Appendix 2.1 Calorimetry Worksheet, authored by Ngoc-Loan Nguyen

Calorimetry Worksheet

When energy is transferred to an object of mass m in the form of heat transfer Q, the magnitude of the object's temperature change ΔT depends on its specific heat c, a quantity that is characteristic of the material: \( \Delta T = \frac{Q}{mc} \). If heat transfer is positive (\( Q > 0 \)), the object's temperature increases (\( \Delta T > 0 \)).

3. Suppose we have two samples, A and B, of the same material placed in a partitioned insulated container which neither absorbs energy nor allows it to pass in or out. Sample A has the same mass as sample B. Energy but no material can pass through the conducting partition. The gas inside the container has negligible mass; it allows energy transfer but absorbs no energy. (Assume specific heat is independent of temperature)

\[ \begin{align*}
\text{A} & \hspace{1cm} \text{B} \\
\end{align*} \]

a. A long time after time zero, what ratio do you expect for the temperatures of the two samples? 
\( \frac{T_A}{T_B} = \ldots \)? Explain your answer.

b. Complete the bar charts below for temperature and energy transfer. If any quantity is zero, label that quantity as zero on the bar chart. Explain your reasoning below.

Energy Transfer to Sample:

\[ \begin{align*}
\text{Energy Transfer to Sample:} \\
\text{A} & \hspace{1cm} \text{B} \\
+4 \text{ kJ} & \hspace{1cm} +2 \text{ kJ} \\
+2 \text{ kJ} & \hspace{1cm} 0 \text{ kJ} \\
0 \text{ kJ} & \hspace{1cm} -2 \text{ kJ} \\
-2 \text{ kJ} & \hspace{1cm} -4 \text{ kJ} \\
-4 \text{ kJ} & \hspace{1cm} \\
\end{align*} \]

Absolute Temperature

\[ \begin{align*}
\text{Absolute Temperature} \\
\text{A} & \hspace{1cm} \text{B} \hspace{1cm} \text{A} \hspace{1cm} \text{B} \\
\text{Time Zero} & \hspace{1cm} \text{Long After} \\
\text{0} & \hspace{1cm} \text{0} \hspace{1cm} \text{0} \hspace{1cm} \text{0} \\
\end{align*} \]
Calorimetry Worksheet

4. Suppose we have two samples, A and B, of the same material placed in a partitioned insulated container which neither absorbs energy nor allows it to pass in or out. Sample A has three times the mass of sample B. Energy but no material can pass through the conducting partition. The gas inside the container has negligible mass; it allows energy transfer but absorbs no energy. (Assume specific heat is independent of temperature.)

a. If the internal energy of sample A changes by an amount $|\Delta U_A|$ (absolute value), what is the amount of internal energy change (absolute value) of sample B?

b. If the temperature of sample A changes by $\Delta T_A$, what would be the corresponding change in the temperature of sample B? $\Delta T_B = \ldots$ (Check that the sign of your answer is correct.)

c. Complete the bar charts below for temperature and energy transfer. If any quantity is zero, label that quantity as zero on the bar chart. Explain your reasoning below.

- Energy Transfer to Sample:
  - A: $+4 \text{ kJ}$, $+2 \text{ kJ}$, $0 \text{ kJ}$, $-2 \text{ kJ}$, $-4 \text{ kJ}$
  - B: $0 \text{ kJ}$

- Absolute Temperature:
  - A: $0 \text{ kJ}$
  - B: $0 \text{ kJ}$

Time Zero
Long After
Calorimetry Worksheet

5. Suppose we have two samples, \( A \) and \( B \), of different materials, placed in a partitioned insulated container which neither absorbs energy nor allows it to pass in or out. Sample \( A \) has the same mass as sample \( B \). Energy but no material can pass through the conducting partition. The gas inside the container has negligible mass; it allows energy transfer but absorbs no energy. (Assume specific heat is independent of temperature.) The specific heat of material \( A \) is twice that of material \( B \).

![Diagram of A and B samples separated by a dotted line]

a. If the temperature of sample \( A \) changes by \( \Delta T_A \), what would be the corresponding change in the temperature of sample \( B \)? \( \Delta T_B = \) __________? Explain your answer.

b. Complete the bar charts below for temperature and energy transfer. If any quantity is zero, label that quantity as zero on the bar chart. Explain your reasoning below.

