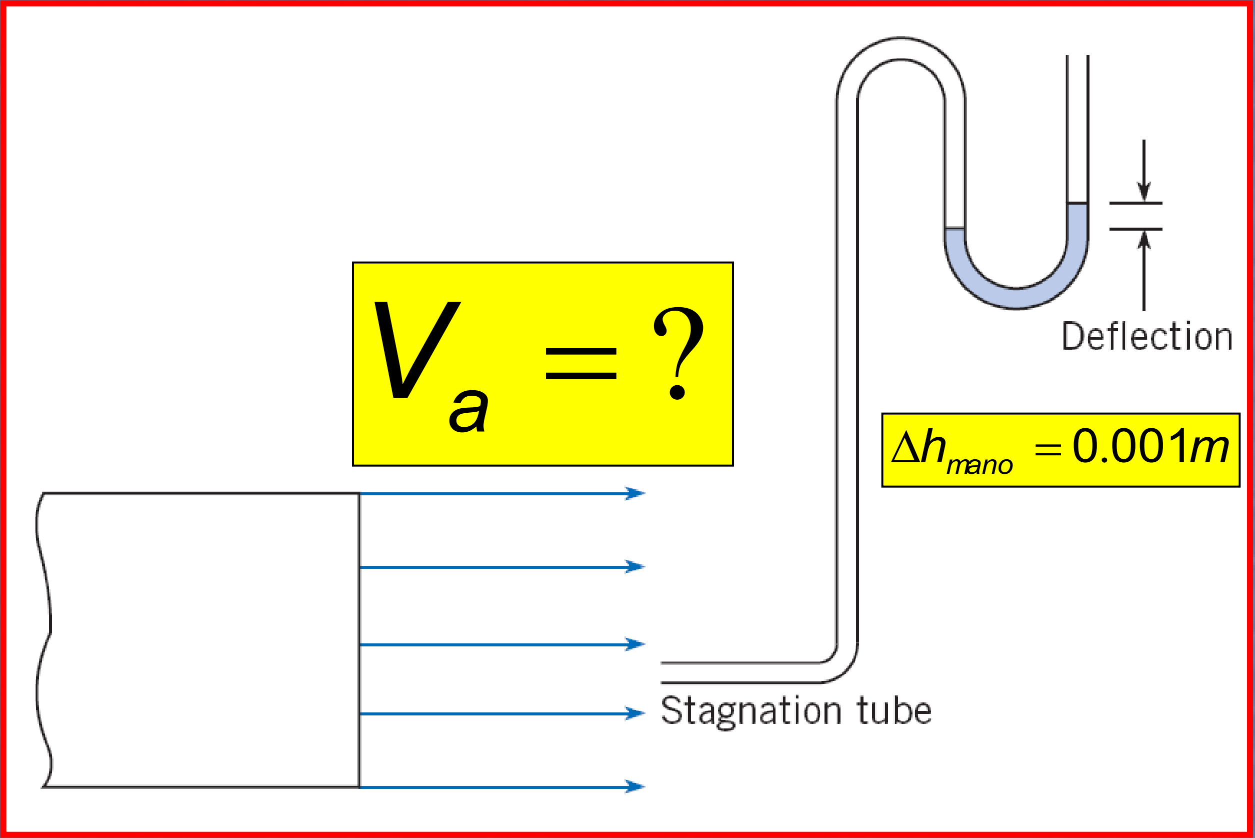
Problem (13.3)



PROBLEM 13.3

Situation: A stagnation tube ($d = 2$ mm) is used to measure air speed. Manometer deflection is 1 mm-H_2O.

Find: Air Velocity: V

ANALYSIS

$$\Delta P_a = \Delta P_w$$

$$\rho_a g \Delta h_a = \rho_w g \Delta h_w$$

$$\Delta h_a = \frac{\rho_w}{\rho_a} \Delta h_w$$

$$\begin{aligned} \rho_{air} &= 1.25 \text{ kg/m}^3 \\ \Delta h_{air} &= 0.001 \times 1000/1.25 \\ &= 0.80 \text{ m} \end{aligned}$$

From Bernoulli equation applied to a stagnation tube

$$V = \sqrt{2g\Delta h} = \boxed{3.96 \text{ m/s}}$$

Problem (13.9)

Find :

