# Physics Invention Sequences Users' Guide: Entropy

## ENTROPY INVENTION SEQUENCE

**Includes:** *possibility rule* (total entropy change of naturally occurring process >0)

**Teacher Notes:** Entropy change is a challenging concept, and the 2nd law has new structures that confound students. Unlike energy, there is no balancing that has to take place, yet students tend to see entropy as a conserved quantity. One challenge for students is to understand what is meant by the 'total entropy change of the universe'. We make no pretense of teaching entropy rigorously in the statistical mechanics sense, but do think all students who have studied introductory thermodynamics should understand the limits that the 2nd law puts on energy transformation processes. A correct qualitative understanding of the 2nd law is essential for many engineers, and for life science majors.

**Levels:** This sequence is appropriate for college level.

**Possibility Rule**

There are 6 events described in Table 1 below. Some are realistic, others are ones you've never seen before. Are all of them possible? If not, why not?

Let's explore based on the relevant conservation laws. If it doesn't happen, does that mean it violates the conservation of energy? Use each as a test of the first law of thermodynamics (conservation of energy) by finding the total energy exchanged by the heating/cooling combinations below. Then do the same for the entropy changes.

**Table 1:**

| | **Event 1** | **Event 2** | **Event 3** | **Event 4** | **Event 5** | **Event 6** |
|---|---|---|---|---|---|---|
| | Two touching blocks $T_1$=280K and $T_2$=320K come to thermal equilibrium in perfect thermal isolation from their surroundings. Each has a heat capacity $C_p$=200 J/K. | Two touching blocks are at the same initial temperature of 300K. Block 1 cools to $T_1$=280K and thereby warms Block 2 to $T_2$=320K in perfect thermal isolation from their surroundings. Each has a heat capacity $C_p$=200 J/K. | Ice cube (m=0.1 kg) melts in kitchen (which can be treated as a hot reservoir that transfers heat to ice) that is 300K. $L_{f(ice)}$=3.34 x $10^5$ J/K | Puddle of 0°C water forms into an ice cube (m=0.1 kg) in a kitchen, thereby transferring heat to the hot reservoir that is 300K. $L_{f(ice)}$=3.34 x $10^5$ J/K | Sun(1) Transfers 58 MJ of thermal energy to the earth(2)<br><br>$T_{sun}$= 5800 K<br>$T_{earth}$= 290 K | Earth(2) Transfers 58 MJ of thermal energy to Sun(1)<br><br>$T_{sun}$= 5800 K<br>$T_{earth}$= 290 K |
| ***Final Temps*** | $T_1$=$T_2$=300 K | $T_1$=280 K<br>$T_2$=320 K | $T_1$=273 K<br>$T_2$=300 K | $T_1$=273 K<br>$T_2$=300 K | $T_1$=5800 K<br>$T_2$=290 K | $T_1$=5800 K<br>$T_2$=290 K |
| $Q_1$ | *+4 kJ* | *- 4 kJ* | *3.34 x $10^4$ J* | *-3.34 x $10^4$ J* | | |
| $Q_2$ | *- 4 kJ* | *+4 kJ* | *-3.34 x $10^4$ J* | *3.34 x $10^4$ J* | | |
| $\Sigma Q$ | 0 | 0 | 0 | 0 | | |
| $\Delta S_1$ | *+ 13.8 J/K* | *- 13.8 J/K* | + 122 J/K | - 122 J/K | | |
| $\Delta S_2$ | *- 12.9 J/K* | *+ 12.9 J/K* | - 111 J/K | + 111 J/K | | |
| $\Sigma(\Delta S)$ | +0.9 J/K | - 0.9 J/K | +11 J/K | -11 J/K | | |

**Follow up questions**

1. Describe the conservation of energy, in words, in the context of thermal energy transfer between two objects for each event.

2. Do any of the events violate your description of the conservation of energy? If so, which ones?

3. Do you notice any patterns in the table? Namely, is there anything that all of the everyday occurrences share, that the impossible ones don't?

4. Describe this pattern in the form of a hypothesis that starts with "Events occur spontaneously in nature if…"

**Applying the Rule**

A. The following events describe heat transfer between two objects, 1 and 2. Based on your rule in I, which of the following events in Table 2 can occur?

**Table 2**

| | $Q_1$ | $T_1$ | $Q_2$ | $T_2$ |
|---|---|---|---|---|
| **Event A** | +20J | 100K | -20J | 101K |
| **Event B** | -50J | 75K | +50J | 75K |
| **Event C** | +33J | 201K | -33J | 200K |
| **Event D** | +47J | 300K | -45J | 302K |

**In your own words:** What must be true about processes that involve heat transfer in order for them to be physically possible?

**Name that quantity:** Invent a name for $\Sigma(\Delta S)$