UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING
FINAL EXAMINATION, DECEMBER 2001
AER 307S - AERODYNAMICS
2 pages

1. Assume that you have a library of reliable computer codes available which solve the following equations: (i) the Reynolds-averaged Navier-Stokes equations, (ii) the Euler equations, and (iii) the linear potential-flow equation. Indicate whether each of these codes would provide a reasonably accurate answer for the following problems. In each case, the Reynolds number is 5 million. You must provide an answer (accurate or inaccurate) for each computer code for each case, i.e. 15 answers. No explanation is necessary. (1 mark for a correct answer, -1 for a wrong answer, maximum 15, minimum 0)

(a) Pressure coefficient on a cylinder at a Mach number of 0.01.

(b) Pressure coefficient on an airfoil at zero angle of attack and a Mach number of 0.1.

(c) Drag coefficient of an airfoil at zero angle of attack and a Mach number of 0.1.

(d) Pressure coefficient on an airfoil at zero angle of attack and a Mach number of 0.95.

(e) Pressure coefficient for a high-lift multi-element airfoil geometry at an angle of attack of 22 degrees and a Mach number of 0.1.

2. Using a Taylor table, find a second-order finite-difference approximation to a third derivative in the form (25 marks):

$$\left(\frac{\partial^3 u}{\partial x^3}\right)_j \approx \frac{1}{\Delta x^3}(bu_{j-2} + au_{j-1} - au_{j+1} - bu_{j+2})$$

The Taylor series you will need are:

$$u_{j\pm1} = u_j \pm \Delta x u_j{}' + \frac{1}{2}\Delta x^2 u_j{}'' \pm \frac{1}{6}\Delta x^3 u_j{}''' + \frac{1}{24}\Delta x^4 u_j{}'''' + \ldots$$

and

$$u_{j\pm2} = u_j \pm 2\Delta x u_j{}' + \frac{1}{2}(2\Delta x)^2 u_j{}'' \pm \frac{1}{6}(2\Delta x)^3 u_j{}''' + \frac{1}{24}(2\Delta x)^4 u_j{}'''' + \ldots$$

3. An airplane weighing 7.36×10^4 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: you are asked to find the induced drag, not the induced drag coefficient.) (15 marks)

4. 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 two significant figures. (20 marks)

5. A wedge having a total vertex angle of 60 degrees is traveling at a Mach number of 3 at an altitude of 15 km (at this altitude, the density of the standard atmosphere is 0.194 $\mathrm{Kg/m^3}$, and the temperature is 216.5 K, $R = 287\mathrm{m^2/(s^2 \cdot \mathit{K})}$, $\gamma = 1.4$, $c_v = 717\mathrm{m^2/(s^2 \cdot \mathit{K})}$, $c_p = 1004\mathrm{m^2/(s^2 \cdot \mathit{K})}$). Determine the static and stagnation values of the pressure, density, and temperature downstream of the shock, that is p_2, p_{02}, ρ_2, ρ_{02}, T_2, and T_{02}. What percentage of the stagnation pressure is lost across the shock wave? What is the minimum speed (not Mach number) of the wedge required in order to maintain an oblique shock attached to the nose? (25 marks)

Thanks for an enjoyable term - have a nice holiday!