

Article

Entropy and Its Correlations with Other Related Quantities

Jing Wu ^{1,*} and Zeng-Yuan Guo ²

¹ School of Energy and Power Engineering, Huazhong University of Science & Technology, Wuhan 430074, China

² Key Laboratory for Thermal Science and Power Engineering of Ministry of Education, Department of Engineering Mechanics, Tsinghua University, Beijing 100084, China; E-Mail: demgzy@tsinghua.edu.cn

* Author to whom correspondence should be addressed; E-Mail: jingwu12@gmail.com; Tel. +86 27 87542420.

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Abstract: In order to find more correlations between entropy and other related quantities, an analogical analysis is conducted between thermal science and other branches of physics. Potential energy in various forms is the product of a conserved extensive quantity (for example, mass or electric charge) and an intensive quantity which is its potential (for example, gravitational potential or electrical voltage), while energy in specific form is a dissipative quantity during irreversible transfer process (for example mechanical or electrical energy will be dissipated as thermal energy). However, it has been shown that heat or thermal energy, like mass or electric charge, is conserved during heat transfer processes. When a heat transfer process is for object heating or cooling, the potential of internal energy U is the temperature T and its potential “energy” is $UT/2$ (called entransy and it is the simplified expression of thermomass potential energy); when a heat transfer process is for heat-work conversion, the potential of internal energy U is $(1 - T_0/T)$, and the available potential energy of a system in reversible heat interaction with the environment is $U - U_0 - T_0(S - S_0)$, then T_0/T and $T_0(S - S_0)$ are the unavailable potential and the unavailable potential energy of a system respectively. Hence, entropy is related to the unavailable potential energy per unit environmental temperature for heat-work conversion during reversible heat interaction between the system and its environment. Entropy transfer, like other forms of potential energy transfer, is the product of the heat and its potential, the reciprocal of temperature, although it is in form of the quotient of the heat and the temperature. Thus, the physical essence of entropy transfer is the unavailable

potential energy transfer per unit environmental temperature. Entropy is a non-conserved, extensive, state quantity of a system, and entropy generation in an irreversible heat transfer process is proportional to the destruction of available potential energy.

Keywords: potential energy; entransy; entropy; unavailable energy; thermomass

1. Introduction

It is well known that entropy has a wide use in the second-law analysis of engineering devices. However, its macroscopic physical meaning is thought to be difficult to understand, even for Prigogine, the Nobel Prize winner, who has indicated that [1] "...entropy is a very strange concept without hoping to achieve a complete description...". People are so confused about this concept that the macroscopic physical meaning of entropy is rarely discussed both in textbooks and the literature. By now, an answer to the physical meaning of entropy is mostly derived by considering the microscopic nature of matter, that is, entropy can be viewed as a measure of molecular disorder [2]. The more disordered a system becomes, the more entropy of this system is. However, the microscopic interpretation is not adequate to show the essence of entropy for engineers and researchers who are more interested in the macroscopic significance of entropy related to the efficiency of heat-work conversion of a heat engine or/and the heat transfer irreversibility *etc.*

This paper aims to further clarify more correlations between entropy and other related quantities within the framework of classical thermodynamics in terms of introducing the potential and potential energy of heat based on the analogy of thermodynamics/heat transfer with other branches of physics. It is hoped that the discussion will shed some light on the macroscopic physical meaning of entropy.

