MAE3311 Quiz3
Spring 2007
04/09/2006 11:00am - 12:00pm

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1. (50 points) A vapor compression heat pump circulates R-134a at a mass flow rate of 6kg/min. The refrigerant enters the compressor at -10°C, 140kPa and exits at 700kPa, whose isentropic efficiency is 67%. The refrigerant leaves the condenser as saturated liquid at 700kPa. (a) Draw the cycle in both T-s and p-h diagram. Ignoring heat and pressure loss, determine (b) the heat transfer rates at the condenser and evaporator; and (c) the coefficient of performance.

2. (35 points) Nitrogen enters a turbine operating at steady state at 10MPa and 300K and exits at 4MPa and 245K. Determine the amount of work generated by the turbine (a) using ideal gas assumption, and (b) using enthalpy departure factor summarized in Table.

Enthalpy Departure Factor ($Z_h = \frac{\bar{h}_{ideal} - \bar{h}}{R_u T_{cr}}$)

	$P_R = 1.18$	$P_R = 2.95$
$T_R = 1.94$	0.31	0.75
$T_R = 2.38$	0.25	0.5

Universal gas constant R_u =8.314kJ/kmolK
For nitrogen, T_{cr} = 126.2K, P_{cr} = 3.39 MPa and Molecular Weight = 28.013 kg/kmol
Cp = 1.039kJ/kgK and Cv = 0.743 kJ/kgK

3. (15 points) Two grams of an unknown substance is stored in a piston-cylinder assembly. Its initial thermodynamics state is saturated liquid at 200kPa and 80°C. It is converted to a saturated vapor by being heated at constant pressure. Due to the evaporation, the volume increases by 1000cm^3 and 5kJ of heat is required. Estimate the boiling temperature of this substance when its pressure is 180kPa.

1. R 134a

$\eta_{comp} = \frac{h_{2s} - h_1}{h_{2a} - h_1} = .67$ ✓

$\dot{m} = 6 \frac{kg}{min}$

$T_1 = -10°C$ $h_1 = 246.36$ ✓ $h_{2a} = \frac{h_{2s} - h}{.67} + h_1$

$P_1 = 140 kPa$ $s_1 = .9724$

$P_2 = 700 kPa$ $T_2 = 42.65°C$ $h_{2a} = 298.389$ ✓

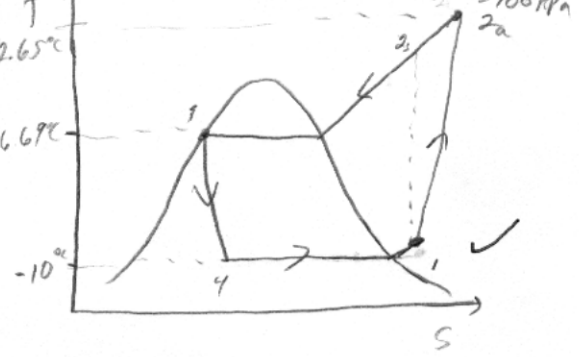
$s_2 = s_1 = .9724$

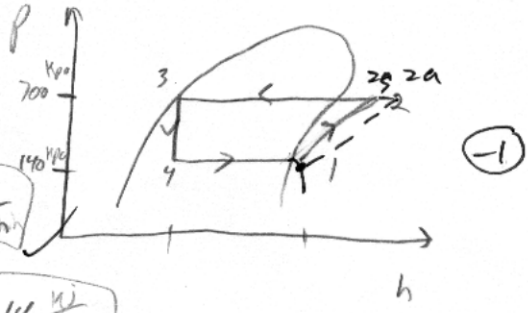
$\eta_{comp} = 67\%$ $h_{2s} = 281.22$ ✓

$P_3 = 700 kPa$

Sat liq. $h_3 = 88.82$ $h_3 \approx h_4 = 88.82$ ✓

$T_3 = 26.69$





(-1)

