Submit the 5 problem solutions in order given below.

Text Problems:
9.9 (extend table to include 3-5 air/water vehicles. Try to cover a range of size/speeds, e.g., micro/mini UAV, gliders, large aircraft), 9.26 (consider different car speeds between 10-70 mph and comment on results).

Handout Problems:
H4.1 Consider boundary layer flow over a flat plate. Water at 20°C flows over a plate with length $L = 30$ cm and width $W = 60$ cm. The constant freestream velocity is 0.5 m/s. Using the Blasius solution (class handout Table 9.1, see also text section 9.2.2):

a. Is the Blasius solution applicable for this flow? Explain and verify.

b. Explain how the boundary layer thickness, $\delta(x)$, is determined from Table 9.1. Plot $\delta(x)$ for given flow.

c. Plot the nondimensional velocity profile $u/U$ (abscissa) versus $y/\delta$ (ordinate). Next, plot a few dimensional velocity profiles $u(y)$ at several $x$ locations along the plate ($x = 10, 20, 30$ cm).

d. Derive an expression for the $y-$component of the velocity, $v/U$, in terms of the similarity variables and $Re_x$. Plot $v/U$ versus $y/\delta$. Evaluate $v$ at $y = \delta/2$ at $x = 10, 20, 30$ cm. Compare with $u$ at these locations.

e. Show how $\tau(x,y)$ and $\tau_w(x)$ are obtained from Table 9.1 (in handout). Note: boundary layer analysis considers $\partial v/\partial x << \partial u/\partial y$. Plot the nondimensional shear stress profile $\tau/\tau_w$ versus $y/\delta$. Plot the wall shear stress distribution, $\tau_w(x)$.

f. Determine the drag force [N] on the plate (one side).

g. If the plate is rotated so that $L = 60$ cm and $W = 30$ cm, with respect to the flow, determine the corresponding drag force. Compare with part f. and explain the results.

H4.2 Consider a laminar boundary layer flow over a flat plate for which the velocity profile can be approximated by cubic equation, $u/U = 3(y/\delta)^2 - (y/\delta)^3/2$ (see profile in text Fig. 9.12).

a. Show that this profile satisfies the appropriate boundary conditions.

b. Using the momentum integral relation, equ. (9.26), derive expressions for $\delta/x$ and $\tau_w(x)$. Integrate $\tau_w(x)$ and obtain an expression for the drag coefficient, $C_D$, as a function of $Re_l$, where $l$ is length of plate. Compare with results in Table 9.2.

H4.3 Repeat H4.2 part b. but now consider a turbulent boundary layer for which the velocity profile can be approximated by a power law equation, $u/U = (y/\delta)^{1/6}$. Compare with results given in text Example 9.6 for 1/7 power law profile.

H4.4 Watch the rest of the film, Fundamentals of Boundary Layers (link from class website). Don’t worry about discussions of vorticity and circulation. Do pay attention to discussion of pressure gradients.