2. Exergy and Entropy

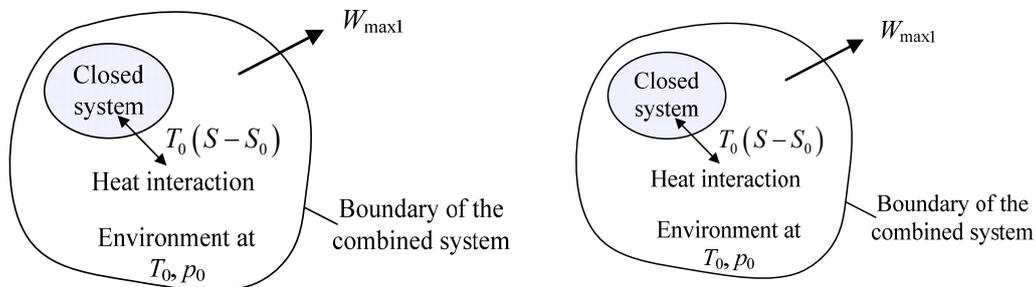
The macroscopic physical meaning of available energy (exergy) is easier to be understood compared with that of entropy. Under the environmental conditions of T_0 and p_0 , the available energy transfer accompanying heat transfer is the maximal possible useful work produced from heat, while the available energy of a system is the maximum useful work obtainable during a process that brings the system into equilibrium with the environment. The concept of entropy is more easily appreciated to some extent with the help of the concept of available energy. For instance, the product of entropy generation and the environmental temperature is the available energy destruction during an irreversible process with regard to environmental dead state, and thus the entropy generation may represent the available energy destruction per unit environmental temperature.

In the previous studies, there is a generally adopted notion that entropy is a measure of the unavailability of a system [3–5]. However, it has been manifested that the notion holds only when the volume of a system is kept constant [6]. By separating the reversible interactions between a closed system and the environment into two forms, *i.e.*, the reversible heat interaction and work interaction [7], as shown in Figure 1, the available energy of the system, E_x , can be expressed as [6]:

$$E_x = W_{\max 1} + W_{\max 2} = \underbrace{U - U_0}_{-\Delta U} - \underbrace{T_0(S - S_0)}_{A_1} - \underbrace{p_0(V_0 - V)}_{A_2} \tag{1}$$

where U_0 , S_0 , and V_0 are respectively the internal energy, entropy and volume of the system at the dead state (a state in equilibrium with the environment), A_1 is the unavailable energy during reversible heat interaction where the volume of the system is kept constant and the useful work is converted from the transferred heat through numerous heat engines operating between the system and the environment indirectly, A_2 is the unavailable energy during reversible work interaction where the useful work is derived directly by the expansion of the system itself. Note that the process of reversible heat interaction is different from the irreversible heat transfer process at finite temperature difference.

Figure 1. The sketch of energy exchange during the reversible (a) heat interaction and (b) work interaction between the system and the environment [6].



It can be clearly seen from the term A_1 in Equation (1) that the influence of entropy on the unavailability of the closed system displays only in the reversible process of heat interaction. That is, entropy is related to the unavailability of a system during reversible heat interaction between the system and the environment. In general, the value of T_0 is taken as typical value, such as 25 °C. In addition, for a closed system with designated composition, its entropy at the dead state, S_0 , is a fixed value. Under this condition, the more entropy of a closed system is, the more unavailable energy will be through reversible heat interaction only. Particularly, for a system with constant volume (for instance, an incompressible substance), there is no work interaction, that is, $A_2 = 0$, and then $T_0(S - S_0)$ is the unavailable energy of the system. It is shown that the environmental temperature or the available energy serves as the role of an auxiliary line as in solving geometrical problems to help clarify the macroscopic physical meaning of entropy.

3. Unavailable Potential Energy per Unit Environmental Temperature

3.1. Potentials and Potential Energies in Mechanics and Electrics

The term “potential energy” was coined by W. Rankine in the 19th century [8]. At present, as one of the most important forms of energy, the concept of potential energy has wide applications in the areas of mechanics and electrics. In incompressible fluid mechanics, the gravitational potential energy of a liquid in a vessel with uniform cross section is $MgH/2$, where M is the mass of liquid and gH is the gravitational potential of the mass. Likewise, for an electric capacitor where the electrical potential increases in parallel with the charge stored in it, the resulting electrostatic potential energy is $Q_eV_e/2$.

Table 1. Analogous parameters in mechanics, electrics and thermodynamics/heat transfer.

