Problem Set 8, PS8 due Monday June 7

PS8-1
4-61. Air at 300 kPa, and 200°C enters a nozzle at 30 m/sec and leaves at 100 kPa and 180 m/sec. The nozzle has an inlet area of 80 cm². Determine a) the mass flow rate, b) the exit temperature of the air and, c) the exit area of the nozzle.

PS8-2
4-83. Steam at 10 MPa, 500°C enters an adiabatic turbine at 3 kg/sec and leaves the turbine at 20 kPa. The turbine produces 2 MW. Neglecting kinetic energy changes determine the temperature of the steam leaving the turbine.

PS8-3
4-86. R-134a at a flow rate of 1.2 kg/sec is compressed in an adiabatic compressor from a saturated vapor at -20°C to .7 MPa and 70°C. Determine a) the power input to the compressor and, b) the volume flow rate at the compressor inlet.
\[ v_1 = \frac{RT}{p} = \frac{.287 \times (273.15 + 200)}{300 \text{ kPa}} = .4526 \text{ m}^3/\text{kg} \]

a) \[ m = \frac{AV}{v} = \frac{80}{10^4} \times 30 \text{ m/sec} \times \frac{1}{.4526} = .5303 \text{ kg/sec} \]

b) open system

\[ Q = 0, W = 0 \]
\[ h + \frac{V^2}{2} = \text{constant} \]
\[ h_1 + \frac{V_1^2}{2} = h + \frac{V_2^2}{2} \]
\[ c_p(T_1 - T_2) = \frac{V_2^2}{2} - \frac{V_1^2}{2} \]
\[ (T_1 - T_2) = \frac{1}{c_p} \left( \frac{V_2^2}{2} - \frac{V_1^2}{2} \right) \]
\[ (T_1 - T_2) = \frac{.5}{1.02} \left( 180^2 - 30^2 \right) \]
\[ T_2 = 184.5^\circ \text{C} \]

\[ v_2 = \frac{RT_2}{p_2} = \frac{.287 \times (273.15 + 184.5)}{100 \text{ kPa}} \]
\[ v_2 = 1.313 \text{ m}^3/\text{kg} \]
\[ m = \frac{A_2 V_2}{v_2} \]
\[ A_2 = \frac{m \times v_2}{V_2} = \frac{1.313 \times .5303 \text{ kg/sec}}{180 \text{ m/sec}} = .00387 m^2 \]
h @ 10 MPa, 500° C = 3737.7 kJ/kg
open system
region in space
W = mΔh
W = 2000 kJ/sec = 2 kg/sec(3737.7 − h2)

h2 = 3373.7 − \frac{2000}{3} = 2707 kJ/kg

@ h = 2707, p = 2 kPa, T = 110.8° C by interpolation

<table>
<thead>
<tr>
<th></th>
<th>0.01kPa</th>
<th>0.02kPa</th>
<th>0.05kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2687.5</td>
<td>2686.5</td>
<td>2682.5</td>
</tr>
<tr>
<td>200</td>
<td>2879.5</td>
<td>2879.2</td>
<td>2877.7</td>
</tr>
</tbody>
</table>

h@0.01kPa, 100° C = 2687.5 − \frac{0.02 − 0.01}{0.05 − 0.01} \times (2687.5 − 2682.5) = 2686.5

h@0.05kPa, 200° C = 2879.5 − \frac{0.02 − 0.01}{0.05 − 0.01} \times (2879.5 − 2877.7) = 2879.2

T@0.02kPa, h = 2707 = 100 + \left( \frac{2707 − 2686.5}{2879.2 − 2686.5} \right) \times 100 = 101.6° F
@ $-20^\circ$C, $v_g = .146 \text{ m}^3/\text{kg}$, $h_g = 235.3 \text{ kJ/kg}$

@ $70^\circ$C, $.7 \text{ MPa}$, $h_g = 307. \text{ kJ/kg}$

open system

$W = m\Delta h = 1.3 = 2\text{ kg}$ (307. kJ/kg $- 235.3$ kJ/kg)

$W = 86.04 \text{ kJ/sec}$

$V = m v_1 = 1.2 \text{ kg} \times .146 \text{ m}^3/\text{kg} = .176 \text{ m}^3/\text{sec}$