

**PROBLEM B8.**

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. that the boundary layer on the hull remains laminar (even though in practice this would not be the case) and unseparated.

The water density and kinematic viscosity 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  $HP = 746 kg m^2/s^3$  ) and if half of this energy is uselessly dissipated in the rowing process what would be the top speed of the boat?

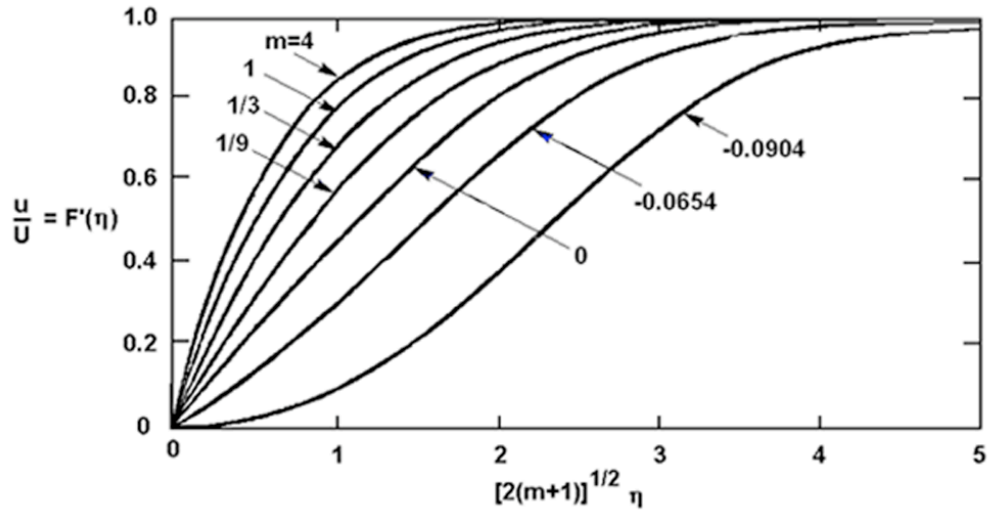
**PROBLEM B9.**

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,  $\delta_D$  (in  $m$ ), at a distance  $x$  (in  $m$ ) from the entrance. Assume the kinematic viscosity of the air is  $2.5 \times 10^{-6} m^2/s$ .

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 B10.**

Using the graph below find expressions for the laminar boundary layer thickness,  $\delta_{0.99}$  (defined as the distance from the wall at which the velocity has reached 99% of the velocity outside the boundary layer) for the flow past wedges of half-angle  $\pi/10$ ,  $\pi/4$  and  $\pi/2$  (the last being a flat plate normal to the on-coming stream) in terms of the distance  $x$  measured along the surface from the vertex, the kinematic viscosity,  $\nu$ , and the constant,  $C$ , which describes the velocity external to the boundary layer through the formula  $U = Cx^m$ .



**PROBLEM B11.**

If we assume that the velocity profile in a laminar boundary layer on a flat plate (zero pressure gradient) is of the approximate form

$$\frac{u}{U} = \sin \frac{\pi y}{2\delta} \quad \text{for } 0 < y < \delta$$

( and  $u/U = 1$  for  $y > \delta$  ) then find the resulting expressions for the displacement thickness,  $\delta_D$ , the momentum thickness,  $\delta_M$ , and the skin friction drag on the plate ( length =  $L$  , breadth =  $B$  ). Compare and comment on the comparison of these results with those of the exact Blasius solution.