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Re-examination of Fundamental Concepts of Heat, Work, Energy, Entropy, and Information Based on NGST

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In order to use the framework of general system theory (GST) to unify the three mechanics subjects of classical mechanics, quantum mechanics, and relativistic mechanics, a new general system theory (NGST) is developed based on a new ontology of ether and minds as the fundamental existences in the world. Based on this new ontology, many fundamental concepts have been detected to be ambiguously defined nowadays and particularly lack of ontological support. In our previous work, some of the fundamental concepts such as universe, world, time, space, matter, ether, mind, life, field, force have been redefined. The purpose of this paper is to clarify the concepts of energy, heat, work, entropy, and information in our NGST. This is an important and necessary step in the development of the NGST.

Keywords: new general system theory, heat, work, energy, entropy, information

Introduction

It is well-known that philosophical conflicts in ontology and epistemology exist among classical mechanics, quantum mechanics, and relativistic mechanics (e.g., Whitker, 2006). In order to explain the new phenomena observed such as wave-particle duality, black-body radiation, photoelectric effect, many scientists such as Einstein, Bohr, Planck, Von-Neumann, Heisenberg, Schrödinger adopted various approaches to solve the problems. This leads to the fact that no clear ontology is given in some newly developed theories such as quantum mechanics and relativistic mechanics. Many fundamental concepts such as time, space, matter, force, field, energy, heat, work have changed their meanings and the newly defined concepts such as entropy and information have blurred images due to the lack of ontological support. The story was well described by Heisenberg in his famous book *Physics and Philosophy: The Revolution in Modern Science* (Heisenberg, 2007).

In order to use the framework of general system theory (Bertalanffy, 1968; 1972; Chen & Stroup, 1993) to unify these three mechanics subjects, a new general system theory (NGST) is developed based on a new ontology of ether and minds as the fundamental existences in the world. Some of the fundamental concepts such as universe, world, time, space, matter, ether, mind, life, field, force have been redefined in our previous papers (Cui & Kang, 2020; Cui, 2021a; 2021b; Ma & Cui, 2021; Pan & Cui, 2021a; 2021b).

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The purpose of this paper is to re-examine the fundamental concepts of energy, work, heat, entropy, and information based on the mind-ether ontology and they are presented in section by section. Finally, some conclusions are drawn.

Energy

The word energy designates a key concept in modern physics, but as pointed out in the famed *Feynman Lectures on Physics* (Feynman, 1963) that present-day physicists do not know what energy is. This is because that there are various kinds of energy: kinetic, elastic, thermal, gravitational, electric, magnetic, nuclear, chemical, etc. (Bunge, 2000). Every particular concept of energy is defined in a given chapter of physics or in different fields such as Newtonian mechanics, thermodynamics, quantum mechanics, and relativistic mechanics. While in Newtonian mechanics, energy is a property of matter in parallel with the other properties such as mass, position, velocity, momentum, it was gradually turned into an independent existence in parallel with matter after Planck explained the black-body radiation in 1900 (Planck, 1901; 1914), Einstein explained the photoelectric effect in 1905 (Einstein, 1905; 1916), and Bohr explained the wave-particle duality in 1913 (Bohr, 1913; 1934). Nowadays in quantum mechanics and relativity theory, matter and energy are always treated as two independent existences. For example, Bevolo (2021) cited Grudin (2010), "Design focuses on the organization of energy, be it the energy flows within a building or a city, as well as the energy sustaining production processes and product manufacturing" (Grudin, 2010, p. 5). It is obvious that it is better to use matter to replace the energy here. It is our definition that "Design focuses on the organization of matter into a particular structure meeting certain performance requirements".

In order to explain the accelerating inflation of the world we can observe, another two existences of dark matter and dark energy have been introduced (Arun, Gudennavar, & Sivaram, 2017) and after more than 70 years search of dark matter, no discovery occurred. Furthermore, with these four independent existences, phenomena related to information cannot be explained and some philosophers and scientists suggested that information is another independent existence in parallel with matter and energy; a triangle of matter-energy-information was proposed (e.g., Draganescu, 1990; Gaiseanu, 2020). Following the same logic of dark matter and dark energy, it may also have dark information. Thus, there are six independent existences. This is very different from the original monist materialism which modern sciences are supposed to be based on.

Do we really need six independent existences in order to explain the phenomena we have observed? Based on the relativity of simultaneity axiom (Cui & Kang, 2020; Cui, 2021b), the answer is no. We think only two fundamental existences, ether and minds, are adequate to explain all the phenomena we have observed. Our ontology for the new general system theory has been presented in many other papers (Cui & Kang, 2020; Cui, 2021a; 2021b; Pan & Cui, 2021a; 2021b). In this section we mainly introduce our understanding of the concept of energy.

