AE 360
Examination 2
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10 April 1997

1. (33) Calorically perfect ideal air flows through a converging-diverging nozzle designed to give exit Mach number, $M = 2.80$. The upstream stagnation conditions are $P_o = 100\ kPa$, $T_o = 300\ K$; the back pressure is maintained by a vacuum pump. Determine
   - the back pressure required to cause a normal shock to stand in the exit plane, and
   - the flow speed after the shock.
2. (33) Consider a freestream flow of inviscid calorically perfect ideal air at $M_1 = 1.5$, $P_1 = 100\ kPa$ and $T_1 = 300\ K$. A very thin flat plate airfoil with chord length 1.5 m and span 4 m is at angle of attack of 1°. A very thin flap of chord length 0.2 m and span 4 m is attached to the trailing edge of the airfoil. The flap turns the flow an additional 1°. Assuming two-dimensional theory captures most of the relevant physics, use *small disturbance theory* to calculate
   - the lift force, and
   - the drag force.
3. (34) Analyze a shock wave as Sir Isaac Newton may have been tempted to do by considering the flow of a gas which is calorically perfect, $\gamma = \frac{7}{5}$; ideal, $R = 287\ \frac{J}{kg\ K}$; inviscid, $\mu = 0\ \frac{N\ s}{m^2}$; *isothermal*, $T = 300\ K$; one dimensional; and unsteady. For such a flow
   - write the conservative form of the mass and momentum equations as two partial differential equations in two unknowns: $\rho(x,t), u(x,t)$,
   - write these equations in discrete form using a two-step Lax-Wendroff technique,
   - considering now the flow to be steady and a stationary shock to be standing in a duct, calculate the shock density ρ_2, fluid velocity u_2, and pressure P_2 if the unshocked pressure is $P_1 = 100\ kPa$ and the unshocked velocity is $u_1 = 500\ \frac{m}{s}$.