ME19b. **HOMEWORK.** **Feb. 11, 2010. Due Feb. 18**

PROBLEM B14

Consider the long thin racing boats used in competitive rowing events. Assume that the major component of resistance to motion is the skin friction drag on the hull of the boat. Estimate this drag force for any velocity, U, by assuming that

1. the hull/water interface is like a flat plate with a length of 10 m and a width of 1 m.
2. the boundary layer on the hull remains laminar (even though in practice this would not be the case) and unseparated.

The water density, ρ, and kinematic viscosity, $\nu = \mu/\rho$, are respectively 1000 kg/m^3 and 10^{-6} m^2/s.

If the boat is propelled by eight humans *each* capable of a rate of output of work of 0.1 HP (1 $HP = 746$ $kg{\cdot}m^2/s^3$) and if half of this energy is uselessly dissipated in the rowing process what would be the top speed of the boat?

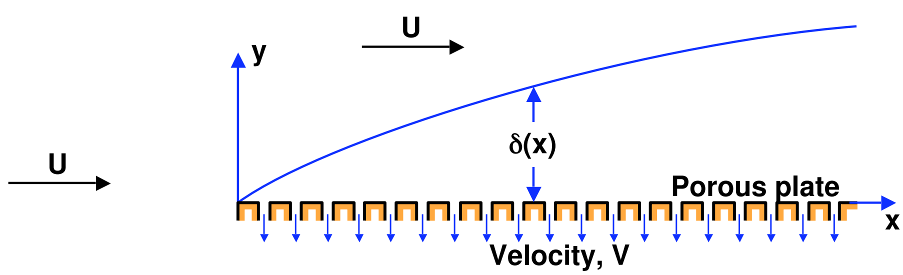
PROBLEM B15

Air enters a long horizontal ventilation duct of circular cross-section (radius 0.25 m) with a velocity of 1.0 m/s. At the entrance it is assumed that this velocity is uniform over the entire cross-section. However as the flow proceeds down the duct a thin laminar boundary develops on the inside wall of the duct. If we first assume that this is like the boundary layer on a flat plate and that the velocity away from the boundary layer remains at 1.0 m/s find the displacement thickness, δ_D (in m), at a distance x (in m) from the entrance. Assume the kinematic viscosity of the air is 2.5×10^{-6} m^2/s.

Having calculated this displacement thickness we recognize that the velocity outside the boundary layer cannot remain precisely constant at 1 m/s. Using the above calculated displacement thickness find the uniform velocity outside the boundary layer at a point 200 m from the entrance. What is the pressure difference between the entrance and this point 200 m from the entrance?

PROBLEM B16

A laminar boundary layer forms on a **porous** flat plate. Fluid is removed through the porous flat plate at a uniform velocity, V.



In other words, the volume of fluid removed through the porous plate per unit plate length, per unit breadth (perpendicular to figure) and per unit time is equal to V. The thickness of the boundary layer is denoted by $\delta(x)$ and the velocity outside the boundary layer is a constant, U. Using approximate boundary layer methods assuming similarity of the velocity profile (in other words that $u/U = F(y/\delta)$ where the function F is not a function of x) find a relation between the coefficient of friction ($= \tau_w / \frac{1}{2}\rho U^2$) and the quantities V, U, $d\delta/dx$ and α where α is the profile parameter

$$\alpha = \int_0^1 F(1-F)d\left(\frac{y}{\delta}\right)$$

PROBLEM B17

A laminar boundary layer in a planar, incompressible flow experiences a velocity, U, external to the boundary layer which increases with distance, x, measured along the surface as follows:

$$U = Ax^{1/2}$$

where A is a known constant.

Approximate boundary layer methods (the Karman momentum integral equation) are to be used to find the boundary layer thickness, δ. An approximate velocity profile is assumed and the profile parameters, α, β, and γ, are calculated. Assume that this has been done and that α, β, and γ are known.

The answer is that the boundary layer thickness is given by

$$\delta = Cx^m$$

where C and m are constants. Determine the index m. Find the constant C as a function of A, α, β, γ, and the kinematic viscosity, ν, of the fluid.