The Second Law of Thermodynamics and the Psychology of Science

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The evidence for and explanation of fundamentally missing knowledge in thermodynamics, as presented in my paper "The Proell Effect: A Macroscopic Maxwell's Demon" in Issue #52 of *Infinite Energy*, create more than a stir about the scientific details. It also raises the issues of what science is and how it functions.

It is appropriate to begin by quoting the final comments of that paper:

> This paper stands in stark comparison to mainstream, conventional thermodynamics. Because of the facts it contains and the conclusions that are drawn from them, one wonders how thermodynamics got so far afield that an adjustment based on these recent findings will have to be so severe. Percy Bridgman, 1946 Nobel Laureate in physics, wrote his perspective on the historical acceptance of scientific developments in the introduction of his book, *The Thermodynamics of Electrical Phenomena in Metals*. It illuminates one source of error in science and a good reason for the shock that this paper will undoubtedly create: "The progress of physics is unsystematic. . .The result is that physics sometimes passes on to new territory before sufficiently consolidating territory already entered; it assumes sometimes too easily that results are secure and bases further advance on them, thereby laying itself open to future possible retreat. This is easy to understand in a subject in which development of the great fundamental concepts is often slow; a new generation appears before the concept has been really salted down, and assumes in the uncritical enthusiasm of youth that everything taught in school is gospel truth, and forgets the doubts and tentative gropings of the great founders in its eagerness to make applications of the concepts and pass on to the next triumph. . .But each new young physicist. . .is in danger of forgetting all the past rumination and present uncertainty, and of starting with an uncritical acceptance of the concepts in the stage of development in which he finds them."[1]

Bridgman could just as well have been talking specifically about the Second Law of Thermodynamics, instead of about physics and science in general.

To repeat for the clarity of the readership, the Second Law is often stated as: "Heat flows spontaneously from a hotter to a colder object but not vice versa."[2] It is most succinctly stated as, "When an isolated system undergoes change, its change in entropy will be zero or greater than zero."[3-6]

The Second Law may be mathematically reduced to

$$\Delta S_{net} \geq 0, \qquad (1)$$

where S is entropy.

Carnot's Theorem is a specific embodiment of the Second Law, describing the interaction of heat and work. It states that a heat engine's maximum efficiency of converting heat into work is the ratio of the absolute temperature change of the heat passing through the engine divided by the absolute temperature of the heat input,

$$\eta_c = (T_{hi}-T_{lo})/T_{hi}. \qquad (2)$$

This theorem is a specific expression of the Second Law, therefore Carnot efficiencies are considered to be as inviolable as the Second Law itself.

The Second Law is, however, merely a statement of the collective experience of observed phenomena and has never been proven.[7-9] The Second Law was not understood by all of its founders to be universal and absolute.

Willard Gibbs wrote, "The laws of thermodynamics may easily be obtained from the principles of statistical mechanics, of which they are the incomplete expression"—and Ludwig Boltzmann expressed similar sentiments.[10]

James Clerk Maxwell summed up his perspective of the limitations of the Second Law:

> It is probably impossible to reduce the second law of thermodynamics to a form as axiomatic as that of the first law, for we have reason to believe that though true, its truth is not of the same order as that of the first law. The first law is an extension to the theory of heat of the principle of conservation of energy, which can be proved mathematically true if real bodies consist of matter "as per definition" acted on by forces having potentials. The second law relates to that kind of communication of energy which we call work. According to the molecular theory the only difference between these two kinds of communications of energy is that the motions and displacements which are concerned in the communication of heat are those of molecules, and are so numerous, so small individually, and so irregular in their distribution, that they quite escape all our methods of observation; whereas when the motions and displacements are those of visible bodies consisting of great numbers of molecules moving altogether, the communication of energy is called work. Hence we have only to suppose our senses sharpened to such a degree that we could trace the motions of molecules as easily as we now trace those of large bodies, and the distinction between work and heat would vanish, for the communication of heat would be seen to be a communication of energy of the same kind as that which we call work. The

> second law must either be founded on our actual experience in dealing with real bodies, or on the hypothesis that the behaviour of bodies consisting of millions of molecules may be deduced from the theory of the encounters of pairs of molecules, by supposing the relative frequency of different kinds of encounters to be distributed according to the laws of probability. The truth of the second law is therefore a statistical, not a mathematical truth, for it depends on the fact that the bodies we deal with consist of millions of molecules, and that we never can get hold of single molecules.[11]

