1. A heat pump uses R–134a as a working fluid. The evaporator pressure is 165 kPa and the condenser pressure is 1.6 MPa. The R–134a enters the compressor as a saturated vapor and leaves the condenser as a saturated liquid. The compressor is adiabatic and has an isentropic efficiency of $\eta_c = 0.85$. The power input to the compressor is $\dot{W}_c = 5$ kW. Determine

a) The mass flow rate of the R–134a

b) The rate of heat transfer from the condenser

c) The coefficient of performance of the cycle.

Advice: the heat from the condenser could be obtained from $q_H = (h_3 - h_2)$, where 2 and 3 are the compressor exit and condenser exit, or it could also be obtained from $q_H = q_L + w_{net} = h_4 - h_1 + w_{net}$, where $w_{net} = h_1 - h_2 = (h_1 - h_{2s})/\eta_C$ is the compressor work and $h_4 = h_3$ across the throttle. The latter approach bypasses the need to calculate the actual enthalpy at state 2 (although this would not be too difficult). Here are some numbers via the latter method:

\[ w_c = w_s/\eta_c = 55.9 \text{ kJ/kg}, \quad h_2 = h_1 + w_c = 297 \text{ kJ/kg} \]

\[ \dot{m} = \dot{W}/w_c = 0.0894 \text{ kg/s} \]

2. An ideal vapor–compression refrigeration cycle that uses R-134a maintains the condenser at 1 MPa and the evaporator at 4°C. Determine the system COP and the amount of power required to service a 400 kW cooling load. Answers: 6.46, 61.9 kW.

3. Combustion products exiting a stack consist of 20% CO$_2$, 10% H$_2$O, 5% O$_2$, and the remainder N$_2$ on a volume basis.

(a) Determine the mixture molecular mass $M$ (kg/kmol) and specific heat $c_p$ (kJ/kg·K) for the combustion products. Use data given in the following table:

<table>
<thead>
<tr>
<th>chemical:</th>
<th>CO$_2$</th>
<th>H$_2$O</th>
<th>O$_2$</th>
<th>N$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M$, kg/kmol</td>
<td>44</td>
<td>18</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>$c_p$, kJ/kg·K</td>
<td>1.014</td>
<td>1.872</td>
<td>0.918</td>
<td>1.039</td>
</tr>
</tbody>
</table>

(b) Calculate the dew point of the mixture (i.e., the temperature at which the water condenses). The total pressure is 1 atm.

Volume fractions correspond to mole fractions. Calculate the partial pressure of the water via $P_v = y_v P$, and equate to the saturation pressure in the saturation tables to find the dew point temperature.

4. Helium (He) and oxygen (O$_2$) gas are mixed in a steady–flow and adiabatic process. Helium enters the mixing chamber at 150 kPa and 400 K, and oxygen enters at 150 kPa and 250 K. The mass flow rates of both entering streams are equal at 0.1 kg/s, and the mixed streams exit at 150 kPa pressure.

(a) Taking the gases to be ideal with constant specific heats, calculate the temperature of the exiting stream. Use the data given below.

(b) Determine the partial pressures of the helium and the oxygen in the mixed stream.

(c) Determine the rate of entropy generation.

Data for helium and oxygen are

<table>
<thead>
<tr>
<th>Helium:</th>
<th>$M = 4$ kg/kmol</th>
<th>$c_p = 5.193$ kJ/kg·K</th>
<th>$R = 2.077$ kJ/kg·K</th>
</tr>
</thead>
<tbody>
<tr>
<td>oxygen:</td>
<td>$M = 32$ kg/kmol</td>
<td>$c_p = 0.918$ kJ/kg·K</td>
<td>$R = 0.260$ kJ/kg·K</td>
</tr>
</tbody>
</table>

I believe I went over this adequately in class.

5. Air enters a heating and humidification system at 5°C, 50% relative humidity. The air first passes over a heater, and is then humidified with steam. The steam is supplied at 200 kPa pressure and 300°C. The air leaves the system at 30°C, 60% relative humidity.

(a) Determine the heat transfer to the air, per unit mass dry air.

(b) Determine the temperature and relative humidity of the air leaving the heating section (i.e., prior to the humidification section).
(c) Determine the required mass flow of steam, per unit mass of dry air.

Use the psychrometric chart and the steam tables to work this problem.

Notes: get the steam enthalpy from the steam tables, and the $h$ and $\omega$ values for the air/vapor mix, at the initial (state 1) and final (state 3) states from the P chart. Apply the first law between states 1 and 3 to get the heat transfer. Now apply the first law between states 1 and 2, where 2 is the exit from the heater. There is no water addition between 1 and 2, and there is no external heat transfer between 2 and 3. You should be able to deduce $h_2$ and $\omega_2$ to get state 2 from the P chart. Answers: $q = 16 \text{ kJ/kg}$, $\dot{m}_w/\dot{m}_a = 0.014$, $T_2 = 22^{\circ}\text{C}$. I read the values off of the chart on my laptop, so there is likely some error in them.

6. A volumetric flow rate of $\dot{V}_1 = 0.5 \text{ m}^3/\text{s}$ enters an air conditioning system at $T_1 = 30^{\circ}\text{C}$ and $\phi_1 = 60\%$ relative humidity. The air is cooled to $T_2 = 10^{\circ}\text{C}$. Determine
   
   a) The rate of heat transfer from the air, in kW.
   b) The rate at which water condenses from the flow, in kg/s.

Use the psychrometric chart for this problem.

Answers (approximately): $\dot{Q} = 17 \text{ kW}$, $\dot{m}_l = 0.0034 \text{ kg/s}$

7. A flow of 10 m$^3$/min of saturated ($\phi = 100\%$) air at 10 $^{\circ}\text{C}$ enters an adiabatic mixing chamber, and is mixed with outside air at 28 $^{\circ}\text{C}$ and 70% R.H.. The mixed air leaves the chamber at a temperature of 20 $^{\circ}\text{C}$.

   (a) Using the psychrometric chart, determine the relative humidity of the air exiting the mixing chamber.

   (b) Determine the volumetric flow rates of the outside air stream and the mixed air stream.

States 1 and 2 (inlets) are completely specified. Draw a straight line between the two state points on the P-chart. Now intersect the line with the given exit $T_3$; this point is state 3. Find $\omega_3$, and

$$\dot{m}_{a,1}\omega_1 + \dot{m}_{a,2}\omega_2 = (\dot{m}_{a,1} + \dot{m}_{a,2})\omega_3$$

Solve for $\dot{m}_{a,2}$. The rest should be straightforward.