Subject		Transferred quantity (conserved, extensive)	Transferred quantity (in the rate form)	Potential of transferred quantity (intensive)	Potential energy transfer	Potential energy transfer (in the rate form)	
Fluid Mechanics		M	\dot{M}	gH	MgH	$\dot{M}gH$	
Electrics		Q_e	\dot{Q}_e	V_e	$Q_e V_e$	$\dot{Q}_e V_e$	
Heat transfer	Purpose	Object heating or cooling	Q_h	\dot{Q}_h	T	$Q_h T$	$\dot{Q}_h T$
		Heat-work conversion			$1 - \frac{T_0}{T}$	$Q_h \left(1 - \frac{T_0}{T}\right)$	$\dot{Q}_h \left(1 - \frac{T_0}{T}\right)$
					$\frac{T_0}{T}$	$Q_h \cdot \frac{T_0}{T}$	$\dot{Q}_h \cdot \frac{T_0}{T}$
		$\frac{1}{T}$	$Q_h \cdot \frac{1}{T}$	$\dot{Q}_h \cdot \frac{1}{T}$			

Table 1. Cont.

Subject		Quantity stored in the system (or capacitor)	Differential potential energy of a system	Potential energy of a system (non-conserved, extensive)	Transfer law (a balance between driving force and resistive force)	Dissipation (or generation) rate of potential energy	
Fluid Mechanics		$M = C_m H$	$dM \cdot gH$	$\int_0^H dM \cdot gH = \frac{1}{2} MgH$	$\dot{M} = -\frac{KA\rho}{\nu} \nabla(gH)$ Darcy's law	$\frac{K\rho}{\nu} [\nabla(gH)]^2$	
Electrics		$Q_e = C_e V_e$	$dQ_e \cdot V_e$	$\int_0^{Q_e} dQ_e \cdot V_e = \frac{1}{2} Q_e \cdot V_e$	$\dot{Q}_e = -\sigma A \nabla V_e$ Ohm's law	$\sigma (\nabla V_e)^2$	
Heat transfer	Purpose	Object heating or cooling	$dU \cdot T$	$\int_0^U dU \cdot T = \frac{1}{2} UT$	$\dot{Q}_h = -kA \nabla T$ Fourier's law	$k(\nabla T)^2$	
		Heat-work conversion	$U = C_v T$	$dU \cdot \left(1 - \frac{T_0}{T}\right)$	$\int_{U_0}^U dU \cdot \left(1 - \frac{T_0}{T}\right) = U - U_0 - T_0(S - S_0)$	$\dot{Q}_h = L_{qq} A \nabla \left(\frac{1}{T}\right)$ Fourier's law in the entropy form	$L_{qq} T_0 \left(\nabla \frac{1}{T}\right)^2$
			$dU \cdot \frac{T_0}{T}$	$\int_{U_0}^U dU \cdot \frac{T_0}{T} = T_0(S - S_0)$	$L_{qq} \left(\nabla \frac{1}{T}\right)^2$		
$dU \cdot \frac{1}{T}$	$\int_{U_0}^U dU \cdot \frac{1}{T} = S - S_0$						

It can be seen that the expressions of the gravitational and electrostatic potential energies have some common features. Each of them is the product of an extensive quantity and an intensive quantity. Moreover, in mass or charge transfer processes, each of the extensive quantity is conserved, and the intensive quantity serves as the transfer potential of its corresponding extensive quantity, as shown in Table 1. The gravitational potential energy transfer rate accompanying mass transfer rate and the electrostatic potential energy transfer rate accompanying charge transfer rate are $\dot{M}gH$ and $\dot{Q}_e V_e$ respectively.

In both mass and charge transfer processes, there are two different types of extensive quantities: conserved and non-conserved ones. Mass and charge are both conserved, while the potential energy in specific form is dissipative and non-conserved due to the presence of resistance. The ‘dissipative’ process refers to that during irreversible transport processes some part of energy in the type with higher grade must be dissipated into other type of energy with the same amount but lower grade. For example, the mechanical energy/electrical energy is dissipated into heat during viscous fluid flow/electric charge transfer process. In each transfer process, if the resistance is large enough, the variation of kinetic energy of transferred mass or charge is negligible compared with its potential energy. Hence, the dissipation rate of potential energy, as listed in the last column of Table 1, may measure the irreversibility of each transfer process. Moreover, Table 1 shows the transfer laws for each transfer process, which can be obtained by the equation of conservation of momentum in the absence of inertial force, that is, when the driving force is in equilibrium with the resistive force. For stationary, incompressible flow through an isotropic porous media with a constant velocity driven by the gravitational potential, Darcy’s law describes the proportional relationship between the mass flow rate and the potential gradient, which can be derived from the Navier-Stokes equations via homogenization [9] when neglecting the inertial terms. Similarly, Ohm’s law can be obtained by the Newton’s second law when the inertial force can be neglected [10].