Basically, we agree with Bunge (2000) that energy is a property of matter and it describes the ability of movement of the matter. Without the material object, no matter it is a lifeless object or a living creature, it is meaningless to talk about the movement and its related quantities such as force and energy. As given in our previous papers (e.g., Cui, 2021b), matter is defined as an object of mass and it occupies finite space and possesses a particular position at any given time t. In our ontology, there is no need to use "self" concept to describe some behaviours related to living creatures such as self-regulation, self-organization, autopoiesis (Maturana & Varela, 1980), or dissipative structure (Prigogine, 1980) since we have the mind to explain these functions. Any macro material object is created by a life or several lives by accumulating ether in the world we are living which is a part of the whole universe and a life also possesses the ability to decompose the material object into small particles or ether (unobservable particles) and these particles enter into the world. In our ontology, we emphasize the importance of the distinction between universe and world (Cui, 2021a; 2021b). Any created object must have creator and creator must have resources for creation. This could resolve the paradoxes related to materialism and idealism. A body of matter with a mind is defined as a life or a living creature which can produce the active force to do work, generate information, and communicate with other lives. Mechanics is a subject to study the movement of observable material objects including both lifeless objects and living creatures but not the non-matter minds or spirits or unobservable ether. In our ontology, field is a concept used to explain the force phenomena (action at a distance) (Pan & Cui, 2021a) and field is also not a physical existence in parallel with matter. However, nowadays, the materialized field concept has been used in quantum field theory (e.g., Peskin & Schroeder, 1995) or relativistic field theory (e.g., Sundermeyer, 2014). In our ontology, both electromagnetic radiation and heat radiation are an object radiating unobservable particles and they are the carriers of mass, momentum, energy; all these are properties of matter rather than "electromagnetic radiation being the carrier of energy and entropy" as speculated by Beretta and Gyftopoulos in the title of their paper (2015a).

Energy can be divided into many types such as kinetic, elastic, thermal, gravitational, electric, magnetic, nuclear, chemical, etc. (Bunge, 2000). Common forms of energy include the kinetic energy of a moving object, the potential energy stored by an object's position in a force field (gravitational, electric or magnetic), the elastic energy stored by stretching solid objects, the chemical energy released when a fuel burns, the radiant energy carried by photons or other small particles, and the thermal energy due to an object's radiating small particles under higher temperature. Thus, this property can be used to describe the state of an object or a system. In a process from one state to another, several conservation laws should be followed and one of them is the conservation of energy (the first law of thermodynamics). The latest expression is as follows (Mandl, 1988, p. 4): "The total energy of an isolated system is constant; energy can be transformed from one form to another or transferred from one body to another, but can be neither created nor destroyed".

We argued that there are two problems in this definition. One is whether the isolated system contains living creature or not and the other is the energy creation which is also related to the living creature. Basically, the above statement may be only valid to an isolated system of lifeless objects. Cui recommended to revise it as: "For a given lifeless object of constant mass, its energy is conserved in any physical or chemical process; its energy can be transferred or changed from one form to another" (Cui, 2021a, p. 260).

For a closed system, it depends on whether a living creature exists or not. A living creature can create or increase energy to a lifeless object by doing work to it. For example, to lift a stone from the ground to the seventh floor, the potential energy of the stone is increased while the other state parameters are the same. How to calculate the energy consumption of the person due to this work is an unsolved problem at the moment. This will be discussed in "Heat" section.

In the relativistic mechanics (Einstein, 1916), mass is supposed to vary with velocity and rest mass and relativistic mass concepts together with the famous mass-energy equivalence principle ($E = m\mathrm{C}^2$) have been introduced and many objections have received (e.g., Adler, 1987; Okun, 1989a; 1989b; Wong & Yap, 2005; Hecht, 2009). In our ontology, mass and energy are two parallel material properties and energy must have a carrier of matter. Without that carrier, energy cannot exist. Thus, we do not accept zero-mass particles such as photon (Tu, Luo, & Gillies, 2005) or others. We think the zero-mass of photon is the consequence of Lorentz transformation and it is not the physical reality but mathematical extrapolation. If we have observed a particle, it will certainly have mass although we cannot measure it at the moment. Even for those unobservable particles whose ensemble is defined as ether, all the particles in the ensemble of ether have masses. In any process of state change, the mass conservation law should always be followed. There is no such a conversion that mass can be transformed into energy or energy transformed into mass. In different from the hypothesis of invariant format of physical laws made by Einstein (1916), we use the hypothesis of invariant fundamental parameters such as mass, length, time, temperature (Phipps, 2014; Sato, 2018) since these units are defined by our human beings. We still use the Galilean transformation rather than the Lorentz transformation (Selleri, 1997) since the latter is against our life experience; we do not rely on the concepts of inertial coordinate system and the absolute vacuum which all exists in our minds but not physical reality (Pan & Cui, 2021b).

Work

In a dictionary, work has many meanings and may refer to: (1) human activity, intentional activity people perform to support themselves, others, or the community; manual labour, physical work done by humans; housework, or homemaking; (2) work (physics), the product of force and displacement; work (electric field); work (thermodynamics), energy transferred by the system to its surroundings; (3) creative work, a manifestation of creative effort, work of art.

In the new general system theory, work is specifically reserved for the definition in physics, that is, work is a physical quantity transferred to or from an object via the application of force along a displacement, so work equals the product of force and displacement. This force can include both active force from a living creature such as a human being or a horse, active force from a steam engine and passive force of a charged particle by an electric field, a massive particle by the gravitational field.

