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Supreme Theory of Everything: Deep Mysteries of Thermodynamics

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Abstract

Everything has emerged from energy and energy is essentially information. It is the problem of sole thermodynamics. (Nonequilibrium) thermodynamics is called a metatheory, a theory of theories. But thermodynamics has to be connected with hysteresis to be more complete, divine, and alive. Because hysteresis has a lot of stunning properties such as memory, cyclicity, singularity, saturation, and so on, thermodynamics can thus be linked through hysteresis to everything: entropy, negentropy, information, spacetime, the arrow of time, and superconductivity. Both thermodynamics and hysteresis are universal. Thermodynamics contains entire information about everything, while hysteresis describes its structure. When the two are combined, a complete theory will be created. The results of my 5-years studies show that among many counter-intuitive ideas and basic partial theories, the law of hysteresis can explain the full physical world. In this paper, to clarify the big picture of everything many separate subjects of thermodynamics are attempted to be summarized based on hysteretic trigonometry.

Humanity waits for a united theory of physics. Science has two ways to reach this final result: first, infinitesimally detailed scientific research, and second, the study of general trends. The painful lesson of our centuries of research reveals that when one tries to the more detailed the research result, the deeper we go into the endless confusion of information. Instead, the scientific study of the macroscopic and general levels is radically different, like a view from a high mountaintop: no doubt, crystal-clear, easy to understand, ordered, and including the gateway to detailed research. Additionally, the theory of everything is not as complex as theorists think, but very simple, beautiful, and perfect.

Keywords: hysteretic thermodynamics, Carnot cycle, its work, nature of spacetime, the simultaneity of time, arrow of time, entropy-negentropy, entropy deficits in HRD

1. Introduction

Thermodynamics, which covers energy, entropy, the arrow of time, and information, is undoubtedly the basis of everything theory.

Thermodynamics is universal, and hence, in principle, it applies to everything in nature - from simple engineering systems to complex living organisms to our expanding universe. The laws of thermodynamics form the theoretical underpinning of diverse disciplines such as biology, chemistry, climatology, ecology, economics, engineering, genetics, geology, neuroscience, physics, physiology, sociology, and cosmology, and they play a key role in the understanding of these disciplines (Wassim M., 2002, 2010, 2015, 2016, 2017, Hou, S.P. and Wassim M., 2015).

The laws of thermodynamics involving the conservation of energy and the non-conservation of entropy are, without a doubt, two of the most useful and general laws in all sciences. (Wassim M., 2017)

Thermodynamics is studied under two major branches: equilibrium and nonequilibrium and has four laws: the 0th law to the third law.

Equilibrium Thermodynamics is the systematic study of transformations of matter and energy in systems in terms of a concept called thermodynamic equilibrium. Equilibrium thermodynamics, in origins, derives from analysis of the Carnot cycle, (Equil. Thermo., Wikipedia) while nonequilibrium thermodynamics is a metatheory, a theory of theories. (P.Ván, 2020, Philos. Trans. Royal Soc., 2020), The biggest unsolved problem is Non-equilibrium thermodynamics. (Unsolved problems in Thermod, physicsforums.com)

It is a theory where the powerful methods of equilibrium are missing and considered an emergent theory; its fundamental principles, like the second law, are due to microscopic or mesoscopic properties of matter. (Non-equi. Thermod. wikipedia.org)

"*G. P. Beretta wrote:* One of the 'great laws' of nature is the second law of thermodynamics." (P.Ván, 2020)

It is a physical law based on universal empirical observation concerning heat and energy interconversions. (Second law of thermo., wikipedia.org)

The Second Law of Thermodynamics represents a milestone in the history of not only physics but also chemistry, engineering, and, more generally, life and natural sciences. It is a fundamental law of the universe and its universality can be proven by demonstrating its equivalence across all types of thermodynamic systems. To strengthen its generality and impact, it is sometimes elevated to the level of a principle and named the Second Principle of Thermodynamics [Paglietti, A., 1976, 1977, Iribarne, J.V.; Godson, W.L.1973), providing it with a philosophical nature. (P.Ván, 2020)

The microscopic point of view of thermodynamics was first established by Maxwell (Maxwell, J.C.1866) and further developed by Boltzmann (Boltzmann, L. 1910) by reinterpreting thermodynamic systems in terms of molecules or atoms.

The second law of thermodynamics has been expressed in many ways. Starting from Carnot, Clasius, Kelvin, Boltzmann, Planck, and Carathéodory they proposed various forms of the law but it was German scientist Rudolf Clausius who laid the foundation. (Equation That, https://www.facebook.com)

The Second Law in the form of statements:

- Clausius' Statement: it is not possible to make a change whose final result consists of transferring heat from a cold source to a warm one.

- Kelvin (-Planck)'s Statement: it is impossible to make a thermal machine work in the cycle whose final result is production work by exchanging heat with just one source.

Both statements are equivalent. (Thermo. and Entropy $S = k\ logW$, https://www.facebook.com)

Unfortunately, resulted in an extensive amount of confusing, inconsistent, and paradoxical formulations of thermodynamics accompanied by a vague and ambiguous lexicon giving it its anthropomorphic character. (Wassim M., 2017)

The limitations of the Second Law of Thermodynamics are: (What are the limitations…, byjus.com/)

1. The second law of thermodynamics only deals with the irreversibility of heat conversion to another form.
2. The second law of thermodynamics only deals with closed systems.

However, unlike other principles in physics that are viewed as unprovable postulates, it is empirical and has been rigorously proved. This law is generally applied to closed thermodynamic systems, physical systems in which the exchange of heat is allowed but the exchange of matter with the surrounding is not. (Roberto Zivieri, 2023)

Some examples of unsolved problems in thermodynamics include the question of whether (Unresolved Problems in Thermo, physicsforums.com)

1) the second law of thermodynamics applies to individual particles,
2) the existence of negative absolute temperature, and,
3) the connection between thermodynamic irreversibility and the arrow of time.

In the cyclic process, since the internal energy is a state variable, ΔU = 0, i.e., the internal change is zero. The initial and final internal energies remain equal. By applying the first law of thermodynamics to a cyclic process, the formula we get is: (Cyclic process, **(**collegedunia.com/)

$$\Delta E = Q + W \tag{1}$$

Where, ΔE = 0, W = Q

We don't see any cyclicity in Formula 1 and the entire thermodynamics description. We want to use the mathematical formula of cyclicity for the thermodynamic processes. Many derivations and conclusions are to be made from their mathematical formulas. There is no doubt that the language of science is mathematics. But there is also no indication that the more mathematized a scientific work is, the better it is.

If a theory is merely mathematically rigorous, it doesn't make it true. (Angela Collier, youtube.com) “Great physics does not automatically imply complicated mathematics.”-said Martinus Veltman.

Anyway, one should have suitable mathematics for physical research.

Thermodynamics pertains to the deepest secrets of the universe. So, in this paper, we consider some unsolved problems in equilibrium and non-equilibrium thermodynamics with the help of trigonometry which is one of the mathematical dynamical systems because the theory of hysteresis can be a critical player in thermodynamic processes.

2. Hysteretic Thermodynamics

2.1 About Study of the Hysteresis in a Few Words

Many brilliant scientists in the history of mankind, such as Newton, Coulomb, Ohm, Wien, Curie, Planck, Einstein, de Broglie, Neel, Everett, Heisenberg, Schrödinger, Yukawa, Landau, and so on, contributed to some extent to create the law of hysteresis. The reason is that their theories, laws, and formulas include the inverse square law or the law of inverse proportionality, which are approximately the same as the hysteresis law. (Ulaanbaatar, T., 2021a)

If the hysteresis is used in the formulation of thermodynamics it gives us a great possibility to explain both reversible and irreversible processes because hysteresis is the dependence of the state of a system on its history. It means the memory of the system.

Modern continuum thermodynamics has been extended to account for nonlinear irreversible processes such as the existence of thresholds, plasticity, and hysteresis [Duhem, 1911, Kestin, J. 1979, Maugin, G.A. 1999).

The thermodynamic system has memory, and hence, the dynamic behavior of the system is not only determined by the present value of the thermodynamic state variables but also by the history of their past values. (Wassim M., 2017)

The vast majority of the scientific community up to date have not been convinced with the Second Law challengers and demonologists. (Milivoje M. Kostic, 2020) It is difficult to define hysteresis precisely. Isaak D. Mayergoyz wrote "...the very meaning of hysteresis varies from one area to another, from paper to paper and from author to author. As a result, a stringent mathematical definition of hysteresis is needed in order to avoid confusion and ambiguity." (Wassim M. 2017)

In summary, I am not against the 2nd Law of Thermodynamics, but we, XXI centurists need to advance the 2nd Law of Thermodynamics.

2.2 Some Mistakes in the Formulation of Thermodynamics

First of all, some common mistakes are overviewed shortly in thermodynamics.

