Homework #5

MEMS 0051 - Introduction to Thermodynamics

Assigned: June 11$^{\text{th}}$, 2020
Due: June 18$^{\text{th}}$, 2020

Problem #1

A heat engine is operating at a thermal efficiency of $\eta_{th} = 40\%$ and produces 1,000 [kJ/hr]. The power produced is used to drive a refrigerator. The refrigerator removes the same amount of heat, $\dot{Q}_L$, that is rejected by the heat engine. The heat rejected by the refrigerator is then supplied to the heat engine.

a) What are $\dot{Q}_L$, $\dot{Q}_H$, and the COP of the refrigerator?
b) Is this system realistic? Why or why not?
c) Allow Q_L and/or Q_H to be any number. At what value are the thermal efficiency, η_{th}, and the COP, β, equal to one another?

Problem #2

Consider 2 [kg] of nitrogen, N_2, in a piston-cylinder undergoing a Carnot cycle between temperature reservoirs at 300 [K] and 1,100 [K]. The isothermal heat addition process results in the volume expanding from an initial value of 2.0 [m^3] to 6.0 [m^3]. The nitrogen (N_2) may be treated as an ideal gas. Use the tabulated values in Table A.8 to determine changes in internal energy (because u_2-u_1=$C_{\forall O}(T_2$-$T_1)$ is no longer a good approximation at temperatures as high as 1,100 [K].)

a) Calculate the Carnot efficiency of this cycle;
b) Determine the heat added during the isothermal expansion (q_H) and the heat rejected during the isothermal compression (q_L);
c) Determine the changes in internal energy for the adiabatic expansion and the adiabatic compression processes;
d) Determine the net work done by this cycle;

Problem #3

A powerplant is operating in a cycle with the following information given:

- Boiler: 1 [MW] of heat added to the water
- Turbine: ? [MW] of power produced by the turbine
- Condenser: 0.58 [MW] of heat removed from the water
- Pump: 0.02 [MW] of power required to operate the pump

With this information, answer the following:

a) What is the thermal efficiency, η_{th}?
b) What is the power produced by the turbine?
c) If the process was reversed and the system could be operated as a refrigerator, what would the COP value be?

Problem #4

A heat engine operates between a high-temperature reservoir T_{H1} and a low-temperature reservoir T_{ambient}. The work produced, $\dot{W}_1$, which is the difference of heat input $\dot{Q}_{H1}$ and heat rejected $\dot{Q}_{L1}$, powers a heat pump. Part of the work from the heat engine enters the heat pump $\dot{W}_2$, whereas the difference between $\dot{W}_1$ and $\dot{W}_2$ is designated as the net work, $\dot{W}_{\text{net}}$. The heat pump accepts heat $\dot{Q}_{L2}$ from the same low-temperature reservoir (T_{ambient}) and rejects heat $\dot{Q}_{H2}$ to a secondary high-temperature reservoir T_{H2}. Assuming $T_{H1} > T_{H2} > T_{\text{ambient}}$, determine, based upon the following cases (a-f), if this system satisfies the First Law and/or violates the Second Law.

	$\dot{Q}_{H1}$	$\dot{Q}_{L1}$	$\dot{W}_1$	$\dot{Q}_{H2}$	$\dot{Q}_{L2}$	$\dot{W}_2$
a	5	3	2	3	2	1
b	6	4	2	5	4	1
c	5	4	1	3	1	2
d	3	2	1	4	3	1
e	5	3	2	2	2	0
f	6	7	1	5	4	1