3.2. Potentials and Potential Energies in Thermodynamics/Heat Transfer

In thermodynamics, internal energy, enthalpy, Gibbs free energy and Helmholtz free energy are usually taken as thermodynamic potentials (in fact, they are thermodynamic potential energies), each of which can be expressed as the product of a generalized force and a generalized displacement and they are useful in the study for a system to attain thermodynamic equilibrium under various conditions. The thermodynamic potentials are thought to play a similar role as the potentials in mechanics and electrics in some sense [11] since a thermodynamic system will tend towards lower values of potential and the potential is an unchanging minimum value at equilibrium. Moreover, the changes of the thermodynamic potentials equal to the maximum amount of work that can be extracted from a thermodynamic system in certain reversible processes. However, notice that, unlike the mechanical or electrical potential energy whose changes may measure the irreversibility of mass or charge transfer processes, the changes in internal energy, enthalpy, Gibbs free energy and Helmholtz free energy during irreversible heat transfer processes cannot be used to measure the irreversibility of heat transfer processes. It is therefore desirable to introduce physical quantities with the physical meaning of potential energy for heat transfer processes.

The often used method of analogy provides us with a good deal of guidance in introducing the potential energies in heat transfer and thermodynamics, since the heat transfer process has similar transfer law with that for mass and charge transfer processes, as shown in Table 1. During a heat transfer process, heat is an extensive, conserved quantity revealing the mass-like characteristics. Taking into account that the temperature T is usually taken as the potential of the transferred heat for heat transfer processes not involved in thermodynamic cycles [12–15] and, the potential energy transfer rate accompanying heat transfer rate can then be defined as $\dot{Q}_h T$, a product of the extensive quantity, \dot{Q}_h , and the intensive quantity, T .

Like a mass capacitor (liquid in a vessel) which stores mass, M , and the gravitational potential energy, $MgH/2$, or an electric capacitor which stores electrical charge, Q_e , and the electrostatic potential energy, $Q_e V_e/2$, a closed incompressible system at temperature T can be taken as a thermal capacitor which stores heat, that is, internal thermal energy, and the potential energy of the heat, which has been coined as entransy describing the ability of object heating or cooling of the system [16]. For constant specific heat, the entransy of a closed system for object heating or cooling is $UT/2$ or $Mc_v T^2/2$, determined by integration from $\int_0^U dU \cdot T$, as shown in Table 1. Here, $U = Mc_v T$ is the internal thermal energy of the system, M is the mass, and c_v is the specific heat at constant volume. It can be seen that the entransy or the potential energy of heat of a closed system is a state quantity (or state function). When the properties of the system are not uniform, the entransy of the system can be determined by integration form, that is, $\int_V \frac{1}{2} \rho c_v T^2 dV$, where V is the volume of the system and ρ is the density.

The entransy of a closed system $UT/2$ in unit of J·K is in fact a simplified expression of the potential energy of thermomass in unit of J, that is, there is only a proportional coefficient between $UT/2$ and the potential energy of thermomass [17].

Like fluid flow through a porous media where gravitational potential energy is dissipated or charge transfer through a conductor where electrostatic potential energy is dissipated, the potential energy of heat is also dissipated during heat transfer. As shown in Table 1, for a heat transfer process with the purpose of object heating or cooling, the entransy dissipation rate with the expression $k(\nabla T)^2$ can be taken as a measure of its irreversibility [16–20].