Despite some founders' perspectives that the Second Law as described is not universal, absolute and insurmountable, interpretations of universality abound, and a smug attitude of certitude in the daily practice of science has replaced the actual mathematical uncertainty. One interpretation of the Second Law is the Kelvin-Planck Statement: "It is impossible to construct an engine that, operating continuously, will produce no effect other than the extraction of heat from a single reservoir and the performance of an equivalent amount of work."[12]

Another is the Klausius Statement: "It is impossible to construct a device that, operating continuously, will produce no effect other than the transfer of heat from a cooler body to a hotter body."[13]

The Kelvin-Planck and Klausius Statements are accepted as specific interpretations of the Second Law. Some scientists even *define* the Second Law by the Kelvin-Planck and Klausius Statements.[14-16]

Other comments from various sources are quoted to depict the general attitude regarding the Second Law:

Rudolf Klausius

> "To date, no experiment has been conducted that contradicts the second law, and this should be taken as sufficient evidence of its validity."[17]

> "The first law says you can't win; the second law says you can't even break even."[18]

> "Each failure, each fraud exposed, established the laws of thermodynamics more firmly."[19]

> "Extending mistrust of scientific claims to include mistrust of the underlying laws of physics, however, is a reckless gamble."[20]

> "The conservation of energy would let us think that we have as much energy as we want, Nature never loses or gains energy. Yet the energy of the sea, for example, the thermal motion of all the atoms in the sea, is practically unavailable to us. In order to get that energy organized, herded, to make it available for use, we have to have a difference in temperature, or else we shall find that although the energy is there we cannot make use of it. There is a great difference between energy and availability of energy. The energy of the sea is a large amount, but it is not available to us."[21]

> "The issue is not whether the second law of thermodynamics is valid in the ordinary world; nobody doubts that."[22]

> "Maxwell's Demon is therefore no longer regarded as a limitation of the second law."[23]

> "The second law of thermodynamics rules out the possibility of constructing a *perpetuum mobile* of the second kind. . .The experimental evidence in support of this law consists mainly in the failure of all efforts that have been made to construct a *perpetuum mobile* of the second kind."[24]

> "To Gell-Mann, science forms a hierarchy. At the top are those theories that apply everywhere in the known universe, such as the second law of thermodynamics and his own quark theory.'"[25]

> "Some authors argue that the universe is an isolated system and that, therefore, all processes in the universe cause its entropy to increase. The entropy of the universe tends to a maximum, and when that will have been reached, no processes will be possible. The universe will 'die' an 'entropy death.'"[26]

> "This is the true significance of the term, *irreversible*. The state of the Universe can never be completely restored."[27]

> "No exception to the second law of thermodynamics has ever been found—not even a tiny one."[28]

> "As Albert Einstein put it, 'A theory is the more impressive the greater the simplicity of its premises, the more different kinds of things it relates, and the more extended its area of applicability. Therefore the deep impression which classical thermodynamics made upon me. It is the only physical theory of universal content concerning which I am convinced that, within the framework of the applicability of its basic concepts, it will never be overthrown.'"[29]

Even Rudolf Klausius took a universal view of the Second Law, doing so by decree:

> Everything we know concerning the interchange of heat between two bodies of different temperatures confirms this, for heat everywhere manifests a tendency to equalize existing differences of temperature . . .Without further explanation, therefore, the truth of the principle will be granted.[30]

Max Planck, the founder of Quantum Mechanics, once said, "We have no right to assume that any physical laws exist, or if they have existed up to now, that they will continue to exist in a similar manner."[31]

What Max Planck meant is that our *understanding* of the physical principles which govern the universe are susceptible to change. A "law" is merely a statement of what we perceive of a physical principle; it is not the principle itself. Reality is what we realize. Our realizations are limited to our bodily senses, our thoughts, and our emotions. The scientific method was developed to assist the transcendence of our realities, which are well known to be imperfect, in an attempt to arrive at a knowledge of what "is," what the author calls "actuality." We cannot know an actuality; we can only know a reality. When a reality is based upon an objective (naturally occurring) and reproduceable source of information, we call that "science." Since objective data obtained by the scientific method are merely data and not conclusions, and the data are interpreted by our realities, the data's ultimate significance is questionable. By recognizing what a "law" is and how scientific "truth" is established, as just described, the laws of physics and scientific truth are inherently imperfect.