A force is said to do positive work if (when applied) it has a component in the direction of the displacement of the point of application. A force does negative work if it has a component opposite to the direction of the displacement at the point of application of the force. When the force F is constant and the angle between the force and the displacement s is θ, then the work done is given by:

$$W = Fs\,cos(\theta) \tag{1}$$

Work is a scalar quantity, so it has only magnitude and no direction. The unit of work is the same as energy, but for work done by all passive forces, they correspond to a specific name of energy. For example, the potential energy for the gravitational force and the magnetic energy for the electric force. So only the active force does not correspond to the specific name of energy. Thus, work in our theory is specifically reserved for active force such as the force from a human being or a horse or the active force from a steam engine. In the process of work, it does not involve the exchange of matter, so we regard work and energy are two different concepts. Exchange of energy including heat discussed in the next section from one object (or system) to another always involves the exchange of matter; however, one object (or system) doing work to another does not involve the exchange of matter, that is the emphasis we want to make in this section for the concept of work.

In our ontology, there are all together five types of forces. The currently known four (gravitational force, electromagnetic force, strong and weak force) are all related to matter and they are called passive forces. The active force is called psychic force which is due to the interaction of mind and body (Cui, 2021b). All the forces can be explained by the concept of corresponding field (Pan & Cui, 2021a).

Work is closely related to energy. The work-energy principle states that an increase in the energy of a body is caused by an equal amount of positive work done on the body by the resultant external force acting on that body. Conversely, a decrease in energy is caused by an equal amount of negative work done by the resultant force. Thus, if the net work is positive, then the particle's energy increases by the amount of the work. If the net work done is negative, then the particle's energy decreases by the amount of work (Walker, Halliday, & Resnick, 2011). In particular, a man can increase energy to an object through doing work, for example, a man lifts a stone from the ground to the 7th floor of a building; the potential energy of this stone is increased due to the work done by this man.

While energy can be viewed as a state variable, work is certainly not and it only occurs in the process of displacement change and it is the consequence of force and the change of positions. Without force, there is no work and without the change of positions (i.e., displacement), there is no work. In the process of work, there is no exchange of matter while both position and force are state variables and need the carrier of matter.

Heat

The concept of heat is also one of the most poorly understood concepts in physics. Beretta and Gyftopoulos (2015b) carried out a specific survey to the definition of heat. Many different definitions have been found and they are re-cited here for readers' convenience. Feynman (1963) described heat as

> one of several different forms of energy related to the jiggling motion of particles stuck together and tagging along with each other (pp. 1-3 and 4-2), a form of energy which really is just kinetic energy—internal motion (p. 4-6), and is measured by the random motions of the atoms (p. 10-8).

Obviously, if the particle has only mass, then, the movement in the gravitational field involves the change of kinetic energy and potential energy. If the particle has mass and charge, the movement involves the change of kinetic energy, potential energy, electric energy, and magnetic energy. So in Feynman's concept of heat, it is actually the total energy of the particle, not just kinetic energy. Thus, heat is basically another name for the total energy but not another type of independent energy. In most situations, the change of potential energy for the massive particle may be negligible in comparing with the change of kinetic energy. Tisza (1966) argued that such slogans as "heat is motion", in spite of their fuzzy meaning, convey intuitive images of pedagogical and heuristic value. Landau and Lifshitz (1980) defined heat as the part of an energy change of a body that is not due to work done on it. Guggenheim (1967) defined heat as an exchange of energy that differs from work and is determined by a temperature difference. Keenan (1941) defined heat as that which transfers from one system to a second system at lower temperature, by virtue of the temperature difference, when the two are brought into communication. Similar definitions are adopted in notable textbooks, such as Van Wylen and Sonntag (1978), Wark (1983), Huang (1976), Modell and Reid (1983), and Moran and Shapiro (1988). Beretta and Gyftopoulos (2015b) criticized that

> none of these definitions, however, addresses the basic problem. The existence of exchanges of energy that differ from work is not granted by mechanics. It is one of the striking results of thermodynamics, that is, of the existence of entropy as a property of matter. (p. 1)

Hatsopoulos and Keenan (1965) have pointed out explicitly that without the second law heat and work would be indistinguishable and, therefore, a satisfactory definition of heat is unlikely without a prior statement of the second law. In order to overcome above mentioned problems, Gyftopoulos and Beretta (1990) made great efforts to develop the basic concepts without ambiguities and logical inconsistencies. Their definition of heat is given as follows: “Heat is a particular kind of nonwork interaction that involves only energy and entropy transfers, and that is entirely distinguishable from work. The existence of heat interactions is a consequence of the first and second laws of thermodynamics” (Beretta & Gyftopoulos, 2015b, p. 1).

We agree with their emphasis that heat should be very different from work but still did not agree with their definition because they treat heat as an independent existence. A typical illustration of such a concept can be found in the following example. “When two otherwise isolated bodies are connected together by a rigid physical path impermeable to matter, there is the spontaneous transfer of energy as heat from the hotter to the colder of them” (Beretta & Gyftopoulos, 2015b, p. 6). Another example is

> Denbigh concluded that it seems, however, that when a system is able to exchange both heat and matter with its environment, it is impossible to make an unambiguous distinction between energy transported as heat and by the migration of matter, without already assuming the existence of the “heat of transport”. (Denbigh, 1981, p. 56)

Furthermore, their definition refers to another concept of entropy which occurred much later than the heat and this is not necessary from our point of view.

