75½ / 100

ENME 3770 Engineering Thermodynamics
Test # 3, Summer 2010

Part 1: Closed Books and Notes (57 %, Recommended Time: 40 minutes)   Name Nicholas March

1. Circle the T for True and F for False for the followings: (1½% for each)

(T) (F) (a) According to Thermodynamic second law, heat cannot pass from a cold to a hot body.

(T) F (b) It is possible for a device operating in a cycle to absorb heat from a single reservoir and produce a smaller amount of work.

T (F) (c) Inelastic deformation is a reversible process.

T (F) (d) Perpetual motion machine of second kind violates the second law of thermodynamics as well as the first law.

T (F) (e) Coefficient of Performance for a refrigeration cycle, $\beta_{max} = \dfrac{Q_H}{Q_H - Q_C} = \dfrac{T_H}{T_H - T_C}$. $\frac{Q_C}{W}$

(T) F (f) Work in an irreversible cycle is more than reversible one for refrigeration cycle.

T (F) (g) Entropy at 0°C is 0.

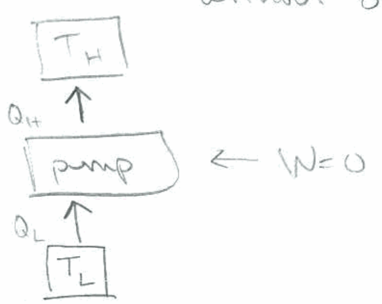
(T) F (h) Entropy and gas constant have the same dimension (unit).   -4½

T (F) (i) Carnot cycle in P-v diagram looks like a rectangle.

(T) (F) (j) Entropy and entropy production are point functions.

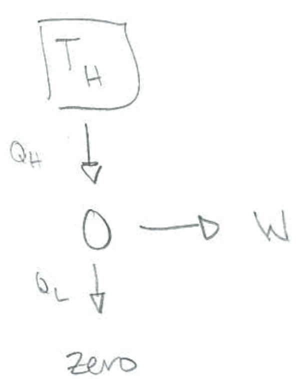
2. State and illustrate the Clausius statement of the thermodynamic second law. (5%)

It is impossible for a device to operate in such a manner that it passes temperature from a cold object to a hot object without outside work

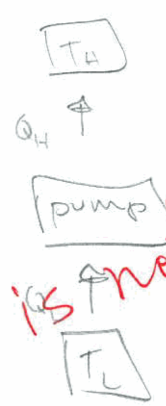


(violation)   -1

3. Show that the Clausius statement is violated if Kelvin-Plank statement is violated (You don't need to state the Kelvin-Plank statement, use block diagram). (6%)



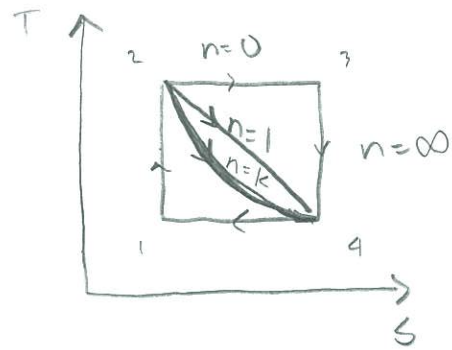
This is 100% efficiency which is impossible so there for this violates Thermodynamics   -6



This is not question

Nicholas March

6. Show the reversible polytropic process for an ideal gas in T-S diagram for Pv^n = Constant, where n = 0, n = 1, n = k and n = ∞ (4%)



-4

7. Prove that (6%)
(i) Entropy is a property
(ii) For an ideal gas, $dS = C_P \frac{dT}{T} - R\frac{dP}{P}$

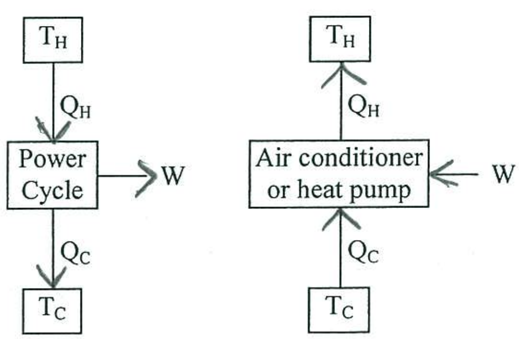
(i) Entropy is a property because it is a point function, not a path function

(ii) I.I.I.