Boyle’s law is a gas law that states that the pressure exerted by a gas (of a given mass, kept at a constant temperature) is inversely proportional to the volume occupied by it (Figure 1). For a gas, the relationship between volume and pressure (at constant mass and temperature) can be expressed mathematically as follows. [30]

$$P \propto (1/V) \tag{2}$$

Where P is the pressure exerted by the gas and V is the volume occupied by it.

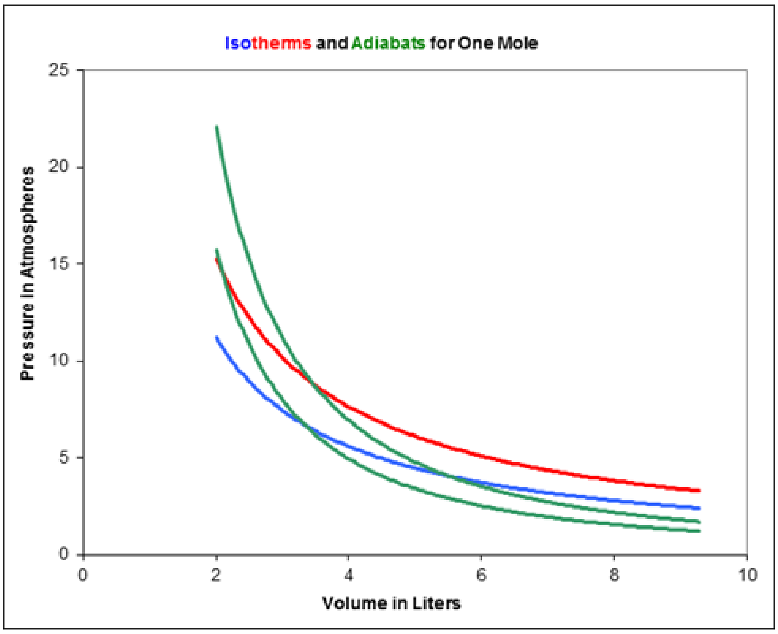

Figure 1. The Carnot cycle (Michael Fowler, galileo.phys.virginia.edu)

Carnot's cycle is around that curved quadrilateral having these four curves as its sides. (Michael Fowler, galileo.phys.virginia.edu)

From Figure 1 we need to answer the following questions:

- What types of curves make up the Carnot cycle? Or, conversely, what curves does the Carnot cycle consist of?
- Are these curves random or not?
- What are the reasons for two isothermal processes and two adiabatic processes in the Carnot cycle, respectively?
- How do formulate all of these simultaneously?
- What is the formula of the cyclic process?
- Are there any limits to the pressure or volume of the cyclic process shown in Figure 1?
- Does explain that this diagram is derived empirically from Boyle's Law and the Carnot cycle?
- Can the second law of thermodynamics exactly describe entropy?

So far as I know there is no formula for the Carnot cycle. It is impossible to calculate the amount of work determined by the area of the Carnot cycle, and nothing can be said about non-equilibrium thermodynamics. Figure 1 should appear from the cyclic process formula.

Entropy arises directly from the Carnot cycle. It can also be described as the reversible heat divided by temperature. (Entropy, https://en.wikipedia.org)

Pure thermodynamic or phenomenological, entropy is introduced by the ratio of elementary change in the heat transfer into the system, δQ, to the absolute temperature T at which this increment happened: (Second law of thermo., sciencedirect.com)

$$\Delta S = \frac{\delta Q}{T} \tag{3}$$

Where S is entropy. However, this introduction implies a reversible process of heat transfer.

For an irreversible process,

$$\Delta S > \frac{\delta Q}{T}. \text{ (Second law of thermo, sciencedirect.com)} \tag{4}$$

If we consider the boundary conditions for it:

$$\Delta S = \lim_{T\to 0} \frac{\delta Q}{T} = \infty \text{ contradicting the definition.} \tag{5}$$

$\Delta S = \lim_{T\to \infty} \frac{\delta Q}{T} = 0$ entropy decreases with increasing temperature, also a contradiction.

It follows from Formula 3 that as temperature increases, entropy decreases. But the basic definition is as above (See Subsection 4.1).

In superconductivity, it follows:

$$\lim_{T_H\to 0}\left(\frac{T_H-T_C}{T_H}\right) = -\frac{T_C}{0} = -\infty \text{ or undefined} \tag{6}$$

The efficiency of the heat engine:

$$\lim_{T_C\to 0}\left(\frac{T_H-T_C}{T_H}\right)\cdot 100\% = 100\% \tag{7}$$

The efficiency of a Carnot engine is given by 1−Tc/Th. Critical temperature (Tc) cannot reach absolute zero. This tells us that even with an idealized cycle we can never have a 100% efficient heat engine unless Tc is 0 K or Th approaches infinity. (Why can Carnot efficiency…, physics.stackexchange.com)

Since all-disturbing entropy is more stable at low temperatures and negative singularities, this is where all physical phenomena unfold, manifest, and focus. You can explore everything here. Therefore, it is possible to completely determine everything by completely solving the negative singularity.

2.3 The Equilibrium Thermodynamics

Let's use the hysteresis formula for reversible processes and the Carnot cycle. According to the law of hysteresis, it is formulated in the next form:

$$\mathrm{c(x)} = \frac{\mathrm{A}\sin\left(\mathrm{x}+\frac{\pi}{\mathrm{k}}\right)}{|\cos(\mathrm{x})|} \tag{8}$$

Now, to explain it we select $A = 5$ and $k = 0.37$

$$\mathrm{c(x)} = \frac{5\sin\left(\mathrm{x}+\frac{\pi}{0.37}\right)}{|\cos(\mathrm{x})|} \tag{9}$$

Formula (9) is a left-uplifted hysteresis in which negentropy is lower than entropy (Figure 2).

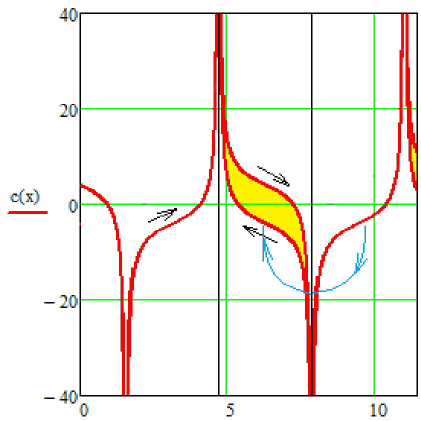

Figure 2. Equilibrium cycle

Note that this figure is not computational

The third law of thermodynamics states that the entropy of a closed system at thermodynamic equilibrium approaches a constant value when its temperature approaches absolute zero. His constant value cannot depend on any other parameters characterizing the system, such as pressure or applied magnetic field. At absolute zero (zero kelvins) the system must be in a state with the minimum possible energy. Entropy is related to the number of accessible microstates, and there is typically one unique state (called the ground state) with minimum energy. (Wassim M. 2017) In such a case, the entropy at absolute zero will be approximately zero. (J. Wilks, 1961) See entropy and negentropy in Subsection 4.1.

Thermodynamics, however, says that you need an infinite amount of energy to cool anything down exactly to absolute zero. (Absolute Zero, news.scihb.com/2023)

In equilibrium thermodynamics, the downward flow is higher than the upward flow of the closed hysteresis (yellow-colored) (Figure 2).

2.3.1 Formula of the Carnot Cycle

The Carnot cycle is formed 4 intersection points of 2 reversible hysteresis which consist of 2 isothermal and adiabatic expansions, and 2 isothermal and adiabatic compressions. For instance, there are three Carnot cycles illustrated in Figure 3.

$$c1(x) = \frac{5\cdot\sin\left(x+\frac{\pi}{0.37}\right)}{|\cos(x)|} + 5; \quad c2(x) = \frac{15\cdot\sin\left(x+\frac{\pi}{0.35}\right)}{|\cos(x)|} + 5; c3 = \frac{5\sin\left(x+\frac{\pi}{0.37}\right)}{|\cos(x)|} - 20,$$

$$c4 = \frac{15\sin\left(x+\frac{\pi}{0.32}\right)}{|\cos(x)|} + 10 \tag{10}$$

$$c5 = \frac{10\sin\left(x+\frac{\pi}{0.37}\right)}{|\cos(x)|} - 10; \quad c6 = \frac{10\sin\left(x+\frac{\pi}{0.37}\right)}{|\cos(x)|} + 10$$