The entransy transfer rate, $\dot{Q}_h T$, the entransy, $UT/2$, and its dissipation rate can be derived by the energy conservation equation. For heat conduction of a closed system without heat-work conversion and without any heat source, the energy conservation equation per unit of system volume is:

$$\rho c_v \frac{\partial T}{\partial t} = -\nabla \cdot \dot{q}_h \quad (2)$$

where t is the time, \dot{q}_h is the heat flux. Multiplying Equation (1) by temperature, T , leads to:

$$\rho c_v T \frac{\partial T}{\partial t} = -\nabla \cdot (\dot{q}_h T) + \dot{q}_h \cdot \nabla T \quad (3a)$$

Integrating Equation (3a) over the whole volume of the closed system, we have:

$$\int_V \left(\rho c_v T \frac{\partial T}{\partial t} \right) dV = \int_V -\nabla \cdot (\dot{q}_h T) dV + \int_V (\dot{q}_h \cdot \nabla T) dV \quad (3b)$$

which was called as entransy balance equation in Reference [16]. The left term of Equation (3b) can be rewritten as:

$$\int_V \left(\rho c_v T \frac{\partial T}{\partial t} \right) dV = \frac{d}{dt} \left(\int_V \frac{1}{2} \rho c_v T^2 dV \right). \quad (4a)$$

Furthermore, Gauss's theorem gives:

$$\int_V -\nabla \cdot (\dot{q}_h T) dV = \int_S -(\dot{q}_h T) \cdot \vec{n} dS \quad (4b)$$

where S is the boundary surface of the closed system. Substituting Equations (4a) and (4b) as well as Fourier's law, $\dot{q}_h = -k\nabla T$, into Equation (3b), we obtain the entransy balance equation as:

$$\frac{d}{dt} \left(\int_V \frac{1}{2} \rho c_v T^2 dV \right) = \int_S -(\dot{q}_h T) \cdot \vec{n} dS - \int_V k (\nabla T)^2 dV \quad (3c)$$

where k is the thermal conductivity.

The left term in Equation (3c) is the time variation of the potential energy of heat stored in the closed system. The first term on the right is the transfer rate of potential energy of heat or the entransy transfer rate associated with heat transfer across the system boundary, and it is simplified as $\dot{Q}_h T$ for the uniform heat flux across the uniform temperature boundary. The second term on the right is the total entransy dissipation rate within the system boundary, which resembles the dissipation rates of electrostatic potential energy in an electrical conduction system and gravitational potential energy in viscous fluid flow. Equation (3c) indicates that during a heat transfer process without volume variation, entransy is non-conserved and dissipated due to the thermal resistance induced irreversibility although heat is conserved revealing the mass-like characteristics.

On the other hand, if what we concern is the amount of the useful work we can extract from the transferred heat, the transfer rate of potential energy of heat accompanying heat transfer rate is nothing but the available energy transfer rate $\dot{Q}_h (1 - T_0/T)$ or $\int_S -[\dot{q}_h (1 - T_0/T)] \cdot \vec{n} dS$. Thus, $1 - T_0/T$ can be regarded as the available potential of heat for doing work. Correspondingly, T_0/T is the unavailable potential of heat for doing work, and $\dot{Q}_h T_0/T$ is the unavailable potential energy transfer rate. Furthermore, $1/T$ and \dot{Q}_h/T are respectively the unavailable potential and the unavailable potential energy transfer rate per unit environmental temperature, as shown in Table 1. Note that the entropy transfer rate \dot{Q}_h/T is essentially the product of \dot{Q}_h and $1/T$, although it is in form of the quotient of the heat transfer rate \dot{Q}_h and the temperature T . From the point of view of nonequilibrium thermodynamics, a thermodynamic force is proportional to the gradient of the potential [21], and $\nabla(1/T)$ is the thermodynamic force that drives the thermodynamic flux for a heat transfer process, \dot{q}_h , [22], manifesting that $1/T$ is the thermodynamic potential.

Correspondingly, the potential energy for heat-work conversion of an incompressible system is $\int_{U_0}^U dU \cdot \left(1 - \frac{T_0}{T} \right)$, where U_0 is the internal energy of the system at the dead state. Note that the lower limit of this integral is U_0 rather than 0 for the reason that the system must be in thermodynamic

equilibrium with the environment at the end of process when calculating the available energy of the system. For the reversible heat interaction only (*i.e.*, $dV = 0$ and $dU = \delta Q_h$), the integral result is:

$$\int_{U_0}^U dU \cdot \left(1 - \frac{T_0}{T}\right) = U - U_0 - T_0(S - S_0) \quad (5)$$

which means that $U - U_0 - T_0(S - S_0)$ and $T_0(S - S_0)$ are respectively the available and unavailable potential energies of a system for heat-work conversion. Hence, $S - S_0$ is the unavailable potential energy of the system per unit environmental temperature. As mentioned above, when S_0 is fixed, the value of entropy of a system may represent the unavailable potential energy per unit environmental temperature.

