EAE 127 - MIDTERM 11/05/08

(Open Notes, open Book)

(Give unambiguous answers. Use results derived in Class)

1. Inviscid, Incompressible Flow (20 points)

Design Requirements: A thin airfoil design is considered for which the center of pressure is located at mid-chord, i.e. $\frac{x_{c.p.}}{c} = \frac{1}{2}$, when the airfoil is operating at *ideal angle of attack* (*adapted leading edge*) at a lift coefficient $C_{l,adapt} = 0.5$. The purpose of the analysis is to find the *simplest airfoil* that will satisfy the requirements, i.e. with the least number of non-zero coefficients $A_1, A_2, ...A_n$, and the global aerodynamic coefficients at adaptation.

1.1 Definition of the Center of Pressure

Give the definition of the *Center of Pressure.*

1.2 Finding the Fourier Coefficients

How does "adapted leading edge" translate in terms of the Fourier coefficients?
Find **all** the Fourier coefficients *at adaptation* that satisfy the design requirements.

1.3 Equation of Cambered Plate

Give the equation of the cambered plate. What is the relative camber $\frac{d}{c}$ of the profile?

1.4 Results

Give the *incidence of adaptation* (ideal angle of attack). Make a sketch of the flow in this case, showing in particular the streamlines in the leading edge and trailing edge regions.
Give the lift coefficient C_l, the moment coefficient $C_{m,o}$ and the drag coefficient C_d at the incidence of adaptation.

2. Linearized Supersonic Flow (20 points)

Let $\beta = \sqrt{M_\infty^2 - 1}$, $M_\infty > 1$. Consider a thin cambered plate of equation $d(x) = 4d\,\frac{x}{c}\left(1 - \frac{x}{c}\right)$ where $\frac{d}{c}$ is the relative camber ($d > 0$).

2.1 Pressure Distribution on a Thin Cambered Plate

Calculate the pressure coefficients $C_p^+(x)$ and $C_p^-(x)$ along the plate in terms of β, for $\alpha = 0$.
Plot on a graph $-C_p^+(x)$ and $-C_p^-(x)$.

2.2 Global Coefficients: C_l, C_d, $C_{m,o}$

Give the lift coefficient $C_l(\alpha)$ and calculate the aerodynamic coefficients $(C_d)_{\alpha=0}$, $(C_{m,o})_{\alpha=0}$, for $\alpha = 0$.

2.3 Static Equilibrium About an Axis

If the profile can rotate freely about an axis placed at the leading edge (neglect weight), find α_{eq}, the equilibrium angle and $C_{l,eq}$. Sketch the profile at equilibrium and indicate with a vector $\overrightarrow{C}_{l,eq}$ the resulting force and its point of application on your drawing.

2.4 Static Stability

Is the equilibrium statically stable, neutral or unstable?