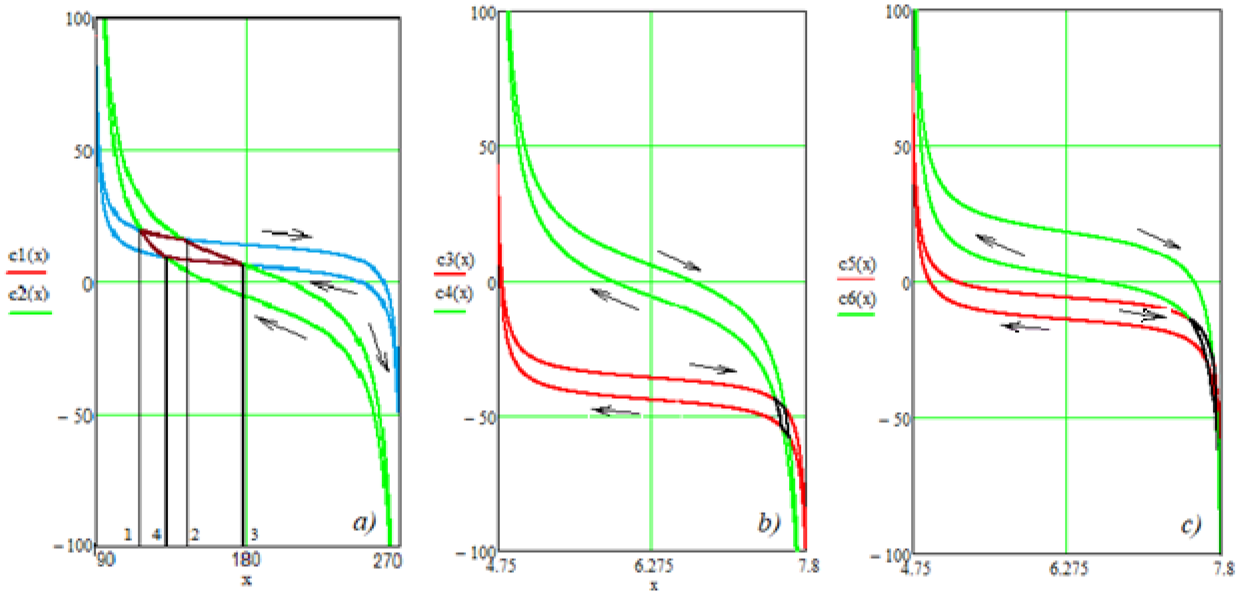

Figure 3. Carnot cycle generated from two hysteresis in equilibrium process

"For reversible processes, in infinitesimal form, it is $dS = \delta Q/T$, with dS being the infinitesimal entropy change or variation and δQ being the infinitesimal heat exchange." [20]

The generic form of the Carnot cycle is the same as Formula 8.

When two hystereses intersect the Carnot cycle occurs, and the equilibrium thermodynamics is formed. In the case of two non-crossing hysteresis, the non-equilibrium thermodynamics happens.

2.3.2 Work Done in Carnot Cycle

The work done in a cyclic process is equal to the area enclosed by the cycle on a pressure-volume graph (How do you calculate, tutorchase.com/)

The work generated by the heat engine needs to be based on a mathematical formula. The coordinates of the Carnot cycle are described as the intersections of two hysteresis (Formula 11):

$$f1(x) = \frac{A\sin\left(x+\frac{\pi}{n}\right)}{|\cos(x)|} \quad \text{and} \quad f2(x) = \frac{B\sin\left(x+\frac{\pi}{m}\right)}{|\cos(x)|} \tag{11}$$

When $f1(x) = f2(x)$, we get solutions: x1, x2, x3, x4 in the first half (90^0-270^0) and x1', x2', x3', and x4' in the second half (270^0-450^0) of Figure 4.

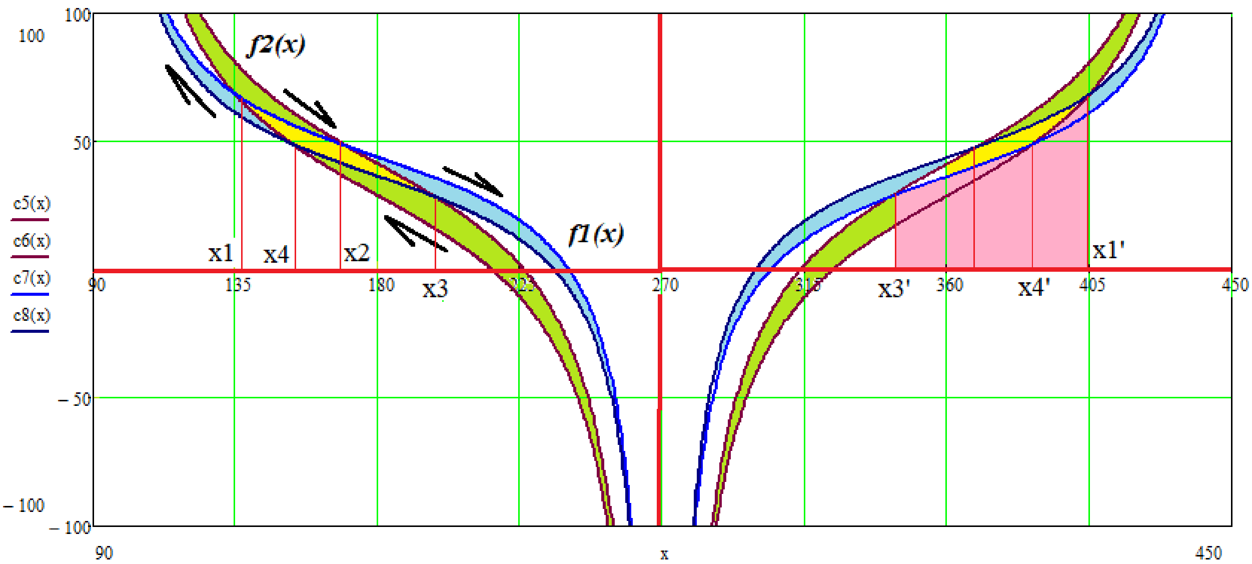

Figure 4. Emergence of the Carnot cycle from intersections of two hysteresis

The work done in the Carnot cycle equals its area (S) which equals the area under x1_x2_x3 extracts the purple-colored area (x3'_ x4'_ x1'). To calculate the area of the Carnot cycle and to avoid the negativity of logarithm heat we add 50 units to the vertical axis. The addition does not influence to calculation of the area (S).

$$f'1(x) = f1(x) + 50; \quad f'2(x) = f2(x) + 50$$

$$S_{carnot} = \int_{x1}^{x2} f'1(x)dx + \int_{x2}^{x3} f'2(x)dx - \int_{x3'}^{x4'} f'1(x)dx - \int_{x4'}^{x1'} f'2(x)dx \tag{12}$$

2.4 Nonequilibrium Thermodynamics

To assess irreversible processes Formula 13 needs to be written in the following form:

$$c(x) = \frac{A\,sin\left(x-\frac{\pi}{k}\right)}{|cos(x)|} \tag{13}$$

For example, when $A = 5\ and\ k = 0.37$ we get Formula 14 and Figure 5.

$$a1(x) := \frac{5\sin\left(x - \frac{\pi}{0.37}\right)}{|\cos(x)|} \tag{14}$$

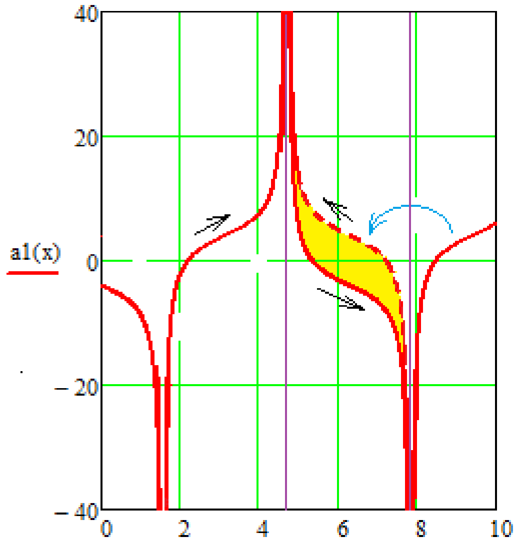

Figure 5. The hysteresis of the irreversible process by STE (Ulaanbaatar T., 2023)

Note that this figure is not computational

From Figure 5 we see that its first half decreases from 90 degrees to 270 (4.7-7.8 in the graph). It is a right-lifted hysteresis. The second half (270-450 degrees) may turn to the first half (Ulaanbaatar T., 2023a).

In nonequilibrium thermodynamics, the upward flow of the closed hysteresis is higher than the downward flow (Figure 5). An irreversible process means that more energy is required than equilibrium. But nature follows the principle of minimum energy. So, the irreversible process dominates in nonequilibrium thermodynamics. Figure 5 shows directly this irreversible process is reversible in closed hysteresis.

The principle of minimum energy is essentially a restatement of the second law of thermodynamics. (Principle of minimum energy, wikipedia.org)

In closed hysteresis and nonequilibrium thermodynamics, the backward increasing entropy of the upper adiabatic process requires more energy than the negentropy of the lower adiabatic (Figure 5).

The horizontal axis of all above Figures is not a line, but a circle, which includes miraculous secrets like spacetime and the arrow of time.