The destruction rate of the available potential energy or the generation rate of the unavailable potential energy can be used to measure the irreversibility of a heat transfer process with the purpose of heat-work conversion. It is worth noting that the unavailable potential energy always increases since the unavailable potential, *i.e.*, $1/T$, always increases in irreversible heat transfer processes. The entropy generation rate is just the generation rate of the unavailable potential energy per unit environmental temperature. In nonequilibrium thermodynamics, Fourier's law in the entropy form can be expressed as the linear flux-force relations as $\dot{q}_h = L_{qq} \nabla(1/T)$, where L_{qq} is a phenomenological coefficient that equals to kT^2 . The entropy generation rate is the product of the thermodynamic flow, \dot{q}_h , and the thermodynamic force, $\nabla(1/T)$, with the expression of $L_{qq} \left(\nabla \frac{1}{T}\right)^2$ [23].

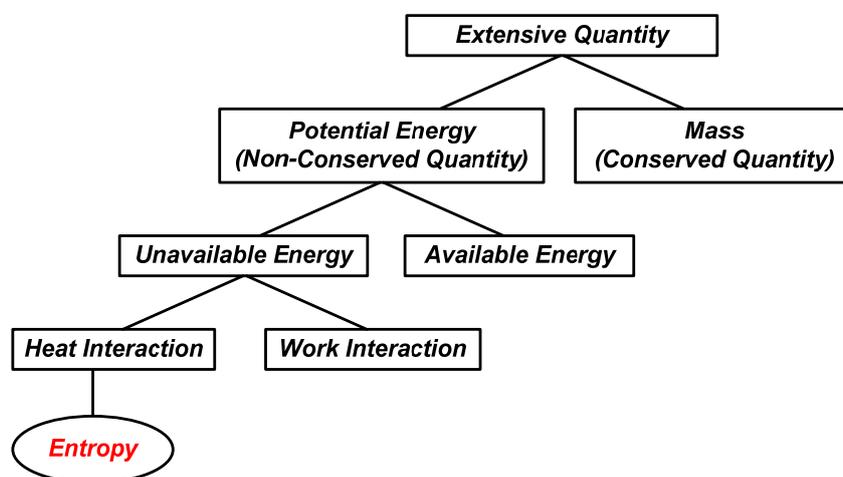
It seems that the concept of unavailable energy is unique to the thermodynamic systems since it is rarely mentioned or used in other kinds of transport phenomena. In fact the unavailable energy also exists in fluid mechanics and electrics. Consider a circuit consisting of switch S, and two identical capacitors with same capacitance C but different electrical potentials, where No. 1 capacitor's electrical potential, U_1 , is higher than that of No.2, U_2 . When the switch flips, the No. 1 capacitor charges the No. 2 capacitor until $U_1 = U_2$. The potential energy initially stored in the No. 1 capacitor is $CU_1^2/2$ which cannot be entirely transferred to No. 2 capacitor when the charge process ends since $U_2 \neq 0$. The rest potential energy stored in No. 1 capacitor at the final state, $C(U_1 + U_2)^2/8$, is in fact the unavailable potential energy. This example shows that the unavailable energy is essentially due to the non-zero reference point of the potentials. Since people are used to taking the reference point as zero when analyzing mechanical and electrical systems, the concept of unavailable energy is of little value and no longer needed for these conditions. But for thermodynamic systems, the reference point, that is, the environmental temperature, T_0 , is non-zero and the concept of unavailable energy is needed to evaluate the heat to work efficiency.

