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Entropy, the Universe and Man

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"You can't unscramble an egg." This phrase and many others throughout literature are examples of what physicists have come to call entropy. The concept of entropy is unique because, unlike the conservation of momentum and the conservation of energy, there is no principle of conservation of entropy. In teaching this second law of thermodynamics to sophomore students at the junior-college level, I used the concept employed by Sears and Zemansky, *University Physics,* that an increase in entropy is a "loss of opportunity" and some paragraphs of Erwin Schrödinger's book, *What Is Life?* emphasizing that the maximum entropy of man is death. The applications of the concept of entropy were also applied to speech communication, order and disorder in our society and its physical environment, and, finally, to the speculative Peter Principle.

* * *

"Humpty Dumpty sat on a wall
Humpty Dumpty had a great fall
All the kings horses and all the kings men
Couldn't put Humpty Dumpty together again."

"The Moving Finger writes; and, having writ,
Moves on: nor all thy Piety and Wit
Shall lure it back to cancel half a Line."

"You can't unscramble an egg."

For those of you who can't see how the above three phrases are related, perhaps the following will help. At last fall's ISEA (Iowa State Education Association) convention in Des Moines, perhaps some of you noticed the following banner that hung above the convention floor:

ENTROPY OF MAN

I asked Mr. Jack Hudson, ISEA's president, what he had in mind when he had this particular banner put up. He said that he felt the significance of the banner was up to the individual, but he gave me his idea. When applied to teaching, a class may seem to be in disorder to an outsider, but to the teacher of the class order does exist if his objectives are being accomplished by his students. I would like to share with you the order I attempted to obtain in teaching the concept of entropy as its applies to man and the universe he finds himself part of.

A brief review of the laws of thermodynamics might be in order here to establish where the concept of entropy fits in.

First Law of Thermodynamics

$$Q = (U_2 - U_1) + W$$

Q is positive when heat goes into the system.
W is positive when the force exerted *by* the system and the displacement have the same sign.

Second Law of Thermodynamics

"No process is possible whose sole result is the absorption of heat from a reservoir at a single temperature and the conversion of this heat completely into mechanical work."

$$\text{Change in entropy} = S_2 - S_1 = \int_1^2 \frac{dQ}{T} \quad \text{along any reversible path}$$

The first law of thermodynamics is the law of energy, the second law of thermodynamics is the law of entropy, and every process that takes place in nature, whether it be mechanical, electrical, chemical or biological, must proceed in conformity with these two laws. But one of the features which distinguishes entropy from such conservation laws of energy, momentum and angular momentum, is that there is *no conservation principle of entropy*. In fact, the reverse is true. Entropy can be created at will and there is an increase in entropy in every natural process, if all systems taking part in the process are considered.

When I reached the chapters on thermodynamics while teaching 15 sophomore students at Blackhawk Junior College in Moline, Illinois, I recalled the *ENTROPY OF MAN* banner. I tried to tie everything around the following main concept. All interacting units of matter tend toward equilibrium states in which the energy content (enthalpy) is a minimum and the energy distribution (entropy) is most random. In the process of attaining equilibrium, energy transformations or matter-energy transformations occur. Nevertheless, the sum of energy and matter in the universe remains constant.

For a midterm take-home test, I gave the following essay assignment: "Using the explanation on page 441 in your text (Sears and Zemansky—*University Physics*) that an increase in entropy is a 'loss of opportunity' and the included short essay by Erwin Schrödinger, discuss *your ideas* about whether the universe is 'running down'; include the terms irreversible, adiabatic, isochoric, isothermal and isobaric processes, if you can fit them in." On the final exam I gave them the essay assignment: "Comment on how the concept of entropy can be applied to human behavior."

Parts of the Sears and Zemansky essay are most interesting.

> Consider the example of the mixing of hot and cold water. We might have used the hot and cold water as the high and low temperature reservoirs of a heat engine, and in the course of removing heat from the hot water and giving heat to the cold water we could have obtained some mechanical work. But once the hot and cold water have been mixed and have come to a uniform temperature—this opportunity of converting heat to mechanical work is lost forever, and moreover, it is lost irretrievably. The lukewarm water will never unmix itself and separate into hot and cold portions. Of course, there is no decrease in energy when the hot and cold water are mixed, and what has been 'lost' in the mixing process is not energy, but *opportunity;* the opportunity to convert a portion of the heat flowing out of the hot water to mechanical work. Hence, when entropy increases, energy becomes more unavailable, and we say that the universe has 'run down' to that extent. . . . The goal toward which we appear headed has been described as the 'heat death' of the universe.

The other source I used was Erwin Schrödinger's book entitled *What Is Life?* published in 1945.

> What is the characteristic feature of life? When is a piece of matter said to be alive? When it goes on "doing nothing,"—moving, exchanging material with its environment, and so forth, and that, for a much longer period than we could expect an inanimate piece of matter to "keep going" under similar circumstances. When a system that is not alive is isolated or placed in a uniform environment, all motion usually comes to a standstill very soon as a result of various kinds of friction, differences of electrical or chemical potential are equalized-substances which tend to form a chemical compound do so—temperature becomes uniform by heat conduction. After that the whole system fades away into a dead inert lump of mass. A permanent state is reached, in which no observable events occur. The physicist calls this the state of thermodynamical equilibrium or of "maximum entropy."

He goes on to say:

> What then is that precious something contained in our food which keeps us from death? That is easily answered. Every process, event, happening—call it what you will: in a word, everything that is going on in Nature means an in-

crease of the entropy of the part of the world where it is going on. Thus a living organism continually increases its entropy—or, as you may say, produces positive entropy and thus tends to approach the dangerous state of maximum entropy, which is death. It can only keep aloof from it, i.e., alive, by continually drawing from its environment negative entropy.

He then goes on to discuss

. . . sucking orderliness from the environment. Indeed, in the case of high animals, we know the kind of orderliness they feed upon well enough. The extremely well-ordered state of matter in more or less complicated organic compounds, which serve as foodstuffs. After utilizing it they return it in a very much degraded form—not entirely degraded form however, for plants can still make use of it. These plants, of course, have their most powerful supply of "negative entropy" in the sunlight.

The applications of this concept of entropy appear in all fields. Speech communication, order and disorder of our society and its physical environment, and, yes, even the now almost-famous Peter Principle.

Teachers Group Calls For Scientific Literacy

The nation's science teachers are proclaiming scientific literacy as the goal of their efforts for the 1970s. If they achieve this goal, the schools will be turning out people who are comfortable in science, understand its limitations and possibilities, can use it skillfully and intelligently, and who will continue its development. In other words, the science teachers are aiming at a facility in science comparable to what many now have in literature, economics or the arts, for example.

This goal was set forth by the National Science Teachers Association in a position paper published in its official organ, *The Science Teacher*, November 1971 issue. "School Science Education for the 70s" is the Association's first major statement on curriculum goals and philosophy since 1962, when the NSTA urged the use of the great conceptual schemes of science as the framework for the development of science content and processes.

The present document also calls for attention to the social aspects of science and technology and the values deriving from science. "Scientifically literate persons," it says, "will use the achievements of science and technology for the benefit of mankind. . . . Emphasis on values and on the social aspects of science and technology must be integral parts of any science curriculum."

The document spells out the characteristics of a scientifically literate person and recommends Association action to implement the proposals in the statement. The NSTA is the largest organization dedicated to science education at elementary, secondary and collegiate levels.