<table>
<thead>
<tr>
<th>Energy Transfer to Sample:</th>
<th>Absolute Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>+4 kJ</td>
<td></td>
</tr>
<tr>
<td>+2 kJ</td>
<td></td>
</tr>
<tr>
<td>0 kJ</td>
<td></td>
</tr>
<tr>
<td>-2 kJ</td>
<td></td>
</tr>
<tr>
<td>-4 kJ</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time Zero</th>
<th>Long After</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
</tbody>
</table>
6. Suppose we have two samples, $A$ and $B$, of different materials, placed in a partitioned insulated container which neither absorbs energy nor allows it to pass in or out. Sample $A$ has 1.5 times the mass of sample $B$. Energy but no material can pass through the conducting partition. The gas inside the container has negligible mass; it allows energy transfer but absorbs no energy. (Assume specific heat is independent of temperature.) The specific heat of material $B$ is twice that of material $A$.

![Diagram of A and B samples](image)

a. If the temperature of sample $A$ changes by $\Delta T_a$, what would be the corresponding change in sample $B$? $\Delta T_b = \ldots$? Explain your answer.

b. Complete the bar charts below for temperature and energy transfer. If any quantity is zero, label that quantity as zero on the bar chart. Explain your reasoning below.

**Energy Transfer to Sample:**

<table>
<thead>
<tr>
<th>Energy Transfer to Sample:</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 4 kJ</td>
</tr>
<tr>
<td>+ 2 kJ</td>
</tr>
<tr>
<td>0 kJ</td>
</tr>
<tr>
<td>−2 kJ</td>
</tr>
<tr>
<td>−4 kJ</td>
</tr>
</tbody>
</table>

A  B

**Absolute Temperature**

<table>
<thead>
<tr>
<th>Absolute Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

A  B  A  B

Time Zero Long After
Appendix 2.3 Entropy State-Function Worksheet

Entropy Worksheet

A system consisting of one mole of a monatomic ideal gas goes through two different processes as shown below. The initial values of volume ($V_i$), pressure ($P_i$), and temperature ($T_i$) are the same for each process. Also note that the final volume ($V_f$) is the same for each process.

Process #1 occurs very slowly so that it is always at the same temperature as the surroundings, and the pressure applied to the piston may vary. Note that the piston for Process #1 slides without friction. (Processes #1 is reversible.)

The system is thermally insulated from its surroundings in Process #2. In Process #2, the gas is initially trapped in one half of the container by a thin partition; the other half of the container contains vacuum. The partition is suddenly removed, and the gas quickly fills the rest of the volume.

1.1 Consider Process #1: Explain the meaning of "isothermal."

1.2 During this process, state whether the following quantities increase, decrease, or remain the same:
   a. temperature
   b. volume
   c. pressure

1.3 For an ideal gas, internal energy is directly dependent on temperature by the equation $U = \frac{3}{2} nRT$. Does the internal energy of the system in Process #1 (the system consists of the gas only) increase, decrease, or remain the same? Explain.

1.4 In Process #1, the gas molecules exert a force on the piston by colliding with it while the piston is moving. Does this mean work done by the system on the surroundings is positive, negative, or zero?

1.5 According to the first law of thermodynamics, is the heat transfer to the system from the surroundings in Process #1 positive, negative, or zero? Explain.

Check that you and your group members have the same answers and consistent explanations for the questions above. If not, reconcile the responses and enter the group explanation.
Entropy State-Function Worksheet (pg 2)

Entropy Worksheet

#1: Reversible Isothermal Expansion

Initial State:

Final State:

#1: Free Expansion into a Vacuum

Initial State:

Final State:

2.1 Consider Process #2: According to the information, the system in Process #2 is thermally insulated. Explain what “thermally insulated” means.

2.2 In Process #2, is the heat transfer to the system from the surroundings positive, negative, or zero?

2.3 In Process #2, the gas is expanding but there is nothing for the molecules to collide against therefore there is no force exerted during the expansion. Is the work done by the system on the surroundings positive, negative, or zero? Explain.

2.4 According to the first law of thermodynamics, does the internal energy of the system in Process #2 increase, decrease, or remain the same? Explain.

2.5 During this process, state whether the following quantities increase, decrease, or remain the same:
   a. temperature
   b. volume
   c. pressure

2.6 Is the final volume of the system in Process #2 greater than, less than, or equal to the final volume of the system in Process #1? Answer the same question for the initial volumes. HINT: Check the information at the top of page 1.