Just like any other law, the Second Law and its corollaries are inherently imperfect and therefore are susceptible to correction and amendment. There is evidence that the Second Law and its corollaries are incomplete or partly wrong, some of which were presented in the author's previously cited paper.[32]

An anonymous physics professor once said, "Light travels in straight lines, except when it is bent." This humorous, poetic statement contains much wisdom and is exemplary of the dynamics of knowledge in the realm of science. For those who are taught that light travels in straight lines, it is a truth for general life. It is not a statement of universal and absolute truth, as under certain circumstances light does not travel in a straight path. These exceptions are often obscure to the common person, even though they are within the realm of common experience: the effect of heat waves seen above the hot pavement of a long stretch of highway in the summertime, the twinkling of a star, or wavy images from under the surface of a swimming pool, which are also at an apparently strange location below the surface. The same thing applies to the science community, as scientists are human beings also. Humans have the characteristics of imperfect perception and limited consciousness. These attributes undermine the practice of science. Though science is a systematic method for gaining knowledge, and is of particular usefulness for understanding the physical universe, the practice of pure science as a supposedly *infallible* tool of learning is not within the realm of human experience. This is because, as far as we know, the human condition is inseparable from the practice of science. Our science not only needs correction and expansion as part of the growth process of life, but it also needs refreshment, reminders, and re-education. With this dynamic between the human condition and the scientific method in mind, the reader is admonished to be open to the possibility that science, as it exists today, is not in a state of completion nor a state of correctness. Life is more than a state of being; it is also a process of becoming.

Lord Kelvin

The Second Law, as it is accepted today, is comparable to the "light travels in straight lines" axiom. Nature is not so simple, and our laws may not be a full description of the natural phenomena. Maybe like light, heat can be "bent," showing a different manifestation than we were aware of. Besides, light seems to have a dual nature, both as a wave and as a particle, yet science still functions with this paradox.

Carnot's Theorem results from the application of the Second Law to energy transformations from heat into work. Engine efficiencies greater than stipulated by Carnot would have an isolated system net entropy decrease, and would "violate" or contradict the Second Law, plus violate the Kelvin-Planck and Klausius Statements.[33] Engine efficiencies approaching 100% without extremes of temperatures seem to be impossible.

Stating something is impossible, which is the same thing as stating that something does not exist, is illogical. In order for someone to state that something does not exist, that person must be able to examine everything that *does* exist to be sure that what is hypothesized does indeed *not* exist. This requires omniscience or all-knowing, and the author resolutely doubts that any human being has this capability.[34] Something might not exist, but we as human beings cannot be certain of that.

A negative hypothesis or conclusion has the same logical pitfall as the claim of an impossibility. It is based upon limited information and cannot be proven. All it takes to disqualify a negative claim is for one more piece of data or premise to be added, which can change the outcome. Two examples illustrate the point. If a negative conclusion is made from experience that water cannot remain a liquid if its temperature is below zero degrees Celsius (condition one) and the water is pure (condition two), a truth seems to be stated. Add a third condition of high pressure, and the negative conclusion with the two conditions becomes false; it is not universally true. The original conditions (the first two premises) are still true, but the conclusion is false. Everyone who has ice skated knows that if pressure is applied to the ice by the blades of one's skates, effortless gliding on the ice is possible. Liquifaction of the ice is what occurs. The second example of the fallacy of a negative conclusion comes from the science of nutrition. It has been common knowledge that vegetarians do not get enough vitamin B_{12} from their food. No known fruits and vegetables provide enough B_{12} for proper health, so it has been stated that vegetarians do not get enough B_{12}. Recent research has discovered that this is not true. Small populations of an obscure, indigenous, bacterial species in the small intestines of humans produce adequate B_{12} for good health in strict vegetarians.[35] Since one can never be sure that all possible conditions are identified (due to limited human consciousness), a negative hypothesis is not provable and a negative conclusion is invalid as a universal conclusion. It is illogical to state that something is impossible or that it does not exist.

