
WHAT IS ENTROPY FOUNDED ON?

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ABSTRACT

These days people talk about entropy everywhere, ranging from scientific and philosophical communities to random conversations between friends. Sometimes all you hear in justification of an event or phenomenon revolves overwhelmingly around entropy. But where is this entropy coming from, what is it founded on? Entropy simply emerges from the collision of underlying degrees of freedom that is founded on the basic laws of physics.

Keywords Thermodynamics · Relativity · Entropy · Energy

1 Introduction

It was over twenty years ago in pre-college that for the time I heard about entropy as something that measures the disorder within a system. In other words, I learned that more disorder in the system corresponds to a higher entropy. Later on in college, I encountered this seemingly superstitious concept of entropy again through my physical chemistry course at the University of Guilan. Being a twenty-one-year-old student majoring in chemistry and trying to get good grades, I only was able to pertain to a very vague and ambiguous idea about entropy, looking at it as a principle inherent to the universe that does not allow all the energy to convert to work in a process. Thereafter, during my Master's study, around fourteen years ago, at the Sharif University of Technology, I was supervised by G.A.Parsafar who asked me to work on the investigation of entropy and energy effect on the distribution of particles in a confined box.(1) It is shown that particles prefer to lay near the wall due to depletion forces with no attractive forces present in the system. Quasi-gravitational force emerged from random collisions of Brownian particles in maximizing their entropy and therefore is perceived as depletion or entropic forces.(1)

My curiosity about entropy owing to my Master's study penetrated deep into my mind as something important that I need to understand to feel entitled as a researcher in the field. But never thought I would understand this concept to my current level.(2) During my Ph.D. at the University of Maine, doing molecular dynamics simulations on the basis of Newtonian laws of motion, I realized all the forces within the system are physical, and nothing there comes from nothing. Besides this, I participated in a talk by C.Jarzynski on the equality between average microscopic work and free energy change,(3; 4) and also further encountered the derivation of entropic gravity from thermodynamics by E.Verlinde(5) which made me motivated to understand the formation of force as an emergent property.(6) Here, through the equalization of total energy from special relativity and thermodynamics, I deduce that the entropy emerges from the underlying degrees of freedom, the same ones that result in the emergence of the rest mass.(7)

Everyone agrees that the total energy of a system is the sum of the kinetic energy and the potential energy of its constituents given in Eq. 1:

$$E = E_k + E_p. \quad (1)$$

Here, E_k — and E_p are the total potential and kinetic energy of the system. In thermodynamics, part of the energy of the system is not available for useful work. This is shown with Helmholtz free energy (A) as follows:

$$A = E - TS. \quad (2)$$

A is the available energy to do work. entropic term (TS) and is the part of the total energy that cannot be converted into useful work. The entropy (S) is perceived as a representative of the uncertainty about the position of the particle within the phase space of the system. We believe that this uncertainty or randomness in the position of the particles is emergent.

Imagine that all the available energy converts to kinetic work with a mass of m_0 , then with rearranging the Eq. 2, we will have Eq. 3 for total energy:

$$E = TS + \frac{1}{2}m_0v^2. \quad (3)$$

Now let's substitute Hawking radiation temperature(8):

$$E = \frac{\hbar c^3}{8\pi GM}S + \frac{1}{2}m_0v^2. \quad (4)$$

We know that the change in entropy (ΔS) for the smallest displacement is $2\pi k$.(9; 10) If we imagine the radiated particle initially has an entropy of zero, then the final entropy of the radiated particle would be $2\pi k$. Using $S = 2\pi k$ and the Schwarzschild radius(11), we get the following result:

$$E = \frac{\hbar c}{2\pi r_s} + \frac{1}{2}m_0v^2. \quad (5)$$

Using Unruh(12) and Hawking(8) temperatures formalism, one can deduce that Schwarzschild radius is half of the smallest displacement,

$$r_s = \frac{\Delta x}{2} = \frac{\hbar}{2m_0c}. \quad (6)$$

Substituting Eq. 7 into Eq. 5, we receive the special relativity relation(13; 14) as follows:

$$E = m_0c^2 + \frac{1}{2}m_0v^2. \quad (7)$$

We know that for an infinitely small system, all the energy converts to work. Part of entropy is coming from the collisions of standard particles. But the other part that is responsible for the fluctuations of Brownian particles in the so-called vacuum results from hidden particles in space.(2) Consequently, from a realistic perspective, one is obligated to believe that space is filled with unknown fluid-like particles that move in space randomly and emerge as disordered forces on the ordinary particles. These random fluctuations act as resistance to the applied external energy similar to friction in a macroscopic context.

Essentially, any phenomenon in the universe occurs owing to collective displacements of particles in a nonequilibrium process from a macroscopic perspective. On the other hand, if we take a closer look at the system from a microscopic point of view, we comprehend that the constituent degrees of freedom randomly fluctuate in a seemingly reversible process. Accordingly, one can confirm that it is the collective motions of underlying degrees of freedom in an equilibrium state that result in a nonequilibrium process in a macroscopic realm. This makes one believe if a macroscopic phenomenon is emerging from underlying degrees of freedom, why is it difficult to imagine it is indeed a collective behavior of underlying degrees of freedom that leads to the displacement of any object in a nonequilibrium process?

2 Conclusions

Showing the equality between the total energy formalism in special relativity and thermodynamics, we drew that the same property that causes the rest mass on a body is responsible for the emergence of the entropy. It is the underlying degrees of freedom that surround the body and result in inherent inertia for the body, and the same underlying particle results in a waste of energy which we interpret as entropy.

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