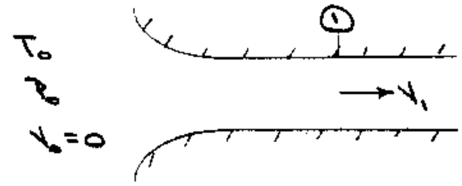
Problem 6.40

Given: Air flow in open circuit wind tunnel as shown.

$p_{atm} - p_1 = 45\ mm\ H_2O$

$T_0 = 25C$

$p_0 = p_{atm}$



Consider air to be incompressible.

Find: Air speed in tunnel at section ①

Solution:

Basic equations: $\frac{p}{\rho} + \frac{V^2}{2} + gz = \text{constant}$

Assumptions:
(1) steady flow
(2) incompressible flow
(3) frictionless flow
(4) flow along a streamline
(5) air behaves as an ideal gas
(6) stagnation pressure = p_{atm}

From the Bernoulli equation, $\frac{p_0}{\rho} = \frac{p_1}{\rho} + \frac{V_1^2}{2}$

$$p_0 - p_1 = p_{atm} - p_1 = \frac{1}{2}\rho V_1^2$$

$$V_1 = \left[\frac{2(p_{atm} - p_1)}{\rho}\right]^{1/2}$$

From the manometer reading, $p_{atm} - p_1 = \rho_{H_2O}\, g\, h$ $\quad h_m$

$$V_1 = \left[\frac{2\rho_{H_2O}\, g\, h}{\rho}\right]^{1/2}$$

From the ideal gas equation of state

$$\rho = \frac{p}{RT} = 100 \times 10^3 \frac{N}{m^2} \times \frac{kg \cdot K}{287\ N \cdot m} \times \frac{1}{298\ K} = 1.17\ kg/m^3$$

$$V_1 = \left[\frac{2\rho_{H_2O}}{\rho}gh\right]^{1/2} = \left[2 \times \frac{999}{1.17} \times 9.81\frac{m}{s^2} \times 0.045\ m\right]^{1/2} = 27.5\ m/s \quad \longleftarrow V_1$$