The definition of heat was originated from the description of a process and thus heat is certainly a parameter for process; however, since heat can also be used to describe the total energy of an object or a system, heat can also be regarded as a parameter for state. No matter it is used for describing the state or process, heat is definitely a property of matter. In the early definition by Joule, the father of heat, this point can be seen very clearly.

> Heat must therefore consist of either living force or of attraction through space. In the former case we can conceive the constituent particles of heated bodies to be, either in whole or in part, in a state of motion. In the latter we may suppose the particles to be removed by the process of heating, so as to exert attraction through greater space. I am inclined to believe that both of these hypotheses will be found to hold good, —that in some instances, particularly in the case of sensible heat, or such as is indicated by the thermometer, heat will be found to consist in the living force of the particles of the bodies in which it is induced; whilst in others, particularly in the case of latent heat, the phenomena are produced by the separation of particle from particle, so as to cause them to attract one another through a greater space. (Joule, 1884, p. 274)

The treatment of heat as an independent existence was started with Planck in 1900 (Planck, 1901; 1914) when he explained the black-body radiation and afterwards, Einstein moved a bit further to treat all energy as an independent existence without the carrier of matter especially with the zero-mass concept of photons (Einstein, 1916). This is exactly the point where heat or energy was treated as an independent existence and in our ontology, the previous statement should be changed to: “When two otherwise isolated bodies are connected together by a rigid physical path impermeable to macroparticles of ideal gases, each macroparticle could radiate small particles of ether and these small particles of ether will move from hotter system to the colder system, this leads to the transfer of energy called heat”. Due to the exchange of ether, other quantities such as mass, momentum, entropy, and even information may also be transferred. Eventually, they reach a state of mutual thermal equilibrium, in which heat transfer has ceased, and the bodies’ respective state variables have settled to become unchanging (Bailyn, 1994). One statement of the zeroth law of thermodynamics is that if two systems are each in thermal equilibrium with a third system, then they are also in thermal equilibrium with each other.

Now for description of a system, what we need to distinguish two types of quantities: properties of state variables and properties of process variables. For example, for a particle moving from position A to B, the state variables include: time t, position (x, y, z), mass m, force F, temperature T, charge e, velocity v, momentum p, kinetic energy K, potential energy U, heat Q, entropy S, information I. Some of the state variables can be measured directly while other state variables are the limit of process variables, for example, the speed is the derivative of position with respect to time. The changes of all the state variables can be used for process variables including heat while work can only be used as a process variable and is not a state variable. In the later of the "Entropy" section when we discuss the concept of entropy, we will find that the introduction of the concept of entropy is to explain the process phenomena similar as the introduction of the concept of heat. However, later, these two concepts are also refined to be state variables. Other examples of specific process variables may exist. In any process, several principles must follow such as the conservation laws for mass, momentum, and energy. Entropy and information may follow the non-conservation laws such as second thermodynamics law.

In the calculation of heat, temperature is an important concept. So a brief discussion is given here. Temperature is a physical quantity that expresses hot and cold for an object or a system. It is the manifestation of thermal energy, present in all matter, which is the source of the occurrence of heat, a flow ability of energy, when a body is in contact with another that is colder or hotter (Dictionary.com, n.d.). Temperature is measured with a thermometer. Thermometers are calibrated in various temperature scales that historically have used various reference points and thermometric substances for definition. The most common scales are the Celsius scale (formerly called "centigrade", denoted as ℃), the Fahrenheit scale (denoted as ℉), and the Kelvin scale (denoted as K), the last of which is predominantly used for scientific purposes by conventions of the International System of Units (SI).

Temperature is important in all fields of natural science, including physics, chemistry, earth science, astronomy, medicine, biology, ecology, material science, metallurgy, mechanical engineering, and geography as well as most aspects of daily life. Many physical processes are related to temperature, for example: (1) the physical properties of materials including the phase (solid, liquid, gaseous, or plasma), density, solubility, vapor pressure, electrical conductivity, hardness, wear resistance, thermal conductivity, corrosion resistance, strength; (2) the rate and extent to which chemical reactions occur (International Atomic Energy Agency, 1974); (3) the amount and properties of thermal radiation emitted from the surface of an object; (4) air temperature affects all living organisms; (5) the speed of sound which is a function of the square root of the absolute temperature (Watkinson, 2001).

The lowest theoretical temperature is absolute zero, at which no more thermal energy can be extracted from the body as heat, a fact expressed in the third law of thermodynamics. Experimentally, absolute zero can be approached only very closely. The current world record for effective temperatures was set in 2021 at 38 picokelvins (pK), or 0.000000000038 of a Kelvin, through matter-wave lensing of rubidium Bose-Einstein condensates (Deppner et al., 2021).