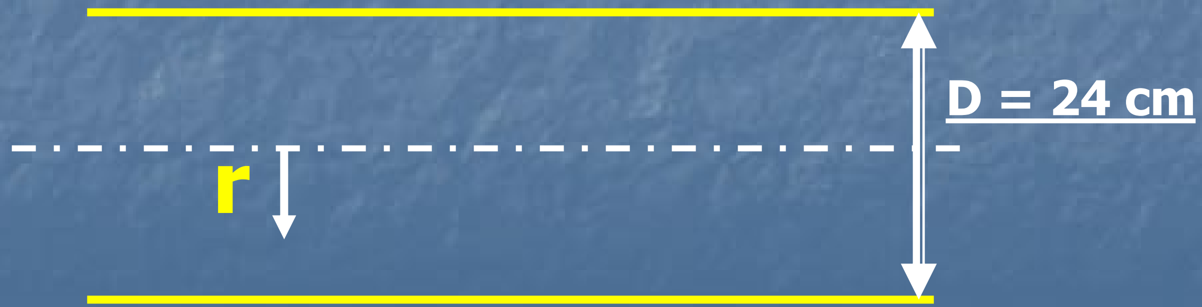
$\dot{Q} = ?$

$V_{Mean} = ?$

$\dfrac{V_{Max}}{V_{Mean}} = ?$

r, cm	V, m/s	r, cm	V, m/s
0	8.7	7	5.8
1	8.6	8	4.9
2	8.4	9	3.8
3	8.2	10	2.5
4	7.7	10.5	1.9
5	7.2	11.0	1.4
6	6.5	11.5	0.7

Always take (r) from center of the pipe



PROBLEM 13.9

Situation: Velocity data in a 24 inch oil pipe are given in the problem statement.

Find: (a) Discharge.
(b) Mean velocity.
(c)Ratio of maximum to minimum velocity.

ANALYSIS

Numerical integration

$$Trapezium\,Area = \frac{y_1 + y_2}{2}(x_2 - x_1)$$

r(m)	V(m/s)	$2\pi Vr$	area (by trapezoidal rule)
0	8.7	0	
0.01	8.6	0.54	0.0027
0.02	8.4	1.06	0.0080
0.03	8.2	1.55	0.0130
0.04	7.7	1.94	0.0175
0.05	7.2	2.26	0.0210
0.06	6.5	2.45	0.0236
0.07	5.8	2.55	0.0250
0.08	4.9	2.46	0.0250
0.09	3.8	2.15	0.0231
1.10	2.5	1.57	0.0186
0.105	1.9	1.25	0.0070
0.11	1.4	0.97	0.0056
0.115	0.7	0.51	0.0037
0.12	0	0	0.0013

Always take (r) from center of the pipe)

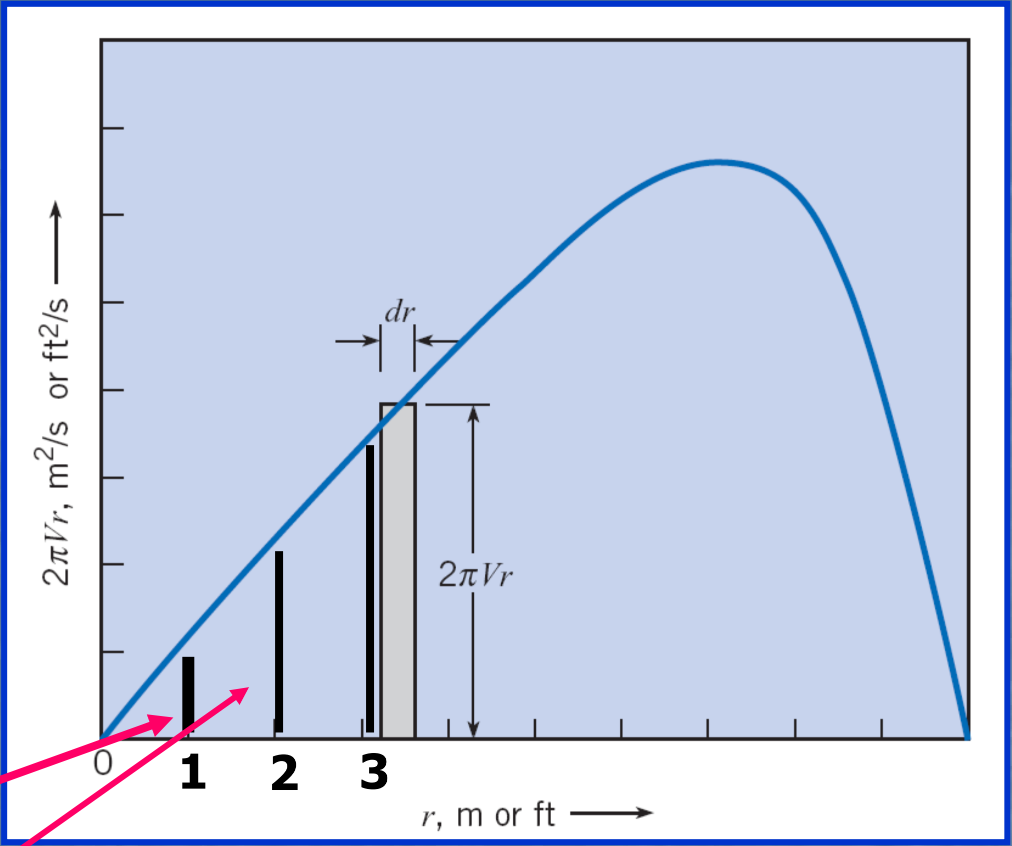
$$\dot{Q} = \int_0^r V\,dA = \int_0^r V\,2\pi\,r\,dr$$