$\dot{Q}_L = \dot{m}(h_1 - h_4) = 6 \frac{kg}{min}(246.36 - 88.82) = 945 \frac{kJ}{min}$

$\dot{Q}_H = \dot{m}(h_2 - h_3) = 6 \frac{kg}{min}(298.389 - 88.82) = 1257.414 \frac{kJ}{min}$ ✓

$\dot{W} = \dot{m}(h_2 - h_1) = 6(298.389 - 246.36) = 312.17 \frac{kJ}{min}$

$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{1257.414}{312.17} = 4.026$ ✓

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$P_1 = 10\,mpa$ at $300K$

$P_2 = 4\,mpa$ @ $245K$

$w = (h_2 - h_1) - (u_2 - u_1)$

$w = \Delta h - \Delta u$

$Pv = RT$

$dh = c_v dT$

$\Delta h = C_p \Delta T$ +13

$\Delta h = 1.039\,(300-245) = 57.145\ \frac{kJ}{kg}$ ✓

$\Delta u = .743\,(300-245) = 40.865\ \frac{kJ}{kg}$

$w = 57.145\ \frac{kJ}{kg}$

$T_r = \frac{T}{T_{cr}}$

$P_r = \frac{P}{P_{cr}}$

$Z_h = \frac{h_{ideal} - h}{R_u T_{cr}}$

$Z_{h_1} = .5$

$Z_{h_2} = .31$

$h_1 = -Z_{h_1} R_u T_{cr} + h_{ideal} = \underline{-.5} \cdot 8.314 \frac{kJ}{kmol} \cdot 126.2 = -524.26$ + hideal1

$h_2 = -Z_{h_2} R_u T_{cr} + h_{ideal} = \underline{.31} \cdot 8.314 \cdot 126.2 = 325.26$ + hideal2

$T_{cr_1} = 126.2K$

$P_{r_1} = 2.949$ ✓

$T_{r_1} = 2.377$

$T_{r_2} = 1.9913$ ✓

$P_{r_2} = 1.1799$ +8

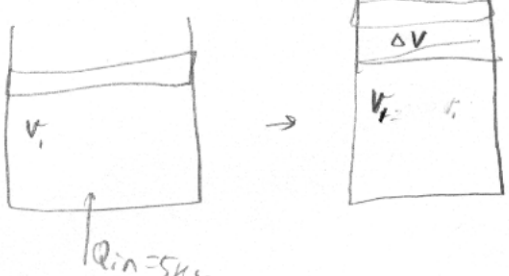
$(h_2 - h_1) = w = (-Z_{h_2} R_u T_{cr} + h_{ideal}) - (-Z_{h_1} R_u T_{cr} + h_{ideal})$ ✓ +5

+6/35

3.

State 1
Sat liq
@ 200 kPa
$T_1 = 80°C$
$h_1 = h_f$

State 2
Sat vap



$\Delta V = 1000 cm^3 = .001 m^3$ $V_2 = V_1 + \Delta V$

$Q_{in} = 5 kJ$ $\frac{5}{.002}$

$P_0 = 180 kPa$

$h_g = h_g$

$Q = \frac{5 kJ}{.002 kg} = 2500 \frac{kJ}{kg}$ ✓ +3

$\Delta V = \frac{.001}{.002} = .5 \frac{m^3}{kg}$ +3 ✓

$Q_{in} + \quad) = W_{out} + (h_2 - h_1)$

in out

$\Delta(PV) + h_{fg}$

$P_2 V_2 - P_1 V_1 + h_{fg}$ $P_1 = P_2$

$V_2 - V_1 = \Delta V$

$P \Delta V$

$= 200 (.5)$

$2500 = 100 + h_{fg}$

$\Delta P = 20 kPa$

$\Delta T = T_2 - 80°C$

$h_{fg} = \left(\frac{\partial P}{\partial T}\right)_{sat} T V_{fg}$ ✓ +5

$\Delta Q = \frac{20}{T_2 - 353} (353)(.001 m^3) \cdot V_{fg}$

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