University of California
Dept. of Mechanical Engineering
ME 105, Thermodynamics

Name________________

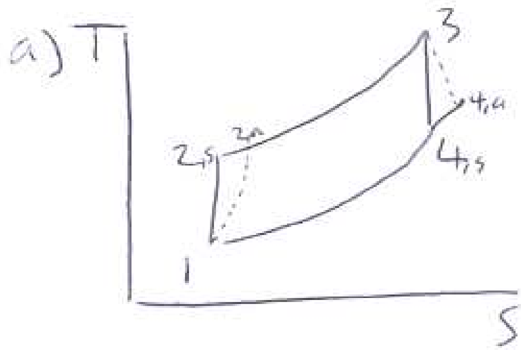
November 8, 2005
Open Book/Notes

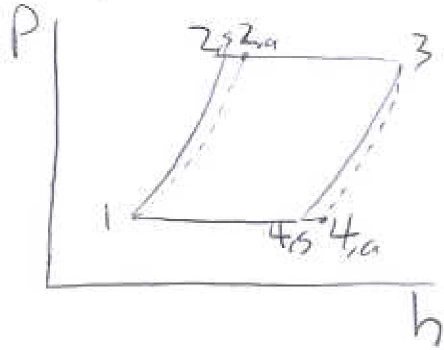
MIDTERM #2

1. (35 pts.) An Brayton cycle is run with incoming air at atmospheric pressure and a temperature of 25 °C, and a pressure ratio of 18.39. The heat addition downstream of the compressor is 445.62 kJ/kg air. The turbine outlet pressure is 1 atmosphere. If the compressor and turbine are both 75% efficient:

a) draw the cycle on T-s and P-v diagrams
b) calculate the maximum temperature (do **not** assume a constant specific heat)
c) calculate the net work produced
d) what is the thermodynamic efficient of this cycle?

a)





b) $\frac{P_2^o}{P_1^o} = \frac{P_2}{P_1}$ $\quad P_1^o = 1.3715$ from Table 5s

$P_2^o = P_1^o \frac{P_2}{P_1} = 25.22 \rightarrow h_{2,s} = 685.5 \frac{kJ}{kg}$ from Table 5s

$h_1 = 299.03 \frac{kJ}{kg}$ " " "

$\eta_c = \frac{h_{2,s} - h_1}{h_{2,a} - h_1} = .75 \quad h_{2,a} = \frac{h_{2,s} - h_1}{.75} + h_1 = 814.3 \frac{kJ}{kg}$

$Q_{in} = h_3 - h_2 = 445.62 \frac{kJ}{kg} \rightarrow h_3 = 1259.9 \frac{kJ}{kg}$

$T_{max} = \boxed{T_3 = 910.66°C}$ From Table 5s

c) $W_{net} = h_3 - h_4 - (h_2 - h_1) \quad \frac{P_3}{P_4} = \frac{P_3^o}{P_4^o} \quad P_3^o = 228.624$

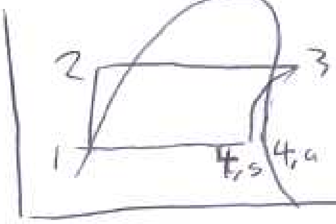
$P_4^o = P_3^o \frac{P_4}{P_3} = 12.43 \rightarrow h_{4,s} = 559.64$

$\eta_t = \frac{h_3 - h_{4,a}}{h_3 - h_{4,s}} = .75 \quad h_{4,a} = -.75(h_3 - h_{4,s}) + h_3 = 734.71$

$\boxed{W_{net} = 9.944 \frac{kJ}{kg}}$

d) $\eta = \frac{W_{net}}{q_{in}} = \frac{9.944}{445.62} = 0.0223 = 2.2\%$

2. (35 pts.) A solar-driven water vapor Rankine cycle is considered for residential electrical energy generation. The heat into the solar collector on a clear sunny day is 10 kW. The flow rate of water is set such that the maximum temperature is 300 °C; the maximum pressure is 200 kPa. The turbine is 75% efficient and the ambient temperature is 20 °C. Downstream of the turbine is a condenser that operates at ambient temperature. The water leaves the condenser with zero quality. The pump may be assumed have an efficiency of 100%



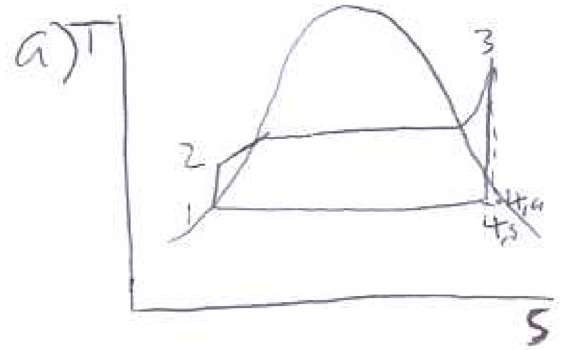
a) Draw the process on T-s and P-v diagrams

