Homework #5 Solutions

MEMS 0051 - Introduction to Thermodynamics

Assigned February 17$^{\text{st}}$, 2020
Due February 21$^{\text{st}}$, 2020

Problem #1

Determine the final temperature of 15 [kg] of carbon dioxide, that while undergoing a constant-pressure process which starts at a temperature of 25 °C, receives 10.2 [MJ] of heat, by treating the constant-pressure specific heat as:

(a) A constant taken from Table A.5;
(b) A constant evaluated at the average temperature (i.e. average of the initial and final temperature) using the polynomial expression from Table A.6;
(c) A constant evaluated at the average constant-pressure specific heat (i.e. the average of specific heat evaluated at the initial and that at the final temperature) using the polynomial expression from Table A.6;
(d) As the integral-average evaluated between the initial and final temperature using the polynomial expression from Table A.6.

Note: items (b)-(d) require an iterative approach. You are to use Matlab to develop the iterative approach and to solve for items (a)-(d). Your Matlab code will be submitted through an assignment link on Courseweb. Your code should have your name and assignment number at the top, as well as comments explaining your code. You are to use the fprintf command to output out results for items (a)-(d).
MATLAB script solution to the problem above is available for viewing on the course's GitHub page.

Problem #2

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_{ambient}, determine, based upon the following cases (a-c), if this system satisfies the First Law and/or violates the Second Law. Then, assuming $T_{H1} > T_{H2} > T_{\text{ambient}}$, determine if this system satisfies the First Law and/or violates the Second Law.

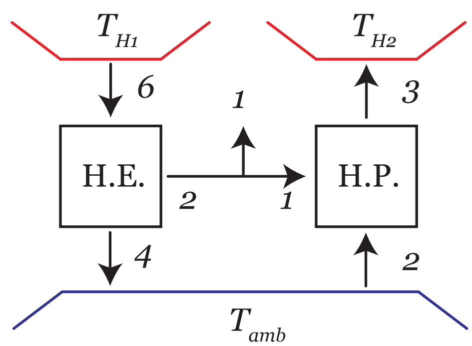
	$\dot{Q}_{H1}$	$\dot{Q}_{L1}$	$\dot{W}_1$	$\dot{Q}_{H2}$	$\dot{Q}_{L2}$	$\dot{W}_2$
a	6	4	2	3	2	1
b	6	4	2	5	4	1
c	3	2	1	4	3	1

To determine if the system adheres to the first and second law of thermodynamics, it must be shown that the system- its components and the whole system- abides by the principals and postulates that define said laws. For the sake of this problem, we will us units of [J] to represent the numbers.
(*Note: units of power or energy do not matter as long as they are the same for all components*)

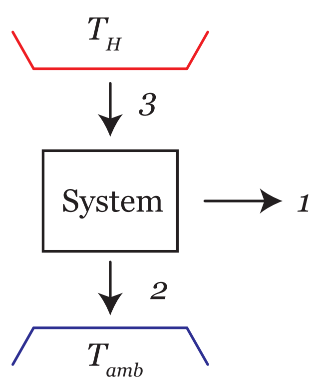
First Law of Thermodynamics: Conservation of energy in a system.
Second Law of Thermodynamics:

1. Kelvin-Planck Statement: All energy transferred from a high temperature reservoir can not turn into output work.
2. Clasius Statement: Heat can not transfer from a cold temperature reservoir without external work applied.

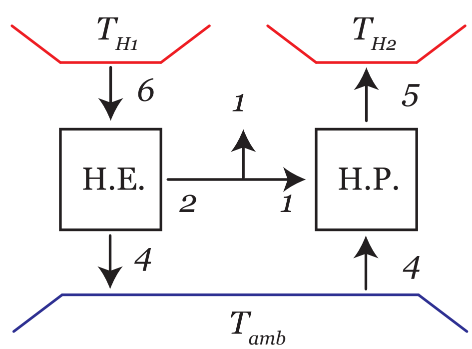
Case 1:



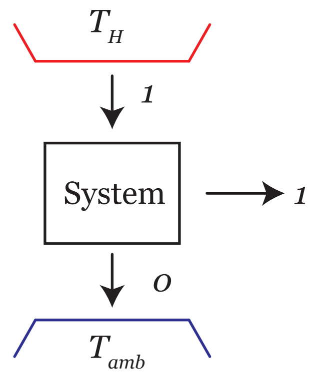
Heat Engine (H.E): The heat engine takes in 6 [J] of energy from the hot temperature reservoir, rejects 4 [J] into the cold temperature reservoir and produces 2 [J] work. Here, the first law and the Kelvin-Planck postulate of the second law is satisfied.
Heat Pump (H.P): The heat pump takes in 2 [J] of energy from the cold temperature reservoir, rejects 3 [J] into the hot temperature reservoir and uses 1 [J] of work to do this. Here, the first law and the Clausius postulate of the second law is satisfied.
System: The whole system takes in a net 3 [J] of energy from the hot temperature reservoir, rejects a net 2 [J] into the cold temperature reservoir and produces 1 [J] of net work. Here, the first law and the Kelvin-Planck postulate of the second law is satisfied



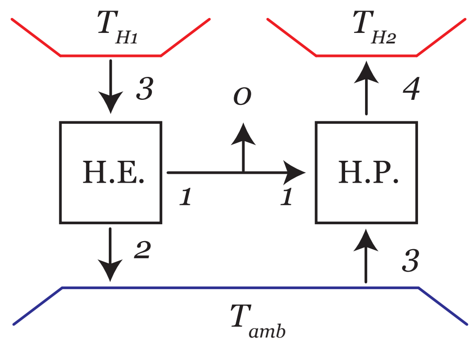
Case 2:



Heat Engine (H.E): The heat engine takes in 6 [J] of energy from the hot temperature reservoir, rejects 4 [J] into the cold temperature reservoir and produces 2 [J] work. Here, the first law and the Kelvin-Planck postulate of the second law is satisfied.
Heat Pump (H.P): The heat pump takes in 4 [J] of energy from the cold temperature reservoir, rejects 5 [J] into the hot temperature reservoir and uses 1 [J] of work to do this. Here, the first law and the Clausius postulate of the second law is satisfied.
System: The whole system takes in a net 1 [J] of energy from the hot temperature reservoir, rejects 0 [J] into the cold temperature reservoir and produces 1 [J] of net work. Here, the first law is satisfied, but the Kelvin-Planck postulate of the second law is violated.



Case 3:



Heat Engine (H.E): The heat engine takes in 3 [J] of energy from the hot temperature reservoir, rejects 2 [J] into the cold temperature reservoir and produces 1 [J] work. Here, the first law and the Kelvin-Planck postulate of the second law is satisfied.

Heat Pump (H.P): The heat pump takes in 3 [J] of energy from the cold temperature reservoir, rejects 4 [J] into the hot temperature reservoir and uses 1 [J] of work to do this. Here, the first law and the Clausius postulate of the second law is satisfied.

System: The whole system takes in a net 1 [J] of energy from the cold temperature reservoir and rejects 1 [J] into the cold temperature reservoir. While it may appear that no work was applied to perform the operation, keep in mind that 1 [J] of work was taken from the heat engine within the system to perform this operation. In other words, the system is powering itself and not producing any net work for other use. Therefore, it can be said that the Clausius postulate is still satisfied along with the first law of thermodynamics.