Entropy

Entropy is another widely used but hardly understood concept; it is supposed to be a measurable physical property for an object or a system that is the most commonly associated with a state of disorder, randomness, or uncertainty (Wehrl, 1978). The concept is used in diverse fields from classical thermodynamics, where it was first recognized (Clausius, 1867), to the microscopic description of nature in statistical physics (Boltzmann, 1964), and to the principles of information theory (Shannon, 1948). Nowadays, it has found far-ranging applications in chemistry and physics, in biological systems and their relation to life, in cosmology, economics, sociology, weather science, climate change, and information systems including the transmission of information in telecommunication.

The classical approach defines entropy in terms of macroscopically measurable physical properties, such as bulk mass, volume, pressure, and temperature. The thermodynamic concept was referred to by Scottish scientist and engineer Macquorn Rankine in 1850 with the names “thermodynamic function” and “heat-potential” (Truesdell, 1980). In 1865, German physicist Rudolph Clausius, one of the leading founders of the field of thermodynamics, defined it as the quotient of an infinitesimal amount of heat to the instantaneous temperature (Clausius, 1867). He initially described it as “transformation-content”, and later coined the term “entropy” from a Greek word for “transformation”. Entropy arises directly from the Carnot cycle. It can also be described as the reversible heat divided by temperature. Clausius’ definition of entropy is given as follows:

For any reversible cyclic process, it has $\oint \frac{\delta Q_{rev}}{T} = 0$. This means the line integral $\int_L \frac{\delta Q_{rev}}{T}$ is path-independent. So Clausius defined a state function S, called entropy, which satisfies $dS = \frac{\delta Q_{rev}}{T}$. To find the entropy difference between any two states of a system, the integral must be evaluated for some reversible path between the initial and final states (Atkins & Paula, 2006). Since entropy is a state function, the entropy change of the system for an irreversible path is the same as for a reversible path between the same two states (Engel & Reid, 2006). However, the heat transferred to or from, and the entropy change of, the surroundings is different.

In this definition, one can find that the absolute values for the initial state and final state have not been defined but only the difference between the two states is specified. This leaves quite room to be re-interpreted in the statistical mechanics. Wehrl concluded that “a correct definition is only possible in the framework of quantum mechanics, whereas in classical mechanics entropy can only be introduced in a somewhat limited and artificial manner” (Wehrl, 1978, p. 222).

Entropy is central to the second law of thermodynamics, which states that the entropy of isolated systems left to spontaneous evolution cannot decrease with time, as they always arrive at a state of thermodynamic equilibrium, where the entropy is highest. Historically, the concept of entropy evolved to explain why some processes are irreversible. For isolated systems, systems tend to progress in the direction of increasing entropy. However, in our ontology, this is true only for a lifeless system. If a closed system contains self-cycling living creatures, the second law of thermodynamics can be violated. The following is a schematic closed system which can reach the steady state.

In Figure 1, it is assumed that people grow plants and eat plants, consume oxygen, and release carbon dioxide and waste. People generate electricity to provide light. Plants grow by light and waste. Plants absorb carbon dioxide and release oxygen. By a propel design and control of the system and with the supply of the modern equipment, it is possible for this idealized closed system to survive a very long time without the exchange of matter and information with the external environment.

Figure 1. A schematic isolated system of self-cycling living creatures which could survive itself.

Austrian physicist Ludwig Boltzmann explained entropy as the measure of the number of possible microscopic arrangements or states of individual atoms and molecules of a system that comply with the macroscopic condition of the system. He introduced the concept of statistical disorder and probability distributions in the 1870s by analyzing the statistical behavior of the microscopic components of the system. Entropy is a logarithmic measure of the number of system states with significant probability of being occupied (Boltzmann, 1964):

$$S = -k_B \sum_i p_i log p_i \tag{2}$$

where p_i is the probability that the system is in i-th state, usually given by the Boltzmann distribution; if states are defined in a continuous manner, the summation is replaced by an integral over all possible states or, equivalently, the expected value of the logarithm of the probability that a microstate is occupied:

$$S = -k_B \langle log p \rangle \tag{3}$$

where k_B is the Boltzmann constant, equal to 1.38065×10^{-23}J/K. The summation is over all the possible microstates of the system, and p_i is the probability that the system is in the i-th microstate (Frigg & Werndl, 2010). This definition assumes that the basis set of states has been picked so that there is no information on their relative phases. In quantum statistical mechanics, the concept of entropy was developed by John von Neumann (1955) and is generally referred to as “von Neumann entropy”; its expression is

$$S = -k_B Tr(\rho \log(\rho)) \tag{4}$$

where ρ is the density matrix, is trace, and log is the matrix logarithm. This density matrix formulation is not needed in cases of thermal equilibrium so long as the basis states are chosen to be energy eigenstates. For most practical purposes, this can be taken as the fundamental definition of entropy since all other formulas for S can be mathematically derived from it, but not vice versa.

Boltzmann showed that his definition of entropy was equivalent to the thermodynamic entropy to within a constant factor—known as Boltzmann’s constant (Boltzmann, 1964) and Von Neumann showed that his definition was equivalent to Boltzmann entropy (Von Neumann, 1955). In summary, the thermodynamic definition of entropy provides the experimental definition of entropy, while the statistical definition of entropy extends the concept, providing an explanation and a deeper understanding of its nature. Quantum definition of entropy by Von Neumann (1955) provides the most fundamental definition of entropy.

