1. A fluid with density ρ, viscosity μ, and velocity V flows through a pipe with diameter D and length L. The frictional pressure loss Δp in the pipe flow can be expressed by other variables:

$$\Delta p = \Delta p(\rho, V, \mu, D, L, a) \tag{1}$$

where a is the speed of sound. You are asked to perform a dimensional analysis for Eq. (1) using the dimensional system, mass-length-time, and assuming

$$\Delta p = C_1 \rho^{b_1} V^{b_2} \mu^{b_3} D^{b_4} L^{b_5}, \quad C_1 = \text{const.}$$

in which $b_i, i = 1, 2, ..., 5$, are to be determined. Note that the equation you obtained should be expressed in a dimensionless form. (15%) Moreover, identify some common parameters (their common names) (5%).

2. Consider an air flow in a circular pipe, see the figure. Flow passes the screen at $x = 0$ which results into momentum loss.

Assume: (i) At x = -1d, flow is uniform in velocity distribution with the velocity U_1 and the pressure P_1 measured.

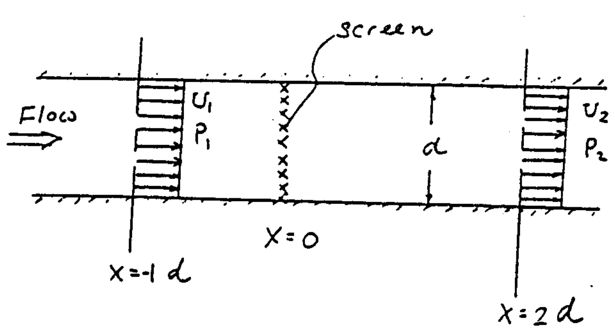
(ii) At x = 2d, flow is uniform in velocity distribution with the velocity U_2 and the pressure P_2 measured.

Questions: (20%)

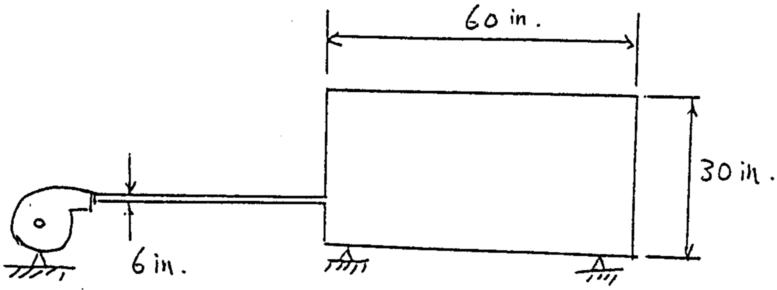
(i) Is $U_1 = U_2$, $U_1 > U_2$, or $U_1 < U_2$? why?

(ii) Is $P_1 = P_2$, $P_1 > P_2$, or $P_1 < P_2$? why?

(iii) Can you apply the Bernoulli's equation for flow in the entire region -1d < x < 2d?

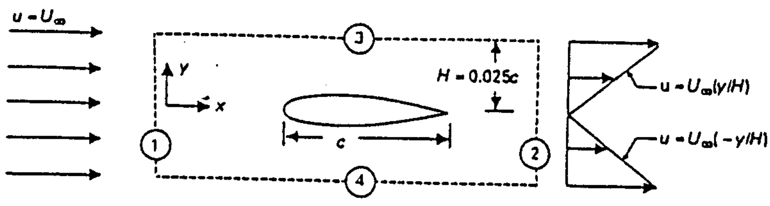


3. An air compressor is used to pressurize an initially evacuated tank. The tank is 30 inches in diameter and 60 inches long. The supply line is 6 inches in diameter and conveys a flow of 5 ft/s. The air compressor's output pressure and temperature are constant at 50 psia and 90° F. The tank temperature of 70° F is also constant. Calculate the time required for the tank pressure to reach 15 psia. (20%)



4.

Velocity Profiles are measured at the upstream end (surface 1) and at the downstream end (surface 2) of a rectangular control volume, as shown in the following figure. Assume that the flow is incompressible, two-dimensional and steady. Assume also that the pressure is P_∞ (a constant) over the entire surface of the control volume. What is the drag coefficient for the airfoil? (20%)



5.

An engineer is assigned to design an aircraft with rectangular wing. The wing has an aspect ratio AR= 4, chord length C=5 ft. Its $C_L - C_D$ and $C_L - \alpha$ curves are shown below. Assuming the body of the aircraft produces no lift and its drag is negligibly small. Assuming the aircraft weights 3000 lbf and is propelled by an engine with 300 lbf thrust,

1. How fast can this aircraft "cruise" ? (in feet per second) (10%)
2. At what angle of attack the wing has? (2%)
3. If the airfoil is extremely long (nearly a two dimensional design), also the thrust, weight, wing area and cruise speed remain the same, what will the angle of attack be? (5%)
4. Which angle of attack in problems 2 and 3 is larger ? explain. (3%)

density of air =0.00238 slug/cubic ft