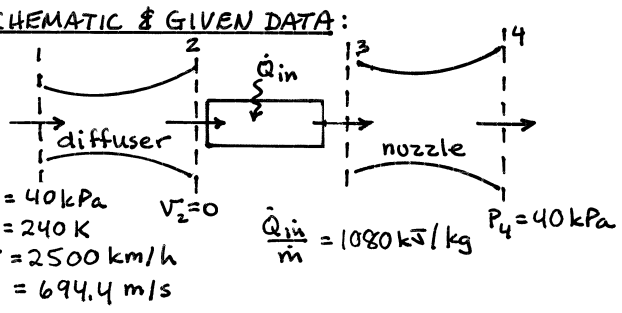
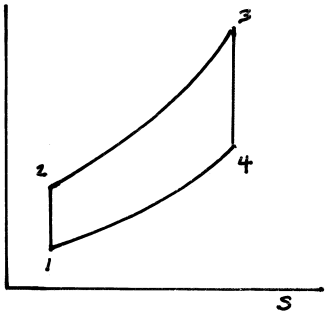
PROBLEM 9.8E*

KNOWN: Air enters the diffuser of a ramjet with known conditions. The heat addition per unit mass of air flowing is specified.

FIND: Using air-standard analysis, determine (a) the pressure at the diffuser exit and (b) the velocity at the nozzle exit.

SCHEMATIC & GIVEN DATA:





ASSUMPTIONS: (1) Each component is analyzed as a control volume at steady state. (2) The combustion process is modeled as a constant pressure heat addition. (3) The diffuser and nozzle operate isentropically. (4) Neglect kinetic energy at locations 2 & 3 and neglect potential energy throughout. (5) The working fluid is air modeled as an ideal gas.

ANALYSIS: (a) For the diffuser; $0 = \left(h_1 + \frac{V_1^2}{2}\right) - h_2$

Thus
$$h_2 = h_1 + \frac{V_1^2}{2} = 240.02 \frac{kJ}{kg} + \frac{(694.4)^2}{2} \frac{m^2}{s^2} \left| \frac{1\ N}{1\ kg \cdot m/s^2} \right| \left| \frac{1\ kJ}{10^3\ N \cdot m} \right|$$
$$= 481.1 \ kJ/kg$$

Interpolating in Table A-22; $T_2 \approx 479$ K and $P_{r_2} = 7.197$

Therefore
$$P_2 = \left(\frac{P_{r_2}}{P_{r_1}}\right) P_1 = \left(\frac{7.197}{0.6355}\right)(40\ kPa) = 453.0\ kPa \longleftarrow P_2$$

(b) State 3 is fixed by considering the heat addition process

$$0 = \dot{Q}_{in} + \dot{m}(h_2 - h_3)$$

or
$$h_3 = \frac{\dot{Q}_{in}}{\dot{m}} + h_2 = 1080 + 481.1 = 1561.1\ kJ/kg$$

Again, from Table A-22; $T_3 \approx 1438$ K, $P_{r_3} = 504.0$

For isentropic expansion through the nozzle

$$P_{r_4} = (P_4/P_3)\, P_{r_3} = (40/453.0)(504.0) = 44.50 \Rightarrow h_4 = 805.78 \frac{kJ}{kg}$$

The velocity is obtained from; $0 = h_3 - \left(h_4 + \frac{V_4^2}{2}\right)$

or
$$V_4 = \sqrt{2(h_3 - h_4)}$$
$$= \sqrt{2(1561.1 - 805.78) \frac{kJ}{kg} \left| \frac{10^3\ N \cdot m}{1\ kJ} \right| \left| \frac{1\ kg \cdot m/s^2}{1\ N} \right|}$$
$$= 1229\ m/s \longleftarrow V_4$$