AE 2020 Final Examination
Fall 2000
Closed book and Two Pages of Notes
One Hour and 30 Minutes

1. Explain what is the physical process behind induced drag experienced by finite wings.

   For a given aspect ratio, and lift coefficient, what can be done to keep this drag as small as possible?

   A wing with an area of 4000 ft^2 and a total span of 20 feet is being designed to carry a weight of 96000 lbf at sea level conditions (Density, ρ = 0.00238 slugs/ft^3), at a free stream velocity of 200 feet/sec. The same symmetric airfoil is used all along the span. The airfoil has a 2-D lift curve slope of 0.1 per degree, The wing has been designed to have the minimum possible induced drag, as discussed above.

   Compute the lift coefficient, drag coefficient, and the geometric angle of attack for this wing.

   Sketch the spanwise variation of circulation, downwash, and the effective angle of attack. (A sketch will do, you need not compute the numerical magnitudes).

   35%

2. Consider viscous flow over an airfoil. All conditions being equal (angle of attack, Reynolds number), what condition will produce a thicker boundary layer- laminar flow or turbulent flow? Why?

   Which condition will produce a higher drag for this case- laminar flow or turbulent flow?

   10%

3. Compute the variation of momentum thickness θ, displacement thickness δ^*, and the skin friction coefficient C_f over a flat plate at zero angle of attack, as a function of x, the viscosity ν, and the freestream velocity. Use Von Karman integral momentum equation. Assume the following velocity profile:

$$\frac{u}{u_e} = A + B\frac{y}{d} + C\left(\frac{y}{d}\right)^2$$

   25%

4. Apply Thwaites' method to laminar boundary layer growth over a circular cylinder. Determine the separation point. Note that the potential flow distribution is given by:

$$u_e(x) = 2V_\infty \sin\left(\frac{x}{R}\right)$$

   where x is the distance along the cylinder surface, measured from the front stagnation point. Since the cylinder radius R or the freestream velocity V_∞ will not affect the separation point, you may take these quantities be unity (i.e. 1).

   Note: $\int \sin^5 f\, df = \frac{2}{3}\cos^2 f - \cos f - \frac{\cos^5 f}{5}$

   25%

5. Who won the 2000 Tech-UGA football game? 5%