Inventing Possibility Rule

A. Finding patterns

There are 4 events described in Table 1 below. Some are realistic, others are ones you have never seen before. You will be answering: Are all of them possible? If not, why not?

Let us explore them based on the relevant conservation laws. If the event does not 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:

<table>
<thead>
<tr>
<th>Event 1</th>
<th>Event 2</th>
<th>Event 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two identical touching blocks with $T_1=280\text{K}$ and $T_2=320\text{K}$ come to thermal equilibrium in perfect thermal isolation from their surroundings. Each has a heat capacity $C_p=200\text{ J/K.}$</td>
<td>Two identical touching blocks are at the same initial temperature of 300K. Block 1 cools to $T_1=280\text{K}$ and thereby warms Block 2 to $T_2=320\text{K}$ in perfect thermal isolation from their surroundings. Each has a heat capacity $C_p=200\text{ J/K.}$</td>
<td>Sun(1) transfers 58 MJ of thermal energy to the earth(2).</td>
</tr>
<tr>
<td>$T_1=T_2=300\text{ K}$</td>
<td>$T_1=280 \text{ K}$ $T_2=320 \text{ K}$</td>
<td>Tsun=$5800\text{ K}$ Tearth=$290\text{ K}$</td>
</tr>
<tr>
<td>$Q_1$</td>
<td>$Q_2$</td>
<td></td>
</tr>
<tr>
<td>+$4\text{ kJ}$</td>
<td>-$4\text{ kJ}$</td>
<td></td>
</tr>
<tr>
<td>$Q_2$</td>
<td>$Q_1$</td>
<td></td>
</tr>
<tr>
<td>-$4\text{ kJ}$</td>
<td>+$4\text{ kJ}$</td>
<td></td>
</tr>
<tr>
<td>$\Sigma Q$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$\Delta S_1$</td>
<td>$\Delta S_2$</td>
<td></td>
</tr>
<tr>
<td>+13.8 $\text{ J/K}$</td>
<td>-13.8 $\text{ J/K}$</td>
<td></td>
</tr>
<tr>
<td>-12.9 $\text{ J/K}$</td>
<td>+12.9 $\text{ J/K}$</td>
<td></td>
</tr>
<tr>
<td>$\Sigma (\Delta S)$</td>
<td>+0.9 $\text{ J/K}$</td>
<td>-0.9 $\text{ J/K}$</td>
</tr>
</tbody>
</table>
B. Reasoning questions:

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

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 do not?

4. Describe this pattern in the form of a hypothesis that starts with “Events occur spontaneously in nature if…”
Below are six designs that were submitted for reversible heat engines. None have been built, and it is your job to decide which is the best design using the possibility rule you developed in parts A and B. The amount of thermal energy transferred from the hot reservoir to the engine, and from the engine to the cold reservoir is shown for one cycle. The amount of work done in one cycle is also shown.

**Heat engine**

**A**
- \( T_H = 650 \text{ K} \)
- \( T_C = 250 \text{ K} \)
- \( 800 \text{ J} \) transferred from hot reservoir to the engine
- \( 0 \text{ J} \) transferred from engine to cold reservoir
- **Work = 800 J**

**B**
- \( T_H = 550 \text{ K} \)
- \( T_C = 250 \text{ K} \)
- \( 900 \text{ J} \) transferred from hot reservoir to the engine
- \( 450 \text{ J} \) transferred from engine to cold reservoir
- **Work = 400 J**

**C**
- \( T_H = 700 \text{ K} \)
- \( T_C = 350 \text{ K} \)
- \( 2000 \text{ J} \) transferred from hot reservoir to the engine
- \( 1200 \text{ J} \) transferred from engine to cold reservoir
- **Work = 800 J**

**D**
- \( T_H = 480 \text{ K} \)
- \( T_C = 320 \text{ K} \)
- \( 1000 \text{ J} \) transferred from hot reservoir to the engine
- \( 600 \text{ J} \) transferred from engine to cold reservoir
- **Work = 400 J**

**E**
- \( T_H = 600 \text{ K} \)
- \( T_C = 300 \text{ K} \)
- \( 1000 \text{ J} \) transferred from hot reservoir to the engine
- \( 500 \text{ J} \) transferred from engine to cold reservoir
- **Work = 400 J**

**F**
- \( T_H = 400 \text{ K} \)
- \( T_C = 240 \text{ K} \)
- \( 800 \text{ J} \) transferred from hot reservoir to the engine
- \( 500 \text{ J} \) transferred from engine to cold reservoir
- **Work = 300 J**
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a) Which of the engines, A through F, are allowable by the 1st law of thermodynamics? Please explain in words your reasoning.

b) Of those that are allowable by the 1st law (that you selected in part a), which ones are also allowable by the 2nd law of thermodynamics? Please explain in words your reasoning.

c) We can assume that these are not all Carnot engines. Of those that are allowable by both the 1st law AND the 2nd law of thermodynamics, which one has the greatest real efficiency, based on the predicted work outcome of the engine? (show your work)