2.7 Is the final temperature of the system in Process #2 greater than, less than or equal to the final temperature of the system in Process #1? Explain.

2.8 Is the final pressure of the system in Process #2 greater than, less than or equal to the final pressure of the system in Process #1? Explain.
Entropy State-Function Worksheet (pg 3)

3. Draw points to represent the initial and final states of the two processes on the same P-V diagram; label each state 1_i, 1_f, 2_i, and 2_f respectively. (e.g. 1_i is the initial state of Process #1, etc.)

4. Which process has the greatest magnitude of heat transfer to the system? If the two are equal, indicate with an "=" symbol.

5. Is S_(1(initial state)), the initial entropy of the system in Process #1, greater than, equal to, or less than S_(2(initial state)), the initial entropy of the system in Process #2?

The change in the entropy of a system that begins in initial state i and ends in final state f can be expressed as \[ \Delta S = \frac{Q_{\text{reversible}}}{T} \]. Here, \( Q_{\text{reversible}} \) represents the heat transfer to the system only during a process from i to f that is reversible; the \( T \) in this equation is related to the average temperature of the system during the process.

6. Does the entropy of the system increase, decrease, or remain the same for Process #1?

Is your answer to Question #6 consistent with \( \Delta S = \frac{Q_{\text{reversible}}}{T} \)? Explain.

Do NOT continue until you check your answers with the recitation instructor.
Entropy State-Function Worksheet (pg 4)

Entropy Worksheet

7. Consider $\Delta S_2$ and $\Delta S_1$, the changes in the entropy of the system during Process #2 and Process #1, respectively: $\Delta S = S_{\text{final state}} - S_{\text{initial state}}$. Three students are discussing whether $\Delta S_2$ is greater than, equal to, or less than $\Delta S_1$. Read through the discussion and follow the directions below.

**Student A:** "I think that the entropy for Process #2 is going to stay the same. The system is thermally insulated so if there is no heat transfer to the system from the surroundings there is no change in the entropy of the system because $\Delta S = \frac{Q_{\text{system}}}{T}$.

**Student B:** "That makes sense from the $\Delta S$ equation we were given, but that is only correct for a reversible process. We must remember that entropy is a state function. Process #2 has the exact same final pressure, volume, and temperature as Process #1, so I think that the entropy in Process #2 will increase the same amount that entropy in Process #1 increases."

**Student C:** "I think you are on the right track, but Process #2 can’t go back to its initial state like Process #1; that means that it’s not reversible. So even though it has the same final state as Process #1, I think the change in entropy for Process #2 will be different from that in Process #1."

**Student B responds to Student C:** "I agree that #2 is irreversible, but we already determined that the initial entropy for both processes was the same in Question #5. The change in entropy is $\Delta S = S_{\text{final state}} - S_{\text{initial state}}$, so if the initial AND final states of Process #2 and Process #1 are the same the change in entropy in Process #2 has to be the same as Process #1 regardless of whether it’s reversible or irreversible."

Re-read each student’s statement and comment on the parts with which you agree, and identify the statements that you believe are incorrect. Explain your reasoning.

Discuss your reasoning and that of your group with the recitation instructor before continuing.

Continue to Page 5
8. Is $\Delta S_{\text{system}1}$, the change in entropy of the system for Process #1, greater than, equal to, or less than $\Delta S_{\text{system}2}$, the change in entropy of the system for Process #2? Explain.

9. Is $\Delta S_{\text{surroundings}1}$, the change in entropy of the surroundings for Process #1, greater than, equal to, or less than $\Delta S_{\text{surroundings}2}$, the change in entropy of the surroundings for Process #2? Explain. Hint: $Q_{\text{system}} = -Q_{\text{surroundings}}$

10. Using your answers from Questions 8 and 9, is the magnitude of $|\Delta S_{\text{system}1}|$ greater than, equal to, or less than the magnitude of $|\Delta S_{\text{surroundings}1}|$? Hint: $Q_{\text{system}} = -Q_{\text{surroundings}} \Rightarrow \Delta S = \frac{Q_{\text{system}}}{T}$

11. Is $\Delta S_{\text{universe}1}$, the change in entropy of the universe for Process #1, greater than, equal to, or less than $\Delta S_{\text{universe}2}$, the change in entropy of the universe for Process #2? Explain your answers. (Note that $\Delta S_{\text{universe}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$)

