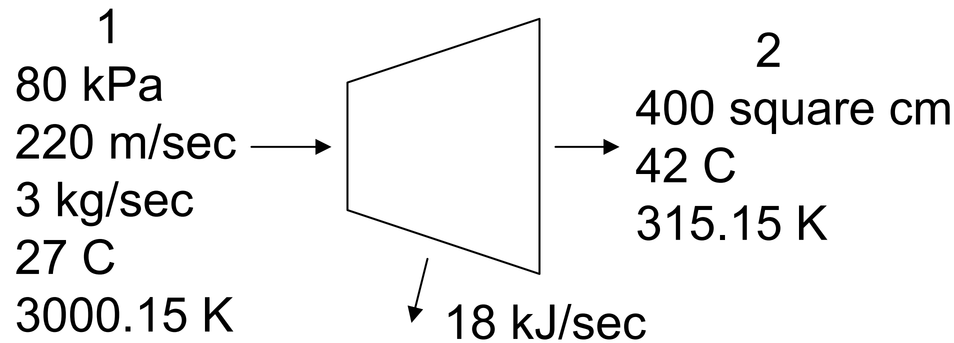
<u>Problem Set 1 (PS1) Due Tuesday January 24</u>

1. Air at 80 kPa, 27 C and 220 m/sec enters a diffuser at a rate of 3 kg/sec and leaves at 42 C. The exit area of the diffuser is 400 square cm. The air looses heat a a rate of 18 kJ/sec. Determine the exit velocity and the exit air pressure

2. In an insulated heat exchanger air is heated at atmospheric pressure from 25 C to 100 C and 2 kg/sec of water is cooled at atmospheric pressure from 150 C to 100 C. What is the entropy change for the air stream, the water stream and for the overall heat transfer process?

3. 3 lbs of air is expanded in an adiabatic isentropic process from 500 R and a gage pressure 200 psi to a gage pressure off 100 psi. Atmospheric pressure is 14.6 psi. What are the temperature, pressure, specific density and total volume at the end of the process ?

PS1.1



steady flow energy equation

$$m\left(c_p\ T_1+\frac{u_1^2}{2\times 1000}\right)+Q=m\left(c_p\ T_2+\frac{u_2^2}{2\times 1000}\right)$$

$$3\ \mathrm{kg}\left(1.005\times 300.15\frac{220^2}{2000}\right)+18\ \mathrm{kJ/sec}=3\mathrm{kg}\left(1.005\times 315.15\frac{u_2^2}{2000}\right)$$

$$941+18=950.18+.0015\ u_2^2$$

$$u_2=76.7\ \mathrm{m/sec}$$

continuity equation

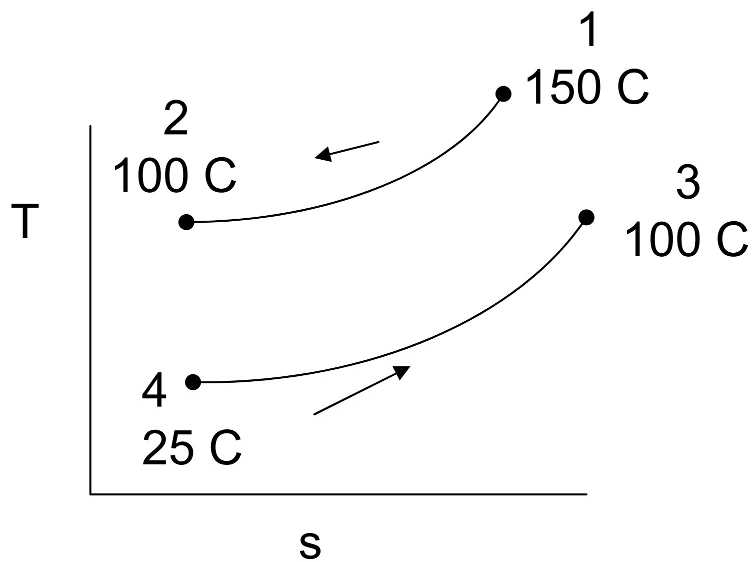
$$m=\rho_2\ A_2\ u_2$$

ideal gas law

$$m=\frac{p_2}{R\ T_2}A_2\ u_2$$

$$p_2=\frac{m\ R\ T_2}{A_2 u_2}=\frac{3\times 8.324\ \mathrm{kPa/kgmole\ K}\times 315.5\ \mathrm{K}}{28.97\times .04\ \mathrm{m}^2\times 76.68\ \mathrm{m/sec}}=88.46\ \mathrm{kPa}$$