The analogies between the parameters in fluid mechanics, electrics and thermodynamics/heat transfer show that heat exhibits the mass-like characteristics since it is conserved in heat transfer processes without volume change. Apart from the method of analogy, the mass nature of heat can be further understood by the recently proposed thermomass theory [24]. Thermomass is the equivalent mass of thermal energy calculated from the Einstein's mass-energy relation. Heat conduction can be treated as the motion of thermomass in the media driven by the gradient of the thermal potential, *i.e.*, the temperature [24–29]. The momentum equation for the thermomass can be established based on the Newtonian mechanics, and it reduces to the Fourier's law when the inertial force can be neglected,

revealing that the physical essence of Fourier's law is the balance between the driving force and the resistive force acting on the thermomass [24], analogous to other transfer laws for mass and charge transfer processes as listed in Table 1.

Figure 2 shows symbolically the classifications of some physical quantities discussed for understanding the physical meaning of entropy. In thermodynamics we have to distinguish the state quantity (pressure p , temperature T , internal energy U and entropy S , etc.) from process quantity (heat Q , work W etc.). The state quantity can be divided into two folds: extensive quantity (internal energy U and entropy S , etc.) and intensive quantity (pressure p , temperature T , etc.). The extensive, state quantity can further be classified into two kinds: conserved quantity (mass M , electric charge Q_e , etc.) and non-conserved (available energy E_x , entropy S , etc.) due to its dissipation or generation in an irreversible transfer process. The non-conserved, extensive, state quantity has also two folds: unavailable (unavailable potential energy, $T_0(S-S_0)$, etc.) and available quantities (available energy E_x , etc.). Note that when the entropy of a system at dead state, S_0 , is fixed, the value of entropy of a system may represent the unavailable potential energy per unit environmental temperature. Hence, entropy belongs to the fold of unavailable energy as shown in Figure 2. Furthermore, as stated in Section 2, the influence of entropy on the unavailability of the closed system displays only in the reversible process of heat interaction. Based on the above analysis, it can be concluded that entropy is an extensive, non-conserved, state quantity that has a relation with the unavailability during reversible heat interaction between the system and the environment with $T_0 \neq 0$.

Figure 2. Classification of the quantities discussed in this paper.



4. Conclusions

The analogies between thermodynamics/heat transfer and fluid mechanics, electrics show that the potential and the potential energy transfer accompanying heat transfer are the temperature, T , and the product of the heat transfer and temperature, QT , respectively as the transferred heat is for object heating or cooling, while the potential and the potential energy (available energy) transfer accompanying heat transfer are $1-T_0/T$ and $Q(1-T_0/T)$, respectively, as the transferred heat is for heat-work conversion, where QT_0/T is the unavailable energy transfer. Thus it can be seen that, Q/T , usually referred to as entropy transfer, is the unavailable potential energy transfer per unit

environmental temperature. Therefore, though the entropy transfer is in form of the quotient of the heat transfer and the temperature, its physical essence, like other forms of potential energy transfer, is the product of the extensive quantity, *i.e.*, the heat transfer Q and its unavailable potential, the reciprocal of temperature $1/T$.

For an incompressible system for doing work through the reversible heat interaction only its potential energy (available energy) is $U - U_0 - T_0(S - S_0)$, where $T_0(S - S_0)$ is the unavailable potential energy of system and $S - S_0$ is the unavailable potential energy per unit environmental temperature. Therefore, the entropy of the system can be understood as the unavailable potential energy of a system per unit environmental temperature for heat-work conversion under the reversible heat interaction only between the system and its environment.

The analogies between thermodynamics/heat transfer and fluid mechanics, electrics show that the unavailable energy of heat or a system is essentially due to the non-zero reference point of the potential, that is, non-zero environment temperature, $T_0 \neq 0$. Hence, the environmental temperature can help clarify the macroscopic physical meaning of entropy, like an auxiliary line added to a diagram to help in a proof of geometrical problem. For instance, entropy generation is the available energy destruction per unit environmental temperature and the entropy transfer is the unavailable potential energy transfer per unit environmental temperature and so on.

Entropy, as a state function of a system, is an extensive, non-conserved quantity that related to the unavailable part of the internal energy during reversible heat interaction between the system and the environment with $T_0 \neq 0$.

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