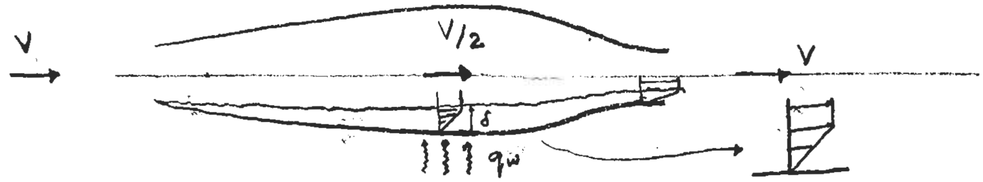
16.13 Aerodynamics of Viscous Fluids
Problem Set 8

Handed out: 3 Dec 03
Due: 10 Dec 03



Consider the idealized linear-velocity boundary layer inside a diffuser/nozzle device sketched above. The boundary layer is very rapidly accelerated though the nozzle which doubles u_e from $V/2$ back to V. The Mach number is small thoughout.

1a) Estimate the exit momentum defect $\rho_e u_e^2 \theta$ in terms of V and δ.

1b) The boundary layer is heated before the acceleration, so that the initial density profile is

$$\frac{\rho}{\rho_e} = 0.9 + 0.1\frac{y}{\delta}$$

What is its exit momentum thickness now?

1c) Is it possible to heat the boundary layer so much that the momentum defect at the exit becomes negative? Does the diffuser/nozzle device become a propulsor then?

The profile drag of a 3-D body is related to the momentum defect integrated over the plane normal to the wake

$$D = \iint (V - u)\, \rho u \, dZ \, dY$$

where Y, Z are the cartesian directions perpendicular to the freestream velocity V along X, and u is the velocity along X inside the viscous wake.

2a) For a straight wing at low incidence, use the 3-D BL equations to determine how this quantity relates to the skin friction components τ_x, τ_z, the surface velocity components u_e, w_e, and other relevant BL quantities. Be sure to define the x, z coordinates in which your BL quantities are defined.

2b) Qualitatively, what happens to the drag if the wing is swept in a way so that the normal-direction angle of attack is kept the same (i.e. $u_{e_\perp}/V_\perp$ is kept the same)?

2c) What happens to the lift/drag ratio if the wing is swept?