The Second Law is not based upon a principle that universally precludes the possibility of the complete conversion of heat into work. The only principle at the foundation of the Second Law is what was stated at the beginning: heat flows to lower temperature. This principle does not contain a basis for a universal stipulation about heat engine efficiencies. A universal stipulation that prevents the unity efficient conversion of heat into work requires that all possible conditions be identified in order to exclude the unity conversion of heat into work. By the human factor mentioned before, omniscience is not available to bequeath legitimacy to such a claim; it is thus illogical to arrive at such a conclusion. Because all possible conditions are not knowable, a negative hypothesis cannot be proven, a negative conclusion is not universal, and a positive conclusion is subject to limitation despite being called "universal."

James Joule, the champion of the Kinetic Theory of Heat and a founder of modern thermodynamics, was a clear-headed proponent of the conservation of energy, which became the First Law of Thermodynamics. From his own writings he said,

> Experiment has enabled us to answer these questions in

> a satisfactory manner; for it has shown that whenever living force is "apparently" destroyed, an equivalent is produced which in process of time may be reconverted into living force. This equivalent is "heat."[36]

"Living force" is Joule's term for work. Joule's statement contains a hint that he may have believed in more than what became the First Law. He may have believed in the *unity efficient* transformation of heat into work, in addition to his acceptance of energy conservation. Can there be any basis for the unity transformation of heat into work in contradiction to the Second Law? A further statement by Joule in the same document shows his belief in complete conversion more clearly:

> But the most convincing proof of the conversion of heat into living force has been derived from my experiments with the electro-magnetic engine, a machine composed of magnets and bars of iron set in motion by an electrical battery. I have proved by actual experiment that, in exact proportion to the force with which this machine works, heat is abstracted from the electrical battery. You see, therefore, that living force may be converted into heat, and that heat may be converted into living force, or its equivalent attraction through space. All three, therefore,—namely heat, living force, and attraction through space (to which I might also add "light," were it consistent with the scope of the present lecture)—are mutually convertible into one another. In these conversions nothing is ever lost.[37]

The meaning of his words is not perfectly clear, but there is a strong hint that he meant more than the mere conservation of energy; he was suggesting that the complete conversion of heat into work is possible. The key to understanding this is the "heat abstracted" in his example, which is heat removed from the environment through the battery. Why would Joule refer to this obscure energy flow as "the most convincing" if he were only referring to the conservation of energy, when his famous paddlewheel water heating experiment would surely be a more convincing demonstration due to its simplicity to observe and to measure? The author postulates that Joule *did* observe the unity efficient conversion of all of the heat flow into electrical work in the discharging battery and intended such in his statement. History has swept his apparent meaning away from this quotation.

An electrical battery can have a heat flow upon electrical discharge of its chemical energy, and this does not refer to resistance heating. The relationship is found in the Gibbs-Helmholtz equation,

$$\Delta G = \Delta H - T\Delta S, \tag{3}$$

where ΔG is the Gibbs Free Energy change, ΔH is the enthalpy change, T is absolute temperature, and ΔS is the entropy change.[38] The discharge of the chemical energy represented by ΔG is work and entrains any heat that may be absorbed. The battery can only transmit ΔG by way of its electrical connections to its load. By the First Law, the heat must be accounted for, and it goes into ΔG. As Joule noted, nothing else happens to this thermal energy; it merely becomes work.

The electrolysis of water demonstrates this phenomenon in detail. Though it is not a "battery,"[39] it is a galvanic cell; work must be done on it to make it operate. The water electrolysis cell is often thought of as the opposite of a fuel cell. A fuel cell is a battery with inert electrodes and an external and potentially unlimited supply of chemical reactants. For one mole of liquid water, split into hydrogen and oxygen gas at 25°C and one atmosphere, the electrolysis energies are,

$$\Delta H = +285.58 \text{ kJ / mole, and} \tag{4}$$
$$\Delta G = +236.96 \text{ kJ / mole.}^{40} \tag{5}$$

The positive signs mean the energies are absorbed by the reactants undergoing change. Their difference, $T\Delta S$, according to the Gibbs-Helmholtz equation above, is the heat absorbed in the reaction,

$$Q = T\Delta S = +48.62 \text{ kJ / mole.} \tag{6}$$

This is the unity efficient conversion of heat into chemical energy, which is potential energy and a form of stored work. When T is high enough, ΔG is zero and the heat required to dissociate water equals the absolute value of the heat of combustion of water, which is the heat of formation of water. This is the direct thermal decomposition of water, requiring no electricity.[41] It also is a demonstration of the complete conversion of heat into chemical energy, a form of stored work. The water electrolysis example is not a spontaneous conversion of heat into work, but clearly shows that heat can be completely converted into a form of energy that can be produced completely from work. In spontaneous, voltaic cells which are endothermic such as lead-acid batteries, absorbing heat upon discharge, heat is converted to a directly useful and desired form of work, electricity.[42-44] This is what Joule observed.

