2005 - AER 307 - Problem Set 2

(At sea level, the density of the standard atmosphere is 1.226 Kg/m^3, and the temperature is 288K. Also, $R = 287\text{m}^2/\text{s}^2\text{K}$, $\gamma = 1.4$, $c_v = 717$ Nm/Kg K, and $c_p = 1004$ Nm/Kg K.)

1. An airplane weighing 73,600 N has elliptic wings 15.23 m in span. For a speed of 90 m/s in straight and level flight at low altitude, find the induced drag. (Hint: Note that you are asked to find the induced drag, not the induced drag coefficient.) [**10 marks**]

2. Consider an untwisted wing with an aspect ratio of 9. The chord at the tip is 0.4 times the chord at the root and varies linearly in bewteen. The zero-lift angle of attack is $-1.2°$ across the span. Using four stations located at $\frac{\pi}{8}$, $\frac{\pi}{4}$, $\frac{3\pi}{8}$, and $\frac{\pi}{2}$, find the linear system of equations for A_1, A_3, A_5, and A_7. Find the lift coefficient and the induced drag coefficient as functions of the geometric angle of attack. Find their values when the geometric angle of attack is 4°. [**20 marks**]

3. Sea level air moving at a Mach number of 2.2 is turned isentropically in an expansive direction through an angle of 12°. Find the exact Mach number at the end of 4° turning and at the end of 12° turning. [**10 marks**]

4. A Pitot tube on an airplane (which measures total pressure) flying at sea level reads 1.3 atm. Calculate the speed of the airplane using a) the incompressible Bernoulli equations and b) the isentropic relations. [**10 marks**]

5. A two-dimensional airfoil is so oriented that its point of minimum pressure occurs on the upper surface. At a freestream Mach number of 0.4, the pressure coefficient at this point is -0.782. Using the Prandtl-Glauert rule, estimate the critical Mach number of the airfoil to three significant figures. [**20 marks**]

6. A wedge having a total vertex angle of 55° is traveling at a Mach number of 3.5 at an altitude of 15km (at this altitude, the density of the standard atmosphere is $0.194\frac{\text{kg}}{\text{m}^3}$, and the temperature is 216.5°K, R = $287\frac{\text{m}^2}{\text{s}^2\,°\text{K}}$, $\gamma = 1.4$, $c_v = 717\frac{\text{Nm}}{\text{kg}°\text{K}}$, and $c_p = 1004\frac{\text{Nm}}{\text{kg}°\text{K}}$). Determine the static and stagnation values of the pressure, density, and temperature downstream of the shock. What percentage of the stagnation pressure is lost across the shock wave? What is the minimum speed of the wedge required in order to maintain an oblique shock attached to the nose? [**20 marks**]

7. Do Anderson, Chapter 8, Problems 8, 9, and 15. [**10 marks each**]