12. Use the results from the worksheet to fill out the Table below

<table>
<thead>
<tr>
<th>Process #1</th>
<th>Process #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reversible or irreversible?</td>
<td></td>
</tr>
<tr>
<td>$Q_{\text{to system}} &gt; 0$, $Q_{\text{to system}} &lt; 0$, or $Q_{\text{to system}} = 0$?</td>
<td></td>
</tr>
<tr>
<td>$\Delta S_{\text{system}} &gt; 0$, $\Delta S_{\text{system}} &lt; 0$, or $\Delta S_{\text{system}} = 0$?</td>
<td></td>
</tr>
<tr>
<td>$Q_{\text{to surr}} &gt; 0$, $Q_{\text{to surr}} &lt; 0$, or $Q_{\text{to surr}} = 0$?</td>
<td></td>
</tr>
<tr>
<td>$\Delta S_{\text{surroundings}} &gt; 0$, $\Delta S_{\text{surroundings}} &lt; 0$, or $\Delta S_{\text{surroundings}} = 0$?</td>
<td></td>
</tr>
<tr>
<td>$\Delta S_{\text{universe}} &gt; 0$, $\Delta S_{\text{universe}} &lt; 0$, or $\Delta S_{\text{universe}} = 0$?</td>
<td></td>
</tr>
</tbody>
</table>

In any real (or irreversible) process, does the entropy of the universe increase, decrease, remain the same, or is this not determinable without additional information?
Appendix 2.5 Entropy Spontaneous-Process Worksheet

Entropy Tutorial – Phys 224, March 10, 2006

I. Energy Reservoir

A metal cube, one meter on each side, is enclosed in a thermally insulating jacket. Another metal cube of the same size is enclosed in its own insulating jacket. The temperature of this second cube is higher than the temperature of the first cube. We'll refer to the high-temperature cube as "H," and the other as "L," and their temperatures as \( T_H \) and \( T_L \), respectively. The only connection between the cubes is through a narrow metal rod that has a very small mass. Heat transfer to or from the cubes can take place only through this narrow metal rod. We will assume that when heat transfer does take place, the rate of energy change is so small that neither of the metal cubes undergoes any measurable change in temperature.

![3-D side view](image)

![2-D cutout view](image)

*Is it reasonable to assume the temperature of the two cubes will remain constant?*

A quantitative argument: Suppose we have two different copper blocks each with volume of 1 m³, assume that the temperature difference between the blocks is 50 K and that they are connected by a copper rod 20 cm long, with diameter 1 cm. There would be 5 joules of energy transferred each second through heat conduction. However, given the mass of the blocks (each weighs roughly 10 tons), it would take almost 12 days before the temperature of the blocks changed even by one kelvin.

**Definition:** The term used for a system so massive that it does not change temperature even when heat transfer takes place is “energy reservoir” or “thermal reservoir.”

- Does the high-temperature cube fit the definition of an energy reservoir? Why or why not?
- Does the low-temperature cube fit the definition? Why or why not?

The following questions refer to the process that takes place when the cubes are connected by the metal rod; consider a process with duration of one minute.

II. What do you expect will happen? (These questions are meant to get you thinking about the problem, don’t be concerned if you are unsure of your answers.)

- a) Consider the system consisting only of the low-temperature cube. While the two cubes are connected with the rod, does the entropy of this system increase, decrease, or remain the same?

- b) During the same process, does the total entropy of the high- and low-temperature cubes together increase, decrease, or remain the same? Explain your reasoning.

- c) State whether the following quantities are conserved during this process: (i) energy; (ii) entropy.

→ On the diagram above, draw an arrow to indicate the direction of positive heat transfer.
Entropy Spontaneous-Process Worksheet (pg 2)

Entropy Tutorial – Phys 224, March 10, 2006

III. Heat transfer and entropy

1. During a process with duration of one minute, consider \( Q_H \) and \( Q_L \), the heat transfers to the high-temperature and low-temperature cubes, respectively.

   a) Is \( Q_H \), the heat transfer to the high-temperature cube, positive, negative, or zero?

   b) Is \( Q_L \), the heat transfer to the low-temperature cube, positive, negative, or zero?

   c) Compare the magnitudes (absolute values) of \( Q_H \) and \( Q_L \); is one larger than the other? If so, which one?

   d) Is the sum \([Q_H + Q_L]\) positive, negative, or zero?

   e) For this process, is energy a conserved quantity? Explain.

