Veronica Loomis
Problem 1.1

At nose of missile, $P = 5.6$ atm, $T = 850°R$

Calculate density (ρ) and specific volume (v)

Note: 1 atm = 2116 lbf/ft^2

Assuming a perfect gas:

$P = \rho R T$ [Eqn 1.9]

$$5.6 \text{ atm} \times 101325 \frac{N}{m^2} \frac{1}{atm} = \rho \left(287 \frac{J}{kgK}\right)\left(850°R \times \frac{5}{9} \frac{K}{R°}\right)$$

$$\rho = \frac{5.6(101325)}{287(850)(5/9)} \frac{kg/s^2m}{m^2/s^2} = 4.1867 \text{ kg/m}^3$$

$$v = 1/\rho = 0.2388 \text{ m}^3/\text{kg}$$

$$\boxed{\begin{aligned} \rho &= 4.1867 \text{ kg/m}^3 \\ v &= 0.2388 \text{ m}^3/\text{kg} \end{aligned}}$$

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Problem 1.3

For a caloriically perfect gas, derive $C_p - C_v = R$

Repeat for a thermally perfect gas

Calorically Perfect Gas:

$e = C_v T$ and $h = C_p T$

we know $h = e + Pv$

$e + PV = e + RT = C_p T$

Rearrange

$$T = \frac{e}{C_p - R}$$

Substitute into $e = C_v T$

$$e = \frac{C_v e}{C_p - R}$$

$C_p - R = C_v$

$C_p - C_v = R$ ✓

Thermally Perfect

$de = C_v dT$ and $dh = C_p dT$

Similar to caloriically perfect,
$dh = d/dT(e + Pv) = d/dT(e + RT)$
$= de + RdT = C_p dT$

Replace

$C_p dT - RdT = C_v dT$

$C_p - C_v = R$ ✓

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Problem 1.4

Across a given portion of a shockwave:

$\frac{P_2}{P_1} = 4.5$ $\frac{T_2}{T_1} = 1.687$ 1. ahead of SW
2. behind SW

Calculate change in entropy in (a) [ft·lb/slug°R] (b) [J/kgK]

Assuming calorically perfect gas
$S_2 - S_1 = C_p \ln(T_2/T_1) - R \ln(P_2/P_1)$ [Eqn 1.36]

(a)
If we assume $\gamma = 1.4$

$C_v = \frac{R}{\gamma - 1}$ [Eqn 1.23]

$C_v = \frac{1716}{0.4}$ ft lb/slug°R

$C_v = 4290$ ft lb/slug°R

$C_p = C_v + R = 6006$ ft lb/slug°R

$S_2 - S_1 = 6006 \ln(1.687) - 1716 \ln(4.5)$

$\boxed{S_2 - S_1 = 559.85 \text{ ft lb/slug°R}}$

(b)
$C_v = \frac{287}{0.4} = 717.5$ J/kgK

$C_p = C_v + R = 1004.5$ J/kgK

$S_2 - S_1 = 1004.5 \ln(1.687) - 287 \ln(4.5)$

$\boxed{S_2 - S_1 = 93.63 \text{ J/kgK}}$

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Problem 1.5

Air flow through given duct is isentropic

At one point, $P_1 = 1800\ lb/ft^2$ $T_1 = 500°R$

At second point, $T_2 = 400°R$

Calculate P and ρ at second point

$$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\gamma/(\gamma-1)} \quad [\text{Eqn } 1.43]$$

Assume $\gamma = 1.4$

$$P_2 = (1800)\left(400/500\right)^{1.4/0.4}$$

$$\boxed{P_2 = 824.3\ lb/ft^2}$$

Assume ideal gas

$$(P = \rho RT)_2$$

$$\rho = \frac{824.3}{(1716)(400)} \frac{lb/ft^2}{\frac{ft\,lb}{slug\,R}\ R} = 0.0012\ slug/ft^3$$

$$\boxed{\rho_2 = 0.0012\ slug/ft^3}$$

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