AA200A Midterm Exam 2012 -2013 Cantwell May 2013

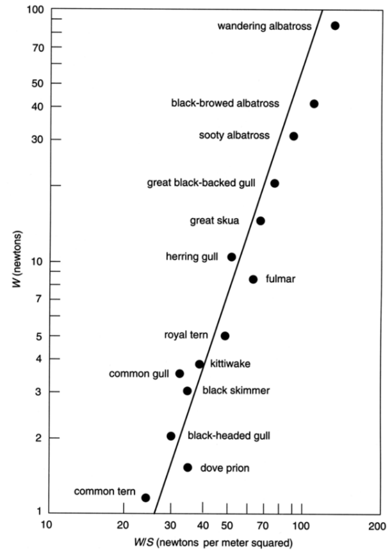
Tuesday May 7, 2013, 2:15-3:30 - 25 points

Open books, papers, notes, laptop if needed to access course notes

1) 5 points – The figure on the right shows the scaling of weight (newtons) versus wing loading (newtons per meter squared) for a wide variety of birds from the common tern (about 1 newton) to the wandering albatross (about 90 newtons). The dimensional argument used to derive the relationship is the following: Let the wingspan measured tip-to-tip with the wings fully outstretched be called b. The wing area is proportional to b^2 and the bird weight is proportional to b^3. The wing loading W/S is therefore proportional to b which is proportional to the cube root of the weight W. Thus one can expect the wing loading and weight to be related by a power law of the form

$$W/S = CW^{1/3} \quad \text{or} \quad Ln(W/S) = Ln(C) + (1/3)Ln(W)$$

where C is a constant. The correlation shown in the figure is pretty good but not perfect and there is a fair amount of scatter. What are the main assumptions needed to arrive at this result?



2) 6 points – The equation below, called Burgers equation is often used to illustrate the balance between nonlinear convection and viscous diffusion in one space dimension and time.

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} - \nu\frac{\partial^2 U}{\partial x^2} = 0$$

a) Transform the equation using the group

$$\tilde{x} = e^a x \qquad \tilde{t} = e^b t \qquad \tilde{U} = e^c U$$

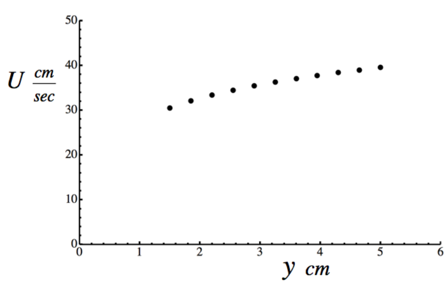
b) How do the parameters a, b, and c have to be related for the equation to be invariant, ie, transformed to itself by the group.

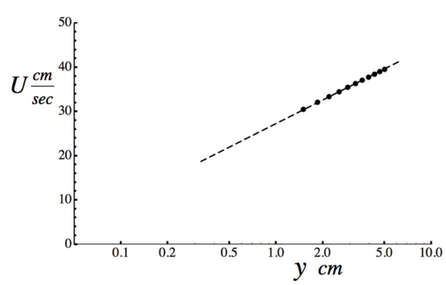
3) 8 points - A wind tunnel experiment is designed to produce a laminar boundary layer on a flat plate subject to a strongly favorable pressure gradient. The free stream velocity is $U_e/U_\infty = e^{x/L}$ where U_∞ is the free stream velocity ahead of the plate and L is the length of the plate.

a) Determine the momentum thickness of the boundary layer. Evaluate $\theta/L|_{x=0}$ and $\theta/L|_{x=L}$.

b) Determine the Thwaites parameter m at $x=0$ and $x=L$. Does separation occur anywhere?

4) 6 points – Mean velocity data near a smooth wall under a turbulent boundary layer are shown below.





On the left the velocity is plotted versus distance from the wall and on the right the same data is plotted versus the natural logarithm of the distance from the wall. In the right figure the data falls on a straight line of slope $dU/d(Ln(y)) = 7.5$. The fluid is air with kinematic viscosity $\nu = \mu/\rho = 0.15 \ \ cm^2/\sec$.

a) Determine the friction velocity, u^*.

b) Determine the slope of the velocity profile at the wall, $dU/dy|_{y=0}$.