Examples of unity efficient energy conversion exist within well-documented and accepted phenomena. Photovoltaic cells, though only about 10% efficient with the solar spectrum with silicon semiconductor material, are ideally capable of unity conversion efficiencies with monochromatic radiation at their photoelectric potentials. Though photovoltaic cells are not heat engines, they nonetheless have unity efficient conversion under reversible conditions. Electric, magnetic, and gravitational fields are conservative, in conformance with the law of conservation of energy, the First Law of Thermodynamics. The energy transformations in these fields may not be thermodynamic (heat related) in nature, but all of these transformations demonstrate that one form of energy may be converted into another without some of the first energy being converted into heat. The only bearing these phenomena have in connection with entropy and the Second Law is the awareness that the proposed conversion of heat into work at unity efficient transformation is not without parallel in the physical universe. Waste is not necessary in energy transformations under all conditions.

The unity efficient conversion of heat into work is supported by the existing science of thermionics, and it occurs at uniform temperature. The Richardson-Dushman equation,

$$j = AT^2 e^{-\phi/kT}, \tag{7}$$

is the basic equation of thermionic emission, where j is current density, A is a constant of the material emitting the electrons, T is absolute temperature, e is the base of naperian logarithms, ϕ is the material's work function, and k is the Boltzmann constant. The equation was derived from both thermodynamics and quantum mechanics, each derivation arriving at the same equation.[45] This equation allows electrons to emit from a surface, which is a form of work, when the material is at one temperature. Though thermionic emission is commonly utilized with the presence of a second electrode that is at another temperature, that second electrode at another temperature is not necessary because the Richardson-Dushman equation contains only one temperature. If any materials at thermal equilibrium are identified as an isolated energy system, any thermionic emission of electrons would be a decrease in the system's entropy, which is a "violation" of the Second Law. Such behavior has been reported. Dr. Xu Yelin of China built a large array of cold vacuum tubes wired in parallel that exhibited voltage across a resistive load when the array was at thermal equilibrium, and a consistent DC voltage persisted for over five years.[46,47]

Poignant examples of unity efficiency are found within the heart of classical thermodynamics. Blackbody radiation is a unity conversion process; no heat must be wasted in order for thermal energy to be converted into electromagnetic radiation. Isothermal expansion of an ideal gas under reversible conditions has unity conversion of heat into pressure-volume work. The same is true for isentropic, adiabatic expansion, but also under irreversible conditions; the work is still produced from *only* the working fluid's internal energy. Though these processes are not complete engine cycles, the bounds of Carnot's Theorem seem inconsistent with these phenomena. Why can *single processes* be unity efficient transformations, yet *cycles* must not only be less than unity according to Carnot, but also less than a certain variable fraction? The Second Law definitely is not limited to cycles; it also includes single step, non-repeating phenomena, such as chemical reactions, making the cyclic requirement for sub-unity work generation even more inconsistent.

Carnot's Theorem applies to a cycle and denies unity conversion efficiency, yet thermodynamic processes do exist which are of unity efficiency. The incongruity of the existence of unity efficient one-way thermodynamic processes and the Carnot limitation for cycles has no other explanations than to conform to the Kelvin-Planck and Klausius Statements and to conform to the specific definition of the Second Law that the net entropy change of an isolated energy system must be zero or greater than zero. *The author proposes that this "requirement" of a cycle is only a hypothesis based upon experience to date and the generalized theoretical understandings of the Second Law.*

Carnot's Theorem has been shown to be not universally true.[48] It is based upon limited premises, plus there are faults in the logic of the arguments that established it so firmly in scientific "dogma." The result of these conditions is that universality is not a proper conclusion.