$$\dot{Q} = \int_0^r V\, dA = \int_0^r V\, 2\pi\, r\, dr$$

$$Trapezium Area = \frac{y_1 + y_2}{2}(x_2 - x_1)$$

$$A_1 = \frac{0 + 0.54}{2} \times 0.01 = 0.0027$$

$$A_2 = \frac{0.54 + 1.06}{2} \times 0.01 = 0.0082$$



Summing the values in the last column in the above table gives $Q = 0.196\ \text{m}^3/\text{s}$. Then,

$$V = \left(V_{\max}\right)_{r=0}$$

$$\begin{aligned} V_{\text{mean}} &= Q/A \\ &= 0.196/(0.785(0.24)^2) \\ &= \boxed{4.33\ \text{m/s}} \\ V_{\max}/V_{\text{mean}} &= 8.7/4.33 \\ &= \boxed{2.0} \end{aligned}$$

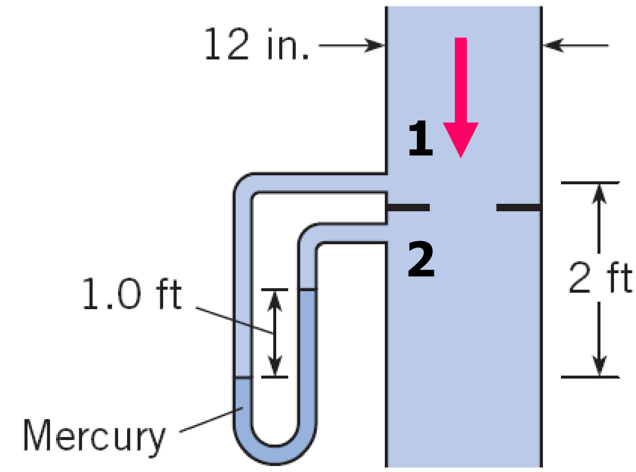
This ratio indicates the flow is laminar. The discharge is

$$\boxed{Q{=}0.196\ \text{m}^3/\text{s}}$$

Problem (13.20)

$$Q = KA_o\sqrt{2g\Delta h}$$

$$d_{orifice} = 6\,inch$$



<u>Situation</u>: Water flows through a 6 inch orifice in a 12 inch pipe. Assume $T = 60$ °F, $\nu = 1.22 \times 10^{-5}$ ft^2/s.

<u>Find</u>: Discharge: Q

APPROACH

Calculate piezometric head. Then find K and apply the orifice equation.

ANALYSIS

Apply manometer Eqn. between (1) & (2)

$$p_1 = p_2 + \gamma_{Hg}(1.0ft) - \gamma_w(1.0ft)$$

Piezometric head

$$\Delta h = (1.0)(13.55 - 1) = 12.55 \text{ ft}$$

$$\Delta h = \frac{p_1 - p_2}{\gamma_w} = 1.0\left(\frac{\gamma_{Hg}}{\gamma_w} - 1\right)$$

Find parameters needed to use Fig. 13.13.

$$\begin{aligned}(d/D) &= 0.50 \\ (2g\Delta h)^{0.5} d/\nu &= (2g \times 12.55)^{0.5}(0.5)/(1.22 \times 10^{-5}) \\ &= 1.17 \times 10^6\end{aligned}$$

