Entrance Examine, Aerodynamics, May 1997

1. A viscous flow of viscosity $\mu$ is given by the stream function
(20%)

$$\psi = -Axy, \qquad A > 0.$$

Assume that there is no body force. You are asked to obtain a relation between the pressure, density, $A$, $x$, and $y$.

2. Show that
(20%)

$$\phi = Ar^{\frac{\pi}{\alpha}} cos(\frac{\pi}{\alpha}\theta)$$

is a velocity potential of an inviscid flow, where $A$ and $\alpha$ are constants, and $r, \theta$ are the polar coordinates.

3. The two-dimensional steady incompressible uniform flow over a flat plate will produce
(20%) a boundary layer flow. The boundary flow has the following governing equations

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\mu}{\rho}\frac{\partial^2 u}{\partial y^2}$$

$$\frac{\partial p}{\partial y} = 0$$

where $u, v$ are the velocity components in $x$ and $y$-directions, respectively, $p$ is the pressure, and $\rho$ is the density.

a. Derive the von Karman momentum integral equation for the boundary layer flow. (8%)

b. Assume linear variation of velocity within the boundary, say $\frac{u}{U} = \frac{y}{\delta}$, where $U$ is the free stream velocity, $\delta = \delta(x)$ is the boundary layer thickness. Prove that the boundary thickness satisfy the following relation

$$\delta = \delta(x) = \frac{3.46x}{\sqrt{Re_x}}$$

where $Re_x = \frac{\rho U x}{\mu}$ (8%)

c. Draw a schematic diagram to show a more correct velocity distribution within the boundary layer, and discuss why the above boundary layer thickness of item(2) is underestimated. (The exact solution is $\delta = \frac{5x}{\sqrt{Re_x}}$.) (4 %)

(背面仍有題目,請繼續作答)

4.(20%)

a. Draw a schematic diagram to shown the lift coefficient variation with respect to angle of attack of a thin airfoil, and brief describe you lift diagram. (7 %)

b. List all the possible methods you known to improve the lift-coefficient of an NACA0012 airfoil. (3%)

c. Assume a thin airfoil with chord 1 meter and of infinite span. If the free stream speed is 100 meter/second and angle of attack is 2°, air density is $1.23 kg/m^3$. Find the lift force of the airfoil per unit span. (10 %)

5.(20%)

Consider a thin and symmetric airfoil with a trailing-edge flap in a two-dimensional inviscid incompressible flow.

(A) When the flap deflection is zero, draw the $\alpha - C_l$ diagram where $C_l$ is the lift coefficient and $\alpha$ is the angle of attack. What is the value of the slope of the lift curve $\frac{\partial C_l}{\partial \alpha}$? What is the value of zero lift angle of attack $\alpha_{L=0}$? Assuming that stall occurs at 15°, what is the value of the maximum lift coefficient $C_{l,max}$?

(B) When the flap deflection is positive (downward), say 10°, draw a typical $\alpha - C_l$ diagram showing the effects of the flap deflection. Compare the magnitude of $C_{l,max}$, $\frac{\partial C_l}{\partial \alpha}$, $\alpha_{L=0}$ and the stall angle with the results in (A).

(C) When the flap deflection is negative (upward), say -10°, draw a typical $\alpha - C_l$ diagram showing the effects of the flap deflection. Compare the magnitude of $C_{l,max}$, $\frac{\partial C_l}{\partial \alpha}$, $\alpha_{L=0}$ and the stall angle with the results in (A).