AAE 412 **SPACE SYSTEMS ENGINEERING**

COMPRESSIBLE FLOW EQUATIONS

Mach number: $M = V/c$ where $c^2 = kRT$ *note*: T is in K

ADIABATIC PROCESS:

Adiabatic stagnation temperature ratio: $T_o/T = 1 + V^2/(2C_pT) = 1 + M^2 (k-1)/2$

ISENTROPIC PROCESS:

Isentropic stagnation pressure ratio: $P_o/P = [1 + M^2 (k-1)/2\,]^{k/(k-1)}$

Isentropic stagnation density ratio: $\rho_o/\rho = [1 + M^2 (k-1)/2\,]^{1/(k-1)}$

Mach-Area relation #1: $dA/A = dV\,(M^2-1)/V$

Mach-Area relation #2: $dA/A = -dP\,(M^2-1)/(\rho V^2)$

Critical ("sonic") properties:

$T^*/T_o = 2/(k+1)$

$P^*/P_o = [2/(k+1)]^{k/(k-1)}$

$\rho^*/\rho_o = [2/(k+1)]^{1/(k-1)}$

Sonic area ratio: $A/A^* = M^{-1}[(1 + M^2 (k-1)/2) / (1 + (k-1)/2)]^{(k+1)/[2(k-1)]}$

Mass flow rate: $m = PAM\,[k/(RT)]^{½}$

Maximum mass flow rate: $m_{choked} = 0.68473\,P_oA^*/(RT_o)^{½}$

NORMAL SHOCK RELATIONS:

Static temperature ratio: $T_2/T_1 = [1 + M_1^2 (k-1)/2] / [1 + M_2^2 (k-1)/2]$

Static pressure ratio: $P_2/P_1 = M_1/M_2\,[T_2/T_1]^{½}$

Stagnation pressure ratio: $P_{o2}/P_{o1} = M_1/M_2\,[T_1/T_2]^{(k+1)/[2(k-1)]}$

Downstream Mach number: $M_2^2 = [M_1^2 + 2/(k-1)] / [\,2 M_1^2\,k/(k-1) - 1]$

OBLIQUE SHOCK RELATIONS:

Where β is the oblique shock angle and θ is the flow deflection angle:

$M_{1n} = M_1 \sin(\beta)$ and $M_{2n} = M_2 \sin(\beta - \theta)$

$\tan(\theta) = 2\cot(\beta)\,[M_1^2 \sin^2(\beta) - 1] / [M_1^2 (k + \cos(2\beta)) + 2]$

PRANDTL-MEYER EXPANSION FLOWS:

Prandtl–Meyer supersonic expansion function: $\theta = \omega(M_2) - \omega(M_1)$

Forward Mach line angle: $\mu_1 = \sin^{-1}(1/M_1)$

Back Mach line angle: $\mu_2 = \sin^{-1}(1/M_2)$