PS1.2



energy balance

$$Q_{water} = Q_{air}$$

$$m_{water} \times c_p \times (T_1 - T_2) = m_{air} \times c_p \times (T_1 - T_2)$$

$$m_{air} = \frac{2\ \text{kg} \times 4.18\ \text{kJ/kg K} \times (150 - 100)}{1.005\ \text{kJ/ kg K} \times (100 - 25)}$$

$$m_{air} = 5.5\text{kg/sec}$$

entropy change

$$\Delta S_{air} = m_{air} c_p \ln\left(\frac{T_2}{T_1}\right) - R\ \ln\left(\frac{p_2}{p_1}\right)$$

$$\Delta S_{air} = 5.5 \times 1.005 \times \ln\left(\frac{373.15}{298.15}\right) = +1.228\ \text{kJ/K}$$

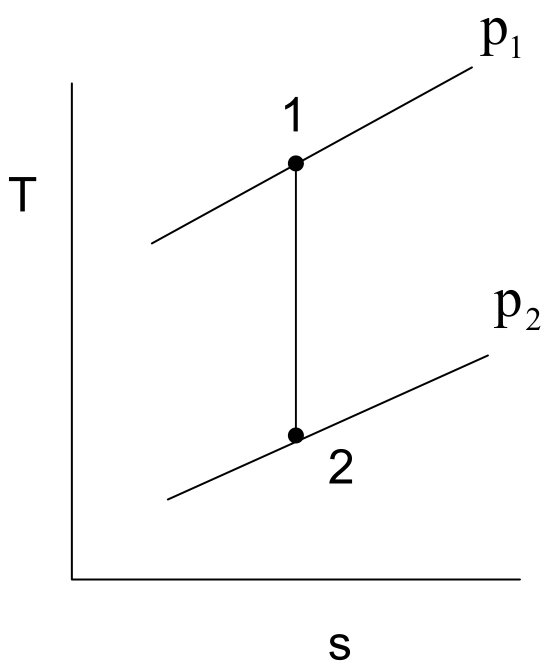
$$\Delta S_{water} = 2 \times 4.18 \times \ln\left(\frac{373.15}{423.15}\right) = -1.0512\ \text{kJ/K}$$

$$\Delta S_{process} = \Delta S_{air} + \Delta S_{water} = +1.228 - 1.0512$$

$$\Delta S_{process} = +.177\ \text{kJ/K}$$

$$\Delta S_{\substack{isolated \\ system}} \geq 0$$

PS 1.3



ideal gas law

$$\rho_1 = \frac{p}{RT} = \frac{214.6\ \text{lbf/in}^2 \times 144\ \text{in}^2/\text{ft}^2}{\dfrac{1545.15\ \text{ft lbf/lbmole}}{28.97} \times 500\ \text{R}}$$

$$\rho_1 = 1.158\ \text{lbm/ft}^3$$

isentropic process

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{114.6}{214.6}\right)^{.2857} = .8359$$

$$T_2 = 500 \times .8359 = 417.96\ \text{R}$$

$$\frac{\rho_2}{\rho_1} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{\gamma}} = \left(\frac{114.6}{214.6}\right)^{.7143} = .6388$$

$$\rho_2 = .6388 \times 1.158 = .7398\ \text{lbm/ft}^3$$

$$V_2 = \frac{m}{\rho} = \frac{3\ \text{lbm}}{.7398} = 4.055\ \text{ft}^3$$