3. Concept of Spacetime and Arrow of Time

Louis de Broglie's wave-particle duality hypothesis which lies at the heart of Schrodinger's wave function (ψ) produces a complex wave equation whose mathematical structure can be described by Euler's famous equation, which describes a helix wave in 3D space (Bichara Sahely, 2015) (Figure 6).

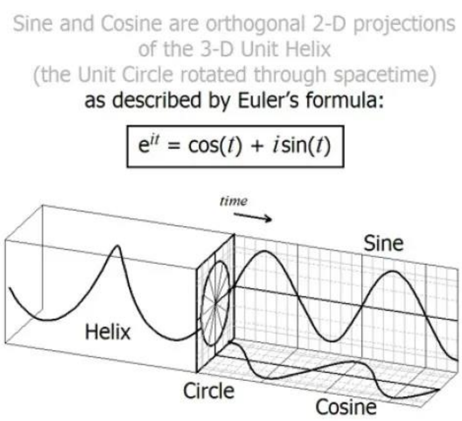

Figure 6. Euler's formula and its connection to the sine and cosine waves

(Bichara Sahely, 2015)

In 1748, Euler obtained his formula for complex analysis:

$$e^{ix} = cos\ x + isin\ x \qquad \text{(Euler, Leonard (1748), Euler's Formula, cuemath.com)} \qquad (15)$$

Here, *cosine* and *sine* are trigonometric functions, i is the imaginary unit, and *e* is the base of the natural logarithm.

$$e^{ix} = 1 + ix + \frac{(ix)^2}{2!} + \frac{(ix)^3}{3!} + \frac{(ix)^4}{4!} + \frac{(ix)^5}{5!} + \cdots \qquad (16)$$

So, Euler’s formula (15 and 16) is an approximation function. In reality, that is an approach.

Euler’s formula also so-called the Euler polyhedron formula in the case of ellipse, is topological invariance relating the number of faces, vertices, and edges of any polyhedron. It is written as $F + V = E + 2$, where F is the number of faces, V is the number of vertices, and E is the number of edges. (Euler’s formula, britannica.com)

We have described the first formula derivation of open hysteresis in electromagnetism in 2018 which illustrates a helical wave in 3D space same as the above shown in Figure 6. (Ulaanbaatar T., 2018a, 2018b, 2018c, 2019a, 2019b, 2020, 2021b, 2021c, 2021d) This formula has been used in different fields of research (2021e, 2022a, 2022b, 2022c, 2022d, 2022e, 2022f, 2023b, 2023c 2023d, Planck, M. 1926). Then, we also found another, but the same formula of the hysteresis based on the ellipse (Formula 19). (2021e)

Our hysteresis model (Formula 19) can solve exactly with the tools of mathematics so that neither approximations nor computer simulations are required.

Let's compare Formula (19) of hysteresis with Euler's formula (Formula 15 and Formula 16).

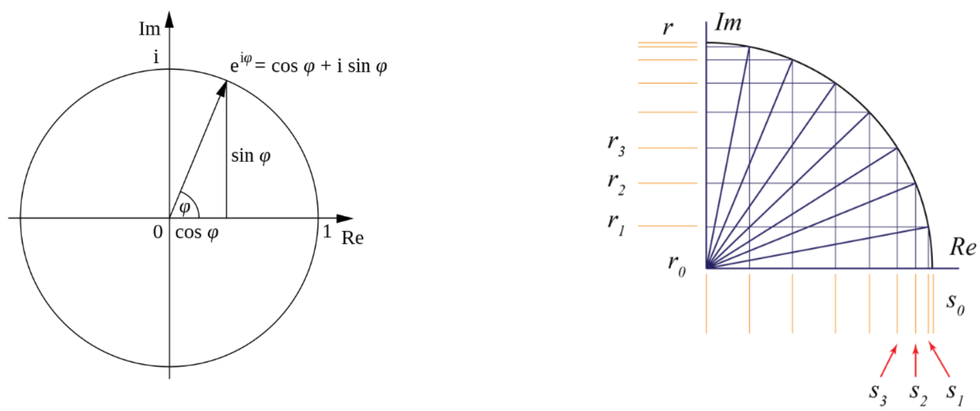

Figure 7. The imaginary concept in Euler’s formula (a) (Euler's Formula, cuemath.com) and formulation of hysteresis (b) (2021e)

(Projection scales (s) on the real part and (r) on the imaginary part)

Figure 7a shows that Euler’s formula derives from the addition of vectors in a circle ($\sin(\bar{\varphi})$ and $\cos(\bar{\varphi})$). At the same time, the Supreme Theory of Everything describes the division (ratio) of both functions ($\sin(\varphi)/\cos(\varphi)$) shown in Figure 7b.

According to the trigonometric method, we can determine the scale of circle projection on the horizontal and vertical axis as the next form:

$$\sin(\theta) = \frac{r_\theta}{r}; \quad \cos(\theta) = \frac{s_\theta}{r}; \quad tan(\theta) = \frac{r_\theta}{s_\theta} \qquad (17)$$

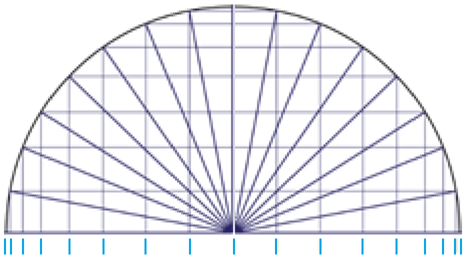

Figure 8. Circle scale

The circle scale is more suitable than the logarithm scale (2019a) for determining large-scale quantities.

The cosine function is real, while the sine function can be the imaginary part (Figure 7b). From Formula 17 emerges a circle scale, a fundamental base of the sphere projection (Figure 8).

In the case of time, the circle scale is also a time scale. Formula 17 and Formula 18 indicate that:

$$tan(\theta) = \frac{r_\theta}{s_\theta} = \frac{Imaginary\ number}{Real\ number} = \frac{Im}{Re} = \frac{\sin(\theta)}{\cos(\theta)} \tag{18}$$

In mathematics, a real number is a value of a continuous quantity that can represent a distance along a line (or a quantity that can be represented as an infinite decimal expansion) (2021d and The real number, wikipedia.org). For this reason, there is no negative distance or space and the denominator of Formula 5 must be written in absolute value. Only space is always absolute, everything else is always relative.

Formula 19 represents that cosine represents space and sinus represents time.

$$f_{circle}(\theta) = \frac{\sin(\theta)}{|\cos(\theta)|} \tag{19}$$

As written above Euler showed also the sine function is imaginary.

Table 1. Responses of different incident angles in Euler's Formula (1) and Formula (5)

Angle			0	45	90	135	180	225	270	315
Euler's	Formula (1)	$e^{i\theta}$	1		$\sqrt{1}$	-1	-1		$-\sqrt{1}$	
		$e^{-i\theta}$	1		$-\sqrt{1}$	1	-1		$\sqrt{1}$	
Hysteresis'	Formula (5)		0	1	∞	1	0	-1	$-\infty$	-1
	Formula (5) is the ratio of sine to cosine		0:1	1	1:0	1	0:1	-1	$-$ 1/0	-1

Note: The ratio is a comparison, not a division.

From the rows of Table 1, we see that the real numbers are at 0, 45, 135, 180, 225, and 315 degrees, while the imaginary characters if we wish, may be included at 90 and 270 degrees. But the *i* is not useful in our Formula 18 and Formula 19. So, it means the concept of spacetime in which the sine function possesses the time domain and the cosine function is the space domain. Also, we may understand Formula 18 and Formula 19 as ratios of sine and cosine functions. In this case, the ratio is more understandable and closer to reality.

In the case of an ellipse, Euler's formula shows the so-called Euler polyhedron formula. In contrast, the hysteresis formula is easy to describe for most natural phenomena because it is without an imaginary number. (2021e, 2022a, 2022b, 2022c, 2022d, 2022e, 2022f, 2023b, 2023c, 2023d):

$$f_{ellipse}(\theta) = \frac{imaginary}{real} = \frac{A \cdot sin(\theta \mp \gamma)}{|cos(\theta)|} \tag{20}$$

Where A is the amplitude of a function or eccentricity of the ellipse and γ is an initial angle with 0 degrees of circle.

When A is equal to 0 the shape of the geometrical figure is a circle. And if $A < 1$, it means a horizontal ellipse, and finally, $A > 1$ vertical ellipse (Formula 20).

The solutions at 90 and 270 degrees of the Formula 19 are undefined or infinite. However, its renormalization is not needed because Formula 19 is not only a division of sine and cosine functions but also their ratio (fourth row in Table 1).