In 1948, Bell Labs scientist Claude Shannon developed similar statistical concepts of measuring microscopic uncertainty and multiplicity to the problem of random losses of information in telecommunication signals. Upon John von Neumann's suggestion, Shannon named this entity of "missing information" in analogous manner to its use in statistical mechanics as "entropy", and gave birth to the field of information theory. This description has been proposed as a universal definition of the concept of entropy (Ben-Naim, 2008).

When viewed in terms of information theory, the entropy state function is the amount of information in the system that is needed to fully specify the microstate of the system. Entropy is the measure of the amount of missing information before reception (Balian, 2004). Often called "Shannon entropy", it was originally devised by Claude Shannon in 1948 to study the size of information of a transmitted message. The definition of information entropy is expressed in terms of a discrete set of probabilitiesso that

$$H(X) = -\sum_{i=1}^{n} p(x_i) \log p(x_i) \tag{5}$$

In the case of transmitted messages, these probabilities were the probabilities that a particular message was actually transmitted, and the entropy of the message system was a measure of the average size of information of a message. For the case of equal probabilities (i.e., each message is equally probable), the Shannon entropy (in bits) is just the number of binary questions needed to determine the content of the message (Frigg & Werndl, 2010).

Proofs of equivalence between the definition of entropy in statistical mechanics (the Gibbs entropy formula and in classical thermodynamics together with the fundamental thermodynamic relation) are known for the microcanonical ensemble, the canonical ensemble, the grand canonical ensemble, and the isothermal-isobaric ensemble. These proofs are based on the probability density of microstates of the generalized Boltzmann distribution and the identification of the thermodynamic internal energy as the ensemble average (Callen, 2001). Thermodynamic relations are then employed to derive the well-known Gibbs entropy formula. However, the equivalence between the Gibbs entropy formula and the thermodynamic definition of entropy is not a fundamental thermodynamic relation but rather a consequence of the form of the generalized Boltzmann distribution (Gao, Gallicchio, & Roitberg, 2019).

Here we can take an idealized model for this analysis. Let us take an adiabatic room as an isolated system, the pressure is p, the volume is V, and the temperature is T. Inside the room, there is a glass bottle of ice water. Please calculate the steady state of this system and its changing process from initial state of half ice half water to the final state. The volume of the glass bottle is Vg. The problem is schematically shown in Figure 2.

This model may be used to explain the "heat death of the Universe" problem. If one assumes the whole universe is a finite and isolated system, then one may derive the conclusion that the entropy of the universe is steadily increasing, and means that its total energy is becoming less useful: Eventually, this leads to the "heat death of the Universe" (Thomson, 1852). However, if inside the room there exists a self-circulated living system, then it could be always a living system if the conservations of ether and minds, energy, momentum, mass, are followed, as illustrated in Figure 1. There are two ways to refute the heat death conclusion. One is that no scientific theory can be applied to the whole universe and thus this conclusion cannot be reached scientifically. The second way is that the room is a self-circulated living system. No matter what disturbance happened locally, it always approaches to a locally stable state similar as a system of dissipative structure.

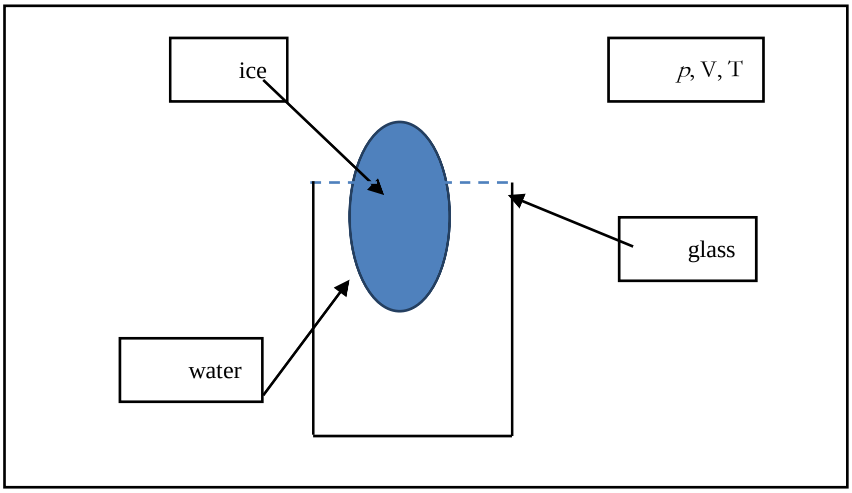

Figure 2. An ideal problem of an isolated system with an open subsystem.

Although the concept of entropy was originally a thermodynamic concept, it has been adapted in other fields of study, including information theory, psychodynamics, thermoeconomics/ecological economics, and evolution. For instance, an entropic argument has been proposed for explaining the preference of cave spiders in choosing a suitable area for laying their eggs. With this expansion of the fields/systems to which the second law of thermodynamics applies, the meaning of the word "entropy" has also expanded and is based on the driving energy for that system. The concept divides systems into three categories, natural, hybrid, and man-made, based on the amount of control that humans have in slowing the relentless march of entropy and the time-scale of each category to reach maximum entropy.

