MAE 101B, Spring 2009
Midterm II, 11:00 AM - 11:50 AM

Guidelines: Closed-book, closed-notes, no-calculator exam. Give all formulae used and **explain your steps** in each problem. When there are numbers in the problem, insert them into formulae (using SI units). Perform simple calculations but there is **no need for complex calculations** to obtain numerical answers. Attach question paper to the exam that you turn in.

1.

a. A flat plate of length $L_1 = 10m$ is dragged through water with given velocity $V_1 = 10m/s$. The power, P_1, required to drag the plate is measured and known. What is the power, P_2, required to drag the plate with a velocity, $V_2 = 2V_1$, which is twice the original velocity. Give the answer in terms of the original power, P_1. Take $\nu = 10^{-6}\, m^2/s$.

b. The Blasius equation for a laminar boundary layer is:

$$f^{'''} + \frac{1}{2} f f^{''} = 0\,. \qquad (1)$$

What are the three boundary conditions on $f(\eta)$?
Here, $\psi(x, y) = Uh(x)f(\eta)$, is the stream function and and $u(x, y) = Uf^{'}(\eta)$ is the streamwise velocity. Note that $\eta = y/h(x) = \frac{y}{\sqrt{\nu x/U}}$ is a similarity variable.

50 points

2.

a. A sphere of given density ρ_s and given diameter D is dropped from rest in an infinite fluid of given properties: density ρ and viscosity μ. Assume *high-Re* flow with constant drag coefficient, C_D, that is given. Obtain an ordinary differential expression for V in terms of the given quantities.

b. The wall boundary layer in a converging-diverging nozzle can separate in the diverging portion if the diffuser wall angle exceeds a critical angle. Explain why does the flow separate in the diverging portion and not the converging portion.

50 points

3. Extra credit Consider a turbulent boundary layer over a fully rough plate under a stream of constant velocity, U. The momentum thickness can be shown to vary as $\theta(x) \propto x^n$; obtain the value of n.

15 points