The arrow of time remains one of physics' most perplexing enigmas (Planck, M.1926, Reichenbach, 1956. Grünbaum, A. 1967, Earman, J. 1967, Irreversibility and temporal asymmetry. *J. Philos.* 1967, Willems, J.C., 1974, Lyon, R.H. 1975, Kroes, P. 1985, Horwich, P. 1987). Even though time is one of the most familiar concepts humankind has ever encountered, it is the least understood. Puzzling questions of time's mysteries have remained unanswered throughout the centuries. Questions such as, where does time come from? (Wassim M. 2017)

Human experience perceives time flow as unidirectional; the present is forever flowing towards the future and away from a forever fixed past. Many scientists have attributed this emergence of the direction of time flow to the second law of thermodynamics due to its intimate connection to the irreversibility of dynamical processes (Yang, C.N.; Milles, R. 1954). In this regard, thermodynamics is disjoint from Newtonian and Hamiltonian mechanics (including Einstein's relativistic and Schrödinger's quantum extensions), since these theories are invariant under time reversal, that is, they make no distinction between one direction of time and the other. Such theories possess a time-reversal symmetry, wherein, from any given moment, the governing laws treat the past and future in the same way [Christenson, J.H.; 1964, Lamb, J.S.W.; 1998, Entropy as… wikipedia.org, Time's Dual Faces… facebook.com). It is important to stress here that time-reversal symmetry applies to dynamical processes whose reversal is allowed by the physical laws of nature, not a reversal of time itself.

In statistical thermodynamics, the arrow of time is viewed as a consequence of high system dimensionality and randomness. However, since in statistical thermodynamics, it is not absolutely certain that entropy increases in every dynamical process, the direction of time, as determined by entropy increase, has only statistical certainty and not an absolute certainty. Hence, it cannot be concluded from statistical thermodynamics that time has a unique direction of flow.

There is an exception to this statement involving the laws of physics describing weak nuclear force interactions in Yang-Mills quantum fields (Yang, C.N.; Milles, R.1954). In particular, in certain experimental situations involving high-energy atomic and subatomic collisions, meson particles (K-mesons and B-mesons) exhibit time-reversal asymmetry (Christenson, 1964). However, under a combined transformation involving *charge conjugation* $\mathcal{C}$, which replaces the particles with their antiparticles, *parity* $\mathcal{P}$, which inverts the particles' positions through the origin, and a time-reversal *involution* $\mathcal{R}$, which replaces t with $-t$, the particles' behavior is $\mathcal{CPR}$-invariant. For details see (Lamb, J.S.W. 1998)

When we consider the arrow of time the concept of entropy becomes particularly intriguing.

Entropy is one of the few quantities in the physical sciences that require a particular direction for time, sometimes called an arrow of time. (Entropy as an…Wikipedia.org)

The time circle is illustrated in Figure 7b, Figure 8, and Figure 9. Since, the past, present & future all exist simultaneously.

From Figure 2, we can see the cycle of time as follows: The projection step of the angle (s) horizontal axis (Re axis) at each unit angle of the circle will decrease and reach the zero value. Then the projection steps will continue to increase and then decrease each quarter, becoming a full circle. On the contrary, the angular projection steps on the vertical axis (Im axis) are decreased and increased. Thus, the steps of the projection on the two axes alternately increase and decrease. This is the cycle of time. Theoretically, the arrow of time can turn right or left. But because negentropy is getting smaller and higher orders in singularity, the arrow of time obeys in the direction of the low negentropy. On the other condition, the irreversible processes require more and more energy than the reversible ones. Nature prefers situations that require a minimum of energy.

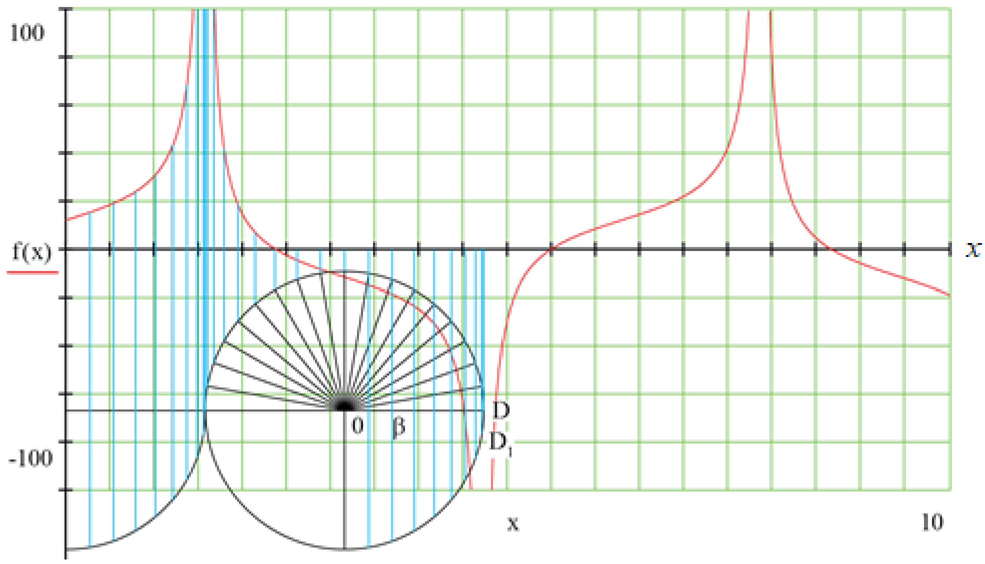

Figure 9. Circle of time showing the arrow of time [Ulaanbaatar T. 2018b]

Figure 9. illustrates the time circle by perpendicular circumstance. But when we see it from 0 perspectives or angles along the x-axis, half of the time circle is projected objectively on the x-axis and the other subjective half is impossible to watch. It hides the understanding of time (Figure 10).

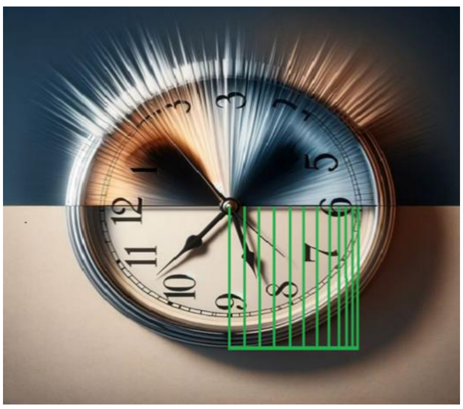

Figure 10. Time's Dual Faces: Objective and Subjective Perception (Time's Dual Faces, facebook.com)

Scientifically, time is an objective and measurable dimension, while subjectively, it is perceived differently by individuals, leading to a complex interplay between measurable phenomena and philosophical and personal experience. (Time's Dual Faces, facebook.com) Thus, time has a possibility of an imaginary one.

Formula 19 indicates objective perception is real, and subjective perception is imaginary.

The so-called 'arrow of time' supposedly points to a move spread out and a 'random' future, toward which everything is moving. This is also known as entropy, which tends to increase with time. Entropy, a consequence of the Second Law of Thermodynamics, will increase as energy dissipates and matter and energy disperse. (Time's Dual Faces, facebook.com)

Time is not linear, it happens simultaneously. Everything, including the past and future, all are happening right now. Past lives are actually parallel lives. Time is a manmade 3D construct. In higher dimensions, there's no such thing as time because we experience everything happening simultaneously in the NOW. As ONE. (Time is an illusion, facebook.com)

Reversible processes fulfill time-reversal symmetry and irreversible processes break time-reversal symmetry. Irreversible processes are real processes resulting also in changes in the rest of the thermodynamic universe. (Absolute Zero… news.scihb.com)

In statistical thermodynamics, the arrow of time is viewed as a consequence of high system dimensionality and randomness. However, since in statistical thermodynamics, it is not certain that entropy increases in every dynamical process, the direction of time, as determined by entropy increase, has only statistical certainty and not an absolute certainty. Hence, it cannot be concluded from statistical thermodynamics that time has a unique direction of flow. (Andreas Henriksson, 2023)

Humanity has long known that any event repeats itself in a short or long time. Some repetitions are seen and felt, others are not. Philosophy recognizes that history repeats and has a cause-and-effect relationship, but it cannot mathematize philosophy to explain its recurrence over time. The repetition of history represented by hysteresis with memory obeys subject to the cycle of time. All the good and bad things you do are saved in the memory of the system and come back to you. Memory is too mechanical because it does not make mistakes, it does not get lost in the road, and it cannot forgive. In other words, the memory of hysteresis contains everything including information, intuition, consciousness, neuroscience, and biological movement.

The new theory of time suggests that the past, present, and future co-exist in the universe. (Jonathan O'callaghan, dailymail.co.uk/sciencetech)

“We’re not located at a single time.” (Peter Dizikes, 2015, news.mit.edu)

Some say this may lead to a ‘heat death’ future where everything is spread so thinly that nothing can exist anymore. (The Arrow of Time, news.sciandnature.com)

Rather, he favors a theory known as the ‘block universe’, which states that the past, present, and future already exist. Dr. Bradford Skow said that he does not think events sail past us and vanish forever - instead, they exist in different parts of space-time. (Jonathan O'callaghan, dailymail.co.uk/sciencetech)

4. Entropy, Information, Superconductivity in Hysteretic Thermodynamics

4.1 Entropy and Negentropy

These subjects work in hysteresis.