Second Law analyses of heat engine cycles sometimes involve a concept of work reservoirs, in addition to heat reservoirs. An engine device that expands and contracts, in contact with the surrounding atmosphere, gives work to and receives work from the atmospheric work reservoir. Such transformations are treated as perfect.[49] The atmosphere stores the work given to it thermally, along with gravitational potential, and gives it back in the form of work, perfectly. Air is known to dissipate acoustic energy as heat, and the mechanism is called molecular thermal relaxation.[50] Acoustic energy is a form of pressure-volume work. Since work is dissipated in the atmosphere and also returns work as a true work reservoir, work reservoirs contradict the common understanding of the Second Law that demands losses.

Charles Steinmetz, a contemporary and peer of Thomas Edison and Nikola Tesla, and a prominent engineer in the early days of General Electric, presented a mathematical argument that the Earth's atmosphere is a spontaneous heat separator, contradicting the Klausius Statement.[51] High kinetic energy atoms and molecules in the atmosphere can separate from the remainder of the atmosphere by escape velocity against the Earth's gravity, as a normal consequence of the wide range of particle velocities that occur at one temperature according to the Kinetic Theory of Heat. Steinmetz's adiabatic, First Law analysis[52] includes a plot of absolute temperature as a function of altitude; it predicts the atmosphere would reach absolute zero at 29 kilometers. Actual data shows a commensurate decline in temperature with altitude close to Steinmetz's calculations, but not only does the atmosphere *not* reach absolute zero at 29 km, it shows that the atmosphere has appreciable temperature beyond the zero point predicted by classical thermodynamics, *rising* in temperature above this altitude, exceeding the temperature of the surface of the Earth above 100 kilometers.[53] It is true that this temperature rise is at least partly due to high energy photon and particle absorption from solar and cosmic radiation. It is not sufficient evidence to constitute proof of spontaneous heat separation, but it is evidence nonetheless. The altitude of the temperature inversion also supports the spontaneous heat separation hypothesis, as only a miniscule fraction of atoms and molecules in the atmosphere would be significantly separated over long distances, those being the very high velocity ones, and this tiny fraction would thus skew the temperature only near the conditions where the vast majority of particles contribute next to nothing to the average kinetic energy, near absolute zero. The probability of this inversion altitude being due only to the absorption of radiation is small.

A forward biased thermocouple junction in a thermoelectric generator (TEG) or thermoelectric heat pump converts heat into electricity, demonstrating one polarity of the Peltier effect. This is the unity efficient conversion of heat into work. When examined as the cold junction of a heat pump, it becomes obvious that this conversion is unity efficient, as the cold junction has nowhere to reject any heat to; it is below the temperature of the environment it is in. A Second Law analysis of a thermocouple junction which converts heat into electricity shows that this isolated system has a net entropy change which is negative: heat is absorbed and thus the entropy change of the heat reservoir is negative, and that energy received by the junction is now electricity which is work and thus has no entropy. Electrical current enters and leaves the isolated system, but this is merely current and not energy. A cooling thermoelectric junction is an exception to the Second Law, coming from conventional science. Not only is it an exception under ideal conditions, it also occurs under common, every day, practical, irreversible conditions.

Joseph Yater developed substantial theories for a new type of TEG that conclude that Carnot can be exceeded in his devices.[54-63] The importance of his work is that individual junctions, which he calls quantum well diodes, are unity efficient in transforming heat into work, and if the energy input is non-blackbody electromagnetic radiation, the TEG as a whole has an efficiency exceeding Carnot, despite reversed biased junctions which normally make a TEG Carnot-limited.[64-69] Yater plays with words in order to "pander" to United States Patent and Trademark Office administrative policy regarding "perpetual motion machines." He states high electron temperatures for the energy input of his devices, and states normal, truly thermal temperatures for the heat output side, in order for his devices to conform to Carnot; this is a false Carnot efficiency, as true input side temperature is not considered, just like electromagnetic input energy of a solar cell has no thermal nature as normally understood. To quote Yater,

> In general, the utilization of quantum effects in absorbing radiation in the first layer of the REF [reversible energy fluctuations] converter can enable a higher total efficiency to be achieved than that of the Carnot cycle between the temperature of the lattice of the first layer and the temperature of the cooler rectifying layer.[70]

See the author's deeper treatment of Yater's unique TEG concepts.[71]

Nobel Laureate Ilya Prigogine has clarified misunderstandings about the nature of irreversibility, a driving concept for the traditional understanding of the Second Law.

