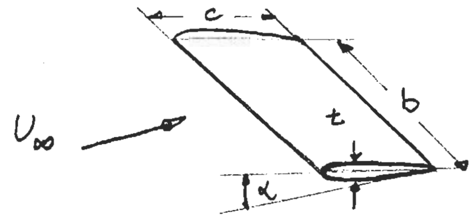
16.13 Aerodynamics of Viscous Fluids Handed out: 15 Sept 03
Problem Set 2 Due: 22 Sept 03

A rectangular wing of chord c and span b, has an elliptical "airfoil" of max thickness t. This wing is operated at an angle of attack of attack α in a flow with freestream speed U. The fluid has a constant viscosity ν and density ρ.



1a) Identify the physical scales of this flow, and determine the associated nondimensional groupings (i.e. the nondimensional parameters).

1b) Nondimensionalize the governing continuity and momentum equations using the scales of your own choice.

$$\nabla \cdot \vec{u} = 0$$
$$\vec{u} \cdot \nabla \vec{u} = -\nabla(p/\rho) + \nu \nabla^2 \vec{u}$$

If you were to solve the nondimensional equations to obtain a flow solution $\vec{u}, p$, how/where would all the nondimensional parameters you identified in 1a) come in?

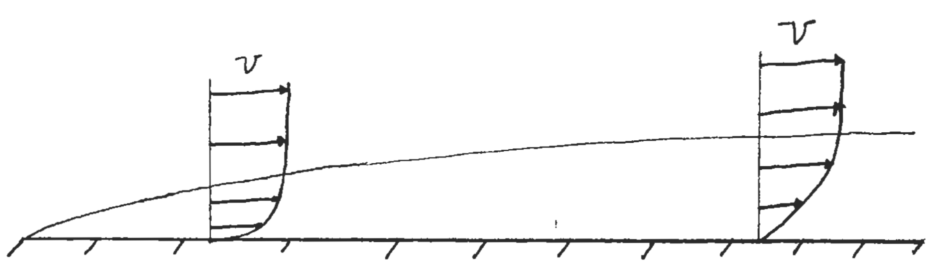
Normally, laminar viscous flows over bluff bodies like the wing with the elliptical airfoil above are inherently unsteady, with periodic vortex shedding at some frequency f.

1c) How would you expect f to relate to your physical scales in 1a)?

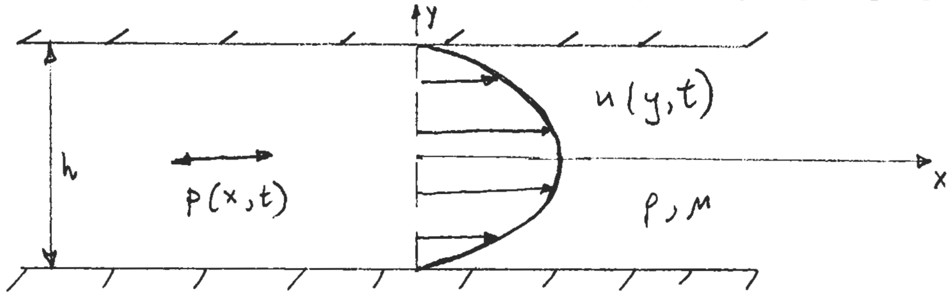
Consider the Blasius boundary layer growing on a semi-infinite plate. The freestream speed is U and the fluid kinematic viscosity is ν.

2a) Is there a geometric length scale associated with this flow situation?

2b) What is the significance of the derived length scale $\ell = \nu/U$? (i.e. how does it relate to the geometry of the flow?)



A fully-developed 2-D Poiseuille flow is established between two plates by imposing a pressure gradient $\partial p / \partial x$.



The pressure gradient is then changed, causing the velocity profile to change. Explain (or determine quantitatively if possible) how the velocity field evolves in time if $\partial p / \partial x$ is changed

2a) very slowly, and

2b) very quickly.

2c) What is the magnitude of $\partial(\partial p / \partial x) / \partial t$ where the behavior changes from one type to the other? i.e. What is a suitable definition of "slowly" and "quickly"?