Truly understanding entropy leads to a radical change in the way we see the world. Ignorance of it is responsible for many of our biggest mistakes and failures. (Entropy: The Hidden Force, fs. blog/entropy/#_ftnref1) Entropy is a fundamental concept in physics that underlies the evolution and fate of our universe. (Alpha Macharia, vocal.media/education) Entropy is one of the most important, yet least understood concepts in all of physics. (Derek Muller, aatventure.news) The amount of thermal energy per unit temperature in a system that is not available for useful work is referred to as entropy. **(**Why is entropy always increasing? byjus.com) Basically, entropy is a reflection of the statement that "It's easier to destroy than to build". Left unchecked disorder increases over time. (Jonathan O'callaghan, dailymail.co.uk/sciencetech)

Entropy is the measure of a system’s thermal energy per unit temperature that is unavailable for doing useful work. (Why does the entropy of the universe keep increasing? www.quora.com)

The third law of thermodynamics states that the entropy of a closed system at thermodynamic equilibrium approaches a constant value when its temperature approaches absolute zero. These are some of the most challenging and fascinating questions in physics that have not been answered yet. (Entropy, https://www.britannica.com) Entropy is not energy, but a measure of how much energy is lost in a system. If a system loses too much energy, it will disintegrate into chaos while negentropy is reverse entropy. It means things are becoming more in order. By 'order' is meant organization, structure, and function: the opposite of randomness or chaos. As a general rule, everything in the universe tends towards entropy. Star systems eventually become dead. All energy has gone, and everything in the system is at the temperature of the surrounding space. The opposite of entropy is negentropy. It is a temporary condition in which certain things are hotter and more highly organized than the surrounding space. This is the second law of thermodynamics: The second law of thermodynamics states that the total entropy of an isolated system always increases over time. The increase in entropy accounts for the irreversibility of natural processes, and the asymmetry between future and past. (Antonio Paixao, 2023) The good news is that entropy has an opposite – negentropy. (Negentropy, https://simple.wikipedia.org)

The term *negative entropy* was introduced by the Austrian physicist Erwin Schrödinger (1887–1961) in his book What is Life? (Alison Carr-Chellman, 2021, Negentropy, wiktionary.org)

Entropy is the curve in the 2nd half of the open hysteresis, while negentropy is the curve in the 1st half (Figure 11a). Also, it delegates that the main sequence of the Herzsprung-Russell Diagram represents the negentropy, while entropy represents the energy mass reserve. [Ulaanbaatar, T., 2018a, 2018c, 2019a, 2021c)

$$c(x) = \frac{A\sin\left(x - \frac{\pi}{b}\right)}{|\cos(kx)|} \quad (21)$$

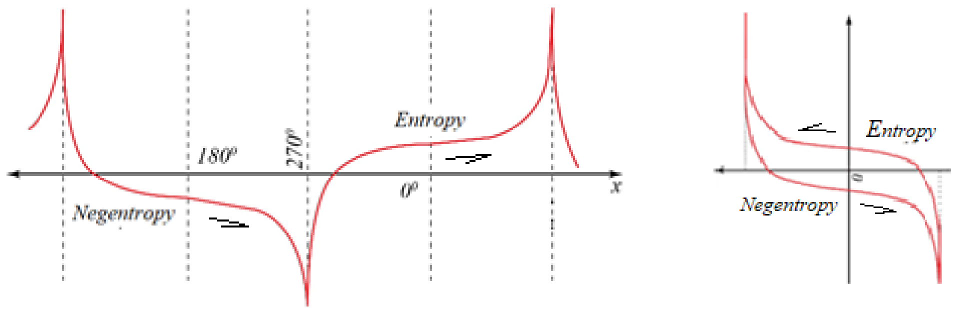

Figure 11. Entropy and negentropy in the open hysteresis (a) and closed hysteresis (b)

Therefore, the area of the closed hysteresis is limited by the range of entropy and negentropy (Figure 11b). Entropy is all the resources such as energy, mass, electromagnetism, consciousness, and so on.

If as we follow the arrow of time we find more and more of the random element in the state of the world, then the arrow is pointing toward the future; if the random element decreases the arrow points toward the past. (Entropy: The Hidden Force, fs. blog/entropy/#_ftnref1)

It happens at 270^0 in Figure 11.

I would like to remember Schrödinger's big. In his book, Schrödinger originally stated that life feeds on negative entropy, or negentropy as it is sometimes called, but in a later edition corrected himself in response to complaints and stated that the true source is free energy. [Roberto Zivieri, 2023, Eshel Ben-Jacob, Yoash Shapira, Alfred I Tauber, 2006, Entropy and life, https://en.wikipedia.org)

Schrödinger's first explanation is incorrect, life feeds on entropy, and entropy may call itself free energy.

A common misconception of the principle of the entropy increase is surmising that if entropy increases in forward time, then it necessarily decreases in backward time. However, entropy and second law do not alter the laws of physics in any way—the laws have no temporal orientation. In the absence of a unified dynamical system theory of thermodynamics with Newtonian and Einsteinian mechanics, the second law is derivative of the physical laws of motion. Thus, since the (known) laws of nature are autonomous to temporal orientation, the second law implies, with identical certainty, that entropy increases both forward and backward in time from any given moment. This statement, however, is not true in general; it is true only if the initial state of the universe did not begin in a highly ordered, low entropy state. This further establishes that the concept of time flow directionality, which rarely enters any physical theory, is a defining marvel of thermodynamics. (Wassim M. 2017)

One of the recurring features of history is the so-called "past hypothesis". It was the correct theory.

In cosmology, the past hypothesis is a fundamental law of physics that postulates that the universe started in a low-entropy state, (Callender, Craig 2011) by the second law of thermodynamics. The second law states that any closed system follows the arrow of time, meaning its entropy never decreases. Applying this idea to the entire universe, the hypothesis argues that the universe must have started from a special event with less entropy than is currently observed, in order to preserve the arrow of time globally. (John Earman 2006, Past hypothesis, https://en.wikipedia.org)

"Past Hypothesis": Not even false, wrote John Earman (Callender, Craig 2011). He was right because the Universe began in a high-ordered negative singularity (Figure 11).

There is negentropy in the first half and entropy in the second half of the open hysteresis (Figure 11a). When the entropy transfers into the first half of Figure 11b, they form a closed hysteresis. In other words, negentropy goes by the arrow of time to more ordered states.

In short, we can define entropy as a measure of the disorder of the universe, on both a macro and a microscopic level. Entropy is simply a measure of disorder and affects all aspects of our daily lives. We have all observed entropy in our everyday lives. (Entropy: The Hidden Force, https://fs.blog/entropy/#_ftnref1)

Anyway, entropy is omnipotent. As a result of entropy, negentropy is formed. But I did not know the relationship between negentropy and entropy as described above, I would agree that entropy is a measure of the disorder of the universe. Now it's different, I underline that entropy is not a measure of chaos, but a very fine order of the universe.

4.2 Information in Both Entropy and Negentropy

Entropy and negentropy are the same forms of information.

A key measure in information theory is entropy. (Information theory, wikipedia.org)

In information theory, the entropy of a random variable is the average level of "information", "surprise", or "uncertainty" inherent to the variable's possible outcomes. (Entropy (information theory), wikipedia.org) In digital electronics, however, there are only two states -- ON or OFF. Using these two states, devices can encode, transport, and control a great deal of data. Logic levels, in the broadest sense, describe any specific, discrete state that a signal can have. In digital electronics, we generally restrict our study to two logic states - Binary 1 and Binary 0. (Logic Levels, learn.sparkfun.com)

Thus, electronic systems work alone with digital signals which seem to develop more and more analog due to information technology while the universe lies in a world of analog signals.

Connections between thermodynamics and system theory, as well as information theory have also been explored in the literature (Willems, J.C.1974, Ziman, J.M., Pavon, M.1989, Brunet, J.1989, Bernstein, D.S.; Hyland, D.C.1993, Haddad, W.M.; Chellaboina, V.; August, E.2001, Brockett, R.W.; Willems, J.C.1978, Bernstein, D.S.; Bhat, S.P.2002, Willems, J.C.1972, Ydstie, B.E.; Alonso, A.A.1997). Information theory has deep connections to physics in general, and thermodynamics in particular. Many scientists have postulated that information is physical and have suggested that the bit is the irreducible kernel in the universe and it is more fundamental than matter itself, with information forming the very core of existence Gleick, J. 2011, Landauer, R.1991).

