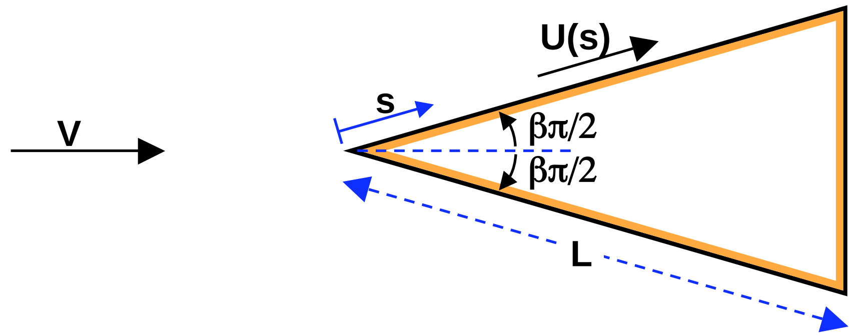
Problem 280B

This problem comprises an analysis of the flow of a uniform stream of incompressible fluid and velocity, V, impinging on a wedge of half-angle and side length, L, as shown in the sketch. For convenience the half-angle, α, is also denoted by $\beta\pi/2$.



The flow is planar and the Falkner-Skan solutions are to be used to assess the skin friction due to the laminar boundary layers on the inclined sides of the wedge. Recall that the Falkner-Skan solutions relate to laminar boundary layers for which the velocity exterior to the boundary layer, $U(s)$, is of the form:

$$U(s) = C\ s^m$$

where s is a coordinate measured along the surface and C and m are constants. Note that the Falkner-Skan solutions lead to wall shear stresses, τ_w, given by:

$$\frac{\tau_w}{\rho} = A(\beta)\frac{\nu^{\frac{1}{2}}U^{\frac{3}{2}}}{s^{\frac{1}{2}}}$$

where ρ and ν are the fluid density and kinematic viscosity and the factor $A(\beta)$ turns out to behave approximately like

$$A(\beta) = 0.332 + 0.87\beta$$

over the range $0 < \beta < 1$.

The drag coefficient on the wedge, C_D, is defined as:

$$C_D = D/\frac{1}{2}\rho V^2 H$$

where D is the drag per unit dimension perpendicular to the sketch. The drag is comprised of additive components due to the pressure distribution and due to the shear stress. Find expressions for the two separate components of the drag coefficient referred to as the form drag coefficient and the skin friction drag coefficient respectively. These expressions include β and the Reynolds number, $Re = VL/\nu$, which is assumed to be much larger than unity. Find the Reynolds number at which these two components are equal for a wedge with a half-angle of 7.5° ($\beta = 0.0833$).

Assume that the pressure on the back of the wedge is the same as that of the uniform stream and that the velocity exterior to the boundary layer at the rear corners, $U(L)$, is equal to V.