A flat plate at zero angle of attack is mounted in a wind tunnel where

\[ \rho_\infty = 1.01325 \times 10^3 \text{ N/m}^2 \quad U_\infty = 100 \text{ m/s} \]
\[ \mu_\infty = 1.7894 \times 10^{-5} \text{ kg/m} \cdot \text{s} \quad \rho_\infty = 1.2250 \text{ kg/m}^3 \]

A Pitot probe is to be used to determine the velocity profile at a station 1.0 m from the leading edge (Fig. P4.11).

(a) Using a transition criterion that \( \text{Re}_{x_s} = 500,000 \), where does transition occur?

(b) Use equation (4.74) to calculate the thickness of the turbulent boundary layer at a point 1.0 m from the leading edge.

(c) If the streamwise velocity varies as the \( \frac{1}{4} \) power law [i.e., \( u/u_e = (y/\delta)^{1/4} \)], calculate the pressure you should expect to measure with the Pitot probe \( p_s(y) \) as a function of \( y \). Present the predicted values as

1. The difference between that sensed by the Pitot probe and that sensed by the static port in the wall [i.e., \( y \) versus \( p_s(y) - p_\text{static} \)]
2. The pressure coefficient

\[ y \text{ versus } C_p(y) = \frac{p_s(y) - p_\infty}{\frac{1}{2} \rho_\infty U_\infty^2} \]

Note that for part (c) we can use Bernoulli's equation to relate the static pressure and the velocity on the streamline just ahead of the probe and the stagnation pressure sensed by the probe. Even though this is in the boundary layer, we can use Bernoulli's equation, since we relate properties on a streamline and since we calculate these properties at "point." Thus, the flow slows down isentropically to zero velocity over a very short distance at the mouth of the probe.

(d) Is the flow described by this velocity function rotational or irrotational?
\[ P_t - P_o = \frac{1}{2} \rho U_e^2 \left( \frac{V}{8} \right) \]

\[ P_t - P_o = \frac{1}{2} \left( 1.225 \right) \left( 100 \right)^2 \frac{V^2}{0.01609} \]

\[ \rho = \frac{P_t - P_o}{\frac{1}{2} \rho U_e^2 \left( \frac{V}{8} \right)} \]

\[ C_\rho = \left( \frac{\rho}{\rho} \right) = \frac{1}{2} \rho U_e^2 \left( \frac{V}{8} \right) \]

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\[ U = U_e \left( \frac{Y}{6} \right) \quad \text{and} \quad \theta = 0.3747 \frac{X}{(Re_x)^{0.2}} = 0.3747 \left( \frac{M}{\rho U_e} \right)^{0.2} \]

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\[ U = C_1 X^{-0.1143} \quad \text{and} \quad \frac{\partial U}{\partial X} = 0.1143 \frac{C_1}{X} \]

Using continuity, \( \frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0 \)

\[ \frac{\partial V}{\partial Y} = 0.1143 C_1 \frac{Y}{X} \]

\[ \sqrt{\frac{\partial V}{\partial Y}} = C_2 \frac{Y}{X} \]

\[ \nabla \times \vec{V} = \begin{vmatrix} \frac{\partial}{\partial Y} & \frac{\partial}{\partial Z} & \frac{\partial}{\partial X} \\ V_Y & Z & X \\ C_1 X^{-0.1143} & C_2 Y X & 0 \end{vmatrix} \]

\[ \nabla \times \vec{V} = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix} \]

\[ \vec{D} \vec{V} \neq 0 \quad \text{Flea is Rotational} \]