Introduction to Marine Hydrodynamics (NA235)

(2014-2015, 2nd Semester)

Assignment No.9

(6 problems, given on June 11th, submit on June 18th, 2015)

Problem 1: Given velocity profile of a laminar boundary layer

$$u = U\frac{y}{\delta}, \qquad 0 \le y \le \delta$$

where U is the outer velocity, and y the distance to the wall. Please ① calculate ratio of displacement thickness, δ^*, to the boundary layer thickness, δ, and ② calculate ratio of momentum thickness, θ, to the boundary layer thickness, δ.

Problem 2: In a laminar boundary layer near a flat plate, velocity gradient on the wall is expressed as $k\left(=\left.\frac{\partial u}{\partial y}\right|_{y=0}\right)$. If the flow is steady and driven by a favorable pressure gradient, $\frac{\partial P}{\partial x}$, prove that velocity profile near the wall can be expressed as $u = \frac{1}{2\mu}\frac{\partial P}{\partial x}y^2 + ky$, where y is the distance to the wall.

Problem 3: Given velocity profile in a 2-dimensional laminar boundary layer near flat plate

$$\frac{u}{U} = \sin(\frac{\pi}{2} \cdot \frac{y}{\delta})$$

where y is the distance to the wall. Please write down expressions of $\delta(x)$, $\delta^*(x)$, $\theta(x)$ and frictional drag R_t for a plate with length L.

Problem 4: Given velocity profile of a laminar boundary layer near a flat plate

$$u = A\sin(By) + C$$

where y is the distance to the wall. Please list boundary conditions, then determine coefficients A, B and C.

Problem 5: A flat plate is placed in a uniform flow under favorable pressure gradient. If double the length of the plate, how many times the plate drag will become? State of the boundary layer near the plate is assumed to be laminar.

Problem 6: A flat plate is placed in a uniform flow under favorable pressure gradient. If velocity profile, $u(y)$, in the boundary layer near the wall can be expressed as a polynomial up to cubic term, where y is the distance to the wall, prove the velocity profile will be expressed as

$$\frac{u}{U} = \frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$

where δ stands for the boundary layer thickness.