Look up K on Fig. 13.13

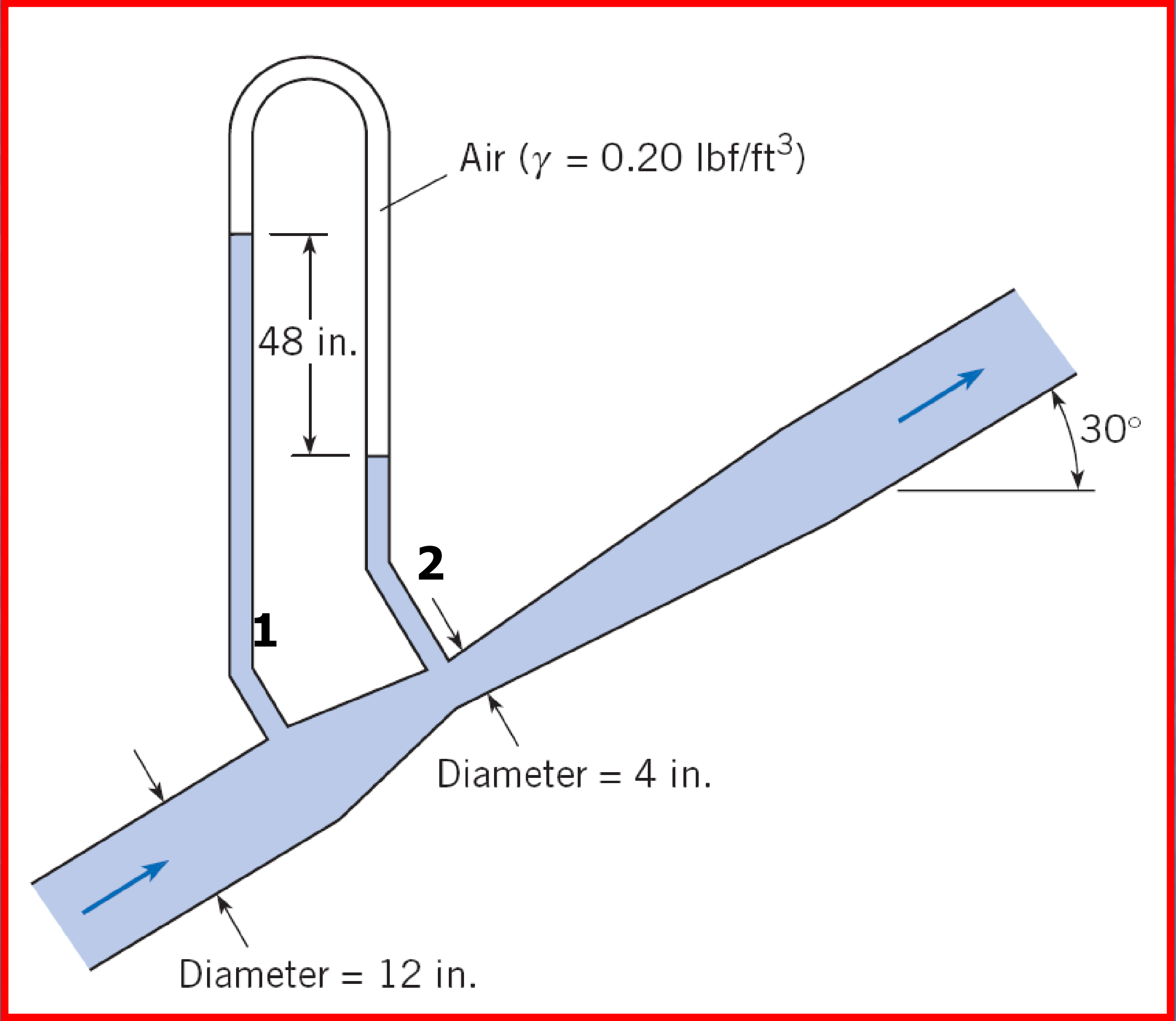
$$K = 0.625$$

Orifice equation

$$\begin{aligned}Q &= KA_0(2g\Delta h)^{0.5} \\ Q &= 0.625(\pi/4 \times 0.5^2)(64.4 \times 12.55)^{0.5} = \boxed{3.49 \text{ cfs}}\end{aligned}$$

Problem (13.36)

$$\dot{Q} = ?$$



PROBLEM 13.36

Situation: A venturi meter is described in the problem statement.

Find: Rate of flow: Q

ANALYSIS

Find K

$$\begin{aligned}\Delta h &= 4 \text{ ft and } d/D = 0.33 \\ \text{Re}_d/K &= (1/3)\sqrt{2\times 32.2\times 4}/1.22\times 10^{-5}) = 4.4\times 10^5 \\ K &= 0.97 \text{ (Estimated from Fig. 13.13)}\end{aligned}$$

Venturi equation

$$\begin{aligned}Q &= KA\sqrt{2gh} \\ &= 0.97(\pi/4\times 0.333^2)\sqrt{2\times 32.2\times 4} \\ & \boxed{Q = 1.36 \text{ cfs}}\end{aligned}$$

Problem (13.49)

PROBLEM 13.49

Situation: Water flows over a rectangular weir. $L = 4$ m; $H = 0.20$ m, $P = 0.25$ m.