We understand information more or less in general, but we don't know much about entropy. According to the Supreme Theory of Everything, entropy is itself a lot of resource information terms which includes energy, mass, impulse, power, heat, direction, size, and so on. For this reason, both entropy and information are described by Formula 19 and Formula 20.

Entropy is a measure of the amount of hidden or missing information contained in a system, not a measure of the amount of available or unavailable energy. (Domino Valdano, 1017)

4.3 Superconductivity in Negative Singularity

The reversible and irreversible processes assimilate into the superconductivity. So, as mentioned at the beginning of Section 3 the efficiency of a Carnot engine was given by

$$1-\frac{T_C}{T_H} \text{ and } T_H > T_C.$$

If T_H reaches T_C we cannot talk about the Carnot cycle but can about the superconductivity.

$$\eta = \lim_{T_h \to T_c}\left(1-\frac{T_C}{T_H}\right) = 0$$

According to the traditional definition of entropy, it equals heat divided by temperature. In other words, it should be expressed by the Temperature-Heat diagram. It is not determined by Boyle's law or Planck's law but by the Modified Spectral Density of Electromagnetic Radiation (NonPlanck's) [52] which is written by the next Formula:

$$\Delta S = \frac{A\cdot sin(T_h - T_c)}{|cos(T_h)|} \tag{22}$$

Where A is the amplitude of the entropy, T_c is the critical temperature in an angle of time circle and T_h is the temperature of the superconductivity in Kelvin.

Formula 22 expresses the left-open hysteresis of the entropy. (Ulaanbaatar, T., 2023d) Now, Tc is the critical temperature which is the upper limit of the remnant superconductivity and cannot reach absolute zero.

Superconductivity is the property of certain materials to conduct direct current (DC) electricity without energy loss when they are cooled below a critical temperature (referred to as Tc). Superconductors are materials that offer no electrical resistance so that electricity can pass through them with close to 100 percent efficiency. These materials also expel magnetic fields as they transition to the superconducting state. (DOE Explains...Superconductivity, energy.gov)

We insert the general formula of hysteresis in the superconductivity surrounding 0 K as the next:

$$f_{circle}(\theta) = \frac{\sin(\theta \mp \tau)}{|\cos(\theta)|} \tag{23}$$

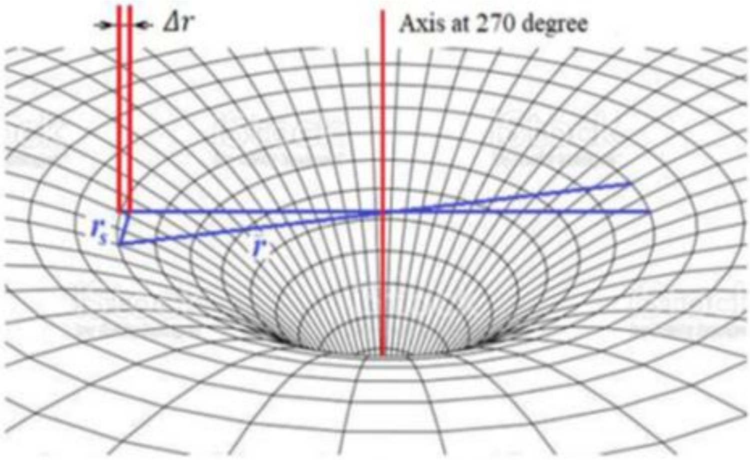

Figure 12. The negative singularity of the open hysteresis is a critical temperature of the superconductivity

(The picture transformed based on (Abstract wireframe tunnel, istockphoto.com)

(Credit: Mykola Kaplun)

The negative singularity shown in Figure 12 illustrates its 3D space near 270 degrees of vertical axis in the singularity. The critical temperature (Tc) fluctuates around the 0 K temperature in the unit of a circle. The dependence (Formula 24 and Table 2) between the depth of the singularity (d(x)) and the critical temperature of the superconductivity is as follows:

$$d(x) = \frac{\sin(270^0 + T_c)}{|\cos(T_c)|} \tag{24}$$

Table 2. The influence depth of critical temperature in a negative singularity

Tc	$d(x)$	Tc	$d(x)$
20	-2.75	0.01	-5,729.58
15	-3.73	0.005	-11,459.15
10	-5.67	0.0001	-572,957.79
5	-11.47	0.00005	-1,145,915.59
1	-57.29	0.000001	-57,295,779.51
0.5	-114.59	0.0000005	-114,591,559.02
0.1	-572.96	0.00000001	-5,729,577,951.31
0.05	-1145.91	0.000000005	-11,459,155,902.61

The coercive force of hysteresis is related to the resources of energy and mass reserves and relations of the entropy to negentropy.

If the system does not have a well-defined order (if its order is glassy, for example), then there may remain some finite entropy as the system is brought to very low temperatures, either because the system becomes locked into a configuration with non-minimal energy or because the minimum energy state is non-unique. The constant value is called the residual entropy of the system. (Third law of thermodynamics, https://en.wikipedia.org)

The entropy is essentially a state function meaning the inherent value of different atoms, molecules, and other configurations of particles including subatomic or atomic material is defined by entropy, which can be discovered near 0 K. (Third law of thermodynamics, https://en.wikipedia.org)

For reversible processes, in infinitesimal form, it is $dS = \delta Q/T$, with dS being the infinitesimal entropy change or variation and δQ being the infinitesimal heat exchange. (Absolute Zero Is Attainable? news.scihb.com/2023)

If we want to understand the thermodynamics of individual particles, we first have to analyze how thermodynamics and quantum physics interact—and that is exactly what Marcus Huber and his team did. "We quickly realized that you don't necessarily have to use infinite energy to reach absolute zero," says Marcus Huber. (Absolute Zero Is Attainable? news.scihb.com/2023, Absolute zero in the quantum computer, https://phys.org/news/2023)

5. Macroscopic Thermodynamics

5.1 Exchange Interaction Between Negentropy and Entropy

Nonequilibrium thermodynamics is common in all the scales from quantum to macroscopic and Universe-scale.

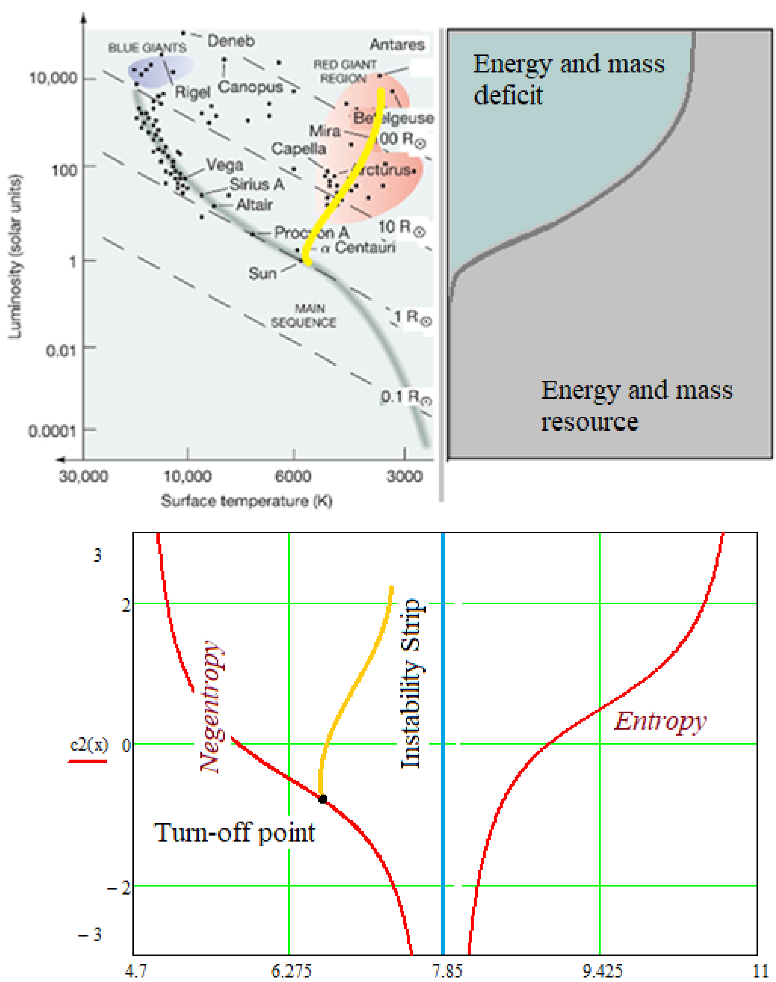

Figure 13. Main sequence (negentropy) and resources (entropy) on HRD Ulaanbaatar T., 2019a, 2020]

HRD in Figure 13a copied from Brau, J (Brau, J., pages.uoregon.edu.html)

(These intervals and figures are approximations and not exact)

Figure 13 shows the turn-off points and instability strip of stars in HRD as a result of the exchange interaction of Zero-age sequence stars (main sequence) and their resources of energy and mass. (Ulaanbaatar, 2020) The life of a star is fueled by entropy, which is located in the second half of Figure 13a and Figure 13b. Their first parts show the more in-order state of the negentropy, while the entropy in the second part is the amount of fuel (energy and mass resource).