Information

In our ontology (Cui, 2021b), information is defined as messages used for communication purpose by living creatures. It can be expressed by a language developed by living creatures in either verbal format (sound signal) or written format. On the earth only human beings have developed the written language and in the following we confine ourselves to human understood written information only. This information can be divided into data and knowledge. For human beings, information can also be thought of as the resolution of uncertainty. It answers the question of "What an entity is" and defines both its nature (the essence which cannot be observed) and phenomena (which can be observed) of its characteristics. In our ontology (Cui, 2021b), a dualist answer to the mind-body problem is selected which is based on the axiom of the relativity of simultaneity. The essence of a lifeless body (matter) is ether (ensemble of unobservable particles) and the essence of a life is a mind which is a non-matter existence. Information is generated by a mind and stored in a mind. Since a mind can neither be created nor destroyed and exist permanently, information can never be destroyed after its generation. Of course information can also be recorded into a matter medium and this piece of information can be destroyed.

After education, each person can generate new information, and can store, process, transmit, and receive information. For the efficiency of information transmission, various information technologies have been developed. Nowadays, the concept of "information" has been widely used in many different fields and may have slightly different meanings in different contexts (Floridi, 2010). Thus the concept becomes synonymous to notions of constraint, communication, control, data, form, education, knowledge, meaning, understanding, mental stimuli, pattern, perception, proposition, representation, and entropy.

Information can be expressed as an organized and structured data and encoded into various forms for transmission and interpretation. Data can also be compressed. Information can be transmitted in time, via data storage, and space, via communication and telecommunication (World_info _capacity_ animation, YouTube, 11 June 2011). Information can also be encrypted for safe storage and communication. In our ontology, quantum entanglement is re-interpreted as entanglement of minds. Information transmission can also be transmitted through entanglement of minds in addition to the currently used two methods, information transmission through matter vehicles such as trains and airplanes or matter waves such as sound waves, magnetic waves, or light waves. The speed of each mean is different. While the speed of matter waves and matter vehicles cannot exceed the speed of light, the speed through the entanglement of minds could be superluminal.

The uncertainty of an event is measured by its probability of occurrence. Uncertainty is inversely proportional to the probability of occurrence. Information theory takes advantage of this fact by concluding that more uncertain events require more information to resolve their uncertainty. The bit is a classical unit of information. It is "that which reduces uncertainty by half" (DT&SC 4-5, Information Theory Primer, 2015). For example, the information encoded in one "fair" coin flip is $\log_2(2/1) = 1$ bit, and in two fair coin flips is $\log_2(4/1) = 2$ bits. In quantum information theory, the basic unit of information is defined as qubit. A qubit is a two-state (or two-level) quantum-mechanical system, one of the simplest quantum systems displaying the peculiarity of quantum mechanics. Examples include the spin of the electron in which the two levels can be taken as spin up and spin down; or the polarization of a single photon in which the two states can be taken to be the vertical polarization and the horizontal polarization. In a classical system, a bit would have to be in one state or the other. However, quantum mechanics allows the qubit to be in a coherent superposition of both states simultaneously, a property that is fundamental to quantum mechanics and quantum computing. Classical information is measured using Shannon entropy (Shannon, 1948), while the quantum mechanical analogue is Von Neumann entropy (Nielsen & Chuang, 2010). Given a statistical ensemble of quantum mechanical systems with the density matrix ρ, it is given by $S(\rho) = -\mathrm{Tr}(\rho \ln\rho)$. A 2011 science article estimated that 97% of technologically stored information was already in digital bits in 2007, and that the year 2002 was the beginning of the digital age for information storage (with digital storage capacity bypassing analog for the first time) (Hilbert & López, 2011). Information is very important in the decision-making process.

Information theory is the scientific study of the quantification, storage, and communication of information. The field was fundamentally established by the works of Harry Nyquist and Ralph Hartley in the 1920s, and Claude Shannon in the 1940s. The field is at the intersection of probability theory, statistics, computer science, statistical mechanics, information engineering, and electrical engineering. A key measure in information theory is entropy. Entropy quantifies the amount of uncertainty involved in the value of a random variable or the outcome of a random process. For example, identifying the outcome of a fair coin flip (with two equally likely outcomes) provides less information (lower entropy) than specifying the outcome from a roll of adie (with six equally likely outcomes). Some other important measures in information theory are mutual information, channel capacity, error exponents, and relative entropy. Important sub-fields of information theory include source coding, algorithmic complexity theory, algorithmic information theory, and information-theoretic security.

