1. A system undergoes a process in which the entropy change is $+5.97 \text{ J K}^{-1}$. The process is isothermal with $T = 500K$ and in the process $2.500 \text{ kJ}$ of heat is added to the system.

   (a) Is the process reversible?
   
   (b) If it is not reversible, how much heat would be added to the system in the corresponding reversible process?

2. A sample of an ideal gas that initially occupies $15.0 \text{ L}$ at $250 \text{ K}$ and $1.00 \text{ atm}$ is compressed isothermally. If the absolute value of the entropy change of the system is $5.0 \text{ J K}^{-1}$, what is the final volume of the system?

3. Calculate $\Delta H$, $\Delta S_{\text{system}}$, $\Delta S_{\text{surroundings}}$ and $\Delta S_{\text{universe}}$ when two $10.0 \text{ kg}$ copper bricks, one at $200^\circ \text{ C}$ and the other at $45^\circ \text{ C}$ are placed in contact in an isolated container. The specific heat capacity of copper is $0.385 \text{ J K}^{-1}\text{g}^{-1}$ and is constant over the temperature range involved in this problem.

4. Problem 2, chapter 3 of Tinoco et al: The temperature of the heat reservoirs for a reversible Carnot-cycle engine [pictured in 3.2 and 3.2 and in the handout from class] are $T_{\text{hot}} = 1200K$ and $T_{\text{cold}} = 300K$. The efficiency of the engine is $0.75 \epsilon = 1 - \frac{T_{\text{cold}}}{T_{\text{hot}}}$. In this problem you are going to verify (for yourself) that that no engine can be more efficient than a reversible Carnot-cycle engine.

   (a) If $w_{\text{cycle}} = -100kJ$, calculate the heat absorbed by the system in steps 1 and 3, $q_1$ and $q_3$. Explain the meaning of the signs of $w_{\text{cycle}}$, $q_1$ and $q_3$.

   (b) The same engine can be operated in reverse [state 4 $\rightarrow$ state 3 $\rightarrow$ state 2 $\rightarrow$ state 1] if $w_{\text{cycle}} = +100kJ$, calculate $q_1$ and $q_3$. Explain the meaning of the signs of $w_{\text{cycle}}$, $q_1$ and $q_3$.

   (c) Suppose it were possible to have an engine with lower efficiency ($\epsilon = 0.6$). If $w_{\text{cycle}}' = -100kJ$ [the work for the more efficient cycle], use the relationship $\epsilon = 1 + \frac{q'_3}{q'_1}$ to calculate $q'_1$ and $q'_3$.

   (d) If we use all of the work done by the engine in part (c) to drive the heat pump in part (b),

      i. calculate $(q_1 + q'_1)$ and $(q_3 + q'_3)$, the amount of heat transferred.
      
      ii. Explain the signs of the two sums in part (d)(i)

Note that the net effect of the combination of the two engines is to allow a “spontaneous” transfer of heat from a colder reservoir to a hotter reservoir, which should not happen. Therefore there cannot be an engine with greater efficiency than the reversible engine.
5. Problem 7, chapter 7 of Tinoco et al: For the following processes, determine whether each of the thermodynamic quantities is greater than, less than or equal to zero for the system described. Consider all of the gases to behave ideally. Indicate your reasoning and state any assumptions or approximations you have made.

(a) A sample of gas is carried through a complete Carnot cycle (shown in Fig. 3.1 and 3.2 and in the handouts from class). What are the signs of:
   i. $\Delta T$
   ii. $q$
   iii. $w$
   iv. $\Delta E$
   v. $\Delta H$
   vi. $\Delta S$
   vii. $\Delta G$

(b) A sample of hot water is mixed with a sample of cold water in a thermally insulated closed container at fixed volume. What are the signs of:
   i. $w$
   ii. $q$
   iii. $\Delta E$
   iv. $\Delta H$
   v. $\Delta S$

(c) An ideal gas expands reversibly and adiabatically. What are the signs of:
   i. $\Delta V$
   ii. $\Delta T$
   iii. $q$
   iv. $w$
   v. $\Delta E$
   vi. $\Delta H$
   vii. $\Delta S$

(d) A flask of a liquid nutrient solution is inoculated with a small sample of bacteria is maintained for several days at constant temperature until the bacteria have multiplied 1000-fold (there are 1000 times more bacteria than there were initially). Indicate the signs of:
   i. $\Delta T$
   ii. $\Delta S$
   iii. $\Delta G$
   iv. $\Delta H$
6. In this problem you are going to develop an expression for the entropy of mixing of two ideal gases at the same initial Temperature and Pressure \( \Delta S \) when the stopcock is removed in figure 1(a).

![Figure 1: The cycle described in Problem 6.](image)

(a) Write an expression for the Volume of each of the two bulbs and the total volume of the system in terms of \( n_{tot} = y + z \) [the total number of moles of gas], \( P \), \( T \), \( X_{Ar} \) and \( X_{Ne} \), where \( X_{\alpha} \) is the mole fraction of the gas. \( X_{Ne} = \frac{y}{n_{tot}} \) and \( X_{Ar} = \frac{z}{n_{tot}} \).

(b) Use these expressions to find the total pressure of the system after mixing.

(c) Since entropy is a state function, we can consider the expansion of the two gases separately. Since the partial pressure of Ne on the right side of the apparatus and the partial pressure of Ar on the left side are both initially zero, the process of mixing can be broken into two steps where each of the gases are expanded into a vacuum [shown in figures 1(b) and 1(c)]. Calculate \( \Delta S \) for each of these irreversible isothermal expansions.

(d) Substitute the expressions you obtained for the volumes, in part (a), into the expression for entropy in part (b) and evaluate the \( \Delta S = \frac{\Delta S}{n_{tot}} \) for the isothermal mixing of \( y \) moles of Ne with \( z \) moles of Ar. \{ If you did not make any mistakes, you should get the result \( \Delta S = -X_{Ne} R \ln X_{Ne} + -X_{Ar} R \ln X_{Ar} \}\)

(e) What can you say about the sign of \( \Delta S \) for this process? Is your result consistent with what you expect from the second law?