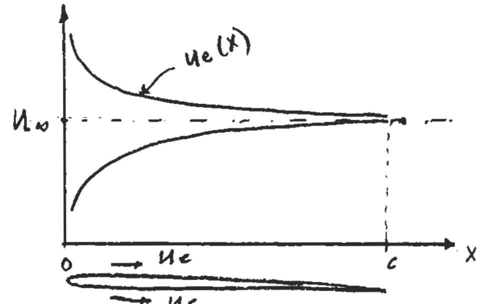
16.13 Aerodynamics of Viscous Fluids Handed out: 24 Sep 03
Problem Set 3 Due: 29 Sep 03

1) A thin airfoil at small angles of attack has a surface velocity very closely described by a power law.

$$u_e(x) \simeq u_\infty \, (x/c)^{\pm a}$$



The exponent a magnitude depends on the angle of attack, and its $\pm$ sign corresponds to the pressure/suction sides.

2 1a) Compute the surface pressure coefficient $C_p(x)$ and lift coeffcient c_ℓ as functions of a.

4 1b) Assume the chord Reynolds number $Re_c = u_\infty c/\nu$ is sufficiently small so that laminar flow is maintained. What is the maximum c_ℓ you expect this airfoil to have? (just before separation and stall)? Does this maximum c_ℓ depend on Re_c? Explain.

3 1c) For $Re_c = 5000$, which might correspond to the wing of a dragonfly, determine the momentum thickness $\theta(x)/c$ and skin friction coefficient $C_f(x)$ on each of the two surfaces. Estimate the profile drag coefficient c_d and profile c_ℓ/c_d ratio. How might the size of the insect affect its flight efficiency?

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2) The transformation $(x, y) \rightarrow (\xi, \eta)$:

$$\xi = x \qquad\qquad \eta = \frac{y}{\Delta(x)}$$

was shown to give similarity in (ξ, η) space if $u_e \sim x^m$, and $\Delta(x)$ is suitably chosen (e.g. as in the Falkner-Skan case $\Delta = \sqrt{\nu x/u_e}$).

Assuming that $u_e \sim x^m$, determine whether the following Δ definitions can or cannot produce similarity.

1 2a) $\Delta = \mu u_e/\tau_w$

1 2b) $\Delta = \delta^*$

1 2c) $\Delta = \theta + \delta^*$

1 2d) $\Delta = \delta_{99}$ (δ_{99} is the y location where $u = 0.99u_e$)

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