Statistical Mechanics Notes for L. Susskind's Lecture Series, Part 2

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Abstract

This paper contains my notes on Lecture Two of Leonard Susskind 2013 presentation on Statistical Mechanics for his Stanford Lecture Series. (He also made a 2009 video series on the same topic.) They can be found on YouTube. In this chapter we introduce the flow of heat.

Second Law of Thermodynamics

Let A and B be two systems sharing heat energy with each other. Let dS_A and dS_B be the changes in entropy of the respective systems in a short amount of time. Then

$$dS_A + dS_B > 0\,. \tag{1}$$

Most of this lecture concerns us with using the laws of thermodynamics to determine the direction of flow of energy from a body A at temperature T_A and a body B at temperature T_B. We define temperature T as

$$T = \frac{\partial \bar{E}}{\partial S}\,, \tag{2}$$

or

$$\Delta S = \frac{\Delta \bar{E}}{T}\,, \tag{3}$$

where $\bar{E}$ is the average energy. We choose to set

$$T_B > T_A\,. \tag{4}$$

Now,

$$d\bar{E}_A = T_A dS_A\,, \tag{5a}$$

$$d\bar{E}_B = T_B dS_B\,. \tag{5b}$$

Since

$$d\bar{E}_A + d\bar{E}_B = 0\,, \tag{6}$$

then

$$T_A dS_A + T_B dS_B = 0\,. \tag{7}$$

On solving for dS_B, we get

$$dS_B = dS_A\big[-\frac{T_A}{T_B}\big]\,. \tag{8}$$

Plugging this into (1), we get

$$(T_B - T_A)dS_A > 0\,. \tag{9}$$

Since we've already decided that $T_B > T_A$, this implies that $dS_A > 0$, hence $T_A dS_A > 0$. And this implies that

$$d\bar{E}_A > 0\,. \tag{10}$$

This means that object A took on energy; thus, energy flowed from B to A.