Find: Discharge: Q

ANALYSIS

Flow coefficient

$$\begin{aligned} K &= 0.40 + 0.05\left(\frac{H}{P}\right) \\ &= 0.40 + 0.05\left(\frac{0.20}{0.25}\right) \\ &= 0.440 \end{aligned}$$

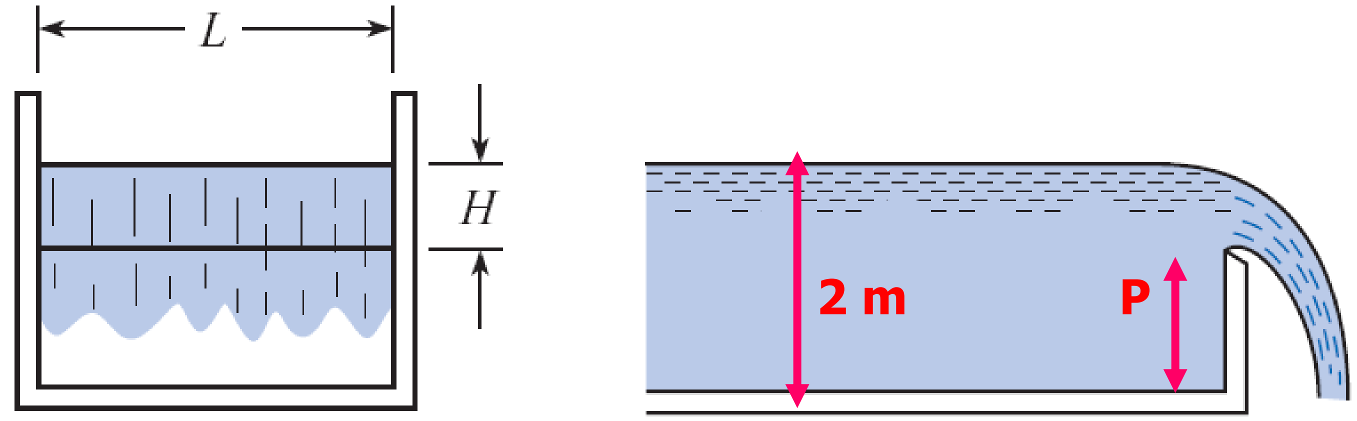
Rectangular weir equation

$$\begin{aligned} Q &= K\sqrt{2g}LH^{3/2} \\ &= 0.44 \times \sqrt{2 \times 9.81} \times 4 \times (0.2)^{3/2} \\ &= 0.6973\,\mathrm{m}^3/\,\mathrm{s} \end{aligned}$$

Thus

$$\boxed{Q = 0.697\ \mathrm{m}^3/\mathrm{s}}$$

Problem (12.41)



(a) Rectangular weir (end view)

(b) Elevation view

PROBLEM 13.53

Situation: A rectangular weir is being designed for $Q = 4\ m^3/s$, $L = 3$ m, Water depth upstream of weir is 2 m.

Find: Weir height: P

$$H = (Q/(K\sqrt{2g}L))^{2/3}$$

$$Q = \frac{2}{3} C_d \sqrt{2g} L H^{3/2}$$
$$= K \sqrt{2g} L H^{3/2}$$

$$K = 0.40 + 0.05 \frac{H}{P}$$

ANALYSIS

First guess $H/P = 0.60$. Then

$$K = 0.40 + 0.05(0.60) = 0.43.$$

Rectangular weir equation (solve for H)

$$\begin{aligned} H &= (Q/(K\sqrt{2g}L))^{2/3} \\ &= (4/(0.43\sqrt{(2)(9.81)}(3))^{2/3} = 0.788 \text{ m} \end{aligned}$$

Iterate:

$$\begin{aligned} H/P &= 0.788/(2 - 0.788) = 0.65; \; K = 0.40 + .05(.65) = 0.433 \\ H &= 4/(0.433\sqrt{(2)(9.81}(3))^{2/3} = 0.785 \text{ m} \end{aligned}$$

Thus:

$$P = 2.0 - H = 2.00 - 0.785 = \boxed{1.215 \text{ m}}$$

END OF SOLVED PROBLEMS

FLOW MEASUREMENTS

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