Applications of fundamental topics of information theory include lossless data compression (e.g., ZIP files), lossy data compression (e.g., MP3s and JPEGs), and channel coding (e.g., for DSL). Its impact has been crucial to the success of the voyager missions to deep space, the invention of the compact disc, the feasibility of mobile phones, and the development of the Internet. The theory has also found applications in other areas, including statistical inference (Preskill, 2018), cryptography, neurobiology (Nisbet-Jones et al., 2013), perception (Qudits, 2017), linguistics, the evolution (Lucatto et al., 2019) and function (Morton et al., 2008) of molecular codes (bioinformatics), thermal physics (Saeedi et al., 2013), quantum computing, black holes, information retrieval, intelligence gathering, plagiarism detection (Náfrádi et al., 2016), pattern recognition, anomaly detection (Wang et al., 2021), and even art creation. For the concept of information, our emphasis is that its ontology is mind and information can never be completely destroyed after its generation. Information transmission can be superluminal through entanglement of minds.

Summary and Conclusions

It is well-known that philosophical conflicts in ontology and epistemology exist among classical mechanics, quantum mechanics, and relativistic mechanics (e.g., Whitker, 2006). In order to use the framework of general system theory (Bertalanffy, 1968; 1972; Chen & Stroup, 1993) to unify these three mechanics subjects, a new general system theory (NGST) is developed based on a new ontology of ether and minds as the fundamental existences in the world. In the presentation of this new ontology, we have found that the meanings of many fundamental concepts have been changed. This fact can also be supported from the following citations.

In the Introduction of the book *Physics and Philosophy* (Heisenberg, 2007) written by Paul Davis, an internationally acclaimed physicist, writer, and broad-caster, the following sentences can be found.

> The central theme of Heisenberg's exposition, which is based on his 1955—6 Gifford lectures at the University of St Andrews, is that words and concepts familiar in daily life can lose their meaning in the world of relativity and quantum physics. (p. viii)

For example,

> Relativity contains some strange ideas, such as time dilation and length contraction, curved space and black holes.
>
> Probably the deepest philosophical problem presented by the theory of relativity is the possibility that the universe may have had its origin at a finite moment in the past and that this origin represented the abrupt coming into being not only of matter and energy but of space and time as well. Indeed, the central lesson of the theory of relativity is that space and time are not merely the arena in which the drama of the universe is acted out but part of the cast. That is, space-time is as much a part of the physical universe as matter; in fact, the two are intimately interwoven.
>
> By contrast with the theory of relativity, quantum mechanics presents us with much greater conceptual and philosophical problems. (p. ix)

It is our belief that by changing completely the fundamental concepts, ontology and epistemology is not a good way to explain the newly observed phenomena since we are educated under classical conditions. We could slightly extend their meanings but should not abandon them completely. This is our philosophy for the unification, generalization rather than revolution. By gradually extending the classical mechanics, a new general system theory is expected to be developed. In our previous papers (Cui & Kang, 2020; Cui, 2021a; 2021b; Ma & Cui, 2021; Pan & Cui, 2021a; 2021b), some of the fundamental concepts such as universe, world, time, space, matter, ether, mind, life, field, force have been redefined. In this paper, we particularly focus on the re-examination of the fundamental concepts of energy, work, heat, entropy, and information based on the mind-ether ontology. Through this discussion, the following conclusions can be drawn.

(1) Mass is the fundamental property of matter and any observed particles which occupy finite space must have mass. Energy is a property of matter which can be divided into different types such as kinetic, elastic, thermal, gravitational, electric, magnetic, nuclear, chemical. No matter what type of energy is, it must have a carrier of matter. Energy cannot exist without the carrier of matter. Energy can be transformed from one form to another in a process following the energy conservation principle.

(2) There are two types of variables: One is state variable and the other is the process variable. The change of all the state variables can be used for process description but some concepts are only suitable for process. Work is the variable for process only and it is not a state variable. Work is closely related to energy but work does not involve the exchange of mass, so we regard work and energy are two different concepts. The work-energy principle states that an increase in the energy of a body is caused by an equal amount of positive work done on the body by the resultant external force acting on that body. Since work done by all passive forces corresponds to energy, it is recommended work to be used only by active forces. This may solve the potential confusion between work and energy.

(3) Heat should not be treated as an independent existence and even not a new type of energy but a new name for the total energy of an object or a system. Exchange of heat between objects or systems always involves the exchange of matter possibly in the form of ether (unobservable particles). In our ontology, when two otherwise isolated bodies are connected together by a rigid physical path impermeable to macroparticles of ideal gases, each macroparticle could radiate small particles of ether and these small particles of ether will move from hotter system to the colder system, which leads to the transfer of energy called heat.

(4) Currently entropy is defined to be a measurable physical property for an object or a system that is most commonly associated with a state of disorder, randomness, or uncertainty. When viewed in terms of information theory, the entropy state function is the amount of information in the system that is needed to fully specify the microstate of the system. Actually, entropy is a concept of merging matter and information, whether it is a measurable physical property for an object or a system is a question to be further examined. Currently there are three definitions for the entropy and whether they are really consistent with each other needs further study.

(5) Information is defined as messages used for communication purpose by living creatures. It can be expressed by a language developed by living creatures in either verbal format (sound signal) or written format. Information is generated by a mind and stored in a mind. Since a mind can neither be created nor destroyed and exist permanently, information can never be destroyed after its generation. Information may be transmitted superluminally through entanglement of minds. This is certainly a direction of future research.

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