Thermodynamics and Energy

Part III - The Second Law of Thermodynamics

By Lee Langston, Ph.D.

You’ve learned that the First Law of Thermodynamics deals with energy and its conservation. During a process involving a system and its surroundings, energy is neither created nor destroyed, but changed in form. This denies the possibility of creating or destroying energy.

The Second Law of Thermodynamics deals with entropy, a measure of disorder. Entropy analysis gives directions and restrictions on how energy transfers can take place. This second law denies the possibility of utilizing energy in particular ways.

The second law has such far-reaching consequences that it is difficult to cover in one simple statement. In fact, the instructor in a university thermo class may hand out three or four pages listing various statements of the second law!

The second law’s origin goes back to the 1800’s and an engineering book by Sadi Carnot. Carnot set out to define the physical principles that could be used to understand and improve steam engines. The text discussed an ideal engine that operated between high and low temperature (now called a Carnot engine), the efficiency of which all real engines could approach, but could not exceed. It sets a standard by which the performance of real engines is compared.

Building on Carnot’s results, Lord Kelvin and Rudolf Clausius both arrived at statements for the second law.

- In 1865, Clausius wrote: “It is impossible to construct a device that, operating continuously, will produce no effect other than the transfer of heat from a cooler to a hotter body.” Heat will not, of itself, flow from a colder body to hotter body. A refrigerator can do this, but we must supply costly energy-electricity-to transfer heat from the cold food and drinks to the warmer kitchen air surrounding the refrigerator.

Clausius also identified a property he called entropy. Entropy changes can be calculated by measuring the heat transfer to or from a system during a process. Think back to the rubber band in Part II: In stretching, the entropy decrease of the rubber band is approximately equal to the heat transferred from the rubber band to its surroundings, divided by the air temperature. When the rubber band is relaxed, its entropy is increased, calculated in the same way.

The entropy of the universe tends to a maximum. In other words, all processes in life result in a net increase of entropy. You stretched the rubber band to decrease its entropy, but your (you being the rest of the universe) entropy increase caused by furnishing that stretching, exceeded that of the rubber band’s decrease. Still puzzled by entropy and disorder? Consider the Mother Goose rhyme on entropy production:

“Humpty Dumpty sat on a wall.
Humpty Dumpty had a great fall.
All the king’s horses and all the king’s men
Couldn’t put Humpty together again.”

NIE thanks Lee Langston, Professor Emeritus of Mechanical Engineering, University of Connecticut, & Member, Connecticut Academy of Science and Engineering

Entropy is a measure of molecular disorder. Stretching produced a more ordered, aligned arrangement of rubber band molecules. Relaxing allowed rubber band molecules to revert to their intercoiled, more disorganized (increased entropy) state.

THINK ABOUT THE QUOTE

“The law that entropy always increases – the second law of thermodynamics – holds I think, the supreme position among the laws of Nature.” – Arthur Stanley Eddington (1882-1944)

THINK ABOUT THE QUOTE

- Rewrite the quote in your own words.
- What examples of entropy do you see in your daily life?