-6

Bonus (8%)

8. Indicate the appropriate directions of heat and work for both the power and refrigeration cycles and define the power cycle efficiency and coefficients of performance for the refrigeration and heat pump cycles, respectively.



efficiency $\eta = \frac{Q_H - Q_L}{Q_H}$

COP refrigeration $\beta = \frac{Q_c}{W}$ = ?.

COP heat pump $\gamma = \frac{Q_H}{W}$ = ?.

X6

ENME 3770 Engineering Thermodynamics
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Part 2: Open Books and Notes (43 %, Recommended Time: 45 minutes) Name: Nicholas March

9. 2kg of water executes a Carnot power cycle. During the isothermal expansion, the water is heated at 250°C from a saturated liquid to a saturated vapor. The vapor then expands adiabatically to a temperature of 40°C and a quality of 75%.
   (a) Sketch the cycle on P-v and T-s coordinates. (9%)
   (b) Evaluate the heat and work for each process, in kJ, a table is provided for your convenience, fill the table up. (16%)

$T_H = 250°C = 523.15\ K$ isothermal expansion

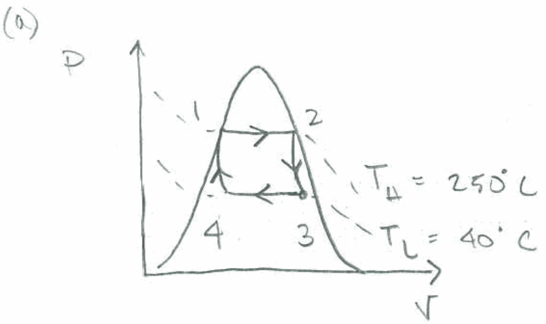
$T_L = 40°C = 313.15\ K$

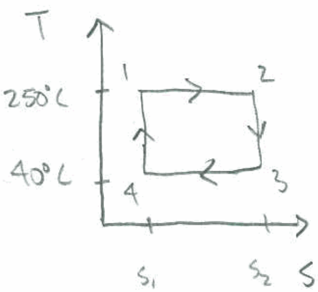
$m = 2\ kg$

Process	Q (kJ)	W (kJ)
1→2	3432	388
2→3	0	1475
3→4	-2055	-122.6
4→1	0	-364.8
Total	1377	1375.6

$Q_{net} \approx W_{net}$

(a)





(b)

$Q = m(h_2 - h_1)$

$\frac{W}{m} = P(v_2 - v_1)$

$W = m(u_1 - u_2)$

Process 1-2

$Q_{12} = m(h_2 - h_1)$ use table A-2 @ 250°C

$= 2\ kg\ (2801.5 - 1085.4\ \frac{kJ}{kg})$

$= \boxed{3432\ kJ}$

$W_{12} = P(v_2 - v_1)$ use table A-2 @ 250°C

$= 39.73\ bar\ (0.05013 - 0.0012512\ \frac{m^3}{kg}) \left(\frac{10^5\ \frac{N}{m^2}}{1\ bar}\right) \left(\frac{1\ kJ}{10^3\ N \cdot m}\right)$

$= 194.2\ \frac{kJ}{kg}\ (2\ kg) = \boxed{388\ kJ}$

Process 3-4

$Q = m(h_4 - h_3)$ use table A-2 @ 40°C & interpolate

$x_3 = \frac{h_3 - h_f}{h_g - h_f} \Rightarrow h_3 = x_3(h_g - h_f) + h_f$

$= 0.75(2574.3 - 167.57) + 167.57$

$= 1972.62\ kJ/kg$

$\frac{Q_{34}}{Q_{12}} = \frac{T_L}{T_H} \Rightarrow \frac{(h_4 - h_3)}{\frac{Q_{12}}{m}} = \frac{T_L}{T_H} \Rightarrow h_4 = \frac{Q_{12}}{m}\left(\frac{T_L}{T_H}\right) - h_3$