The second half of Figure 13 and Figure 13b are the entropy of HRD. On the other hand, the main sequence is the negentropy of HRD.

Entropy must be higher than negentropy to live in a star. When entropy (any resources) decreases and approaches the negentropy, the negentropy (star) begins to break down. An example is that the turn-off point begins on the negentropy of the HRD at this time, and then the instability strip jumps rapidly to the Giant and Supergiant branches.

The superposition between negentropy and entropy determines the instability strip of HRD shown in Figure 13, which is the same as the ferrimagnetic phenomenon in the open hysteresis It looks like, in the quantum scale, the exchange interaction between the ferromagnetic and antiferromagnetic emerges as ferrimagnetic (See Figure 5 in (Ulaanbaatar, 2020)). If the repulsion wing is insufficient, the turn-off point begins, and then the instability strip jumps rapidly to exit. It is the horizontal branch of Supergiant in HRD. If the mass and energy resources are insufficient, the stars as SNIa and Supergiants in the instability strip of HRD explode rapidly and go backward. On the other words, if the strength of the repulsion wing is not enough, the instability strip turns rapidly back to the attraction wing. (Ulaanbaatar, T., 2021b)

Another example of hysteresis is the age of the celestial bodies. HRD diagram was directly inferred from astronomical observations.

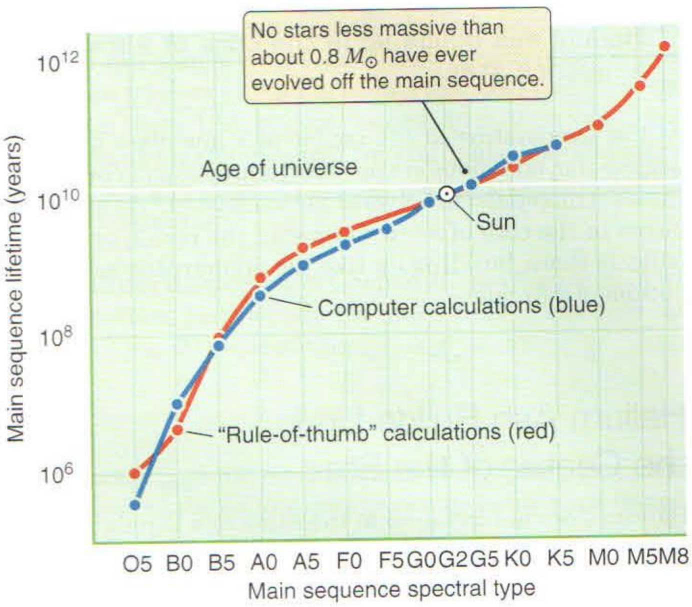

Figure 14. The main sequence lifetimes of stars (Jeff Hester, and others, 21st Century Astronomy)

We see that the age of stars obeys the law of hysteresis in Figure 14. But the age graph of the stars needs to extend from 40000 K (Kelvin) to at least 1 million K upward and from 2000 K to at least 10^{-6} K downward.

A main sequence star can live for only so long time. But how long is "long"? The question "How long can a main sequence star continue to burn hydrogen in its core?" is much like the question "How long can you drive your car before it runs out of gas?". In the case of the car, the answer depends in part on how much gas your tank holds. The larger the gas tank, the more fuel you have and so the longer your motor might run. But the answer also depends on the size and efficiency of your motor. (Jeff Hester, and others, 21st Century Astronomy)

The competition between these two effects size and motor size is most readily expressed as a ratio. How long your motor runs is given by the amount of gas in the tank, divided by how quickly the motor uses it:

$$Lifetime\ of\ tank\ of gas(hours) = \frac{Amount\ of\ fuel\ (gallons)}{Rate\ at\ which\ fuel\ is\ used\ (gallon/hour)} \tag{25}$$

The same principle works for main sequence stars. The "amount of fuel" is determined by the mass of the star. An expression for the lifetime of the star looks very similar to our previous expression for the time it takes for your car to run out of fuel:

$$Lifetime\ of\ star = \frac{Amount\ of\ fuel\ (mass\ of\ star)}{Rate\ fuel\ is\ used\ (luminosity\ of\ star)} \tag{26}$$

Higher mass means a short lifetime. Low-mass stars live much longer than high-mass stars.

The high spectral type stars live for a short time while the dim stars and celestial bodies including the dark matter stay "eternal" (Figure 14).

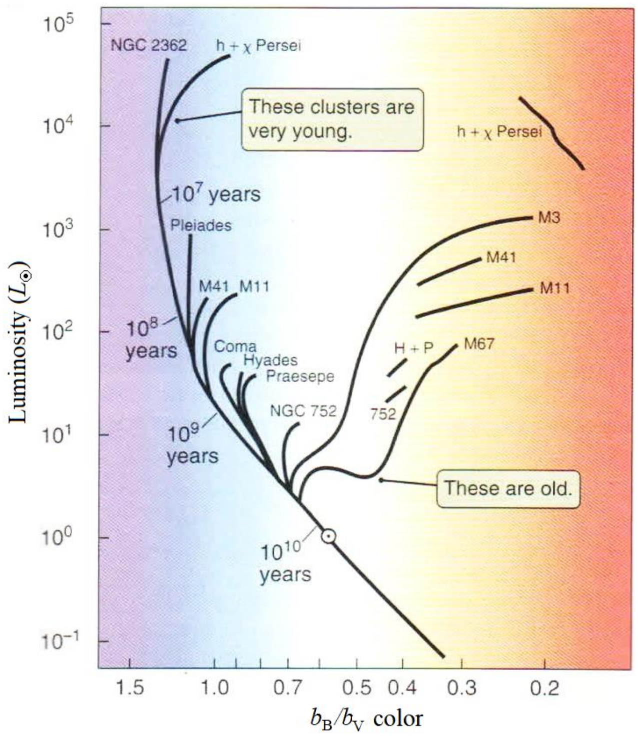

Figure 15. HRD of various galactic star clusters (Jeff Hester, and others, 21st Century Astronomy)

The HRD of stars shows their turn-off points and unstable strips for main sequence stars (Figure 13a). It is the same for different galaxies (Figure 15). The turn-off points and unstable strips are the consequences of negentropic and entropic interactions and reflections of their mass and energy reserves. Blue Giants, Rigel class stars among the main sequence stars in Figure 13a, and NGC2362 and h+χPersei galaxies have the largest energy and mass resources. The instability strip branching from the main sequence means the signs of the depletion of energy and mass reserves in the entropy.

The h+χPersei has a high turn-off point, because of its hysteresis loop, which is wider than the M41 or M11 (Figure 15). The curves of the negentropy and instability strip give us a great possibility to determine the entropy as a dark side of the H-R diagram.

The open hysteresis gives us a great possibility to evaluate the "dark side" in the second half of HRD assess the state of entropy and recognize all its features and characteristics.

6. Conclusion

Based on the overview of this article I can conclude that:

1. The reversible processes are formulated in the next form:

$$c(x) = \frac{A\,sin\left(x + \frac{\pi}{k}\right)}{|cos(x)|}$$

2. The irreversible processes are formulated in the next form:

$$c(x) = \frac{A\,sin\left(x - \frac{\pi}{k}\right)}{|cos(x)|}$$

3. The Carnot cycle forms 4 intersecting points of 2 reversible hysteresis which consist of 2 isothermal and adiabatic expansions, and 2 isothermal and adiabatic compressions.
4. The Carnot cycle has intersection coordinates of the two hysteresis.

$$f1(x) = \frac{A\sin\left(x+\frac{\pi}{n}\right)}{|\cos(x)|} \quad \text{and} \quad f1(x) = \frac{A\sin\left(x+\frac{\pi}{m}\right)}{|\cos(x)|}$$

5. The next formula indicates that cosine represents space and sinus represents time in the case of the circle:

$$f_{circle}(\theta) = \frac{imaginary}{real} = \frac{\sin(\theta)}{|\cos(\theta)|}$$

6. The formula becomes in the case of the ellipse:

$$f_{ellipse}(\theta) = \frac{imaginary}{real} = \frac{A \cdot sin(\theta \mp \gamma)}{|cos(\theta)|}$$

7. Negentropy and entropy are the first and second halves of the open hysteresis and the frame of closed hysteresis.
8. Negentropy of the open hysteresis is the same as the main sequence of the HRD and various galactic star clusters while the entropy includes all the resources.
9. Entropy must be higher than negentropy. When entropy decreases and approaches the negentropy, the negentropy begins to break down. An example is that the turn-off point begins on the negentropy of the HRD, and then the instability strip jumps rapidly to the Giant and Supergiant branches.

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No additional data are available.

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