> Boltzmann's probability-based interpretation makes the macroscopic character of our observations responsible for the irreversibility we observe. If we could follow the individual motion of molecules, we would see a time-reversible system in which each molecule follows the laws of Newtonian physics. Because we can only describe the number of molecules in each compartment, we conclude that the system evolves toward equilibrium. According to this interpretation, irreversibility is not a basic law of nature; it is merely a consequence of the approximate, macroscopic character of our observations.[72]

> The main reason to discard the banalization of irreversibility is that we can no longer associate the arrow of time only with an increase in disorder. Recent developments in nonequilibrium physics and chemistry point in the opposite direction. They show unambiguously that the arrow of time is a source of *order*.[73]

The manifestation of a physical law can be altered or superceded by other physical laws. The laws interact, and rarely do laws exhibit their behavior in pure form; this is why the protocols of laboratory experimentation are so demanding. Venturi's principle alters the effect of gravity in an airplane. Heat engines that have efficiencies higher than Carnot do not necessarily violate Carnot any more than an airplane violates gravity. The principles that can break the Carnot barrier coexist with Carnot just as gravity keeps an airplane from soaring into the stratosphere.

Not all interactions of physical principles are obvious. An example shows how unobviousness can lead to false predictions of a result. Pascal's principle states that when a pressure is applied to a confined fluid, the pressure equalizes over the entire fluid's boundary. Gravity also has an interaction here. The interaction of gravity and Venturi's principle is commonly obvious in the airplane, but the interaction of gravity and Pascal's principle in a pressure tank is not. In hydraulics, when the force created by gravitational acceleration is large enough, it appears as if Pascal's principle is violated because the typical prediction of equalized pressure in a vessel is untrue. In actuality, both principles coexist simultaneously.[74] The vertical pressure gradient in a municipal water tower demonstrates this.

Fuel cells that combust hydrogen, releasing the same chemical energy as burning hydrogen in internal or external combustion engines, have higher absolute conversion efficiencies than allowed by Carnot for the same maximum and minimum fuel cell temperatures. The same energy is released, yet a different set of conditions produces a different result. Carbohydrate metabolism in living organisms by enzymatic oxidation that produces motion by muscle contraction, and thus work, is not Carnot-limited for the same reason: the conversion process is not thermal, but is ΔG-driven.

By the preceding examples, it is presumptuous to require that one established physical "law" be the sole determinant of a physical outcome, that nothing else will alter the result. Since one physical law can supercede another, no law can be claimed to be absolute, in the sense that it can definitively predict a physical result. The unrelenting demand that the Second Law be applied under all conditions and with no exceptions is short-sighted and incorrect. The general observation of the phenomenon of one physical law asserting itself over another precludes the necessarily absolute manifestation of any law.

For a clearer understanding, the law of gravity is examined by itself. The law of gravity is accepted as universal. Despite this, no one concludes that all matter will agglomerate and that no matter will separate, having absolute manifestation. The common sense of such an understanding needs to be applied to the Second Law. Apparent exceptions will occur, not because the Second Law is invalid, but merely because other laws are active and interact for a composite result which may seem contradictory to a specific law.

There is at least one specific exception to the Second Law that is acknowledged and accepted within the scientific community. Negative absolute temperature in quantum mechanical systems has been well established. Heat can be extracted from a negative temperature reservoir with no other effect than the performance of an equivalent amount of work.[75]

Other exceptions are being debated within the scientific community.[76] Recent work in solid state physics aided by nanotechnology developments has proposed the possibility of the generation of work from a single, uniform temperature reservoir.[77]

All of these examples from conventional science and the preceding arguments, including the theoretical and experimental arguments for a macroscopic Maxwell's Demon in Issue #52, are provided as a basis for an open-minded examination that what has been known about the behavior of heat and entropy, as embodied in the Second Law of Thermodynamics, is incomplete.

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34. This is as close as the author gets to stating an impossibility. If anyone claims to have omniscience, the author can merely ask that person what the author ate for breakfast the day before. If that person cannot answer the question correctly, that person is not omniscient. The author is more certain of a lack of omniscience in any human being than the Scientific Community is certain of the universality of the Second Law.
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