The entropy change in a reversible process is given by \( \Delta S = \int_{\text{initial}}^{\text{final}} \frac{dQ_{\text{reversible}}}{T} \). For any process involving heat transfer to an energy reservoir at constant temperature \( T \), this expression can be rewritten as \( \Delta S_{\text{reservoir}} = \frac{Q_{\text{reservoir}}}{T_{\text{reservoir}}} \), where \( Q_{\text{reservoir}} \) is the heat transfer to the reservoir during the process and \( T_{\text{reservoir}} \) is the temperature of the reservoir.

2. During the heat transfer process, consider \( \Delta S_H \) and \( \Delta S_L \), the change in entropy of the high-temperature cube and low-temperature cube, respectively.

   a) Is \( \Delta S_H \), the change in entropy of the high-temperature cube, positive, negative, or zero?

      Does this mean the entropy of the high-temperature cube increases, decreases, or remains the same?

   b) Is \( \Delta S_L \), the change in entropy of the low-temperature cube, positive, negative, or zero?

      Does this mean the entropy of the low-temperature cube increases, decreases, or remains the same?

   c) Consider the magnitudes (absolute values) of \( \Delta S_H \) and \( \Delta S_L \). Is the absolute value of one larger than the other? If so, which one? Explain.

   d) If we consider the actual values, is the sum \([\Delta S_H + \Delta S_L]\) positive, negative, or zero?

   e) For this process, is entropy a conserved quantity? Justify your answer. Explain any differences between this answer and your answer to 1(e) above.
Entropy Spontaneous-Process Worksheet (pg 3)

IV. Outside the Insulation...

3. In Question #2, we determined the change in entropy of everything inside the insulating jackets, (i.e. the cubes). We must now consider the change in entropy of everything else apart from the cubes and the rod.

If you were to physically describe "everything else," what are some things that would be considered to be part of "everything else?" Discuss this with your group (and don't be afraid to think big).

   a) If we assume the jackets that surround the cubes and the rod are perfectly insulating, is there any heat transfer to the outside world from the metal cubes or rod? Why or why not?

   b) Calculate the change in entropy of everything outside the insulation due to heat transfer from the metal cubes and rod. $\Delta S_{\text{EVErything ELSE}} =$

   c) Based on your answer to (b), does the entropy of everything else due to heat transfer from the cubes and rod increase, decrease or remain the same?

V. System and surroundings

4. For now, let us refer to the high-temperature cube alone as the thermodynamic "system." We will define "surroundings" (same as "surrounding environment") as everything that is not the system.

   a) If we define the high-temperature cube as the system, describe what would be considered the "surroundings." Would the surroundings include the low-temperature cube? Hint: What criteria are we using to determine whether or not something should be considered as part of the surroundings?

   b) With this definition of system and surroundings, and considering the same one-minute time interval.

      i) does the entropy of the system increase, decrease, or remain the same?

      ii) does the entropy of the surroundings increase, decrease, or remain the same?

Be sure to explicitly address the change in entropy of everything that is not the system.
Entropy Tutorial

V. System and surroundings (cont.)

5. Now, let us refer to the low-temperature cube alone as the "system."
   a) Using our previously stated definition, describe what would be considered the "surroundings," or "surrounding environment." Would the surroundings include the high-temperature cube?

   b) With this new definition of system and surroundings,
      i) does the entropy of the system increase, decrease, or remain the same?

      ii) does the entropy of the surroundings increase, decrease, or remain the same?

6. Given our definition of system and surroundings in Question #4, can one determine the sign of entropy change of the [system + surroundings]? If no, why not? Answer the same question for the case of Question #5.

   If you can determine the sign in both cases, is the sign the same in both, or different? Explain.

   Summarize the results from Question #4 and Question #5 in the following table.

<table>
<thead>
<tr>
<th></th>
<th>Question #4</th>
<th>Question #5</th>
</tr>
</thead>
<tbody>
<tr>
<td>System consists of...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surroundings consist of...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entropy of system increases, decreases, or remains the same?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entropy of surroundings increases, decreases, or remains the same?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entropy of system + surroundings increases, decreases, or remains the same?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   Discuss the results with your group. What can you say about the entropy of the system + surrounding; for these two processes?
Entropy Tutorial

V. System and surroundings (cont.)

7. You overhear a group of students discussing the above problem. Carefully read what each student is saying.

   **Student A:** Well, the second law says that the entropy of the system is always increasing. Entropy always increases no matter what.

