MEMS 0051
Spring 2018
Midterm #2
3/23/2018

Name (Print): ____________________________

This exam contains 4 pages (including this cover page) and 5 problems. Check to see if any pages are missing. Enter all requested information on the top of this page, and put your initials on the top of every page, in case the pages become separated.

You may *not* use your books or notes. Calculators are permitted on this exam.

The following rules apply:

- All work must be done in the blue testing book. Any work done on the exam question sheet will not be graded.
- All work must be substantiated. A result with no methodology and mathematics will not be graded.

Do not write in the table to the right.

Problem	Points	Score
1	20	
2	20	
3	20	
4	20	
5	20	
Total:	100	

BONUS (5 pts):

This date, March 23$^{\text{rd}}$, 1942, marked the on-going persecution of which group of Americans by forcibly relocating them to isolated assembly centers, which are commonly referred to internment camps.

Conceptual Question #1

1. (20 points) Do the following systems violate the 2nd Law of Thermodynamics (yes or no):

   (a) (5 pts) A system that transfers heat from a low-temperature to a high-temperature reservoir while simultaneously requiring power. No

   (b) (5 pts) A system that takes heat from a high-temperature reservoir, produces power, and rejects heat to a low-temperature. No

   (c) (5 pts) A system where an irreversible heat engine takes heat from a high-temperature reservoir, produces work while rejecting heat to a low-temperature reservoir, and said work is used to run a reversible refrigerator that takes heat from a low-temperature reservoir and transfers it to a high-temperature reservoir. No

   (d) (5 pts) A system that converts heat to work with 30% efficiency. No

Short Answer #1

2. (20 points) Consider a Carnot cycle heat engine that operates between two thermal reservoirs at 300 [K] and 1,200 [K]. The heat engine produces 120 [kJ] of power.

   1. (5 pts) Calculate the efficiency of this cycle.

   $$\eta = 1 - \frac{T_L}{T_H} = 1 - \frac{300\,[\mathrm{K}]}{1,200\,[\mathrm{K}]} = 0.75$$

   2. (5 pts) Determine the heat transfer into this cycle (Q_H)

   $$\eta = \frac{W}{Q_H} \implies Q_H = \frac{W}{\eta} = \frac{120\,[\mathrm{kJ}]}{0.75} = 160\,[\mathrm{kJ}]$$

   3. (5 pts) Determine the heat rejected by this cycle (Q_L)

   $$W = Q_H - Q_L \implies Q_L = Q_H - W = (160 - 120)\,[\mathrm{kJ}] = 40\,[\mathrm{kJ}]$$

   4. (5 pts) Evaluate the Clausius inequality for this cycle.

   $$\oint \left(\frac{\delta Q}{T}\right)_b = \frac{Q_H}{T_H} - \frac{Q_L}{T_L} = \frac{160\,[\mathrm{kJ}]}{1,200\,[\mathrm{K}]} - \frac{40\,[\mathrm{kJ}]}{300\,[\mathrm{K}]} = 0$$

Short Answer #1

3. (20 points) Using your tables, determine the change of enthalpy for the following:

   (a) (5 pts) Carbon dioxide heated from 200 [K] to 2,000 [K]

   $$dh = h_2 - h_1 = (2,290.51 - 135.28)\,[\mathrm{kJ/kg}] = 2,155.23\,[\mathrm{kJ/kg}]$$

   (b) (5 pts) Liquid water at 2,500 [kPa] heated from 20°C to 105°C

   $$dh = h_2 - h_1 = h_f(T_2) - h_f(T_1) = (440.13 - 83.94)\,[\mathrm{kJ/kg}] = 356.19\,[\mathrm{kJ/kg}]$$

(c) (5 pts) Concrete cooled from 40°C to 20°C

$$dh = h_2 - h_1 = C(T_2 - T_1) = (0.88\,[\text{kJ/kg-K}])(293.15 - 313.15)\,[\text{K}] = -17.6\,[\text{kJ/kg}]$$

(d) (5 pts) Argon gas heated from 20°C to 50°C

$$dh = h_2 - h_1 = C_P(T_2 - T_1) = (0.520\,[\text{kJ/kg-K}])(323.15 - 293.15)\,[\text{K}] = 15.6\,[\text{kJ/kg}]$$

Written Problem #1

4. (20 points) A piston-cylinder initially contains 0.1 [m^3] of superheated water vapor at 600 [kPa] and 300°C. The piston then slowly compresses the water vapor in a reversible, isothermal process until it reaches a final quality of 0.5.

   1. (5 pts) Calculate the mass of water inside the piston-cylinder. $T > T_{sat}$ at 600 [kPa], therefore State 1 is a superheated vapor,

   $$m = \frac{\forall_1}{\nu_1} = \frac{0.1\,[\text{m}^3]}{0.43437\,[\text{m}^3/\text{kg}]} = 0.23\,[\text{kg}]$$

   2. (5 pts) Determine the change in total internal energy, U_2-U_1, for this process.

   $$dU = m(u_2 - u_1) = (0.23\,[\text{kg}])((1,331.97 + 0.5 \cdot 1,230.99) - 2,801)\,[\text{kJ/kg}] = -196.5\,[\text{kJ/kg}]$$

   3. (5 pts) Determine the heat transfer, $Q_{1\to2}$, to the water during this process.

   $$Q_{1\to2} = mT(s_2 - s_1) = (0.23\,[\text{kg}])(573.15\,[\text{K}])((3.2533 + 0.5 \cdot 2.4511) - 7.3723)\,[\text{kJ/kg-K}]$$
   $$= -381.43\,[\text{kJ}]$$

   4. (5 pts) Determine the work, $W_{1\to2}$, done by the water in this process.

   $$W_{1\to2} = Q_{1\to2} - (U_2 - U_1) = -184.93\,[\text{kJ}]$$

Written Problem #2

5. (20 points) Consider N_2 in a piston-cylinder undergoing a Carnot cycle between temperature reservoirs at 300 [K] and 2,000 [K]. The isothermal compression process results in the specific volume shrinking from 2.5 [m^3/kg] to 0.5 [m^3/kg].

   a) (5 pts) Calculate the Carnot efficiency of this cycle.

   $$\eta = 1 - \frac{T_L}{T_H} = 1 - \frac{300\,[\text{K}]}{2,000\,[\text{K}]} = 0.85$$

b) (5 pts) Determine the heat added during the isothermal expansion (q_H) and the heat rejected during the isothermal compression (q_L).

$$q_H = RT_H \ln\left(\frac{\nu_2}{\nu_1}\right) = (0.2968\,[\text{kJ/kg-K}])(2,000\,[\text{K}])\ln(5) = 955.36\,[\text{kJ/kg}]$$

$$q_L = RT_L \ln\left(\frac{\nu_3}{\nu_4}\right) = (0.2968\,[\text{kJ/kg-K}])(300\,[\text{K}])\ln(5) = 143.3\,[\text{kJ/kg}]$$

c) (5 pts) Determine the changes in internal energy for the adiabatic expansion and the adiabatic compression processes.

$$u_3 - u_2 = u(300\,[\text{K}]) - u(2,000\,[\text{K}]) = (222.63 - 1,720.07)\,[\text{kJ/kg}] = -1,497.44[\text{kJ/kg}]$$

For compression

$$u_1 - u_4 = u(2,000\,[\text{K}]) - u(300\,[\text{K}]) = (1,720.07 - 222.63)\,[\text{kJ/kg}] = 1,497.44[\text{kJ/kg}]$$

d) (5 pts) Determine the net work done by this cycle.

$$w_{net} = q_H - q_L = 812.06\,[\text{kJ/kg}]$$