$h_4 = \frac{3432.4\ kJ}{2\ kg}\left(\frac{313.15\ K}{523.15\ K}\right) - 1972.62\ \frac{kJ}{kg}$

$= 945.3\ \frac{kJ}{kg}$

$Q_{34} = m(h_4 - h_3) = 2\ kg\ (945 - 1972.62)$

$= -2055\ kJ$

(Continued on BACK)

Process 2-3

$Q_{23} = \boxed{0}$

$W_{23} = m(U_2 - U_3)$ use table A-2 @ 250 & 40°C

$U_2 @ 250°C = 2602.4\ kJ/kg$

$U_3 @ 75\%\ 40°C = 0.75(2430.1 - 167.56) + 167.56$

$= 1864.5\ \frac{kJ}{kg}$

$W_{23} = m(U_2 - U_3)$

$= 2\ kg\ (2602.4 - 1864.5\ \frac{kJ}{kg})$

$= \boxed{1475\ kJ}$

Nicholas March

10. Air is compressed by a compressor from 300K and 1atm to 12atm. Compressor has an isentropic efficiency of 88%. Find the final temperature by three different processes.

(a) (i) Using table of air property having reduced pressure in consideration. (5%)

(ii) Isentropic relationship. (5%)

(iii) Balancing entropy. (5%)

(b) Entropy production during the actual compression for process (iii). (Bonus 7%)

$T_i = 300\,K$ $\quad T_f = ?$

$P_i = 1\,atm$ $\quad$ Assume reversible

$P_f = 12\,atm$

$\eta_c = 88\%$

$$\frac{T_f}{T_i} = \left(\frac{P_f}{P_i}\right)^{\frac{n-1}{n}} \Rightarrow T_f = T_i\left(\frac{P_f}{P_i}\right)^{\frac{n-1}{n}}$$

Entropy Balance: $\sigma = \Delta S - \int_i^f \left(\frac{\Delta Q}{T}\right)_b = \Delta S - \frac{Q}{T}$

isentropic compressor efficiency $= \eta_c = \frac{h_{2s} - h_1}{h_2 - h_1}$

efficiency $= \eta = \frac{Q_H - Q_L}{Q_H}$

-9

$\eta = 88\%$ $\quad Q_L = 300\,K$ @ 1 atm

since heat will rise at higher pressure

$Q_H = ?$

Nicholas March

4. Describe five phenomena that manifest the second law. (Must be different from the Clausius and Kelvin-Planck statements) (5%)

① The sum of entropy must be greater than or equal to zero

② If entropy equals zero, the process is reversible

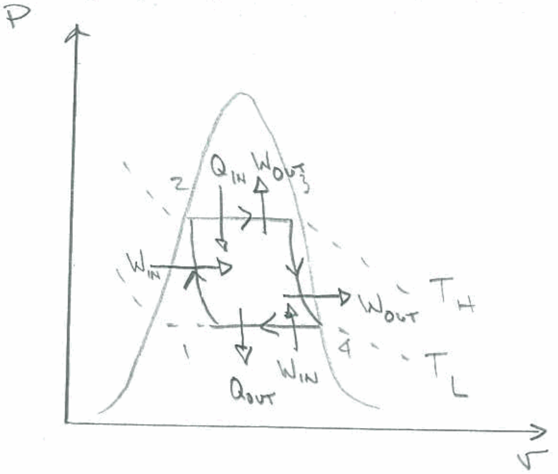
③ Entropy is a point function, not a path function

④ Heat cannot pass itself from a cold body to a hot body

⑤ two mixed gases cannot separate themselves

5. Describe in detail of each process of the Carnot power cycle including the characteristics of the process (e.g. isometric or isobaric), heat transfer (Q, in or out), work (W, in or out). Illustrate it on the P-V diagrams for both steam (involves phase change) and gas cycles. (Total two P-V diagrams and one T-S diagrams). (16%)

Steam



1-2 Adiabatic compression
$Q=0$ W_{IN}

2-3 Isothermal Expansion
Q_{IN} W_{OUT}

3-4 Adiabatic Expansion
$Q=0$ W_{OUT}

4-1 Isothermal Compression
Q_{OUT} W_{IN}

Gas