   **Student B:** But how do you know which one is the system? Couldn’t we just pick whatever we want to be the system and count everything else as the surroundings?

   **Student C:** I don’t think it matters which we call the system or the surroundings, and because of that we can’t say that the system always increases. The second law states that the entropy of the system plus the surroundings will always increase.

Analyze each statement and discuss with your group the extent to which it is correct or incorrect. How do the students’ ideas compare with your own discussion about the table on the previous page?

8. For both Questions #4 and #5, we made a specific designation for the “system” and considered the “surroundings” to include *everything* that was not the system.

   a) If we wanted to describe the “system,” and the “surroundings” with one word—where surroundings refers to everything outside the system—what word could we use?

   **Hint:** Remember to think big!

   Write this word in the box in part (c) below.

   b) Review your answers from Question #6: did you determine that the $S_{\text{system}} + S_{\text{surroundings}}$ increases, decreases, or remains the same, for the case in Question #4? What about for the case in Question #5?

   Would these answers change whether or not we included objects outside the insulation in “the surroundings?” Why or why not?

   c) Complete this sentence: During any real process, the entropy of the _____ increases, _____ decreases, _____ remains the same.
VI. Heat flow from low to high?

9. Suppose for a moment that heat transfer occurred spontaneously from low-temperature objects to high-temperature objects; draw an arrow to indicate the direction of positive heat transfer in this case.

![Diagram showing heat transfer between two insulated cubes, one at a lower temperature and one at a higher temperature.]

a) Could such a situation actually occur “spontaneously” (that is, without any outside intervention)?

If it did occur, how would it affect your answers to Question #2? Explain in detail for each part a-d.

b) In real processes where high- and low-temperature objects are in thermal contact, is there ever actually zero heat transfer?

Suppose heat transfer between the high- and low-temperature cubes were zero; how would that affect your answers to Question 2?

c) Based on your answers to (a) and (b), can you make any specific statements regarding the change in \( [S_{\text{system}} + S_{\text{surroundings}}] \) that could occur in any real process? (For example, could that total change be negative or zero?) Explain.
VII. Reversible Processes

10. Let’s now consider a situation that is similar to our original problem. The temperature of the L cube is the same as it was before, but the temperature of the H cube is lower than its previous value and is designated by $T_H’$. Although the H cube now has a lower temperature, it is still higher than that of the L cube.

We’ll designate the heat transfers to the high- and low-temperature cubes in this case as $Q_H$ and $Q_L$, respectively. Consider that the heat transfer process, that originally lasted one minute, now lasts sufficiently long to ensure that the heat transfer to the higher-temperature cube is exactly the same as it was before, that is, $Q_H = Q_H$.

a) Is $Q_L$ greater than, less than, or equal to $Q_L$?

b) Consider the magnitudes (absolute values) of the entropy changes in the high-temperature cube, $|\Delta S_H|$, and the low temperature cube, $|\Delta S_L|$, and compare them to the values in the original case $|\Delta S_H|$ and $|\Delta S_L|$ (see Question #2):

i) Is $|\Delta S_H|$ greater than, less than, or equal to $|\Delta S_L|$?

ii) Is $|\Delta S_L|$ greater than, less than, or equal to $|\Delta S_H|$?

C) Is the total entropy change in this present case $[\Delta S_H’ + \Delta S_L]$ greater than, less than, or equal to the total entropy change in the original case $[\Delta S_H + \Delta S_L]$ (when the temperature difference between the cubes was larger)?
Entropy Tutorial

VII. Reversible Processes (Cont.)

Suppose the temperature of the L cube remains the same, and the H cube drops to a temperature that is still higher, but infinitesimally close to the temperature of the L cube.

\[ \text{d) For this case, what will happen to the total entropy change of the two cubes during the process, assuming that the heat transfers continue to remain the same as before? What can you say about the time required for this new process, compared to those before?} \]

\[ \text{e) As the temperatures of the cubes come closer together, what happens to the total entropy change of the universe, compared to that in the previous cases?} \]

\[ \text{f) In reversible heat transfer processes, all temperature differences are infinitesimally small (and there is no frictional dissipation). Such processes are idealizations of real processes; no real process is completely reversible.} \]

\[ \text{i) Based on your answers to the questions above, what would be the entropy change of the universe in a completely reversible process?} \]

\[ \text{ii) Could this be the entropy change of any real process? Why or why not?} \]

Check that your answer is consistent with your statements in Question #9, part c.