Physics 301: Problems #8
Oct. 18, 2019

1. Efficiency and Entropy: Specify a heat engine that operates between two reservoirs at temperatures hot T_H and cold T_C, but do not assume reversibility.

   - For a forward cycle express the entropy change of the environment ΔS_{env} in terms of the heat transfers Q_H and Q_C and the temperatures.
   - Express the engine's efficiency in terms of ΔS_{env}, Q_H and the temperatures.
   - What conclusions can you conclude about maximum efficiency?

2. Heat engines at negative temperatures: Consider using two heat reservoirs cold and hot to run an engine (analogous to the Carnot cycle), but specify that both temperatures, are negative temperatures, so that $T_C < T_H < 0$. The engine is to run reversibly.

   - If the engine is to do a positive net amount of work, from which reservoir must the energy be extracted? (Hint: Define T_2 as the temperature where Q_2 is removed and that the engine deposits Q_1 at temperature T_1, then figure out the inequality between T_1 and T_2.)
   - Under the same conditions, what is the engine's efficiency?
   - If you drop the requirement of reversibility, what is the maximum efficiency, and how would you achieve it?

3. In the context of a fixed positive temperature (and fixed external parameters), the Helmholtz free energy F attains a minimum at thermal equilibrium. What is the corresponding property for F at a negative temperature? Justify your response. (Hint: What is the inequality for $Q - T\Delta S$ when $T < 0$?)