THE LAWS OF THERMODYNAMICS
By
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Energy (e.g. electrical, mechanical, heat, etc.) is the capacity to do work. Thermodynamics is that branch of physics that deals with energy transformations from one form into another. The 3 laws of thermodynamics are perhaps the most basic in all science. They call attention to two properties that are fundamentally responsible for the behaviour of matter - energy and entropy. They tell us that the eventual course of all physical events can be summarised by 2 statements - 'The energy of the universe is conserved', and 'The entropy of the universe increases'.

The First Law of Thermodynamics is the easiest to understand. It was formulated in the 1840s by the German physicist Hermann von Helmholtz. It states that energy can neither be created nor destroyed (the law of conservation of energy). The total energy in the universe is constant. We all know that different forms of energy can be converted one into the other, for example mechanical work can be converted into heat by briskly rubbing your hands together. The First Law says that in any of these conversions energy neither increases not decreases; it just changes form. It will never be possible therefore to invent a machine that creates more energy than it consumes.

The First Law says nothing about the direction that processes take - this is the province of The Second Law of Thermodynamics, originally conceived in 1850 by the German physicist Rudolf Clausius. He noted that, in any energy conversion, e.g. conversion of electric energy into light, some of the energy is wasted, i.e. is converted into heat that is dissipated into the environment. (It will never be possible to invent a perpetual motion machine). That portion of the energy that is unavoidably lost as non-useful heat (unavailable to do work) is called entropy. Entropy is a measure of disorder. The Second Law of Thermodynamics states that the entropy of the universe is continually increasing, since in every process involving a flow of energy there is always some loss.

Clausius reached his conclusions largely by studying heat flow, for example the familiar observation that when two bodies, each at different temperatures, come into contact, heat always flows from the hotter to the cooler body, and stops flowing when the temperatures of both bodies reach the same value. There is nothing in the First Law to preclude heat flowing from the cooler to the hotter body, but this never happens spontaneously. Energy would be conserved regardless of the direction of flow. The second law predicts the direction in which all spontaneous changes proceed.

In 1872, the Austrian physicist Ludwig Boltzmann first explained the spontaneous flow of heat in terms of an increase in atomic disorder. Boltzmann defined temperature as a measure of the speed of molecules - molecules in a hot body move quickly, molecules in a colder body move more slowly.

When a hotter block is placed on top of a colder block, the initial state is one of relative order, with faster moving molecules segregated from the slower ones. However, at the interface between the blocks, hotter faster molecules bump into cooler slower ones, sharing energy with them. Gradually over time, higher and lower velocity molecules become completely mixed together top and bottom. Disorder (entropy) has increased overall.

The Second Law says that this process will never spontaneously reverse itself, with all the faster moving molecules again segregating themselves into one block, leaving the slower molecules in the other block. But the Second Law allows this to happen if work is performed on the system from the outside. Entropy can be caused to decrease locally by doing work but, in the process, the entropy of the surroundings beyond the local is increased by a greater amount than the local entropy is decreased and, overall, the entropy of the universe increases.

This concept can be understood by considering the domestic refrigerator. Electrical energy powers the extraction of heat from the inside conpartment, which lowers the entropy inside the fridge. The extracted heat is dumped into the room increasing its entropy. The increased room entropy exceeds the localised decreased frige entropy.

Life is highly organised and therefore low in entropy. Nature gathers various elements from the environment and assembles them into complex living systems, thereby decreasing entropy. This does not violate the Second Law because the assembly of life depends on the expenditure of much work, powered by harnessing the energy of the sun. While entropy is decreased temporarily on a local level by maintaining life, when the overall sums are done, the entropy of the universe increases. The high grade energy of the stars may be used to temporarily decrease entropy in localised regions of the universe, but there is a constant and inevitable leakage of this energy into entropy. The long-term fate of the universe is a state of total disorder, variously called ‘entropic doom’ or ‘the heat death of the universe’. Some people think the universe always existed. But, the incessant tendency for entropy to increase argues against this. If the universe always existed we would now have entropic doom.

Since temperature represents the speed of molecules we can conceive of absolute zero temperature when molecules are motionless. It can be calculated that absolute zero temperature is reached at minus 273.15 degrees Celcius. The Third Law of Thermodynamics states that the entropy of a perfect crystal is zero at absolute zero temperature.

The laws of thermodynamics prevail with inexorable sway in the life of the universe and in our individual lives. And yet, most people know nothing of them. The novelist and physicist C.P. Snow (1905-1980) was struck by this and made the observation that knowledge of the Second Law of thermodynamics should have a recognised cultural value equal to familiarity with a work of Shakespeare.

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