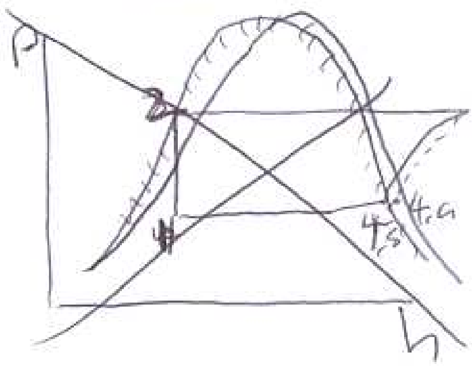
b) Calculate the water flow rate (kg/s).

c) What is the net power from the cycle?

d) What is the thermal efficiency of this cycle?

a)





b) $\dot{Q}_{in} = \dot{m}(h_3 - h_2) = 10\,kW$

$h_1 = 83.835\,\frac{kJ}{kg}$

$v_1 = 0.001002\,\frac{m^3}{kg}$

$h_3 = 3071.4\,\frac{kJ}{kg}$

} From Table

$h_2 = h_1 + v\Delta P \approx 84\,\frac{kJ}{kg}$

$$\dot{m} = \frac{10\,kJ/s}{3071.4\,\frac{kJ}{kg} - 84\,\frac{kJ}{kg}} = \boxed{3.3\times10^{-3}\,\frac{kg}{s}}$$

c) $\dot{W}_{net} = \dot{Q}_H - \dot{Q}_C = \dot{W}_t - \dot{W}_p = \dot{m}\left[(h_3 - h_2) - (h_4 - h_1)\right]$

$s_{4,s} = s_3 = 7.893\,\frac{kJ}{kg\cdot K} \rightarrow h_{4,s} = 2309.09\,\frac{kJ}{kg}$ From Table

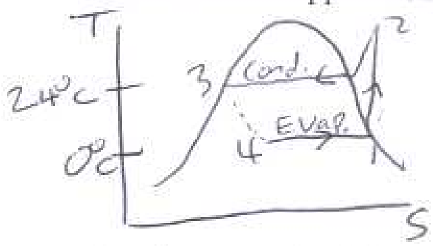
$\eta_t = \frac{h_3 - h_{4,a}}{h_3 - h_{4,s}} = 0.75 \quad h_{4,a} = h_3 - 0.75(h_3 - h_{4,s}) = 2500\,\frac{kJ}{kg}$

$\dot{W}_{net} = 10\,kW - \dot{m}(h_4 - h_1) = 2.03\,kW$

d) $\eta = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{2.03\,kW}{10\,kW} = 20.3\%$

3. (30 pts) A heat pump is used to provide space heat. The compressor is run by a 2000 kW motor, the evaporator temperature is 0 °C, and the condenser temperature is 26.72 °C. For a compressor efficiency of .8, and R134a qualities of 0 and 1 leaving the condenser and evaporator, respectively:

a) What is heat transfer rate from the condenser (kW)?
b) What is the coefficient of performance?
c) Briefly discuss the energy efficiency of the use of a heat pump versus a gas-fired furnace for this application.



NOTE: This Problem is overspecified, So There are Two valid Solutions!

Solution 1: a) $\dot{Q}_H = \dot{m}(h_2 - h_3)$

$h_1 = 247.23 \frac{kJ}{kg}$

$h_3 = 86.78 \frac{kJ}{kg}$
$s_{2,s} = s_1 = 0.9190 \frac{kJ}{kg}$ } From Table
$h_{2,s} = 265.37 \frac{kJ}{kg}$

$\eta_c = \frac{h_{2,s} - h_1}{h_{2,a} - h_1} = 0.8 \quad h_{2,a} = \frac{h_{2,s} - 1}{0.8} + h_1 = 269.9 \frac{kJ}{kg}$

if $\dot{m} = 22$ kg/s

$\dot{Q}_H = 22 \text{ kg/s} (269.9 - 86.78) \frac{kJ}{kg} = $ **4,029 kW**

b) $COP_{HP} = \frac{\dot{Q}_H}{\dot{W}_{net}} = \frac{\dot{m}(h_2 - h_3)}{\dot{m}(h_2 - h_1)} = $ **2.01**

Solution 2: a) ~~Values from table still correct but calculating mass ṁ from given compressor work~~
~~$\dot{W}_c = \dot{m}(h_2 - h_1)$ $\dot{m} = 2000$ kW~~ 26

Same values from Table { $h_1 = 247.23 \frac{kJ}{kg}$ $\quad 2000 = \dot{W}_c = \dot{m}(h_2 - h_1) \quad h_2 = \frac{\dot{W}_c}{\dot{m}} + h_1 = 338.14 \frac{kJ}{kg}$
{ $h_3 = 86.78 \frac{kJ}{kg}$

$\dot{Q}_H = \dot{m}(h_2 - h_3) = 22 \frac{kg}{s} (338.14 - 86.78) \frac{kJ}{kg} = $ **5,529.9 kW**

b) $COP_{HP} = \frac{\dot{Q}_H}{\dot{W}_{net}} = 2.776$

(c) Since η_{th} is usually 30-40% for a power cycle, a heat pump must have a COP of greater than $\frac{1}{.3} - \frac{1}{.4}$ to have a greater efficiency than burning the gas directly, where all of the thermal energy can be used.